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CHIARA LUBICH CARDOSO FURTADO

PESCA ESPORTIVA NO MÉDIO RIO NEGRO, AMAZONAS: DIRETRIZES PARA A SUSTENTABILIDADE

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Orientador: Carlos Edwar de Carvalho Freitas, Dr
Coorientadora: Flávia Kelly Siqueira de Souza, Dra

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mestrado, possibilita a continuidade nos estudos de doutorado e, posteriormente, no pós-doutorado. O equilíbrio entre o sucesso dos PPGs e o bem-estar dos discentes é um fator essencial para construir uma relação sólida e contribuir para o fortalecimento da educação brasileira.

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RESUMO

A pesca esportiva é uma atividade em crescimento na Amazônia brasileira, com destaque para a região do médio rio Negro (Amazonas), reconhecida nacional e internacionalmente como principal destino para sua prática. No entanto, a escassez de informações científicas sobre sua sustentabilidade impõe desafios à gestão dessa atividade. Esta tese teve como objetivo avaliar a sustentabilidade da pesca esportiva no médio rio Negro de forma integrada, considerando os três pilares da sustentabilidade: ecológico, econômico e social. No Capítulo I, uma revisão sistemática da literatura revelou que a maioria dos estudos foca no aspecto ecológico, com lacunas nos campos econômico e social, especialmente na região Norte. No Capítulo II, estimativas baseadas no Método do Custo de Viagem indicaram que o valor recreativo anual da atividade é de aproximadamente US$ 49,2 milhões, com a disposição a pagar dos turistas positivamente associada ao tamanho dos peixes capturados, principalmente tucunarés (*Cichla temensis*) médios e grandes. O Capítulo III avaliou, por meio da metodologia RAPFISH, a percepção de diferentes grupos de atores sobre a sustentabilidade da atividade, revelando desempenho “menos que satisfatório”, com destaque para fragilidades nas dimensões ecológica e de gestão. Conclui-se que, apesar da relevância econômica, social e ecológica da pesca esportiva na região, sua sustentabilidade depende de ações coordenadas de manejo, monitoramento contínuo e participação ativa dos diversos atores envolvidos. Recomenda-se, ainda, que a gestão da atividade incorpore diretrizes voltadas à proteção de peixes de maior porte, visando à conservação dos estoques e à geração de benefícios duradouros para o território.

Palavras-chave: Amazônia, gestão pesqueira, indicadores de sustentabilidade, pesca amadora, tucunaré, turismo

ABSTRACT

Recreational fishing is a growing activity in the Brazilian Amazon, with particular emphasis on the Middle Negro River region, which is recognized nationally and internationally as a prime destination for this practice. However, the lack of scientific information regarding its sustainability poses challenges for effective management. This thesis aimed to assess the sustainability of recreational fishing in the Middle Negro River in an integrated manner, considering the three pillars of sustainability: ecological, economic, and social. Chapter I presents a systematic literature review, revealing that most studies on recreational fishing are focused on ecological aspects, with significant gaps in the economic and social dimensions, especially in the Northern region. In Chapter II, estimates based on the Travel Cost Method indicated that the annual recreational value of the activity is approximately US$ 49.2 million, with tourists' willingness to pay positively associated with the size of the fish caught, particularly medium and large-sized peacock bass (*Cichla temensis*). Chapter III applied the RAPFISH methodology to assess the perceptions of different stakeholder groups regarding the sustainability of the activity, revealing a "less than satisfactory" performance, especially concerning ecological sustainability and management. It is concluded that, despite the economic, social, and ecological relevance of recreational fishing in the region, its sustainability depends on coordinated management actions, continuous monitoring, and the active participation of the various stakeholders involved. It is further recommended that management strategies incorporate guidelines aimed at protecting larger fish, in order to conserve fish stocks and generate long-term benefits for the territory.

Keywords: Amazon, fisheries management, sustainability indicators, amateur fishing, peacock bass, tourism

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INTRODUÇÃO GERAL[1]

A pesca esportiva é uma atividade econômica que pode ser definida, de forma geral, como a captura de peixes por diversão (Pitcher e Hollingworth, 2002; FAO, 2012). Embora haja essa definição universal, no Brasil, a pesca esportiva é um segmento da pesca amadora com fins exclusivamente recreativos, sem finalidade comercial, no qual é obrigatória a prática do pesque e solte, sendo vedado o direito à cota de transporte de pescados (Brasil, 2009; Amazonas, 2019). A prática do pesque e solte é amplamente associada à sustentabilidade, pois permite que os peixes capturados sejam devolvidos ao ambiente natural com possibilidade de sobrevivência, contribuindo para a manutenção das populações e a conservação das espécies.

O conceito de sustentabilidade surgiu no cenário internacional a partir do Relatório Brundtland, publicado em 1987 pela Comissão Mundial sobre Meio Ambiente e Desenvolvimento da ONU, que definiu o desenvolvimento sustentável como aquele que atende às necessidades do presente sem comprometer a possibilidade das gerações futuras de atenderem às suas próprias necessidades (WCED, 1987). No contexto da pesca esportiva, essa abordagem se torna essencial, pois a atividade depende diretamente da saúde dos ecossistemas aquáticos e da manutenção das populações de peixes (Cooke e Cowx, 2004). A adoção de boas práticas, como a gestão eficiente dos recursos pesqueiros, o monitoramento da atividade e a conscientização dos pescadores, é fundamental para garantir a longevidade desse setor (Cooke e Cowx, 2006; García-Asorey *et al*., 2011).

A sustentabilidade da pesca esportiva envolve um equilíbrio entre conservação ambiental, viabilidade econômica e benefícios sociais (Arlinghaus *et al*., 2019). Essa modalidade vem crescendo no Brasil (Petrere, 2014), sendo praticada em rios, lagos, mares, represas ou em pesqueiros (propriedades privadas denominadas de "pesque e pague") (Caminhas, 2015). Além de gerar relevância social e alto valor econômico em diversas partes do mundo (Rudd *et al*., 2002; Tufts *et al*., 2015; Hyder *et al*., 2018), a pesca esportiva desempenha um papel significativo na conservação aquática (Brownscombe *et al*., 2019), promovendo ações voltadas à conservação de peixes e seus habitats (Arlinghaus e Cooke, 2009; Cowx *et al*., 2010; Cooke *et al*., 2013), bem

[1] *Referências estruturadas de acordo com as diretrizes da ABNT NBR 10520:2023*

como fomentando debates em eventos de âmbito nacional (Lopes *et al*., 2011) e internacional (Brownscombe *et al*., 2019).

Estima-se que, em países desenvolvidos, aproximadamente 220 milhões de pessoas pratiquem a pesca esportiva, com gasto anual em torno de 19 bilhões de dólares apenas em equipamentos (The World Bank, 2012). Esse setor movimenta uma cadeia produtiva extensa, com forte efeito multiplicador, gerando empregos diretos e indiretos e dinamizando economias locais (Schork *et al*., 2010; Brasil, 2012; Tsuruda *et al*., 2013). Além do impacto econômico, a atividade possui dimensões sociais relevantes, promovendo interações entre diferentes atores e gerando benefícios psicológicos, como relaxamento e bem-esta (Knopf *et al*., 1973; Fedler e Ditton, 1994; Ross e Loomis, 2001; Calvert, 2002). As motivações dos pescadores são diversas, incluindo contato com a natureza, desafio, sociabilidade, privacidade e captura de peixes troféu (Holland e Ditton, 1992). Entretanto, ainda há lacunas quanto à mensuração de empregos e à qualificação da mão de obra gerada pela atividade.

Apesar de sua relevância, os estudos sobre pesca esportiva apresentam assimetrias. A maior parte das pesquisas foi conduzida em países da América do Norte (Brownscombe *et al*., 2014) e da Europa (Lloret *et al*., 2008; Tunca *et al*., 2016; Pita *et al*., 2018; Martínez-Escauriaza *et al*., 2020). No Brasil, os trabalhos concentram-se na região Sudeste (Pixer e Petrere Jr, 2009; Barcellini *et al*., 2013; Barrella *et al*., 2016a, 2016b; Silva *et al*., 2016; Alves-Junior *et al*., 2020), havendo escassez de informações sobre outras regiões.

A região Norte, em especial o Amazonas, concentra elevado fluxo de turistas dedicados à pesca esportiva, motivados sobretudo pela captura do tucunaré (*Cichla* spp.), espécie de grande valor esportivo (Amazonastur, 2019). Atualmente, cerca de 24 dos 62 municípios amazonenses desenvolvem essa modalidade turística (Amazonastur, 2020; Lubich *et al*., 2024a). Entre eles, destaca-se Barcelos, no médio rio Negro, considerado um dos principais destinos nacionais e conhecido como a “Capital Internacional da Pesca Esportiva” (Freitas e Rivas, 2006; Lubich *et al*., 2023, 2024) (Figuras 1A e 1B). Estima-se que o município receba anualmente pouco mais de 13.600 pescadores esportivos (Figuras 1C e 1D), movimentando aproximadamente R$ 245 milhões (US$ 49,2 milhões) (Lubich, 2025 – Capítulo II).

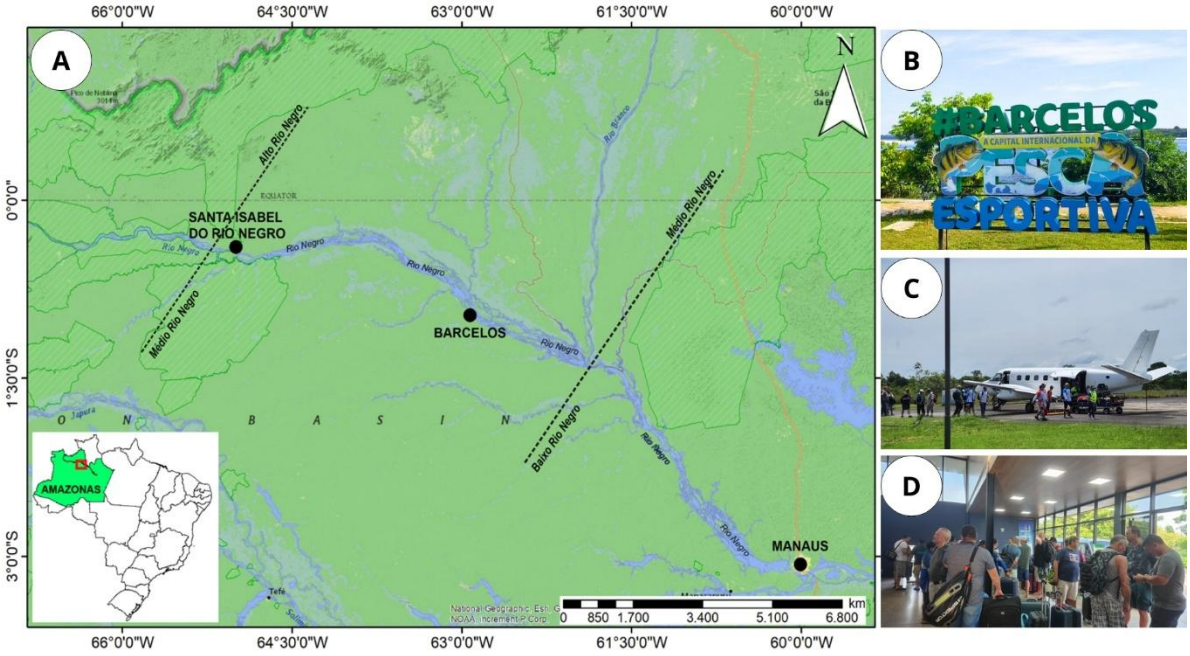

Figura 1 – Área de estudo. A) Localização do médio rio Negro, destacando o município de Barcelos; B) Barcelos, reconhecido como a “Capital Internacional da Pesca Esportiva”; C) e D) intensa movimentação de pescadores brasileiros e estrangeiros durante a temporada de pesca.

Barcelos apresenta características territoriais, ambientais e socioeconômicas que o tornam singular nesse contexto. Com área de 122.445 km², é o segundo maior município do Brasil em extensão territorial (Figura 1A), mas conta com apenas 18.834 habitantes, resultando em densidade populacional de 0,15 hab./km² (IBGE, 2025). A população está distribuída principalmente em comunidades ribeirinhas e indígenas, com forte dependência dos recursos pesqueiros. O município apresenta indicadores que revelam vulnerabilidades: PIB per capita de R$ 8.844,22, IDHM de 0,500 e quase 60% da população vivendo com até meio salário mínimo per capita mensal (IBGE, 2025). O mercado de trabalho formal é restrito (1.316 pessoas ocupadas), com baixa diversificação produtiva, e apenas 8,32% da população tem acesso a esgotamento sanitário (IBGE, 2025). Nesse cenário, a pesca desempenha papel central na organização econômica e social, englobando modalidades de subsistência, comercial artesanal, ornamental e esportiva (Freitas e Rivas, 2026).

No caso da pesca esportiva, a atividade ocorre ao longo de seis meses, com picos de visitação em outubro e novembro, coincidindo com a vazante do rio (Lubich et al., 2023). A espécie-alvo é o tucunaré-açu (*Cichla temensis* Humboldt, 1821), apreciado mundialmente pelo porte e pela força de luta (Lubich et al., 2023). O perfil dos turistas que frequentam Barcelos é majoritariamente masculino (97%), embora haja crescente participação feminina (Lubich et al., 2024b). A atividade é estruturada

em cinco modalidades de hospedagem e operação: acampamentos, barcos-hotel, pousadas, hotéis flutuantes e hotéis de selva, que articulam uma cadeia de serviços envolvendo guias de pesca, cozinheiros, pilotos, operadores turísticos e comunidades locais (Lubich et al., 2023). Apesar de sua importância econômica e social, a atividade também está associada a desafios, como conflitos no uso dos recursos pesqueiros (Sobreiro e Freitas, 2008; Sobreiro, 2015; Vieira et al., 2025), dependência de um único segmento econômico e pressões ambientais.

Embora o médio rio Negro seja amplamente conhecido pela pesca esportiva, há carência de estudos científicos integrados sobre essa atividade. A maioria das pesquisas concentra-se na espécie-alvo, o tucunaré-açu (*Cichla temensis* Humboldt, 1821) (Figura 2), avaliando aspectos como relações filogenéticas (Willis *et al*., 2007), padrões de movimentação de juvenis (Garcez *et al*., 2014) e adultos (Sousa *et al*., 2016), genética populacional (Willis *et al*., 2015), idade e crescimento (Campos *et al*., 2015), ecologia trófica (Aguiar-Santos *et al*., 2018), relações biométricas entre dimensões do corpo e otólito (Mereles *et al*., 2020), estoque pesqueiro (Campos *et al*., 2020) e discriminação de espécies e populações usando morfometria otolítica (Mereles *et al*., 2021). Os poucos estudos que abordam a pesca esportiva na região tratam de temas como conflitos e territorialidade no uso de recursos pesqueiros (Sobreiro e Freitas, 2008; Sobreiro, 20214; Vieira et al., 2025), mortalidade associada ao pesque-e-solte (Thomé-Souza *et al*., 2014; Barroco *et al*., 2018), efeitos da pesca sobre os troféus de tucunaré-açu (Holley *et al*., 2008; Lubich *et al*., 2021) e caracterização da atividade (Lubich *et al*., 2023). Assim, não há informações suficientes para avaliar conjuntamente os três pilares da sustentabilidade (ecológico, econômico e social) da pesca esportiva no médio rio Negro.

tucunaré-açu
(*Cichla temensis* Humboldt, 1821)

Figura 2 – Espécie-alvo dos pescadores esportivos que visitam o médio rio Negro, município de Barcelos: tucunaré-açu (*Cichla temensis* Humboldt, 1821).

Nesse contexto, esta tese busca responder às seguintes questões: i) Qual o status atual do conhecimento sobre a pesca esportiva no Brasil? ii) Qual o valor econômico da pesca esportiva praticada no médio Rio Negro? iii) A pesca esportiva realizada no médio Rio Negro é sustentável? Tendo essas perguntas norteadoras, a tese foi estruturada em três capítulos. O primeiro capítulo apresenta uma revisão sistemática sobre o status atual da pesca esportiva no Brasil. O segundo capítulo analisa a valoração econômica da pesca esportiva no médio Rio Negro, Amazonas. Por fim, o terceiro capítulo realiza uma análise da sustentabilidade da pesca esportiva no médio Rio Negro, Amazonas, abordando de forma integrada os aspectos ecológicos, econômicos e sociais, além da perspectiva dos atores direta e indiretamente envolvidos na atividade.

OBJETIVOS

Geral

Avaliar a sustentabilidade da pesca esportiva realizada no médio rio Negro (Amazonas – Brasil), considerando integradamente aspectos ecológicos, econômicos e sociais.

Específicos

i. Realizar uma revisão sistemática da literatura para investigar, analisar e sintetizar a atual situação e as perspectivas da pesca esportiva no Brasil;
ii. Estimar o valor econômico da pesca recreativa na região do médio Rio Negro;
iii. Avaliar a sustentabilidade da pesca esportiva com base na percepção e perspectivas dos atores diretamente e indiretamente envolvidos na atividade, na região do médio Rio Negro, Amazonas;
iv. Desenvolver e propor recomendações de políticas públicas que promovam a sustentabilidade da pesca esportiva no médio Rio Negro, Amazonas;

BOLETIM DO INSTITUTO DE PESCA
Review Article

Sport fishing in Brazil: the current state

Chiara Lubich[1,2*], Flávia Siqueira-Souza[1,2], Carlos Freitas[1,2]

[1.] Universidade Federal do Amazonas, Programa de Pós-Graduação em Ciência Animal e Recursos Pesqueiros – Manaus (AM), Brazil.
[2.] Universidade Federal do Amazonas, Departamento de Ciências Pesqueiras – Manaus (AM), Brazil.
* Corresponding author: lubichchiara@gmail.com

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Sport fishing in Brazil: The current state

Chiara Lubich[1,2]*, Flávia Siqueira-Souza[1,2], Carlos Freitas[1,2]

[1]Universidade Federal do Amazonas, Programa de Pós-Graduação em Ciência Animal e Recursos Pesqueiros –Manaus (AM), Brazil.

[2]Universidade Federal do Amazonas, Departamento de Ciências Pesqueiras – Manaus (AM), Brazil.

*Corresponding author: lubichchiara@gmail.com

Abstract

Sport fishing has ecological, economic and social importance, but there are few studies that characterize it according to the sustainability tripod. Due to this gap, we present a systematic review of the literature to evaluate the current situation of sport fishing in Brazil. The papers on the subject were systematically evaluated based on quantitative criteria. Additionally, in order to create a list of the species of interest of sport fishers, the survey of 22 papers was carried out regarding the species caught. A total of 70 complete papers published between 1994 and 2021 were included in the study. Since the 90s, publications have increased quantitatively, with the vast majority of studies coming from the south-eastern region of Brazil (39.19%). The papers published discussed, in the majority, the sport fishing carried out in marine environment (55.38%), and the main focus was “fishing and fishers” (30%). Evaluating the sustainability tripod, most of the papers provided only information regarding the ecological aspect (58.57%). About 330 species of marine and freshwater fish of interest to sport fishers were dealt with in the studies. This information reflects the current state of knowledge about Brazilian sport fishing, and can serve as a basis for the management of the activity and the target species used by fishers. Additionally, the present review can serve as an aid for future research on this topic.

Keywords: fishery management; recreational fishing; fishery resources; sustainability.

A pesca esportiva no Brasil: O estado atual

Resumo

A pesca esportiva apresenta importância ecológica, econômica e social, mas são pouco os estudos que a caracterizam segundo o tripé da sustentabilidade. Devido a essa lacuna, apresentamos uma revisão sistemática da literatura para avaliar a atual situação da pesca esportiva no Brasil. Os artigos foram avaliados sistematicamente com base em critérios quantitativos. Por fim, com o objetivo de criar uma lista com as espécies de interesse dos pescadores esportivos, foi realizado o levantamento das espécies capturadas em 22 artigos científicos. Foram incluídos no estudo 70 artigos completos, publicados no período de 1994 a 2021. A partir da década de 90 as publicações incrementaram quantitativamente, sendo a grande maioria estudos oriundos da região Sudeste do Brasil (39,19%). Os artigos publicados em sua maioria abordam sobre a pesca esportiva realizada em ambiente marinho (55,38%), e cujo foco principal foi sobre a “pesca e os pescadores” (30%). Avaliando o tripé de sustentabilidade, a maioria dos artigos trazia apenas informações sobre o aspecto ecológico (58,57%). Cerca de 330 espécies de peixes marinhos e de água doce de interesse dos pescadores esportivos foram levantadas nos estudos. Essas informações refletem o estado atual de conhecimento sobre a pesca esportiva brasileira, e podem servir como base para gestão da atividade e das espécies alvos utilizadas pelos pescadores. De outra forma, a presente revisão pode servir de auxílio para as futuras pesquisas realizadas nesta temática.

Palavras-chave: gestão pesqueira**;** pesca recreativa; recursos pesqueiros; sustentabilidade.

INTRODUCTION

Sport fishing is a term used , in general, to define the capture of fish for fun, where the individual does not use the fishery resources to meet their basic nutritional needs and the animals caught are usually neither sold nor traded in the export, domestic or black market (FAO, 2012; Pitcher and Hollingworth, 2002a).

Although this universal definition exists, in Brazil, this practice is called amateur fishing, which is divided into recreational and sport fishing, as established in Brazilian federal legislation (11.959/2009 and 4/2009). The main difference between these two

forms is in the catch quota of fish for recreational fishing. While, in sport fishing, it is mandatory to practice catch and release, and keeping fish after catching them is prohibited (ICMBIO, 2009). In the present study, the terminology used to refer to the fishing activity that aims to catch fish as a recreational activity will be that of “sport fishing”.

Sport fishing is one of the most popular tourism and leisure activities in the world and is widely practiced in many countries (Cowx, 2002; Cooke and Cowx, 2004; FAO, 2012), such as the United States (Muoneke and Childress, 1994; Siepker et al., 2007), Australia (Mcleay et al., 2002; Broadhurst et al., 2005), Canada (Brownscombe et al., 2014), European countries (Aas et al., 2002; Lloret et al., 2008; Veiga et al., 2011; Tunca et al., 2016; Pita et al., 2018; Martínez-Escauriaza et al., 2020) and Brazil (Catella, 2004; Fabri, 2005; Holley et al., 2008; Peixer & Petrere Júnior, 2009; Thaissa Sobreiro et al., 2010; Barcellini et al., 2013; W. Barrella et al., 2016; Walter Barrella et al., 2016; Alves-Junior et al., 2020). This activity is also recognized as being of ecological importance (because it has an impact on the environment and food chains, as well as promoting environmental awareness), economic (because the market is worth billions of US$) and social (because it is a traditional and cultural activity, which is passed on between generations) (Pitcher and Hollingworth, 2002a; Cooke and Cowx, 2004; FAO, 2012; Fenichel et al., 2013).

These three aspects together make up the sustainability tripod that is internationally known as the triple bottom line (TBL) and, by using the ecological or environmental, economic and social lines, it provides a framework to measure the performance of the activity and its success (Elkington, 1997). Considered a benign activity, sport fishing has importance within the lines of the tripod (Pitcher and Hollingworth, 2002b). However, there are few studies that characterize it according to the criteria proposed by the TBL (Arlinghaus and Cooke, 2009).

Due to this gap, we present a systematic review of the literature to evaluate the current situation of sport fishing in Brazil and discuss the following questions:

i) what is the temporal trend of publications on sport fishing in Brazil?

ii) how many papers are published per geographical region?

iii) what types of environments were studied? iv) what are the main focuses of study in the publications?

v) which aspects of sport fishing have been studied the most in relation to sustainability (ecological, economic and social)?, and

(vi) what species are of interest to sport fishers?

MATERIALS AND METHODS

Search system

Considering the time interval from 1945 (limit on search platforms) to June 2021, a systematic keyword-based review was carried out using four databases: Google Scholar (scholar.google.com.br), Periodicos CAPES (www-periodicos-capes-gov-br), Scopus (scopus.com) and Web of Science (apps-webofknowledge). In the Google Scholar and Periódicos CAPES platforms, five search terms were used in Portuguese since it is a platform that searches for papers published in Portuguese (Figure 1), while, in the Scopus and Web of Science platforms, in order to locate papers published in English, the same terms were searched in English, totaling 10 search terms (Figure 1).

Selection criteria

The searches carried out on the platforms resulted in 648 publications, originating from papers, end of course papers (monographs, dissertations and theses), book chapters and summaries of work presented at scientific events (Figure I: 1). Following this, a refinement in the search was carried out on the basis of a time interval, language and type of document, which resulted in 191 complete papers (457 papers were removed) (Figure I: 1). The remaining papers were exported to a digital spreadsheet (Microsoft® Excel® 2019) for organization and final refinement. At this stage, duplicated papers were excluded, and the selection and permanence of the paper for further analysis was carried out based on the reading of the title and abstract. Finally, 121 papers were excluded, leaving 70 complete papers for analysis (Figure I: 1).

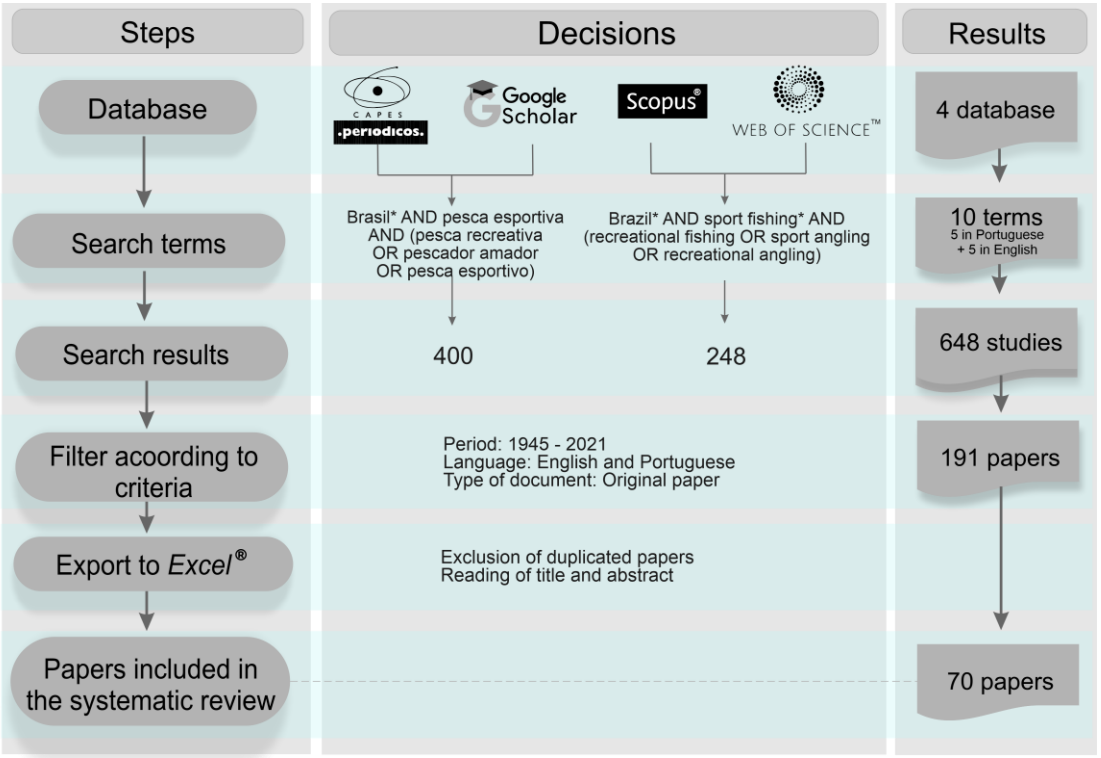

Figure I: 1 – Flow chart with stages, decisions and results of the systematic search of publications on sport fishing in Brazil, in the period from 1945 to 2021. Boolean operators used: AND, OR and asterisk (*).

Collection of information

The papers were systematically evaluated based on quantitative criteria (Table I: 2) in order to summarize, evaluate and present the current situation of sport fishing in Brazil. Some papers contained information from two or more Brazilian states, so the data presented in some analyses may not necessarily represent the amount of complete papers incorporated in the study.

In order to obtain information on the aspects that comprise the sustainability of an activity, i.e., the ecological, economic and social aspects, each paper was organized into six categories (Table I: 2).

Table I: 1 – Categories established for the evaluation of papers on the subject of Brazilian sport fishing published between 1945 and 2021.

Category	Description
Publications	
Temporal distribution of publications on Brazilian sport fishing	Number of publications per year
Number of publications according to Brazilian geographic region	Location of the study described in the title and verified in the Material and Methods section
Study environment	
Marine	Estuary, bay, beach, coastal lake and reef
Freshwater	Lake, “fish and pay” nursery, reservoir and river
Main focus of the paper	
Eye injuries	Accidents occurring during sport fishing
Fish stocks	Assessment of the fishing stock using sport fishing data
Introduction of new species	Species introduced for sport fishing
Fishing	Fishing techniques
Fishers	Social and ecological (socio-ecological) aspects involving sport fishers, such as demographic aspects, species caught and fishing areas
Fishing and fishers	Fishing techniques and social and ecological (socio-ecological) aspects of sport fishers
Catch and release	Mortality after catch and release
Economic potential	Assessment of the economic value of sport fishing
Live bait production	Production of foraging species for sale as live bait
Water quality	Assessment of water quality where sport fishing is carried out
Sustainability of the activity	Assessment of the sustainability of sport fishing, considering the ecological, economic and social aspects of the activity

Table I: 2 – Category established for grouping papers on the subject of Brazilian sport fishing published between 1994 and 2021.

N	Category	Description
1	Ecological	Contains information about the environment and the species caught.
2	Economic	Contains information about the economic value of sport fishing.
3	Social	Contains information about demographic and social aspects of sport fishers, as well as social issues within the activity of sport fishing, such as accidents in the practice of the activity.
4	Socio-ecological	Deals jointly with social and ecological aspects.
5	Socio-economic	Deals jointly with social and economic aspects.
6	Ecological, economic and social	Deals jointly with ecological, economic and social aspects.

A survey of all the species caught by sport fishers was carried out with the aim of creating a list of the species of interest for sport fishing aficionados. Using the

FishBase database (www.fishbase.se), information on the maximum length, environment of origin and trophic level of each species was included, as well as the taxonomic classification, which was conducted according to Van der Laan et al. (2021).

The species were grouped into three categories in relation to the environment of origin: i) freshwater: freshwater species that migrate only in fresh water (potamodromous); ii) marine: marine species that migrate only in salt water (oceanodromous) and iii) freshwater-marine: species that use both environments during their life cycle (diadromous, anadromous, catadromous and amphidromous). The trophic level, obtained from the Fishbase website, was used to group the species into three trophic categories: carnivorous/piscivorous, herbivorous and omnivorous (Pauly and Palomares, 2000).

Data analysis

Based on the quantitative criteria, the data extracted were evaluated using descriptive statistics (mean and standard deviation), absolute frequency (N) and relative frequency (%) (Zar, 2010).

RESULTS

A total of 70 complete papers were included in the study, which addressed the sport fishing activity in Brazil, and had publication dates from 1994 to 2021 (Appendix 1[3]). In general, the number of publications has been increasing since the first paper published in 1994, with the years 2016 (N=8) and 2020 (N=12) presenting the largest quantities of publications (Figure I: 2).

The first paper found during the systematic review, published in 1983 in the Journal Boletim de Ciência do Mar (Appendix 1[1]), predates the earliest date of the papers incorporated in the study. However, it was not incorporated into the study since online access to it was unavailable. Thus, the first paper considered in the study was the one published in 1994.

Since the 90s, several studies have been developed in different Brazilian geographical regions (Figure I: 3A and 3B). Our results indicate that most of the papers

[3] O apêndice 1 não foi incluído neste documento devido ao tamanho do arquivo (9 páginas; 136 KB), com o objetivo de evitar que o arquivo final se tornasse excessivamente extenso. Contudo, o Apêndice 1 completo está disponível através do link fornecido pela Revista Boletim do Instituto de Pesca (https://institutodepesca.org/index.php/bip/article/view/1745/1573).

published come from the south-eastern region (39.19%, **Erro! Fonte de referência não encontrada.**A). While, the mid-western region presented the lowest amount (9.46%, Figure I: 3A).

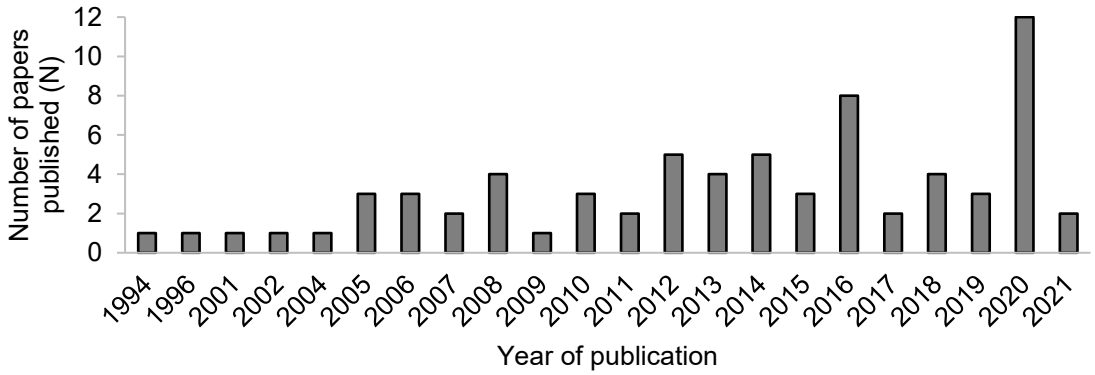

Figure I: 2 – Temporal pattern of publications of papers on sport fishing in Brazil, considering 22 years of data.

At the state level, São Paulo (32%) is the state with the highest concentration of published papers, followed by Amazonas (10.67%), Paraná (8%) and Bahia (6.67%) (Figure I: 3B). There were no published papers on studies evaluating sport fishing in seven Brazilian states, nominally: Acre, Alagoas, Amapá, Distrito Federal, Piauí, Rondônia and Tocantins (Figure I: 3B).

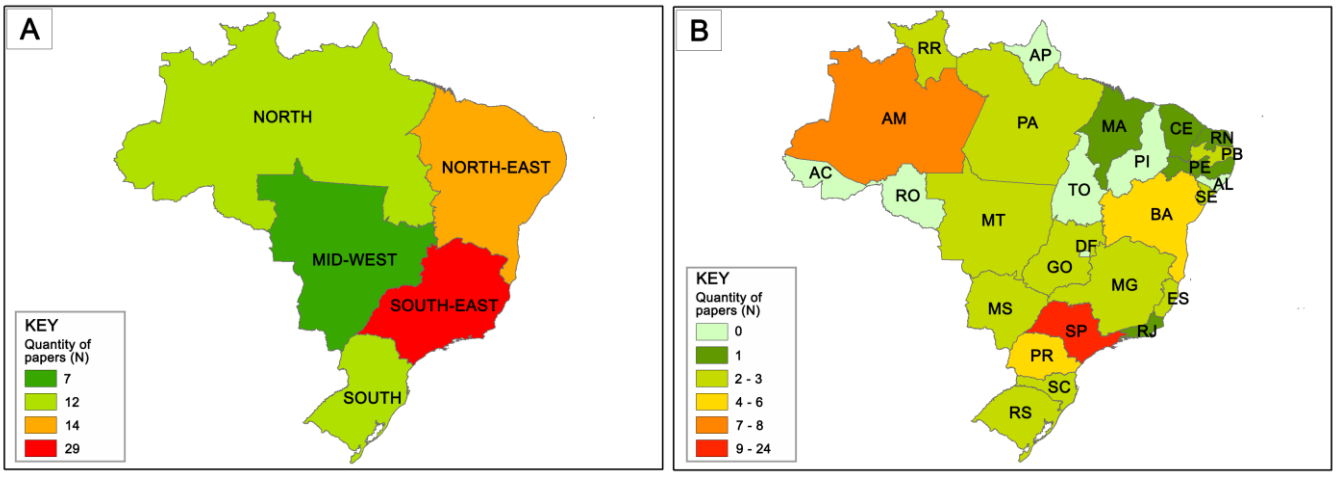

Figure I: 3 – Number of papers published on the subject of Brazilian sport fishing, considering: A) geographic regions and B) Brazilian states. There is no information regarding review papers that deal with sport fishing at a countrywide level (number of review papers=6).

Just over half of the papers published analyzed sport fishing in the marine environment (55.38%), with emphasis on the estuary region (41.67%) and the coastal region (33.33%) (Figure I: 4A). However, in freshwater environment most of the papers

conducted studies on sport fishing in rivers (68.97%) and in “fish and pay” nurseries (17.24%), these are places where fishers pay to catch fish that are being raised in nurseries located on private property (Figure I: 4B).

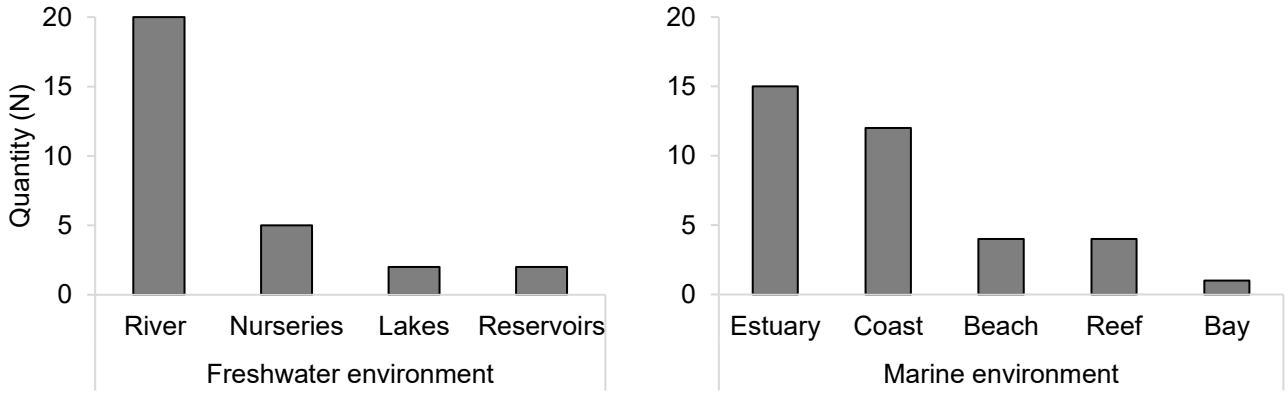

Figure I: 4 – Environments evaluated in papers published between 1994 and 2021 on the subject of Brazilian sport fishing. This quantity does not contain information regarding review papers (review papers=6).

The main focus of the papers was “fishing and fishers” (30%), followed by “fishing stock” (28.57%) (Figure I: 5). When evaluating them according to the sustainability tripod (ecological, economic and social), most of the papers were focused on the ecological aspect of the activity (58.57%), followed by the socioeconomic (18.57%) and social (8.57%) aspects (Figure I: 6). Only two papers jointly addressed two aspects of the sustainability of sport fishing, both of which were literature review papers (2.86%; Figure I: 6).

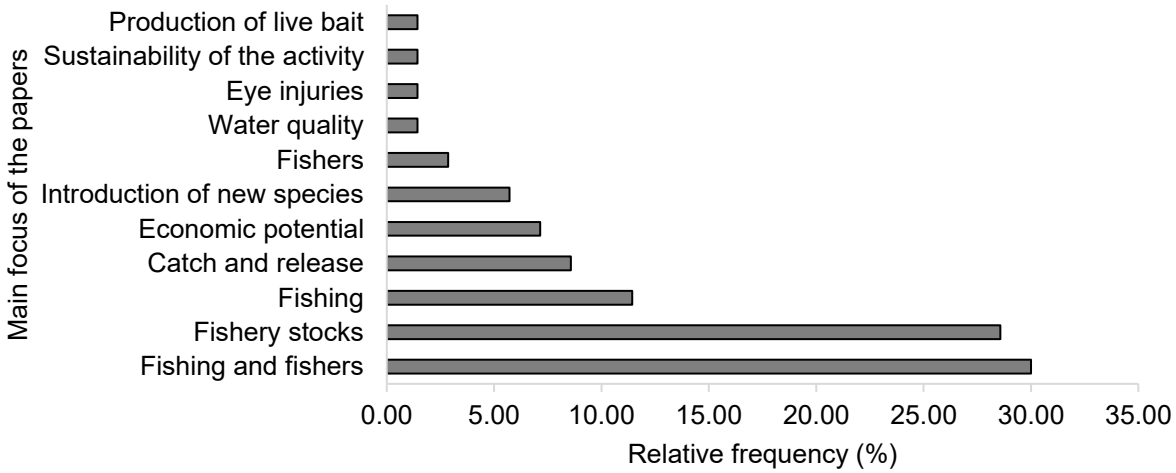

Figure I: 5 – Focal theme of papers published between 1994 and 2021 on the subject of Brazilian sport fishing.

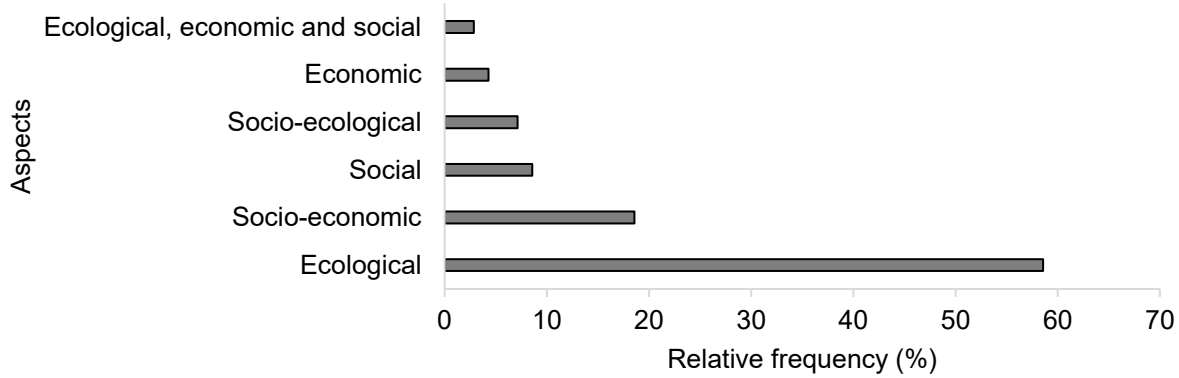

Figure I: 6 – Main aspects of the sustainability of Brazilian sport fishing addressed in papers published between 1994 and 2021.

In all environments evaluated, 330 species of fish of interest to sport fishers were found. Of these, 286 species were identified at the lowest taxonomic level, and belong to 30 orders and 80 families (Appendix 2[4]). The remaining species (44) were identified only at the genus level. The results show that most species are of marine origin (49%), followed by those of freshwater origin (43.7%), and 7.3% inhabit freshwater-marine environments (Table 3).

The species of the families Carangidae (14.3%), Sciaenidae (11.4%), Serranidae (7.9%) and Scombridae (7.9%) aroused greater interest in sport fishers who performed the activity in marine environments. In freshwater environments, representatives of the families Cichlidae (20.8%), Pimelodidae (15.2%) Serrasalmidae (12.8%) and Anostomidae were the main targets (12%) (Appendix 2[2]).

Regarding the trophic level, the target species of sport fishing were mainly carnivorous/piscivorous (40.7%) and omnivorous (40.4%), followed by herbivorous (18.9%). When evaluated according to the environment of origin, the sport fishing species of marine origins were mainly omnivores (47.4%), followed by carnivores/piscivores (46%) and herbivores (6.6%). In freshwater, the species were mostly herbivorous (34.4%), carnivorous/piscivorous (33.6%) and omnivorous (32%) (Table I: 3).

[4] O Apêndice 2 não foi incluído neste documento devido ao tamanho do arquivo (20 páginas; 234 KB), com o objetivo de evitar que o arquivo final se tornasse excessivamente extenso. Contudo, o Apêndice 2 completo está disponível através do link fornecido pela Revista Boletim do Instituto de Pesca (https://institutodepesca.org/index.php/bip/article/view/1745/1574).

Table I: 3 – Quantities of the species of interest of Brazilian sport fishing according to environment and trophic category. N= number of species.

Environment	N	Trophic category		
		carnivore/piscivore (n)	herbivore (n)	omnivore (n)
Freshwater	125	41	42	39
Marine	140	63	9	65
Freshwater/marine	21	10	2	9
Total	286	114	53	113

DISCUSSION

The number of publications on sport fishing in Brazil since 1994 has increased since the first decade of publication, considering 1945 as the first year of the survey. This increase may be related to the attention that the activity has received, especially after the emergence of conflicts with other users, since different actors use the same resources, whether spatial or fishing (Sobreiro and Freitas, 2008; Sobreiro et al., 2010). Moreover, the growth of activity and its economic importance in different environments and Brazilian states (Albano and Vasconcelos, 2013) are also perceived, since the activity involves an extensive production chain, which includes the air travel, travel agencies, fishing tourism companies, clothing and gear, among others.

Although the studies on sport fishing are centralized in the south-eastern and north-eastern regions, they were also conducted in other regions of Brazil (Figure 3A). This centralization may be related to the ease of access to the locations as it is classed as urban fishery, i.e., one carried out near cities and urban centers (Albano and Vasconcelos, 2013). These places are safe and have infrastructure for carrying out the activity, which is considered a great cost benefit since fishers can access the places by land and return to their homes on the same day, spending only a few hours fishing (Silva et al., 2016; Alves-Junior et al., 2020). In the municipality of Santos, São Paulo state, most of the fishers who use the fishers' deck (fishing spot known among users) reside in the municipality itself (50%), or within the limits of the state of São Paulo (50%), a situation that facilitates travel by land via automobile, bicycle, motorcycle or bus (Barrella et al., 2016). However, fisheries are usually also carried out in beach environments (Freire et al., 2014; 2017) and from fishing platforms (Barrella et al., 2016; Alves-Junior et al., 2020).

On the other hand, in a freshwater environment, the activity is mainly carried out on rivers, such as the central region of the Negro River basin, municipality of

Barcelos, Amazonas state, which is in the style of tourist sport fishing due to the distance of the region from large urban centers (Albano and Vasconcelos, 2013). These fisheries are carried out on boats, and the dynamics are more complex. Fishers typically buy packages for a period of seven days, which cost around US$ 3,000 during the main fishing season (Freitas and Rivas, 2006). According to Shrestha et al. (2002), the practice of tourist sport fishing has a higher value than urban sport fishing, since many costs include flights and travel to the fishing area, as well as the fishing package, which has full accommodation, fishing guides and fisheries logistics.

Regarding the focus of the papers, the results presented “fishing and fishers” as the main topic of research in Brazil. These papers, in general, mainly provide information on the characteristics of sport fishing, such as fishing sites, species caught, length of species caught and fishing licenses, as well as socio-economic aspects of fishers, such as gender, professions, equipment and baits used. Data regarding the fishers is also mentioned, such as the observation that the majority are male (90%), ranging in age from seven to eighty-eight years (43.66±27.28) (Pereira et al., 2008; Peixer and Petrere Júnior, 2009; Barcellini et al., 2013; Tsuruda et al., 2013; Freire et al., 2014; Barrella et al., 2016; Silva et al., 2016; Freire et al., 2017; Felizola-Freire et al., 2018; Alves-Junior et al., 2020), and have a monthly income that exceeds US$ 352 (Schork et al., 2010; Freire et al., 2012; Abreu et al., 2015).

The theme “sustainability” was the subject of analysis in several areas of research that involve the relationship of people and the environment (Elkington, 1997). Most of the papers on sport fishing in Brazil are aimed at presenting the ecological aspects of the activity, though leave out the evaluation of the cultural, social and economic impacts that it exerts. The only two of the studies found addressed the three aspects together, and discussed the absence of management and incentives for the activity. These pointed to problems such as i) lack of training courses for tour guides, ii) lack of a development plan of the activity, iii) lack of supervision, and iv) absence of environmental education initiatives involving sport fishers (Albano and Vasconcelos, 2013; Vitório and Vianna, 2016).

Aris et al. (2017) carried out an evaluation of economic, social and management aspects of marine recreational fishing in Indonesia, and concluded that the activity presented a high score in the sustainability index, but with less evidence for the environmental/ecological aspect. In Brazil, as yet, there are no published studies that jointly evaluate the aspects of the sustainability tripod (economic, ecological and

social), or provide an indication of the real situation of the activity. However, sport fishing appears to be sustainably economical, as, according to Shrestha et al. (2002), the value of sport fishing for the Brazilian Pantanal alone fluctuates between US$ 35-56 million annually.

Among the papers with an ecological focus, one of the most discussed topics is the evaluation of fish stocks, mainly in reef areas, as well as the effect of species introduction, either as a target species for sport fishing or for use as bait. Assessments of stocks of reef species that are exploited in sport fishing have received attention, since species such as groupers, snappers and parrot fish can be considered vulnerable due to their biological characteristics (large body size, late maturation and seasonal reproduction, shoal formation and absence of fear of humans) (Samia et al., 2019). As a consequence, some stocks have shown signs of overexploitation (Oliveira Freitas et al., 2011; Moura et al., 2013; Giglio et al., 2020).

Another factor of great importance associated with the ecological aspect of sport fishing is the introduction of species. In Brazil, species introductions are the result of formal stocking programs that are supported by the State and are due to the perceived lack of adequate native species, but may be due to cultural imperialism or illegal stocking with the aim of encouraging sport fishing in certain locations (Vitule, 2009; Vitule et al., 2009). Several species, such as *Salminus brasiliensis* (Cuvier 1816) (Vitule et al., 2014), *Micropterus salmoides* (Lacepède 1802), *Erythrinus erythrinus* (Bloch & Schneider 1801), *Hoplerythrinus unitaeniatus* (Spix & Agassiz 1829) (Britton and Orsi, 2012), *Pygocentrus nattereri* Kner 1858, *Astronotus ocellatus* (Agassiz 1831), *Clarias gariepinus* (Burchell 1822), *Oreochromis niloticus* (Linnaeus 1758), *Hoplosternum littorale* (Hancock 1828), *Colossoma macropomum* (Cuvier 1816) (Latini et al., 2004) and the species of the genus *Cichla* (Latini et al., 2004; Pelicice and Agostinho, 2009; Britton and Orsi, 2012; Ferraz et al., 2019;) have been reported in basins other than those of their origin. The introductions of these species can quickly result in a significant decline in the diversity of native fish species and, therefore, are a potential threat to local biodiversity (Pelicice and Agostinho, 2009; Vitule, 2009; Vitule et al., 2009; Britton and Orsi, 2012).

Another problem reported in the literature is the use of fish eggs as bait. Machado et al. (2020) cite that, in the south-eastern region of Brazil, sport fishing of *Genidens barbus* (Lacepède 1803) is carried out with eggs of the same species as natural bait. The adoption of this practice can intensify the pressure of fishing on their

populations, and the use of other species as bait can also cause indirect introduction to the environment and affect the way of life of fish.

Many species are the target of sport fishing. Zeinad and Prado (2012) list 114 species of freshwater fish and Anon (2015) cites that approximately 60 species of marine fish are of interest to fishers. Our results show the existence of 286 species that are of interest to sport fishers, and 44 more species that have been identified only at the genus level. Sport fishing involves the catching of fish of different classes, including chondrichthyans (sharks and rays) and actinopterygians (fish with radiated fins). Although there are laws that prohibit the capture, transport, storage, management, processing and marketing of species classified in categories such as critically endangered (CR), endangered (EN) and vulnerable (VU), and those constantly included in the official National List of Endangered Species of Fauna-Fish and Aquatic Invertebrates (MMA No. 445/2014; MMA No. 98/2015, and MMA No. 163/2015), some of these species, such as *Megalops atlanticus* Valenciennes 1847 (VU), *Brycon insignis* Steindachner 1877 (EN), *Brycon orbignyanus* (Valenciennes 1850) (EN), *Genidens barbus* (Lacepède 1803) (EM), *Sciades parkeri* (Traill 1832) (VU), *Scarus trispinosus* Valenciennes 1840 (EM), *Thunnus thynnus* (Linnaeus 1758) (CR) and *Makaira nigricans* Lacepède 1802 (EN), have been cited in the papers as being caught and/or making up part of the landings of sport fishers.

In general, as a result of this review, the absence of papers with the main objective of evaluating the sustainability of sport fishing and which consider the tripod (ecological or environmental, economic and social) is evident. The only two studies found that addressed the subject during the systematic review were review papers. Considering that the study was conducted in a universe of 22 years of scientific publication on the subject, it is recommended that new studies should take into account the sustainability tripod, since this information can be useful for activity management. This is mainly due to fact that the use of resources is shared by different users who have different objectives, as is the case of commercial and sport fishing, which in some regions share the same fishing sites and same species with different objectives for the fish caught, culminating in greater pressure of use on the resource.

The information presented here reflects the current state of studies and knowledge about Brazilian sport fishing, and can serve as a basis for the management of the vulnerable species that are used by fishers and the activity, as well as an inspiration for future research that may be carried out in relation to this theme.

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CAPÍTULO II – The recreational fisher's behavior and the value of amazonian recreational fishery

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Autores: Chiara Lubich, James Kahn, Flávia Siqueira-Souza e Carlos Freitas

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The recreational fisher's behavior and the value of amazonian recreational fishery

A B ST R AC T

Objective: The aim of this study was to perform the first estimate of the economic value of recreational fishing in the Amazon basin.

Methods: The questionnaires applied were aimed at assessing the demographic and socioeconomic profile of the fishers, in addition to their points of view on spending on fisheries and the willingness to pay for the conservation of peacock bass (*Cichla* sp.) in the middle Rio Negro, Amazon basin. The travel cost method (TCM), contingent valuation method (CVM), were employed to measure economic value.

Results: The TCM revealed a positive relation between the cost of fishing packages and the desire to fish. An average estimate of total social welfare of US$49,228,286.61 per year was obtained, with a lower bound estimate of US$21,847,435.43 and upper bound estimate of US$80,496,514.81. The CVM model showed that there is an increase in willingness to pay related to the size of the peacock bass.

Conclusions: The proper approach to recreational fishing policy must consider both fish size and environmental conservation, aiming to provide lasting benefits for the participants, the local communities and the linked forest/aquatic ecosystem. Additionally, take into account the estimated value of the recreational fishery in the middle Rio Negro, a proportion of the profits made from fishing packages could be allocated to financing community projects.

K EY WOR DS: consumer surplus, economic impact, management, recreational fishing, social well-being, travel cost method

L A Y S U M M A R Y

Recreational fishing in the Rio Negro, Amazon, has high economic value but is not well measured. This study estimates its impact, showing that fishing costs affect demand and fishers are willing to pay more for larger peacock bass conservation. Sustainable policies should balance fish size and conservation, benefiting communities and ecosystems.

I N T RODUCT ION

Recreational fishing is an activity that is carried out by approximately 350 million people in various parts of the world and provides leisure and well-being to the participants in this activity (Arlinghaus et al., 2019). In addition, this type of fishing can increase local and regional economic development and support small and medium-sized enterprises, especially those linked to tourism based on renewable natural resources (Moksness et al., 2011; Stensland, 2010).

In Brazil, recreational fishing is among the segments of tourism with the highest economic growth. According to the latest estimate by SEBRAE (2023), in 2019, fishing tourism generated US$201,207,243.50 in expenditures. This large sum is due to the emergence of specialized segments to meet the demands of the participants in the activity. According to Franquesa et al. (2004) and Schork et al. (2010), the most prominent expenditures associated with recreational fishing were boat trips, specialized equipment, hotels and restaurants.

In Brazil, although recreational fishing is growing, information on the economic aspects of the activity is still limited and centralized in government institutions. Although the activity boosts some sectors, there are few studies on the economic value of the activity in the country (Lubich et al., 2023). Existing economic estimates are restricted to the midwestern regions, mainly the Brazilian Pantanal (Massaroli et al., 2021; Shrestha et al., 2002), and to the southeast, on the Mogi-Guaçu River (Peixer et al., 2011), most likely because they are more populous and easily accessible regions.

The Amazon region has been highlighted as an important location for Brazilian recreational fishing (Lubich et al., 2023) due to the abundance of large peacock bass (*Cichla* sp.), a species that has attractive characteristics for the recreational fisher, especially in the blackwater river basins (Kullander, 2003). The middle Rio Negro region is the main reference point for recreational fishing in the Amazon and attracts fishers from all over the world, who come in search of the ferocity and exuberance of the speckled peacock bass (*Cichla temensis*) (Freire et al., 2016; Freitas & Rivas, 2006; Lubich et al., 2023).

During the season, fishers who visit the middle Rio Negro region spend, on average, US$ 3,000 (monetary value corresponding to US$4,600.00 in 2024) in a seven-day period (Freitas & Rivas, 2006). Annually, the number of recreational fishers who visit the municipality of Barcelos is around 1,400 to 1,800

individuals, which gives an approximate value of US$5 million, which is almost 10% of the GDP of the municipality that serves as a base for fishing operations (Holley et al., 2008).

Although these figures are noteworthy, they are measures of expenditures, not economic value, there are still no studies that link the economic value of recreational fishing to environmental services. The economic studies that have been developed used different economic approaches, from simple analyses, such as estimation based on individual spending per fishing day (Massaroli et al., 2021), up to more complex approaches, with the use of economic valuation models such as the travel cost method (TCM) (Shrestha et al., 2002) and the contingent valuation method (CVM) (Peixer et al., 2011). According to Brownscombe et al. (2019), the valuation of the activity is extremely important, as it provides economic justification for investments in management activities and conservation of fish stocks. In addition, the authors suggest that there is potential to involve fishers in these activities, through education and information, as a perceived decrease in catches correlates with the willingness to pay to improve the situation.

This study aims to estimate the economic value of recreational fishing in the region of the middle Rio Negro using the techniques of TCM and CVM. Using the TCM, we tested the hypothesis that the desire to fish in the middle Rio Negro is not influenced by demographic, socioeconomic and fishing-related variables and the environment. The CVM model uses an open-ended willingness to pay question to test that the hypothesis that anglers are willing to pay for an experience with catch of the known as "trophies" (Holley et al., 2008; Lubich et al., 2021; 2023), Consequently, we proposed three willingness-to-pay (WTP) scenarios based on peacock bass size: small (≤30 cm), medium (31 to 50 cm) and large (≥51 cm). We tested the hypothesis that the socioeconomic aspects of fishers, as well as factors related to fishing and the environment, do not influence the value of WTP for the conservation of peacock bass stocks in the region of the middle Rio Negro, Barcelos, Amazonas.

M ET H O D S

Study area

In the state of Amazonas, the middle Rio Negro is the main destination for recreational fishers, and 22 rivers are utilized for the pursuit of peacock bass (*Cichla* sp.) (Lubich et al., 2023; 2024). Therefore, the study was conducted in the region of the middle Rio Negro, with the city of Barcelos, Amazonas, as the focal point (Figure II: 1). Barcelos is located on the right bank (when looking downstream) of the Rio Negro, 490 km up-river from the capital Manaus.

The rivers of this region have typically black waters (cola colored) (*senso* Sioli, 1984), with an estimated 1,233 species of fish already described (Jézéquel et al., 2020). Among the different types of environments in the region, sandbanks are the most common and are used by peacock bass (*Cichla* spp.) for foraging (Hoeinghaus et al., 2003; Winemiller et al., 1997), a situation that makes them the most exploited places by recreational fishers in the fishing season.

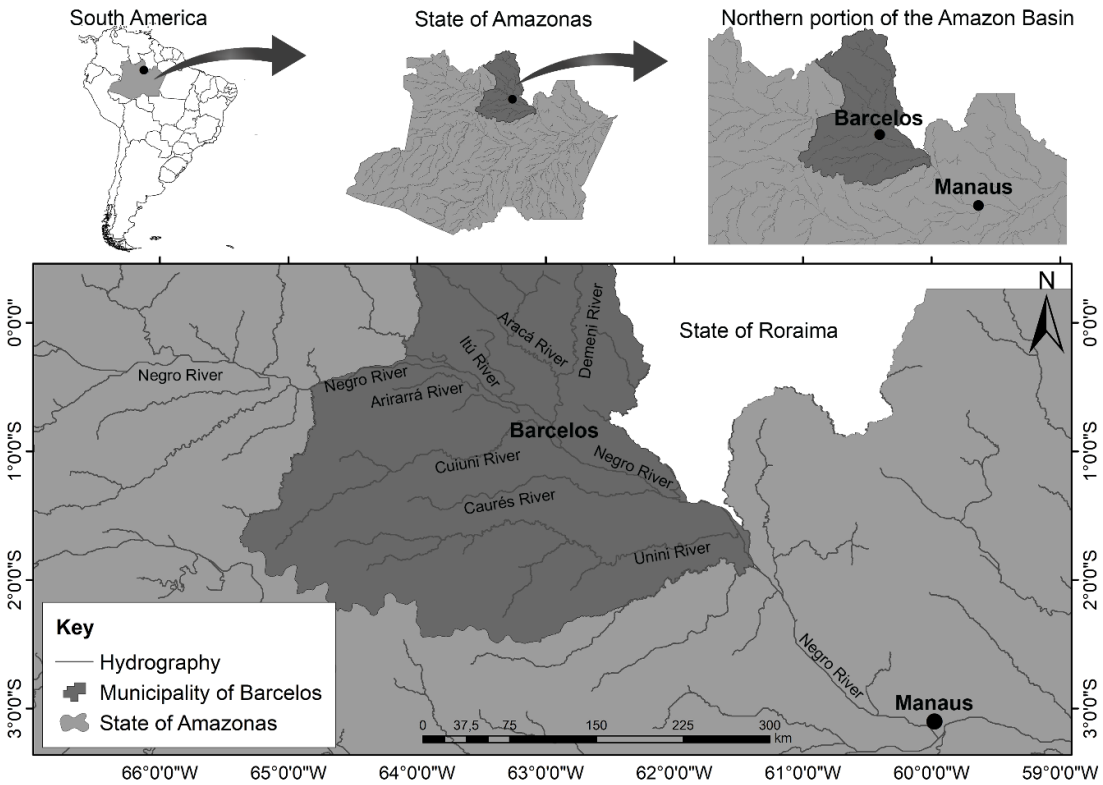

Figure II: 1 The study area showing the main rivers used for recreational in the municipality of Barcelos, where the questionnaires were applied to recreational fishers operating in the middle Rio Negro region, located in the northern portion of the Amazon basin, Amazonas, Brazil.

Data collection

The data were collected in the city of Barcelos, Amazonas, via the application of 58 semi-structured questionnaires that were applied to recreational fishers in the period from October 7 to November 5, 2022. This period reflects the fishing season, which occurs from October to March of each year.

The questionnaires presented demographic, socioeconomic and fishing-related questions (Table II: 1; Appendix A), with the aim of identifying the variables that influenced the number of visits to go fishing in the middle Rio Negro and the willingness of users to pay an environmental compensation fee for the conservation of peacock bass stocks.

Obtaining the average cost (in US$) of the trip with a plane ticket (ATC variable)

To get to the place where they embark for the fishing, fishers need to buy tickets to Manaus, capital of the state of Amazonas, and then board a small aircraft to Barcelos. The values of the ATC variable were obtained by surveying the average values of airline tickets in economy class, in the month of October, 2022, on the Skyscanner platform (www.skyscanner.com.br), which offers a travel metasearch service, i.e., it is a web 2.0 search system that allows the user to search in several simple search engines simultaneously, and has data from the most important airlines. For cities without a direct flight to Manaus, the search was performed using the city of Brasilia as a stopover, and the values were added. The month of October was defined because, according to Lubich et al. (2023), it is the month with the highest intensity of recreational fishing on the middle Rio Negro.

Table II: 1 – Definitions and codes of the variables used in the regression model. WISHTRAVEL represents the response variable of the travel cost method (TCM) model; WTP represents the response variable of the contingent valuation model (CVM).* denotes binary variables.

Variables	Definition
WISHTRAVEL[1]	**Response variable –** "Ideal" number of times you would like to fish in Barcelos per year
WTP[2]	**Response variable –** Willingness to pay a fee for the conservation of peacock bass stocks in Barcelos (three scenarios) No willingness to pay = 0; willing to pay = 1 Value of willingness to pay (US$
Demographic and socioeconomic information	
AGE	Age of fishers
EDU*	Do you have a university degrees? (No = 0, Yes = 1)
INCOME	Average income per hour (US$)
NATIONALITY*	Nationality: (Brazilian = 0; Foreign = 1)

Fishing related information	
ATC	Average cost, with plane ticket (US$)
ABUN	Trip motivated by the abundance of peacock bass (No = 0; Yes = 1)
DAY	Duration of fishing trip (in days)
ENVIRONPERCEP*	Degree of perception of environmental degradation in the middle Rio Negro. None or low = 0 / medium and high = 1
EXPF	Fishing experience (in years)
FISHPAC	Fishing package cost (US$)
NAT.AM*	Travel motivated by nature/Amazon (No = 0; Yes = 1)
PURCHASEF	Average annual expenditure on the purchase of fishing equipment (including garments)
TRIPS	Number of fishing trips in the last 12 months
TROPHY*	Trip motivated by catching trophy fish (No = 0; Yes = 1)
TUCU*	Peacock bass motivated trip (No = 0; Yes = 1)

The cost of tickets from Manaus to Barcelos were set at US$201.21/fisher since the flights are chartered and private, this being the average cost of the ticket/fisher. The transformation of the values of Brazilian reais (R$) to US dollars (US$) was set at US$1.00 = R$4.97, according to our consultation of the exchange rate on August 16, 2023 (Google Finance, 2023 – www.google.com/finance/).

Removing the variable monthly income (US$) from the models

A correction needed to be made regarding the use of income as an economic indicator in the study. During the application of the questionnaires, some interviewees (Brazilians) questioned the relationship between the question on monthly income and the Federal Inland Revenue Service of Brazil, even after the explanation that the data did not have a link and that the purpose was exclusively scientific and academic, many seemed skeptical. In a similar study, Donfouet et al. (2011) also faced similar questions when investigating the willingness to pay among community members in rural areas of Cameroon, leading them to exclude income data from the analysis. In addition, studies indicate that respondents often show a certain hostility towards questions about their assets and income, resulting in biases in the answers (Chaudhry & Tewari, 2006; Donfouet et al., 2011; Moore et al., 2000). Due to these problems, associated with the variable income, we chose not to include this variable in the economic models. This omission is not too important, since the high cost of the

fishing experience means that the sample Is largely limited to middle class and high income people. The variable FISHPAC, which represents the cost of the fishing package (in US$), provides an indication of the purchasing power of the fisher and is associated with the variable income.

Data analysis

Descriptive analysis was performed to estimate amplitude, mean and standard deviation of the variables (Zar, 2010). All the analyses were developed using R software version 4.3.1 (R Core Team, 2023).

TCM model

To test the hypothesis that the desire to fish in the middle Rio Negro is not influenced by demographic, socioeconomic and fishing-related variables and the environment, we used the responses of 35 fishers who fished in the middle Rio Negro region once or more than once. The 23 interviewed fishers who were visiting the region for the first time were not included. We ran a logistic model, with Poisson distribution, the following predictive variables: AGE, ATC, DAY, EDU, EXPF, FISHPAC, PURCHASEF and TRIPS, and WISHTRAVEL as a response variable. For the development of the model, the *stats* package and the *glm* function were used (R Core Team, 2003).

Although the negative binomial distribution is recommended in logistic models with a dichotomous response variable (Englin & Shonkwiler, 1995; Haab & McConnell, 2002; Juutinen et al., 2022; Pang, 2022), models with Poisson and negative binomial distributions were tested and presented the same results. In the end, we chose to present the results obtained with the Poisson distribution due to the comparison between the AIC values (model with Poisson distribution: AIC=127.19 versus models with negative binomial distribution: AIC= 129.2).

The premise of homoscedasticity in the distribution of the residues was evaluated by plotting the graphs of residues versus adjusted values (Appendix B). The existence of collinearity of the variables was verified using the variance inflation factor (VIF), with an exclusion value equal to 7 (Dormann et al., 2013), using the *car* package (Fox & Weisberg, 2019). Overdispersion was verified using the *performance* package (Lüdecke et al., 2021). There was no violation in homogeneity (Appendix B) or overdispersion ($p>0.05$). The “AGE” variables; “ATC" and "DAY" were collinear (VIF>7) and were removed from the model (Appendix C).

The estimate of ordinary consumer surplus (CS) is considered a good approximation of the measure of value or contribution to well-being associated with the use of natural resources (Willig, 1976). Thus, the CS was estimated for the middle Rio Negro region considering the result of the estimates of the TCM model, using the inverse of the coefficients (1/β) included in the final model (Creel & Loomis, 1990; Englin & Shonkwiler, 1995). To obtain the confidence intervals (95%) for the CS estimates, the bootstrap method was used, with 999 replications, through the *car* package (Fox & Weisberg, 2019).

Despite the fact that TCM is widely accepted and is generally considered one of the success stories of non-market valuation (Smith, 1993), in practical applications, there are a number of difficulties in using the TCM (Freeman et al., 2014). In general, some of the difficulties are treatment in relation to time, visitors from various locations, foreign visitors (Fleming & Cook, 2008), and trips with multiple destinations or multiple purposes (Chaudhry & Tewari, 2006). In this study, we adopted the solutions cited by Fleming & Cook (2008). “Time” was solved by not including time costs in the evaluation, “visitors from various locations“ using the total travel costs of all visitors and “foreign visitors" by omitting all foreign visitors from the sample. Given these changes, the consumer surplus measure can be a lower bound estimate. In addition, some issues in the model deserve attention, such as the wide confidence intervals observed in the results (Table 6). This result can be explained by the lack of data or by the uncertainty inherent in the process (Torres-Ortega et al., 2018), which has already been reported by several studies (Chotikapanich & Griffiths, 1998; Fleming & Cook, 2008; Heldt & Mortazavi, 2016; Lansdell et al., 2003).

CVM model

The responses of 58 recreational fishers were included in the model designed to assess the willingness to pay to fish in the region of the middle Rio Negro, Barcelos, Amazonas. Considering the fishers' interest in the larger specimens of peacock bass, called "trophies" (Holley et al., 2008; Lubich et al., 2021; 2023), the conitngent valuation question was structured according to the size of the peacock bass, with the definition of three scenarios: Scenario I (small peacock bass: ≤30 cm), Scenario II (medium peacock bass: 31 to 50 cm), and Scenario III (large peacock bass: ≥51cm) (Appendix A).

For each scenario, the factors that determine willingness to pay (WTP) were evaluated using the 2-step Heckman estimation model (Heckman correction) with normal-distribution treatment effect models (Toomet & Henningsen, 2008). Predictive variables included ABUN, AGE, DAY, EDU, ENVIRONMENTPERCEP, EXPF, FISHPAC, NATIONALITY, NAT.AM, PURCHASEF, TROPHY, TUCU and TRIPS, while WTP (No=0; Yes=1) was defined as the response variable.

In the second “outcome equation" of the 2-step Heckman model, the value of $p<0.10$ was used as a criterion for inclusion of variables, maintaining the predictor variable NATIONALITY and the fishers' willingness to pay (US$) as the response variable. For the execution of the model, the *sampleSelection* package was used (Toomet & Henningsen, 2008).

In Scenario III, it was not possible to run the 2-step Heckman (heckit) estimation model because all the respondents were willing to pay, so there was no variability in the response variable. This scenario was discussed based only on the results of the descriptive analysis.

General model predictions

Socioeconomic variables such as age, education level, income and nationality affect the desire to visit and the willingness to pay for environmental services. In addition, fishing variables, such as average cost of air tickets (ATC), duration of fisheries (DAY), fishing experience (EXPF), fishing package value (FISHPAC), average annual expenditure on equipment (PURCHASEF) and frequency of visits to Barcelos for fishing per year (TRIPS), also influence these aspects. When considering the willingness to pay for environmental conservation and/or a specific resource, it is essential to include variables related to use, especially related to the success of the fishery, such as the capture of trophy fish (TROPHY) and target species of fishers, such as the peacock bass (TUCU).

Travel Cost Method (TCM)

Positive relationships are expected between TRIPS and the variables AGE, EDU and INCOME, since it is taken into account that older fishers may have greater availability to travel, people with higher education have a greater desire to visit other places and, that a higher income increases the possibility for leisure activities. We also expect positive responses in the variables DAY, ENVIRONMENTPERCEP and TRIPS, which are related to greater satisfaction

during travel. On the other hand, the increase in costs associated with the variables ATC, FISHPAC, PURCHASEF should induce negative responses from the number of trips.

Contingent Valuation Method (CVM) model predictions

As in the TCM model, positive relationships are expected with the variables AGE, EDU and INCOME, i.e., these indicate that older fishers (over 65), with high university degree and a higher income/hour will be more willing to pay for the conservation of peacock bass stocks in Barcelos. Similarly, we expect that the increase in the length of fishing days (DAY), low environmental degradation (ENVIRONMENTPERCEP), the change from Brazilian to foreign fishers (NATIONALITY) and a greater number of fishing trips (TRIPS) will lead to an increase in willingness to pay, while negative relationships associated with increases in costs identified with the variables FISHPAC and PURCHASEF are expected.

R E S U L T S

TCM

All respondents were male, with a mean age of 52 years, predominantly had a university degree (85.71%) and a mean income/hour of US$25.75 (Table 2). Most of them fish in the middle Rio Negro at least twice a year, with an average cost of US$2,234.68 in air tickets (ATC) and US$1,740.10 in fishing packages (FISHPAC), and trips had an average duration of six days (Table II: 2). However, they wish to fish in the region about three times a year (WISHTRAVEL; Table 2). Other expenditures include purchase of fishing equipment and clothing (PURCHASEF), totaling on average US$1,430.04 per year (Table II: 2).

Table II: 2 – Amplitude, mean and standard deviation values for the demographic and socioeconomic variables included in the TCM model, with the application of 35 questionnaires to recreational fishers in Barcelos, Amazonas. * Binary variables.

Variables	Descriptive analysis Range (mean ± standard deviation)
WISHTRAVEL (Variable response)	1.00–5.00 (3.14 ± 1.12)
Demographic and social information	
AGE	27.00–80.00 (51.89 ± 15.82)
EDU*	No university degree = 05 University degree = 30
INCOME (US$)	1.91–75.45 (25.75 ± 20.79)

Fishing-related information	
ATC (US$)	1,204.2 –3,592.56 (2,234.68 ± 643.78)
DAY	5.00–15.00 (6.54 ± 1.88)
ENVIRONPERCEP	No or low environmental degradation = 26 Average and high environmental degradation = 9
EXPF	1–50 (27.11 ± 15.54)
FISHPAC (US$)	1,167.00–3,420.52 (1,740.10 ± 608.18)
PURCHASEF	100.60–6,036.22 (1,430.04 ± 1,522.20)
TRIPS	1.00–4.00 (2.14 ± 0.94)

The model presented a high degree of explanation (pseudo-R^2: 90.27868), with FISHPAC and TRIPS being significant variables ($p<0.05$; Table 4). None of the demographic and socioeconomic variables showed a significant effect (Table II: 3).

Table II: 3 – Values obtained from the regression model with Poisson distribution to estimate travel cost of fishers who recreational fishing in Barcelos, Amazonas. *** significance level ($p<0.001$). AIC = 127.19.

Variables	Estimate	Std. Error	z-value	p-value
EDU	4.904e-02	2.412e-01	0.203	0.8389
EXPF	-4.679e-03	6.412e-03	-0.730	0.4656
ENVIRONPERCEP	-1.175e-01	2.325e-01	-0.506	0.6131
FISHPAC	2.766e-04	1.257e-04	2.201	0.0278*
PURCHASEF	-3.146e-05	6.638e-05	-0.474	0.6355
TRIPS	3.438e-01	8.729e-02	3.938	8.21e-05 ***

Although not predicted, there was a positive sign in the relationship with the FISHPAC variable, indicating that the higher the cost of fishing packages, the greater the desire to fish in the middle Rio Negro region. This may be because the higher cost packages are higher in non-fish amenities, such as the quality of food and accommodations. Another positive relationship was observed for the TRIPS variable, which indicated that recreational fishers who have fished in the region have a desire to return more often.

The marginal value of consumer surplus (CS) per trip obtained in the model was US$3,615 (calculated as 1/β, where β= 0.00027663), ranging from US$1,604 to US$5,911 (95% CI; standard error: 11,008) (Table II: 4).

The social welfare value of recreational fishing opportunities in the middle Rio Negro region was estimated based on the total annual visits of the fishers. Considering that 42 companies operate in the region, and these receive an

average of 13.51 fishers per enterprise per week for 6 months (24 weeks) (according to Lubich et al. 2023), the estimate per season was 13,618.08 fishers (and fishing trips). Multiplying the number of trips by the consumer surplus per trip (3615) the total consumer surplus is calculated to be US$49,229,000, with a lower bound estimate of US$21,847,000 and an upper bound of 89,496,000).

Table II: 4 – Results obtained through the bootstrap developed for the FISHPAC variable of the TCM model for calculating the consumer surplus (CS) of recreational fishers in the middle Rio Negro region, Amazonas.

Variable	estimate (original) (95% CI)	bootBias	bootSE	bootMed
FISHPAC	0.00027663 (0.0001691760 - 6.233263e-04)	-1.1695E-06	9.0846E-05	2.6243E-04

CVM model

The interviewees were men, most of whom were Brazilian (89.66%), with a mean age of 54 years, with a university degree (82.76%) and a mean income/hour of US$21.92 (Table 5). Most fishers fish in the middle Rio Negro twice a year, acquiring fishing packages with an average value of US$1,714.38 and with an average duration of six days (Table 5). Fishers spend on average US$1,150.95/year on the purchase of fishing equipment and clothing (Table 5).

In the three CVM scenarios, the majority of respondents showed a willingness to pay for the conservation of peacock bass stocks in the region (>68%). We emphasize that in Scenario III – large peacock bass, everyone was willing to pay. Regarding the willingness to pay values (US$), there was an increase in the willingness to pay related to the size of the peacock bass (Scenario I; mean = US$49.52; Scenario II; mean = US$70.42 and Scenario III; mean = US$94.40) (Table II: 5). In all CVM scenarios, the survey respondents were reminded of their budget contstraints.

Table II: 5 – Amplitude, mean and standard deviation values for the demographic and socioeconomic variables included in the CVM model from the application of the 58 questionnaires to recreational fishers in Barcelos, Amazonas. * Binary variables.

Variables	Descriptive analysis Range (Average ± standard deviation)
Variable responses	
Scenario I*	Not willing to pay = 18 Willing to pay = 40
Scenario II*	Not willing to pay = 15 Willing to pay = 43
Scenario III*	Not willing to pay = 0 Willing to pay = 58
WTP – Scenario I (US$)	10.06 – 204.37 (49.52 ± 37.40)
WTP – Scenario II (US$)	10.06 – 204.37 (70.42 ± 59.95)
WTP – Scenario III (US$)	10.06 – 510.93 (94.40 ± 103.56)
Demographic and social information	
AGE	27.00 – 80.00 (54.12 ± 14.66)
EDU*	No university degree = 10 University degree = 48
INCOME (US$)	1.91 – 75.45 (21.92 ± 17.71)
NATIONALITY*	Brazilian = 52 Foreigner = 6
Fishing-related information	
DAY	5.00 – 15.00 (6.35 ± 1.52)
ENVIRONPERCEP*	No or low environmental degradation = 46 Average and high environmental degradation = 12
EXPF	1 – 55 (25.98 ± 16.33)
FISHPAC (US$)	1,167.00 – 3,420.52 (1,714.38 ± 556.35)
NAT.AM*	No = 34 Yes = 24
PURCHASEF	100.60 – 6,036.22 (1,150.95 ± 1,279.41)
TRIPS	1,00 – 5.00 (2.14 ± 0.94)
TUCU	No = 29 Yes = 29

The Scenario I model presented a good degree of explanation (df=39; R^2=0.7189), with marginally significant variables, EXPF (p=0.07) and TUCU (p=0.05; Table 6). In the second “outcome equation” model, the following variables were significant: NATIONALITY and EXPF (p<0.05; Table II: 6). The effect of the variable "NATIONALITY" on willingness to pay (WTP) is positive, with an expected increase of US$1.76 in WTP when the fisherman is a foreigner, even considering small peacock bass (Table II: 6). Conversely, the variable "EXPF" presents a negative relationship, indicating that an increase in the fisher's experience results in a reduction of US$1.37 in WTP in this scenario (Table II: 6).

Table II: 6 – Values obtained from the models using the two-step Heckman selection method to estimate the willingness to pay in Scenario (I: small peacock bass and II: medium peacock bass) of fishers who recreational fishing in Barcelos, Amazonas. ***significance level (p<0.001). Scenario I: df= 39; R2= 0.7189; Scenario II: df= 39; R2= 0.7279. Periods (.) after a value indicate values close to the significance level (0.05).

Scenario I – small peacock bass				
Variables	**Estimate**	**Standard error**	**t-value**	**p-value**
(Intercept)	1.16158	59.48487	0.020	0.9845
ABUN	-0.26250	0.25580	-1.026	0.3111
AGE	-0.09856	0.29931	-0.329	0.7437
DAY	0.05410	0.35636	0.152	0.8801
EDU	-0.17829	0.26061	-0.684	0.4979
ENVIRONPERCEP	-0.05394	0.25368	-0.213	0.8327
EXPF	-0.45786	0.24998	-1.832	0.0747 .
FISHPAC	0.13284	0.28299	0.469	0.6414
NATIONALITY	1.88798	176.64692	0.011	0.9915
NAT.AM	0.35855	0.22651	1.583	0.1215
PURCHASEF	0.13949	0.28260	0.494	0.6244
TROPHY	-0.16189	0.22989	-0.704	0.4855
TUCU	-0.55588	0.27769	-2.002	0.0523 .
TRIPS	0.09620	0.23182	0.415	0.6804
Outcome equation:				
NATIONALITY	1.7624	0.6198	2.843	0.00707 **
EXPF	-1.3752	0.6042	-2.276	0.02841 *
TUCU	-0.8025	0.5754	-1.395	0.17103
Scenario II – medium peacock bass				
(Intercept)	1.216801	61.040958	0.020	0.9842
ABUN	-0.203474	0.263319	-0.773	0.4443
AGE	-0.012953	0.312877	-0.041	0.9672
DAY	-0.029328	0.357617	-0.082	0.9351
EDU	-0.127082	0.259370	-0.490	0.6269
ENVIRONPERCEP	0.046963	0.258973	0.181	0.8570
EXPF	-0.267849	0.249058	-1.075	0.2888
FISHPAC	-0.007745	0.273934	-0.028	0.9776
NATIONALITY	1.747017	181.266095	0.010	0.9924
NAT.AM	0.412470	0.237243	1.739	0.0900 .
PURCHASEF	0.204657	0.300290	0.682	0.4996
TROPHY	-0.340887	0.229984	-1.482	0.1463
TUCU	-0.641979	0.296988	-2.162	0.0368 *
TRIPS	0.038621	0.136935	0.282	0.7794
Outcome equation:				
NATIONALITY	2.1405	0.7608	2.813	0.00764 **
NAT.AM	1.4208	0.6942	2.047	0.04747 *
TUCU	-1.0689	0.7063	-1.513	0.13823

Scenario II, with a good degree of explanation (df=39; R^2=0.7270), had as significant variables TUCU (p=0.03) and, marginally, NAT.AM (p=0.09; Table II: 6). In the outcome equation, the following variables were significant: NATIONALITY and NAT.AM (p<0.05; Table II: 6). Similarly to Scenario I, the positive relationship between the variable "NATIONALITY" and willingness to pay (WTP) was maintained, with an expected increase of US$2.14 in WTP when the fisher is a foreigner. The variable "NAT.AM" also demonstrated a positive relationship, indicating an expected increase of US$1.42 in WTP, and demonstrating the importance of the Amazon as an environment.

In Scenario III, all fishers were willing to pay for the conservation of peacock bass stocks since, in this scenario, peacock bass are large "trophies" (≥51 cm) (Table II: 5).

D I S C U S S I O N

Profile of fishers fishing in the middle Rio Negro, Amazonas

The profile of recreational fishers that fish in the middle Rio Negro is typically male, Brazilian and aged between 27 and 80 years (54.12 ± 14.66). This was already expected, considering the profile of anglers in other Brazilian freshwater (Freire et al., 2012; Lubich et al., 2023; Moraes & Seidl, 2019), marine (Basaglia & Vieira, 2005; Schork et al., 2010; Tsuruda et al., 2013) and estuarine environments (Barcellini et al., 2013; Barrella et al., 2016). This profile is similar in other countries such as Spain (Lloret et al., 2008; Pita et al., 2018), Mozambique (Pereira et al., 2003), Portugal (Martínez-Escauriaza et al., 2020) and Turkey (Unal et al., 2010).

Recreational fishers who visit the middle Rio Negro have university degrees and income/hour between US$1.91 and US$ 75.45, and fish in the region at least twice a year, but would like to travel three times each year. In other states of Brazil, such as Mato Grosso do Sul (Moraes & Seidl, 2019) and São Paulo (Schork et al., 2010), and countries such as Turkey (Tunca et al., 2016), most fishers also have higher education and high income. However, there are countries in which the education level of most recreational fishers is high school, such as Spain (Pita et al., 2018), Portugal (Martínez-Escauriaza et al., 2020) and some areas of a marine reserve in Turkey (Tunca et al., 2016), showing that the

education and income profile may vary, depending on the fishing sites and the cost of accessing those fishing sites.

To carry out the fisheries in the middle Rio Negro, fishers spend between US$1,167.00 and US$3,420.52 on the purchase of fishing packages. The annual cost of purchasing fishing gear (including clothing items) ranges from US$100.60 to US$6,036.22. Recreational fishing implies significant spending resulting from the acquisition of specialized equipment, appropriate clothing that offers comfort and safety for the fisher, as well as fishing packages and the services of specialized guides. In Spain, fishers stated that they spend most of their annual spare income on trips, followed by gear and clothing (Pita et al., 2018), with an average of US$ 331,272,000.00 per year (95% CI = US$212,463,000.00 – US$434,601,000.00). According to estimates by the World Bank (2012), in developed countries, about 220 million recreational fishers annually spend about 19 billion dollars on the purchase of equipment alone.

Travel Cost Modeling

Although no variables with socioeconomic basis were significant, previous studies have shown that factors associated with the income of recreational fishers can influence travel decisions (Johnston et al., 2019; Moore et al., 2000; Peixer et al., 2011; Shrestha et al., 2002; Toivonen, 2004). The positive relationship of the FISHPAC variable, which reflects the amount spent on fishing packages, is an indication of the investment that the fisher makes in choosing places that have an abundance of large fish, known as “trophies”, and the appropriate conditions that they expects to find during fishing. Therefore, this relationship may be associated with the quality found in the services offered by the most expensive fishing packages, which include the option to access to the most exclusive fishing areas, as well as a support structure that may include faster and better-equipped boats, floating cabins in remote areas, extra items in the all-inclusive package and even seaplanes. Lubich et al. (2023) identified six types of fishing structure in the middle Rio Negro region, ranging from simpler options, such as camping grounds (regionally known as “bate e volta”) to more luxurious options, such as jungle hotels. Thus, the positive association of the variable "FISHPAC" may be indicative of the level of income that the fisher has in order to choose to travel to the middle Rio Negro region (WISHTRAVEL), considering the benefits of being

able to catch trophy fish in an environment that offers good infrastructure and contact with nature.

The positive correlation with the variable "TRIPS" is related to previous successful experiences fishing in the middle Rio Negro. Fishers who have been to the middle Rio Negro and have been successful, either in catching large specimens or in significant quantities of fish, have shown an inclination to return on subsequent occasions. In addition, fishers who fish for a long time in a given location tend to follow ecosystem changes and changes in fish stocks over time (Peixer et al., 2011), as well as acquire knowledge about fishing sites and the fish (Loki et al., 2023; Pita et al., 2020).

The consumer surplus (CS) estimate found in the study was US$267.57 per fisher (US$118.74-437.52), and is higher than estimates for recreational fishing in Australia, estimated at US$166.82 (US$127.54 – US$243.64) (Prayaga et al., 2010). In Sweden, consumer surplus values vary throughout the fishing season, with average values of US$38.83, US$158.35 and US$19.11 for January – April, May – August and September – December, respectively (Carlén et al., 2021).

The estimated CS/annual value of US$49,228,286.61 (CI US$21,847,435.43 – US$80,496,514.81) in the middle Rio Negro region was similar to that obtained by Shrestha et al. (2002) (US$35,059,424 to US$56,400,310) for recreational fishing in the Brazilian Pantanal, slightly higher than that found in billfish recreational fishing in Puerto Rico, estimated at US$43,918,775.00 (Clark et al., 1999) and the abalone (*Haliotis rufescens*) in Northern California, US$24,000,000.00 – US$44,000,000.00 (Reid et al., 2016). However, it was much higher than the estimate for fisheries in the Aegean Sea in Turkey (US$5,531,866.20) (Tunca et al., 2012). The high estimated value for the consumer surplus highlights the economic potential of fishing in the middle Rio Negro region and in the state of Amazonas. Several factors contribute to boost and enhance this activity, including the presence of voracious species such as the peacock bass, the chance to fish other species of equal or greater strength, such as catfish pirara (*Phractocephalus hemioliopterus*), Surubim (*Pseudoplatystoma* sp.) and paraiba (*Brachyplatystoma filamentosum*) among others, and the abundant catches of large fish. The unique landscape of the Amazon also enriches the experience.

Willingness to Pay

The direct relationship between the willingness to pay, estimated in the CVM model, and the the size of the peacock bass (*Cichla* sp.) was expected, since recreational fishers are motivated by catching large specimens of the target species (Arlinghaus & Cooke, 2009; Barroco & Freitas, 2014; Cooke et al., 2021; Fenberg & Roy, 2008; Hauser et al., 2002; Hixon et al., 2014; Lubich et al., 2021, 2023; McClenachan, 2009). The size of the fish caught is notably important in recreational fishing of aggressive species, such as *Cichla temensis*, since they can reach large size (Campos et al., 2015; Hoeinghaus et al., 2003; Holley et al., 2008; Jepsen et al., 1999; Lubich et al., 2021) and forcibly attack the bait, which increases the fight that the fisher may have with the fish during the catch.

The positive association with the “NATIONALITY” variable in all scenarios can be attributed to the following two factors: cultural influence, since fishing is a traditional leisure activity in several countries, and this may reflect in a great diversity of users (Arlinghaus et al., 2020; FAO, 2012; Franquesa et al., 2004), and the higher income of fishers who can make trips to other countries, having as criteria the pre-disposition of success in catching fish and the fishers’ well-being during fishing days. Joohnston et al. (2006) carried out a meta-analysis of the WTP values of recreational fishing and showed that fishers who travel abroad are willing to pay more for catching fish than local fishers. The same pattern was found by Clark et al. (1999) for recreational billfish fishing in Puerto Rico and differences in willingness to pay between local and other visitors were detected. In general, recreational fishers have an interest in the conservation and management of the resources on which their leisure activities depend (Arlinghaus, 2006).

The negative relationship observed in the fishing experience of recreational fishers in Scenario I, who cite only small peacock bass being available, may be related to the ability and interest of more experienced fishers in capturing larger individuals that cause the “fight” and the feeling of accomplishment in fisheries, especially if there is the capture of trophy fish.

It is recognized that recreational fishing is related to essential components for human well-being, such as improved mental and physical health, social affirmation and bonding with the natural environment (Driver et al., 1987; Fedler & Ditton, 1994). Therefore, the level of satisfaction and willingness to pay of

recreational fishers is not only related to the fish (Blicharska & Rönnbäck, 2018). The positive relation to the variable “NAT.AM” (trip motivated by nature/Amazon) can be an extension of the explanation of the results for the “EXPF” variable, since fishing involves the connection and experience of living with nature, which fishers enjoy throughout the fishing days. The recreational fishing experience not only includes catching fish, but also potentially valuable ensembles like relaxation and time with friends. In the case of the Amazon, the opportunity to visit a place considered environmentally preserved is included. Recreational fishers in the Brazilian Pantanal also indicated the natural environment and the possibility of sighting wild animals, such as jaguars and caimans, as important factors for willingness to pay (Shrestha et al., 2002). The middle Rio Negro region has several conservation units, such as the Anavilhanas and Jaú National Parks; Serra do Aracá State Park, Unini River Extractive Reserve and Mariuá Environmental Protection Area, among others (SNUC, 2024), which form unique landscapes in the Amazon rainforest. In addition, the respondents' perceptions of the quality of the natural environment significantly influence the number of recreational visits to areas with interesting landscapes (Juutinen et al., 2022).

Recreational fishing in the middle Rio Negro is economically relevant to the region. Two important results for public policies emerge from this analysis: the size of the peacock bass and environmental conservation. Regarding the size of the peacock bass, the model indicates that the recreational fishers’ willingness to pay is linked to the size of these peacock bass that are caught. This suggests that, for fisheries management, preserving stocks with an adequate population structure, including trophy fish, is essential to ensure the sustainability of recreational fishing. In addition, environmental conservation is also relevant, as it can influence the willingness to pay of fishers.

The proper approach to recreational fishing policy must consider both fish size and environmental conservation, aiming to provide lasting benefits for the participants, the local communities and the linked forest/aquatic ecosystem. Additionally, take into account the estimated value of the recreational fishery in the middle Rio Negro, a proportion of the profits made from fishing packages could be allocated to financing community projects. Moreover, the high values for consumer surplus and willingness to pay that we estimate indicate that there is some room for the participants to contribute to the maintenance of the fishery,

and still have benefits from the trip exceeding their costs. These initiatives would have the potential to promote sustainable development through investment in infrastructure, education and health services in communities located in the middle Rio Negro basin. In this way, fishing would transcend its recreational purpose, thereby contributing significantly to the social and economic well-being of the region.

DATA AVAILABILITY

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

ETHICS STATEMENT

Research involving Human Participants - Survey data were collected under the principles of voluntary participation, informed consent and anonymity. Personal information was administered in accordance with the Ethics Committee in Research Involving Humans of the Federal University of Amazonas (Certificate of presentation of ethical assessment: 52326221.6.0000.5020).

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CONFLICTS OF INTEREST

None declared.

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CAPÍTULO III – Avaliação integrada de indicadores de sustentabilidade para a pesca esportiva no Médio Rio Negro, Amazônia brasileira

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Avaliação integrada de indicadores de sustentabilidade para a pesca esportiva no Médio Rio Negro, Amazônia Brasileira

C. Lubich[a*], F. Siqueira-Souza[a,b] and C. Freitas[a,b]

[a]Universidade Federal do Amazonas – UFAM, Programa de Pós-graduação em Ciência Animal e Recursos Pesqueiros, Manaus, AM, Brasil
[b]Universidade Federal do Amazonas – UFAM, Departamento de Ciências Pesqueiras, Manaus, AM, Brasil

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Integrated assessment of sustainability indicators for recreational fishing of the Middle Negro River, Brazilian Amazon

C. Lubich[1*], F. Siqueira-Souza[1,2] and C. Freitas[1,2]

[1]Programa de Pós-graduação em Ciência Animal e Recursos Pesqueiros, Universidade Federal do Amazonas, Manaus, Amazonas, Brazil. https://orcid.org/0000-0003-2216-0542

[2]Universidade Federal do Amazonas, Manaus, Amazonas, Brazil. https://orcid.org/0000-0002-8723-8956 | https://orcid.org/0000-0001-5406-0998

*e-mail address of the corresponding author: lubichchiara@gmail.com

With eight figures

Palavras-chave: abordagem ecossistêmica, gestão pesqueira, avaliação multidisciplinar, RAPFISH

Keywords: ecosystem approach, fisheries management, multidisciplinary assessment, RAPFISH

Running Title: Sustainability of recreational fishing

Abstract

The sustainability of recreational fishing in the Middle Negro River, in the Brazilian Amazon, was evaluated using 26 indicators representing five evaluation fields (ecological sustainability, economic sustainability, fishing experience, management performance and social sustainability). The method employs a restricted multidimensional scale ordering technique and uncertainty is expressed through a Monte Carlo simulation and sensitivity using leverage analysis. The results of this study indicate that the overall performance of recreational fishing in the Middle Negro River, according to the perspectives of the five actors studied, was considered “less than satisfactory”, indicating the need for measures to improve all the dimensions evaluated, especially management performance and ecological sustainability. The creation of an integrated management plan, which involves all the actors involved in recreational fishing, is essential, and should focus on ecological sustainability and management performance. This instrument should have frequent data collection, aiming at monitoring the activity as a condition for the sustainability of fishery resources in the medium and long term. The evaluation approach used also proved suitable for contexts with limited data availability, as is often the case in developing countries.

Avaliação integrada de indicadores de sustentabilidade para a pesca esportiva no Médio Rio Negro, Amazônia brasileira

Resumo

A sustentabilidade da pesca esportiva no Médio Rio Negro, na Amazônia Brasileira, foi avaliada utilizando 26 indicadores distribuídos em cinco dimensões de análise (sustentabilidade ecológica, sustentabilidade econômica, experiência de pesca, desempenho da gestão e sustentabilidade social). O método emprega uma técnica de ordenamento em escala multidimensional restrita, com a incerteza sendo expressa por simulação de Monte Carlo e análise de sensibilidade por alavancagem. Os resultados indicam que, de acordo com a perspectiva dos cinco grupos de atores envolvidos na atividade, o desempenho geral da pesca recreativa no Médio Rio Negro foi considerado “menos que satisfatório”, evidenciando a necessidade de medidas para melhorar todas as dimensões avaliadas, especialmente o desempenho da gestão e a sustentabilidade ecológica. A criação de um plano de gestão integrada, com participação ativa de todos os atores envolvidos, é essencial e deve priorizar a sustentabilidade ecológica e a eficácia da gestão. Esse instrumento deve incluir a coleta frequente de dados, com o objetivo de monitorar a atividade como condição para a sustentabilidade dos recursos pesqueiros no médio e longo prazo. A abordagem de avaliação utilizada também se mostrou adequada para contextos com disponibilidade limitada de dados, como costuma acontecer em países em desenvolvimento.

1 Introduction

Recreational fishing is an activity of great cultural and economic importance in many regions of the world (Hyder et al., 2018; Rudd et al., 2002; Tufts et al., 2015). Globally, the average participation in recreational fishing is 11% of the population, with 120 million fishers in Europe, North America and Oceania (Arlinghaus et al., 2015, 2021). Recreational fisheries are generally considered sustainable at the population level and promoting ecosystem awareness among users (Arlinghaus and Cooke, 2009).

In developing countries, recreational fishing can contribute to the livelihoods of rural populations by generating income via fishing tourism for underserved coastal communities (Smith et al., 2005). In addition, it includes improvements in psychological well-being, strengthening ties between man and nature, supporting livelihoods and

generating billions of dollars in economic benefits (Griffiths et al., 2017; Hughes, 2014; Hyder et al., 2018; Tufts et al., 2015). Due to these factors, assessments of the benefits of recreational fishing often take a socio-economic approach, but ethical considerations must go beyond monetary values (Bova et al., 2024; Pitcher, 2003). According to Cooke et al. (2019), the sustainability of recreational fishing depends on the responsible behavior of all the actors at individual levels, this being a crucial factor to achieve the sustainability of the activity.

The promotion of sustainability in recreational fishing raises the question: Can this activity really be considered sustainable? There are few studies that have evaluated the sustainability of marine (Pitcher, 2003) and freshwater (Braz Neto et al., 2021) recreational fishing. Most studies focus on commercial fisheries (Aris et al., 2017; Castello et al., 2009; Cissé et al., 2014; Franco-Meléndez et al., 2021; Haerunnisa et al., 2013; Harahab et al., 2021; Jimenez et al., 2021; Machado et al., 2015; Ramadhanty et al., 2021; Suresha Adiga et al., 2015; Tesfamichael and Pitcher, 2006). For example, Castello et al. (2009) evaluated estuarine and marine fishing production systems in southern Brazil and concluded that none of them could be considered truly sustainable, largely due to conflicting performance across ecological, economic, and social dimensions. Similarly, Franco-Meléndez et al. (2021) assessed the sustainability of 19 artisanal TURFs in Chile and found an overall medium sustainability level, with strong performance in the social dimension but weaknesses in ecological, ethical, and institutional aspects. Tesfamichael and Pitcher (2006), analyzing 26 fisheries in the Red Sea, also reported wide variation in sustainability across countries and fishery types, highlighting that even in data-poor contexts it is possible to identify concerning ecological and ethical issues using multidimensional approaches. However, some studies indicate that both activities can lead to a decline in fish stocks (Cooke and Cowx, 2004, 2006; Cowx et al., 2010; Lewin et al., 2019) and that they should be treated with equal importance (Abbott et al., 2018; Arlinghaus et al., 2019). For recreational fishing to be considered sustainable, it must maintain fish populations at healthy levels (environmental sustainability), provide long-term economic opportunities (economic sustainability), and respect local cultures and promote equitable access and benefits for communities (social sustainability). These dimensions form the basis for evaluating whether the activity contributes to or undermines broader sustainability goals.

Sustainability in fisheries is assessed via models that use statistical and mathematical calculations to estimate the status and trends of a fish stock, including abundance, mortality and productivity (Hilborn and Walters, 1992; King, 2007; Quinn and Deriso, 1999). Despite this, these models require substantial and reliable data, which are rarely available to the recreational fisheries, mainly if it is performed as a catch and release fishery. In addition to ecological aspects, sustainability assessments should consider the social factors of the fishers, such as behavior, preferences, perceptions, attitudes and well-being (Hunt et al., 2013; Ostrom, 2009). These factors are essential to support fisheries management efforts. Finally, there is still a lack of standard monitoring for hundreds of freshwater fish stocks (Bonar and Hubert, 2002).

Recreational fishing in Brazil is still developing, with estimates showing that up to 5% of the population participates in the activity (Arlinghaus et al., 2019). The activity has a wide production chain, generating revenues and employing many workers, thereby boosting the economy (Schork et al., 2010; Tsuruda et al., 2013). However, despite its expansion and international reputation as an important fishing destination, the activity is not fully recognized by the government, remaining unmanaged or poorly managed (Freire et al., 2016). Nevertheless, it is widely practiced in several states of Brazil (Albano and Vasconcelos, 2013; Freire et al., 2012, 2016; Lubich et al., 2023b).

The state of Amazonas is the main center of Brazilian freshwater recreational fishing, principally the Middle Negro River region, a hotspot known nationally (BGFA, 2024) and internationally (IGFA, 2024) for catches of large peacock bass (*Cichla* sp.). The existing studies on the region focus mainly on the ecological aspects of the peacock bass (*Cichla temensis* Humboldt, 1821) (Aguiar-Santos et al., 2018; Campos et al., 2015, 2020; Garcez et al., 2015; Holley et al., 2008; Lubich et al., 2021; Mereles et al., 2020, 2021; Sousa et al., 2016; Willis et al., 2007), in mortality by catch and release (Barroco et al., 2017; Thomé-Souza et al., 2014), in the effects of fisheries on the stock of the species (Campos et al., 2020; Holley et al., 2008; Lubich et al., 2021), in social conflicts (Sobreiro, 2015; Sobreiro and Freitas, 2008) and in the characterization of sport fishing involving peacock bass (Lubich et al., 2023a). These gaps reinforce the lack of studies focused on sustainability assessments in this context.

The rapid appraisal technique for evaluating the sustainability of fisheries (RAPFISH) is a fast and practical technique for assessing the sustainability of fisheries and it has been around for approximately 26 years (Pitcher et al., 1998; Pitcher and Preikshot, 2001). This technique involves the integrated assessment of ecological and

human dimensions: ecological, technological, economic, social and institutional (Kavanagh and Pitcher, 2004; Pitcher et al., 2013). The technique can be employed for different types of fisheries, together or separately, over time or under different perspectives (Kavanagh and Pitcher, 2004; Pitcher, 2003; Pitcher et al., 2013; Pitcher and Preikshot, 2001; Preikshot et al., 1998).

In Brazil, RAPFISH has been used to evaluate commercial fisheries in estuarine and marine environments (Castello et al., 2009; Isaac et al., 2009, 2011; Jimenez et al., 2021; Martins et al., 2009, 2011; Pereira et al., 2020) and freshwater systems (Braz Neto et al., 2021). Among these, only one study incorporated recreational fishing a multidimensional assessment of 14 fishing systems at the Tucuruí hydroelectric reservoir in Pará, northern Brazil (Braz Neto et al., 2021). The study found that recreational fishing showed a strong association with ecological sustainability indicators. However, several fishing systems shared similar attribute scores across the dimensions analyzed, which led to overlapping results and limited the method's ability to clearly differentiate the sustainability status of each system. As a result, the conclusions regarding the sustainability of recreational fishing in that context were considered inconclusive.

Therefore, the present study aims to bridge this knowledge gap, having as guiding elements the evaluation of the ecological, economic, management and social aspects of the activity in the region, in addition to the fishing experience, based on the perception of the actors that are directly and indirectly involved: fishing guides, local community, Brazilian fishers, foreign fishers and fishing entrepreneurs. The integrated assessment of these factors was carried out using the RAPFISH method and highlights the dimensions that need improvement to ensure the sustainability of the fishery in the Negro River region.

2 Materials and Methods

2.1 Study area

The study was conducted in the municipality of Barcelos, located in the Middle Negro River region, northwest of the state of Amazonas, in northern Brazil (Figure III: 1). The municipality of Barcelos covers 122,462.086 km^2, with 4.98 km^2 of urbanized area (IBGE, 2024). The municipality has an estimated population of 18,626 people and a very low population density of 0.15 inhabitants per km², which indicates a highly dispersed population in a vast territory (IBGE, 2024). Socioeconomic indicators also

reflect conditions of vulnerability: the Municipal Human Development Index (MHDI) is 0.50, considered low, and the per capita Gross Domestic Product (GDP) is US$ 1,428.48 (IBGE, 2024), suggesting limited economic activity and income levels well below national averages. These indicators characterize the municipality as small, sparsely populated, and socioeconomically underdeveloped, which may influence local livelihoods and the potential role of recreational fishing in supporting income and well-being.

The Negro River basin is the second largest sub-basin that supplies the Amazon basin (Goulding et al., 2003). The Middle Negro River is composed mainly of blackwater rivers, though some tributaries present white and mixed water (Piedade et al., 2025; Venticinque et al., 2016). Recreational fishing has existed in this region for just over 30 years (Lubich et al., 2023a), and it is the main destination of Brazilian and foreign fishers who seek to capture peacock bass (*Cichla temensis* Humboldt, 1821) trophy fish (Lubich et al., 2021, 2023a). The development of the activity has generated different demands and actors involved, the latter directly (fishing guides, recreational fishing entrepreneurs, Brazilian and foreign fishers) and indirectly (local community) (Lubich et al., 2024a, 2024b).

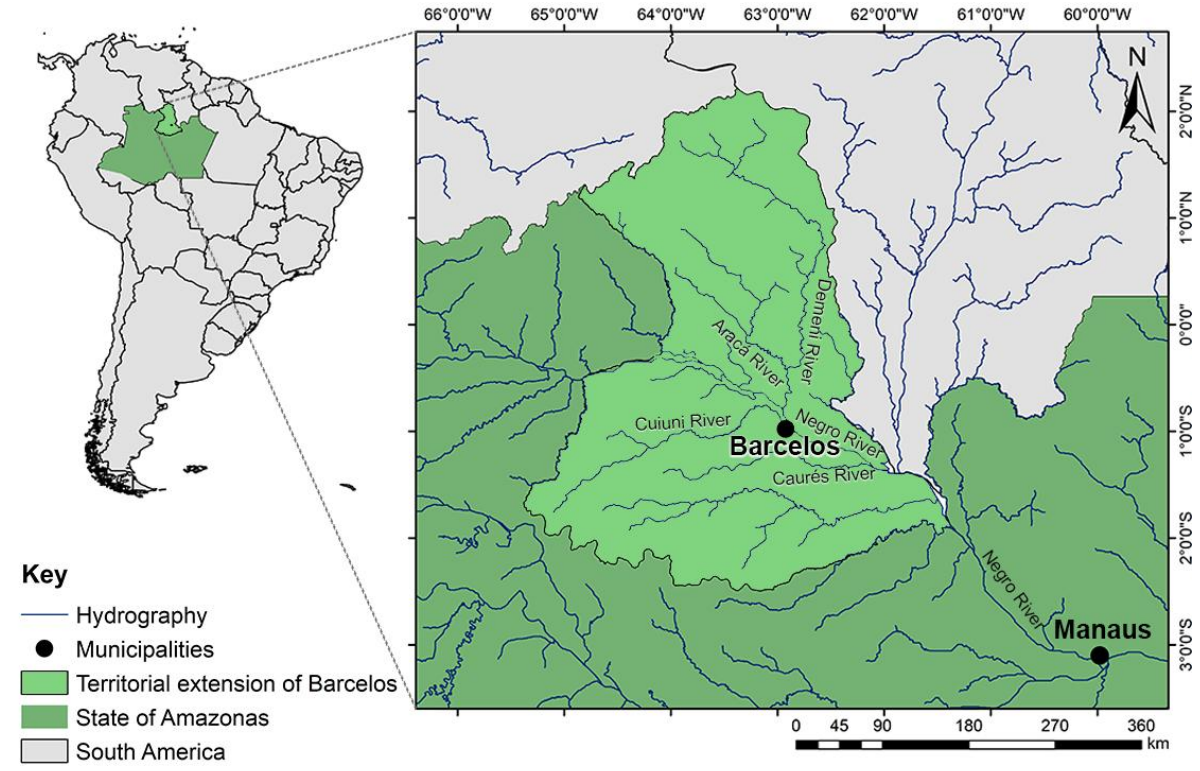

Figure III: 1 – Study area, municipality of Barcelos located in the state of Amazonas, northern region of Brazil, South America.

2.2 Data collection

A total of 433 questionnaires were applied to five types of actors that participate in the activity: fishing guides (n= 52), local community (n= 201), Brazilian fishers (n= 130), foreign fishers (n= 20) and fishing entrepreneurs (n= 30) (Figure III: 2). The structured questionnaires contained demographic and social information, as well as questions on ecological, economic, social aspects, fishing experience and management of the activity (Appendix A). The interviews were conducted in October 2022 and May 2023. These months were strategically selected based on the work routines and availability of the target participants. In the case of sport fishers, October corresponds to the peak of the sport fishing season in the region (which generally runs from September to March), when most of these visitors are present in the municipality. On the other hand, fishing guides are fully engaged in their work during the fishing season, making it difficult for them to participate in the study. Therefore, interviews with guides were scheduled for May, which falls in the off-season period (April to July), when their workload is reduced. The dates for the application of the questionnaires were thus carefully chosen to align with lower work intensity periods, in order to minimize interference with participants' routines and increase the likelihood of their participation. The inclusion criteria of the participants were: i) being 18 years or older and ii) being willing to participate in the research. All the interviews were conducted using active search, which consists of searching for and directly addressing the participants. In the case of fishing guides, the snowball sampling method was used (Biernacki and Waldorf, 1981).

The data were tabulated and stored in digital spreadsheets, using Microsoft Excel® software (Microsoft Corporation, 2024) for organization and analysis. The interviews were conducted with the authorization of the Ethics Committee in Research with Human Beings of the Federal University of Amazonas (Certificate of presentation of ethical assessment: 52326221.6.0000.5020).

Figure III: 2 - Data collection process with the use of: A) printed questionnaires applied in interviews with the five types of actors studied, B) fishing guides, C) local community, D) Brazilian fishers, E) foreign fishers and F) fishing entrepreneurs. The questionnaires were applied in situ in the municipality of Barcelos, state of Amazonas, northern region of Brazil, Brazilian Amazon.

2.3 Data analysis

Data were analyzed using descriptive statistics (Zar, 2010). The analysis of the sustainability of recreational fishing in relation to the perspective of the five types of actors (fishing guides, local community, Brazilian and foreign fishers and fishing entrepreneurs) was carried out using the RAPFISH technique (Pitcher, 2003; Pitcher et al., 1998) since this technique can be used to evaluate different types of fisheries, jointly or individually, depending on time or from different perspectives (Pitcher et al., 2013; Pitcher and Preikshot, 2001).

RAPFISH analyzes sustainability via a set of defined criteria (attributes) that are grouped into five dimensions (ecological sustainability, economic sustainability, social, technological and ethical sustainability) that are critical to the long-term viability of fishing activities (Pitcher et al., 2013; Pitcher and Preikshot, 2001). The method employs a restricted multidimensional scale ordering technique and uncertainty is expressed through a Monte Carlo simulation and sensitivity using leverage analysis

(Pitcher et al., 2013; Pitcher and Preikshot, 2001). For recreational fisheries, five dimensions are defined: ecological sustainability, economic sustainability, fishing experience, “management performance" and social sustainability (Pitcher, 2003). The choice of attributes was based on three criteria: ease of collection of information, objectivity of scoring and suitability for the activity to be evaluated. To adapt the RAPFISH analysis to this study, new attributes were added (Table III: 1). Although the standard attributes have been carefully modified, in relation to the description, the scale from 0 to 10 was maintained (Table III: 1; Appendix B) and represents the worst to best scenario in terms of sustainability (Pitcher et al., 1998, 2013).

To better reflect the specific characteristics of recreational fishing in the Middle Negro River, some original RAPFISH attributes were adapted, and new attributes were introduced. For example, the attribute “Company headquarters” was added to capture the spatial distribution of economic benefits, since many fishing tourism operators are based outside the region, which affects local economic sustainability. Similarly, “Organization of activity” was included to assess whether the tourism operation is structured in a way that ensures fairness, legal compliance, and clear benefit-sharing mechanisms. These additions were informed by field experience, interviews with stakeholders, and prior studies identifying critical gaps in the governance and distribution of benefits in Amazonian recreational fisheries. The inclusion of such attributes strengthens the methodological sensitivity of the RAPFISH approach to local governance and socioeconomic dynamics, allowing for a more nuanced sustainability assessment tailored to the regional context.

Table III: 1 – List of attributes, description, scoring criteria and data sources of each attribute of the five assessment dimensions of RAPFISH, used to assess the sustainability of recreational fishing in the Middle Negro River region, Amazonas, Brazil. The score scale goes from zero (worst) to 10 (best), expressing how close the current state of the fishery is to the status of "worst" or "best" situation in terms of sustainability. * Value of the Brazilian Real (BRL) converted to US dollar (USD) is 6.192 BRL for 1 USD as of 12/31/2024 (www.bcb.gov.br/conversao).

Sustainability attributes	**Description and Scoring**	**Reference**	**Data source**
I. Ecological	*This dimension highlights the main ecological and ecosystem factors that influence the sustainability of fisheries, considering the target species and the environment.*		
Exploitation status	Assesses the level of exploitation of the peacock bass stocks (*Cichla* spp.) in the region of the Middle Negro River, Barcelos, Amazonas: under exploited (10 – 8); little exploited (7 – 6); partially exploited (5 – 3); over exploited (0 – 2);	Modified standard attribute Pitcher (2003) and Pitcher et al. (2013)	Socioeconomic questionnaire - perception of respondents
Vulnerability	Assesses the susceptibility of species in fisheries through the intrinsic vulnerability index (V-Index) of Cheung et al. (2005): low (10 – 8), moderate (7 – 6), high (5 – 4), or very high (3 – 0)	Modified standard attribute Pitcher (2003) and Pitcher et al. (2013)	Socioeconomic questionnaire - perception of respondents and V-Index available per species from Froese & Pauly (2024)
Habitat status	Level of environmental degradation in the region of the Middle Negro River, Barcelos, Amazonas: none= (10 – 8); low= < 25% (7 – 6); average= 25% – 50% (5 – 4); high= 50% – 75% (3 – 2) or very high=75% – 100% (1 – 0)	Modified standard attribute Pitcher (2003) and Pitcher et al. (2013)	Socioeconomic questionnaire - perception of respondents
Apparent mortality	Assesses the level of apparent mortality of peacock bass after release into the environment (due to injury, mishandling or visualization of predation by predators (dolphins)): none= (10 – 8); low= 0 – 25% (7 – 6); average= 25% – 50% (5 – 4); high= 50% – 75% (3 – 2) or very high=75% – 100% (1 – 0)	Modified standard attribute Pitcher (2003) and Pitcher et al. (2013)	Socioeconomic questionnaire - perception of respondents
Fish size	Evaluates the change in the size of peacock bass in the region of the Middle Negro River, Barcelos, Amazonas: increasing rapidly (10 – 8); increasing slowly (7 – 6); remains constant (5 – 4); reducing slowly (3 – 2); reducing rapidly (0 – 1).	Modified standard attribute Pitcher et al. (2013)	Socioeconomic questionnaire - perception of respondents
Percentage of juveniles (specimens < 30 cm (L_{50})	Percentage of peacock bass individuals captured before reaching the first sexual maturation in the Middle Negro River region, Barcelos, Amazonas: none= (10 – 8); low = 0 – 25% (7 – 6); medium = 25% – 50% (5 – 4); high = 50% – 75% (3 – 2) or very high = 75% – 100% (1 – 0)	Modified standard attribute Pitcher (2003) and Pitcher et al. (2013)	Socioeconomic questionnaire - perception of respondents
II. Economic	*This dimension highlights the main economic factors that influence the sustainability of fishing, considering the price of the trip and the economic importance of the activity.*		
Price of trip*	Evaluates the average price of the fishing trip for recreational fishing in Barcelos, Amazonas: > US$ 1,615.00 (10 – 8); US$ 1,615.00 – US$	Modified standard attribute	Socioeconomic questionnaire perception of respondents

	1,453.00 (7 – 6); US$ < 1,292.00 – US$ < 969.00 (5 – 3) and < US$ < 807.00 (2 – 0).		
Importance in the local economy	Percentage of the degree of importance of the activity in the economic of the municipality of Barcelos, Amazonas: very high= 100% – 75% (10 – 8); high = 75% – 50% (7 – 6); average = 50% – 25% (5 – 4) and low = < 25% (3 – 2) or none (1 – 0).	New attribute	Socioeconomic questionnaire - perception of respondents
Subsidies	Interviewees' perception of subsidies provided by government agencies (state and municipal) to support recreational fishing in Barcelos, Amazonas: high = 100% – 50% (10 – 8); average = 50% – 25% (7 – 6); low = < 25% (5 – 3) or none (2 – 0).	Modified standard atribute Pitcher et al. (2013)	Socioeconomic questionnaire - perception of respondents
Company headquarters	Determines the location of the headquarters of the fishing company that sells trips to the Middle Negro River region: Barcelos (10 – 8), Manaus or another municipality (7 – 6), another state (5 – 3) or another country (2 – 0)	New attribute	Socioeconomic questionnaire - perception of respondents
Local guides	Place of residence of fishing guides working in fishing companies: Barcelos (10 – 8), Manaus or another municipality (7 – 4) or another state (3 – 0).	Modified standard attribute Pitcher (2003) and Pitcher et al. (2013)	Socioeconomic questionnaire - perception of respondents
III. Fishing experience	*This dimension highlights the main factors of the fishing experience that influence the sustainability of fishing, considering the catch rate and fishing licenses.*		
Trip duration	Evaluates the duration of the trip to the municipality of Barcelos for recreational fishing: short (10 – 7), moderate (6 – 4) or long (3 – 0)	Modified standard atribute Pitcher et al. (2013)	Socioeconomic questionnaire - perception of respondents
Fishing modality	Evaluates the rate of adoption of the practice of catch and release by fishers in the Middle Negro River region, Amazonas: high= 100% – 50% (10 – 8); average= 50% – 25% (7 – 4); low= < 25% (3 – 0).	New attribute	Socioeconomic questionnaire - perception of respondents
Fishing license	Evaluates whether fishers have an amateur fisher's license (sports or recreational): Has one and is valid (10 – 7); has one but it is out of date (6 – 4); does not have one or did not know it was needed (3 – 0).	New attribute	Socioeconomic questionnaire - perception of respondents
Catch rate	Assesses the level of catchability of peacock bass (*Cichla* spp.) in the region of the Middle Negro River, Barcelos, Amazonas: very high (10 – 8), high (7 – 6), medium (5 – 4) r low (3 – 0).	New attribute	Socioeconomic questionnaire - perception of respondents
Environmental impact of recreational fishing	Assesses the level of impact of recreational fishing on natural and fishery resources in the Middle Negro River region, Barcelos, Amazonas: none (10 – 8), low (7 – 6), medium (5 – 4), high (3 – 0).	Modified standard atribute Pitcher (2003)	Socioeconomic questionnaire - perception of respondents
IV. Management performance	*This dimension highlights the main management performance factors that influence the sustainability of fisheries, considering infrastructure and organization of the activity.*		
Infrastructure	Evaluates the level of existing infrastructure in the municipality of Barcelos for the reception of fishers (ex: airport, streets, port of anchorage of boats	New attribute	Socioeconomic questionnaire - perception of respondents

	and etc.): very good (10 – 8); good (7 – 6); indifferent (5 – 4), bad (3 – 2) or terrible (1 – 0)		
Organization of activity	Evaluates the level of organization of the activity to maximize the income of/benefits to the municipality (e.g.: visits to historical sites, fairs, sale of local crafts, etc.): very good (10 – 8); good (7 – 6); indifferent (5 – 4), bad (3 – 2) or terrible (1 – 0)	New attribute	Socioeconomic questionnaire - perception of respondents
Data collection for management	Evaluates data collection by local management on recreational fishing activities in the Middle Negro River region, Barcelos, Amazonas: high = 100% – 50% (10 – 8); average = 50 – 25% (7 – 6); low = < 25% (5 – 4) or none (3 – 0)	Modified standard atribute Pitcher (2003) and Pitcher et al. (2013)	Socioeconomic questionnaire - perception of respondents
Oversight	Evaluates the level of supervision carried out by local management in recreational fishing in the region of the Middle Negro River, Barcelos, Amazonas: High= 100% – 50% (10 – 8); average= 50% – 25% (7 – 6); low= < 25% (5 – 4) or none (3 – 0)	Modified standard attribute Pitcher (2003) and Pitcher et al. (2013)	Socioeconomic questionnaire - perception of respondents
Communication of rules	Assesses the level of communication of environmental and fisheries rules for recreational fishing: high = 100% – 50% (10 – 8); average = 50% – 25% (7 – 6); low = < 25% (5 – 4) or none (3 – 0)	Modified standard attribute Pitcher (2003) and Pitcher et al. (2013)	Socioeconomic questionnaire - perception of respondents
V. Social	*This dimension highlights the main social factors that influence the sustainability of fisheries, considering conflicts and socioeconomic aspects.*		
Increase in fishers in the region	Evaluates the growth in the number of fishers visiting the region of the Middle Negro River, Barcelos, Amazonas for recreational fishing: remains constant (10 – 8); slowly reducing (7 – 6); rapidly reducing (5 – 4); slowly increasing (3 – 2); or rapidly increasing (1 – 0)	New attribute	Socioeconomic questionnaire - perception of respondents
Level of education	Evaluates the level of formal education of the actors: higher education (10 – 8); secondary education (7 – 6); elementary education (5 – 3) or illiterate (2 – 0)	Modified standard atribute Pitcher and Preikshot (2001)	Socioeconomic questionnaire - perception of respondents
Conflict	Evaluates the existence of level of social conflicts among users of fishing resources in the Middle Negro River, Barcelos, Amazonas: none = (10 – 8); low = < 25% (7 – 6); average = 25 – 50% (5 – 3) or high = 50% – 100% (2 – 0).	Modified standard atribute Pitcher and Preikshot (2001), Pitcher (2003) and Pitcher et al. (2013)	Socioeconomic questionnaire - perception of respondents
Monthly income*	Evaluates the average monthly income of the interviewed actors: > US$ 1,174.00 (10 – 9); US$ 1,174.00 – US$ 783.00 (8 – 7); US$ 783.00– US$ 391.00 (6 – 5); US$ 391.00 – US$ 197.00 (4 – 2); < US$ 197.00 (1 – 0)	Modified standard atribute Pitcher et al. (2013)	Socioeconomic questionnaire - perception of respondents
Age profile	Assesses the age profile of the interviewees: age > 60 years (10 – 9); 59 – 50 years (8–7); 49 – 40 years (6 – 5); 39 – 30 years (4 – 3); < 30 years (2 – 0)	Modified standard atribute Pitcher et al. (2013)	Socioeconomic questionnaire – perception of respondents

In general, the method orders the attributes through a multidimensional scaling technique (MDS), resulting in two-dimensional ordering graphs for the evaluation field. The orderings are anchored by fixed reference points (anchor points) that simulate the worst (bad = 0%) and best (good = 100%) possible classifications. These were fixed in the upper left and right portion on the x-axis (horizontal) (Kavanagh and Pitcher, 2004; Pitcher and Preikshot, 2001). While on the y-axis (vertical), it represents other factors, unrelated to sustainability (or whatever status is being scored), that distinguish the perspectives. In addition, the anchoring (down = -50 and up = +50) ordered on the graph (circular shape) serves to block the problem against the problem of the upper and lower goals of the graph (Kavanagh and Pitcher, 2004; Pitcher and Preikshot, 2001). The rating scale was defined following the steps of Pitcher et al., (2009) and used by (Jimenez et al., 2021): “not sustainable” (<40%), “less than safisfactory” (40% to <60%), “acceptable” (60% to <70%) or “satisfactory” (≥70%).

In the literature, the RAPFISH method is described in detail (Kavanagh and Pitcher, 2004; Pitcher, 1999; Pitcher et al., 1998, 2013; Pitcher and Preikshot, 2001). The R code for the RAPFISH algorithm was downloaded from the site (www.rapfish.org). All analyses were performed in the R software (R Core Team, 2023).

3 Results

3.1 Socioeconomic profile of groups of actors

In all the groups, men formed the majority of the interviewees and were aged between 18 and 80 years old (Table III: 2). Regarding the level of education, most fishing guides had elementary education (Table III: 2). The local community and entrepreneurs had an average level of education, while the fishers (Brazilian and foreign) had a predominantly higher education level (Table III: 2). Guides and the local community formed the majority of respondents in the lowest income brackets, while the Brazilian and foreign fishers formed the majority in the highest middle-income brackets (Table III: 2).

Table III: 2 – Descriptive analysis of demographic and socioeconomic variables of stakeholder groups interested in assessing the sustainability of recreational fishing in the Negro River region, Brazilian Amazon. *Value of Brazilian real (BRL) converted to US dollar (USD) is 6,192 BRL for 1 USD as of 12/31/2024 (www.bcb.gov.br/conversao).

Demographic and socioeconomic variables		Fishing guides	Local community	Brazilian fishers	Foreign fishers	Fishing entrepreneurs
Total respondents		52	201	130	20	30
Sex	**Female**	0	98	1	0	1
	Male	52	103	129	20	29
Age (years)		23 – 69 (44.18 ± 11.85)	18 – 75 (46.09 ± 16.92)	27 – 80 (54.22 ± 13.55)	28 – 71 (54.83 ± 20.82)	27 – 56 (42.58 ± 9.94)
Level of Education	**Illiterate**	0	1	0	0	0
	Elementary school	31	81	0	0	10
	High school	20	104	16	4	18
	Higher education	1	15	114	16	2
Average monthly income range *	**< US$ 197.00**	23	123	0	0	3
	US$ 197.00 – US$ 391.00	23	68	1	0	6
	US$ 391.00 – US$ 783.00	4	9	2	0	7
	US$ 783.00 – US$ 1,174.00	1	1	5	0	10
	> US$ 1,174.00	1	0	122	20	4

3.2 Comparison between different actors' perspectives on recreational fishing

The average scores for the sustainability of recreational fishing in the five evaluation dimensions ranged from 8.85% to 81.65% (Table III: 3). In general, the perspectives of fishing guides, local community, fishing entrepreneurs and foreign sport fishers showed an overall performance that was “less than satisfactory” (40% to <60%; Figure III: 3). From the perspective of Brazilian fishers, the overall performance was “acceptable” (60% to <70%; Table III: 3; Figure III: 3). In general, in most perspectives, the best performance rating was obtained for the “fishing experience” dimension, and the worst performance in the “management performance” dimension (Table III: 3; Figure III: 3).

Table III: 3 – Performance of the five dimensions of sustainability of recreational fishing in the Middle Negro River, Amazonas, Brazil, according to the ordering of the RAPFISH method and the perspectives of the five groups of actors directly involved in the activity.

Perspectives on fishing	Ecological Sustainability	Economic Sustainability	Fishing experience	Management performance	Social Sustainability	Mean	Rank
Brazilian fishers	55.24	66.68	78.64	18.57	**81.65**	**60.16**	1
Foreign fishers	50.67	63.19	77.49	16.06	79.32	57.35	2
Fishing entrepreneurs	**60.25**	**67.53**	80.98	11.11	60.03	55.98	3
Local Community	52.76	52.96	71.09	**19.66**	43.94	48.08	4
Fishing guides	54.98	58.58	**81.55**	8.85	35.26	47.84	5

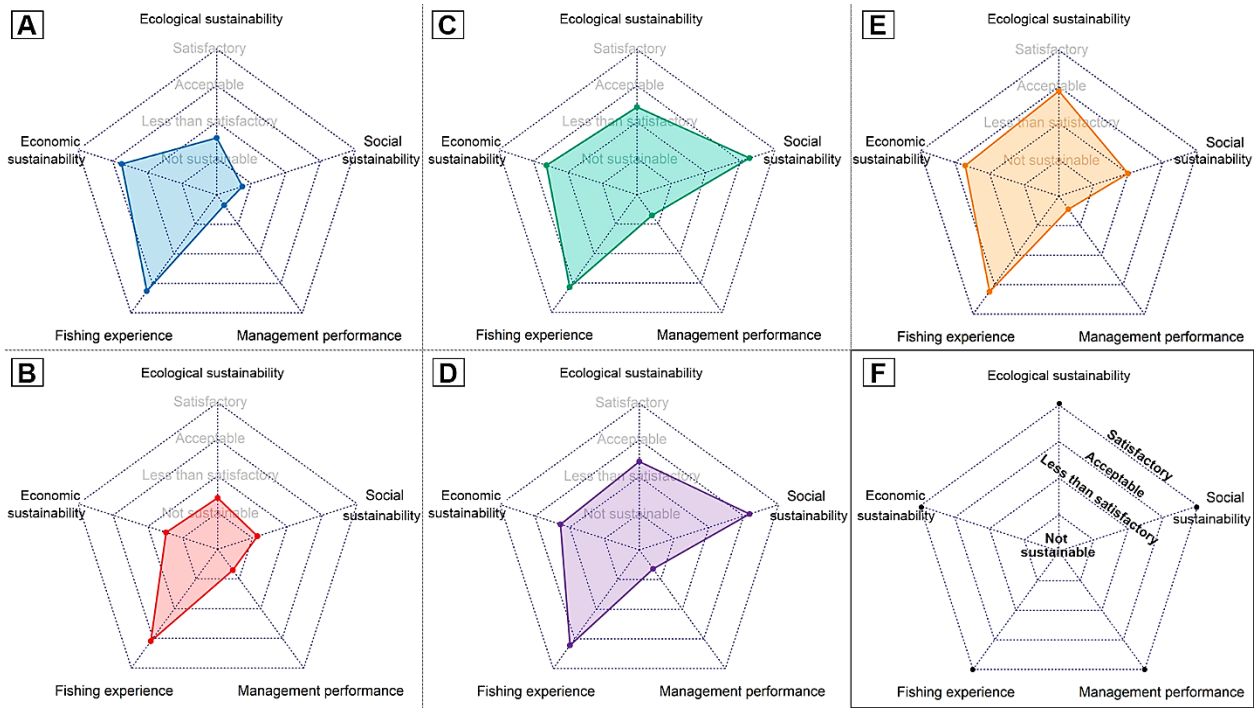

Figure III: 3 - Multidimensional kite diagrams showing the sustainability scores in the five evaluation dimensions, according to the perspectives of the groups of actors involved in recreational fishing in the Middle Negro River region, Brazilian Amazon. A) fishing guides, B) local community, C) Brazilian fishers, D) foreign fishers, E) fishing entrepreneurs, and F) model diagram with the five dimensions and identification of sustainability levels.

3.3 Performance analysis of each group of actors in the different dimensions of sustainability

In the dimension of ecological sustainability, the perspective of foreign fishers and fishing entrepreneurs was of worst and best performance, respectively (Figure III: 4A and Figure III: 4B). In the perspective of all the actors, the ecological dimension was “less than satisfactory”, with the exception of fishing entrepreneurs who indicated an “acceptable” performance (Figure III: 4B). The two main attributes that influenced

the position of the ordering of the perspectives were vulnerability and apparent mortality (Figure III: 4C).

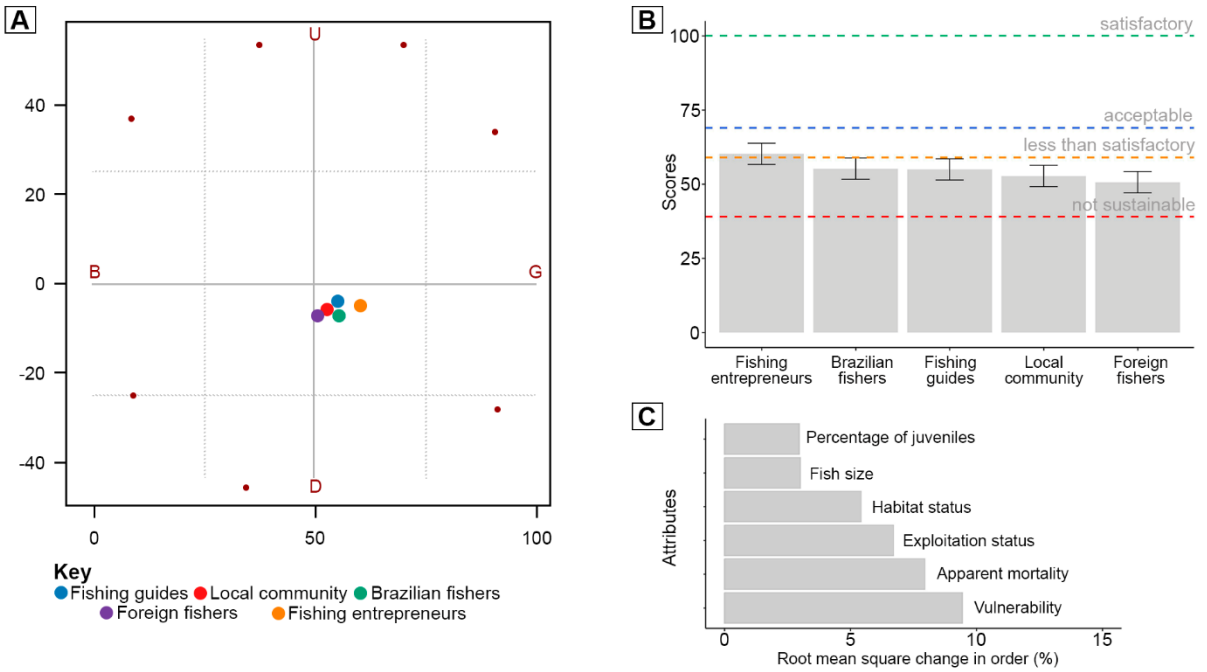

Figure III: 4 – RAPFISH ecological sustainability assessment of the perspectives of five stakeholder groups regarding recreational fishing in the Middle Negro River, Brazilian Amazon. A) two-dimensional ordering of multidimensional scaling (MDS) analysis. The reference anchor points were set at 100 (G= Good) and 0 (B= Bad) on the x-axis, and at -50 (D= Down) and +50 (U= Up) on the y-axis. B) sustainability scores from the perspective of the actors, indicated in order of performance classification, from left to right. Dashed lines indicate performance rating: “satisfactory” (≥70%); "acceptable"(60% to <70%), “less than safisfactory” (40% to <60%) and “not sustainable” (<40%), and C) attribute leverage analysis of RAPFISH ordering, based on standard error as a percentage (se%).

In the dimension of economic sustainability, the perspectives of the local community and fishing entrepreneurs was the worst and best performing, respectively (Figure III: 5A and Figure III: 5B). From the perspective of the fishing entrepreneurs, Brazilian and foreign fishers, the economic dimension had an “acceptable” performance. While from the perspective of the fishing guides and the local community, the performance was “less than satisfactory” (Figure III: 5B). The two main attributes that influenced the position of the ordering of the perspectives were subsidies and importance to the local economy (Figure III: 5C).

In the fishing experience dimension, the perspectives of the local community indicated the worst performance; while, for the fishing guides, it was the best (Figure III: 6A and Figure III: 6B). In general, the fishing experience dimension was of “satisfactory” performance for all the actors (Figure III: 6B). The two main attributes

that influenced the position of the ordering of the perspectives were fishing modality and catch rate (Figure III: 6C).

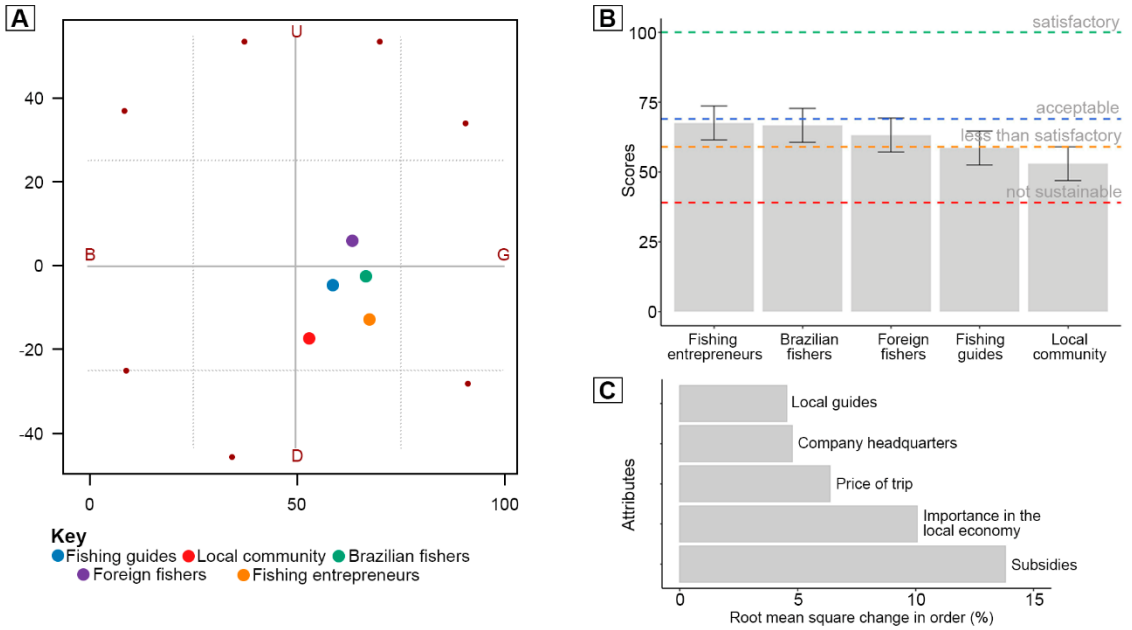

Figure III: 5 – RAPFISH economic sustainability assessment of the perspectives of the five groups of actors on recreational fishing in the Middle Negro River, Brazilian Amazon. A) two-dimensional ordering of multidimensional scaling (MDS) analysis. The reference anchor points were set at 100 (G=Good) and 0 (B= Bad) on the x-axis, and at -50 (D= Down) and +50 (U= Up), on the y-axis. B) sustainability scores from the perspective of the actors, indicated in order of performance classification, from left to right. Dashed lines indicate performance rating: “satisfactory” (≥70%); “acceptable” (60% to <70%), “less than safisfactory” (40% to <60%) and “not sustainable” (<40%), and C) attribute leverage analysis of RAPFISH ordering, based on the standard error in percentage (se%).

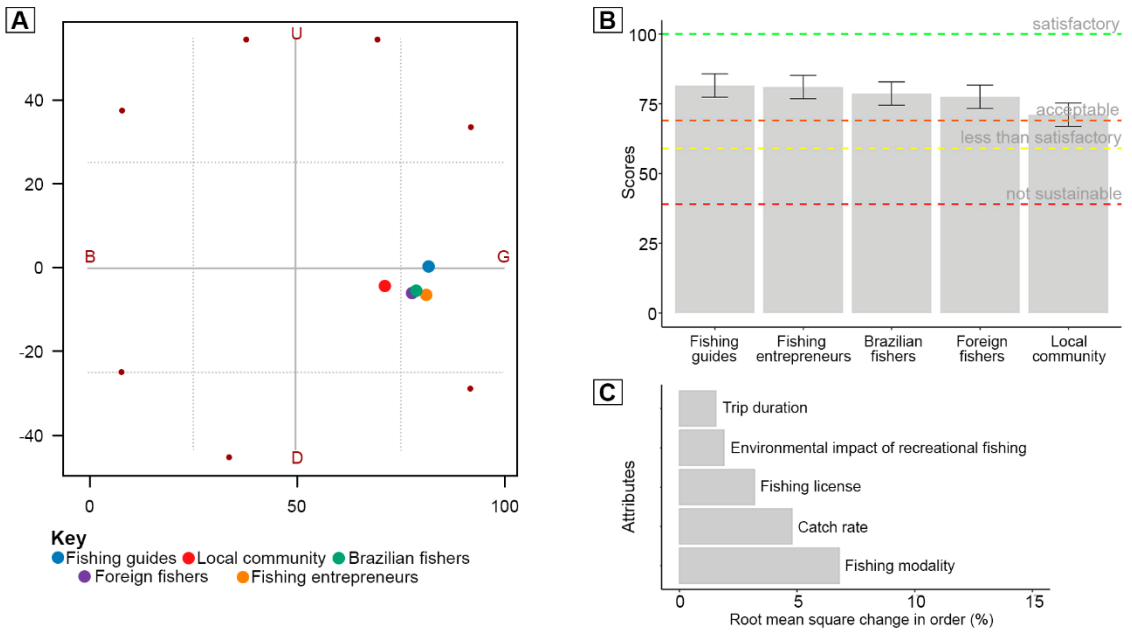

Figure III: 6 – RAPFISH fishing experience assessment of the perspectives of the five groups of actors on recreational fishing in the Middle Negro River, Brazilian Amazon. A) Two-dimensional ordering of multidimensional scaling (MDS) analysis. The reference anchor points were set at 100 (G=Good) and 0 (B= Bad) on the x-axis, and at -50 (D= Down) and +50 (U= Up) on the y-axis. B)

Sustainability scores from the perspectives of the actors, indicated in order of performance classification, from left to right. Dashed lines indicate performance rating: “satisfactory” (≥70%); “acceptable” (60% to <70%); “less than safisfactory” (40% to <60%) and “not sustainable” (<40%), and C) attribute leverage analysis of RAPFISH ordering, based on the standard error as a percentage (se%).

In the “management performance” dimension, the perspectives of the fishing guides and local community indicated the worst and best performance, respectively (Figure III: 7A and Figure III: 7B). However, for all the actors, the “management performance” dimension had the worst performance, being “not sustainable” (Figure III: 7B). The main attributes that influenced the position of the ordering of perspectives were data collection, organization and infrastructure (Figure III: 7C).

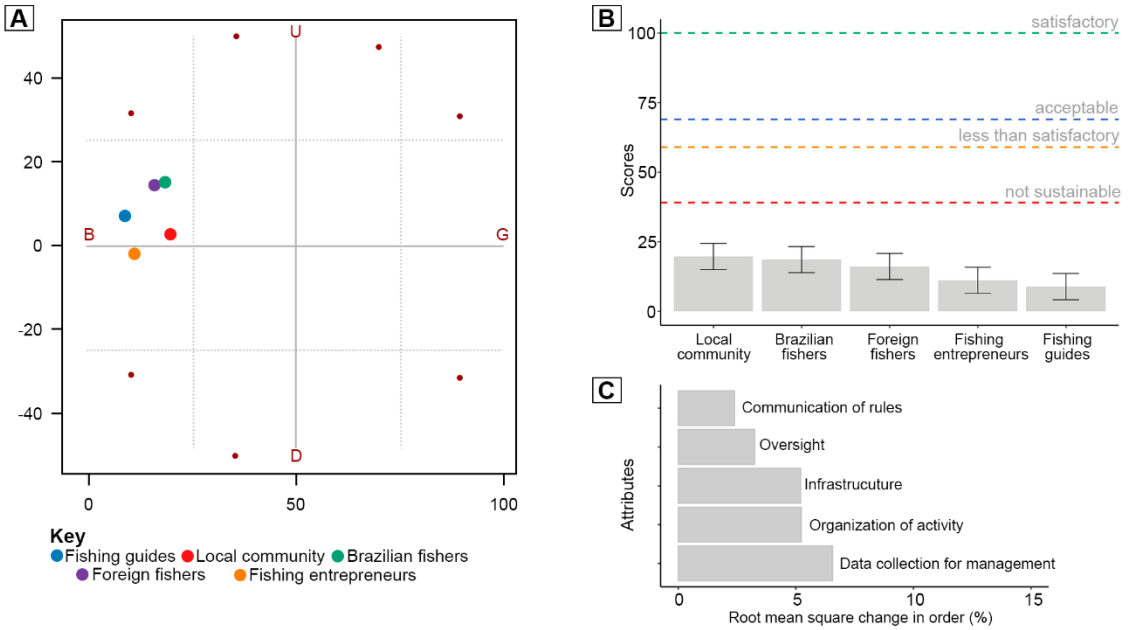

Figure III: 7 – RAPFISH management performance assessment of the perspectives of the five groups of actors on recreational fishing in the Middle Negro River, Brazilian Amazon. A) two-dimensional ordering of multidimensional scaling (MDS) analysis. The reference anchor points were set at 100 (G=Good) and 0 (B= Bad) on the x-axis, and at -50 (D= Down) and +50 (U= Up), on the y-axis. B) sustainability scores from the perspective of the actors, indicated in order of performance classification, from left to right. Dashed lines indicate performance rating: “satisfactory” (≥70%); “acceptable” (60% to <70%); “less than safisfactory” (40% to <60%) and “not sustainable” (<40%), and C) attribute leverage analysis of RAPFISH ordering, based on the standard error as a percentage (se%).

In the social sustainability dimension, the perspectives of the fishing guides and Brazilian sport fishers was the worst and the best, respectively (Figure III: 8A and Figure III: 8B). From the perspectives of Brazilian and foreign sport fishers, the social dimension had a “satisfactory" performance. While for the fishing entrepreneurs and local community, there was “less than satisfactory" performance and, for the fishing guides the performance was "not sustainable" (Figure III: 8B). The two main attributes

that influenced the position of the ordering of the perspectives were monthly income and conflicts (Figure III: 8C).

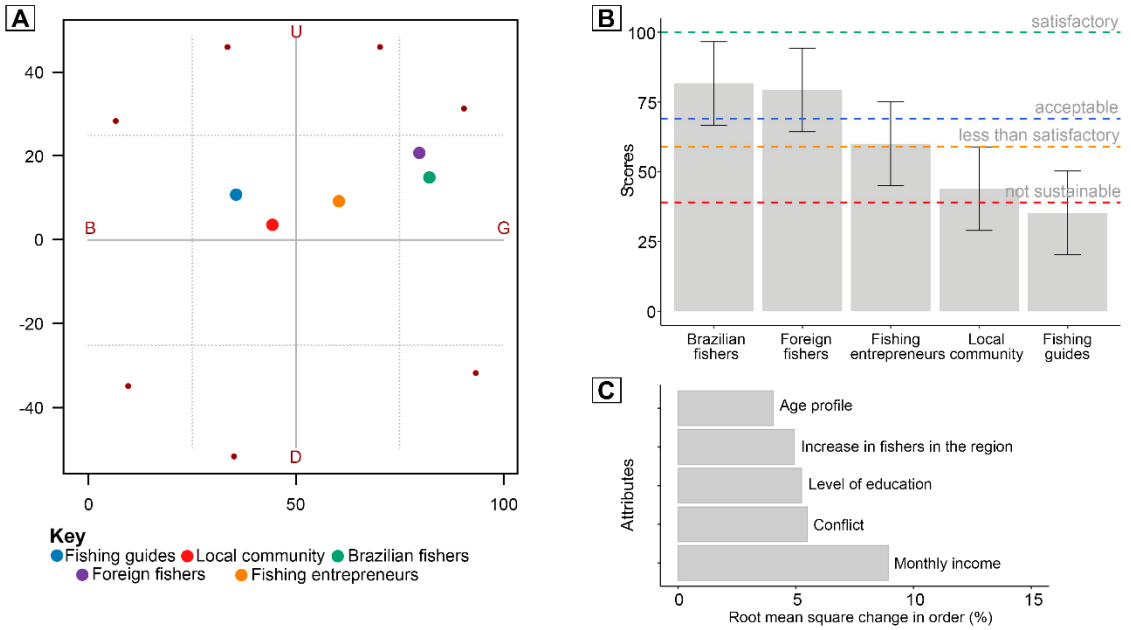

Figure III: 8 – RAPFISH social sustainability assessment of the perspectives of the five groups of actors on recreational fishing in the Middle Negro River, Brazilian Amazon. A) two-dimensional ordering of multidimensional scaling (MDS) analysis. The reference anchor points were set at 100 (G=Good) and 0 (B= Bad) on the x-axis, and at -50 (D= Down) and +50 (U= Up), on the y-axis. B) sustainability scores from the perspective of the actors, indicated in order of performance classification, from left to right. Dashed lines indicate performance rating: “satisfactory” (≥70%); "acceptable” (60% to <70%); “less than safisfactory” (40% to <60%) and “not sustainable” (<40%), and C) attribute leverage analysis of RAPFISH ordering, based on the standard error as a percentage (se%).

4 Discussion

The results of this study indicate that the overall sustainability of recreational fishing in the Middle Negro River, according to the perspectives of the five actors evaluated, was “less than satisfactory”. The activity obtained better results in the dimensions of fishing experience and economic sustainability but performed worse in the dimensions “management performance” and “ecological sustainability”. The best rating in the fishing experience was attributed to the majority adoption of the catch and release modality (91.98%) and the high catch rate (95.24%). Barcelos, on the Middle Negro River, is known as the capital of recreational fishing (Lubich et al., 2023a), as its rivers are the scene of the largest peacock bass catches in Brazil (BGFA, 2024) and the rest of the world (IGFA, 2024). In this way, fishers achieve their fishing goals, which results in satisfaction. Lubich (2025) state that fishers who had successful fishing trips in the Middle Negro River, catching large or significant amounts of fish, are interested in returning.

An important finding of this study is the variation in sustainability perceptions between different groups of actors. While the overall performance was rated as “less than satisfactory” by most groups, Brazilian recreational fishers classified it as “acceptable”. This divergence may be partially explained by the socioeconomic profile of the respondents (Table III: 2). Brazilian fishers, who reported higher education levels and incomes, tended to place greater emphasis on the quality of the fishing experience, as this was a dimension in which they assigned high scores, while showing comparatively less concern for ecological or governance issues. This selective perception may reflect a cognitive bias where personal satisfaction with outcomes, such as successful catches and comfort during trips, overshadows broader concerns related to environmental impacts or management failures. In contrast, local actors such as fishing guides and local community members, who experience the day-to-day realities of the activity and its effects on livelihoods and the environment, were more critical of management and ecological aspects. These differences in perspective highlight the importance of considering socioeconomic context when interpreting sustainability assessments and reinforce the need for inclusive management strategies that integrate the views and experiences of all stakeholder groups.

One of the factors that motivate fishers to return to this recreational activity is related to psychological pleasure, especially relaxation (Calvert, 2002; Fedler and Ditton, 1994; Knopf et al., 1973; Ross and Loomis, 2001). Holland and Ditton (1992) reviewed eleven studies and listed fifteen main reasons that appeal to recreational fishing enthusiasts: nature, escape, sociability, relaxation, catching fish, equipment, nostalgia, exercise, eating fish, achievement, challenge, learning, exploration, privacy and catching trophy fish. In the context of the Middle Negro River, contact with nature, the opportunity to escape from routine, and the pursuit of trophy fish are particularly evident and frequently reported by fishers. The natural beauty and ecological uniqueness of the Amazonian landscape provide a strong connection with nature and a clear break from urban life. Moreover, the region is nationally and internationally recognized for the catch of large peacock bass (*Cichla temensis*), reinforcing its appeal to those seeking both challenge and the satisfaction of capturing trophy specimens. These elements, combined, contribute significantly to the motivation of recreational fishers to return to the region.

Economic sustainability is mainly explained by the non-existence (42.96%) of subsidies or the low (39.26%) value of the subsidy rate and high importance of the

activity to the local economy (66.42%). Globally, the impacts of recreational fishing on the economy are recognized (Arlinghaus et al., 2016; Arlinghaus and Cooke, 2009) and result in the generation of employment and income, as well as spending on food, hotels, fuel, bait and boat rental fees, among others (Potts et al., 2022; Storey and Allen, 1993). In the Middle Negro River, recreational fishing generates jobs for cooks, waiters, boat captains and mechanics (Lubich et al., 2023a). However, in the present study, 15.5% of respondents reported that some service positions related to sport fishing tourism are not filled by local residents. In this way, the generation of employment and income from these jobs do not affect or are not injected directly into the local economy. Estimates indicate that the value of recreational fishing in the Middle Negro River is around US$ 49,228,286.61 per year (Lubich, 2025), evidencing the economic value for the region. In addition to contributing to the local economy, the activity can promote social justice by creating opportunities for the local community.

The main variable in the evaluation of the "management performance" dimension that contributed to the negative result was the lack of a collection system for information (99.08%) on recreational fishing in the Middle Negro River, Amazonas. In general, the absence of collection of information on the activity seems to be common in the national scenario and around the world (Arlinghaus et al., 2019). Policymakers and managers around the world should pay more attention to the often-overlooked recreational fisheries sector (Arlinghaus et al., 2019). For although there is legislation for the activity, this does not necessarily mean that such laws promote comprehensive sustainability practices, resolve conflicts between stakeholders or improve the well-being of fishers (Abbott et al., 2018).

In the municipality of Barcelos, there is no management of the activity and access to fishing areas is free (Lubich et al., 2021). The lack of management is reflected in the precarious infrastructure for tourism in the municipality. As a result, recreational fishers spend money only on fishing trips, hotels (overnight) and crafts, the latter being variable, since there is no place dedicated to the exhibition of local culture or the sale of handicrafts. In addition, studies have shown that the population of peacock bass (*Cichla temensis*) in the region may be overexploited (Holley et al., 2008; Lubich et al., 2021), which is mainly due to the increase in the number of fishers (Lubich et al., 2021). This pattern of overfishing in open access sites is consistent with what is observed globally in recreational fisheries, where high mortality from local

fishing can occur, as well as traffic problems and congestion in fishing areas (Arlinghaus et al., 2019).

The perception of ecological unsustainability identified in this study is also supported by previous ecological modeling efforts in the region. Holley et al. (2008) demonstrated that even modest exploitation rates (5–10%) could reduce the abundance of large *Cichla temensis* (>62 cm) by up to 50%, and rates equal to natural mortality could lead to reductions as high as 89%. Similarly, Lubich et al. (2021) found that rivers with higher fishing intensity had lower average fish length and fewer large individuals, indicating potential overexploitation. These ecological indicators reinforce and help validate the stakeholder perceptions captured by the RAPFISH analysis, highlighting the real and perceived vulnerability of the resource. This alignment strengthens the argument for proactive management to avoid further declines.

At the state level, although there is a legal requirement for sport fishing companies to apply for licenses from the Amazonas Environmental Protection Institute (IPAAM), many do not renew the document after the first year, suggesting clandestine operations (Lubich et al., 2024). Grati et al. (2024) noted that, in Europe, regulatory measures for recreational fishing are usually implemented in response to crises, such as the collapse of stocks due to overfishing or environmental changes. In the Amazonian scenario, the pirarucu (*Arapaima gigas*) is an example of this situation. In the 70s, the species suffered from overfishing (Bayley and Petrere, 1989; Isaac et al., 1998; Queiroz and Sardinha, 1999) and, as a response, measures were subsequently implemented that ensured the increase and sustainability of stocks in the long term (Garcez and Sánchez-Botero, 2006; Queiroz, 2005). Considering the practice of sport fishing, Barcelos can be a place where the planning of this type can provide good results for the activity and the region.

The governance failures observed may stem from a combination of institutional and operational constraints. Although the responsibility for regulation formally rests with the state (IPAAM), limited enforcement, lack of digital transparency, and weak coordination with municipal agencies hinder effective implementation. Additionally, structural issues such as insufficient financial resources, lack of technical capacity, low political priority given to the recreational fisheries sector, and overlapping mandates between governmental spheres further aggravate the management vacuum. These factors contribute to a systemic fragility that compromises long-term planning and the ability to respond proactively to ecological and social challenges. A clear example is

the lack of accessible public data: although agencies like IPAAM are responsible for licensing, they do not provide regular bulletins or digital systems that disclose structured information about fishers, operators or fishing pressure in the region, limiting transparency and accountability.

Taken together, the poor performance in both the “management performance” and “ecological sustainability” dimensions suggests the need for integrated approaches. To ensure sustainability in recreational fishing, it is necessary to consider these two aspects together, since they can promote resilience and equity through proactive and adaptive policies (Arlinghaus et al., 2017; Chapin et al., 2010; Elmer et al., 2017). Nonetheless, for this to happen, the involvement of stakeholders in fisheries management is necessary (Arlinghaus et al., 2017; Brownscombe et al., 2019; Chapin et al., 2010; Dedual et al., 2013; Elmer et al., 2017).

The situation in Barcelos is comparable to other regions where recreational fishing is culturally and economically important. For example, Abbott et al. (2018) highlighted the importance of recreational fishing for red snapper in the Gulf of Mexico, in the United States of America, emphasizing the need for effective governance to manage the economic and social impacts of this activity. Similarly, Grati et al. (2024) found a relatively poor overall performance of recreational marine fisheries governance in Europe and underscored the need for effective governance of the activity to maximize social and economic benefits. Thus, it is evident that recreational fishing is a relevant and valuable component on a regional, national and global scale, and that several factors can compromise its development, thus requiring governance and management to be allied to ensure sustainability and maximize the benefits of the activity (Abbott et al., 2018; Arlinghaus et al., 2019; Grati et al., 2024).

Studies that aim to evaluate the sustainability of marine (Pitcher, 2003) or freshwater (Braz Neto et al., 2021) recreational fishing are scarce. However, similar results to the present study were found in the recreational fishery for marlin off the coast of Kenya, with the best ratings in the dimensions of fishing experience and ecological performance, and the worst in “management performance” and economic performance (Pitcher, 2003). Marine multispecies fisheries in Florida showed different results, with best classifications for the social and economic dimensions (Pitcher, 2003). In general, the pattern of the worst classification being for “management performance” was consistent in all the locations, evidencing the need for improvements to the fisheries management of recreational fisheries.

Compared to commercial fisheries, recreational fishing is poorly studied and undervalued by many governments and management agencies. Despite this, it is important to point out that the management of commercial fisheries in Brazil, and in particular in the Brazilian Amazon, also faces significant challenges and is considered precarious (Batista et al., 2014; Da Cunha and Sousa, 2024; Isaac et al., 2008; Ruffino, 2008). Studies on sustainability are found for commercial fisheries in several regions of the world: Chile (Franco-Meléndez et al., 2021), India (Suresha Adiga et al., 2015, 2016), French Guiana (Cissé et al., 2014), Indonesia (Haerunnisa et al., 2013; Ramadhanty et al., 2021), Africa (Preikshot et al., 1998) and Brazil (Braz Neto et al., 2021; Castello et al., 2009; Isaac et al., 2009; Jimenez et al., 2021; Martins et al., 2009; Pereira et al., 2020). Therefore, there is an evident need for more studies on the development of recreational fishing around the world, as both modalities affect the decline in fish stocks (Bova et al., 2024; Cooke and Cowx, 2004, 2006; Cowx et al., 2010; Lewin et al., 2019).

In the Amazon, recreational fishing not only contributes to the local economy, but it is also deeply linked to the culture and way of life of communities (Lubich et al., 2024a). In Barcelos, there is a new opportunity for work, which is represented by the change from being a commercial fisher to working as a fishing guide, given the value that recreational fishing activity currently generates for the municipality (Lubich et al., 2024a). In addition, fishing guides act as positive behavioral models in recreational fishing with recreational fishers (Lubich et al., 2024a), and they are examples of conservation of the environment and the target species (Farthing et al., 2022). Due to its cultural reach, the activity is increasingly recognized as an important element of the cultures and economies of coastal (Cisneros-Montemayor and Sumaila, 2010; Mora et al., 2009) and of inland waters (Arlinghaus et al., 2016).

The RAPFISH technique presents simplified results in kite diagrams, thereby allowing comparisons of different locations, time periods, projections and specific management scenarios (Pitcher et al., 2013). However, one disadvantage of the method is that the orderings are influenced by the choice of attributes (Jimenez et al., 2021). Despite this, we can be confident in our conclusions, since the method was rigorously applied, and the scores were obtained without interference from the researchers and were based on the perspectives of the interviewees. Jimenez et al. (2021) highlighted the effort to make the scoring system accurate, despite difficulties due to the lack of baseline data. This may have occurred because the authors used

diverse sources of information, including literature, experts and questionnaires. In the present study, we used only the individual perspective of each group of actors studied, which better reflected the reality of the activity in the region of the Middle Negro River, Amazonas, Brazil.

The results found can guide the planning of priority policies in each dimension evaluated. The approach of this study can be replicated or adapted for other local fisheries and in global fishing regions, especially in fishery scenarios with scarce data in developing countries. Promoting sustainable fisheries requires strengthening basic human rights to increase the socio-ecological resilience and sustainability of fisheries resources, in line with the FAO Voluntary Guidelines (FAO, 2015, 2017) and the United Nations Sustainable Development Goals (United Nations, 2024).

5 Conclusions and Recommendations

The findings of this study reinforce the urgent need for an integrated management plan for recreational fishing in the Middle Negro River, with a special focus on improving governance and ensuring ecological sustainability. Given the economic and cultural importance of this activity to the Amazon region, developing participatory and adaptive strategies is essential to safeguard fishery resources, reduce local conflicts, and promote equitable and sustainable development.

The results of this study highlight the lack of efficient management in recreational fishing, especially regarding the aspects “management dimensions” and “ecological sustainability”. Below we highlight some actions that can be proposed for the development of sport fishing in the Middle Negro River:

✓ Implement a robust management system with adequate data collection to monitor activities and ensure the sustainability of fisheries resources in the medium and long term in the study area.

✓ Generate summarized, frequent bulletins on the data collected and other relevant information, available on a digital platform for public consultation.

✓ Create an integrated management plan that involves all the actors of recreational fishing. This plan should include environmental education campaigns for social, cultural and environmental awareness of all those involved, as well as transparency measures and communication of rules among stakeholders.

✓ Municipal management and fishing companies could create a fund to finance training programs, promoting professional skills, employment and income of the local community.

✓ Public-private partnerships to support local infrastructure financing and monitoring of sustainable fisheries.

✓ Encourage the active participation of recreational fishing entrepreneurs in certification programs and enhancement of fishery products, including the acquisition of fish from local fishers as a way to resolve conflicts and ensure the sustainability of activities.

✓ Creation of a local working group or collaboration network, composed of members of the population of Barcelos, technical professionals from public and private entities and researchers, among others, who can establish methods of data collection and analysis. These actions can contribute to performance in the five assessment dimensions used in the study, ensuring that recreational fishing contributes significantly to the sustainable development of the region.

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Data Availability Statement

The entire data set that supports the results of this study was published in the article itself.

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CONCLUSÃO GERAL

Esta tese teve como objetivo principal avaliar a sustentabilidade da pesca esportiva no médio rio Negro (Amazonas – Brasil), de forma integrada, a partir dos aspectos ecológico, econômico e social. A partir de três capítulos complementares, foi possível construir um panorama robusto e inédito sobre essa atividade que, embora amplamente praticada e valorizada na região, ainda carece de reconhecimento e regulação compatíveis com sua importância estratégica para o território amazônico. Os resultados revelaram que a atividade possui elevado valor recreativo, estimado em cerca de US$ 49,2 milhões anuais (245 milhões de reais anuais), diretamente associado ao tamanho dos tucunarés e a conservação ambiental. No entanto, a sustentabilidade foi classificada como “menos que satisfatória”, com fragilidades nas dimensões ecológica e de gestão.

Evidenciou-se, ainda, que a percepção da comunidade local e dos guias de pesca atribui à atividade desempenho social “menos satisfatório” e “insustentável”, respectivamente, ressaltando a necessidade de dar voz a esses atores no processo de ordenamento. Estudos futuros devem aprofundar a análise dessas dimensões sociais e econômicas, ampliando o entendimento sobre a pesca esportiva e fornecendo subsídios mais sólidos para políticas públicas baseadas em ciência, participação e conservação.

Diante desse cenário, a pesca esportiva no médio rio Negro representa uma atividade de alto valor econômico, ecológico e social, mas ainda não opera de forma plenamente sustentável. Para reverter esse quadro, é essencial integrar ciência, gestão pública, setor privado e participação social em um plano de manejo que valorize o conhecimento local e os interesses de longo prazo da região.

Recomendações específicas para a sustentabilidade da pesca esportiva

Gestão Municipal (Barcelos e municípios vizinhos)

- Coordenar, em conjunto com comunidades locais, a criação e implementação de acordos de pesca participativos, com zoneamento de áreas específicas para cada modalidade de pesca.
- Estruturar programas de capacitação de guias de pesca e trabalhadores do turismo, em parceria com operadores turísticos e associações comunitárias.

- Apoiar iniciativas de diversificação econômica (artesanato, gastronomia, turismo cultural e entre outros), fortalecendo a integração entre pesca esportiva e economia criativa.
- Regulamentar e fiscalizar a operação de pesca esportiva (acampamentos, barcos-hotel, pousadas, hotéis flutuantes e hotéis de selva), garantindo padrões mínimos de sustentabilidade.
- Criar espaços permanentes de diálogo entre operadores turísticos, comunidades, guias e órgãos de fiscalização.
- Estabelecer regras de contrapartida econômica local para empresas que operam sem vínculo com o município (ex.: exigência mínima de contratação de mão de obra local, compras no comércio municipal e contribuição a fundos locais de desenvolvimento).
- Implementar mecanismos de taxação ou compensação turística aplicados a empreendimentos que não deixam benefícios diretos na região, revertendo parte da receita para serviços comunitários.
- Incentivar os empreendedores da pesca a aderirem a programas de certificação e valorização dos produtos locais, promovendo acordos entre colônias de pescadores, áreas de manejo comunitário do pirarucu e operadores de turismo para o fornecimento de pescado, incluindo pirarucu manejado de forma legal, destinado à alimentação dos clientes durante a temporada de pesca esportiva.
- Incentivar os operadores de turismo a atuarem dentro da legalidade, estimulando a solicitação e regularização das documentações necessárias.
- Promover parceria com órgãos competentes, para realização de palestras, capacitações e ações de apoio à regularização das operações de turismo de pesca.
- Apoiar a pesquisa científica, por meio de parcerias com instituições de ensino, pesquisa e extensão, fomentando estudos sobre sustentabilidade, impactos ambientais e socioeconômicos da pesca esportiva.
- Desenvolver e implementar um selo de sustentabilidade municipal (“selo verde”) para empresas de turismo de pesca, reconhecendo aquelas que cumprem critérios como contratação de mão de obra local, compras no comércio municipal, regularização junto aos órgãos de fiscalização (municipal,

estadual e federal) e práticas adequadas de gestão de resíduos sólidos e líquidos.

- Estruturar sistemas municipais de coleta, monitoramento e divulgação de dados, com a publicação de boletins informativos destinados a comunidades, pescadores, operadores turísticos, órgãos reguladores e pesquisadores, garantindo transparência e acesso às informações relevantes sobre a pesca esportiva.

Gestão Estadual (Amazonas)

- Elaborar e implementar um Plano Estadual de Manejo da Pesca Esportiva, articulado com o ordenamento pesqueiro, a política estadual de turismo e a estratégia de conservação da biodiversidade amazônica.
- Estabelecer sistemas permanentes de monitoramento ecológico e socioeconômico, em cooperação com universidades, institutos de pesquisa e órgãos ambientais, integrando dados municipais em uma base estadual.
- Promover campanhas de valorização da pesca esportiva como alternativa sustentável frente a práticas extrativas predatórias, associando a imagem do estado a boas práticas ambientais e turísticas.
- Ampliar a fiscalização integrada entre órgãos estaduais de meio ambiente, turismo e segurança pública, com reforço tecnológico (monitoramento remoto, aplicativos de denúncia e rastreamento de embarcações).
- Incentivar que operadores turísticos mantenham parcerias locais e contratação regional, oferecendo benefícios fiscais e selos de sustentabilidade para quem adota boas práticas.
- Criar um fundo estadual de apoio à pesca esportiva sustentável, com recursos oriundos de taxas, compensações ambientais e parcerias privadas, destinado a financiar projetos de manejo comunitário, pesquisa e infraestrutura.
- Fortalecer a capacitação estadual de guias, fiscais e gestores públicos, criando programas de formação continuada em parceria com instituições de ensino.
- Estimular a padronização de protocolos de coleta e divulgação de dados, garantindo transparência e acesso a informações sobre impactos, receitas e benefícios da pesca esportiva em nível estadual.

- Articular ações com estados vizinhos e com a União, visando à gestão integrada de bacias hidrográficas, considerando que espécies e fluxos turísticos ultrapassam fronteiras municipais e estaduais.

Gestão Federal (Brasil)

- Fortalecer e difundir o Plano Nacional para o Desenvolvimento Sustentável da Pesca Amadora e Esportiva (PNPA 2024–2034), garantindo sua articulação com políticas estaduais e municipais e assegurando recursos para sua execução.
- Fortalecer a legislação federal que regula a pesca esportiva, priorizando a proteção de espécies-alvo e a padronização de boas práticas de captura e soltura.
- Criar um sistema nacional unificado de registro e licenciamento eletrônico de pescadores esportivos, guias e operadores turísticos, integrado a plataformas estaduais e municipais.
- Destinar recursos do orçamento federal e de fundos setoriais (ex.: Fundo Nacional de Meio Ambiente, Fundo do Turismo) para apoiar programas de manejo comunitário, fiscalização integrada, capacitação e infraestrutura de apoio ao turismo de pesca sustentável.
- Apoiar e financiar a pesquisa científica nacional, priorizando estudos sobre manejo de espécies-alvo (como tucunaré e pirarucu), impactos socioeconômicos da pesca esportiva e tecnologias de monitoramento e rastreabilidade.
- Estruturar um sistema nacional de monitoramento e dados abertos, agregando informações produzidas por municípios, estados, comunidades locais e instituições de pesquisa, com a publicação de relatórios periódicos de alcance nacional.
- Estimular a promoção internacional da pesca esportiva amazônica, consolidando o Brasil como destino de turismo de natureza de alto valor agregado.
- Estimular a criação de um selo nacional de sustentabilidade, articulado com os selos estaduais e municipais, para dar visibilidade às empresas que cumprem critérios de legalidade, sustentabilidade e benefícios locais.

- Estabelecer critérios nacionais que incentivem empresas de turismo a internalizar benefícios locais, como contratação de mão de obra regional, compras em mercados locais e parcerias com comunidades.
- Reforçar a cooperação internacional em manejo pesqueiro, turismo sustentável e conservação da biodiversidade, aproveitando o protagonismo da Amazônia em fóruns multilaterais e acordos bilaterais.
- Criar mecanismos de governança participativa no âmbito federal, envolvendo estados, municípios, comunidades locais, operadores turísticos e instituições de pesquisa no acompanhamento da execução do PNPA.

Atores Locais e Privados

Empresários e Operadores de Turismo

- Adotar padrões de operação sustentáveis, como limite de turistas por temporada, rotação de áreas de pesca e gestão adequada de resíduos.
- Estabelecer parcerias formais com comunidades locais, garantindo repartição justa dos benefícios econômicos e sociais.
- Priorizar a contratação de mão de obra local e a aquisição de bens e serviços no comércio municipal, evitando modelos de operação que excluam a comunidade do território.
- Apoiar iniciativas de monitoramento científico e comunitário, fornecendo dados e recursos para pesquisas de longo prazo sobre pesca e biodiversidade.
- Buscar certificações socioambientais e selos de sustentabilidade que valorizem a pesca esportiva amazônica no mercado nacional e internacional.
- Incentivar e promover a capacitação dos seus funcionários de forma a agregar na capacitação profissional e melhoria no serviço ofertado.
- Legalizar a operação, cumprindo todas as diretrizes da legislação municipal, estadual e federal.
- Promover educação e conscientização ambiental entre pescadores esportivos e funcionários, contribuindo para práticas de turismo sustentável.
- Apoiar pesquisas voltadas ao fortalecimento da pesca esportiva, fornecendo suporte técnico e financeiro quando possível.

Comunidades Ribeirinhas e Indígenas

- Participar ativamente dos acordos de pesca e conselhos de gestão, fortalecendo a governança local e a tomada de decisão participativa.
- Organizar-se em associações ou cooperativas para negociar coletivamente com operadores turísticos e aumentar a capacidade de barganha.
- Contribuir para a conservação de áreas de reprodução e habitats críticos, integrando o conhecimento tradicional ao manejo sustentável das espécies.
- Diversificar atividades econômicas associadas, como artesanato, gastronomia e turismo cultural, ampliando os benefícios locais da pesca esportiva.
- Participar de programas de capacitação em manejo sustentável, monitoramento ambiental, turismo e gestão de recursos, fortalecendo habilidades comunitárias e profissionais.
- Garantir que os benefícios econômicos e sociais da pesca esportiva sejam coletivos e compartilhados, evitando uso exclusivo ou individual dos recursos.
- Desenvolver mecanismos internos de organização comunitária, como regras de uso, gestão de recursos e decisões sobre rotas e temporadas de pesca.
- Contribuir com a coleta de dados e monitoramento participativo, fornecendo informações sobre espécies, esforço de pesca e impactos ambientais, fortalecendo a pesquisa e a gestão sustentável.
- Promover a educação ambiental e cultural dentro da comunidade, valorizando tradições locais e a conservação do ecossistema.
- Atuar como agentes ambientais, apoiando a fiscalização da pesca esportiva e auxiliando na coleta de informações sobre a biodiversidade e o estado das áreas de pesca.

Guias de Pesca

- Adotar e difundir boas práticas de captura e soltura, reduzindo a mortalidade pós-soltura e promovendo a sustentabilidade da atividade.
- Atuar como mediadores culturais e ambientais, sensibilizando turistas sobre conservação, tradições locais e respeito às comunidades.
- Contribuir para o registro de dados de captura (espécies, tamanhos, esforço de pesca), fortalecendo sistemas de monitoramento participativo.

- Participar de cursos de atualização em ecologia, segurança e primeiros socorros, aumentando a profissionalização e credibilidade da categoria.
- Organizar-se em associações ou cooperativas, garantindo direitos profissionais, negociando coletivamente com operadores turísticos e aumentando a capacidade de barganha e os ganhos financeiros..
- Atuar como agentes ambientais, auxiliando na coleta de informações sobre o ambiente e espécies, além de apoiar a fiscalização das atividades de pesca esportiva.

Os resultados desta tese dialogam diretamente com os Objetivos de Desenvolvimento Sustentável (ODS) da Agenda 2030 da ONU, notadamente aqueles que integram a conservação da biodiversidade, a promoção da equidade social e o fortalecimento do desenvolvimento econômico sustentável em territórios amazônicos:

	**ODS 8 – Trabalho Decente e Crescimento Econômico** A tese reconhece a pesca esportiva como vetor de geração de renda, emprego e dinamização da economia local, fortalecendo cadeias produtivas associadas ao turismo em territórios amazônicos historicamente marginalizados.
	**ODS 10 – Redução das Desigualdades** O estudo evidencia a necessidade de incluir comunidades ribeirinhas, indígenas e guias de pesca no processo decisório, reduzindo assimetrias de poder e promovendo maior equidade na distribuição dos benefícios da atividade.
	**ODS 11 – Cidades e Comunidades Sustentáveis** Ao destacar a relevância da pesca esportiva para o município de Barcelos e comunidades adjacentes, a tese contribui para o fortalecimento de práticas que valorizam a cultura local e promovem resiliência socioeconômica em contextos urbanos e rurais amazônicos.
	**ODS 12 – Consumo e Produção Responsáveis** A pesquisa reforça a importância de práticas como o pesque-e-solte e do manejo sustentável de espécies, associando a atratividade econômica da atividade à conservação de indivíduos de maior porte e à manutenção dos estoques pesqueiros.
	**ODS 14 – Vida na Água** Ao contribuir com conhecimento científico e a análise da dimensão ecológica aponta fragilidades na sustentabilidade da pesca esportiva e destaca a urgência de medidas de conservação voltadas à proteção dos recursos pesqueiros e dos ecossistemas aquáticos do médio rio Negro.
	**ODS 15 – Vida Terrestre** A tese enfatiza a interdependência entre conservação da biodiversidade terrestre, manutenção da floresta e preservação das comunidades ribeirinhas, reconhecendo a importância de práticas integradas de gestão socioambiental.

ODS 17 – Parcerias e Meios de Implementação

Os resultados reforçam que a sustentabilidade da pesca esportiva depende da cooperação entre ciência, gestores públicos, setor privado e comunidades locais, fortalecendo arranjos colaborativos e multissetoriais para o ordenamento da atividade.

Assim, espera-se que os resultados desta tese subsidiem políticas públicas e iniciativas locais, estaduais, federais e privadas, fortalecendo a pesca esportiva como atividade compatível com os princípios da sustentabilidade e promovendo justiça social, valorização ambiental e dinamização econômica no médio rio Negro e em toda a Amazônia.

Além dos artigos científicos publicados como parte da tese, também foram produzidos materiais de divulgação e extensão, voltados a diferentes públicos. Entre eles, destacam-se os livretos sobre a pesca esportiva no Médio Rio Negro – edição 1 (https://riu.ufam.edu.br/handle/prefix/8101; Apêndice C) e edição 2 (https://riu.ufam.edu.br/handle/prefix/8103; Apêndice D), elaborados em linguagem acessível para comunidades, gestores e turistas, e o site www.rionegroam.com (Apêndice E), criado como plataforma de difusão de informações sobre pesca, peixes e conservação no Rio Negro. Esses produtos complementam a contribuição acadêmica ao oferecer ferramentas práticas de educação ambiental, sensibilização e apoio à gestão participativa da pesca esportiva na Amazônia.

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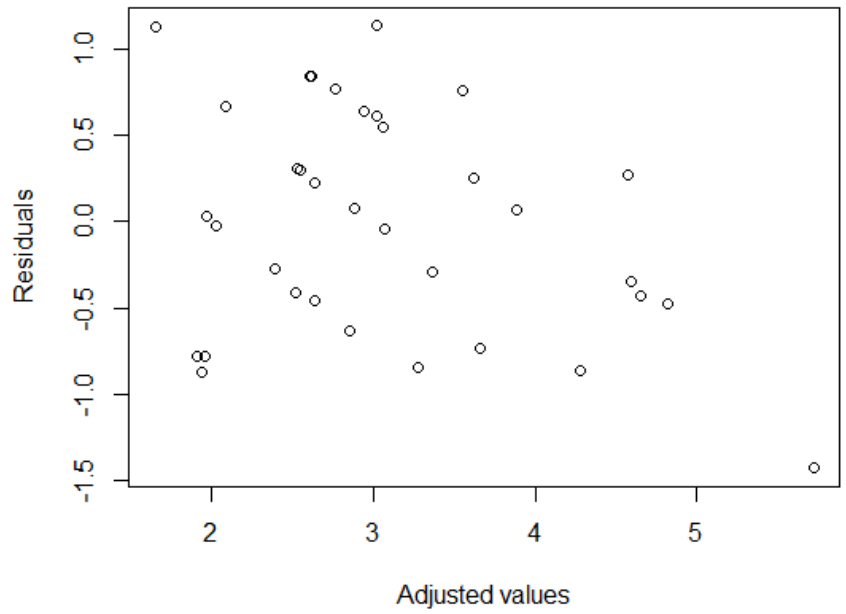
Appendix A (Chapter II) – Study Questionnaire

Demographic, social, and fishing questions in the middle Rio Negro region, Amazonas: recreational fishers
Gender: ( ) Female ( )Male Age:_____ Nationality: ( ) Brazilian ( ) Foreigner
Average income per hour (US$): _____
Educational Level: ( ) No university degrees ( ) University degrees
First time fishing in the middle Rio Negro, Amazonas: ( ) Yes ( ) No
How many years of recreational fishing experience do you have?
How many times have you travelled to the middle Rio Negro for fishing in 12 months?
What would be the ideal frequency for fishing in the middle Rio Negro?
What is your average spending on fishing packages (Brazilian in R$ and foreigners in US$)?
How many days did you fish per trip in the middle Rio Negro?
What is your average annual spending on fishing equipment (including clothing)? (Brazilian in R$ and foreigners in US$)
What is your perception of the environment in the middle Rio Negro region? ( ) No degradation ( ) Low degradation ( ) Medium degradation ( ) High degradation
Was your trip motivated by nature/the Amazon? ( ) Yes ( ) No
Was your trip motivated by the capture of trophy fish? ( ) Yes ( ) No
Was your trip motivated by tucunaré (*Cichla* sp.)? ( ) Yes ( ) No
WTP: Assuming that the administration of Barcelos, Amazonas created an environmental fund, with the aim of adequate maintenance of the environment and tucunaré (*Cichla* sp.) populations, what amount would you be willing to contribute in order to fish in the middle Rio Negro region, Barcelos, Amazonas, considering the following scenarios below: Scenario I: The fish stock in the region consists only of small tucunarés (≤30cm). What amount (US$)?_____ Scenario II: The fish stock in the region consists of medium-sized tucunarés (31 to 50 cm). What amount (US$)?_____ Scenario III: The fish stock in the region consists of large tucunarés (≥51 cm). What amount (US$)?_____ *Please keep in mind the following points when answering the above question:* *1. No other entry fees will be charged for fishing;* *2. Barcelos is a city in the heart of the Amazon, with unique landscapes and one of the largest freshwater archipelagos in the world;* *3. Your income is limited and has important alternative uses;* *4. There are other cities in the Rio Negro basin but, for now, focus only on the city of Barcelos for the assessment of the recreational aspects that can be provided by recreational fishing.*

Appendix B (Chapter II) – Plot to test homocedasticity



Appendix C (Chapter II) – Collinearity summary (variance inflation factor (VIF)) tested in model. An aggregate VIF less than 6 was used as a criterion for deciding whether certain variables should be included in the models (Dormann et al., 2013). *Removed due to the presence of collinearity

Independent variables	VIF
AGE*	>17
ATC*	>20
DAY*	>10
EDU	5.2941
ENVIRONPERCEP	1.4589
EXPF	4.2002
FISHPAC	6.0244
PURCHASEF	2.1898
TRIPS	5.5411

Appendix A (Chapter III) – Questionnaires used in the socioeconomic surveys

#1 SOCIOECONOMIC QUESTIONNAIRE

**Value of Brazilian real (BRL) converted to US Dollar (USD) is 6.192 BRL per 1 USD on 31/12/2024 (www.bcb.gov.br/conversao).*

Interviewer name:	Interview date / /

SOCIAL ASPECTS

Age:	Education level: illiterate ( ) Elementary School ( ) High School ( ) Higher Education ( )
Average monthly income *: ( ) < US$ 197.00 | ( ) US$ 391.00 – US$ 197.00 | ( ) US$ 783.00– US$ 391.00 | ( ) US$ 1,174.00 – US$ 783.00 | ( ) > US$ 1,174.00	
How would you assess the level of social conflicts between fishing modalities in the Middle Negro River, Barcelos, Amazonas? ( ) None= 0 | ( ) Low= < 25% | ( ) Medium= 25-50% | ( ) High= 50 - 100%	
How do you assess the number of recreational fishers who visit the Middle Negro River region, Barcelos, Amazonas for recreational fishing? ( ) Remains constant | ( ) Slowly reducing | ( ) Rapidly reducing | ( ) Slowly increasing | ( ) Rapidly increasing	

ECONOMIC ASPECTS

How would you assess the importance of recreational fishing for the local economy, Barcelos, Amazonas? ( ) None | ( ) Low= < 25% | ( ) Medium= 50% - 25% | ( ) High= 50% - 75 | ( ) Very high= 100% - 75%
Do the fishing guides working in the fishing companies reside in the Middle Negro River region, in Barcelos? ( ) Yes, they are from Barcelos | ( ) No, they are from Manaus or another municipality | ( ) No, they are from another state
Where are the headquarters of fishing companies that sell trips to the region of the Middle Negro River, in Barcelos? ( ) Barcelos | ( ) Manaus or another municipality | ( ) another state | ( ) another country
What is the average value of a recreational fishing trip to Barcelos, Amazonas?* ( ) < US$ < 807.00 | ( ) US$ < 969.00 – US$ < 1,292.00 | ( ) US$ 1,453.00 – US$ 1,615.00| ( ) > US$ 1,615.00
What is your perception about the provision of subsidies by state and municipal agencies to support recreational fishing in Barcelos, Amazonas? ( ) None | ( ) Low= < 25% | ( ) Medium= 25% - 50% | ( ) High= 100% - 50%

ECOLOGICAL ASPECT

How would you assess the exploitation status of peacock bass stocks (*Cichla* sp.) in the region of the Middle Negro River, Barcelos, Amazonas? ( ) Underexploited | ( ) Underexploited | ( ) Partially exploited | ( ) Overexploited
How would you assess the ecological vulnerability status of peacock bass (*Cichla* sp.) in the region of the Middle Negro River, Amazon? ( ) under exploited | ( ) little exploited | ( ) partially exploited | ( ) over exploited
How would you assess the level of environmental degradation in the region of the Middle Negro River, Barcelos, Amazonas? ( ) None | ( ) Low= < 25% ( ) Medium= 25 - 50% | ( ) High= 50% - 75 | ( ) Very high= 75% - 100%
How would you assess the level of apparent mortality, i.e., after the peacock bass is released into the water (either due to injury, mishandling, or viewing predation by predators (dolphins))? ( ) None | ( ) Low= < 25% | ( ) Medium= 25 - 50% | ( ) High= 50% - 75 | ( ) Very high=75% - 100%
How would you assess the change in peacock bass size in the Middle Negro River region, Barcelos, Amazonas? ( ) Rapidly reducing | ( ) Slowly reducing | ( ) remains constant | ( ) slowly increasing | ( ) rapidly increasing
How would you evaluate the percentage of catches of peacock bass individuals before reaching the first sexual maturation (L_{50} < 30 cm) in the region of the Middle Negro River, Barcelos, Amazonas?

( ) None= 0	( ) low= < 25%	( ) medium= 25 - 50%	( ) high= 50% - 75%	( ) very high=75% - 100%

FISHING EXPERIENCE

How would you rate the duration of the fishers' trip to Barcelos to carry out recreational fishing? ( ) Short	( ) Moderate	( ) Long
How would you evaluate the adoption of the practice of catch and release by fishers who fish in the Middle Negro River region, Amazonas? ( ) Low= < 25%	( ) Medium= 25% - 50%	( ) High= 50% - 100%
Do you think that fishers who visit the Middle Negro River, Amazonas, to fish have the amateur fisher's license? ( ) Have one and it's valid	( ) have it but it's out of date	( ) doesn't have one or didn't know I needed one
How would you assess the level of catchability of peacock bass (*Cichla* sp.) in the region of the Middle Negro River, Amazon? ( ) Low	( ) Medium	( ) High
How would you assess the level of impact of recreational fishing on the natural resources and fisheries of the Middle Negro River region, Amazonas? ( ) None	( ) Low	( ) Medium	( ) High

MANAGEMENT PERFORMANCE

How would you assess the infrastructure of the municipality for the reception of fishers (e.g., airport, streets, port of anchorage of boats and etc.)? ( ) Terrible	( ) Bad	( ) Indifferent	( ) Good	( ) Great
How would you assess the level of organization of the activity to maximize the income of the municipality (e.g., visits to historical sites, fairs, sale of local crafts, etc.)? ( ) Terrible	( ) Bad	( ) Indifferent	( ) Good	( ) Great
How would you assess the degree of data collection by local management about activity in the region of the Middle Negro River, Amazonas? ( ) None= 0	( ) Low= < 25%	( ) Medium= 25% - 50%	( ) High= 50% - 100%
How would you assess the level of supervision carried out by local management for recreational fishing activities in the Middle Negro River region, Amazonas? ( ) None= 0	( ) Low= < 25%	( ) Medium= 25% - 50%	( ) High= 50% - 100%
How would you assess the level of communication of environmental and fishing rules to be respected in the Middle Negro River region, Amazonas for recreational fishing? ( ) None= 0	( ) Low= < 25%	( ) Medium= 25% - 50%	( ) High= 50% - 100%

Appendix B (Chapter III) – Scores for each attribute and actor's perspective of recreational fishing in five assessment dimensions

Ecological sustainability

Actors	Exploitation status	Vulnerability	Habitat status	Apparent mortality	Fish size	Percentage juvenile
Fishing guides	5.44	1.92	6.38	7.38	6.46	4.62
Local community	5.30	1.74	6.57	6.33	5.26	6.89
Foreign fishers	4.17	1.50	5.50	8.67	5.00	4.33
Brazilian fishers	5.13	1.64	6.48	8.36	5.06	6.06
Fishing entrepreneurs	5.21	2.50	8.14	6.43	6.86	6.50

Economic sustainability

Actors	Price of trip	Importance to the local economy	Subsidies	Company headquarters	Local guides
Fishing guides	5.52	7.56	2.19	7.23	8.17
Local community	2.15	5.17	3.59	7.64	7.37

Foreign fishers	7.50	9.67	2.00	6.00	8.67
Brazilian fishers	5.75	9.34	2.90	7.41	8.54
Fishing entrepreneurs	4.71	8.79	2.14	9.29	9.29

Fishing experience

Actors	Trip duration	Fishing modality	Fishing license	Catch rate	Environmental impact of recreational fishing
Fishing guides	5.00	9.54	7.31	9.17	5.98
Local community	2.79	8.45	6.03	8.82	4.88
Foreign fishers	2.50	8.83	7.83	8.83	5.33
Brazilian fishers	4.13	8.68	8.17	7.92	7.36
Fishing entrepreneurs	5.07	9.57	6.43	9.14	8.29

Management performance

Actors	Infrastructure	Organization of activity	Data collection for management	Oversight	Communication of rules
Fishing guides	2.81	1.56	0	0.15	1.56
Local community	2.33	3.97	0.02	1.64	2.94
Foreign fishers	4.67	3	0	0.83	1.50
Brazilian fishers	3.99	4.23	0	1.01	1.16
Fishing entrepreneurs	0.79	2.21	0	0.93	2.29

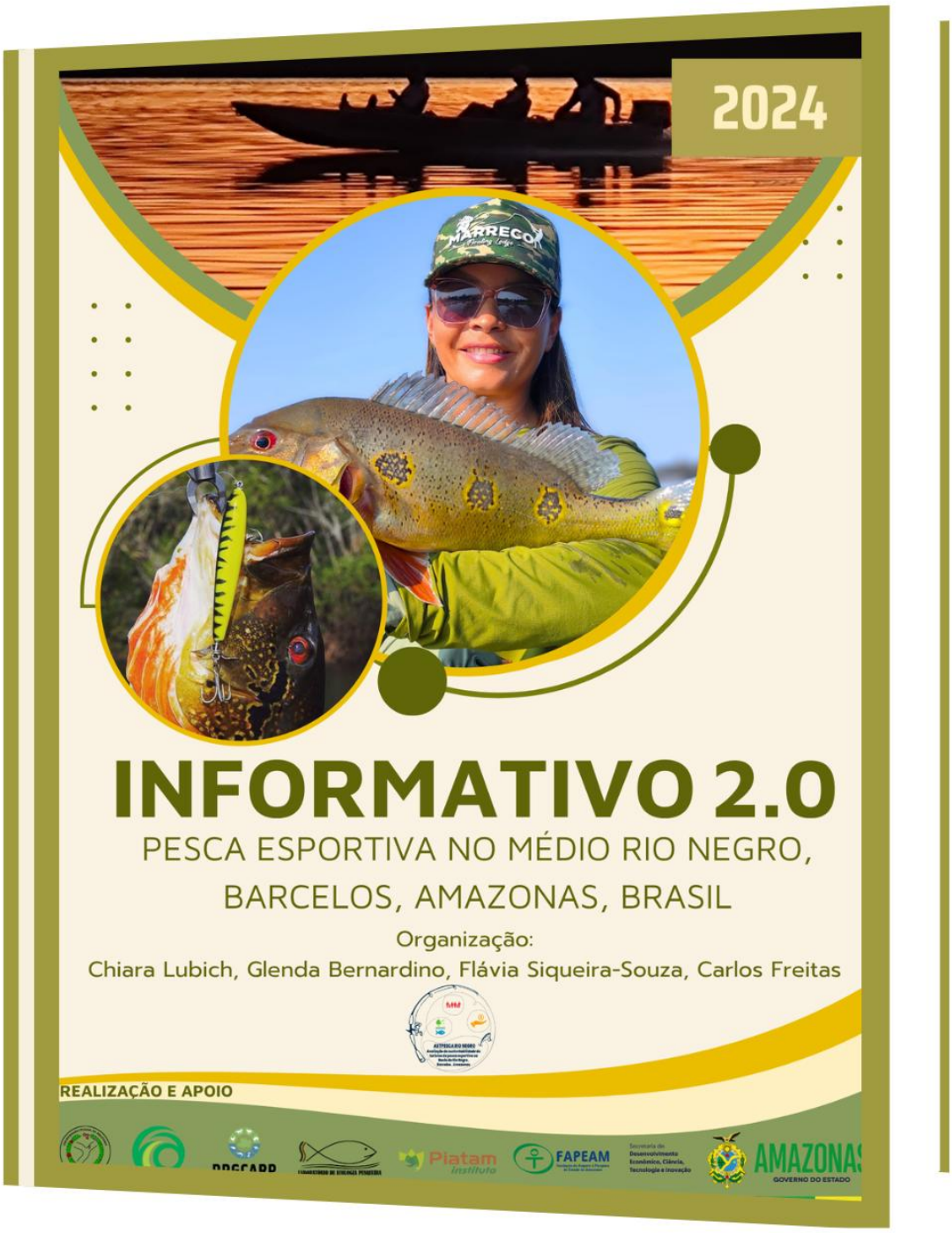
Social sustainability

Actors	Age profile	Level of education	Monthly income	Conflict	Increase in the number of fishers in the region
Fishing guides	5.23	4.71	1.90	4.75	1.12
Local community	4.83	5.62	1.36	7.69	1.87
Foreign fishers	6.83	9.33	9.83	6.83	1.5
Brazilian fishers	6.92	8.38	9.7	8.73	1.9
Fishing entrepreneurs	5.29	6.07	6.79	6.79	1.64

Apêndice C – Capa da 1° edição do livreto sobre a pesca esportiva no médio Rio Negro

Acesse o Informativo completo aqui: https://riu.ufam.edu.br/handle/prefix/8101

Apêndice D – Capa da 2° edição do livreto sobre a pesca esportiva no médio Rio Negro



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Apêndice E – Site produto da tese, com informações sobre pesca esportiva no médio Rio Negro

Acesse o site aqui: www.rionegroam.com