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TESE DE DOUTORADO

Conhecimento ecológico local, tomada de decisão e dinâmica espacial da frota pesqueira artesanal da Amazônia Central.

SAMANTHA AQUINO PEREIRA

MANAUS - AM

2020

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Tese apresentada ao Programa de Pós-graduação em Ciência Animal e Recursos Pesqueiros, como requisito para obtenção do título de Doutor em Ciência Animal e Recursos Pesqueiros, área de concentração Uso Sustentável de Recursos Pesqueiros Tropicais.

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"*A transformação é individual, mas só é possível porque é uma construção coletiva!*"

RESUMO

A pesca artesanal de água interior ou continental é um componente vital para a vida das pessoas em todo mundo, pois proporciona segurança nutricional e renda. Entretanto, os recursos pesqueiros sofrem diferenças ameaças, como práticas irresponsáveis de pesca, degradação do habitat, construção de barragens, poluição e mudanças climáticas promovendo declínios substanciais e outras mudanças nos recursos pesqueiros. Esforços contínuos para estabelecer abordagens de gestão eficazes demonstraram que o modelo de co-gestão apresentou potencial de deter os impactos da pesca, por incorporar a participação do pescador. No entanto, pouca atenção é dada ao comportamento de explotação do pescador. Nesse contexto, esta tese investigou o conhecimento ecológico local (CEL) dos pescadores artesanais como fonte potencial de dados bio-ecológicos para espécies de peixes na Amazônia, a atitude sob risco na escolha dos pesqueiros, a partir da teoria do prospecto. E por fim, compreender a dinâmica espacial da frota pesqueira comercial da Amazônia Central como resposta à anomalias negativas hidrológicas. Para investigação sobre o conhecimento ecológico local dos pescadores foram entrevistados pescadores rurais e urbanos no município de Itacoatiara sobre os aspectos bio-ecológicos do pirarucu (*Arapaima spp.*), tambaqui (*Colossoma macropomum*) e jaraqui (*Semaprochilodus spp.*). Para compreender a atitude sob risco dos pescadores comerciais na escolha do pesqueiros foram entrevistados pescadores e encarregados da embarcação no terminal pesqueiro de Manaus. E para avaliar a dinâmica espacial da frota pesqueira da Amazônia Central como resposta às anomalias hidrológicas negativas foi analisada informações do Banco de Dados de Monitoramento de estatística pesqueira, no período de 1994 a 2004. Sobre o CEL, nossos resultados demonstram que o LEK dos pescadores representa uma fonte de informação potencial e confiável que pode ser usada para fornecer dados sobre peso, comprimento, dimorfismo sexual, dieta, predação e habitat do pirarucu, tambaqui e jaraqui para apoiar as estratégias de conservação e gerenciamento. Sobre a tomada de decisão dos pescadores sobre a escolha dos pesqueiros, nossos resultados demonstraram que os pescadores são avessos as risco, sentindo mais a dor da perda que a satisfação do ganho, de acordo com a Teoria do Prospecto. Esse comportamento de aversão ao risco e o conhecimento dos pescadores artesanais da Amazônia, deve ser apoiado em políticas de longo prazo para ser um participante ativo, incluindo o cumprimento e a responsabilidade de suas ações, preocupações e necessidades. Os pescadores podem fazer parte de um diálogo contínuo com pesquisadores e gerentes como um caminho da justiça social, mas também da eficiência do uso e conservação da biodiversidade. Sobre a dinâmica espacial da frota, nossos resultados indicam que a anomalia negativa não alterou o estado máximo de transformação espacial da frota de pesca comercial na Amazônia. Entretanto, houve a intensificação da explotação do ambiente fluvial próximo a Manaus, focando as espécies rio-lacustres que promoveu um aumento na frequência de viagens e possível esgotamento do recurso em escala local. Devido à heterogeneidade espacial e ecológica característica do ambiente amazônico, é necessário incorporar análises que considerem a escala espacial nas propostas de gestão da pesca, além de demonstrar a necessidade e utilidade do monitoramento da pesca em longo prazo. Assim, demonstramos a importância de incorporar o CEL, a atitude sob risco e a dinâmica espacial dos pescadores no modelo de co-gestão para fortalecer as estratégias de conservação dos recursos pesqueiros no cenário de constante mudanças sociais, econômicas e ambientais.

Palavras-chave: Conhecimento ecológico local, pescador artesanal, avesso ao risco, dinâmica espacial, anomalia hidrológica negativa.

ABSTRACT

Artisanal inland or continental water fishing is a vital component of people's lives around the world because it provides nutritional security and income. However, fishing resources are threatened by differences such as irresponsible fishing practices, habitat degradation, dam construction, pollution and climate change promoting substantial declines and other changes in fishing resources. Continued efforts to establish effective management approaches have demonstrated that the co-management model has the potential to halt the impacts of fishing by incorporating the participation of fishermen. However, little attention is given to the exploitation behavior of the fisherman. In this context, this thesis investigated the local ecological knowledge (CEL) of artisanal fishers as a potential source of bio-ecological data for fish species in regions of difficult access, such as the Amazon, the attitude under risk in the choice of fishing grounds, from the prospect theory. And finally, to understand the spatial dynamics of the commercial fishing fleet in Central Amazonia as a response to negative hydrological anomalies. For research on the local ecological knowledge of fishers, rural and urban fishermen in the municipality of Itacoatiara were interviewed on the bio-ecological aspects of pirarucu (*Arapaima spp*.), tambaqui (*Colossoma macropomum*) and jaraqui (*Semaprochilodus spp*.). In order to understand the attitude under risk of commercial fishers in the choice of fishing grounds, fishers were interviewed and those in charge of the boat in the Manaus fishing terminal. And to evaluate the spatial dynamics of the Central Amazon fishing fleet as a response to negative hydrological anomalies, information from the Fish Statistics Monitoring Database was analyzed from 1994 to 2004. About the CEL, our results demonstrate that the LEK of fishers represents a potential and reliable source of information that can be used to provide data on weight, length, sexual dimorphism, diet, predation and habitat of pirarucu, tambaqui and jaraqui to support conservation and management strategies. On the fisher's decision making about the choice of fishing grounds, our results have shown that fishermen are averse to risk, feeling more the pain of loss than the satisfaction of gain, according to the prospect theory. This risk-averse behavior and the knowledge of the artisanal fishers of the Amazon must be supported by long-term policies to be an active participant, including compliance and responsibility for their actions, concerns and needs. Fishermen can be part of an ongoing dialogue with researchers and managers as a path to social justice, but also to efficiency in the use and conservation of biodiversity. On the spatial dynamics of the fleet, our results indicate that the negative anomaly has not altered the maximum state of spatial transformation of the commercial fishing fleet in the Amazon. However, there has been an intensification of exploitation of the fluvial environment near Manaus, focusing on the river-lacustrine species that has promoted an increase in the frequency of trips and possible depletion of the resource on a local scale. Due to the characteristic spatial and ecological heterogeneity of the Amazonian environment, it is necessary to incorporate analyses that consider the spatial scale in fisheries management proposals, in addition to demonstrating the need and usefulness of long-term fisheries monitoring. Thus, we demonstrate the importance of incorporating the CEL, the attitude under risk and the spatial dynamics of fishers in the co-management model to strengthen the strategies for conservation of fisheries resources in the scenario of constant social, economic and environmental change.

Keywords: Local ecological knowledge, artisanal fisherman, risk averse, spatial dynamics, negative hydrological anomaly.

LISTA DE FIGURAS

CAPÍTULO I.

CAPÍTULO II.

CAPÍTULO III.

LISTA DE TABELAS

CAPÍTULO I.

CAPÍTULO II.

CAPÍTULO III.

Sumário

Introdução geral

A pesca artesanal de água interior ou continental é um componente vital para a vida das pessoas em todo mundo, pois proporciona segurança nutricional e renda (Welcomme et al., 2010). De acordo com estatísticas reportadas à Organização das Nações Unidas para Agricultura e Alimentação (Food and Agriculture Organization of the United Nations (FAO, 2018), o setor tem crescido de forma constante durante as últimas décadas. Entretanto, acredita-se que práticas irresponsáveis de pesca, perda e degradação do habitat, captação de água, construção de barragens, poluição e mudanças climáticas causaram declínios substanciais e outras mudanças nos recursos pesqueiros (Bartley et al., 2015).

Tendências recentes da gestão da pesca interior buscam resolver os impactos gerados pelo crescimento e desenvolvimento da sociedade. Esse crescimento promove um aumento da demanda pelo pescado e o desafio da gestão é conciliar a manutenção da qualidade do ambiente aquático e a exploração sustentável dos recursos pesqueiros (Pauly et al., 2002). Dentre os principais mecanismos de gestão da pesca em águas interiores estão a regulamentação de pesca e a conservação do peixe (Cowx e Gerdeaux, 2004). No entanto, grande parte da atenção dos estudos tem focado em quantificar as capturas da pesca como uma medida da intensidade da pesca em uma determinada área (Walters e Martell, 2002). Embora essa informação seja útil, ela não aborda diretamente uma das questões fundamentais da sustentabilidade da pesca: a dinâmica de explotação dos pescadores. Essa dinâmica pode ser medida pelo comportamento dos pescadores e incorporada nos modelos de avaliação de estoques e de pescarias (Hilborn e Walters, 1992).

Dada à importância social e econômica da atividade pesqueira associada ao eminente risco de sobreexplotação dos estoques (Béné, 2009; Hilborn, 2007), estudos recentes tem priorizado a análise e discussão de formas de gestão dos recursos pesqueiros que incluam o comportamento dos pescadores (Fischer et al., 2015; Salas e Gaertner, 2004).

Nesse sentido, esforços contínuos para estabelecer abordagens de gestão eficazes demonstraram que o modelo de co-gestão apresentou potencial de deter os impactos da pesca (Berkes, 2006; Carlsson e Berkes, 2005; Davis e Ruddle, 2010; Olsson e Folke, 2001). Nesse modelo, o conhecimento ecológico local das populações humanas que dependem diretamente do recurso é uma peça chave servindo como ponto de partida para o manejo e conservação dos recursos (Johannes et al., 2000). Assim, vários casos de co-gestão têm integrado o conhecimento científico e ecológico local (CEL) e fornecido resultados positivos(Francis et al., 2007). Em particular, o CEL dos pescadores pode ser útil para superar os desafios da coleta de dados em rios tropicais, onde os recursos humanos e financeiros são geralmente escassos e os desembarques de peixes são distribuídos por grandes áreas geográficas de difícil acesso (R.E. Johannes, 1998; Silvano e Valbo-Jorgensen, 2008).

O Conhecimento Ecológico Local é o conhecimento de um grupo específico de pessoas sobre os ecossistemas, que trata da interação entre organismos e seu ambiente, que é incorporado nos costumes locais, sistemas de crença e aprendizagem. Como todos os tipos de conhecimento, este evolui constantemente, através de anos de experimentação prática sendo transferido de uma geração para a outra, por meio de transmissão cultural, normas sociais, sistemas de gestão e memória social (Berkes et al., 2000; Olsson e Folke, 2001).

O CEL pode preencher lacunas de conhecimento científico, pois é uma fonte inestimável de informações detalhadas sobre os serviços locais dos ecossistemas, especialmente (mas não exclusivamente) em áreas onde existe pouco conhecimento formal. Por sua integridade, foi reconhecido na Convenção sobre Diversidade Biológica como relevante no gerenciamento de ecossistemas (Fabricius et al., 2004).

O ambiente econômico da pesca artesanal é caracterizado pelo risco financeiro. Isto decorre da incerteza sobre os preços dos produtos, informações imprecisas sobre a abundância e localização dos recursos, mudanças dinâmicas tanto nos preços do pescado quanto na abundância, e a evolução das regulamentações da pesca (Smith e Wilen, 2005**.** Assim, o conhecimento sobre a rentabilidade de diferentes locais e o tempo gasto para pescar em um determinado local são fatores que afetam a renda dos pescadores. Portanto, pescadores que visam a mesma espécie podem ter retornos líquidos drasticamente diferentes dependendo de sua escolha do pesqueiro (Mistiaen e Strand, 2000). A escolha do pesqueiro depende das preferências de risco do pescador, da distribuição do pescado e dos custos associados a cada local de pesca. Sendo assim, um aspecto chave no modelo de gestão é entender as preferências de risco do pescador (Mistiaen e Strand 2000).

Estudos demonstram que os pescadores são avessos ao risco, mas não são tão avessos à variação de renda, e sim à perda de renda total. Este comportamento é o esperado segundo a teoria do prospecto, onde ganhos efetivos e esperados são comparados (Economics, 1969). Nessa teoria a aversão à perda no comportamento de risco é integrada à função utilidade (Kahneman e Tversky, 1979; Nguyen, 2010). Portanto, se uma área considerada pelos pescadores como um pesqueiro produtivo for fechada sem alternativa viável e os lucros associados se tornarem menores, as consequências do fechamento tornam-se dependentes do quanto os pescadores forem avessos ou dispostos ao risco (Nguyen, 2010). Nesse sentido, para a gestão pesqueira eficiente e eficaz, aumenta a importância de entender o que afeta o comportamento do pescador na escolha de onde pescar.

Outro desafio para os modelos de gestão é incorporar os efeitos das mudanças climáticas, tais como eventos climáticos anômalos na dinâmica de explotação da pesca (Galappaththi et al., 2019). As comunidades pesqueiras ocupam e usam diferentes ecossistemas para a explotação dos recursos e possuem culturas e estruturas de governança exclusivas que ao longo do tempo podem levar a ações particular as mudanças ambientais e climáticas (Belhabib et al., 2016; Parry et al., 1998). Mas, de acordo com o quinto relatório de avaliação do IPCC (IPCC, 2014) há poucas informações disponíveis para avaliar as respostas da comunidade à mudança climática em termos de identificar quais adaptações são necessárias e avaliar a eficácia das possíveis opções de adaptação, tanto para a resiliência da frota como dos recursos pesqueiros.

Historicamente as pesquisas sobre pesca e mudança/variabilidade climática focavam documentar tendências e flutuações da abundância bem como a distribuição de peixes (Lynch et al., 2016; Martinho et al., 2007). Recentemente foram feitos mais estudos para investigar as respostas das comunidades pesqueiras sujeitas às mudanças climáticas (Mcclanahan e Abunge, 2016).

Contudo, ainda existem poucos estudos sobre as estratégias de adaptação em escala local de como a variabilidade e a mudança do clima estão afetando as vidas e os meios de subsistência dos pescadores artesanais, os quais representam mais de 90% dos pescadores do mundo (Badjeck et al., 2010). Por exemplo, os pescadores da frota pesqueira artesanal do rio de La Plata mostraram ser resilientes a tensões e perturbações ao utilizar três estratégias de adaptação para lidar com o aumento da variabilidade do fluxo do rio relacionado ao El Niño: 1. Migração sazonal ao longo da costa seguindo os recursos associados ao deslocamento frontal; 2. Mudança do (s) local (ais) de pesca em direção ao mar do sistema frontal, e (3) comportamento de pesca cauteloso sob condições não favoráveis do vento e aceitação da perda de renda (Nagy et al., 2006). No Peru, o evento El Niño de 1997–1998 beneficiou tanto o recrutamento quanto o crescimento de vieira, *Argopecten purpuratus*. E os pescadores responderam rapidamente para o "boom de vieira" mudando de redes para métodos de mergulho, resultando em captura recorde (Badjeck et al., 2009).

Estrutura da Tese

O objetivo geral deste trabalho foi investigar o CEL dos pescadores artesanais como fonte potencial de dados bio-ecológicos para espécies de peixes na Amazônia, a atitude sob risco na escolha dos pesqueiros, a partir da teoria do prospecto. E por fim, compreender a dinâmica espacial da frota pesqueira comercial da Amazônia Central como resposta à anomalias negativas hidrológicas. A tese está dividida em três capítulos e redigida em formato de artigo científico. Cada capítulo aborda um dos objetivos da tese.

Capítulo 1

Hipótese: O CEL dos pescadores urbanos ou rurais não difere da informação fornecida na literatura científica e o CEL dos pescadores mais experientes tende a ser mais consistente com a informação científica.

No primeiro capítulo investigamos o CEL dos pescadores sobre comprimento e peso máximos, dimorfismo sexual, predação, dieta e utilização do habitat do pirarucu carnívoro (*Arapaima* spp.), tambaqui frugívoro (*Colossoma macropomum*) e jaraqui detritívoro (*Semaprochilodus* spp.). Testamos a influência de duas variáveis: categoria dos pescadores (zonas urbanas ou rurais) e tempo de experiência. O foco deste capítulo foi demonstrar que o CEL dos pescadores representa uma fonte de informação potencial e fiável para apoiar estratégias de conservação e gestão.

Capítulo 2

Hipótese: Os pescadores são mais avessos ao risco quando têm mais experiência na pesca, menor escolaridade e maior dependência dos rendimentos

pesqueiros.

No segundo capítulo investigamos o comportamento do pescador sob risco na escolha dos pesqueiros na pesca artesanal comercial da bacia Amazônica, a partir da teoria do prospecto (Kahneman e Tversky, 1979). Testamos ainda a influência das características individuais dos pescadores nível de escolaridade, fonte de renda, função na pesca e tempo de experiência na pesca na atitude sob risco. A atitude dos pescadores é a base para a decisão. Assim, a gestão da pesca deve ter nela um fator essencial a ser considerado para a eficiência dos objetivos da explotação mais sustentável.

Capítulo 3

Hipótese: Expansão espacial do esforço de pesca nos ambientes de rio e consequentemente, aumento do rendimento pesqueiro das espécies rio-lacustres.

No terceiro capítulo investigamos a dinâmica espacial interanual da frota como resposta às anomalias hidrológicas negativas na Amazônia. Testamos os efeitos das anomalias negativas sobre rendimento e esforço pesqueiros entre ambientes de rios e lagos e por grupo de espécies. O foco deste capítulo foi compreender as respostas da frota às mudanças climáticas para identificar os riscos que os recursos pesqueiros e os pescadores estão sujeitos com o aumento da frequência e intensidade dos eventos de El niño previstos para a região.

CAPITULO I

Capítulo I. Assessing biological traits of Amazonian high-value fishes through Local Ecological Knowledge of urban and rural fishers

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Abstract

Local Ecological Knowledge (LEK) has been increasingly recognized as a potential source of information on natural resources and ecosystem services, especially in under sampled areas. In the Amazon, artisanal fishing is multispecific, and fishers are well acquainted with the biology and life history strategies of target fish species. This study analyzed the potential of LEK of artisanal fishers to supply information on the biology and ecology of high-value species, including pirarucu (*Arapaima* spp.), tambaqui (*Colossoma macropomum*, Cuvier, 1816), and jaraqui (*Semaprochilodus* spp.). We interviewed rural and urban fishers about bio-ecological aspects of these species and reviewed the scientific literature on the same aspects. We evaluated the effects of their category (rural or urban) and time of experience. Results demonstrated that fishers have detailed knowledge about species' predation, diet and habitat use, regardless of the time of experience or category they fall into. Their knowledge can be a useful source of ecological traits for these species contributing to Amazonian fisheries management.

Keywords: artisanal fishing – Amazonian fisheries – category of fishers – time of experience.

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Introduction

Small-scale fishery provides a major source of income and protein worldwide (Lynch et al., 2016; Food and Agriculture Organization of the United Nations (FAO), 2018). These fisheries directly employ about 135 million people (Eide et al., 2011) and account for 17% of protein consumption (FAO, 2018) globally. Small-scale fishery is particularly important in tropical developing countries because they ensure food security to rural and coastal communities often immersed in poverty (FAO, 2018). In the Amazon, for example, estimates of fish consumption in rural areas varies from 369g / day to 800g / day (Cerdeira et al., 1997; Batista et al., 1998; Fabré & Alonso, 1998), representing the highest average consumption rates in the world (FAO, 2000). These estimations are not precise though because data on Amazonian fisheries are scarce or inexistent for most of the basin, in part, because fisheries are distributed over large geographical areas difficult to access and human and financial resources are generally scarce (R.E. Johannes, 1998; Santos & Santos, 2005; Begossi, 2010; Lopes et al., 2019). Overcoming the challenges of data collection is needed to understand the degree of dependence on fishing to livelihoods and generate information to support management decision-making and policy. A low-cost alternative for collecting data is to access fishers' local ecological knowledge (LEK) (Francis et al., 2007).

Fishers' LEK has been widely used as a source of data on fishing practices, livelihoods, governance, and fish biology and ecology to subsidize fisheries management and conservation (Olsson & Folke, 2001; Davis & Ruddle, 2010; Fischer et al., 2015). In the Mekong river, Asia, LEK has been used to identify environmental physical structure and population dynamics of the target species to establish fish conservation zones (Baird & Flaherty, 2005). In the Roviana Lagoon, in Western Solomon Islands, LEK has been accessed to inform the conservation status, habitat selection and responses from fishery pressure of the bumphead parrotfish (Aswani & Hamilton, 2004). In the Republic of Guinea, Africa, LEK has been used as a potential source of information for coastal ecosystem services and functioning (Le Fur et al., 2011). In the Brazilian Amazon, fishers have been using LEK to estimate bio-ecological information (Batista & Lima, 2010; Galvão de Lima & Batista, 2012). LEK has been also used to enable fishers themselves to estimate the abundance of giant pirarucu (*Arapaima* spp.) by counting the individuals during their aerial breathing (Castello, 2004). This method has promoted fishers engagement in the management process and lead overexploited arapaima population to recover (Castello et al., 2009; Campos-Silva & Peres, 2016). Moreover, LEK on fishery, farming and extractivism of community members in the Brazilian State of Amazonas was used to create a natural resources accord among the resources' users (Fabré et al., 2012).

Exploring the potential of LEK as a source of information in the Amazon is essential to fill pronounced knowledge gaps associated with the bio-ecological attributes of fish species that can serve as input to management models and decision-making (Ruddle, 1995; Silvano & Valbo-Jorgensen, 2008). For example, information on the length of sexual maturity and period and duration of reproduction are lacking for many species but are essential to define restrictions of fish sizes, gears and seasons of fisheries (e.g., minimal length, mesh sizes, closed season) (Villacorta-Correa & Saint-Paul, 1999; Mclean & Forrester, 2018). These attributes as well as fish length and weight data are useful for estimating values for stock assessments and defining maximum sustainable yields (Campos et al., 2015; Campos et al., 2013; Sparre, P. and Venema, 1998). Yet, these bio-ecological parameters can vary across regions so that species-specific local assessments are many times required (Arantes et al., 2007; Batista et al., 2012; Braga & Henrique Rebêlo, 2014; Doria et al., 2014). Testing the use of LEK to provide these sorts of information is pivotal to improve fisheries data management in poor regions, like the Amazon.

Here, we investigate LEK as a potential source of bio-ecological data for fish species in the Amazon. Specifically, we accessed key information for the management of three species of high commercial and cultural value through LEK. Variables such as length and maximum weight are important to evaluate the fishing stock situation; sexual dimorphism is used to define fishery strategy facing potential differences on sexes' distribution behavior; predation dynamics of exploited species possibly increase mortality affecting resource availability; diet preferences and habitat use define species distribution throughout the environmental mosaic. Our objectives included to investigate knowledge of local fishers on maximum length and weight, sexual dimorphism, predation, diet and habitat use of the carnivorous pirarucu (*Arapaima* spp.), frugivorous tambaqui (*Colossoma macropomum*), and detritivore jaraqui (*Semaprochilodus* spp.). Several factors such as age, time of experience, income, and category or origin of fishers (rural or urban) are known to affect LEK (Davis & Wagner, 2003; Arantes et al., 2007; Martins et al., 2018). Therefore, in our analyses, we accounted for the potential influence of two variables: fisher category (from the urban or rural areas) and time of experience. We evaluated the effects of category and time of experience on LEK estimates, by testing the following hypotheses: 1) LEK of both urban or rural fishers does not differ from information provided in scientific literature; 2) LEK of more experienced fishers tends to be more consistent with scientific information.

Material and Methods

Our study area is located in the floodplain of the Amazon river, an ecosystem comprised by a complex myriad of habitats including shrub, lakes, secondary channels (*igarapé*) and forests (*igapó)* that are periodically flooded by the Amazon river (Castello, 2008a; Arantes et al., 2013). This rich ecosystem provides the basis for a high fish production and intense fishing activity (Junk et al., 2007). The study was conducted in the rural community of São João do Araçá and in the municipality of Itacoatiara, both in the Amazonas State, Brazil. São João do Araçá comprises approximately 30 families whose livelihoods are based primarily on agriculture and fisheries. In this community it is part of the Fishing Agreement. The city of Itacoatiara has an area of 8,892,038 km², being distant 266 km from the capital of the Amazonas State, Manaus, and its population currently is approximately 101,337 inhabitants (Brasil. IBGE., 2019). In the city there is one fishing processing facility, total storage capacity of 2,000 tons and an estimated extractive fishing production of 4,500 tons/year (Gandra, 2010). In the Z-13 fishing colony, 1500 urban and rural fishers are registered (Figure 1.1).

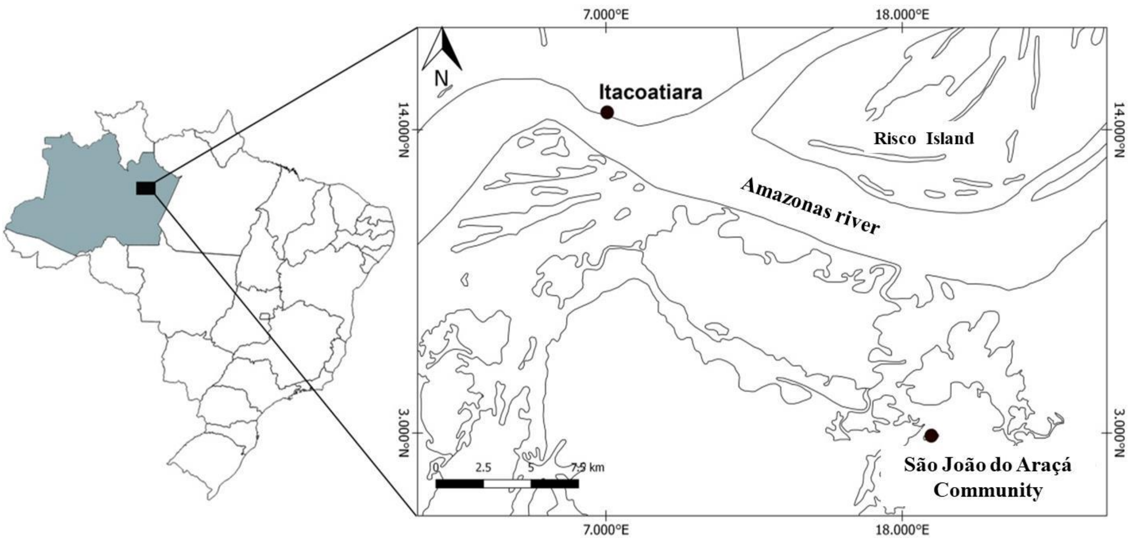


Figure 1.1. Location of Itacoatiara and the rural community of São João do Araçá in Brazilian Central Amazon.

Data collection

Target species

We selected species of high economic and cultural importance in the Amazon:

pirarucu (*Arapaima* spp.), tambaqui (*Colossoma macropomum*) and jaraqui (*Semaprochilodus* spp.), due to their relevance for the Amazonian fisheries management. Pirarucu (*Arapaima* spp.) is a fish of great importance both economically and ecologically (Verissimo, 1970) that has been exploited since pre-Columbian times (Prestes-Carneiro et al., 2016). Although its stocks have experienced dramatic declines throughout its distribution in the Amazon, the implementation of a co-management scheme based on fishing zoning and harvesting quotas has been proved effective in recovering population in a large scale (Arantes et al., 2007; Castello et al., 2013; Campos-Silva & Peres, 2016; Petersen et al., 2016; Campos-Silva et al., 2017, 2019). Tambaqui (*Colossoma macropomum*) is a highly important species that has been largely exploited since the 1970's (Petrere Jr, 1978). Despite the establishment of a minimum catch size of 55 cm and the definition of a closed season throughout the Amazonas state in Brazil, studies have shown signs of overfishing for the species (Arantes e Freitas, 2016; Barthem e Fabré, 2004; Batista, 2012; Campos et al., 2015). Jaraqui (*Semaprochilodus insignis* and *S. taeniurus*) is among the main landed fish resource for urban as well as for rural fisheries (Ribeiro & Petrere Jr, 1990; Batista & Petrere Júnior, 2003; Batista, 2012). Its overfishing was recognized as early as the late 1980's (Ribeiro & Petrere Jr, 1990). However, due to a lack of current data on jaraqui fisheries stocks, it remains unclear what is the status of its populations (Goulding et al., 2018). Scientific data on the biology and ecology of the studied species were obtained through a review of scientific literature. The articles were compiled from the ISI Web of Knowledge database (Thomson Reuters) and SciELO database (Table 1.1).

Table 1.1**.** Literature consulted to compare scientific data with fishers' LEK

	Literature consulted
Growth and Reproductive Maturation	Ribeiro & Petrere, 1990; Isaac & Ruffino, 1996; Fernandes, 1997; Villacorta-Correa &Saint-Paul, 1999; Arantes et al., 2010; Campos et.al., 2015; Petersen et al., 2016; Arantes & Freitas, 2016; Mclean & Forrester, 2018.
Food items	Goulding & Carvalho 1982; Isaac & Ruffino, 1996; Roubach and Saint-Paul,1994; da Silva, Pereira-Filho & de Oliveira-Pereira, 2000; Oliveira et al., 2006; Benedito-Cecilio et al. 2000; Silva et al. 2000; Rebelo et al, 2010;Ruffino & Isaac, 1995; Santos et al., 2006; Rabelo & Araújo-Lima, 2002.

	Goulding & Carvalho 1982; Carolsfeld et al. 2004; Araújo-Lima &
Predation and Habitat use	Goulding 1998; Marques and Resende, 2005; Winemiller et al, 1997; Fernandes, 1997; Ribeiro & Petrere, 1990; Barthem & Fabré, 2004; Castelo et al., 2008; Goulding et al., 1996; Queiroz &Sardinha, 1999; Arantes et al., 2013; Silveira & Magnusson, 1999; Castellanos et al., 2006; Rosas et al 2003; Araíjo-Lima and Goulding,1998; Batista, 2002; Ribeiro, 1993; Braga &Rebêlo, 2014; Neves, 2000.

Assessing Local Ecological Knowledge

To access LEK, we conducted interviews from November 2012 to May 2013 with 44 fishers from São João do Araçá and the city of Itacoatiara. We identified 22 rural fishers and 22 urban fishers, with a minimum of 10 years of fishing experience, all them males. The interviewers were chosen randomly and based on their wiliness to participate in the interviews. Urban fishers live in cities with fishing being their major source of income. The fishing resources are mainly destined for commercialization. They are often related to large boats, which travel long distances in the search of high value species. Rural fishers (also called riverine fishers) live in rural communities and engage in multi-purpose activities including fishing, agriculture, livestock, vegetal and/or animal extractivism - all of which are directly linked to the family production unit (Furtado, 1993; Fraxe et al., 2009).

Urban fishers (N=22) lived in Itacoatiara for 40±18 years, on average, and had a monthly income range of U$ 58.00-U$ 477.00, obtained mainly from fishing. The rural fishers (N=22) lived in the community of São João do Araçá for, on average, 42±14 years, and had monthly income range of U$38.00 -U$1050.00, acquired mainly from agriculture (91%), with fishing being basically directed to subsistence or small-scale sales to complement their income.

The questions for the fishers focused on the biology and ecology of the target fish species, including: 1)What are the maximum length and weight an adult fish can reach?;2) Can you identify any differences among males and females? If yes, what are the differences?; 3) What are this species' predators? ; 4) What are the main items the fish feed upon? Are there differences in the fish diet between the dry and wet seasons? and 5) What are the habitat types you often observe the species in the dry and wet seasons? The interviews were conducted using the common names of the fish species and provided quantitative (question 1) and qualitative (questions 2-5) data that were analyzed as described below. This study was authorized by the Human Research Ethics Committee of the Federal University of Amazonas (CAAE: 02572712.3.0000).

Data analyses

To evaluate the use of LEK for providing bio-ecological data of commercially important species, we first compared the estimated values of LEK for maximum weight and length (quantitative data) of each species group with the mean estimate found in the literature using an analysis of variance. Then, to test the effects of the category of fisher (urban or rural) and the time of fishing experience on LEK, we quantified the difference among fishers estimates of total weight and total length and literature, and model this difference according to the predictors (category and time of experience) using linear models with gaussian distributions. To reduce model selection bias and consider uncertainty, we used the model average approach, which take into account the average regression coefficients across multiple models to capture a variable's overall effect. All models with delta AIC <4 were included in the model average (Anderson & Burnham, 2002). We used lmer in lme4 package to fit the models and MuMIn package (Barton, 2019) to examine all combinations of models. The analyses were performed in R (R Development Core Team, 2017) statistical platform. We evaluated all the model assumptions following Zuur, A., Ieno, E. N., Walker, N., Saveliev, A. A., & Smith, (2010).

Then, we evaluated the quality of the qualitative data on sexual dimorphism, food items, predation and habitats through the use of descriptive statistics, mean and percent. These analyses were used in the comparative cognition table (Silvano & Valbo-Jorgensen, 2008), specifically, was used to compare the knowledge of fishers and the data from the scientific literature (Marques, 1995). The table Integrates data both types of data (LEK and scientific) by means of a perception probability measure classified as: ***High***, when LEK agrees with the scientific literature available; ***Medium***, when these two types of knowledge cannot be adequately compared due to the lack of scientific information and only LEK is available; and ***Low***, when information presented by LEK is unexpected or even contradicts existing biological data.

This classification is useful to assess if information provided by LEK can be incorporated into local fisheries management strategies or if further investigation is needed. To construct the table the food items mentioned by the fishers (Table 1.2) were categorized into: organic matter (detritus and slime), plant material (macrophytes and fruits), fish (species of fish), crustaceans (shrimp and crab), molluscs (species of molluscs), anurans (tadpole of anurans) and chelonians. Fish predators were grouped into fish (all cited species) and birds (all cited species) and the other items were used in a generic way as mentioned by the fishers. Sexual dimorphism characteristics were generally presented as reported by the fishers (e.g., “thin”, “narrow”, “long” characterizing the elongated body of the male). However, in a few cases characteristics were grouped because the terms used by the fishers indicated similar features (i.e., round, curved, ovate abdomen were grouped as ‘wide’, characterizing the body of the adult female during the reproductive period; thin, long and straight were grouped as ‘narrow’ characterizing a shape of the male).

Table 1.2. Food items of the studied fish reported by fishers.

Diet pirarucu		Diet Tambaqui		Diet Jaraqui	
Common name	**Cientific name**	**Common name**	**Cientific name**	**Common name**	**Cientific name**
carangueijo	Crab	fruto do jauari	*Astrocaryum jauari*	lodo	sludge
jaraqui	*Semaprochilodus sp.*	fruto da seringa	*Hevea brasiliensis*	tucumã	*Astrocaryum aculeatum*
cará	Perciformes-Cichlidae	pupunha	*Bactris gasipaes*	jauari	*Astrocaryum jauari*
tamoatá	*Hoplosternum littorale*	catauari/tauari	*Crataeva benthamii*	capim membeca	*Paspalum repens*
tucunaré pequeno	*Cichla sp.*	caramuri	*Ecclinusa guianensis*	mureru	*Cabomba aquatica*
traíra	*Hoplias malabaricus*	socoró	*Mouriri ulei*	barro	mud
branquinha	5 especies de 3 gêneros – Potamorhina, Psectrogaster e Curimata	purui	*Duroia duckei*	arroz bravo	*Oryza sp.*
arari	*Chalceus erythrurus*	capitari	*Tabebuia barbata*	babujo de lago	sludge
jeju	*Hoplerythrnus unitaeniatus*	cajurana	*Simaba guianensis*	frutas	fruits
sardinha	*Triportheus sp.*	abiurana	*Pouteria caimito*	jeju	*Hoplerythrnus unitaeniatus*
sarapó	*Gymnotus carapo*	muruci	*Byrsonima crassifolia*		
carauaçu	*Astronatus sp.*	embaúba	Cecropia		
camarão	Shrimp	fruta da piranheira	*Piranhea trifoliata*		
aracú	Characiformes-Anostomidae-10 espécies	carangueijo	Crab		
curimatá	*Prochilodus nigricans*	uruá	*Pomacea canaliculata*		
piranha	5 especies – Serrasalmus e Pygocentrus	sardinha	*Triportheus sp.*		
tracajá pequeno	Small turtle	goiaba araçá	*Psidium longipetiolatum*		
lebréia,aruanã	Osteoglossum bicirrhosum	jacareuba	*Calophyllum brasiliense*		
acari	Siluriformes-Loricariidae	frutas	fruits		
cubiu	Anodus elongatus (cubiu orana), *Argonectes longiceps* (orana colarino), *Hemiodus sp* (orana flexeira)	camarão	Shrimp		
peixes	fishes	lodo	sludge		
pacu	Mylossoma, myleus e Metynnis	capim membeca	*Paspalum repens*		
girino	tadpole	pupunharana	*Bactris bidentula*		
grilo	cricket	envira	*Rollinia exsucca*		
		louro	*Laurus nobilis*		
		marajá	*Bactris acanthocarpa*		
		Muçurana	Não identificado		
		Jará	Não identificado		
		Bulá	*Não identificado*		

Results

LEK between categories of fishers and literature

Maximum weight and length

LEK estimates of maximum weight for pirarucu were lower than estimates found in the literature (135 kg), on average, 73.9 ± 29.5 kg for rural fishers and 97.6 ± 38.4 kg for urban fishers (Figure 1.2a). Rural fishers tended to estimate significant lower values than the values found in the literature (Figure 1.2a, p=0.001). Between the fishers categories estimates was not statistically different (p=0.09). Urban and rural fishers estimates of maximum length for pirarucu were close to the literature (p=0.91) and did not differ between them (p=0.49) (Figure 1.2d).

Urban fishers estimates of maximum weight for tambaqui were close to the value found in the literature (fishers' estimate=29.6± 11.3 kg and literature=27.2 kg), showing no statistically significant differences (p=0.91) (Figure 1.2b). Rural fishers' estimates were lower (14 ± 6.8 kg) than literature values, but this difference was also not significant (p=0.08). There was significant difference for the estimates between categories of fishers (p=0.001). For length estimates, both urban and rural fishers estimated larger tambaqui (104.5 ± 32.3 cm; 73 ± 24.1 cm, respectively) than the values found in the literature (58 cm) (Figures 2b and 2e), with significant difference for the estimates of urban fishers (p=0.001). There was also a statistically significant difference between the estimates of length between the fishers categories (p=001).

For jaraqui, both estimates of weight and length were, on average, close to values found in the literature (Figure 1.2c and 1.2f), with no significant difference (p=0.55). Estimates of both categories of fishers did not show differences as well (p=0.9).

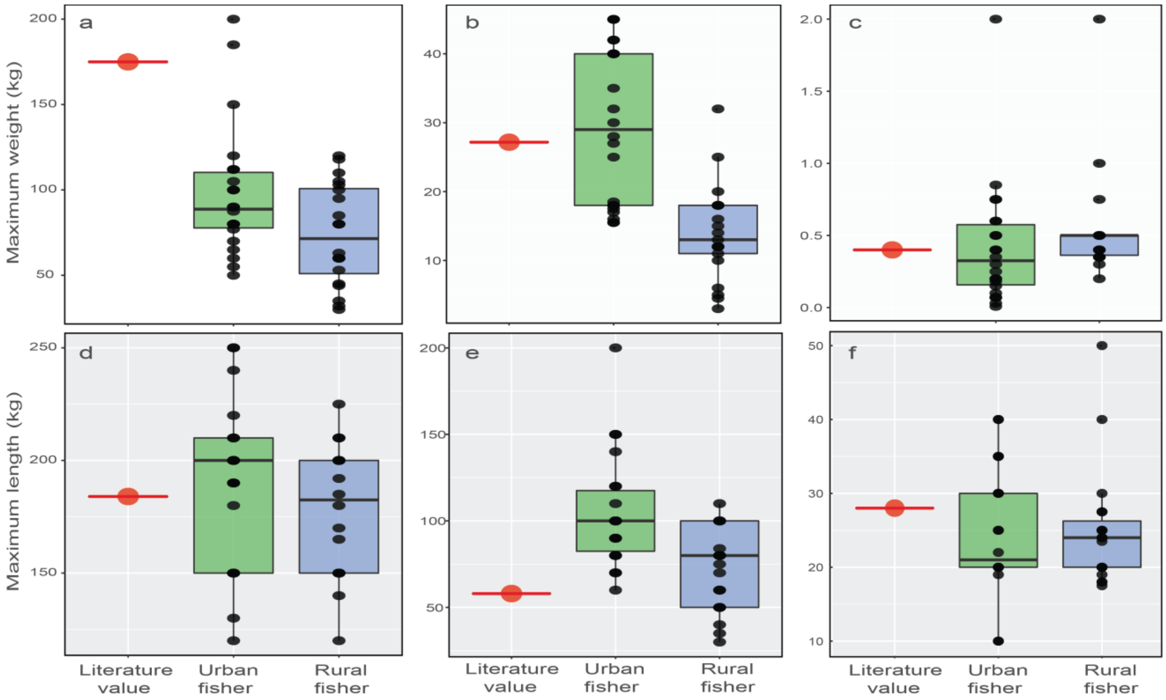
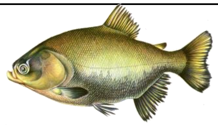


Figure 1.2. Box plot showing variation of estimates from urban and rural fishers at maximum weight (white background) and length (gray background) of high-value fishes. Red symbols represent literature values. Blue and green boxes represent urban and rural fishers, respectively. Lower case in the boxes (a) maximum weight for pirarucu, (b) maximum weight for tambaqui; c) maximum weight for jaraqui; d) maximum length for pirarucu; e) maximum length for tambaqui; and f) maximum length for jaraqui

Sexual Dimorphism

Both urban and rural fishers reported that the female body of pirarucu was longer than the male's, while the male's head was larger than the female's. According to the literature, body size does is not a characteristic that can be used to distinguish the sexes (Lopes & Queiroz, 2009). Another characteristic reported by urban fishers was the female color turning to red. Instead, rural fishers reported that it is the male that does. According to the literature (Monteiro et al., 2010), the most intense red color is a characteristic of males during the reproductive period. Because of disagreement between the characteristics of body size as well as color cited by urban fishers with information from the scientific literature, LEK on sexual dimorphism of pirarucu was classified as having 'medium agreement' (Table 1.3).

Table 1.3. Comparative cognition table on sexual dimorphism. UF = urban fishers and RF = rural fishers. Terms highlighted in bold represent the highest percentage of information reported by them.

Fish species	Fishers' LEK of sexual dimorphism (%)				Scientific literature on sexual dimorphism	Agreement
	UF		RF			
	Male	Female	Male	Female		
Colossoma macropomum (Tambaqui)	**long (28)**	**wide (41.3)**	**long (32.6)**	small head (2.2)	There are morphometric differences between males and females, indicating the existence of sexual dimorphism in the adult phase. Females are larger and heavier in captivity, after reaching reproductive stage (Mello et al., 2015; Almeida et al., 2016).	**High**
	small, narrow and large head (2.2)	small (6.5)	narrow (2.2)	**wide (32.6)**		
	narrow (17.4)			small (2.2)		
Semaprochilodus spp. (Jaraqui)	long (6.4)	thin scale (2)	has scale erection (2)	**wide (19)**	Jaraqui's thin scale can be identified during their reproductive phase through simple observation. Females, in addition to presenting a bulging belly, are slightly bigger, while males present a slimmer body (Alves & FIlho, 1992).	**Low**
	thick scale (2)	**wide (21.3)**	**narrow (8.5)**	large (2)		
	bristly scale (2)	wide and small head (2)	**NA (30)**	**NA (25.5)**		
	slim (10.6)	**NA (25.5)**			Females show a higher growth rate than males, and consequently reach higher lengths for the same age (Vieira et al 1999).	
	small (2)					
	NA (27.6)					
	white secretion (2)					
Arapaima spp. (pirarucu)	**turns red (7)**	small head (2.3)	**turns red (18.2)**	small head (4.5)	Red color is more prominent in males (Queiroz, 2000).	**Medium**
	large head (2)	**turns red (13.6)**	large head (7)	**turns red (9)**	Identifying sexes by means of visual criteria is only possible and efficient on the days prior to spawning, when the color red of males becomes more intense (Lopes & Queiroz, 2009).	
	long (11)	**wide (13.6)**	**long (11.3)**	wide (7)	The orange spots in the lower region of the head were characteristic of males, an aspect confirmed by the hormonal profile of these fish, which showed a higher concentration of male sex hormone (testosterone) (Monteiro et.al, 2010)	
	narrow (9)	**large (11.4)**	narrow (4.5)	large (7)		
	small (7)	white (2.3)	small (4.5)	white (4.5)	Males have a higher proportion of the body surface covered by red than females. The largest female length was not identified as a distinguishing feature of sexes (Lopes & Queiroz, 2009).	
	NA (13.6)	NA (9)		small (4.5)		
	does not turn red (2.2)			does not turn red (4.5)		

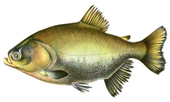
Sixty-five percent urban fishers' LEK about morphological differences between males and females of *Colossoma macropomum* corresponded to the information available in the literature: females have bulging bellies and are slightly larger than males, while males have a very slim body. Therefore, LEK showed high agreement for this feature of the sexual dimorphism of tambaqui (Table 1.3).

On average, 35% of fishers identified female body sizes as being larger than males' during the reproductive phase of jaraqui. Only urban fishers reported bristly scales and white secretion in males. However, there is very little literature for this species to confirm if these characteristics can be used to identify dimorphism. In addition, about 50% of both categories of fishers reported that they were unable to identify any dimorphism features. Thus, LEK of sexual dimorphism on jaraqui showed medium agreement (Table 1.3).

Predation

Overall, LEK of fish predation showed a medium agreement with the scientific literature as fishers reported information that was not found in the literature for any of the species (Table 1.4). The only information matching the literature was that cited by both rural and urban fishers that the main predators of the studied species are fish species, with piranhas *Serrasalmus* spp. and/or *Pygocentrus nattereri* having the largest number of citations. Rural fishers also cited a bird of the Ardeidae family (common name: heron) as a predator of the three studied species. Unfortunately, heron's feeding behavior is not well-known and not described with details in the scientific literature. In addition, rural fishers cited the anaconda (*Eunectes murinus)* as a major predator for pirarucu. However, no record was found in the available scientific literature to support this citation. No information on predators, in general, was found neither for tambaqui or jaraquis.

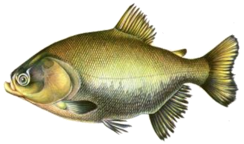
Table 1. 4. Comparative cognition table on predation. UF = urban fishers and RF = rural fishers. Terms highlighted in bold represent the highest percentage of information reported by them.

Fish species	Fishers' LEK of predators (%)		Scientific literature on predators	Agreement
	UF	RF		
Colossoma macropomum (tambaqui)	Alligator (1)	Alligator (1.8)	Fish is an important prey for *Paleosuchus trigonatus* above 40 cm (Magnusson et al., 1987) and the main food item found in the stomach content of alligator-tinged (*Caiman crocodilus*) above 35 cm (Silveira & Magnusson, 1999).	Medium
			Alligator-sugar (*Melanosuchus niger*) adults prey on fish, small mammals, reptiles and birds that are available (Castellanos et al., 2006).	
	Dolphin (5.4)	Dolphin (9)	Red botos (*Inia geoffrensis*) and tucuxi (*Sotalia fluviatilis*) are two species of freshwater cetaceans of the New World which are at the top of the food chain and among the largest predators in the aquatic systems of the Amazon basin. They exploit diverse habitats and have a very diverse diet that includes more than 68 species of fish (Rosas et. al, 2003).	
	Fish (32.1)	**Fish (43.75)**	Pimelodida catfish is highly piscivorous, registering an occurrence of tambaqui as prey of juvenile piraíba (*Branchyplatistoma filamentosum*) (Barthem & Goulding, 1997).	
			In the past, pirarucu (*Arapaima* spp.) may have been an important predator (Araújo-Lima and Goulding, 1998).	
	Human (1)	Human (3.6)	Commercial fishermen have a role as ecological predators of fishing resources (Batista, 2003).	
		Birds (2.7)	No data	
Semaprochilodus spp. (jaraqui)	Alligator (2)	Alligator (11)	Fish is an important prey for *Paleosuchus trigonatus* above 40 cm (Magnusson et al., 1987) and the main food item found in the stomach content of alligator-tinged (*Caiman crocodilus*) above 35 cm (Silveira & Magnusson, 1999).	Medium
			Alligator-sugar (*Melanosuchus niger*) adults prey on fish, small mammals, reptiles and birds that are available (Castellanos et al., 2006).	
	Fish (37)	**Fish (24)**	Large catfish, such as piraíba (*Brachyplatystoma filamentosum*), is the most common predator of Semaprochilodus (Ribeiro, 1993).	
	Dolphin (5)	Dolphin (10)	Red botos (*Inia geoffrensis*) and tucuxi (*Sotalia fluviatilis*) are two species of freshwater cetaceans of the New World which are at the top of the food chain and among the largest predators in the aquatic systems of the Amazon basin. They exploit diverse habitats and have a very diverse diet that includes more than 68 species of fish (Rosas et. al, 2003).	
	Human (3)	Human (5)	Commercial fishermen have a role as ecological predators of fishing resources (Batista, 2002).	
		Birds (2)	No data	
		Giant otter (1)	Increased predation by otters on species that are coming out of central igarapés, located in the mainland (Braga & Rebêlo, 2014).	
Arapaima spp. (pirarucu)	Alligator (9)	Alligator (9)	Fish is an important prey for *Paleosuchus trigonatus* above 40 cm (Magnusson et al., 1987) and the main food item found in the stomach content of alligator-tinged (*Caiman crocodilus*) above 35 cm (Silveira & Magnusson, 1999).	Medium
			Adults of alligator-sugar (*Melanosuchus niger*) prey on fish, small mammals, reptiles and birds that are available (Castellanos et al., 2006).	
		Birds (4)	The birds Anhinga anhinga, Ceryle torquata, Phalacrocorax brasilianus are the "main predators" of juvenile pirarucu. Other important predators are: piranha (*Serrassamus* spp.) and jeju (*Hopterythrinus* spp.). The occasional ones are *Cichla monoculus* (tucunaré) and *Astronotus ocellatus* (Acará açu) (Neves, 2000).	
	Fish (36)	**Fish (22)**	Studies on the diet of *Arapaima* spp. characterize it as piscivorous during the adult phase (Imbiriba, 2001).	
			According to the same authors, shrimps have been frequently found in individuals of more than 150 cm. The only items common to all ages are aquatic insects, mainly Coleoptera and Hemiptera (Queiroz & Sardinha, 1999; Oliveira et. al, 2005).	
			Before spawning in rivers, some species leave igapós to lakes where intense predation occurs by pirarucus (*Arapaima* spp.) and alligators (Braga & Rebelo, 2014).	
		Dolphin (1.3)	Red botos (*Inia geoffrensis*) and tucuxi (*Sotalia fluviatilis*) are two species of freshwater cetaceans of the New World which are at the top of the food chain and among the largest predators in the aquatic systems of the Amazon basin. They exploit diverse habitats and have a very diversified diet that includes more than 68 species of fish (Rosas et. al, 2003).	
	Human (6.4)	Human (9)	Commercial fishermen have a role as ecological predators of fishing resources (Batista, 2002).	
		Giant otter (1.3)	Increased predation by otters on species that are coming out of central igarapés, located in the mainland (Braga & Rebêlo, 2014).	
		Snakes (1.3)	No data	

Diet

LEK of fish diets showed high agreement with the information found in the scientific literature (Table 1.5). Urban and rural fishers mentioned five distinct food items consumed by tambaquis, with the greatest percentage of plant material (above 70%) and three items consumed by jaraqui, with organic material showing the greatest percentage (70.2% of urban fishers and 64% of rural fishers). Fish was the most cited food item for pirarucu (~80%).

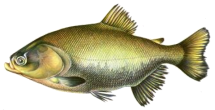
Table 1.5. Comparative cognition table on food items. UF = urban fishers and RF = rural fishers. Terms highlighted in bold represent the highest percentage of information reported by them.

Fish species	Fishers' LEK of food items (%)		Scientific literature on food items	Agreement
	UF	RF		
Colossoma macropomum (tambaqui)	Crustaceans (6.4)	Crustaceans (5.3)	Fruit, seeds and zooplankton (Goulding & Carvalho, 1982).	**High**
	Fish (1)	Fish (5.3)	Fruit and seeds (Isaac and Ruffino, 1996; Roubach and Saint-Paul, 1994).	
	Molluscs (7.3)	Molluscs (2)	Omnivores (da Silva, Pereira-Filho & de Oliveira-Pereira, 2000).	
	Organic matter (12)	Organic matter (10)	Algal carbon in zooplankton was the main source of carbon for tambaqui in Solimões-Amazon River, especially during the low water period, followed by C4 plants (macrophyte leaves and roots). C3 plants were important only during flooding (Benedito-Cecilio et al., 2000).	
	Plant material (71.5)	**Plant material (77.3)**	Presence of fruit and seeds was important, except during periods of low water levels, when food items like insects, sediment, molluscs and fish were mainly present (Oliveira et al., 2006).	
			Decapoda (shrimp), plant material (fruit, flowers, leaves and seeds), Arthropoda (spiders and insects), detritus (mud/land), periphyton (slime), fishes (Rebelo et al, 2010).	
Semaprochilodus spp. (jaraqui)	Fish (3.5)	**Organic matter (64)**	The family representatives (Prochilodontidae: curimatã, jaraqui.) are detritivores, consuming debris, particulate organic matter, algae and periphyton (Santos et al ., 2006).	**High**
	**Organic matter (70.2)**	Plant material (33)	The two species, S. taeniurus and S. insignis, are detritivores (Isaac et. al., 1993).	
	Plant material (21)			
Arapaima spp. (pirarucu)	Anurans (1.8)	Chelonians (1.2)	Piscivore fish (Queiroz, 2000)	**High**
	Crustaceans (10)	Crustaceans (8.3)	Carnivore (Santos et al., 2006).	
	Fish (86.2)	**Fish (89)**		

Habitat use

LEK of habitat use during two seasons of the hydrologic cycle, dry and flooded seasons, also demonstrated high agreement with the information available in the scientific literature (Table 1.6). Lakes were the main habitats reported by fishers as preferred by the studied species. Some fishers highlighted microhabitats within lakes, such as deep areas ("poço") that remain flooded even during strong dry seasons, "aningals" – areas covered by *Aninga* (*Montrichardial inifera*) – and aquatic macrophyte meadows of rice grass (*Oryza* spp.) as important habitats of foraging and refuge for the three species.

Table 1.6. Comparative cognition table on habitat use. UF = urban fishers and RF = rural fishers. Terms highlighted in bold represent the highest percentage of information reported by them.

Fish species	**Fishers' LEK of habitats (%)**				**Scientific literature on habitats**	**Agreement**
	UF		**RF**			
	Dry	**Flood**	**Dry**	**Flood**		
Colossoma macropomum (tambaqui) 	Connecting channel (1.75)	**"Igapó" (33.6)**	**Lakes (37.25)**	**"Igapó" (33)**	Depending on floodplain morphology and water level, fishes remain in flooded forests from four to seven months. When water level drops and flooded forests are drained, most of the adult biomass of *C. macropomum* flees to river channels, while much lesser quantities move into floodplain lakes (Goulding & Carvalho, 1982).	**High**
	Lakes (47.27)				Its life cycle is associated with the floodplains of white water rivers in the Amazon basin. During the flood season, adults and juveniles make lateral migrations into the flooded forest in search of food and shelter. The adult fish exits floodplains at the end of the flood season, forming schools and moving to the river channels where they remain during the dry season (Carolsfeld et al., 2004).	
				Lakes (12)	Floodplains with numerous lakes, fluctuating macrophyte banks and seasonally flooded forests along the main white water rivers in the Amazon are tambaqui's preferred habitats (Araújo-Lima & Goulding, 1998).	
	"Igarapé" (1.75)	Lakes (10.5)	"Igapó" (6.2)	Rivers (2)		
Semaprochilodus spp. (jaraqui) 	"Igapó" (3.7)	**"Igapó" (13)**	"Chavascal" (4)	"Chavascal" (4)	In Rio Negro, migrant jaraqui colonizes 10 distinct biotopes: flooded forest; main channel of the river and its tributaries; marginal open lakes; island open lakes; terra firme central lakes; island central lakes; sand pools in the sedimentation zone of igarapés; muddy pools in the mouthbays of igarapés; littoral zone of igarapés and sand beaches along igarapés, main channel, and islands (Ribeiro and Petrere, 1990).	**High**
	"Igarapé" (5.56)	"Igarapé" (1.85)	"Igapó" (2)	"Igapó" (8)	Young and adult fish occupy simultaneously lacustrine environments of white and black water (Vieira et al.,1999).	
	River beach (1.85)	"Chavascal" (5.56)	**Lakes (24)**	**Lakes (24)**		
	Lakes (26)	Lakes (12.85)	Rivers (12)	Rivers (14)	The headwaters of the igarapés and terra firme lakes of the Amazonian plain have ecological importance for several species of migratory fish, such as jaraquis (*Semaprochilodus insignis* and *S. taeniurus*). The young, newly born jarkys occupy floodplain lakes where they remain during the flood, feeding and growing rapidly, and adults and sub-adults are found in the flooded forest feeding intensely (Barthem & Fabré, 2004).	
	Rivers (18.5)	Rivers (11)				
Arapaima spp. (pirarucu) 	"Igapó" (1.85)	**"Igapó" (27.8)**	Connecting channel (2)	**"Igapó" (26)**	They mainly inhabit lakes and connecting channels and perform lateral migration (Castelo et al., 2008).	**High**
	"Igarapé" (3.7)	Lakes (12.7)	**Lakes (46)**		Live in lake environments (Barthem & Fabré, 2004).	
	River beach (1.85)	Rivers (1.85)		Lakes (12)	They inhabit floodplain lakes during the dry season (Queiroz & Sardinha, 1999).	
	Lakes (48.2)		Rivers (2)	Rivers (6)	The distribution of arapaima in the várzea during low water levels appears to be influenced primarily by the depth and location of lakes (i.e., their dry-season volume; connectivity of such lakes to other water bodies, and by depth of water column in sections of connecting channels (Arantes et al., 2013).	

LEK and time of experience

Fishing experience did not influence LEK estimates between the categories of fishers.

Discussion

Our study reinforces that fishers' ecological knowledge represents a potential source of information on bio-ecological aspects of fishes in the Amazon. Particularly, LEK of diet, predation and habitat of the studied species showed high degree of agreement with the literature. Estimates of weight and length were also similar to those found in the literature, with a few exceptions. These results corroborate previous studies showing that LEK can provide valuable data on life history strategy parameters (Begossi et al., 2016; Froese, 2017), particularly, for species that are part of their daily life as sources of food and income (Barthem & Fabré, 2004; Batista & Lima, 2010; Braga & Henrique Rebêlo, 2014).

Urban and rural fishers' LEK as information source

Maximum weight and length

Although few estimates of maximum weight and length of pirarucu differed from those found in the literature, LEK was mostly consistent with the available knowledge. The few differences of estimates among fishers and literature such as found for pirarucu weight can be explained by the fact that we used averaged values from the literature thereby missing fine scale information and potential spatial variability. For example, although maximum weight values reported by fishers differed (i.e., were smaller) from the averaged maximum values from the literature, they were in accordance with those recorded in the Jurua reserve, Central Amazon (Silva, 2014). It is also possible that differences may be related to a potential pirarucu overexploitation in our study area that may have promoted declines of larger/heavier individuals (Hrbek et al., 2005). Even if fisheries agreements and management initiatives exist, compliance with management rules is generally low and illegal fishing still take place in the region (Cavole et al., 2015; Sagar, 2000) . Previous studies have shown that this region has been under intense fishing pressure since the 1970s (Smith, 1981; Espínola, 2015).

Likewise, the larger values of maximum length for tambaqui reported by fishers than those found in the literature may be also explained by our use of averaged values from the lengths reported in the literature. In this case, some reports were based on landing data that reflects the large scale overexploitation status of the species in both Amazonas and Pará states of Brazil (Isaac et al., 1996, 2000; Campos et al., 2015a) with records of smaller individuals that reduces averaged value obtained from the literature. Another potential explanation is that since a minimal size catch of 55 cm is established by regulation, the fishers we interviewed may have overestimated tambaqui sizes .

Estimates of tambaqui weight and length among fishers categories differed possible because these fishers explore different types of habitats within floodplains, which are selected by distinct length classes of tambaqui: young fish (i.e., smaller individuals) spend most of their life cycle in floodplain lakes (Goulding, 1982) where rural fishers usually fishing (Pereira & Fabre, 2009). In contrast, larger adults (sexually mature tambaquis) are often caught by urban fishers in other habitats such as the river channel (Goulding, 1982). Alternatively, differences in length estimates may also be explained by potential differences in growth patterns occurring in the different fishing areas in response to fishing selection, or even to potential genetic variations (Arantes et al., 2010; Gurdak et al., 2019).

Sexual dimorphism, predation, diet and habitat use

The LEK on sexual dimorphism of pirarucu, tambaqui and jaraqui showed a medium agreement with the literature. This was due to the fact that some fishers reported a few characteristics, such as larger head size for male pirarucus and erect scales for male jaraquis, that were not found in the literature. We suggest further studies to investigate the presence of these characteristics as they can possibly be used as features to identify these species' sex and to inform sustainable fishing strategies such as avoiding catches of females during their reproductive period (Gama, 2014). Understanding the sexual dimorphism characteristics can help refine size regulations using gender-specific minimum size limits in management strategies (Halvorsen et al., 2016) contributing developing fishery biology studies and reproductive monitoring programs (Lopes & Queiroz, 2009).

Rural fishers declared the studied species predators that were not yet recorded in the literature, including herons and the snake *sucuriju*. The little information on the feeding behavior of heron and snakes available for the Amazon river floodplain shows that they feed on a wide variety of items, including diverse fish, amphibians, crustaceans, and sometimes, reptiles, insects, birds and mammals (Martins & Oliveira, 1998; Bernarde & Abe, 2010; Lorenzón et al., 2013; Machado et al., 2018). Therefore, it is possible that these species can indeed predate on tambaqui and jaraqui, especially, on smaller/younger individuals. However, in some cases, such as for species that have parental care and invest in their offspring survivorship such as the pirarucu that protect their eggs and juveniles, predation in earlier stages may be more unlikely (Castello, 2008b). Future studies on fishers' LEK should consider aspects that can influence species vulnerability to these predadors, including the life stage, mobility strategies(sedentary or migratory) and seasonality.

The high number of food items reported by fishers is consistent with studies showing the trophic plasticity among neotropical fishes (McConnell & Lowe-McConnell, 1987; Duarte et al., 2019). Specially, in floodplain ecosystems, fishes diet vary in the amount and quality of food resources in response to seasonal flood pulses (Oliveira et al., 2006; Arantes et al., 2018). Fishers may gain detailed knowledge about fish diets through daily observation of their stomach content while gutting the fish for their own consumption or selling in local markets, or by handling the food items that are used as baits (Ramires et al., 2015). The identification of food items derived from forests such as fruit that serves as food for tambaqui can reinforce the importance of conservation strategies in response to deforestation (McCauley et al., 2012; Arantes et al., 2018; Duarte et al., 2019).

Our results regarding fish predation and diet reinforce that the importance of LEK as tool to increase the understanding on ecological interactions in tropical aquatic environments (Lima & Batista, 2012; Ramires et al., 2015; Braga & Rebêlo, 2017) and the impacts of anthropogenic action on the fishery and fish ecology. For example, tambaqui returns to alluvial plains during high water periods to feed (Goulding & Carvalho, 1982), dispersing seeds of at least 76 plant species (Correa et al., 2015) miles from their place of origin (Anderson et al., 2009, 2011). In this context, local knowledge can be a useful source of knowledge to assess the impacts deforestation on tambaqui food sources (Arantes et al., 2019) also the impact of overfishing on forest dynamic, considering that large individuals of tambaqui play a central role on seed dispersal (Garcez Costa Sousa & De Carvalho Freitas, 2011; (Costa-Pereira & Galetti, 2015).

The fishers reported a variety of habitats that fish use according to river level. This information corroborates data from the scientific literature that describe how the flood pulse influences the spawning and feeding activities of these species (Goulding, 1982; de Brito Ribeiro & Junior, 1990; Queiroz, 2000; Castello, 2008a). Thus, fisher's knowledge of the spatial distribution of species in different types of habitats according to river level can be useful in developing conservation strategies, such as for pirarucu management, particularly considering individuals larger than 1 m, identifying environmental features such as larger, deeper lakes and deeper connecting channels are priority habitats for management. Habitats with these characteristics can also be considered for monitoring arapaima populations, allowing profitable use of scarce human and financial resources. The abundance of arapaima in habitats with these characteristics can also be interpreted as an indicator of population health (Arantes et al., 2013). These habitats should be considered in the development and implementation of protective frameworks in large scale areas for Amazonian freshwater fauna(Hrbek et al., 2007).In this sense, fishers select the habitats where they will fish based on their knowledge of these migrations (Smith, 1979; Ribeiro & Petrere Jr, 1990). This knowledge of the spatial dynamics of fish species related to seasonal migration and reproduction is transmitted over generations (Ruddle, 1991).

LEK and fishing experience time

Contrary to our hypothesis, our results showed no differences of LEK of biological traits according to fishing experience time. This result contradicts previous findings on fishers' experience influencing other estimates of LEK parameters, including fish abundance and production (Castello et al., 2011; Lima et al., 2016). For example, fishers experienced on traditional fishing techniques such as harpoons estimated pirarucu abundance more accurately than non-experienced fishers (Arantes et al., 2007). This contrast may be a result of the different types of information provided by LEK, which in this study were biological parameters that fishers are visually exposed to every day (e.g., length and weight) (Ruddle, 1991; Begossi & de Figueiredo, 1995; Nunes et al., 2011). In other case studies (Hallwass et al., 2019; Lima et al., 2016), other parameters that may require longer time of learning (e.g., resource abundance) were observed.

In this study, a few information provided by fishers were either not found or different from the literature, raising issues to be further addressed. For example, understanding the reproductive behavior of species such as jaraquis, that swim in schools, as well as their sexual dimorphism features can be useful to confirm specific reproductive behavior for each sex. Understanding what are the predators of the fish species will be useful to access the potential roles of terrestrial predators, including herons and snakes, in the aquatic food webs. Thus, continued research on biological traits as well as on LEK of the fishery-targeted species is needed to strengthen knowledge in the Amazon.

In the Brazilian Amazon, the scarcity of human and financial resources to collect and develop studies on bio-ecological parameters of fishes hinder the provision of bio-ecological information that is necessary to ensure proper management plans in a rapid changing environment. Our results demonstrate that fishers' LEK represents a potential and reliable source of information that can be used to provide these data to support conservation and management strategies.

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CAPÍTULO II

Capítulo II. Decision-making on fishing location choices: Are Amazonian artisanal fishers risk lovers?

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Abstract

The variability of fishing yields is usually driven by the decision of where to fish, what is related to the perceptions and risk attitudes of fishers. To decide where to go fishing, the artisanal fisher can follow the basic principles of perception and judgment by assessing changes in resource state and assessing possible gains and perceiving risks of fishing failures. This study analysed the attitude at risk of artisanal fisher to choose the fishing grounds for commercial fishing in the Amazon basin, considering the prospect theory. We interviewed commercial fishers examining cognitive aspects and alternative gain and loss probabilities related to the selection of fishing grounds. We evaluated the effects of individual fishers characteristics, including schooling, source of income, function in the fishery, and time of experience in the fishery on the attitude towards risk. The results showed that commercial artisanal fishers in the Central Amazon are averse to risk in their choices and that the pain of loss is higher than the satisfaction of gains as expected by prospect theory. Time of experience and role in the fishery were the factors that most influenced this attitude. So, fisher attitude at risk is parsimonious between profitability and conservation.

Keywords: Small-scale fisheries; Risk attitude; Fishing ground choice; Local ecological knowledge; Central Amazon

Introduction

Commercial fishing is an economic activity that tends to follow the principle of rational action by fishers to maximize profits and utilities (van Putten et al. 2012). However, short-term behavioural decisions (e.g., choice of fishing grounds), in most fisheries are made under uncertainty as fishers have no precise information on the distribution of stocks and, ignoring where higher utility or profit can be obtained (Smith 2005; Andersen et al. 2012). To access this information, most studies on fisheries choice consider the vessel as the unit, and profits maximization plus the behavioural motivation of fishers as keys to the process (Bockstael and Opaluch 1983; Mistiaen and Strand 2000) mixing structural and psychological variables to define most influential drivers. In this sense, the effect of the variability of fishing yields on the fishing choice is related to the perceptions of risk and attitudes of fishers (Salas and Gaertner 2004) facing structural and environmental possibilities and thresholds. Based on the attitude of the fishers as the basis for the decision, fisheries management should have it as an essential factor to be understood and considered for efficiency in meeting the objectives of exploitation.

The risk-taking attitude in fisheries is addressed mainly using the expected utility theory, pursuing to maximize profit (Eggert and Tveteras 2004) combining physical and financial risk. Such an assumption makes fishery as a unique profession, leading to the conjecture that commercial fishers are intrinsically risk-lovers (Dupont 1993; Eggert and Tveteras 2004). However, pioneering articles on the choice of target species and fishing grounds have observed risk aversion as the standard attitude (Bockstael and Opaluch 1983; Mistiaen and Strand 2000). So, the systematic violation by fishers of the theory of rational behaviour (Vriend 1996), put them far from what was predicted by the theory of expected utility (Wilen et al. 2002; Holland 2008), demonstrating that essential determinants are being ignored. Thus, the fisherman may decide according to the prospect theory (Kahneman and Tversky 1979), whereby decision-makers use the basic principles of perception and judgment to assess the change in their state of wealth or well-being, as measured by function value. The main difference between the prospect theory and the expected utility theory, where actual and expected gains are compared (Nguyen and Leung 2009), is that the first integrates the aversion to loss in behaviour at risk to the utility function. In an environment of uncertainty and high risk of fishing, losses may have more weight than usual, affecting productivity, profitability, and the viability of resource management.

The decision of where to fish is central to commercial fishing, mainly because fishers who target the same resource have different returns depending on their choice of location (Nguyen 2010). Even considering the expected risk aversion of fishers when choosing fishing, the under-risk attitude is potentiated in artisanal fisheries in tropical regions, where there is a high diversity of species, multiplicity of environments and fishing technologies, and with a large spatial scale of operation (Bayley and Petrere Júnior 1989; Allison and Ellis 2001). In addition, choosing a fishing ground is currently an even more difficult decision as area closure is one management tool frequently used by fisheries managers (Mistiaen and Strand 2000; Kellner et al. 2007; Claudet et al. 2008), by fishing communities (Fabré et al. 2012; McClanahan and Abunge 2016) or by government management to protect biodiversity and natural environments (e.g., Ban et al., 2019; Sala and Giakoumi, 2018). Therefore, considering that the consequences of the closure will depend on the profile of the fishers to the risk (Salas and Gaertner 2004; Nguyen 2010), and with viable alternative fisheries that generate similar profits, which references are central in the attitude of the fishers to be identified the best management options available?

Differences in decisions are potentially influenced by individual characteristics, such as the fishing experience (McClanahan et al. 2014) or the memory of past success - leading fishers to revisit fishing grounds (Pascoe and Mardle 2005), generating reliable forecast power to decisions on fisheries dynamics (van Putten et al. 2012). In addition to the empirical learning that life experience provides, schooling level as an indicator of formal education has the potential to affect decision making, with greater risk rejection for those with higher schooling (e.g., Donkers et al., 2001; Hartog et al., 2002). The attitude towards risk is also potentially affected by financial income, expecting that the individual's total income has a negative correlation with the risk aversion (Hartog et al. 2002; Kolawole and Bolobilwe 2019). Similarly to income, the role exercised within the commercial fishing activity can influence the attitude at risk, expecting higher income associated with those more qualified in higher functions, such as being the vessel skipper or the skilled fisher known as the "best fisher" among their peers (Eggert and Lokina 2007). Thus, there are potential relationships of fishers' profile to the decision at risk, affecting fishers yield, ecological knowledge, and their compliance with fishery management rules, impacting on its effectiveness.

Continued efforts to establish effective management approaches, such as co-management, increase the importance of incorporating fishers' attitudes and behaviour in decision making (Hilborn 2007), which has rarely been addressed for inland water environments (van Putten et al. 2012). Thus, understanding the fisherman's attitude towards management alternatives is essential for the effective implementation of a fisheries policy.

Here, we investigated the risk-taking attitude towards the choice of fishing in commercial artisanal fishing in a culturally rich and preserved environment in continental waters, the Amazon basin. The proposal was built based on the concepts of the prospect theory (Kahneman and Tversky 1979), considering characteristics of the fishers, including the level of education, source of income, function in fishing and time of experience as commercial fisher (Eggert and Tveteras 2004; McClanahan et al. 2014). Thus, we test the hypothesis that fishers are more risk-averse when they have more experience in fishing, less education, and greater dependence on fishing income.

Materials and Methods

Study area

Commercial fishing in the Central Amazon lands mostly in Manaus, after exploring the Amazon River (Figure 2.1), its main tributaries (Amazonas-Solimões, Purus, Madeira, Juruá, and Negro rivers) and floodplains. This river-flooded system has about 8,500 lakes, corresponding to approximately 11% of the 62,000 km^2 floodplains (Melack 1984; Hess et al. 2015). These lakes are classified into floodplain or “várzea” lakes, upland or "terra-firme" lakes and composite lakes having different productivity along the hydrological cycle configuring the main fishing grounds (Nolan et al. 2009). This floodplain is among the most biodiverse ecosystems in the world, with around 2400 known fish species (Jézéquel et al. 2020), which are the basis for intense subsistence (Cerdeira et al. 1997; Batista et al. 1998) and commercial fisheries (Batista and Petrere Jr 2007; Nolan et al. 2009; Batista et al. 2012; Goulding et al. 2019).

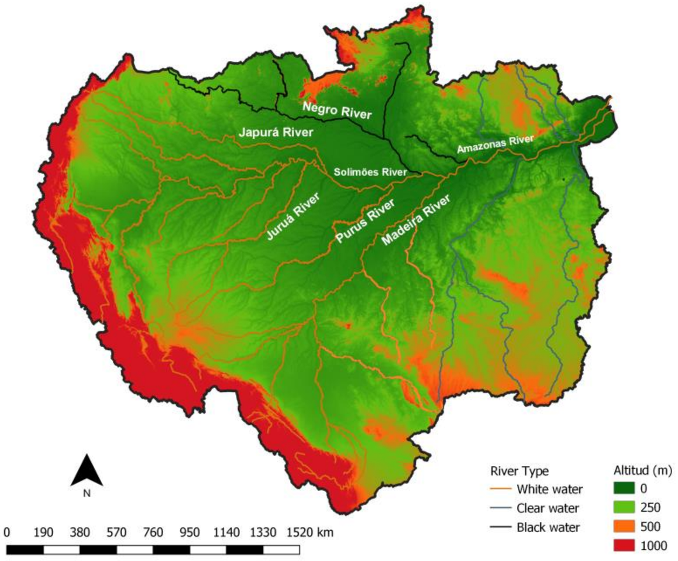

Figure 2.1. Map of the Amazon basin highlighting the main rivers used by the artisanal fishing fleet landing in Manaus.

Data source and processing

The commercial fishing fleet

The fleet landing the Manaus Fishery Terminal contains approximately 1,800 artisanal fishing boats (Batista et al. 2007), 14 meters median length (Batista et al. 2004) taking 5 to 14 fishers per trip (Cardoso et al. 2004) that lasts on average 9±5 days (Batista et al. 2012). Fishing grounds used are located in different habitats in rivers and lakes in the various tributaries (Batista and Petrere Jr 2007). Fishing is multispecific, concentrated on around 20 species, mainly using two fishing gears: seine-nets and gillnets (Batista et al. 2004).

Interviews

Fishers were interviewed with semi-structured questionnaires with questions on potentially impacting topics in decision making and how they make their choices in fishing. Subjects include the time of fishing experience, education, and source (s) of income (single income, exclusive of fishing and income extra, source other than fishing). The questions towards their risk decision profile were based on the model tested by Kahneman and Tversky (1979) containing blocks of statements about the three properties of the prospect theory (certainty effect, reflection effect, and value function).

In addition to these questions, statements for use with a Likert scale with four levels (strongly agree, agree, disagree, and strongly disagree) about the information or knowledge that the fishers use to analyse and make his decision. Kahneman and Tversky (1979) classify these heuristic cognitive aspects in anchoring (weight on information offered), availability (weight on standing events recorded in memory), and representativeness (weight on similarity driving judgement), which were addressed with topics for assessment in the fisheries area by cognitive trait (Table 2. 1).

Table 2. 1. Themes of statements made to fishers by the cognitive trait.

Cognitive aspect	**Themes**
Anchoring	Fishing nearby depending on the period (dry / fall)
	Start fishing trip without profit forecast
	Market conditions
Availability	Next most productive fishing ground
	Relatives near the fishing grounds
	All lake types, focused on the target species
Representativeness	Distant fishing grounds are more profitable
	More productive mainland lakes
	New fisheries more profit

Data analysis

The responses were initially assessed for each property, comparing the extremes of aversion and propensity for each option (Table 2.2). The procedure allowed the definition of the risky attitude of fishers as averse or risk-prone. Values generated were tested with the Student t-test. Fishers' cognitive aspects were characterized using the Likert package (Bryer et al. 2015) in the R environment (R Core Team 2017) considering the proportion of agreement or not on the responses regarding each aspect of the statements made.

Table 2. 2. Criteria for categorizing fishers according to their attitude at risk.

Effect	**Criterion**	**Prospect**		
		Item	Attitude	You need to decide which fishery to go to today, choose an option
Certainty	When exposed to earning prospects, people prefer results that they consider guaranteed rather than	A	Prone	80% of earning $ 4,000 20% of not having gains
			Adverse	100% of earning $ 3,000

Effect	Criterion	Prospect		
	results that have a higher expected value	B	Prone	20% of earning $ 4,000 80% chance of no gains
			Adverse	25% of earning $ 3,000 75% chance of no gains
		C	Prone	45% of earning $ 6,000 55% chance of no gains
			Adverse	90% of earning $ 3,000 10% chance of no gains
Reflection	When exposed to loss prospects, there is an inversion; people prefer to risk losing more value to reduce the likelihood of loss	D	Prone	45% of loss $ 6,000 55% chance of no gains
			Adverse	90% of loss $ 3,000 10% possible loss
		E	Prone	80% of loss $ 4,000 20% chance of no gains
			Adverse	100% of loss $ 3.000,00
Changes in wealth	The choices are changeable, considering the variation in wealth. In prospect F, the interviewee was informed that already has $ 1,000 and in prospect G, $ 2,000	F	Prone	50% of earning $ 1,000
			Adverse	100% of earning $ 500
		G	Prone	50% of loss $ 1,000
			Adverse	100% of loss $ 500
Value function	People are averse to lose because they feel the pain of loss more than the pleasure of gain	H	Prone	25% of earning $ 6,000
			Adverse	25% of earning $ 4,000 25% of earning $ 2,000 50% chance of no gains
		I	Adverse	25% of loss $ 6,000
			Prone	25% of loss $ 4,000 25% of loss $ 2,000 50% chance of no gains

Data on personal characteristics for fisher, including education, source of income, and time experience in fishing, were related to an attitude towards risk qualified based on the Certainty Effect. Initially, it sets the value (-1) for averse responses to risk and (+1) for responses prone. Values were summed, for negative results, the fisher was considered as risk-averse, and if it was positive, risk-prone.

Eight statements were read to fishers' regarding possible decisions involving aversion or willingness to risk in fisheries to test determinants of the fisherman's decision-making attitude, generating a score - here called the Risk Attitude Index (RAI) - from the responses to the Certainty Effect property. Half of the statements were prepared to generate maximum values with conflicting answers, and the other half with concordant responses to avoid confirmation bias (Plous 1993; Klayman 1995). The Likert scale was defined with an increasing weight of 1 to 5 for statements with rising agreement (1-strongly disagree, 2-disagree, 3-neutral, 4-agree, 5-totally agree) and 5 to 1 for those of rising disagreement (5-strongly disagree, 4-disagree, 3-neutral, 2-agree, 1-strongly agree). Only interviews with answers given for all statements were used.

The modelling was initially carried out with evaluation by parsimonious analysis of the fit of the predictors (education, source of income and time of experience in fishing) with all variables and with a reduced model chosen using the MuMIn package (Barton 2015) in the statistical platform R (R Core Team 2017). The most parsimonious model was selected for analysis with adjustment by the generalized linear model using the Gaussian distribution family.

The methodology was recorded in the Research Ethics Committee on the Universidade Federal do Amazonas under # 31299720.8.0000.5020 and 35501520.6.0000.5020.

Results

Decision-making attitude at risk of fishers

The attitude at risk declared was summarized in Table 2.3**Erro! Fonte de referência não encontrada.**. For the Certainty Effect, assessed in cases A, B, and C, 71% 56% 67% of fishers, respectively chose for the highest probability even if they earn less, being risk-averse in this property. For the Reflection Effect, in case D, 68% of fishers would lose the same value in any option but choose the percentage that apparently has the least chance of losing. In case E, 56% of fishers chose the situation that they lose the most, but the choice was based on the least probability to be lost, considered risk-prone for this property. For Change in Wealth, even considering that they already have gains, in cases F and G, respectively, 62% and 63% of the fishers chose the certainty of the lowest value regardless of winning or losing, presenting an attitude averse to risk, contrary to the expected. For the Value function, evaluated in cases H and I, 58 and 61% and the fishers chose the option to earn more and also to risk losing. For this property, their attitudes were considered risk-averse to gain and risk-prone to loss, different from expected.

Table 2. 3. Percentage of fishers choices according to their attitude at risk.

Effect	Case	Attitude	Result
Certainty	A	Prone	29%
		Adverse	**71%**
	B	Prone	44%
		Adverse	**56%**
	C	Prone	33%
		Adverse	**67%**
Reflection	D	Prone	**68%**
		Adverse	32%
	E	Prone	**56%**
		Adverse	44%
Changes in wealth	F	Prone	38%
		Adverse	**62%**
	G	Prone	37%
		Adverse	**63%**
Value function	H	Prone	42%
		Adverse	**58%**
	I	Adverse	39%
		Prone	**61%**

Risk-taking attitude towards the individual characteristics of fishers

Comparing to risk-prone fishers, the risk aversion attitude was higher for illiterate fishers (around 4.5-fold higher) or with elementary school level (around 3.5-fold higher), reducing to high school level fishers (around 2-fold higher). No matter having other income sources, risk averse fishers were also more frequent than risk-prone (from 3 to 5 times more frequent). Risk-averse fishers were younger (experience around 24 years) than those risk-prone (around 30 years), as well as there more fishers risk-prone than those are skippers - around 30% more (Figure 2.2).

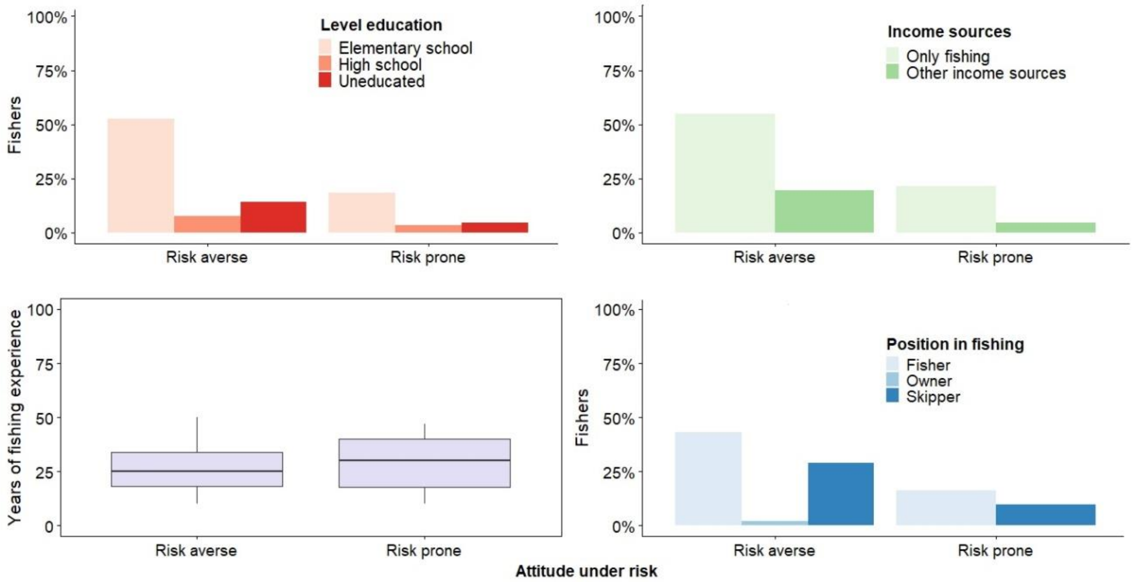

Figure 2.2. Individual characteristics of fishers according to decision-making attitude. A. Level education; B. Income sources; C. Years of fishing experience; D. Position in fishing

Fishers cognitive aspects for decision making

Fishers mainly agreed to all statements given (minimum agreements sum was 63% - Figure 2.3) even when there were expected disagreements like market driven choices or that distant fishing grounds are always more profitable. Facing this confirmation bias tendency, results are analysed comparatively among cognitive aspects and statements.

Anchoring was the heuristic driving the fisher attitude (**Erro! Fonte de referência não encontrada.**). Fishers largely agreed with the statement that they leave for fishing without considering the opportunity cost, making the profit a low valuable projection when choosing fishing grounds. Availability is the most disperse heuristic, showing high weight to parenthood information and support (80% agreement) but also low pressure to most accessible fishing grounds (63%). Representativeness drives decision just on the general perception that already known distant fishing grounds are certainly full of fishes (84%) but not so much if these are not known places (73%), or they are in hard to access areas (70%).

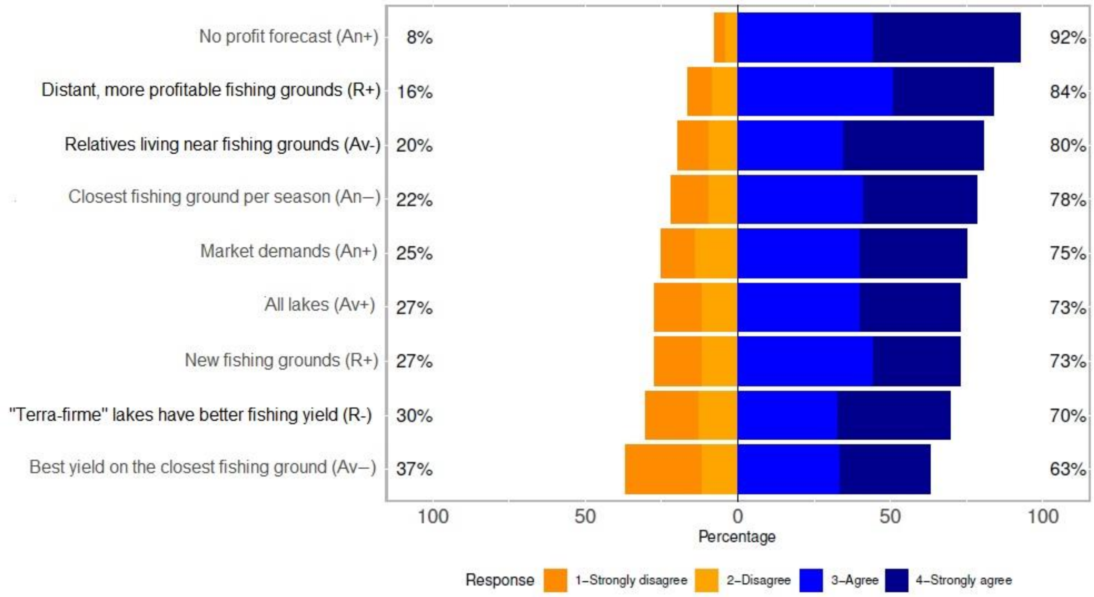

Figure 2.3. Degree of agreement of the cognitive aspects used for decision-making. An = Anchorage; Av = Availability; R = Representativeness; "+" indicates confirmation statements and "–" indicates disconfirming statements.

Drivers of fishers attitude to risk in fishing

The effect of the determinant variables of the fishers' risk-taking attitude was compared among conceptual models (Table 2.4), resulting in the ranking by AICc showing lower values for model 1.

Table 2. 4. AICc table for multiple mixed models of risk attitude modelling in artisanal fishing in Central Amazonia

Model	Equation*	df	AICc
1	TOTCOG = FISH + INC_OUT + ROLE	5	496.77
2	TOTCOG = FISH + SCHOOL + ROLE	5	497.82
4	TOTCOG = FISH + SCHOOL + INC_OUT + ROLE	6	499.03
3	TOTCOG = FISH + SCHOOL + INC_OUT	5	501.02

* TOTCOG=Total cognition; FISH=Years fishing; SCHOOL=Schooling category (1=a year; 2≥more than a year); INC_OUT=total income out of the fishery; ROLE=fisher or skipper.

Model 1 had the fit tested, being significant (r^2=0.09; p = 0.037) with significant contribution to define the risk response in decision making of the attributes experience and the role in the fishery (Table 2.5). The existence of an income parallel to fishing was not a significant driver.

Table 2. 5. Table with the parameters for modelling the attitude towards risk in artisanal fishing in Central Amazonia.

ITEM	Estimate	Std.	Error	t	Pr(>|t|)
(Intercept)	24.1593	1.0747	22.480	<2e-16	>0.01
FISH	-0.0717	0.0322	-2.228	0.0284	>0.05
INC_OUT yes	-0.8452	0.8220	-1.028	0.3066	NS

ROLE fisher	-1.5671	0.7650	-2.048	0.0435	>0.05

Discussion

Commercial artisanal fishers in Central Amazonia are risk-averse in their choice of fishing, with 70% of fishers feeling more the pain of losses than the satisfaction of gains. These results indicate that the prospect theory is an alternative to the theory of expected utility for artisanal fishers. Moreover, cognitive aspects shown the importance of traditions anchoring fishers decisions and the social network as an important decision reference facing environment or yield uncertainties. Results suggest that management measures that lead to the perception of yield stabilization tend to have more acceptance than those that generate a perception of reduced yields, since fishers are averse to losses (Nguyen and Leung 2009), but also averse to food insecurity (Sowman 2006; McClanahan et al. 2015). In this approach, the closure of a fishing area, a standard measure in fisheries management, tends to be disregarded if it includes fisheries that are customary in generating profit (Pascoe and Mardle 2005; Nguyen 2010). Therefore, measures can be accepted if adequate choices have been made about what will be limited in fishing, and the cognitive profile found to determine the attitude at risk favors arrangements that do not exclude higher-income fisheries.

In the Amazon basin, closed reproductive season and minimum size limits are two management tools commonly applied in the artisanal fisheries (Batista et al. 2004). In the first case, fishing is prohibited for main species during the predominant reproductive periods at the beginning of the flooding period, the closed season locally called "defeso". In the second case, there is a minimum size to catch the same species for sell, usually determined by their first maturity size. However, both tools are frequently violated by artisanal fishers, with catches below the legal size (e.g., Castello et al., 2019; Souza and Freitas, 2010) and the closed season also repeatedly unfulfilled (Corrêa et al. 2014; Cavole et al. 2015). Whether or not to take any adverse or risk-prone attitude is usually related to compliance with references recorded in rules, where the economic gain from the violation is compared with the risk of being detected and the effectiveness of sanctions if caught evading rules (Raakjær Nielsen 2003). Considering the classic logic of expected utility, if fishers are risk-averse, they will comply with the regulations avoiding the consequences. If we take the prospect theory references, the losses are by far more rejection to do not comply with current rules. However, considering the inefficient historical inspection (Batista et al. 2004; Castello et al. 2015), the risk of losses is minimized concerning the impact of economic losses. If target species generate expectations of high profits and management is unable to enforce rules and inspect, fishing during the closed season will be valuable facing high gains and low risks (Mistiaen and Strand 2000; Eggert and Lokina 2007). On the other hand, risk-averse fishers would comply with fishing rules if adequate incentives are present (Brick et al. 2012), as well as considering that local participative ecosystem management is supported and experienced in the region (McGrath et al. 1993; Fabré et al. 2012; Lopes et al. 2019). Urban and community-based fisheries are different social environments where attitudes are expected to be different, which indicates the importance of determining the profile and desires of fishers before management strategies are developed and implemented.

Fishers with more experience also were shown to be mainly risk-averse, confirming the proposed model. The result is related to the accumulation of expertise in the exploitation of species and environments increasing the LEK (Hallwass et al. 2013), helps the discrimination of profitable fishing grounds (van Putten et al. 2012), and allows the formation of a network of social relationships in fisheries that facilitate fishing grounds choice (Mueller et al. 2008; Turner et al. 2014). In parallel, LEK increases according to the networks of relationships in or near fisheries (Bodin et al. 2006; Salpeteur et al. 2017), impacting their perception of capture, its variability, and the risk attitude of the fisherman. This LEK added over generations thus includes not only the knowledge of the species but also the spatial dimension of the territory and its productivity (McKenna et al. 2008; Pita et al. 2016). However, even in highly conserved regions like the Central Amazonia, the confidence on LEK based on vertical cultural transmission represents a risk to be assessed as several ongoing environmental changes - including climatic and other directly anthropogenic ones - are altering the dynamics of systems.

The level of education was low and little variable, not significant in modelling the attitude towards risk in part due to the importance of the LEK of artisanal fishers in the Amazon basin (Silvano et al. 2008; Batista and Lima 2010; Lima and Batista 2012), that is the benchmark for fisheries decisions. Low schooling is also considered one of the determinants for the ineffectiveness of fisheries management in the region (Alencar and Maia 2011), hindering a productive dialogue between managers and fishers. In the scope of the private sector in a capitalist economy, the artisanal fisheries business model resigns artisanal fishers to be a worker without modern cultural, social and economic tools, which explains the dependence of fishers on intermediaries who finance fishing trips and receive fish for sales (Parente and Batista 2005). On the other hand, managers must know what the central themes of fishers' knowledge about the environment and resources are, avoiding that the management policy to have low effectiveness for any social or environmental objective. Inserting artisanal fishers in the alternatives of fishing and environmental policies, overcoming the obstacles for this group deal with their interests dialoguing with other stakeholders are relevant inclusion actions to the management efficiency (Haggan et al. 2002).

The extra income from other sources was also not a significant attribute on risk decisions on fishing, which was related to the fact that this additional income in the region is also uncertain and unstable. Commercial artisanal fishers from Central Amazonia can be classified as an economically insecure group (Almeida et al. 2001, 2003; Parente and Batista 2005) and particularly sensitive to changes in external conditions (Maru et al. 2014; Camacho Guerreiro et al. 2016), featuring economic vulnerability (Béné 2009). The vulnerability can either generate a willingness to risk, attitude related to periods of low gains (e.g., Eggert and Lokina, 2007). Alternatively, it can cause risk aversion, due to the trauma of previous unsuccessful experiences in critical periods (Zeelenberg et al. 2000). The fact that the extra fisheries income was not significant as a driver reveals the duality of this condition, which is enhanced by the inefficiency of the State's actions within the fishing sector. The organization of the landing and commercialization of fish is maintained until today by the "despachante", a middlemen central agent in the commercialization process in the region since the 1990s (Parente and Batista 2005), having dominion over fishers and retailers and marketers through simplified financing. In contrast, the role in the fishing activity was significant, where the fishers is more risk-averse than the skippers. It is reasonable since the skipper is usually considered the most competent by the owner (Eggert and Lokina 2007), earning more than others, but assuming the responsibilities to each trip. Skippers profile must be deeper assessed to understand their outcomes, including financial and operational decisions.

Thus, the Amazon artisanal fishers reflects universal drivers of attitude at-risk, but there also have specificities. LEK is high in the region (e.g., Begossi et al., 2019; Silvano et al., 2008), but as we did not compare individual LEK here, its effect on the attitude of the fishers remains to be detailed on priority, mainly facing the typical low fishers scholar level. Economic variables should also be included in new studies, since the level of indebtedness, ambition for gains, and family demands can affect the attitude at risk in the activity. The essentiality of fishing as a cultural value and basis of food security is emphasized in the region (Cerdeira et al. 1997; Batista et al. 1998). Nevertheless, the resource is threatened by overfishing (Bayley and Petrere Júnior 1989; Barletta et al. 2010), increased deforestation (Malhi et al. 2008; Barros et al. 2020), construction of hydroelectric plants (Stickler et al. 2013; Barletta et al. 2015) and impacts from climate change (Melack et al. 2009; Arantes et al. 2018), among other. All those threats urge societies to develop management models that consider all stakeholders' needs and risk-taking attitudes.

Our results demonstrate that understanding the fisherman's risk-taking attitude in fisheries represents an integrating source of more parsimonious strategies between profitability and conservation of fishery resources and biodiversity in the Amazon. The expertise and attitude are losing as weak policies incentives the run for the fish replicating the tragedy of the commons. The worldview and knowledge of the resource user, here represented by artisanal fishers from the Amazon, must be supported on long term policies to be an active stakeholder, including compliance and accountability of their actions, worries, and needs. Fishers may be part of a continuous dialoguing to researchers and managers as a path in the way to social justice but also the efficiency of the use and conservation of biodiversity.

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CAPÍTULO III

Capítulo 3. Concentration of fishing effort as Amazon fishing fleet response to climate anomaly

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ABSTRACT

In aquatic ecosystems impacts on fisheries resources due to recent global climate change have been highlighted, generating several initiatives to globally assess the effects of climate change on fish and continental fisheries. However, there are critical gaps in the basic information available on the threats posed by climate change and anthropogenic responses to them in tropical freshwater ecosystems and rivers with extensive floodplains. Thus the objective of this study was to investigate the effects of negative hydrological anomalies on the spatial dynamics of the commercial fishing fleet in Central Amazonia, considering changes in fishing effort, selection of target species and preference for habitats by evaluating these effects at the macro (rivers) and meso (lakes) scale. Our results show that there was a concentration of fishing effort in locations near the port of landing. In addition, we observed an intensification of fishing on the river-lacustrine species. We observed a decrease in the relative abundance of the river-lacustrine species, mainly in the environments of composite lake and terra-firme lake. Thus, we consider that negative hydrological anomalies affect the development of the river-lacustrine species, diminishing the available resources. This condition associated with intensification of fishing may cause depletion of the resource on a local scale.

Key-words: Negative hydrological anomalies - spatial dynamics - environmental heterogeneity

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Introduction

Climate impacts on fisheries resources are evidenced by fluctuations in fish abundance and distribution, and changes in migration and spawning periods (Lynch et al., 2016; Martinho et al., 2007). In continental water ecosystems, temperature changes may alter species diversity, habitat availability and fishing productivity (Cochrane et al., 2009; Ficke et al., 2007; Hunt et al., 2016). Such issues threaten global food security, especially for the most vulnerable populations (Ficke et al., 2007; O'Reilly et al., 2003; Sumaila et al., 2011), which led to initiatives to globally assess climate change effects fish and continental fisheries (e.g., Paukert et al., 2017). Nevertheless, there are critical gaps in basic available information about threats imposed by climate changes and anthropogenic responses to it in tropical freshwater ecosystems and rivers with extensive floodplains (Dudgeon et al., 2006). Amazon basin particularly, where the largest continental fish biodiversity has been reported (Albert and Reis, 2011), faces similar issues.

Precipitation is the main determinant of climate in tropical floodplains ecosystems (Fisch et al., 1998). Particularly in Amazon, climate influences the flood pulse variability, characterized by a terrestrial phase, with low water levels, and an aquatic phase, with high water levels (Junk et al., 1989). Rainfall variability on annual scale is affected by two factors. The Marine Surface Temperature (TSM) anomalous warming or cooling in the Pacific Tropical causes rainfall deficits in northern and central Amazon basin as a result of El Niño events (Marengo e Espinoza, 2016; Sorribas et al., 2016). On the other hand, the North Tropical Atlantic Oscillation (Alves et al., 2013; Marengo, 2008) is able to alter the flood pulse by stimulating prolonged droughts in Amazon region (Cavalcanti et al., 2013), as the ones registered in 1925-26, 1982-83 and 1997-98 (Marengo, 2006).

Flood pulse controls biological productivity and also the livelihoods of traditional populations (Bayley e Petrere Júnior, 1989; Castello et al., 2018), therefore, understanding climate impacts on this region is essential to guarantee the sustainability of these communities. Studies on climate change impacts on fisheries in tropical freshwater ecosystems have identified dry season as an important explanatory factor. Severe droughts would decrease allochthonous material entry into the aquatic system and reduce spawning habitat (Ficke et al., 2007). In addition, habitat complexity in the river region is also reduced by eliminating the lakes connecting channels, disconnecting them, and drying the headwaters (Elliott 2000; Hakala and Hartman 2004). In Amazon lakes, droughts decrease fish diversity and abundance (Freitas et al., 2013) and change the structure of assemblies (Röpke et al., 2017). Fabré et al (2017) tested the drought intensity effect on the fishing community size-structure in Amazon rivers, suggesting it increases the size spectrum slope of fisheries assemblages by decreasing larger fish abundance in the catches. Furthermore, in lower Amazon region fishing lakes, droughts force fishers to concentrate their efforts on accessible river environments, increasing river fishing productivity due to the reduced access to the lake environments (Pinaya et al., 2016b).

Predicted climate change scenarios in Amazon region are related to the increased frequency and intensity of El Niño South Oscillation (ENSO) or North Tropical Atlantic

Oscillation events (Espinoza et al., 2019; Tomasella et al., 2011). Changes in biological productivity, availability of aquatic habitats and intensification of fishing, and diversification of target species are expected (Cochrane et al., 2009; Musinguzi et al., 2016). Negative hydrologic anomalies are predominantly expected in the northern basin region, where fishing in river channels is intensive (Isaac et al., 2008).

The central Amazon fishing fleet (CAFF) explores the largest and most productive rivers in the basin (Batista e Petrere Junior, 2007), as well as the habitats of highly diverse floodplains, such as floodplains, and terra firme and compost lakes (Nolan et al., 2009). CAFF's annual fish production – around 30,000 tons – is landed in Manaus city, following predictable seasonal cycles driven by the river level of the river (Vallejos et al., 2013). In addition, the largest rivers, types of lakes, target species by habitat (lacustrine and river-lacustrine species), yield and fishing effort are variables that determine the spatial distribution of the fishing fleet (Batista and Petrere Junior, 2007; Nolan et al., 2009). However, fisheries response to climate changes scenarios in Amazon basin in macro (basin rivers) and meso scales (basin lakes) still needed to be investigated.

Here we aimed to identify whether the negative hydrological anomalies affect the dynamic of CAFF between rivers and floodplain habitats by examining the fleet's interannual spatial dynamics as a response to climate anomalies in Amazon. We analyzed a temporal series of multispecies fisheries landing data in central Amazon region comparing spatial dynamics in macro and meso scales in periods with and without negative hydrological anomalies. We expect a riverine fishing spatial expansion in Amazon basin and changes in target pool fish species, increasing river-lacustrine species' capture.

Material and Methods

Our study area corresponded to Amazon river basin and its main tributaries, both white (rivers: Amazonas-Solimões, Purus, Madeira and Juruá), and black water (Negro river), and its flood plains. Amazon basin river-flooded area system has about 8,500 lakes, corresponding to approximately 11% of the 62,000 km^2 of Amazonian floodplains (Hess et al., 2015; Melack, 1984). This area is among the most biodiverse ecosystems in the world, with about 2200 registered fish species (Albert and Reis, 2011). This rich environment provides the basis for high fish production and intense fishing activity (Batista et al., 2012; Batista e Petrere Junior, 2007; Goulding et al., 2018; Nolan et al., 2009) (**Erro! Fonte de referência não encontrada.**).

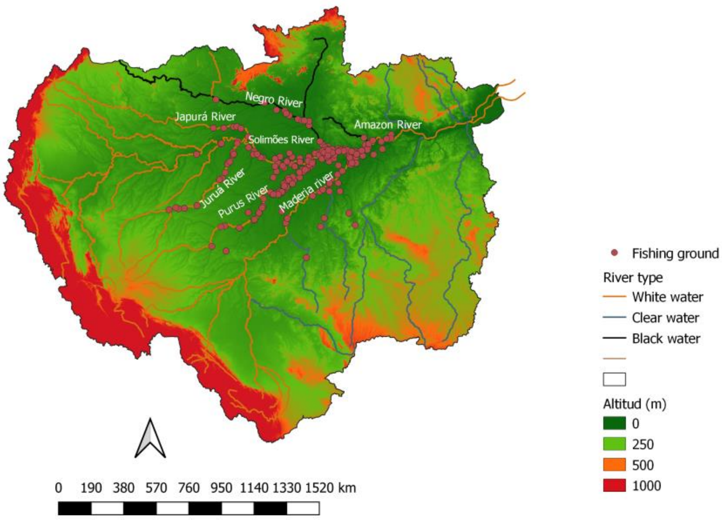

Figure 3 1. Location of the study area, highlighting the main rivers and exploited fishing grounds by the fishing fleet that lands in Manaus, in Amazon basin.

Data source and processing

We analysed an 11-year set of landing data (1994-2004) corresponding to the artisanal commercial fishing monitoring of the main Amazonian fishing fleet based in Manaus. The fleet is composed of approximately 3,000 wooden boats with engine power ranging from 20 to 60HP (Batista, 1998a), with average total length 14±3m, and ice storage capacity 8,000±5 kg. Each fishing trip is operated by an average of 8±3 fishers and lasts 13±11 days. The predominant fishing gear is purse seine (91.4%) followed by gill net (8.25%) (Batista et al., 2012). The database contemplated a total of 27,613 trips along the main Amazonian rivers (Amazonas, Solimões, Madeira, Purus, Negro, Juruá and Japurá).

Negative Hydrologic Anomaly

We obtained the river daily variation, in meters, from the National Water Agency from 1994 to 2004 from Negro river station. These data were used to calculate the river level climatology, which is the average monthly value (amv) of the level and standard deviation (s) of the river level for each month of all years, representing the expected annual variability.

To detect hydrological anomalies, we compared the river level climatology and the mean river variation for each year. An anomaly is considered to have occurred when the mean monthly level (mml) of the river has reached a value that is outside the range amv **± s** in the same month. The anomaly is said to be positive when mml> amv+**s**, and said to be negative when mml< amv-**s** (Apendice 2).We identified two periods within our data: one before the anomalies (from 1994 to 1998 - which encompasses the years when there was a negative hydrologic anomaly) and another after anomalies (from 1999 to 2001), which were used for all other analyses involving temporal comparisons.

Fishing ground environments

Fishing grounds were mapped using name of the fishing ground, river it belongs to and nearest town, present in the database. The 207 locations identified were classified into river or lake environments (Appendix 3). Negro, Madeira, Purus, Juruá, Solimões and Amazonas rivers were considered for macro scale analysis for representing 92% of fishing production. In addition, mouth, channel and creek habitats were included in river environments. For meso scale, the lakes were classified into várzea, terra-firme, and composite (Nolan et al., 2009).

Target species

To identify changes in the target resource, the captured species were identified and classified according to mobility and life strategy in lacustrine and river-lacustrine species (Barletta et al., 2010). River species represent 3% of the catch and for this reason were not considered in the analyses (Appendix 4).

Data analyses

Spatial dynamics

We measured the distance travelled by the fleet from the main landing point in Manaus city to each fishing ground by plotting the coordinates on Google Earth, in kilometres. Then, we used these data to calculate the interannual variability of the distance travelled by the fleet and the number of exploited fishing grounds. We calculated the total distance travelled for all fishing grounds and by scale, macro and meso. To assess whether the negative hydrological anomaly influenced the distance travelled by the fleet, we used the average of the total fishing distance and by scales for the two periods afore mentioned and compared them using T-student test.

The spatial analyses were visualized using the fishing effort (total of trips) by fishing grounds in the two temporal periods. We built the maps highlighting the registered locations and calculated kernel density estimates using the stat_density2d function from the kde2d package (Venables e Ripley, 2002). We highlighted the radius of the distance travelled from the landing port (Manaus).

Fishing yield (CPUE)

To evaluate the capture per unit effort (CPUE) per year, CPUE per trip for each year was calculated using the traditional approach, where CPUE is considered a value proportional to population density (Gulland, 1983). The fishing effort unit used was the effective number of fishers*days (Batista, 1998a; Petrere Jr, 1978). To increase our analyses robustness, we used the model proposed by Batista (1998) for the commercial fishing landed in Manaus (Batista e Petrere Junior, 2007; Gonçalves e Batista, 2008). We tested the following statistical model:

$CI = m + np*dp + diesel + ice + lriver + \varepsilon_{tk}$ where:

CI - capture index,

m - general average of transformed capture
lriver - river level,
np*dp – Number of fishers * number of effective fishing days,
diesel – quantity of diesel oil in liters,
ice - amount of ice in tons,
ε_{tk} - random error of deviations with normal distribution;

All variables were transformed by natural logarithm to normalize data.

The model residues were interpreted as the relative abundance by species group, lacustrines ande river-lacustrines species. The data of relative abundance were adjusted to a periodic regression model in order to verify the occurrence of the periodicity of the group of species by habitat type. Periodic regression is a useful tool to evaluate rhythms (Angelini et al., 1992) and the formula used in the calculation of the periodic regression was defined by the following equation:

$$y = a_0 + \sum_{n=1}^{2} \left(a_n \cos \frac{2n\pi x}{L} + b_n \sin \frac{2n\pi x}{L} \right) + \delta$$

where:
y= dependent variable (relative abundance)
a_n ,b_n = regression coefficients
α_0= general average
x= independent variable
L= number of years
δ= random error

Here we have adopted the name Capture Index to refer to the CPUE calculated in the proposed model. We calculated the total CI for all fishing grounds, grouped the average CI of the total by scales in two periods, and compared the two groups using T - student test.

Model to predict spatial variability

Random Forest (RF) regression trees were used to identify the factors that explain space-time patterns, using the randomForest package (Friedman et al., 2001) in R. We made two models: 1) To predict distance variability as a function of river, year, river level (m), total catch (ton), amount of ice for fish preservation (kilos), fishing effort (number of fishers*fishing days) and 2) To predict distance variability by lakes as a function of year, river level (m), catch by lake species (ton), catch by river lake species and fishing effort. RF models are flexible, built from predictive variables and combined to optimize predictive performance, accommodate continuous or categorical values, collinear variables, interactions between variables and non-linear relationships between predictive and response variables, showing strong predictive performance. These models identify the most important variables to explain the response variable using mean quadratic error - MSE. For each tree, the MSE of prediction is recorded in the test. Then, the same is done after permutation of each forecast variable. The difference between the two is then calculated as the mean over all trees and normalized by the standard deviation of the differences. The larger the difference, the more important the variable. And to demonstrate the effect of the most important variables detected in the RF model on the response variable, we used the partial dependency plot, with the pdp package (Friedman 2001).

All tests were performed considering 5% significance level. All analyses were performed in R (R Development Core Team, 2017) statistical platform.

Results

Fleet displacement interannual variability

The fleet covered an average of 350km a year. However, we observed that in 1995, 1996 and 1997 average distance increased. After this period, there was a general reduction in the distances travelled, with significant difference between those before and after 1998 ($p<0.05$) (**Erro! Fonte de referência não encontrada.** 3.2). A statistically significant decrease in the number of exploited fishing grounds was also detected after 1998.

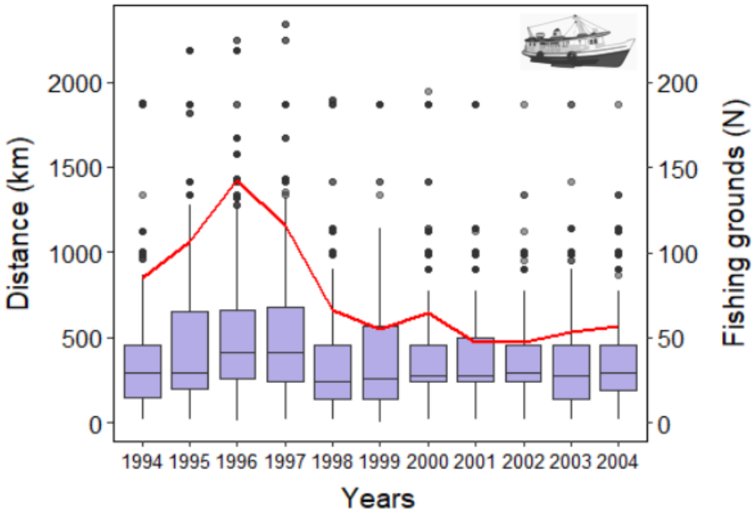

Figure 3 2. Box plot of the total distance travelled by the fleet over years and number of fishing grounds exploited by the fleet per year. The red line represents the number of fishing grounds exploited.

In macro scale, the fleet travels longer distances to Juruá river, followed by Purus and Solimões rivers. However, there is a tendency to decrease distances travelled after 1999 to Juruá river, and after 1997, to Purus river, with low variation to the others (Figure 3.3A). Nevertheless, only the average distance traveled to the Purus River showed significant difference. On the other hand, although meso scale presented a tendency to decrease distances for the three types of lakes, only trips to terra-firme lakes after 1997 showed a significant difference (Figure 3.3B).

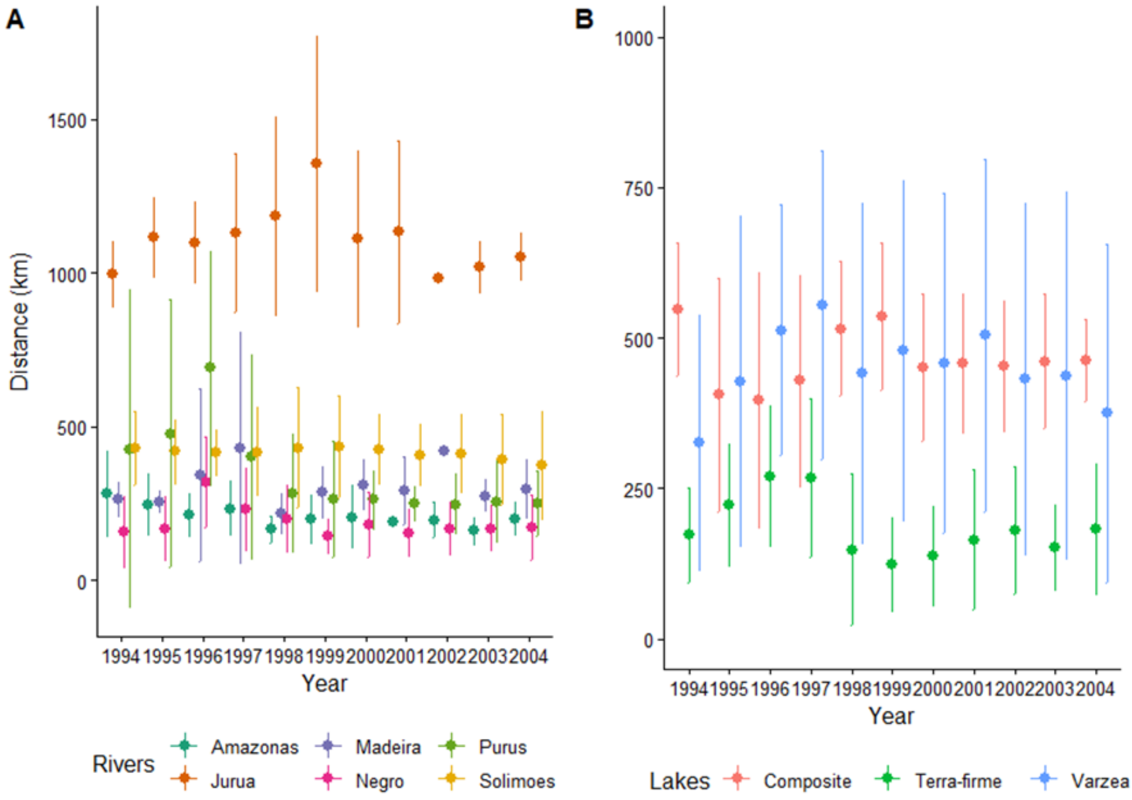

Figure 3 3. Interannual variability of the total distance travelled by the fleet per river (macro scale) (**A**) and per lakes (meso scale) (**B**)

Interannual spatial distribution of the fishing fleet

The fleet presented spatial distribution variability over the 11-year time series. The highest concentration of fishing trips was observed in Solimões-Amazonas and Purus rivers. We also observed a decrease in fishing grounds exploitation above 1500 km far from Manaus city since 1999, changing the spatial dynamics and concentrating the explotation in fishing grounds near the port (**Erro! Fonte de referência não encontrada.**3.4).

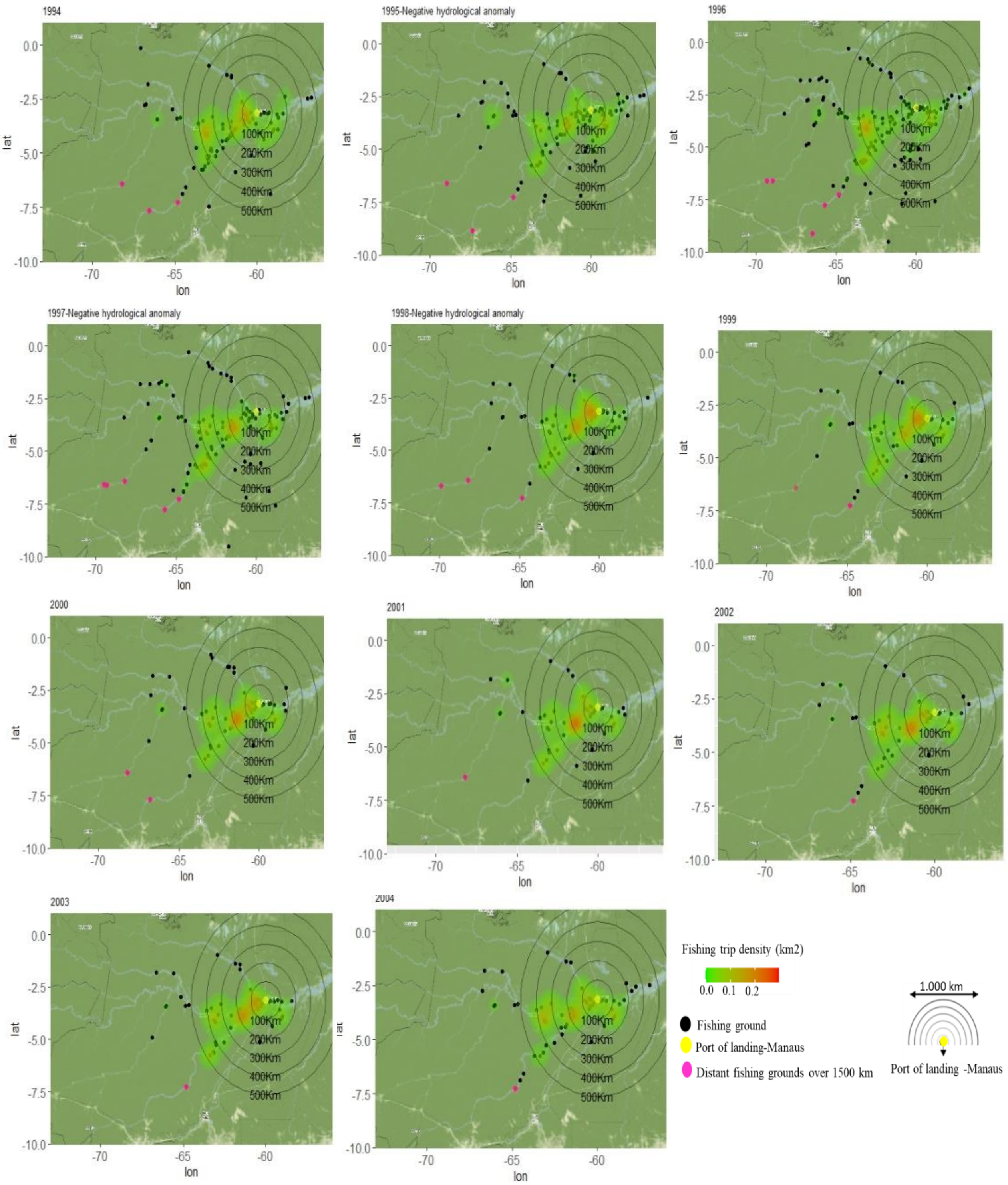

Figure 3 4. Density of fishing grounds heat map over 11 years. Highlighting the port landing in Manaus, fishing grounds located more than 1500km from the port and the radius of the distance.

The average distance traveled by the fleet to river environments was 276 km, with high variability for distance above 350 km before and after the period of negative anomalies (Figure 3.5A). However, more than 70% of the trips are made below 350km, with an increase in the frequency of trips after the negative anomalies (Figure 3.5B).

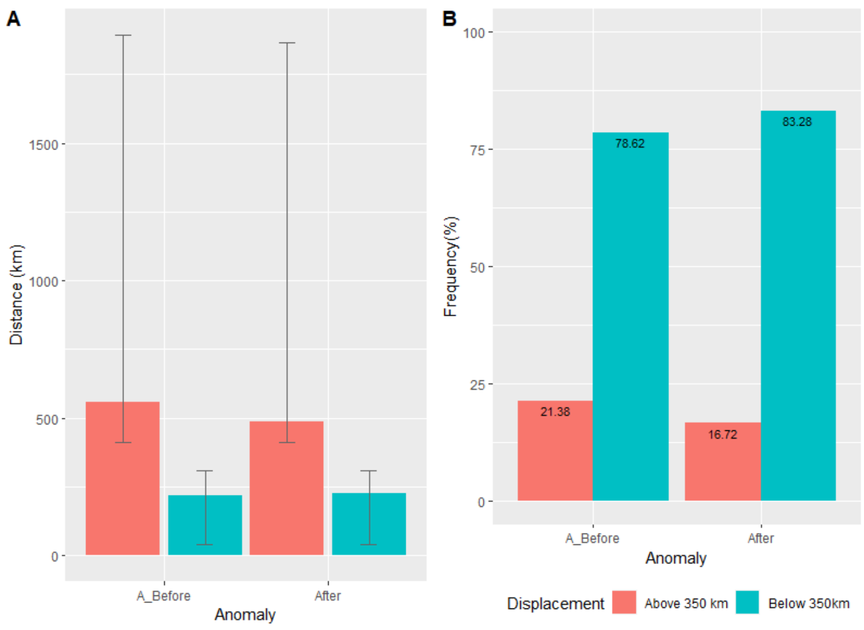

Figure 3 5. (A) Variability of distances covered by the fleet before and after negative hydrological anomalies in river environments. (B) Frequency of trips made before and after negative anomalies differentiating trips made below and above 350 km.

For lake environments, fleet covered an average of 410km, with high variability before and after negative anomalies, with a decrease in the distances covered after anomalies (Figure 3.6A). We observed an equivalent frequency of trips to fishing grounds above and below 350km in the period that there were anomalies, and after anomalies an increase of trips to more distant fishing grounds (Figure 3.6B)

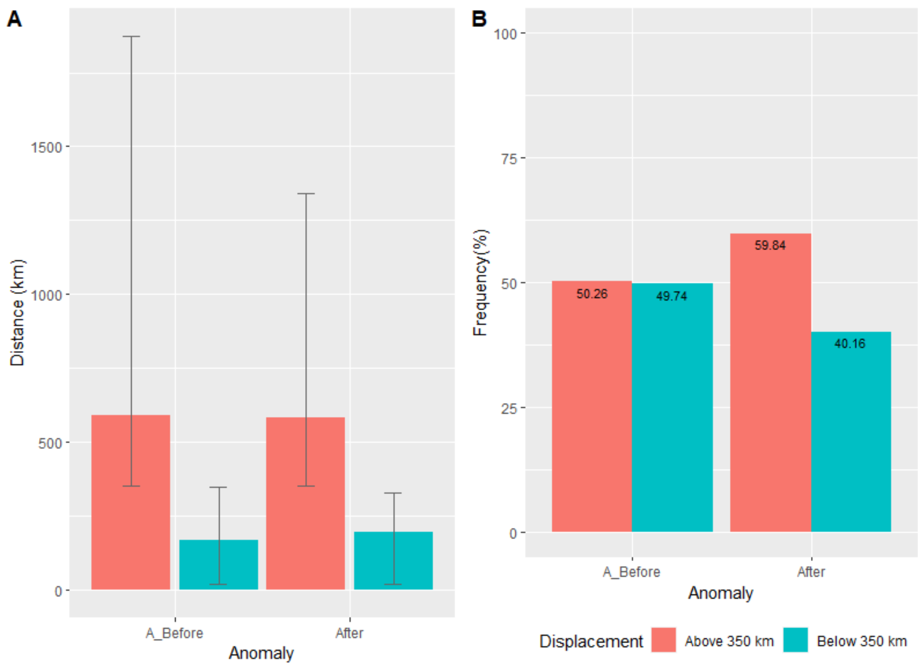

Figure 3 6. (A) Variability of distances covered by the fleet before and after negative hydrological anomalies in lake environments; (B) Frequency of trips made before and after negative anomalies differentiating trips made below and above 350 km.

Interannual Variability of Catch Index

In the proposed model to evaluate the general catch index the effort variables, the product between the number of fishers and fishing days and the river level were not significant (Table 1). And the determination coefficient ($r^2=0.12$) and presenting randomly distributed residues. The result of the model was:

$$CI = 1.27+0.01Ln(effort)+0.23Ln(diesel)+0.64Ln(ice)-0.03L\ (River\ level)+\varepsilon_{tk}$$

Table 3. 1. Estimated coefficients for each variable and the level of significance in the capture index model.

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-5.65	0.32	-17.70	<2e-16 ***
Effort*	0.01	0.01	0.58	0.56
Diesel	0.23	0.03	8.60	<2e-16 ***
Ice	0.64	0.04	16.79	<2e-16 ***
River level (m)	-0.03	0.02	-1.25	0.21

Effort= numbers fishers*days fishing

We observed a statistically significant decrease in days fishing and relative abundance and increased number of trips after drought anomaly ($p<0.05$) (Figure 3.7).

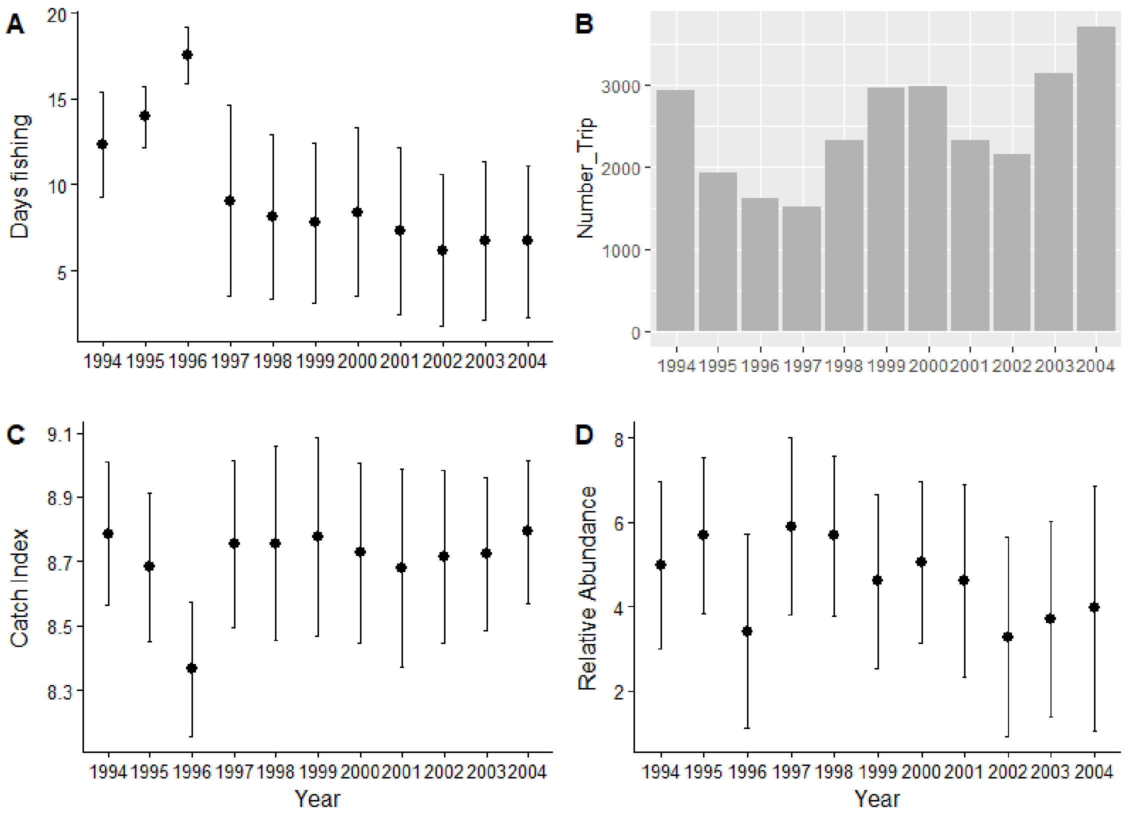

Figure 3 7. Days fishing (A), Number of fishers (B), Number of trips (C) and Relative Abundance (D) time series of the Fishing Fleet.

On the macro scale, the model proposed to evaluate catch index, effort variables, the product between number of fishers and fishing days and river level were not significant (Table 2). And the determination coefficient ($r^2=0.14$) and presenting randomly distributed residues. The result of the model was:

$$CI = 1.26 - 0.03Ln(effort) + 0.20Ln(diesel) + 0.74Ln(ice) - 0.02L\ (River\ level) + \varepsilon_{tk}$$

Table 3. 2- Estimated coefficients for each variable and the level of significance in the capture index model.

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-6.21	0.48	-12.89	< 2e-16 ***
Effort	-0.03	0.02	-1.53	0.13
Diesel	0.20	0.04	4.70	2.78e-06 ***
Ice	0.74	0.06	13.40	< 2e-16 ***
River level	-0.02	0.03	-0.74	0.46
Effort=number fishers*days fishing				

We observe a statistically significant decrease in Relative Abundance after drought anomaly only for the Juruá River ($p<0.05$). And we observe a statistically significant decrease in days fishing after drought anomaly and increased number of trips ($p<0.05$) (Figure 3.8).

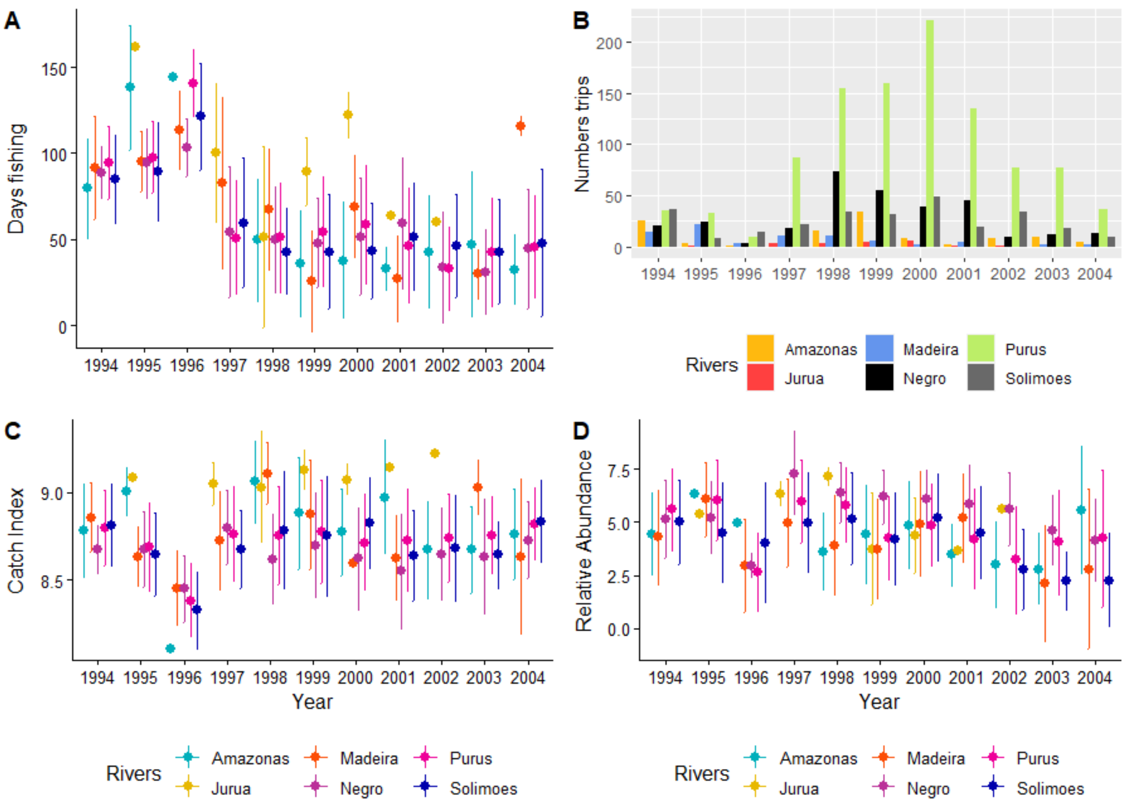

Figure 3 8. Days fishing (A), Numbers fishers (B), Numbers trips (C) and Relative Abundance (D) time series of the Fishing Fleet in the rivers.

In the meso scale, in the proposed model to evaluate the catch index by lakes only at the river level variable was not significant (Table 3.3). And the determination coefficient ($r^2=0.12$) and presenting randomly distributed residues. The result of the model was:

$$CI = 1.28 - 0.04Ln(effort) + 0.26Ln(diesel) + 0.54Ln(ice) - 0.02L\ (River\ level) + \varepsilon_{tk}$$

Table 3. 3. Estimated coefficients for each variable and the level of significance in the capture index

model.

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-5.15	0.43	-12.05	< 2e-16 ***
Effort	0.04	0.02	2.16	0.0308 *
Diesel	0.26	0.04	7.35	2.88e-13 ***
Ice	0.54	0.05	10.45	< 2e-16 ***
River level	-0.02	0.03	-0.72	0.4719

Effort=numbers fishers*days fishing

We observed a statistically significant decrease in the relative abundance after drought anomaly for all types of lakes and days fishing ($p<0.05$) (Figure 3.9).

Figure 3 9. Days fishing (A), Numbers fishers (B), Numbers trips (C) and Relative Abundance (D) time series of the Fishing Fleet in the lakes.

Factors influencing the variability of the distance traveled by the fleet

On macro scale, the rivers are the variables most important to explain the variability of the distance travelled by the fleet (3.12A). This model explains 34% the variability. While on meso scale, the level river is most important and it's model explaining 33% of the variability (Figure 3.12B).

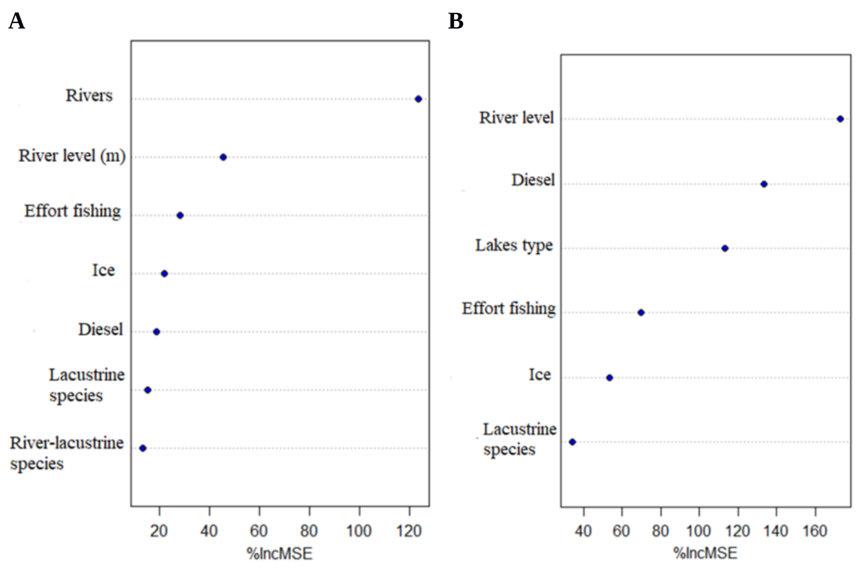

Figure 3.10.Variables important to explain the interannual variability of the distance traveled by river (A) and lakes (B).

In the partial dependence of the model, we observed that river level influences the displacement behavior differently in the two scales. On macro scale, only when river level exceeds 25m the fleet moves to more distant fishing grounds (Figure 3.13 A). On meso scale, the fleet depends on higher river levels to access the most distant fishing grounds (Figure 3.13B).

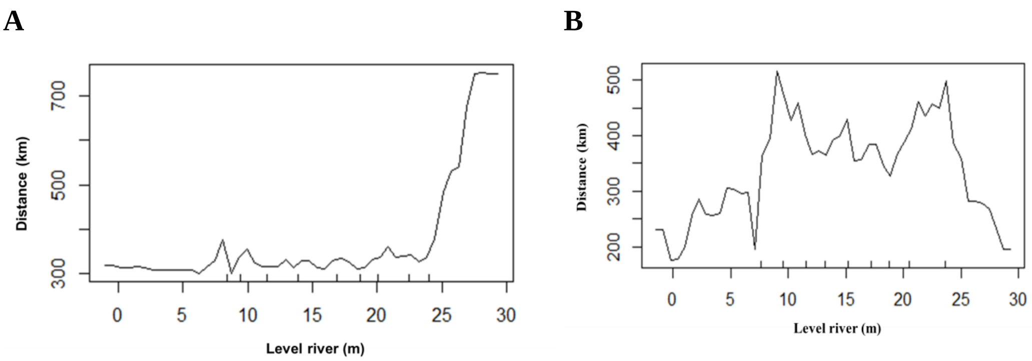

Figure 3. 11. Plots of partial dependence showing the influence of important explanatory variables, level river, on the interannual variability of the distance traveled by the fleet per river(A) and lakes (B).

Discussion

The effect of negative hydrological anomalies on the spatial dynamics of CAFF promoted different responses by scale. On macro scale, we observed that in 1995, 1996 and 1997 the fleet exploited more distant fishing grounds, mainly Purus and Juruá rivers. However, since 1998, there has been an intensification of effort in the closest fishing grounds, decreasing the number of exploited locations. On the same scale, there was a significant increase in effort in 1999, particularly for Terra-firme and Varzea lakes. In general, the fleet traveled distances up to 1800 km, mainly to Purus and Juruá rivers although 83% of trips were made on average within a radius of 350 km. Whereas the negative hydrological anomaly did not promote the maximum transformation state of fishing dynamics in central Amazo, coupled with the intensification of fishing it may have affected the relative abundance of rivers-lacutrine species that have their life cycles entirely associated with the flood pulse.

The large Amazon rivers have distinct physical and environmental characteristics that reflect different levels of accessibility and primary productivity, resulting in specific exploitation conditions for each (Junk et al., 2007; Petrere Jr., 1983; Welcomme, 2002). These conditions allow the commercial fishing fleet of Manaus to explore several fishing grounds up to 1700 km in search of the best yields, such as Purus and Juruá rivers. This behavior of going long distances has been maintained since the 70's (Batista, 1998b; Petrere Jr., 1983). However, we observed a retraction of the fleet radius of 600km (Batista, 1998b), 500km (Petrere Jr., 1983) and our data, 350km. This decrease is evident as in the years after the negative anomaly, distance traveled to Purus river decreased and did not return to previous exploration state. It is considered that intense fishing in consecutive periods associated with the effects of the negative anomaly affected the target species fishing stocks and the quality of their habitats, leading the fleet to abandon these fishing grounds. As observed in Ganga river (India), the reduction of total annual precipitation and its seasonal variation over the years affected the reproduction of carp, thus its recruitment promoted the decrease in fishing productivity (Vass et al., 2009).

In this scenario, the river-lacustrine species become the fishing target, because their mobility in years with drought anomalies is restricted to fluvial environments. This affects migratory cycles on regional scale, reducing upstream dispersion during the ebb, and downstream reproduction during the flood, when the fish seek mixed water environments (white with black or clear water) to spawn. These migratory movements depend fundamentally on the predictable pace of the flood pulse (Barletta et al., 2010) and are reflected in the fishery productivity that traditionally lands in Manaus (Batista, 2012). These species, represented in the catches by Prochilodontidae family, have their reproductive cycle closely associated with the seasonal flood cycles, a fact that qualifies them with strategic r2 species. As they have a short life cycle (6 years of longevity on average) and a high growth rate and high mortality, they are considered special species of high rotation (Winemiller & Jepsen, 1998; Bayley et al., 2018). However, this relationship with seasonal dynamics makes them vulnerable to the expected climate changes in Amazon (Marengo et al., 2012; IPCC, 2014; Pinaya et al., 2016). Thus, we understand that the negative hidrologic anomalies that promoted the increase in fishing production of river-lacustrine species due to the difficulty of access to lake habitats to complete your life cycles may multiply the vulnerability of the traditional jaraquis and curimatãs fishing of Central Amazon.

Our results also reveal a tendency to reduction in relative abundance of lacustrine species in all fishing environments, particularly in terra-firme lakes. This can be explained by the decrease in diversity and abundance of fish species due to extremes of drought (Freitas et al., 2013). As these species are confined in lakes isolated from major rivers (Junk et al., 1989; Tomasella et al., 2011) there is increased natural mortality due to episodes of hypoxia that are exacerbated by higher temperatures that control evaporation and precipitation (Tomasella et al., 2013). Studies in one of Africa's most biodiverse lakes, Lake Tanganyika, have shown that increasing lake temperature decreases primary production and, consequently, the production of pelagic fish promoted and reflected in the decreased fishing productivity of these environments (Cohen et al., 2016; O'Reilly et al., 2003).

Our results identified decreases in distance traveled, amount of fishing grounds exploited, and days of fishing trips, and increase in the number of trips as fleet responses to the climatic anomaly, which indicates intensification of fishing in productive fishing grounds traditionally known closer to the port. Considering the limitation of access to fishing grounds and target fishery resources, the decision to choose fishing grounds known for their productivity and closer to the port reflects the higher probability of making profit (Nguyen, 2010). This fleet strategy to intensify effort traditionally productive locations reflects the aversion to loss of fishers in situations of uncertainty (Kahneman and Tversky, 1979) enhanced by the changes introduced by the anomalies. Moreover, we observed a decrease in river-lacustrine species in terra-firme and compound lakes. Within this, we can infer that the negative anomalies affect these species' reproductive and migratory cycles, which associated with the intensification of fishing, can promote the decline of stock.

Although negative anomalies and environmental heterogeneity partly explain the accessibility to fishing grounds, other environmental and socioeconomic factors can be equally important and complementary. For example, economic aspects are common controls of artisanal fisheries with high dependency on catch rates (Camargo and Petrere, 2001). In our study region fishing operations are highly dependent on the cost of fuel and ice. The direct cost to the captain reflects on the fish price and consequently the profitability of the fishery (Batista et al., 2012). The limitation on the use of fishing grounds by the commercial fleet is established by the Community Fisheries Agreements. Studies demonstrate conflicts among fishers related to the loss of traditional fishing grounds established by the Fisheries Agreements, legitimized by the environmental agency Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis - IBAMA. There are conflicts for the competition between subsistence and commercial fishers, between subsistence and sport fishers, and between commercial fishers and riverine communities (Oviedo et al., 2015; Sobreiro, 2015). However, there is a lack of studies demonstrating the impact of changing the use form of commercial fishers, which can lead to a conflicting relationship between riverine and commercial fishers outside the community.

Our results indicate that the negative anomaly did not alter the maximum state of spatial transformation of the commercial fishing fleet in Amazon. However, the intensification of river environment exploitation near Manaus focusing on riverine-lacustrine species as target species to compensate for the economic loss associated with the value of lacustrine species, which did not have access, due to negative anomaly, promoted an increase in the frequency of trips and possible depletion of the resource on a local scale. Thus, if intensified by the frequency of El Niño anomalous events, the negative anomalies are likely to impact the maintenance of fish populations, which may cause great impacts on fish life cycles and, consequently, on the food security of fishermen. Due to the characteristic spatial and ecological heterogeneity of Amazon environment, it is necessary to incorporate analyses that consider the spatial scale in fisheries management proposals, in addition to demonstrating the need and usefulness of long-term fisheries monitoring.

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Considerações Finais

Nosso estudo trouxe contribuições valiosas para o contexto amazônico demonstrando a importância do CEL, atitude sob risco e dinâmica espacial dos pescadores. Revelamos que o Conhecimento ecológico dos pescadores artesanais da Amazônia Central sobre os aspectos bio-ecológicos de espécies de importante valor econômico e cultural representa uma fonte de informação potencial e fiável que pode ser utilizada para apoiar estratégias de conservação e gestão, particularmente, em locais de difícil acesso e com escassez de recursos humanos e financeiros para coletar e desenvolver estudos sobre parâmetros bio-ecológicos dos peixes. No entanto, pesquisadores e gestores devem considerar a categoria do pescador (urbano e rural), assim como, definir os aspectos biológicos e ecológicos por espécie e por estágio do ciclo de vida.

Nossos resultados também mostraram que os pescadores artesanais da Amazônia são avessos ao risco na escolha do pesqueiro, sentindo mais a dor das perdas do que a satisfação dos ganhos. O tempo de experiência na pesca e a função na atividade influenciaram a tomada de decisão. No entanto, a vulnerabilidade sócio-econômica em que vivem esses pescadores demonstra a necessidade de incorporar mais variáveis sociais e econômicas no modelo. Assim, a compreensão da atitude de risco do pescador na pesca representa uma fonte integradora de estratégias mais moderadas entre rentabilidade e conservação dos recursos pesqueiros e da biodiversidade na Amazônia.

Por fim, constatamos um cenário estável da dinâmica espacial de explotação dos recursos pesqueiros pela frota comercial de Manaus após anomalias hidrológicas negativas. No entanto, observamos um efeito sinérgico da pesca e anomalias hidrológicas negativas sobre os recursos pesqueiros promovendo a concentração do esforço pesqueiro em locais próximos ao principal porto de desembarque (Manaus) e intensificação da pesca sobre as espécies rio-lacustres. Nossos resultados nos alertam sobre a importância do monitoramento pesqueiro contínuo, principalmente para manutenção da qualidade dos estoques das espécies rio-lacustres quanto para segurança alimentar de grande parte da população do Amazonas, que depende diretamente da pesca para sobrevivência.

Quadro Resumo

<table>
<tr><th colspan="2">Capítulo 1. Assessing biological traits of Amazonian high-value fishes through Local Ecological Knowledge of urban and rural fishers.</th></tr>
<tr><th>Principais Resultados</th><th>Contribuições para Gestão Pesqueira</th></tr>
<tr><td>• Diferença de estimativas de peso do pirarucu e comprimento do tambaqui entre pescadores e dados da literatura disponível.</td><td rowspan="4">✓ Os dados de peso e comprimento são úteis para estimar a situação dos estoques pesqueiros e caracterizar a dinâmica das populações;
✓ A capacidade dos pescadores de reconhecer os recursos pesqueiros na fase reprodutiva tem implicações para o recrutamento das espécies. Como as taxas anuais de recrutamento dependem do número de fêmeas "desovando", além da fertilidade individual dessas fêmeas (Csirke, 1980) e de indivíduos maiores e mais pesados, elas tendem a ser mais férteis (Velasco et al., 1990) e Kjesbu et al. (1991). As medidas de manejo podem ter como objetivo evitar que os pescadores pesquem pirarucu com coloração mais esbranquiçada, jaraqui e tambaquis com a barriga mais protuberante.
✓ A biologia e o comportamento alimentar de garças e cobras são pouco conhecidos na Amazônia. Assim, o conhecimento dos pescadores pode ser um indicador útil do papel ecológico potencial desses predadores na manutenção das cadeias tróficas aquáticas.</td></tr>
<tr><td>• Informações sobre a coloração do pirarucu relacionada ao dimorfismo sexual foi diferente entre pescador e literatura. E sobre tambaqui e jaraqui estavam de acordo com a literatura.</td></tr>
<tr><td>• Informações sobre dieta, predação e uso de habitats estavam de acordo com o encontrado na literatura disponível.</td></tr>
<tr><td>• Os pescadores rurais informaram que garças e cobras são predadores do piraruru, tambaqui e jaraqui na fase jovem. Dados não encontrados na literatura disponível.</td></tr>
<tr><th colspan="2">Capítulo 2. Decision-making on fishing location choices: Are Amazonian artisanal fishers risk lovers?</th></tr>
<tr><td>• Os pescadores são avessos ao risco na escolha do pesqueiro, sentindo mais a dor da perda que a satisfação do ganho.</td><td rowspan="3">✓ Como os pescadores são avessos ao risco, limitar o tamanho mínimo do pescado capturado e proibir a pesca em períodos reprodutivos (regulamentação tradicional no Estado), em geral refletem perda financeira ao pescador, logo há grande probabilidade de descumprimento das normas.
✓ O conhecimento empírico sobre as espécies e as estratégias e táticas de pesca estão incorporadas na prática pesqueira atreladas a demanda do mercado proporciona a pressão sobre os estoques das espécies rio-lacustres, como jaraqui e curimatã.
✓ Consequentemente, a gestão pesqueira</td></tr>
<tr><td>• O conhecimento dos pescadores sobre as espécies, habitats e o pulso de inundação é determinante na construção cognitiva para tomada de decisão de onde ir pescar.</td></tr>
<tr><td>• Tempo de experiência na pesca e</td></tr>
</table>

<table>
<tr><td>função da pesca (pescador e encarregado) influenciam na atitude sob risco (aversão a perda).</td><td>na bacia Amazônia Central deve ter como objetivo:
1. Aumentar a fiscalização nos sistemas de co-gestão;
2. Distribuir o esforço de pesca entre mais espécies de peixe.</td></tr>
<tr><td colspan="2">**Capítulo 3. Concentration of fishing effort as Amazon fishing fleet response to climate anomaly.**</td></tr>
<tr><td>• Diminuição da distância percorrida pela frota após anos com anomalia negativa.</td><td rowspan="6">✓ Implementar e manter o monitoramento do recurso pesqueiro (dados espaciais e de produção) para elaborar regulamentos fundamentados em dados consistentes sobre os recursos pesqueiros a longo prazo.
✓ Monitoramento socioeconômico dos pescadores (pescador, encarregado e proprietário da embarcação) que compõem a frota comercial.
✓ Monitoramento conjunto do preço do combustível, gelo, pescado e dados hidrológicos.</td></tr>
<tr><td>• Diminuição do número de pesqueiros explotados após anos com anomalia negativa..</td></tr>
<tr><td>• Diminuição dos dias de pesca após anos com anomalia negativa..</td></tr>
<tr><td>• Aumento do número de viagens, na escala macro, no rio Purus e, na escala meso, lagos de terra-firme após anos com anomalia negativa.</td></tr>
<tr><td>• Na escala macro, os rios e o nível do rio foram as mais importantes para explicar a variabilidade da distância percorrida.</td></tr>
<tr><td>• Na escala meso, o nível do rio foi a variável mais importante para explicar a variabilidade da distância percorrida.</td></tr>
</table>

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Apêndices

Apêndice 1. Formulário de entrevista realizada com os pescadores do porto de desembarque de Manaus, sobre a decisão de onde ir pescar.

ENTREVISTA COM PESCADORES COMERCIAIS DE MANAUS SOBRE TOMADA DE DECISÃO

DATA: ________________________ Id. Entrevista.:______________

Nome ou apelido:____________________

1. FATORES SOCIOCULTURAIS DO PESCADOR

- Idade: Tempo de experiência na pesca na região:
- Escolaridade:
  - Ensino fundamental INCOMPLETO/COMPLETO
  - Ensino médio INCOMPLETO/ COMPLETO
  - Ensino superior / Sem instrução
- Você tem outra fonte de renda? ( ) sim ( ) não
  APOSENTADORIA / AGRICULTURA / SALÁRIO / COMÉRCIO / outro:
- Quais informações você usa/precisa para escolher o pesqueiro?

NÍVEL do rio	ACESSO ao pesqueiro	Presença de CARDUMES	CHUVAS e ventania	PARENTES próximos-residentes nos pesqueiros	Não usa NENHUM

- De onde/como você sabe isso?
  - Experiência de vida
  - Informações dos colegas no porto
  - Informações da Colônia de Pescadores
  - Informações de parentes/amigos nas comunidades próximas aos pesqueiros
  - Informações de sites
- Essa troca de informações acontece por meio de:

Em PESCARIAS	Telefone celular com pescador das comunidades	CONVERSA com PARENTES	Colônia de Pescadores	na DIVERSÃO	em CASA

- O que o lucro na pesca para o senhor?
- O que é risco na pesca ?
- O senhor avalia o risco na hora de decidir onde pesca? ( ) Sim ( ) Não
- Se sim, como avalia?

2. TOMADA DE DECISÃO -Aspecto Cognitivo

- Eu só pesco nos pesqueiros mais próximos do porto, durante todo ano porque é certeza trazer peixe, independente do lucro que terei. (aversão ao risco - Disponibilidade)
- Eu só pesco nos pesqueiros mais próximos do porto, na estação seca e vazante porque é certeza trazer peixe e terei muito lucro (aversão ao risco - ancoragem)
- Eu saio sem previsão de ter ou não lucro. (neutro ao risco –ancoragem, nesse caso probabilidade de pescar pelo menos para comer)
- Eu vou pescar em pesqueiros distantes porque é certeza que terei lucro alto (propensão ao risco - representatividade)
- Quando a estação chuvosa começa atrasada é sinal de safra ruim, por isso só vou pescar nos pesqueiros que tenho amigos/parentes em comunidades próximas (aversão ao risco – representatividade e disponibilidade)
- Lagos de terra firme tem peixe durante o ano todo e é onde sempre tenho lucro.(aversão ao risco–ancoragem e representatividade)
- Pesco em todo tipo de lago porque pesco de acordo com a espécie da época e por isso tenho lucro. (propensão ao risco - disponibilidade)
- Eu costumo ir pescar em novos pesqueiros durante a enchente porque sempre tem lucro. (propensão ao risco- representatividade e disponibilidade)
- Condições de mercado determinam a escolha do pesqueiro (neutro ao risco – ancoragem)

Para esses itens será usado a escala likert

Concorda totalmente	Concorda mais-menos	Concorda um pouco	Indiferente	Discorda um pouco	Discorda mais-menos	Discorda totalmente
-3	-2	-1	0	1	2	3

3. TOMADA DE DECISÃO - Relação perda e ganhos. Assinalar somente uma alternativa em cada situação.

O QUE PREFERES AO IR PESCAR?

- **Efeito certeza**

Você precisa decidir para qual pesqueiro vai hoje, mas você tem duas opções:	
Opção 1 80% de ganhar R$ 4.000,00 20% não ganhar nada R$ 0,00	**Opção 2** 100% de ganhar R$ 3.000,00
Opção 1 20% de ganhar R$ 4.000,00 80% de não ganhar nada	**Opção 2** 25% de ganhar R$ 3.000,00 75% não ganhar nada

- **Escolha entre diferentes probabilidades (dentro do efeito certeza)**

Opção 1 45% de ganhar R$ 6.000,00 55% de não ganhar nada	**Opção 2** 90% de ganhar R$ 3.000,00 10% de não ganhar nada

- **Efeito reflexão**

Opção 1 80% de perder R$ 4.000,00 20% de não ganhar nada	**Opção 2** 100% de perder R$ 3.000,00
Opção 1 80% de perder R$ 4.000,00 20% de não ganhar nada	**Opção 2** 25% de perder R$ 3.000,00 75% de perder tudo

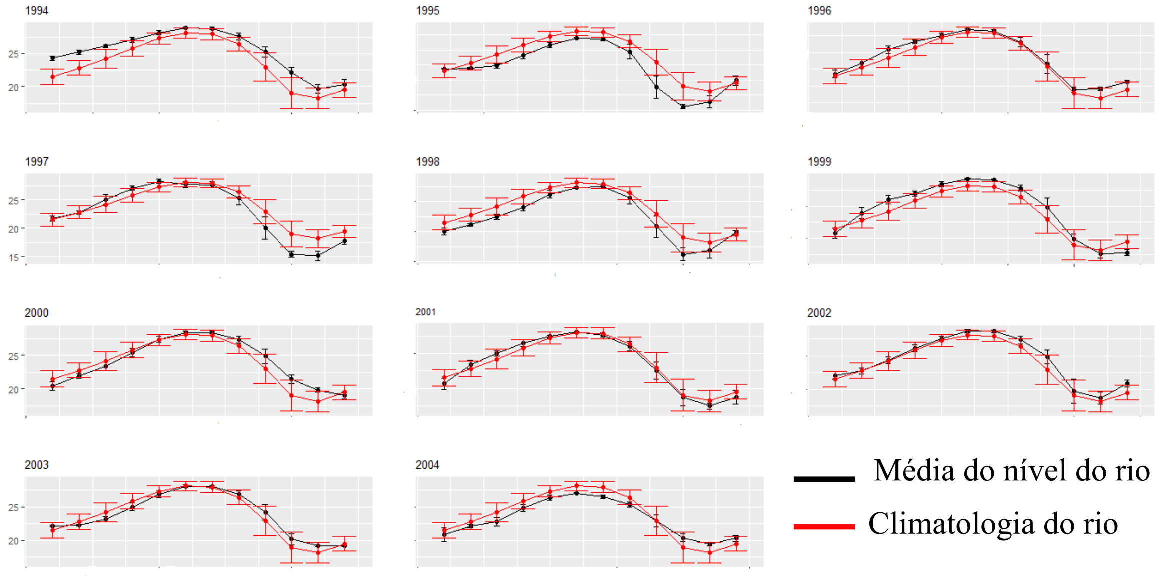
- **Alteração na riqueza**

Opção 1 50% de ganhar R$ 1.000,0	**Opção 2** 100% de ganhar R$ 500,00
Opção 1 50% de perder R$ -1.000,00	**Opção 2** 100% de perder R$ - 500,00

- **Função Valor**

Opção 1 25% de ganhar R$ 6.000,00	**Opção 2** 25% de ganhar R$ 4.000,00 25% de ganhar R$2.000,00 50% de não ganhar nada
Opção 1 25% de perder R$ 6.000,00	**Opção 2** 25% de perder R$ 4.000,00 25% de perder R$2.000,00 50% de não ganhar nada

Apêndice 2. Variação do nível do rio, identificando as anomalias hidrológicas negativas nos anos de 1995, 1997 e 1998.



Apêndice 3.Localização dos pesqueiros explotados pela frota comercial de Manaus.

RIO	Área (km2 × 1000) (Hess et. al.2015)	Lago composto			Lago de várzea			Lago de terra -firme		
Juruá	189				lago Águia	-6.55	-69.48	lago Tres Bocas	-6.61	-69.31
					lago Uniao	-4.47	-66.54	lago Araçá	-6.59	-68.96
					lago Araoari	-3.82	-66.26	lago Andira	-3.96	-66.39
					lago Ipiranga	-3.26	-66.08			
					lago Boa Sorte	-2.75	-65.83			
Madeira	1317.4	lago px_Canuma	-5.58	-59.74	lago das pupunhas	-7.46	-62.95	lago Atininga	-5.60	-60.94
		lago em frenteNovoAripuanã	-5.12	-60.39	lago das 3 casas	-7.19	-62.86	lago Mandi	-4.59	-59.88
		lago Moura	-5.09	-59.85	lago_entreapui_madeira	-7.17	-60.67	lago Abacaxis	-3.91	-58.77
		lago madeirinha	-4.04	-59.83	lago px_Manicoré	-5.86	-61.35	lago Araçá	-3.60	-58.80
		lago Canuma	-4.02	-59.09	lago Monte Alegre	-5.58	-60.37			
		lago Três bocas	-3.92	-59.14	lago Araçazinho	-5.19	-60.37			
		lago px_Maues	-3.40	-57.73	lago Sampaio	-3.86	-59.17			
Negro	721.5	lago Aiparuça	-2.97	-60.62	lago Sapucaia	-1.51	-61.58	lago Bim	-3.13	-60.42
		lago pxBarcelos	-1.09	-62.74	lago Arara	-1.46	-61.65	lago Acajutuba	-3.09	-60.47
		lago Jauari	-0.33	-64.22	lago Caires	-1.31	-62.23	lago Santa Maria	-2.94	-60.46
					lago Saracura	-0.81	-63.01	lago Castanheira	-2.82	-60.76
					lago Moreira	-0.76	-63.50			
Purus	368.2	lago Arima	-5.79	-63.71	lago jacarezinho	-6.77	-63.18	lago São José	-7.75	-65.70
		lago Guajarazinha	-5.74	-63.29	lago px_Canutama	-6.55	-64.35	lago Sacado	-7.69	-66.80
		Lago Jari	-5.13	-62.55	lago jamari	-6.02	-64.26	lago Samaura	-7.64	-66.55
		lago Itaboca	-4.80	-62.80	lago px_Tapaua	-5.77	-63.40	lago Toari	-6.91	-64.54
		lago Tapuru	-4.30	-61.81	lago Itatiba	-5.68	-63.45	lago Madadura	-6.86	-64.54
					lago Maguari	-5.67	-63.86	lago Babona	-6.83	-65.17
					lago Tauari Grande	-5.64	-63.84	lago Jacaré	-5.76	-63.69
					lago Boa Fé	-5.63	-63.13	lago Bacuri	-4.76	-63.69
					lago Taua Mirin	-5.44	-62.97	lago Aruma	-4.76	-62.12
					lago Pupunha	-5.32	-62.89	lago paricatuba	-4.42	-61.90
					lago Abufari	-5.27	-63.03	lago Caviana	-4.32	-61.83
					lago Tambaquizinho	-5.14	-62.95	lago Ipiranga	-4.28	-61.67
					lago Araçá	-5.08	-63.01	lago tigre	-4.19	-61.58
					lago Apauini	-5.04	-62.94	lago Surara	-4.15	-61.53
					lago Pereira	-4.99	-62.65			
					lago Genipapo primeiro	-4.92	-62.47			
					lago Campina	-4.92	-62.76			
					lago SupiáGrande	-4.89	-62.77			
					lago Beaba	-4.85	-62.84			
					lago Caapiranga	-4.72	-62.55			
					lago Aiapua	-4.45	-62.15			
					lago Aruanã	-4.28	-61.81			
					lago Taboca	-4.24	-61.70			
					lago Ubim	-3.98	-61.45			
Solimões -Amazonas	20700 (Sippel et. al. 1998)	lago Amatari	-3.27	-58.85	lago Muritinga	-3.39	-59.18	lago do pantaleão	-3.59	-59.16
		lago Arrozal	-3.12	-58.11	lago Tracajá	-3.34	-59.21	lago Moura	-3.47	-58.38
		lago puraquequara	-3.04	-59.82	lago jacarezinho	-3.27	-59.21	lago Apipica	-3.35	-59.29
		lago Lima	-4.40	-63.49	lago Chibui	-3.22	-59.83	lago andira	-3.08	-57.22
		lago Araua	-4.10	-63.59	lago do Rei	-3.15	-59.72	lago saraca	-2.83	-58.24
		lago Taracua	-3.68	-62.10	lago Marimba	-3.13	-59.62	lago Mamia	-4.17	-63.04
		lago Igaraça	-3.42	-60.07	lago Terra Nova	-3.08	-59.73	lago Beruri	-3.85	-61.33
		lago Tefé	-3.41	-64.86	lago Itapeaçu	-2.96	-58.05	lago Castanho	-3.81	-60.38
		lago Badajos	-3.32	-62.74	lago do Limão	-2.63	-57.29	lago_pxAnori	-3.78	-61.63
		lago Caldeirão	-3.24	-60.24	lago Urucará	-2.56	-57.78	lago Jacare	-3.66	-60.81
					lago Acari	-2.47	-56.97	lago Mamori	-3.63	-60.09
					lago Madabá Grande	-2.44	-56.71	lago_pxCodajas	-3.62	-62.12
					lago Maripana	-2.22	-56.70	lago Miraua	-3.55	-60.49
					lago Tambaquizinho	-4.12	-62.41	lago Anama	-3.54	-61.59
					lago Tucunare	-3.97	-62.60	lago manaquiri	-3.42	-60.48
					lago Laranja	-3.91	-63.42	lago Manacapuru	-3.19	-60.78
					lago Trocaris	-3.82	-62.89			
					lago Araça	-3.77	-62.88			
					lago Copeá	-3.65	-63.59			
					lago Caiambe	-3.57	-64.44			
					lago piorini	-3.52	-63.29			
					lago padre	-3.43	-60.97			
					lago Grande	-3.41	-60.62			
					lago Janauaca	-3.39	-60.31			
					lago Cambaleana	-3.29	-60.67			
					lago Sacambu	-3.28	-60.96			
Área alagada (km2): 92389 (Sippel et al., 1992)										

Apêndice 4. Média da captura (ton) por espécies de peixes capturadas pelos pescadores comerciais de Manaus.

Local name	Family	Species	Média (tones)	Max-Min(tonnes)	Média (%)	Max-Min(%)	Group species
Jaraqui	Prochilodontidae	*Semaprochilodus insignis/ Semaprochilodus taeniurus*	4.89 ± 3.85	19.92 - 0.01	4.99 ± 4.71	3.72- 0.03	Lacustrine-riverine
matrinxa	Characidae	*Mylossoma, myleus e Metynnis – 6 especies no mercado de Manaus*	4.12 ± 3.98	19.59 - 0.04	4.20 ± 4.86	3.66 - 0.14	Lacustrine-riverine
sardinha	Prochilodontidae	*Prochilodus nigricans* Agassi 1829	3.78 ± 3.35	19.78 - 0.02	3.85± 4.09	3.69 - 0.08	Lacustrine-riverine
Cara-de-Gato	Pimelodidae	*Platynematichthys notatus*	3.774 ± 4.24	16.5 - 0.044	3.84 ± 5.18	3.08 - 0.14	Lacustrine-riverine
curimata	Prochilodontidae	*Prochilodus nigricans* Agassi 1829	3.55 ± 3.57	19.476 - 0.0138	3.62 ± 4.362	3.64 - 0.04	Lacustrine-riverine
Pirapitinga	Characidae	*Piaractus brachypomus*	3.40 ± 3.79	19.40 - 0.05	3.46 ± 4.63	3.62 - 0.16	Lacustrine-riverine
pacu	Characidae	*Mylossoma, myleus e Metynnis – 6 especies no mercado de Manaus*	3.28 ± 3.23	19.82 - 0.0121	3.35 ± 3.94	3.70 - 0.04	Lacustrine-riverine
Apapá	Pristigasteridae	Pellona castelnaeana e Pellona flavipinnis	3.01 ± 3.58	17.08 - 0.17	3.07 ± 4.37	3.19 - 0.57	Lacustrine-riverine
tambaqui	Characidae	*Colossoma macropomun*	2.97 ± 3.39	19.8 - 0.01	3.03 ± 4.14	3.70 - 0.05	Lacustrine-riverine
Piramutaba	Pimelodidae	Brachyplatystoma vailantii	2.72 ± 5.29	19.14- 0.06	2.77 ± 6.46	3.57 - 0.20	Riverine
Piracatinga	Pimelodidae	*Calophysus macropterus*	2.66 ± 1.34	4.169 - 1.1	2.71 ± 1.63	0.77 - 3.69	Lacustrine-riverine
Mapará	Pimelodidae	*Hypophthalmus edentadus e H. marginatus*	2.26 ± 3.06	19.8 - 0.08	2.30 ± 3.73	3.70 - 0.27	Lacustrine-riverine
Jatuarana	Characidae	*Brycon melanopterus*	2.21 ± 2.62	15.07 - 0.20	2.25 ± 3.20	2.81 - 0.68	Lacustrine-riverine
aracu	Anostomidae	10 espécies	2.17 ± 2.35	19.52 - 0.01	2.21 ± 2.87	3.65 - 0.05	Lacustrine-riverine
branquinha	Curimatidae	5 especies de 3 gêneros – *Potamorhina, Psectrogaster e Curimata*	2.08 ± 2.02	17.39 - 0.03	2.13 ± 2.47	3.25 - 0.11	Lacustrine-riverine
Aruanã	Osteoglossidae	*Osteoglossum bicirrhosum*	1.80 ± 2.19	19.8 - 0.02	1.83 ± 2.67	3.70 - 0.09	Lacustrine
Cubiu-Orana	Hemiodontidae	*Anodus elongatus (cubiu orana), Argonectes longiceps (orana colarino), Hemiodus sp(orana flexeira)*	2.13± 2.67	17.6 - 0.01	2.23 ± 3.26	3.42 - 0.79	Lacustrine-riverine
Tucunaré	Cichlidae	*Cichla sp.*	1.55 ± 2.17	19.82 - 0.01	1.58 ± 2.65	3.70 - 0.03	Lacustrine
Peixe-Liso			1.515 ± 2.53	13.2 - 0.055	1.54 ± 3.09	2.46 - 0.18	Lacustrine-riverine
Cara-Preto	Cichlidae	*Heros efasciatus*	1.46 ± 1.75	3.96 - 0.09	1.49 ± 2.13	0.74 - 0.30	Lacustrine
Pescada	Sciaenidae	*Plagioscion squamosissimus e P. auratus*	1.39 ± 2.08	19.8 - 0.01	1.42 ± 2.54	3.70 - 0.05	Lacustrine
Pirarucu	Arapaimatidae	*Arapaima spp.*	1.36 ± 2.38	17.85 - 0.11	1.39 ± 2.90	3.33 - 0.36	Lacustrine
Caratai =cangati	Auchenipteridae	**	0.88 ± 0.31	1.1 - 0.66	0.89 ± 0.378	0.20 - 2.21	Lacustrine-riverine
Acara	Cichlidae	22 espécies	0.87 ± 1.33	17.6 - 0.011	0.89 ± 1.62	3.29 - 0.03	Lacustrine
Filhote	Pimelodidae	*Brachyplatystoma filamentosum*	0.83 ± 1	3.96 - 0.022	0.85 ± 1.22	0.74 - 0.07	Lacustrine-riverine
surubim	Pimelodidae	*Pseudoplastystoma fasciatum*	0.70 ± 1.35	19.72 - 0.01	0.71 ± 1.65	3.68 - 0.03	Lacustrine-riverine
Carau-Açu	Cichlidae	Astronatus ocelatus e Astronatus crassipinis	0.70 ± 1.01	19.8 - 0.02	0.71 ± 1.23	3.70 - 0.09	Lacustrine
Rebeca	Doradidae	*Megalodoras uranoscopus* Eigenmann & Eigenmann	0.66 ± **	0.66 - 0.66	0.67 ± *********	0.12- 2.21	Lacustrine-riverine
Dourada	Pimelodidae	Brachyplatystoma rousseauxii e B. Juruense	0.64 ± 1.3	11 - 0.053	0.65 ± 1.58	2.05 - 0.17	Riverine
caparari	Pimelodidae	*Pseudoplastystoma tigrinum*	0.62 ± 0.88	11 - 0.01	0.64 ± 1.07	2.05 - 0.03	Lacustrine-riverine
Tamoatá	Callichthydae	*Hoplosternum littorale*	0.58 ± 0.39	1.21 - 0.17	0.59 ± 0.47	0.22 - 0.58	Lacustrine
Cara-Prata	Cichlidae	Chaetobranchus flavescens e C. Semifasciatus	0.58 ± 0.64	3.3 - 0.02	0.59 ± 0.78	0.61 - 0.07	Lacustrine
Cuiu-cuiu	Doradidae	*Oxydoras niger*	0.51 ± 1.18	13.81 - 0.01	0.52 ± 1.44	2.58 - 0.05	Lacustrine-riverine
Peixe-Cachorro=sara	Cynodontidae	Cynodon gibbus	0.73 ± 0.42	2.07 - 0.51	0.75 ± 0.51	0.37 - 1.73	Lacustrine-riverine
Jandiá	Pimelodidae	*Leiarius marmoratus*	0.41 ± 0.43	1.1 - 0.11	0.42 ± 0.52	0.20 - 0.36	Lacustrine-riverine
Piranha	Characidae	5 especies – Serrasalmus e Pygocentrus	0.39 ± 0.62	4.61 - 0.01	0.39 ± 0.75	0.86 - 0.04	Lacustrine-riverine
Traíra	Erythrnidae	*Hoplias malabaricus*	0.33± 0.72	4.66 - 0.01	0.33 ± 0.87	0.87- 0.05	Lacustrine
Jau	Pimelodidae	*Zungaro zungaro*	0.28 ± 0.17	0.66 - 0.08	0.29 ± 0.20	0.12 - 0.29	Lacustrine-riverine
Pirarara	Pimelodidae	*Phractocephalus hemioliopterus*	0.26 ± 0.27	1.43 - 0.011	0.27 ± 0.33	0.26 - 0.03	Lacustrine-riverine
Cara-Roxo	Cichlidae	*Heros efasciatus*	0.14 ± **	0.14 - 0.14	0.14 ± **	0.02 - 0.48	Lacustrine
Cara-Tinga	Cichlidae	*Geophagus proximus*	8.8 ± **	8.8 - 8.8	8.97 ± **	1.64 - 29.54	Lacustrine
Barba-Chata = pirana	Pimelodidae	*Pinirampus pirinampu*	6.6 ± ***	6.6 - 6.6	6.72 ± **	1.23 - 22.15	Lacustrine-riverine
Arari-bodó	Doradidae	*Liposarcus pardalis*	10.67 ± 4.36	18.66 - 5.77	10.9 ± 5.33	3.48 - 19.37	Lacustrine