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How illegal are tropical small-scale fisheries? An estimate for arapaima in the Amazon

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ABSTRACT

Illegal fishing is a problem that affects about 30% of the world fisheries capture, but most studies on the topic to date have focused on large-scale fisheries, leaving tropical small-scale fisheries nearly unstudied even though they possess many features that foster illegal fishing. This article investigated illegal fishing practices for *Arapaima* spp. in the Lower Amazon Basin, using semi structured interviews and catch and enforcement data. It was found that 77% of the arapaima landings were illegal, with most specimens being caught below the minimum size limit or during the closed season. Also, 86% and 43% of the interviewees stated they have observed declining trends in the landings and size of arapaima, respectively. Finally, spatial and temporal patterns of arapaima landings were not matched by rule enforcement activities. Inadequate enforcement of management rules, combined with geographical dispersion of fishing activities, appear to be a key factors allowing for high levels of illegal fishing, which contribute to the decline of fish populations.

1. Introduction

Illegal fishing – defined as fish catches that contravene international or national laws – is a problem that affects about 30% of the world fisheries capture (Agnew et al., 2009). Illegal fishing causes annual global monetary losses of up to $ 23.5 billion dollars, undermining the effectiveness of fisheries management, causing adverse effects to exploited fish populations and associated livelihood and food security services (FAO, 2001). Although attention to illegal fishing has grown recently, little attention has been paid to illegal fishing practices in small-scale fisheries of tropical developing countries.

Many characteristics cause small-scale fisheries in tropical developing countries to possess high levels of illegal fishing. Tropical developing countries possess large numbers of small-scale fishers that live in geographically dispersed communities where alternative sources of employment are generally scarce (FAO, 2010; Pauly, 1997). Governments in these regions have insufficient human and financial resource to invest in rule enforcement, so compliance with management rules is generally very low (Mahon, 1992; Sagar, 2000). These biodiverse regions possess multispecies fisheries where various species are often simultaneously harvested (Mahon, 1992). Thus, the high monetary value of some key commercial species means fishers have incentives to catch them despite catch restrictions (Pauly et al., 2002; Pauly, 2006), causing impacts on other species (Dayton et al., 2002; Kura et al., 2004; Raby et al., 2011). Data on the illegality of tropical small-scale fisheries is necessary because they produce over half of the global catch (Berkes et al., 2001).

The present article investigated illegal fishing practices for *Arapaima* spp. in the Amazon Basin—a typical tropical small-scale fishery. Amazonian small-scale fisheries are often highly illegal due to the poor performance of management regulations and insufficient institutional capacity to promote co-management with fishing communities (Castello et al., 2009, 2011a; McGrath et al., 1993). Amazon fishing communities are home to riverine fishers who are usually marginalized by governmental institutions because of their low levels of formal education (Agrawal and Gupta, 2005) and the geographically distant nature of their communities

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from (urban) centers of policy making (Pauly, 1997; Castello et al., 2013). Nevertheless, fishing is one of the most important resource extractive activities of the Amazon, with small-scale fisheries contributing about 60% of the total catch (Bayley and Petrere, 1989). These fisheries are multispecies, exploiting about 100 species (Barthem, 1995; Roubach et al., 2003) through the use of several fishing gears, such as gillnets, hook and lines, and harpoons (Castello et al., 2013). These fisheries provide the main source of animal protein for local populations, with per capita consumption estimated between 40 and 94 kg/year, while the world average is 16 kg/year (Isaac and Almeida, 2011).

Arapaima are the historically most important fish of the Amazon basin (Veríssimo, 1895) and the largest fish with scales, growing up to 3 m in total length (TL) and 200 kg in weight (Castello and Stewart, 2010; Arantes et al., 2010). Although multiple species of arapaima have been described, their taxonomy in the study area is unstudied (Stewart, 2013a,b). Because arapaima are obligate breathers, they are traditionally harvested by riverine fishers using harpoons at the time when they surface to breathe (Castello, 2004). Arapaima harvests in most of Brazil are controlled through a closed season (1st December to 31st May) and a minimum size limit (150 cm of total length, TL), which is close to their known TL at first sexual maturity (Arantes et al., 2010). In the States of Acre and Amazonas, arapaima fishing is now banned, due to overfishing (Castello and Stewart, 2010). However, these regulations have been largely ignored by fishers because of the inability of the Brazilian government agency (IBAMA) to enforce them effectively (Castello and Stewart, 2010). Landings and the average size of capture of arapaima have thus decreased over the last few decades (Isaac et al., 1998) with the population in the basin today estimated to be only 13% of their unexploited abundance (Veríssimo, 1895; Castello et al., 2011b). Thus, arapaima are currently largely overfished and even undergoing local extinctions in some regions (Castello and Stewart, 2010; Castello et al., 2014). This situation has led *Arapaima gigas* to be listed in Appendix II of the Convention on International Trade of Endangered Species of Wild Fauna and Flora (Castello and Stewart, 2010), as well as in the IUCN Red List of Threatened Species as 'Data Deficient' (World Conservation Monitoring Centre, 1996).

Compliance with arapaima size limit and closed season is key to sustainability because the harvest of reproductive or sexually immature individuals adversely impacts recruitment (Castello et al., 2011c). Studies around the world and in the Amazon suggest that compliance with regulations of size and season are among the most important steps to ensure the sustainability of exploited fish stocks (Myers, 1998; Castello et al., 2011b). As such, depleted populations of arapaima have been shown to grow at a rate of 25% in abundance per year when closed season and size limit regulations are followed (Arantes et al., 2006). Consequently, some fishing communities have been recovering overexploited populations of arapaima by improving compliance with management rules and developing community-based fisheries management schemes (CBM; McGrath et al., 1993; Arantes et al., 2006; Castello et al., 2009, 2011b).

The objectives of this study were to: (i) quantify levels of illegal fishing for arapaima; (ii) evaluate the sustainability of arapaima populations and associated fishing practices; and (iii) assess if deficient monitoring and enforcement activities can explain illegal fishing levels.

2. Methods

2.1. The study area

The study was conducted between January and March, 2010, in the lower Amazon region, in the cities of Santarém, Alenquer, Curuá, Monte Alegre, Obidos, Oriximiná and Prainha, in Pará State, Brazil, near the confluence of the Amazon and Tapajós rivers (02°25′11″S, 54°43′16″W; Fig. 1). The region is a major fishing ground (Isaac and Ruffino, 2000). The main geographic feature is the floodplain, known as *várzea*, which comprises a mosaic of seasonally flooded forests, lakes and canals adjacent to the main river channel (Irion et al., 1997). Arapaima are targeted by local fishers living in riverine communities for sale in urban markets (Castello and Stewart, 2010; Fig. 1).

2.2. Data sources

We interviewed the 35 most important commercial fish traders in the study area using a semi-structured questionnaire that aimed to quantify over the course of a year: (i) total weight of arapaima trade (kg) per month, (ii), place of harvest (i.e., riverine communities), and (iii) size of the individuals (classified as juvenile or adults, based on the minimum size limit of 150 cm TL). The questionnaire also aimed to identify long-term trends in both landings and body size of arapaima (decreasing, increasing or stable). This information

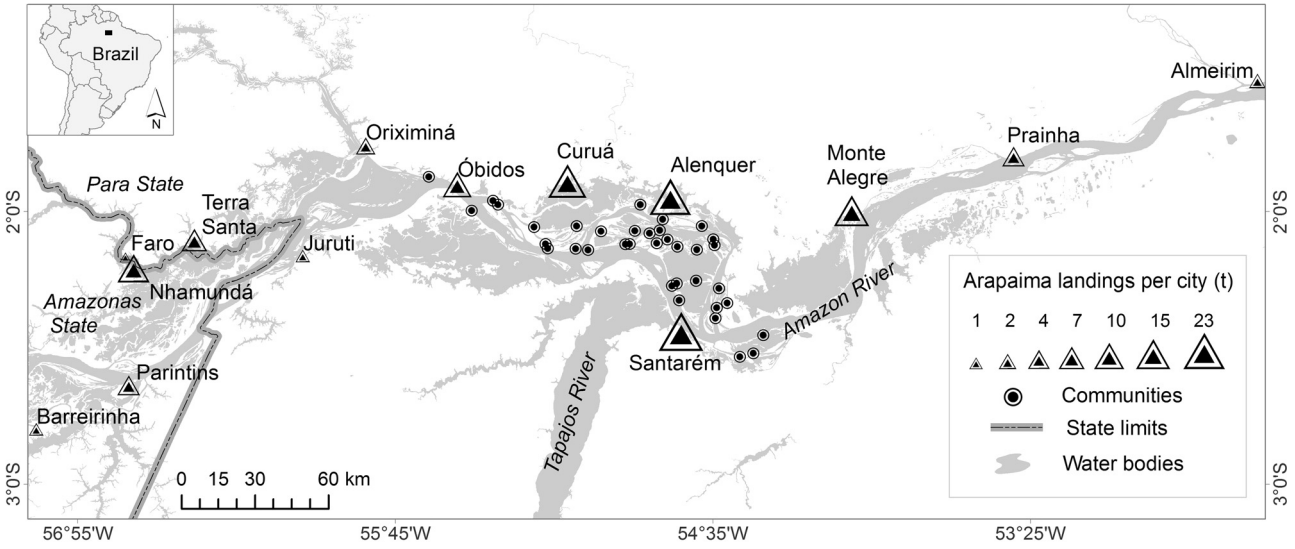

Fig. 1. Arapaima landings in the lower Amazon.

Table 1
Arapaima landings (kg) per city and the number and frequency of enforcement activities in these cities.

Cities	Total landing		Enforcement	
	(kg)	(%)	(*n*)	(%)
Alenquer	11,020	11	2	2
Almeirim	1370	2	4	4
Aveiros	579	1	0	0
Curuá	8860	9	0	0
Faro	579	1	0	0
Itaituba	579	1	2	2
Juruti	1158	1	3	3
Monte Alegre	7528	8	11	10
Óbidos	6949	7	11	10
Oriximiná	2895	3	4	4
Prainha	4053	4	0	0
Santarém	36,481	37	71	66
Terra Santa	4633	5	0	0
Barreirinha (Amazonas)	1158	1	*	*
Nhamundá (Amazonas)	6949	7	*	*
Parintins (Amazonas)	4053	4	*	*

* No available data.

is relatively reliable given that the traders were assured their identity would be kept anonymous. Monthly landings of arapaima were estimated based on the total weight of arapaima traded in each month (January to December), considering the two size classes. To determine the structure of the catch, we also independently weighed 509 arapaima caught by 42 fishers in neighboring riverine communities, and used the data to quantify the proportion of harvested individuals below and above the minimum size limit of 150 cm of TL (Juvenile and Adults). Arapaima weight data measured in situ were converted to TL estimates using morphometric relationships (Martinelli and Petrere, 1999). Finally, we collected data on frequency and location of enforcement activities performed by the Brazilian Institute for Environment and Renewable Resources (IBAMA) during the same time period for comparison with data on arapaima landing and place of harvest (Fig. 1, Table 1). The local IBAMA agency, which is based in Santarém, is responsible for the enforcement activities related to several types of natural resources (e.g. logging, fisheries, turtle and marine mammals hunting) in dozens of cities in an area much greater than that encompassed by this study.

2.3. Data analysis

To quantify the level of illegal fishing for arapaima, we calculated the percentage of landed individuals during the closed season and below the minimum size limit. Amounts in total weight traded between June and November represented the legal catch, and amounts traded between December and May represented illegal catch. Quantities below the minimum size limit represented illegal catch and over this size represented legal catch.

To evaluate the sustainability of arapaima populations, we quantified interviewee responses indicating 'decreasing' trends in body size and landings of arapaima. To evaluate the sustainability of fishing practices, we compared the modal length class in landings against the known size of first sexual maturity for arapaima of 157 cm TL (Arantes et al., 2010).

To assess if deficient monitoring and enforcement activities can explain illegal fishing levels observed, we carried out two analyses. In the first, we used a spatial approach that compared the pattern of production and landings against data on IBAMA's enforcement activities. In the second, we used a temporal approach that compared total weight of arapaima landed per month in Santarém with the number of IBAMA's enforcement activities in each month. We assessed whether there is a match between the cities where there were enforcement activities and the production and landing sites of arapaima. The geographical scale used was "cities" because IBAMA agents record information by city, not by communities or fishing areas.

3. Results

Approximately 77% of the arapaima landed in Santarém in 2010 was illegal. The total amount of arapaima landed was 99,020 kg, of which 53% (52,270 kg) was composed of juveniles caught during fishing season (Figs. 2 and 3). Twenty-four percent of the catch (23,830 kg) was caught during the closed season and was composed of juveniles (16,566 kg) and adults (7264 kg).

Eighty-six percent of the interviewees stated they have observed declining trends in the landings of arapaima, and 43% of them stated the mean body size of arapaima has been decreasing in recent years. Only 9% of interviewees stated they have not observed changes in the landings or body sizes of arapaima in recent years. The modal class of the arapaima harvested in riverine communities was 120–129 cm TL (Fig. 3), which is less than the length of first sexual maturity of 157 cm TL. Considering that 77% of the arapaima landed is illegal and likely declining in terms of total amounts and mean body size and landings, it would seem probable that illegal fishing practices have been playing a role in the overexploitation of arapaima.

The spatial dispersion of enforcement activities did not match the associated patterns of arapaima landings: 66% of the enforcement activities occurred in Santarém, which accounts for only 37% of all landings in the region (Table 1). The remaining 34% of the

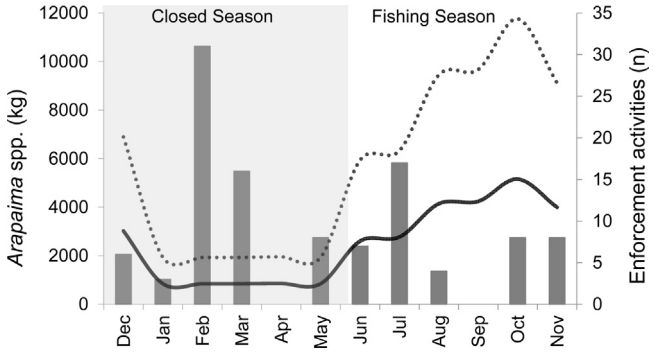

Fig. 2. The seasonality of arapaima landings and enforcement activities. Bars represent the number of enforcement activities. Dotted line indicates monthly landings of arapaima per juvenile class (<150 cm TL) and continuous line indicate adults (>150 cm TL) landings in Santarém, Brazil.

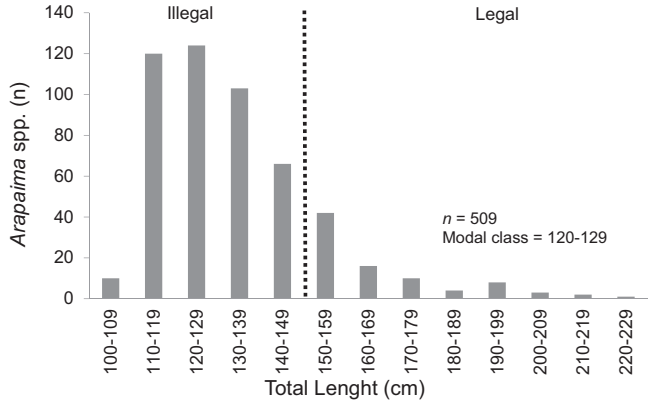

Fig. 3. Total length (cm) frequency of 509 landed arapaima. Dotted line indicates the size at first capture allowed by the government (>150 cm TL).

enforcement activities occurred in seven other cities, which were responsible for only 33% of total landing. There were absolutely no enforcement activities in five cities that accounted for 20% of all landings (Table 1). Approximately 12% of the arapaima production came from the State of Amazonas where arapaima fishing was banned. Such spatial mismatch between enforcement activities and landings was also observed temporally: only about 40% of all enforcement activities occurred when 76% of the production was landed, from June to November (Fig. 3). Most enforcement activities (60%) occurred during the closed season (December to May), when landings of arapaima are naturally low because high river water levels make it hard to catch them.

4. Discussion

The level of illegal fishing of arapaima observed in Santarém of 77% was more than twice the world average of 30% (Agnew et al., 2009). This estimate of illegal fishing in a tropical small-scale fishery contributes to a small but growing number of studies on this important topic (Upton and Vangelis, 2003; High Seas Task Force, 2006). Unreported catches were quite significant in the archipelago of Raja Ampat, Indonesia, ranging from 43% in tuna fisheries to up to 93% in anchovy fisheries (Varkey et al., 2010). Unreported catches of cod in the eastern Baltic Sea were about 35–40% higher than officially reported between 2000 and 2007, though levels of underreporting declined to 6–7% in 2008–2009 (ICES, 2014). In the mid-1990s, the illegal and unregulated fishing of the patagonian toothfish *Dissosticus eleginoides* reached four times the regulated catch in 1997 (Agnew, 2000). The level of illegal fishing of arapaima observed in the Amazon is the highest reported in the literature, though arapaima probably represents an extreme case of illegal fishing in the Amazon floodplain.

In line with previous studies indicating that illegal fishing adversely affects the sustainability of exploited fish populations (Agnew, 2000; Freire et al., 2002), most interviewees reported landings and average body sizes of arapaima to be declining. Arapaima fishing during the closed season (Section 3, Fig. 2) prevents the reproduction of sexually mature individuals, and fishing of juveniles removes potential spawners from the population (Arantes et al., 2010; Castello et al., 2011c). The predominant modal class of catch (120–129 cm TL; Fig. 3) below the size at first sexual maturity (157 cm TL) is a common indicator of overfishing (Hilborn and Walters, 1992; Froese, 2004). The decline in arapaima landings reported here is in agreement with another study that documented the decline and local extinction of arapaima populations in the study area (Castello et al., 2014). Overfishing led to the depletion of arapaima in 76% of 41 riverine communities in the study area, and caused their local extinction in 19% of the communities (Castello et al., 2014). The overexploitation and depletion of arapaima populations in the study area is thus here hypothesized to be explained, in part at least, by the observed high levels of illegal fishing. Arapaima are especially vulnerable to overfishing because of their relatively late maturity, large body size and long life span (Arantes et al., 2010; Castello et al., 2011c).

Geographic regions where government capacity is underdeveloped are particularly vulnerable to non-compliance with management rules (Österblom et al., 2010). The mismatch between enforcement activities of management rules and spatial and temporal patterns of arapaima landing is here suggested to be a key cause of illegal fishing. Enforcement activities were generally inversely related to the patterns of arapaima landings (Section 3, Table 1), allowing large amounts of illegal arapaima to be commercialized (Section 3, Table 1). This phenomenon was particularly evident in the city of Faro, which is adjacent to Amazonas State, where arapaima fishing was banned. Landings of arapaima in Faro were disproportionally larger than in cities of same size in terms of human population, largely through the import from Amazonas State into Pará State of illegal arapaima (Fig. 1). Furthermore, the lowest enforcement effort occurred at the time with the greatest landings, between June and November. Lack of compliance with size and seasons regulations degrades the capacity of fish populations to sustain fishing pressure and recover from overexploitation (Myers, 1998). Because the majority of arapaima fishing is not monitored, the observed high levels of illegal fishing can be expected to continue to undermine arapaima populations, endangering the diversity of arapaima species (Castello et al., 2014).

The present study showed that inadequate rule enforcement, combined with geographical dispersion of fishing activities, appears to be a key factor fostering high levels of illegal fishing in tropical small scale-scale fisheries. This is a major problem because the tropics are home to a large share of the world's biodiversity and the fastest growing human populations. Although there is a need for further studies on the topic, there is also an urgent need to control illegal fishing in these tropical regions. Studies worldwide indicate that there are two main ways to improve the levels of compliance with management rules: fostering enforcement activities and co-management initiatives (Ostrom, 1990; Pomeroy, 1995; McKinlay and Millington, 2000). The conservation of small-scale fisheries in the Amazon and in tropical developing countries in general requires addressing both issues.

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