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Conservation and Management of Arapaima spp. in the Colombian Amazon

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CONSERVATION AND MANAGEMENT OF *ARAPAIMA* SPP. IN THE COLOMBIAN AMAZON

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Ana Alexandra Rojas

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To: Dean Michael R. Heithaus
College of Arts, Sciences, and Education

This thesis, written by Ana Alexandra Rojas, and entitled Conservation and Management of *Arapaima spp.* in the Colombian Amazon having been approved in respect to style and intellectual content, is referred to you for judgment.

We have read this thesis and recommend that it be approved.

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Date of Defense: November 12, 2019

The thesis of Ana Alexandra Rojas is approved.

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ABSTRACT OF THE THESIS

CONSERVATION AND MANAGEMENT OF *ARAPAIMA* SPP. IN THE COLOMBIAN AMAZON

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Professor Elizabeth P. Anderson, Major Professor

In order to conserve megafaunal, charismatic freshwater fish species, an interdisciplinary, translational ecology approach is needed. This thesis explores trends in conservation of the pan-Amazonian *Arapaima* spp., with two major components. First, I examined research trends on *Arapaima* over the last 50 years by categorizing articles by theme and geography. My results showed that aquaculture and biology were dominant themes, with most research conducted in the Brazilian Amazon. Second, I conducted field research in the Colombian Amazon to examine perceptions of *Arapaima* management at various geographic and political scales. One important finding was the crucial role of communities and small-scale fisheries in *Arapaima* conservation. Localized programs that include joint efforts of different institutions, and community members, have boosted population numbers of the fish in several areas of the Amazon. My results also suggest that local programs work, but without enforcement from regional and national authorities, their success for *Arapaima* conservation and management will be limited.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Commonly referred to as *pirarucu* or *paiche*, *Arapaima* spp., was a fish I had never heard of before starting my graduate studies, yet I had always wanted to work in freshwater ecosystems and the Amazon Basin. When I was first introduced to this species, I became instantly fascinated, as it is one of the largest freshwater fish in the world (reaching up to 3 m and 200 kg) and native in much of the Amazon Basin and several countries of South America, including Colombia. As I delved further into my research of *Arapaima,* I found startling facts. For example, it was introduced and potentially invasive in parts of the Bolivian Amazon, and it was listed as highly threatened (yet classified as Data Deficient) under the IUCN Red List of Threatened species. Furthermore, it was an incredibly important species for fisheries in the Amazon. It was clear to me that conserving and managing this species was a topic that needed further examination in the Colombian Amazon.

As this emblematic species continues to decline, there are still several gaps in knowledge of its ecology, human perceptions, and management, that if explored may ameliorate issues pertaining to current threats. My thesis aims to identify those gaps through a literature review and then focusing on a management case study within the Colombian Amazon Trapezium. I used a social-ecological lens in order to explore themes of human-wildlife interactions pertaining to *Arapaima*. Using a social-ecological approach has allowed me to connect with the people in the Amazon that are directly influenced by fisheries management. In my observations, these people have had to pursue local solutions to management and conservation and become local authorities regulating

the harvesting of *Arapaima* resources. Both my first and second chapter have shown this bottom-up management style is successful, yet government support is still needed.

The primary aim of this thesis is to communicate that megafaunal freshwater species are some of the most understudied and mismanaged species yet hold an indispensable value to the people in the regions that need them to survive. Although studies in which biological and ecological data are significant, if we hope to ensure the longevity of said species, we need to incorporate a human dimension.

My first chapter is a systematic literature review on research trends of *Arapaima spp.* over the last 50 years to address gaps in knowledge and find and synthesize connections within conservation and management initiatives. Using the Web of Science, I categorized over 180 articles into major themes; biology, aquaculture, conservation & management, taxonomy, and materials science. Next, I focused on the conservation and management theme to explore the following sub-themes: policy, economics, threats, tourism, ecosystem management, and traditional ecological knowledge. Overall, I found limited studies on the social aspects of *Arapaima* and a high concentration of studies in Brazil, but a serious lack in Colombia. Thus, for my second chapter I decided to conduct field work in Colombia using social science methods to understand *Arapaima* fisheries.

For my second chapter, I travelled to the Colombian Amazonian Trapezium to gauge human-wildlife interactions of *Arapaima.* I stationed myself in two border towns along the mainstem of the Amazon River, Leticia and Puerto Nariño. These towns were both part of a trinational region (within Colombia, bordered by Peru and Brazil) and have flourishing economies in post-conflict Colombia. With such unique characteristics, it was essential to capture the extent of connections between people and *Arapaima.* I

approached my research through key informant surveys, resident surveys and tourist surveys. Most questions were centered on opinion, knowledge, and thought of the species itself, as well as management and conservation. My results support some of the results from studies that I reviewed in the first chapter that were conducted in Brazil on management, but in a different geographic area that was data deficient. Identifying perceptions, population trends, current management actions, strengths, and assets, my thesis was able to expose gaps in information and areas for improvement which could be translated into effective, innovative management strategies for *Arapaima* in the Colombian Amazonian Trapezium.

CHAPTER 1

PAN-AMAZONIAN TRENDS IN CONSERVATION AND MANAGEMENT OF A CHARISMATIC FRESHWATER FISH *(ARAPAIMA* SPP.*)*

1.1 ABSTRACT

1. One of the Amazon's most important freshwater fish, *Arapaima spp.* is highly threatened. Its abundance has been severely diminished, and it now faces local extirpation in some regions of Guyana and Brazil. For that reason, it is essential to explore the multiple interactions between *Arapaima* and humans.
2. This review investigates the varying levels of human-wildlife interaction, as evidenced by research on *Arapaima* over the last 50 years, by analyzing over 190 articles from the database Web of Science and categorizing them into major themes. To understand trends in conservation and management research of *Arapaima*, we asked the following questions: (1) What have been the major themes of research related to *Arapaima* over the past 50 years? (2) Where has most research occurred and by whom? (3) What are the predominant threats to *Arapaima*? (4) What kinds of management and conservation approaches have been applied? and (5) What have been their consequences?
3. Overall, our results indicate that biology and fisheries were major themes of research, with aquaculture leading in fisheries, hinting at the possibility of high levels of interest in this species for consumption. Geographically speaking, research is concentrated in Brazil, particularly along the mainstem of the Amazon River. There were more authors from Brazil than from any other nation. The leading institutional affiliation was academia, followed by government.

4. Upon taking a closer look at the Conservation and Management theme, we found that adaptive co-management, the method of establishing yearly quotas alongside local fishers by actively surveying and working together with regional authorities, increase populations of *Arapaima,* compared to a centralized top-down approach.

Keywords: *Arapaima*, Freshwater Fish, Amazon Basin, Conservation, Management,

1.2 INTRODUCTION

Arapaima spp., the third-largest freshwater fish in the world, is an Amazonian freshwater fish species of high ecological and socioeconomic importance (Castello, 2007; Queiroz, 2000). Historically, *Arapaima* has been a vital food resource to people across the Amazon due to its geographic range—which extends into Brazil, Colombia, Peru, Ecuador, and Guyana—and large biomass. *Arapaima* can reach up to 3 meters long and weigh as much as 150 kilograms (Arantes, Castello, et al., 2010; Castello, 2007; Queiroz, 2000). This species is known for its piscivorous behavior, consuming up to 8% of its biomass daily as it moves short distances between lateral pools and floodplain lakes off the main channels of rivers (Carvalho et al., 2018; Castello, 2008a). Its limited movement and large biomass have made it a target for Amazonian fisheries, both small scale and commercial (Castello, 2007).

Societal demand for *Arapaima* consumption has led to a decrease in populations in their native range over the past 100 years (Castello, Stewart, 2010; Queiroz, 2000; Verissimo, 1895). The abundance of this species has been diminished by overexploitation to the point that it is now facing local extirpation in regions of Guyana and Brazil (Castello, 2007). Region-specific studies have shown fishing to be the main driver

negatively impacting *Arapaima* populations in much of the Brazilian Amazon (Arantes et al., 2010; Campos-Silva, Peres, 2016; Castello, Arantes, et al., 2015; Leandro Castello, McGrath, et al., 2011; Castello, Stewart, et al., 2011). Interviews with fishermen in the Lower Amazon Basin within the State of Para, Brazil, have shown that over half of fishermen in that area believed *Arapaima* populations to be depleted and half of those fishermen admitted to continued harvesting despite knowing the possibility of fishing-induced extirpation, further exacerbating the problem (Castello et al., 2015; Cavole, Arantes, et al., 2015).

Given these challenges, researchers, government officials, and non-profit organizations are increasingly collaborating on efforts for *Arapaima* conservation. The possibility of recuperating population numbers of *Arapaima* has been explored in specific examples throughout the Amazon Basin (Campos-Silva, Hawes, et al., 2018; Campos-Silva, Peres, 2016; Castello, 2004; Castello, Viana, et al., 2011; Fernandes, 2006; Petersen, Brum, et al., 2016). In the Purus River of the Brazilian Amazon, local communities have implemented community-based management programs and conservation agreements, with subsequent reports of species abundance of *Arapaima* at over 99% their original levels (Petersen et al., 2016). However, a challenge noted in these studies was that the scales of management between federal government, regional regulation, and local conservation seem to lack cohesion, which in turn can affect the effectiveness of conservation efforts (Castello, Stewart, 2010; Castello, Viana, et al., 2011; Figueiredo, 2015).

In the published literature, most studies of *Arapaima* have focused on individual cases for its conservation. There has yet to be a pan-Amazonian synthesis of threats and

challenges to the species' persistence, or lessons and outcomes of *Arapaima* management and conservation programs. To that end, this review aims to understand trends in *Arapaima* survival, conservation, and management at a pan-Amazonian scale, focusing on five main questions: (1) What have been the major themes of research related to *Arapaima* over the past 50 years? (2) Where has most research occurred, and by whom? (3) What are the predominant threats to *Arapaima*? (4) What kinds of management and conservation approaches have been applied (5) What have been their consequences?

1.3 LITERATURE REVIEW METHODS

This study is divided into two sections. In the first, we analyzed overall research of *Arapaima* quantitatively to understand temporal and spatial patterns. In the second section, qualitative statements were taken from a specific subset of research relating to *Arapaima*'s management to synthesize where gaps may exist in contemporary literature.

We performed a search on the web database Web of Science, focusing on the core collection using the search term "*Arapaima*." The data year range was from October 1970 to February 2019. Document types that were accepted were articles, proceedings papers, editorial materials, book chapters, reviews, and notes, which returned 264 documents on the latest search date, 01 February 2019. After review of the titles and abstracts, those that did not have *Arapaima* as the study subject were eliminated, leaving us with 196 documents for our analysis. Within the first round of classification, articles were placed in one or more of the following themes: biology, aquaculture, conservation and management, taxonomy, and materials science. In the second round of classification, articles were further examined and placed in sub-themes. A minimum of 3 articles was

needed for a sub-theme to be designated; this meant that it was an area of substantial research or an emerging area of research. A full explanation of the themes and sub-themes is given in Table 1-1.

The second round of classification returned 194 documents, as two documents were discarded due to lack of having *Arapaima* as a study subject upon closer inspection. In the second round, additional components of the articles were extracted for analysis of the first two questions: research themes and by whom and where was research conducted. Categorizing *Arapaima* as a primary or additional study subject signified whether the study focused solely on *Arapaima* or if the species was part of a more extensive study looking at various species. However, for parasitic research, *Arapaima* is designated as the main study subject because it was the main host unless the study considered multiple species of hosts. Country of origin was also determined for the first author of the 100 most prolific authors, and river basin was determined by the specific location of the study, or where the specimen studied was captured, and subsequent categorization was provided under Basin Level 2 (BL2) of Venticinque et al. 2016. This categorization allowed us to identify trends over time (annually) and focal geographic areas (basins) in the Amazon. Basin categorization highlighted the countries where most *Arapaima* research has been concentrated.

For the last three questions of this study, we focused on the sub-theme conservation and management to understand threats to *Arapaima* and societal or managerial responses to those threats. For the 32 articles classified under the conservation and management theme, we extracted vital points, such as management strategy used in the case study, *Arapaima* population dynamics, and recommendations for

protection or management. This component of our study represented a qualitative approach that complemented the systematic literature review of *Arapaima* related research.

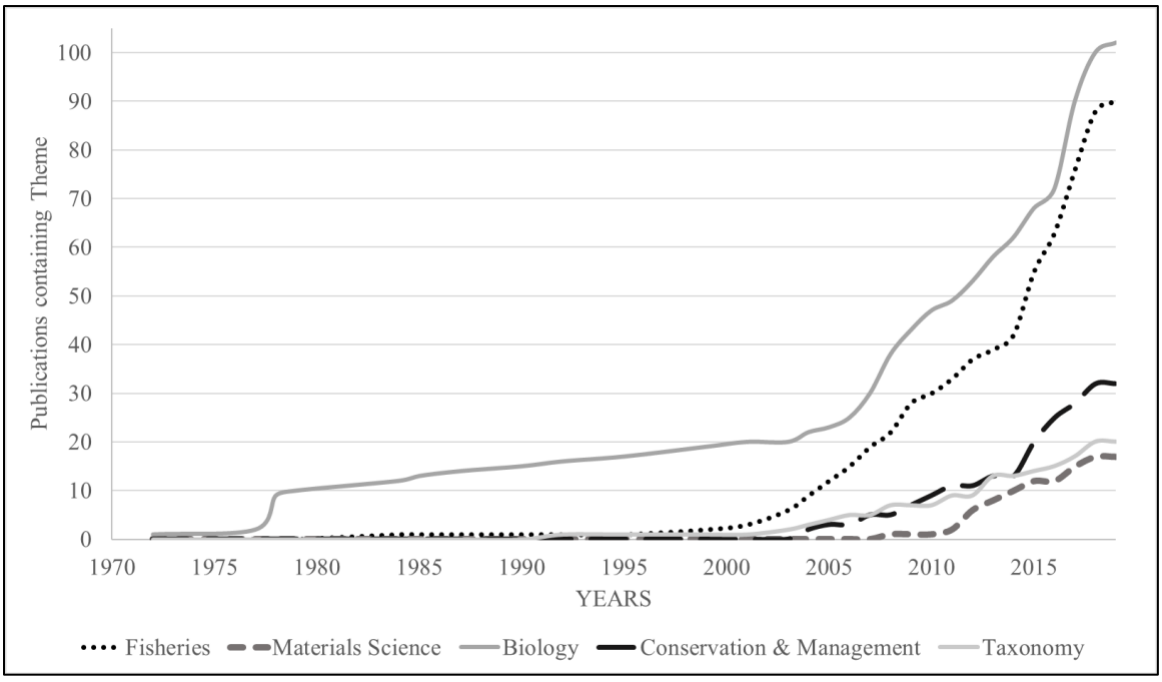
Table 1-1. First and Second Round of Categorization for Major and Sub-Themes

First Round of Categorization by Major Theme	**Taxonomy-molecular studies related to the speciation of *Arapaima***	**Conservation and Management – studies with the purpose of analyzing current management of the species, or potential techniques**	**Fisheries- studies of raising and using *Arapaima* spp for human consumption**	**Biology- studies with methodology or purpose of exploring biological aspects of *Arapaima spp.***	**Materials Science- studies exploring the use of *Arapaima* spp for anything other than alimentary purposes**
Second Round of Categorization by Sub-Theme	Genetics: Research related to the determination of species	Policy: Analysis of policies put in place for the protection of *Arapaima*.	Small scale/Community: Amazonian communities that fish for subsistence not business.	Genetics: Research using genetic techniques to advance molecular understanding of *Arapaima*.	Biomedical: research pertaining to the use of *Arapaima* body components in medical context.
	Systematics: taxonomical organization of *Arapaima*.	Economic: Includes a financial component or analysis regarding management of species	Aquaculture: articles based on farm raising *Arapaima* for consumption	Parisitology: Research exploring parasites which exist in *Arapaima*	Engineering: research pertaining to the use of *Arapaima* body components as a defense/ building material.
		Tourism: Eco-tourism that relates to species survival in some way.	Commercial: larger scale fishing businesses in the Amazon with coolers and may export fish to other locations	Physiology: Functioning of *Arapaima* as a living organism	
		Threats: Understanding and exploring the issues which threaten the livelihood of this species		Ecology: Research trying to understand the interaction between *Arapaima* and the abiotic and biotic environment	
		Ecosystem management: Analysis of habitat protection measures and/or ecosystem preferences of *Arapaima* that then have implications in its management.		Morphology: Body shape and form of *Arapaima*	
		Traditional Ecological Knowledge: information gathered in a social context by scientists that helps understand *Arapaima*			

1.4 RESULTS AND DISCUSSION

In this systematic review, we examined how research regarding *Arapaima* has changed over time, particularly in the focus of the protection of this species within literature containing conservation and management practices. By answering our five main questions, we found that the dominant areas of research were studies for biological and aquaculture purposes. Brazilian authors and institutions contributed around 60% of all analyzed publications. A dominance of Brazilian studies was reflected in our findings on conservation and management, as overexploitation was described most in Brazil through specific plans of management with local communities. Most research regarding conservation and management is new, only appearing in papers in the last 20 years. This general overview of our findings will be delved into further in the following sub-sections.

Figure 1-1. Accumulation of Major Research Topics on Publications of *Arapaima* between 1970 and 2019



In the first round of categorization, the most dominant theme for published articles was biology with 102 publications, followed by fisheries with 90, conservation and management with 32, taxonomy with 20, and finally materials science with 17 (Figure 1-1). Within the sub-themes, under fisheries, aquaculture had 64 publications, which was the highest number for any sub-theme. Under biology, physiology and parasitology had 45 and 24 publications, respectively. Although aquaculture is not the dominant theme that could be attributed to all topics that are within biology, there was a significant portion (26%) of the research conducted for parasitology and physiology that was done with fish in aquaculture settings. This result suggests that a substantial amount of biological research is conducted for human consumption rather than for the protection of the species.

A total of 726 authors contributed to articles considered in our analysis. Brazil was the dominant nation, both in authorship affiliation and country of origin of the research. By focusing on the 100 most prolific authors, we found that 79% came from institutions in Amazonian countries (Brazil, Bolivia, Peru, Colombia), 10% from the USA, and less than that from other regions (Figure 1-2). The most common institutional affiliation was in academia, followed by the government sector, which demonstrates the significance of this species not only for academics but as a natural resource of interest for the general public (Table 1-2).

Figure 1-2. Percentage of Authors in *Arapaima* analyzed literature by country of origin

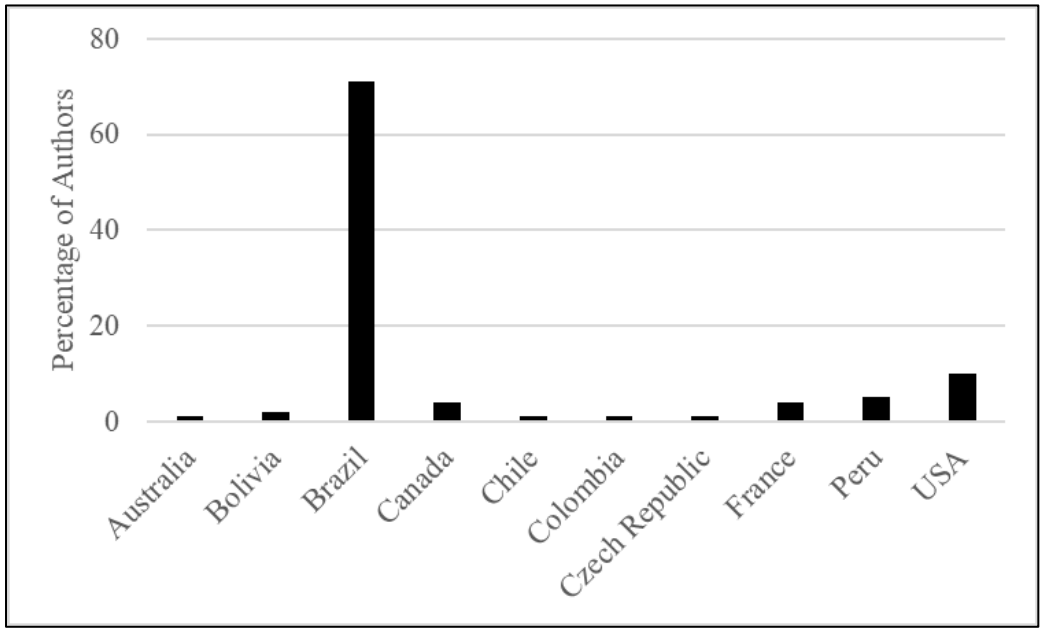


Table 1-2. Institution type and percentage of the top 100 authors

Institution Type	**% of Authors**
academic	68
governmental	29
international research organization	1
non-governmental organization	1
private	1

Figure 1-3. Studies conducted in Amazonian Basins based on the BL2 classification of Venticinque et al. 2016.

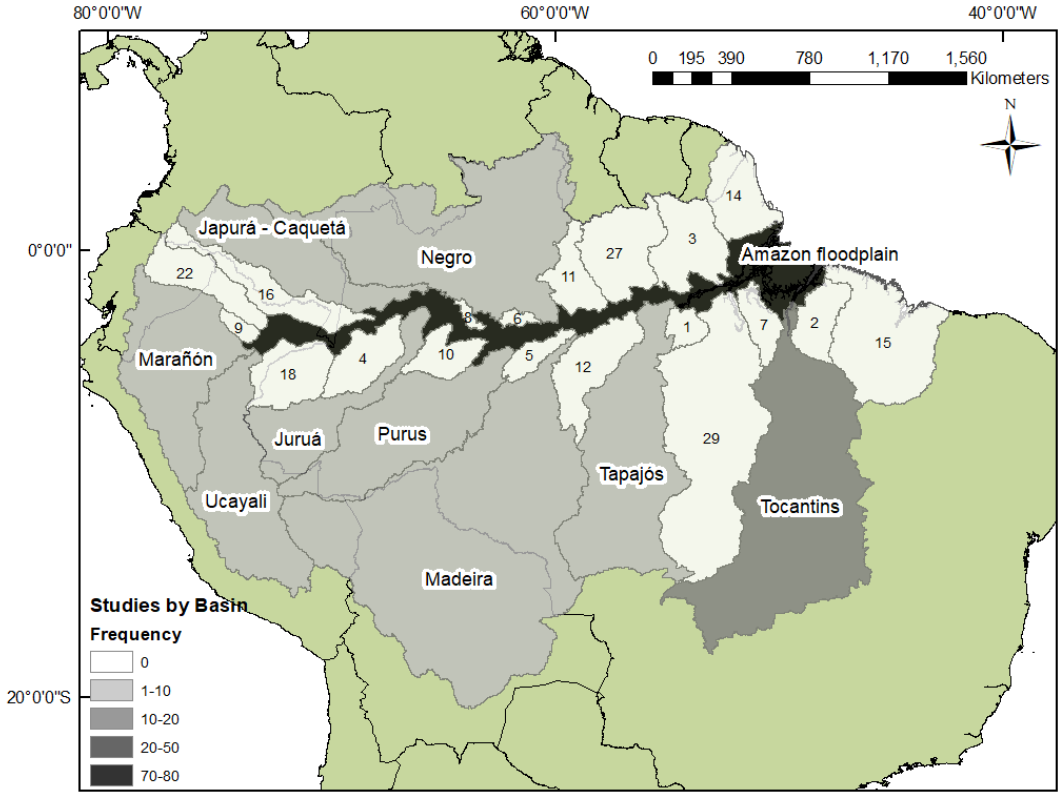
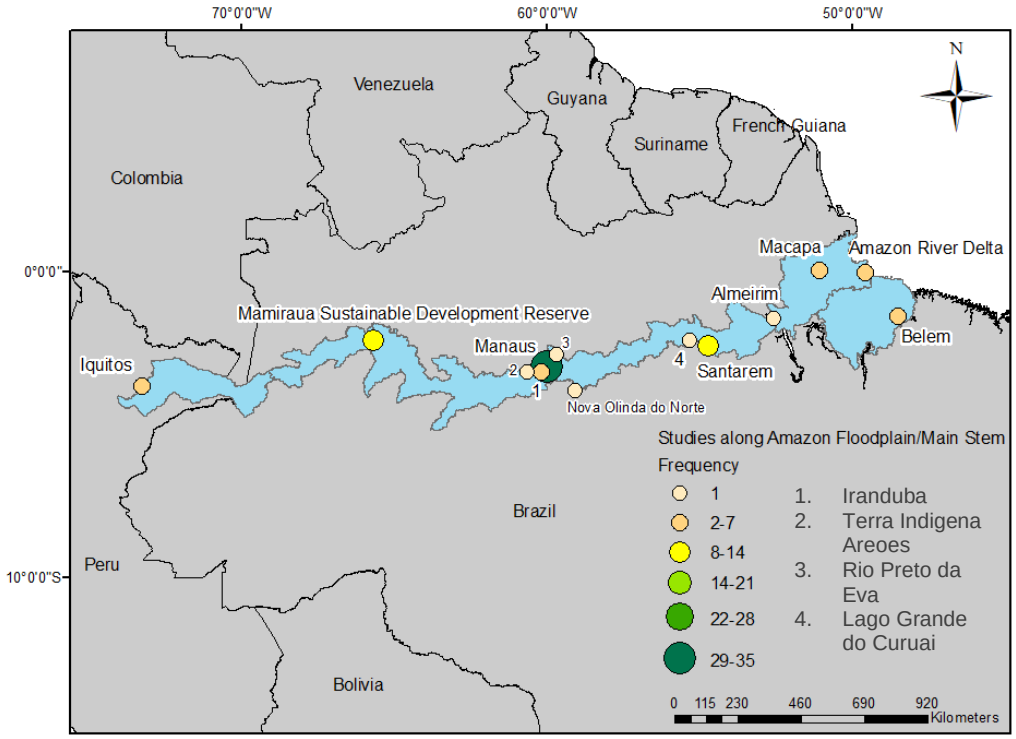


Table 1-3. Additional table labeling basins with 0 studies conducted.

Label	Basin Name
1	Minor Amazon tribs Curuá-una
2	Minor Amazon tribs Guama
3	Minor Amazon tribs Jari
4	Minor Amazon tribs Jutai
5	Minor Amazon tribs Madeirinha
6	Minor Amazon tribs Manacapuru
7	Minor Amazon tribs Pacajá
8	Minor Amazon tribs Piorini
9	Minor Amazon tribs Nanay
10	Minor Amazon tribs Tefe
11	Minor Amazon tribs Uatumã
12	Abacaxis
14	Coastal basins North

15	Coastal basins South
16	Içа - Putumayo
18	Javari
22	Napo
27	Trombetas
29	Xingu

Figure 1-4. Studies conducted in the Amazon Mainstem/ Floodplain



A heavy focus on Brazil in *Arapaima* research is indicated by our analysis of the geographic location of research projects. From the reviewed articles, the highest amount of research conducted was along the Amazon mainstem and associated floodplain lakes in Brazil (Figure. 1-3). However, a closer inspection suggested research is not uniformly spread along the mainstem, but instead that there are epicenters of research in the

Mamirauá Sustainable Development Reserve, Manaus, and Santarem (Figure. 1-4). As the largest city in the Amazon basin, Manaus has historically been an important port on the Amazon mainstem for goods, mainly fish. With a population of 2.1 million people (IBGE, 2019) it contains research institutions, both academic and governmental, such as the Brazilian Agricultural Research Corporation (EMBRAPA) and the National Institute of Amazonian Research (INPA). Mamirauá Sustainable Development Reserve near the city of Tefe in the Amazonas state of Brazil is a 14,000 km reserve that has an integrative environment for the management of natural resources. Initially founded by a team of scientists (biologists and anthropologists), research is a significant part of the development process for sustainable harvest of fish and agricultural products in Mamirauá (Koziell, Inoue, 2006).

1.4.1 CONSERVATION AND MANAGEMENT FOCUSED ANALYSIS

Within our second-round categorization, we focused on articles returned in the conservation and management theme, intending to understand threats to *Arapaima* and societal or management responses to those threats. The conservation and management theme was the third largest, with 32 publications. However, all published research in our analysis was relatively modern, like conservation and management, as dominant themes did not begin appearing in the literature until 2004 (Figure.1-5). Thus, our analysis indicates a substantial uptick in research under this theme in the past 15 years.

Figure 1-5. Percent Breakdowns of Publications by Year in Conservation & Management theme, 1970-2019

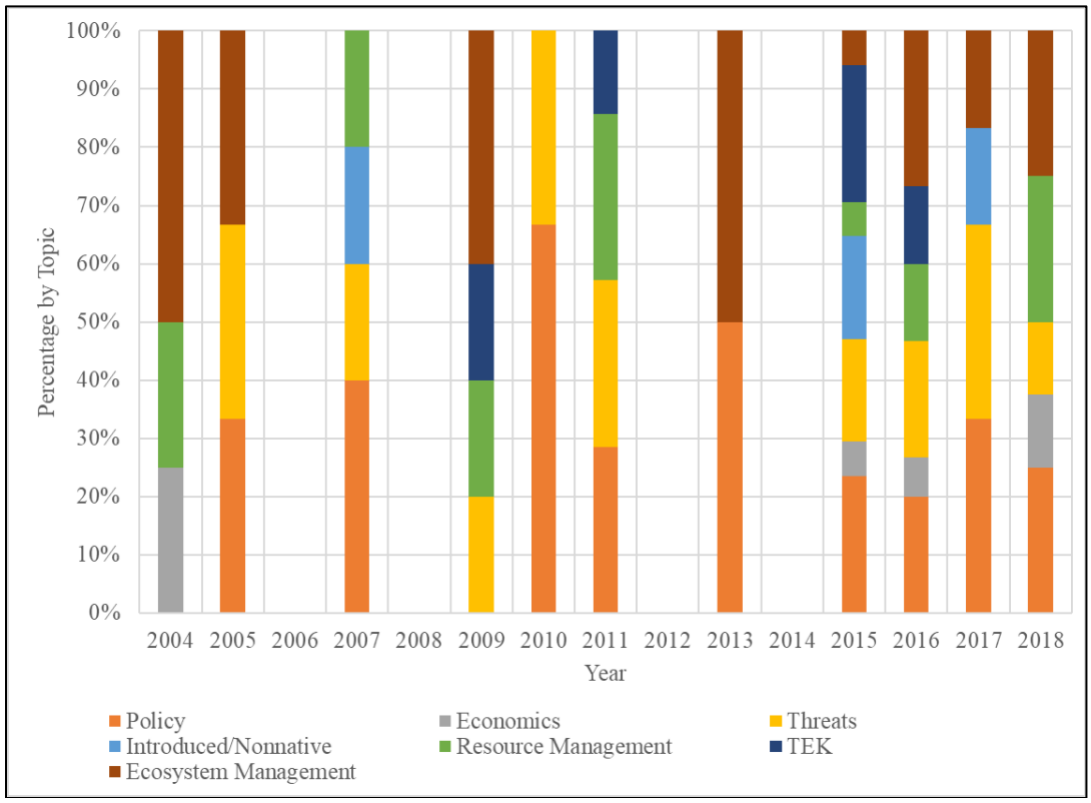


Table 1-4. Lessons for conservation or documented conditions of threat from the literature on conservation and management of Arapaima in the Amazon

Sub-Theme	***Principal lessons / documented conditions***	***Country of Study***	***References***
Policy	Harvest quotas influence life-history traits of *Arapaima*, including growth rate, size/age at first reproduction Decentralizing federal policies	Brazil Peru Brazil	(Arantes et al., 2010) (Garcia, Tello, et al., 2009) (Castello, McGrath, et al., 2011)

while implementing	Brazil	
local self-regulating policies are an effective manner for communities to manage *Arapaima* stocks.	Brazil	(Campos-Silva, Peres, 2016)
	Brazil	(Castello et al., 2015)
	Colombia	(Maccord, Silvano, et al., 2007)
	Brazil	(Mora, Palacios, et al., 2018)
	Brazil	(McGrath, Castello, et al., 2015)
Federal policies can be vague and easily misconstrued when putting into practice		(Petersen et al., 2016)
	Brazil	(Castello, Viana, et al. 2009)
	Brazil	
	Brazil	
Lack of enforcement causes policies to fail		(Campos-Silva, Peres, et al., 2017)
	Brazil	(Castello, McGrath, et al.2013)
	Brazil	(Castello, Stewart, 2010)
	Brazil	
	Brazil	
	Multiple Colombia	(Castello,Stewart, 2010)
		(Castello et al., 2012)
		(Castello et al., 2015)
		(Castello et al., 2013)

			(Cavole et al., 2015) (Hurd et al., 2016) (Mora et al., 2018)
Threats	Illegal Fishing leads to the underestimation of population estimates	Brazil Brazil Brazil	(Cavole et al., 2015) (Castello et al., 2015) (Campos-Silva et al., 2017)
	Fishing down the food web leads to reduced mean body size of *Arapaima*	Peru Brazil Brazil	(Garcia et al., 2009) (Castello et al., 2015)
	Lack of enforcement	Brazil Brazil Brazil Brazil Brazil Brazil Colombia	(Castello, McGrath, et al., 2011) (Castello, Stewart, 2010) (Castello et al., 2012) (Castello et al., 2015)
	Overexploitation produces isolated populations which decrease genetic diversity flow	Bolivia, Brazil, Colombia, Peru Brazil Brazil	(Castello et al., 2009) (Cavole et al., 2015) (Hurd et al. 2016) (Mora et al., 2018)

			(Hrbek et al. 2005) (Hurd et al. 2016) (Vitorino, Nogueira, et al., 2017)
Traditional Ecological Knowledge/Participatory	Working alongside fishers to understand population trends aids in management development	Brazil Brazil Brazil Brazil Brazil Brazil Guyana Brazil	(Campos-Silva, Peres, 2016) (Castello, 2004) (Castello et al., 2015) (Castello et al., 2013) (Castello & Stewart, 2010) (Castello et al., 2009) (Cavole et al., 2015) (de Souza, 2015) (Oviedo, Bursztyn, 2016)
Socio-Economic	Revenue of *Arapaima* increases with effective management measures/ Income household increases with protected areas	Brazil Brazil	(Campos-Silva, Peres, 2016) (Castello et al., 2009)
	Local communities that employ recreational fisheries to tourists can	Guyana	(Lennox, Brownscombe, et al. 2018)

	benefit as they will be in control monetarily and can monitor *Arapaima* wild populations		
Introduced	Introduction of *Arapaima* can affect the native ichthyofauna however there is a lack of quantitative data	Bolivia Brazil	(Macnaughton et al. 2015) (Magalhaes et al., 2017)
	Arapaima is now composing a significant portion of the fish landings in places where it is introduced	Bolivia Bolivia	(Macnaughton et al. 2015) (Van Damme et al., 2015)
Resource Management	Captive breeding of *Arapaima* to bolster wild populations should be avoided.	Bolivia, Brazil, Colombia, Peru	(Hrbek et al. 2005)
	More genetic structure testing is needed to understand the movement of the species across basins.	Bolivia, Brazil, Colombia, Peru Brazil Guyana	(Hrbek et al. 2005) (Vitorino et al., 2017) (Watson, Stewart, et al., 2016)
Ecosystem Management	Floodplain lake protection is critical for survival as there is a preference for deeper lakes in adults and shallow lakes in juveniles.	Brazil Brazil Brazil	(Richard, Castello, et al., 2018) (Campos-Silva, Peres, 2016) (Arantes, Castello, et al. 2013)

Heterogeneity between habitats (forested, barren) needs to be considered when creating management plans for reserves.	Brazil Guyana Brazil Bolivia, Brazil, Colombia, Peru	(Maccord et al., 2007) (Watson et al., 2016) (Hurd et al. 2016) (Hrbek et al. 2005)

Analysis of the conservation and management theme showed that there was no overall trend in the dominance of specific individual sub-themes, nor a consistent number of publications per year (Figure 1-5). Three years (2006, 2008, 2018) had no publications at all in this theme. Similar to the body of *Arapaima* research as a whole, in the sub-themes of conservation and management most research had been conducted in Brazil (Table 1-3). Again, we found that a high proportion of studies took place in the Mamirauá Sustainable Reserve. This IUCN category VI reserves (protected area with sustainable use of resources; Heinen, 2012) has a published technical report that was not found through this literature review (Figueiredo, 2015; Koziell, Inoue, 2006). However many of the case studies from this report published separately into journals were part of initial search results on Web of Science. (Figueiredo, 2015). The examination of case studies like in Mamirauá revealed lessons that are described below on threats and effective management of *Arapaima*.

For Amazonian fishes, damming, deforestation and climate change are considered large scale threats to survivorship of many species (Dudgeon et al., 2006; Hurd et al., 2016; Reis et al., 2016). Our literature review suggests this is not the case for *Arapaima*,

at least based on published studies, and that localized threats within specific lakes or channels are more impactful to the population declines that have been experienced (Hurd et al., 2016; Oberdorff et al., 2015). Overexploitation, combined with illegal fishing, fishing down the food web, and lack of regional enforcement are decreasing populations of *Arapaima*, as well as causing isolation of populations, a condition that decreases gene flow and resiliency of wild populations (Hrbek, Crossa, et al., 2008; Hurd et al., 2016; Vitorino et al., 2017).

Our literature analysis suggests that, historically, top-down management of *Arapaima* was prevalent, in which national law would be instituted and then carried out by regional agencies (Castello, Stewart, 2010). The most well-documented example of top-down management is of that of the Brazilian government, which attempted to implement a minimum catch length and a closed fishing season for *Arapaima* through the Brazilian Institute for Environment and Renewable Resources (IBAMA; Crampton et al., 2005). This approach was practical at first, but eventually proved ineffective and led to rampant illegal fishing in the Amazonas state (Castello, 2007; Crampton et al., 2005). Local governmental agencies in Brazil, such as IBAMA, are responsible for enforcing laws with communities, but a disconnect occurs due to the vast expanse and remoteness of areas of the Amazon where communities reside (Queiroz, 2000). Often, enforcement rates are low, a situation sometimes attributed to agencies' limited budgets and human resources (Petrere, 1989; Castello et al., 2015; Castello, Stewart, 2010; Castello et al., 2009; Cavole et al., 2015; Crampton et al., 2005; Hurd et al., 2016).

Beginning in the 2000s, management trends in Brazil saw a decentralization of policies through implementation of self-regulating local programs that worked jointly

with regional institutions, through co-management and adaptive co-management (Crampton et al., 2005). These approaches pay attention to heterogeneity in small-scale fisheries, not to a one size fits all management approach (Castello et al., 2013; Maccord et al., 2007). The concept of co-management is not new in fisheries, as much of the literature available indicates many positive results in the ecological and social communities in which it has been implemented (Armitage et al., 2007; Garcia Lozano and Heinen, 2016). Co-management is defined as a process that democratizes basic leadership, cultivates compromise, and empowers partner cooperation (Armitage et al., 2007). In terms of *Arapaima* small-scale fisheries, review of the literature suggests that when control is given back to communities, population numbers increase substantially, and there are economic benefits to the households of local fishermen (Campos-Silva, Peres, 2016; Leandro Castello et al., 2009; McGrath et al., 2015; Mora et al., 2018; Petersen et al., 2016).

We encountered a few documented cases in the published literature of communities across the Amazon basin that incorporate community-based management or fishing agreements, with differing levels of success. Again, most documented experiences in the literature were concentrated in the Brazilian Amazon (Table 1-3). The authors of these studies noted that long-term benefits were seen when the adaptive aspect was incorporated, as it is a continuing process with active participation by fishers. The first step to this active participation was often through what were known as 'fishing agreements.' Fishers within a local community convene in a workshop type setting that is facilitated by leaders or elders of the community, regional authorities or NGOs to decide regulations for fish in the water bodies nearby (Hurd et al., 2016; Osorio, Escobar, 2017;

Oviedo et al., 2016). These regulations apply to what can and cannot be fished and for how long, particular fishing practices (i.e., net vs. traditional harpoon), the process of self-monitoring, and consequences for rule-breaking (Clarke, 2016; Mora et al., 2018). It is a highly integrative process that requires time and will power from every participant and facilitator; however, long-term success appears to require adaptive co-management.

Finally, multi-disciplinary studies in which traditional or local ecological knowledge (e.g., Kroloff et al., 2019; Rehage et al., 2019) have been incorporated into the management of *Arapaima*, and successes for *Arapaima* conservation have been reported (Castello et al., 2015, 2013, 2009; Castello, Stewart, 2010; Cavole et al., 2015; de Souza, 2015;). Qualitative methods add social perspectives that can directly influence the outcomes of management. For example, researchers employing these types of methods explained that interviews and surveys with rural fishermen led to improved understanding of where *Arapaima* populations are and how they are behaving in response to fishing pressures (Arantes et al., 2010; Arantes, Garcez, et al., 2006; Castello et al., 2015, 2012). This information can then be translated to authorities of regional agencies that have worked alongside communities to set appropriate harvest quotas yearly. A successful case is in Mamirauá, where yearly counts allow for the adjustment of harvest quotas to avoid exploitation (Castello, Stewart, 2010). Researchers noted that adaptive co-management strengthens fishers and authorities; however it requires a high level of willingness to participate as well as quality control in terms of honesty for setting strict quotas (Armitage et al., 2007; Bayley, Petrere, 1989; Crampton et al., 2005).

1.4.2 FUTURE DIRECTIONS FOR RESEARCH

Our findings highlighted the need for more research in certain areas for this species, and we recommend three future research directions. By starting with the macro-lens of our categorization, we identified the need for greater geographic variation of research conducted in regions of the Amazon where *Arapaima* is found. Such a heavy concentration in few areas of *Arapaima* research in Brazil limits the distribution of knowledge in other Amazonian nations. Furthermore, the lack of geographic spread influences the conservation and management category of research, where we have identified the need for an increase in ecological, genetic and introduced species studies. We make these recommendations in hopes of ensuring the survival of the species throughout its range.

The first relates to the need for more genetic and ecological research, particularly geographic distribution surveys that are related to the speciation of this taxonomic group. From the conservation and management theme, there is a need for increased genetic testing and ecological studies of *Arapaima* (Fazzi-Gomes et al., 2017; Hrbek, Crossa, et al., 2007; Hrbek et al., 2005). The International Union for Conservation of Nature (IUCN) has classified *Arapaima* as 'Data Deficient,' signaling that there are many unknowns about this species. Currently there are four recognized species of *Arapaima,* with a potential additional species being debated (Stewart, 2013; Watson et al., 2016). Nevertheless, limited knowledge of the genetic structure of the species and populations presents a challenge to addressing these data needs.

Second, there is substantial overlap (26 % from our findings) between research in aquaculture and biology that can be used to the advantage of conservation. Potential

integration of aquaculture, physiological and parasitological studies to understand more about the basic biology of this species could address some questions regarding the immunology of specific sub-species. However, what past genetic studies do not recommend is using captive-breed and release programs to increase the viability of wild, and potentially inbred (bottlenecked), populations, such as allocating individuals from aquaculture raised to be released (Hrbek et al., 2005). Aquaculture and its related research should be viewed as a tool and not the ultimate solution to overexploitation.

Last, in terms of ecological knowledge, in its native range, many studies have documented the movement of *Arapaima* across habitats and dispersion (lateral migration) along floodplain lakes and a highly piscivorous appetite that influences the food webs where *Arapaima* is present. (Castello, 2007; Castello, 2008a, 2008b; Queiroz, 2000). What needs to be further explored is the species' behavior in introduced settings, such as in Peru and Bolivia along the Madre de Dios and upper Madeira Rivers, where the presence of non-native *Arapaima* could have serious effects on the native ichthyofauna (Doria et al., 2018; Macnaughton et al., 2015; Miranda-Chumacero et al., 2012; Van Damme et al., 2015).

While this systematic review examined indexed publications on *Arapaima*, one caveat is the singular use of the database Web of Science. Although a reliable resource for finding peer-reviewed academic publications, Web of Science does not contain the government reports and documents that have been realized in collaboration with noteworthy academics and organizations. The reports have been published in Spanish or Portuguese gray literature for people in the Amazon region\ and most are not indexed. Many reports contain valuable information relating to current fishing regulations,

ecology, fisheries and how local management of reserves, such as Mamirauá, have affected *Arapaima* populations (Crossa, Oviedo, et al., 2011; Figueiredo, 2015; Maccord et al., 2007). Future reviews should cover other databases and governmental documents from nations where *Arapaima* is native or introduced.

1.5 SUMMARY

This review's objective was to assess, both quantitatively and qualitatively, the research trends of *Arapaima* over the last 50 years, with a more in-depth examination of documented conservation and management strategies. *Arapaima* is an essential species in the Amazon basin, with a range that extends across international borders. It is an apex predator, and its large size makes it a desirable source of protein for Amazonian people. Given its ecological and fisheries importance, there is a need to improve the understanding of *Arapaima* ecology, conservation, and management.

Current research themes signal that much-indexed research on *Arapaima* relates to human use or consumption, given the number of articles on aquaculture. Based on the limited number of studies found on conservation and management, *Arapaima* populations are most susceptible to overfishing. Fisher behavior and local community cohesion are likely keys to successful management. Our review results suggest that long-term, smaller-scale conservation strategies that involve adaptive management are effective solutions, which possibly could be more influential at scales meaningful to *Arapaima* survival than national government regulations.

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CHAPTER 2
HUMAN-WILDLIFE INTERACTIONS OF A CHARISTMATIC, MEGAFAUNAL FISH IN THE TRINATIONAL REGION OF THE COLOMBIAN AMAZON

2.1 ABSTRACT

1. Human-wildlife interactions can increase the chance of conflict between the two parties in the form of overexploitation or overharvesting for personal consumption. This is common in freshwater fisheries, particularly in the Amazon basin, where human and natural systems are inextricably entwined. Studies on the extent of these interactions require a qualitative approach, which has become popular in human-wildlife interactions research over the last 20 years, yet needs to be further explored in freshwater systems.
2. A megafaunal, charismatic fish of importance in the Amazon, is *Arapaima*. It is pan-Amazonian distribution, and unique lateral migration makes it a desirable source of protein for riparian human communities. Much research on its biology, conservation, and exploitation has been concentrated in Brazil. For that reason, our study focuses on the perceptions of the people within the tri-national region of the Amazon Trapezium, with a focus on the area near Leticia and Puerto Nariño, Colombia.
3. Employing a qualitative methodology of semi-structured surveys and key informant interviews, we sampled the resident and tourist populations of two border-towns, Leticia, and Puerto Nariño. Our questions focused on awareness of ecology, management actions, and attitudes toward the species and future management actions.

4. From our results, we discerned that residents feel that the population is diminishing, and there is a lack of presence by official agencies to regulate the fishery. There is a positive affinity towards the species, and local NGOs are assisting in ensuring its survival in the region.

Keywords: *Arapaima*, Freshwater Fish, Amazon Trapezium, Conservation, Fisheries Management

2.2 INTRODUCTION

In many tropical regions of the world, physical boundaries between ecosystems and social systems are blurred, leading to negative human-wildlife interactions (Rosell, Llimona, 2001). Without adequate regulations, these interactions often become one-sided and end in the exploitation of resources, as shown in the case of freshwater fisheries (Messmer, 2000). As a significant source of protein for many Amazonian countries, freshwater fisheries face surmounting pressures from human populations, with limited regulation by authorities. In order to address this situation, qualitative studies that aim at understanding attitudes and perceptions of locals on natural resources have become often-used tools over the last 20 years (Heinen, 2010; Isaac et al. 2014; Oviedo, Bursztyn, 2016; Pauly et al., 2002). However, much of the literature has been concentrated on terrestrial environments (forests) and mammals (e.g., monkeys, large cats, large ungulates)(Heinen & Paudel, 2015; Carrizo et al., 2017; Dudgeon et al., 2006). There is now a gap in the literature on perception-based studies of freshwater biota that needs to be filled.

A poignant freshwater fish that has left a considerable mark in human-wildlife interaction studies is *Arapaima spp.* (referred to here as *Arapaima*). As the largest

freshwater scaled fish, reaching up to 200 kg and 3 m in size, this species has high ecological and social importance. *Arapaima*'s native geographic range extends across Brazil, Guyana, Colombia, Peru, and Ecuador (Figure 2-1), with habitat preference for floodplain lakes and channels (Arantes et al., 2010; Castello, 2008b, 2008a; Castello, Stewart, 2010; Queiroz, 2000). Using lateral migration along said lakes and channels to move, this species maintains a highly piscivorous behavior (around 8% of its total biomass daily) in the species-rich waters of the floodplains. These biological and ecological aspects lend to highly desirable social aspects; culturally, *Arapaima* is a sign of pride for Indigenous groups of the Amazon, resembling strength and enormity. Nutritionally and economically, fishers catch this species and obtain large amounts of white, delicious meat from single individuals (Castello, 2007).

Several studies on *Arapaima* have documented its importance to Amazonian small-scale fisheries (Campos-Silva, Peres, 2016; Castello et al., 2015, 2009; Castello, Viana, et al., 2011). Implementation of co-management approaches has increased local community control of fisheries resources alongside local governmental institution support and enforcement (Armitage et al., 2007; McGrath et al., 2015). As in many other community-based case studies worldwide (e.g., Heinen, 1995a), results from these cases show that *Arapaima* and other wild species' population numbers have increased following community-based management efforts (Campos-Silva et al., 2017; Castello, Viana, et al., 2011; Mora et al., 2018). Most studies on *Arapaima*, however, have been focused in Brazil, particularly in the Mamirauá Sustainable Development Reserve, and there is a disproportionately greater amount of research being conducted on the use and

consumption of *Arapaima* in aquaculture than on conservation of wild stock (refer to Chapter 1).

If *Arapaima* fisheries management is to be improved in Amazonian freshwaters, several knowledge gaps need addressing. For example, there is an urgent need to understand better the conditions that support sustainable management of *Arapaima* at various scales, from local to regional to national. There is also a need to understand *Arapaima* – human interactions at different locations across the Amazon. Finally, there is a need for more studies outside of Brazil, and in transboundary contexts. For our study, we sorted through published, indexed literature on *Arapaima* over the last 50 years and realized that there were few studies attempting to understand this critical fishery in the Colombian Amazon. To fill these gaps, this study investigated human-wildlife interactions with *Arapaima* and related fisheries management in the tri-national Amazonian Trapezium, focusing on human perceptions of *Arapaima* in Colombia. Our study had four main objectives:

(1) Assess the nature and extent of connections between *Arapaima* and humans, considering both residents of the region and visitors;

(2) Examine the status of *Arapaima* populations according to residents of the region;

(3) Identify the main actions in *Arapaima* fisheries management at different scales;

(4) Document strengths and assets for *Arapaima* conservation and management.

2.1.1 STUDY SITE

The Colombian Amazon exemplifies many of the current conservation challenges and opportunities facing Colombia in a post-conflict era. After 50 years of internal conflict between communist and conservative factions, a resolution was narrowly reached

in 2017, ending a highly disastrous civil unrest that displaced an estimated 7 million people and killed over 250,000 (Baptiste et al., 2017). As a highly biodiverse nation, harboring about 10% of the world's total species, the most significant impact to natural systems in Colombia has been forest loss, with around 1 million hectares lost during civil conflicts over the past half-century (Baptiste et al., 2017; Mendoza-Rojas, Sebastian, 2018). The primary drivers of these losses were due to illegal settlements by guerillas and displaced people as well as coca leaf production by impoverished farmers. However, post-conflict Colombia is also facing the threat of increased resource extraction in previously inaccessible areas and increased deforestation (Suarez, Arias-Arevalo, et al., 2018). The Andean-Amazon region of Colombia, such as the departments of Caquetá, Putumayo, and northwest Amazonas were historically hotbeds of violence and guerilla occupation. The peace process has opened these territories to new possibilities, some positive and others negative for natural resource conservation. Among the most relevant for *Arapaima* conservation and management is the influx of tourists that are arriving to experience the Amazon and increased number of migrants from other regions of Colombia to the Amazon (Maldonado et al., 2016; Sánchez, 2018).

The geographic focal point of our study was in the region surrounding Leticia and Puerto Nariño in the Colombian Amazon (Figure 2-2). These two border towns are part of the Amazonian Trapezium in southeastern Colombia, in which the southern border is delineated by the Amazon River, and on the opposing bank by Peru, the east is bordered by Brazil, and the west is bordered again by Peru (Figure 2-2). This unique tri-national aspect adds difficulty to adequate management and enforcement of environmental regulations in this region. Border towns often face pressures from neighboring countries,

leading to overexploitation of natural resources (Fall, 2009; López-Hoffman, Varady, Flessa, et al., 2010; McNeely, 2001; Baral & Heinen, 2005; Perez, 2009)

It is important to note that Leticia and Puerto Nariño are different from each other in terms of population density and structure. The Amazonas Department of Colombia extends over 100,000 km^2 with 40% of the economy based on agriculture and extraction of natural resources (*Información Departamental: Amazonas*, 2015) The capital of the Department, Leticia, contains 70% (76,243 as of the 2015 census) of the total departmental population (*Información Departamental: Amazonas*, 2015). Currently, it is an important area for tourism, with an airport that offers the opportunity of embarking on daily flights to and from Bogota. It is also an access point for the rest of the mainstem of the Amazon River. Puerto Nariño is a smaller municipality with around 6,000 residents and 21 communities, 20 of which are indigenous (Trujillo, Duque, 2014). Its urban center is a crucial point for tourism as it is a well-kept, clean, and idyllic town with colorfully painted buildings and no motorized vehicles.

We identified four focal areas for research where fishing *Arapaima* is culturally and economically important: (1) Amacayacu National Natural Park (Parque Natural Nacional Amacayacu), (2) the mainstem of the Amazon river, (3) Lagos de Tarapoto and (4) Lagos de Yahuarcaca. The first two sites are essential for their biological and protected status: Amacayacu National Natural Park and the main stem of the Amazon. For this study, we primarily focused on the Lagos de Tarapoto and the Lagos de Yahuarcaca. The Lagos de Tarapoto are located 2 km from the urban center of Puerto Nariño. They are black water wetland lakes on the alluvial plain of the Amazon River at the confluence of the Loretoyacu river, coming from the northwest. The high diversity of

ichthyofaunal in these lakes, with 169 documented fish species (including *Arapaima*) spread across seven orders and 32 taxonomic families, is linked to critical protein and income sources for nearby communities and interests of conservationists (Trujillo, Duque, 2014). In 2017, a joint effort between a local NGO (Fundación Omacha), World Wildlife Foundation (WWF)-Colombia, and the Colombian Ministry of the Environment led to recognition of the Lagos de Tarapoto on the list of Wetlands of International Importance under the Ramsar Convention (Heinen, 1995b; Osorio, Escobar, 2017).

The Lagos de Yahuarcaca, similar to the Lagos de Tarapoto, is a collection of seasonally flooded black-water lakes around 2 km from the city center of Leticia (Alvarado, Gómez, et al., 2012). Also part of the alluvial plain of the Amazon River, these lakes are connected through natural channels that are profoundly affected by the urbanization of nearby Leticia (Prieto Piraquive, Duque, et al., 2016). A study in these lakes found 66 species belonging to 18 families, including *Arapaima* (Andramunio-Acero, 2012). Understanding this background information is essential for understanding the link between social systems and fisheries in this region.

Figure 2-1. Natural distribution of *Arapaima* in the Amazon Basin, South America, adapted from (Castello & Stewart, 2010)

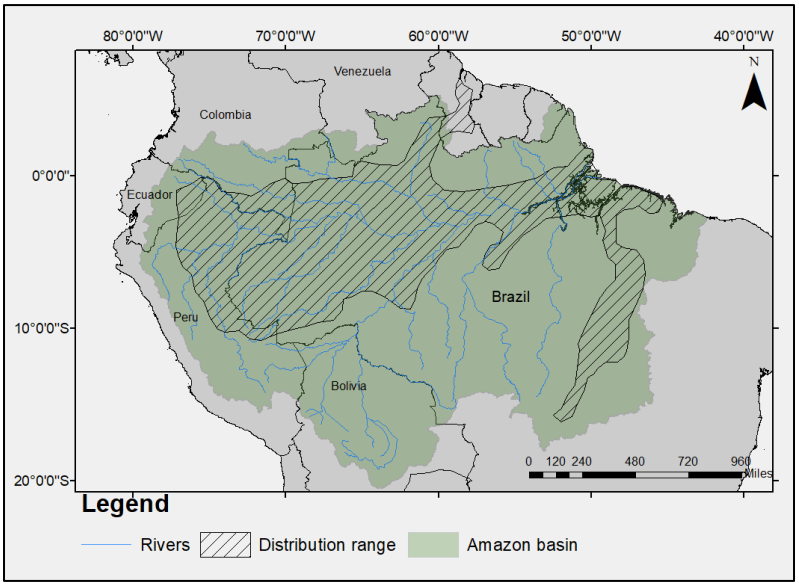
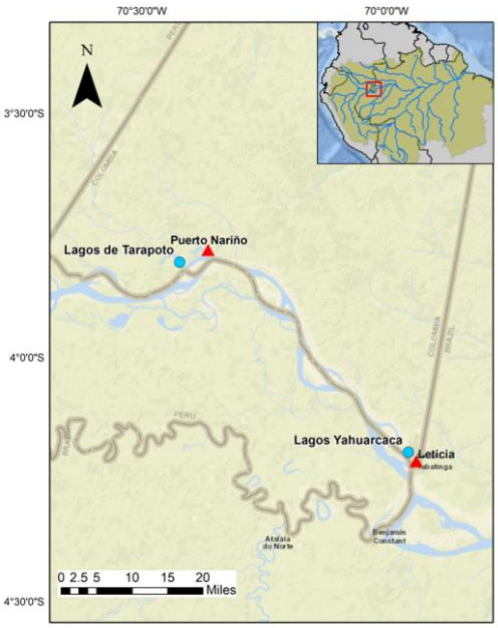


Figure 2-2. Study Area Map, two focal study points, Leticia and Puerto Nariño in blue and red triangles show the floodplain lake systems, Lagos de Yahuarcaca and Lagos de Tarapoto



2.3 METHODS

Our fieldwork occurred in two phases over six months in 2018. During March 2018, we visited Leticia and Puerto Nariño for reconnaissance and initial field observations of fishing practices. We also conducted unstructured interviews with key informants (e.g., Ter-Ghazaryan and Heinen 2006) in local institutions (Table 2-1) over four days. Through our main point of contact, Fundacion Omacha, we conducted participant observation for two hours with the fishermen of the *'balsa,'* a floating station at the entrance of the Lagos de Tarapoto, in which volunteer members of the fishers' cooperative monitor and regulate access to the lakes for fishing. From these interactions, we were able to formulate our research questions and set up our future field season for July-August 2018.

Table 2-1. Key institutions for unstructured interviews in March 2018

Institution Name	***Type***	***Location***
Fundacion Omacha	Non-governmental organization research and education	Puerto Nariño and Bogota
Parque Natural Nacional Amacayacu	Governmental protected area	In-between Puerto Nariño and Leticia
Natütama	Non-governmental organization education	Puerto Nariño
National University of Colombia - Amazon campus	Public, academic university	Leticia
SINCHI Institute of Amazonian Research	Non-profit research institution of the Colombian government	Leticia
Pontifical Xavierian University	Private academic university	Bogota

The second phase of our study was done in July and August 2018 in the same region, during which we spent ten days in Puerto Nariño and 15 days in Leticia. We conducted

household surveys (e.g., Shrivastava & Heinen, 2007) using quota sampling based on selecting participants whose livelihood depended on fishing through being directly involved with the activity or through family members. From our reconnaissance, we noticed the high level of tourists in this region and decided to include a short, structured survey by quota sampling tourists in the area. We used the free Android software Open Data Kit (ODK) to create, administer, and store the survey data electronically. We began by formulating basic questions in test surveys, which contained 16 questions for the general survey and 5 for the tourist survey. We conducted two trials, with 2-3 surveys completed each trial, and then settled on the final version of both surveys.

In the 'general resident' survey, we had 22 questions (Appendix) that were split unevenly into four sections: 1) primary socioeconomic and demographic data, such as age, gender, livelihood practices, 2) personal knowledge of ecology, 3) opinion/perception of the species, and 4) conservation and management of *Arapaima*. The questions were a mix of open-ended and fixed response options (multiple-choice, select one, etc.). We administered the general survey to 186 respondents; 100 were conducted in Puerto Nariño and 86 in Leticia.

The 'tourist' survey contained 11 questions in total that were split unevenly into four sections: 1) necessary socio-economic and demographic data, such as age, gender, country or place of origin, 2) reason for visiting, 3) wildlife tourism perception, and 4) conservation and management of *Arapaima*. The questions were a mix of open-ended and fixed (multiple-choice, select one). We administered the survey to 142 respondents, with 40 conducted in Puerto Nariño and 112 in Leticia.

Last, we conducted a series of semi-structured interviews with different parts of the residential population. These more direct questions regarding our study were done with people we regarded as key informants within the village, such as community leaders, and fishers; we interviewed both men and women, all of adult age (>18; Bernard 2006). We used a purposive sampling technique for the interviews, selecting people that have extensive knowledge of fishing in their community; many were identified in collaboration with our regional contact, Fundación Omacha. In total, we conducted 14 theme-based interviews with key informants. This number aligns with previous studies that have suggested that a sample of 10-20 knowledgeable people is enough to reveal information about specific themes (Bernard 2006).

3 Themes we explored were:

- Perception/opinion of *Arapaima*: introduced or native, dangerous/threat
- Ecological: Feeding/predatory, migratory behavior
- Management of *Arapaima*: what is being done (fishing agreements), do they agree with the fishing agreements, have the fishing agreements changed their economic status, what are some other alternative income options they would like to have
- Fishing of *Arapaima*: how and where it is being caught, how much of the market is comprised of this species

Key informant interviews (Heinen, 2010) were between 12-20 minutes and were recorded with permission from participants. Six interviews occurred in Leticia and eight in Puerto Nariño, with field notes also taken for every interview. Transcription and coding were done through the program NVIVO and discussed in the Data Analysis section (below).

2.3.1 DATA ANALYSIS

Since most of our data was categorical, qualitative data analysis was completed through a three-phase process. In Phase 1, we began by downloading CSV files from the aggregate (Ona.IO) we used to store our data. Surveys were cleaned, and demographic data are broken into categories (Table 2-2 & Table 2-3). We connected where residents lived (Puerto Nariño, Leticia, Brazil, and Peru) to several opinion and perception questions through contingency tables and percentages. Descriptive univariate statistics were applied to examine trends in the data.

Table 2-2. Division of Age Data Based on (CIA World Factbook: Colombia, 2019)

Age	***Description***
18-24	Early Working Age
25-54	Prime Working Age
55-64	Mature Working Age
65-80	Elderly

Table 2-3. Time of Residence in Region Based on (CIA World Factbook: Colombia, 2019)

Time (years)	***Description***
0-1	New residents
2-10	Recently established
11-20	Residents
21-30	Majority of life
31-80	Whole life

In Phase Two, we used the NVIVO program (e.g., Dongol and Heinen, 2012) to transcribe (Spanish to English), code, and sort through 14 key informant interviews. Coding was based on the principles provided by Bernard 2006 and organized as Table 2.

This analysis allowed us to identify most common codes and, thus, significant themes that need further exploration.

We conducted 186 surveys with residents, 142 with tourists, and 14 key informant semi-structured interviews. We divided the general resident and tourist surveys for our analysis and assessed how their results answered our objectives. As for the key informant interviews, they provided information on strengths, assets, and management objectives.

2.4 RESULTS

2.4.1 GENERAL RESIDENT SURVEY AND KEY INFORMANT RESULTS

For our first objective of understanding connections between *Arapaima* and humans, we gauged ecological knowledge, awareness, and emotional perception towards the species. First, we wanted to understand how the local distribution of people may influence where they have seen the species and ecological knowledge by asking about what *Arapaima* eats. In Table 2-5 and 2-6, we present the results of residence of the people vs where they have seen the species and residence vs what they believe the species to eat; highlighted are the most significant frequencies. Here we present textually the most common responses.

Regarding the first question, the respondents residing in Leticia, 26.47%, and of Puerto Nariño, 22.06%, said they saw them in "Other" places. When asked further what these places were, 46.69% said in human-dominated areas (captivity/aquaculture, fishing markets), 34.21% in other parts of Colombia that were not in the Amazon Trapezium, and 19.29 % in other countries such as Brazil and Peru. However, as expected in Puerto Nariño, the most significant response (22.79%) was Lagos de Tarapoto. For distribution

of residence vs what *Arapaima* eats, the most frequent answer was fish (Leticia 40.10% and Puerto Nariño 29.21%), which was expected.

We continued to gauge connection through emotional perceptions by residents in which the top resident emotion (Figure 2-3) was happiness (51.61%), followed by pride (21.51%), and both respect and sadness tied for third with (10.75%). We continued with understanding benefits and found that 93.01% of resident respondents believed that *Arapaima* brought benefits; the top three benefits were monetary (38.09%), food security (25.97%), and tourism (8.65%).

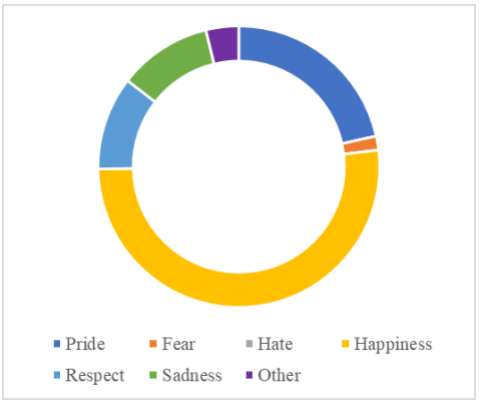
Table 2-4. Percent Frequency of Participants' Residence and Places that they have seen Arapaima.

Places Seen / *Residence*	*Amazon Mainstem*	*Lagos de Tarapoto*	*Lagos de Yahuarcaca*	*Other*	*Grand Total*
Brazil	0.00	0.00	0.00	0.74	0.74
Leticia	9.56	5.88	6.62	26.47	48.53
Peru	1.47	0.00	0.74	3.68	5.88
Puerto Nariño	0.00	22.79	0.00	22.06	44.85
Grand Total	11.03	28.68	7.35	52.94	100

Table 2-5. Percent Frequency of Participants' Residence and what they believe *Arapaima* eats.

Arapaima eats / *Residence*	*Concentrate*	*Fruit*	*Don't Know*	*Other Animals*	*Fish*	*Plant*	*Seed*	*Grand Total*
Brazil	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.50
Leticia	1.49	0.99	5.94	0.00	40.10	1.49	5.45	55.45
Peru	0.00	0.00	0.00	0.00	3.96	0.00	0.00	3.96
Puerto Nariño	0.50	1.49	3.47	0.99	29.21	1.98	2.48	40.10
Grand Total	1.98	2.48	9.41	0.99	73.76	3.47	7.92	100.00

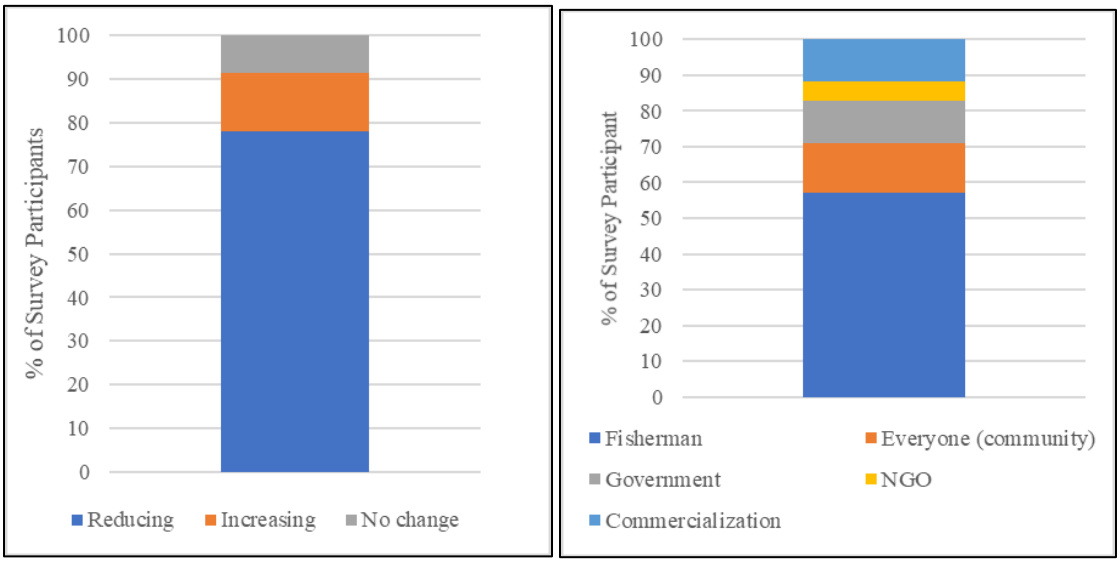
Figure 2-3. Emotional perception of *Arapaima* by residents



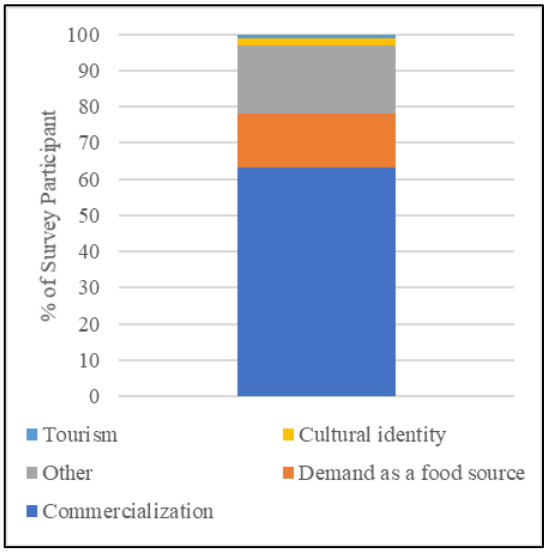
In our second objective, we wanted to know the residents' perceived status of *Arapaima* populations in the area. Our results suggest that 77% of survey participants believed that the population of *Arapaima* is decreasing (Figure 2-4). We proceeded to ask WHO they felt was responsible for the decline, to which 57% of respondents believed that fishers are, followed by everyone (the community as a whole). Moreover, we probed for WHAT was the main reason for the decline in which 63% believed it is the commercialization of fisheries.

Figure 2-4. Results for resident perception of *Arapaima* population trend

A) Participant Response Population Trend B) WHO is responsible for the decline?



C) WHAT is the main reason for the decline?



Related to our third objective on the actions of management of the *Arapaima* fishery, we present the results of selected questions divided by the participant's residence in percentages (Table 2-7). We first observed that Leticia and Puerto Nariño had the highest

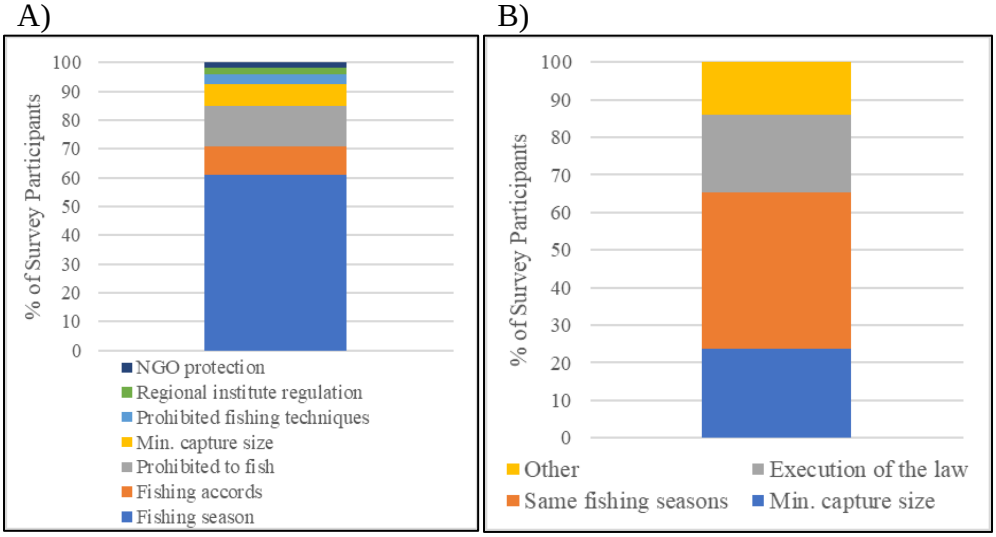
number of residency responses for all questions while residents of Brazil and Peru were deficient. We also include the distribution of percentages in the questions of what fishing regulations did participants know of (nationally) and what type of coordination there was between the three nations (Figure 2-5). There is more variety in the known regulations nationally than international coordination.

Our results show that 85.40% of general resident survey participants were aware of regulations in Colombia, and 60.83% of those that knew there were regulations were aware of the national fishing season. Once we began asking about the tri-national management aspect of the fishery, the results were more mixed. Our results showed that 49.46% of survey participants did not think the same regulations applied across the three nations (Colombia, Peru, and Brazil) while 35.48% thought the same regulations applied. Besides regulations, we wanted to understand if there was coordination between the three nations' authorities, to which 47.31% of participants said there was, 33.87% said there was not, and finally, 18.81% did not know. For those that answered that there was coordination, we probed further to see what the types of coordination; the most common type was consistency of fishing season restrictions (41.67%), followed by the same minimum capture size (23.61%). Lastly, we wanted to know what should or needs to be improved in the *Arapaima* fishery, to which suggestions for management were varied. Overall, 41.67% of participants believed there should be more enforcement, 23.21% believed there should be more regulation (law), and 35.12% believed there should be more of both.

Table 2-6. Selected questions and responses regarding management actions and divided by resident town or nation if not Colombia.

Question	*Responses (%)*	*Residence*			
		Puerto Nariño	*Leticia*	*Brazil*	*Peru*
Awareness of regulations across local, regional, or national levels? n=186	No	3.80	1.63	0.00	0.54
	Don't Know	5.98	1.63	0.00	0.54
	Yes	29.35	52.17	0.54	3.80
Awareness of same regulations applied across the three nations? n=186	No	19.89	26.88	0.00	2.69
	Don't Know	10.22	3.76	0.00	1.08
	Yes	9.14	24.19	0.54	1.61
Awareness of coordination of the authorities of the three nations? n=186	No	12.90	20.43	0.00	0.54
	Don't Know	10.75	7.53	0.00	0.54
	Yes	15.59	26.88	0.54	4.30
What should be done? n=168	More Enforcement	13.10	26.79	0.00	1.79
	More Regulatory Legislation	7.14	15.48	0.60	0.00
	Both	17.86	13.10	0.00	4.17

Figure 2-5. Percentage of selected questions regarding types of management actions taken in Colombia (A) and coordination among the three nations, Colombia, Peru, and Brazil (B).



Finally, for our fourth objective, we used key informant interview results to get to the core of the strengths and assets for *Arapaima* fishery management. We coded for four main categories that kept reappearing across the interviews and related to management: enforcement of fisheries, need/want for aquaculture development, transnational complications of fisheries, and educative conservation programs. Our results highlighted the perceived importance of fishing agreements, which may fill in gaps for management where there is limited enforcement from regional authorities.

The codebook, (Table 2-6) shows the major codes, their explanation, inclusion criteria, exclusion criteria, the most poignant quotes, and finally how many times that code appeared across the 14 interviews. Although we identified four major codes for strengths and assets, there was supplementary information that was not coded yet needs to be mentioned.

Cultural value was discovered through conversations with the NGOs Omacha and Natütama, who told us that every year in November, there is an event called The International Festival of Amazonian Popular Music: El Pirarucu (*Arapaima*) de Oro. The festival, which celebrates the tri-national region's cultural music, is named after this emblematic species for its importance as a muse to many traditional musical compositions. Further, besides being a food commodity, *Arapaima* scales and skin are used for decorative purposes such as jewelry and handbags; these products are both culturally and economically significant to the indigenous groups of the region.

The economic value was also measured to a small degree by mentions of an individual *Arapaima* bringing in a substantial amount of money for low-income communities of fishermen. We informally asked the price of *Arapaima* at 13 different

sellers' stands in the Leticia fish market and calculated an average of 15,000 pesos (at current exchange rate it is $5.00) per kilo. This price is three times higher in comparison to the price per kilo of another popular fish, Bocachico (*Prochilodus nigricans*), estimated at 5,000 pesos ($1.67) per kilo. Finally, an adult individual of *Arapaima* is known to feed several families in one sitting or one family for one to two weeks. These reports provide support for why people of the region showed such an overwhelmingly positive response (Fig. 2-2) toward *Arapaima*.

2.4.2 TOURIST SURVEYS

Tourist responses to our survey provided another view of human-wildlife interactions with *Arapaima*. For example, animals were the most popular response to what tourists were most excited to see. However, only 3.33 % of participants chose *Arapaima* as the animal they were most excited to see. Since we knew *Arapaima* was a popular dish in tourist restaurants, we inquired whether participants had tasted the fish, to which 52.82% had responded yes. However, when probed further whether they knew where the specimen they had been served was caught or brought from aquaculture tanks, 74.64% answered no.

To understand the perceptions of management actions and conservation issues of *Arapaima* among tourists, we asked four nested questions. First, we asked had tourists heard of conservation issues about *Arapaima*. The results were split nearly in half, with 50.49% answering yes and 45.50% no. For those that responded yes, we then inquired about their awareness of conservation issues; the most common issue mentioned was that *Arapaima* is threatened/going extinct (54%), followed by it being overharvested (34%), and that there were prohibitions on fishing the species (12%). Next, we asked if tourists

had heard of management practices related to *Arapaima*, to which 53.92% answered yes, and 46.07% answered no. The most common regulations tourist participants had heard of were seasonal fishing bans (56%), minimum capture sizes (14%) and community-based management (8%).

Table 2-7. Codebook for Key Informant Interviews

CODE NAME	*Detailed description /definition*	*Inclusion criteria*	*Exclusion criteria*	*Typical exemplars*	*Atypical exemplars*	*Count of Code Appearance*
POOR ENFORCE	*Arapaima spp.* fishery is decreasing due to insufficient enforcement from authorities.	Lack of fish due to regional agencies not being present, community having to fulfill the role of regulators	Unity, connectedness,	"Sometimes AUNAP regulates things (at the port of Leticia)".	" In the Lagos de Tarapoto the only way to control what is fished/ extracted is because of the fishing agreements".	19
AQUA CULTURE	Gov't support for aquaculture development is wanted	More options for economic benefit, Construction and monetary resources	Proper government structure, Obtainment of supplementary income is easy	"Yes I would like to have aquaculture ponds". "I don't think it would be possible to have aquaculture without CorpoAmazonia (regional environmental authority) support."	"I would like Puerto Nariño to have more development", (when talking about other options to fishing).	10
TRANS NATIONAL	Ease of access between aquatic environments allows for different groups to cross geopolitical borders and extract resources.	Crossing the Amazon river to access fishing areas, selling in transnational markets.	Regulation across borders, Mutual understanding between nations	"The Peruvians from Caballococha come and fish everything during the high-water season… there are more entrances into the lakes (Tarapoto)."	"All of us are culpable in crossing the river and taking what is not ours… (but) we are all Tikuna (so it is ok).	13
EDUCATION-CONSER	Through education there have been positive changes in fishery extraction.	Local conservation education or tourism conservation education indirectly tell us how the fishery is doing.	Education brings issues, Conservation ineffective	"The children that come to our conservation education program (unknowingly) tell us who catches *Arapaima spp.* …. We can then approach the adults and explain that they shouldn't do that when the fishing season is not in place."	N/A	3

2.5 DISCUSSION

This study aimed to understand human-wildlife interactions between a charismatic freshwater species, *Arapaima*, and the general public (residents and tourists) in the tri-national region of the Colombian Amazon. Through semi-structured surveys and interviews, we investigated the attitudes and perceptions, strengths, and assets for management of *Arapaima.* Our study suggested that *Arapaima* fisheries were positively regarded by residents, yet they feel that limited enforcement of environmental regulations by authorities in the region and overfishing may be negatively impacting population trends. Our study adds information on *Arapaima* from an understudied, transboundary area using a social-ecological lens, with hopes of contributing ideas for improved management strategies.

Riparian human populations are key to understanding species population trends and management through their fishing and harvest activities. In terms of habitat or where people have seen *Arapaima*, we did not expect the most common answer in Leticia to be in human-dominated areas, such as markets and aquaculture facilities. This result exemplifies that, as a growing urban area, people in Leticia that are not directly involved in fishing are at risk of the "extinction of experience." This concept is becoming more prevalent in social-ecological studies and is explained as people or communities not connecting with nature and losing an affinity toward species and natural areas (e.g., Heinen et al., 2017). The fact that many are threatened, and the extinction of experience, could potentially facilitate their eventual extirpation or global extinction (Soga, Gaston, 2016). This scenario, however, does not seem to be the case in Puerto Nariño, since the most common response of seeing the species was the Lagos de Tarapoto. We attribute

this difference to the fact that Puerto Nariño is a smaller, more rural community with a more significant Indigenous presence, and appears to have a greater cultural connection to fishing. The responses from these questions highlight the difference of knowledge and perception between the two localities. However, our questions on opinion of benefits of *Arapaima* suggest the importance of the species in both Leticia and Puerto Nariño. The responses overwhelmingly revealed how this fish is associated with positive attitudes among local people. From this result, we can understand not only the link but also the fragility and potential loss of the human-wildlife link in the absence of effective fisheries management.

Ecological responses reported that local communities perceived *Arapaima* populations to be on a declining trend. We subsequently made connections between the decline, those responsible, and prospects for fishers. The results from general residents' surveys suggest that the decline in fish populations is caused by fishermen. This is in response to local necessity from the community and increased commercialization influences given high demand for *Arapaima* locally and in other urban areas. Thus, when we targeted key informants and received a considerable mention of aquaculture, we suspected that there might be a chain of events leading more fishers to want to pursue aquaculture and other sources of income. However, aquaculture in Colombia is expensive; there are permit costs for land and water allocation, general aquaculture registry cost, and high cost of feed (OECD, 2016). In Puerto Nariño, an agriculture/fishing dependent community that has a mean monthly income of around $138, (representing 65% of the legal minimum wage in Colombia), aquaculture may not

be possible without government assistance. More fishers may turn to commercial fishing to sustain their families (Osorio, 2009).

The issues of commercialization are also influenced by the tri-national nature of this region. We were told that Brazil has a well-developed *Arapaima* aquaculture industry that is actively competing with smaller Colombian-based companies. In Leticia, we observed numerous fishing boats with freezers, which is a sign of commercialization as fishers can stay out longer and get a higher catch per unit effort (OECD, 2016). Several times when we asked the price and location of obtainment of an *Arapaima* individual that was brought in to the Leticia fishing market, people said Brazil, but whether it was wild or farm-raised, was unknown. Based on our results, we suspect that there is a growing sentiment from residents to consider *Arapaima* aquaculture or commercialization. However, the potential social-ecological impacts of these decisions are not well-known and would require monitoring.

Commercialization is also supported by tourism. As this region has experienced an increase in the number of people visiting, the demand to taste the largest scaled fish of the Amazon will also likely increase among tourists. Our results demonstrated that information on conservation issues such as population declines and types of management are not being disseminated to tourists. Without proper environmental education programs and information on sustainably caught or farm-raised *Arapaima*, the demand for this species in tourist restaurants will likely increase.

A unique challenge for conservation that we documented was the growing resident sentiment that there was limited presence of authorities in the region regarding fisheries. Colombia has a national fishing ban on *Arapaima* from October 1st until March 15th of

every year, as instituted and regulated by the Autoridad Nacional de Acuicultura y Pesca-AUNAP (Mendoza Rojas & Sebastian, 2018; Mora et al., 2018). This government institution has a regional authority, yet we came to discover from our key informant interviews that at the moment they only had two staff located in Leticia for the entire Department of Amazonas. Besides this national and regional regulation, there are also local fishing cooperatives and agreements that were put into effect. Since 2011, for the Lagos de Tarapoto there has been a ban on fishing *Arapaima* and several other species until 2021, and limited usage of nets and other fishing techniques. These agreements were facilitated by Fundación Omacha (refer to Figure 2-6 for the picture of the local fishing agreements of the Lagos de Tarapoto; (Osorio & Escobar, 2017). As for Lagos de Yahuarcaca, *Arapaima* fishing is prohibited indefinitely (PESCA, 2016). Considering the tri-national context, Peru has a fishing ban from October 1st until February 28th of every year, and Brazil has an indefinite ban on fishing *Arapaima* in wild areas (Crossa et al., 2011; Macnaughton et al., 2015). When we asked if Colombian residents of the region knew that regulations existed across differing scales, national and international, we got results that aligned with our predictions of mixed knowledge. Colombian residents did know more about fishing regulations in their nation, acknowledging the fishing agreements, the national fishing ban, and even to a much lesser degree NGO participation and regional authority in management. Tri-nationally, there did not seem to be a consensus, as more participants agreed that there were not the same regulations across borders although there might be coordination among the authorities of the region. Residents reported that this coordination could be related to the presence of patrolling

military ships from the surrounding nations, which could be misinterpreted as fishing authorities.

It was our key informant data that revealed to us both areas of improvement and strengths in the current management approach. A lack of enforcement was a trend in responses that we documented both in the surveys and key informant coding. Fishers described how they have had to start policing each other since AUNAP presence was deemed as low. Although community policing has been successful in other co-management strategies of Amazonian fisheries, it appeared to be a complaint from the residents interviewed Colombia (Bremner & Lu, 2016; Clarke, 2016; Fernandes, 2006; Mora et al., 2018). Residents reported that they would like more government help in terms of enforcement; they mentioned the existence of laws and rules but no real punishment for illegal offenses. Further, transnational exploitation reportedly is creating challenges for fisheries management. Colombians said they noticed unknown boats, from what they believe to be Peruvian fishermen, coming into the Lagos de Tarapoto, especially during high waters when there are more entrances to the lakes. These boats reportedly extract resources, forcing fishers and communities to become authoritative enforcement figures.

The strengths that we identified through our study were local conservation efforts, such as the Fishing Agreements, are appearing to contribute positively to local management of *Arapaima*. As previously mentioned, two small but key organizations, Fundación Omacha and Natütama, have changed the paradigm for the conservation of fisheries in Puerto Nariño. Through key informant interviews, we documented proof that local organizations can hold weight and strengthen resource management conditions.

Besides facilitating the designation of the Lagos de Tarapoto as a Wetland of International Importance under the Ramsar Convention and the fishing agreements put into place in 2011, Fundación Omacha also actively manages the 'balsa' for the fishermen cooperative and collects data on catches for species' census studies (Osorio, Escobar, 2017; Trujillo, Duque, 2014). Natütama employs a community-wide education program that allows for the dissemination of information on the importance of following regulations. It also can monitor illegal fishing indirectly by word of mouth from the young participants of this program. Alternatively, in the Lagos of Yahuarcaca near Leticia, there seemed to be more support from regional agencies (SINCHI, National University of Colombia - Amazon campus) for the fishing accords, yet there is a lack of unified management. When we spoke to the head of the fishing cooperative, he instructed us that in that same year (2018), there had not been any fisheries monitoring. It may be that the more urban pressure of Leticia is influencing fishing cooperatives and disengaging them, without the continuous support of agencies. Comparatively, Puerto Nariño, where Omacha and Natütama have more investment in conservation and mostly need more resources to adequately enforce regulations.

2.5.1 RECOMMENDATIONS FOR MANAGEMENT

Our study was primarily based on human-wildlife perceptions and interactions with *Arapaima*. On the basis of our work in the region and results of our study, we offer a few suggestions for management of *Arapaima* in the region: (1) Linking social studies such as this one to fishery census data, (2) Considering *Arapaima* as a flagship species for fishery management in the Amazon, (3) Bringing together all stakeholder

representatives to address effective enforcement, and (4) Facilitating transnational regulation of fisheries.

For our first recommendation, our discussion touched upon the need for more monitoring. This is an issue that many rural communities face with a need for accurate and continuous fish abundance counts. Through our survey, we identified the key areas where *Arapaima* was found, and that small local organizations attempt to keep records of fishers catches. In order to fully understand population trends, we suggest combination of available records from all sources and creation of a population model for past, present and future trends. Without understanding the ecological and geographic distribution of this species; effective protection will be limited.

The second recommendation involves designating *Arapaima* as a flagship species/genus? Based on our study's findings that it is positively regarded among riparian human populations in the Colombian Amazon. Flagship species are selected based on public perception to boost awareness of conservation issues. Although this region has the pink dolphin, river otters, and other animals, there has yet to be a fish species that represent fisheries management. *Arapaima* fits many of the flagship criteria as put into place by previous authors (Bowen-Jones, Entwistle, 2002). Background research supports this species' ecological flagship criteria: sizeable geographic distribution, a declining conservation status (potentially threatened), and its ecological role as a top predator (Home, Keller, et al., 2009; Sergio et al., 2008; Verissimo, MacMillan, et al., 2011). Our study's results support this species' social flagship criteria: high usage and cultural significance among local communities for protein and artisanal crafts, charismatic due to its large size, a fiery red tail, positive associations, and traditional knowledge from

indigenous fishers. Except for the tri-national area where there is so much fishery movement that the designation would highlight many of fisheries management issues that the countries share, *Arapaima* would not serve well as an international flagship as tourists do not generally recognize this species.

Flagship designation would also require stakeholders to come together in a forum to discuss enforcement policies. As our study has shown, enforcement seems to be a weak component of fisheries management in the region. Other small-scale fisheries around the world also have this problem, and it often stems from the lack of communication between regulatory entities and the community (Armitage et al., 2007; Castello et al., 2013; Cavole et al., 2015; Oviedo, Bursztyn, 2016). Although community-based management has been working, our study showed it might not be enough for the protection of *Arapaima*, especially in the transboundary context of our study area*;* there needs to be clear and severe consequences for illegal harvesting of *Arapaima*. This condition would mean that not only would governmental authorities have to sit down and openly discuss issues with the people, but NGOs and international institutions would need a place at the table to discuss options for enforcement to reduce illegal exploitation.

Finally, as briefly mentioned in the latter paragraph, international cooperation needs to set in place a concrete plan to address resource extraction across boundaries. By the three nations having different regulations on the fishing within the same watershed, and the lack of awareness by people regarding said regulations in this tri-national region, illegal activities could increase substantially with commercialization. Coordination and dissemination of information on fisheries management to the public may be possible,

especially if there is a species like *Arapaima* leading the front as symbolic for the region (e.g., flagship designation).

These recommendations are nested within one another and require the effort of many entities to be successful. This study is hopefully the first of many on perceptions and attitudes of *Arapaima* and other socially and ecologically significant freshwater fish in the Colombian Amazon.

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CONCLUSION

Small-scale fisheries in the Amazon hold a lot of significance both culturally and economically but face the surmounting threats of climate change and human population growth. As my thesis has shown, in the case of the largest scaled freshwater fish, *Arapaima spp.*, the most significant threats are human-induced. From overharvesting to commercialization to lack of communication between environmental regulatory agencies and the public, the negative dynamics between human and natural systems as related to *Arapaima* must continue to be explored in order to ensure effective conservation and management. We also presented some positive aspects of the human-wildlife interaction from the standpoints of cultural significance, nutritional value, and tourism value of *Arapaima*, all possible factors that could motivate locals to be actively engaged in the preservation of wild populations.

In Chapter One, through a systematic exploration of research trends in the past 50 years of the literature on *Arapaima,* I identified significant gaps that need addressing. After categorizing articles, I found that most research is taking place in Brazil within the Amazon mainstem, which contains the most significant urban center of the Amazon, Manaus, and a highly significant reserve, Mamirauá Sustainable Development Reserve. This result was surprising, considering *Arapaima* is important and geographically spread throughout the Amazon; thus, there is a need for more studies spanning much larger geographic areas throughout the region. A lack of uniformly distributed studies is also

significant, as the taxonomy of this species/genus is highly debated, and, without better information on gene flow, protection of threatened populations will not be effective at larger scales.

In Chapter One, we also discovered that there is effective management of *Arapaima*, and it comes in the form of co-management. Through co-management, local communities took control of their resources and set harvesting plans that are sustainable and in conjunction with regional authorities. It is through open communication and continuous adaptation that local communities can help ensure the longevity of fishing stocks. Studies on this management technique are relatively new, only appearing in the literature over the last 20 years and thus lack long term monitoring for effectiveness.

The results of Chapter One led me to study a unique case for *Arapaima* fisheries management in the tri-national region of the Amazon Trapezium of Colombia. From a socio-ecological perspective on fisheries, I discovered that residents know the population is in decline and that the species brings benefits and positive attitudes, but also that management is lacking in several places. Residents want more enforcement from regional authorities. Local conservation programs are helping but are not enough to manage the entire fishery, and they primarily address threats from commercialization and the ease of exploitation across borders. Decentralization of small-scale fisheries is one step towards sustainable fisheries management, but it depends on adequate regulatory support.

Through this research and writing process, I was deeply moved by the want, need, and knowledge of residents in the region to improve *Arapaima* fisheries. Historically, management decisions have been made without consideration of the public. From my study, I no longer think that is possible. In areas such as the Amazon, the natural and

human systems are so deeply connected that it would be disastrous to not consider people's emotions, opinions, and ideas throughout the process of conservation and management. *Arapaima* is just one example of human-wildlife interaction, but I hope that the lens and approach I have used to better-understand it in this study can influence and change the way others consider studying wildlife in areas of high resource extraction.

APPENDIX

Management of the threatened *Arapaima* spp. in the Colombian Amazon

General Resident Survey

1. What is your age?

2. What town/city do you live in?
   Probing for tourist or native*

3. Where are you originally from?

4. How long have you been living here?

5. What is your profession?

Basic Ecology

6. Where have you seen *Arapaima?*
   a. Main river channel
   b. Tarapoto Lakes
   c. Lakes of Yahuarcaca
   d. Other Lakes _____
   e. Other river/streams_____

7. What do *Arapaima* eat?

8. Do *Arapaima* migrate?

Perception

9. Which of the following emotions do *Arapaima* evoke?
   a. Pride
   b. Fear
   c. Hate
   d. Happiness
   e. Respect
   f. Sadness

10. Why?

11. Do you believe *Arapaima* brings economic benefit?

12. IF YES, What is the economic benefit?

Conservation and Management

13. (Applicable to those living in the Colombian Amazon for more than a few years) What have you noticed about the abundance of *Arapaima* in the Colombian Amazon*?*
    a. In decline
    b. Non-existent
    c. Increasing
    d. Stagnant

14. (If in decline) Who do you believe is responsible for the decline of population of *Arapaima?*

15. Why do you believe it is in decline?
    a. Food source
    b. Tourism
    c. Tradition
    d. Other_____

16. Do you think tourism influences *Arapaima* population? If YES, how?

17. Do you know of any national, regional or local regulation on the fishing of *Arapaima gigas?* If Yes, Which one?

18. Do the same regulations of fishing *Arapaima* apply within Brazil, Peru, Colombia? If NO, probe how are they different?

19. *If NO from previous question* Do you know if there is any coordination between authorities of different countries regarding the fishery?

20. If YES from previous probe which are they
    a. Minimum fishing sizes
    b. Seasonal bans
    c. Enforcement
    d. Other_____

21. Do you believe there should be more regulation or more enforcement or both on the fishing and commercialization of *Arapaima?*

22. Depending on answer, probe why?

Tourist Survey Questions

1. Age

2. Gender

3. Where are you visiting from?

4. How long have you been here?

5. Reason for visiting the area?
   A) Business
   B) Tourism
   C) Family

6. If tourism on last question, what are you most excited to see?
   A) Amazon River
   B) Indigenous communities, cultural experience
   C) Animals
   D) Other_____

7. If animals, which animal are you most excited to learn about?
   A) Pink Dolphin
   B) Anaconda
   C) Pirarucu, *Arapaima*
   D) Sloth
   E) Monkeys
   F) Giant River Otter

8. Have you tried any of the local fish or bushmeat?

9. If yes, What?

10. Have you heard of any issues pertaining to the fishing of *Arapaima* in the region? If YES, which one and describe.

11. Have you heard of any conservation measures related to the *Arapaima*, Pirarucu? If YES, which one and describe.
    A) Seasonal fishing bans
    B) Community-based management
    C) Aquaculture
    D) Minimum fishing sizes
    E) Other_____