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Artisanal fisheries of the Xingu River basin in Brazilian Amazon

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(With 3 figures)

Abstract

The present study characterises the commercial fisheries of the basin of the Xingu River, a major tributary of the Amazon River, between the towns of Gurupá (at the mouth of the Amazon) and São Félix do Xingu. Between April, 2012, and March, 2014, a total of 23,939 fishing trips were recorded, yielding a total production of 1,484 tons of fish, harvested by almost three thousand fishers. The analysis of the catches emphasizes the small-scale and artisanal nature of the region's fisheries, with emphasis on the contribution of the motorised canoes powered by "long-tail" outboard motors. Larger motorboats operate only at the mouth of the Xingu and on the Amazon. Peacock bass (*Cichla* spp.), croakers (*Plagioscion* spp.), pacu (a group containing numerous serrasalmid species), aracu (various anostomids), and curimatã (*Prochilodus nigricans*) together contributed more than 60% of the total catch. Mean catch per unit effort was 18 kg/fisher^{-1}.day^{-1}, which varied among fishing methods (type of vessel and fishing equipment used), river sections, and time of the year. In most cases, yields varied little between years (2012 and 2013). The technical database provided by this study constitutes an important resource for the regulation of the region's fisheries, as well as for the evaluation of future changes resulting from the construction of the Belo Monte dam on the Xingu River.

Keywords: fish production, fishers, fishing effort, fishery yield.

Pescarias artesanais da bacia do Rio Xingu na Amazônia Brasileira

Resumo

Este trabalho teve como objetivo caracterizar a pesca comercial de consumo na bacia do rio Xingu, afluente do rio Amazonas, no trecho entre a cidade de Gurupá (localizada na foz do Rio Amazonas) até São Félix do Xingu, no estado do Pará, Brasil. No período de abril de 2012 a março de 2014 foram registradas 23.939 viagens de pesca, totalizando uma produção de 1.484 toneladas de pescado, obtidas por quase 3.000 pescadores. A análise dos dados oriundos do monitoramento dos desembarques demonstrou que a pesca na região tem caráter artesanal de pequena escala, destacando-se a participação de canoas motorizadas que utilizam um motor de popa chamado "rabeta". Os barcos motorizados atuam somente na foz do rio Xingu e no rio Amazonas. Tucunaré (*Cichla* spp), pescada-branca (*Plagioscion* spp), pacu (várias espécies de Serrasalmidae), aracu (várias espécies de Anostomidae) e curimatã (*Prochilodus nigricans*) perfazem mais de 60% do total capturado. A captura média por unidade de esforço é de 18 kg.pescador^{-1}.dia^{-1} e muda dependendo da modalidade de pesca (tipo de embarcação e arte de pesca), do pesqueiro utilizado e da época do ano. Na maior parte dos casos, não encontramos diferenças nos rendimentos de 2012 e 2013. As informações técnicas geradas são importantes para subsidiar ações de ordenamento pesqueiro, bem como para avaliar futuras mudanças que possam ocorrer na atividade frente à construção da barragem de Belo Monte no Rio Xingu.

Palavras-chave: produção pesqueira, pescadores, esforço de pesca, rendimentos pesqueiros.

1. Introduction

Artisanal or small scale fisheries involve the commercial exploitation of stocks by relatively small vessels and simple techniques, generally by local fishers who depend on this activity for their livelihood. Generally, the production is sold through informal commercial partnerships with a network of intermediaries who sell the catches at regional and even national markets (Isaac and Barthem, 1995; Barthem et al., 1997; Brasil, 2011).

Amazonia is considered to be a key region for Brazilian small-scale freshwater fisheries, due primarily to its enormous diversity of fish species, the largest in the world (Santos and Santos, 2005), as well as the fundamental importance of fish as a source of animal protein for the local riverside communities (Batista and Petrere Junior, 2003; Barthem and Goulding, 2007; Isaac and Almeida, 2011). Artisanal fishery in the Brazilian Amazon basin is thought to involve some 368,000 fishers and tens of thousands of fishing boats (Brasil, 2012). The fishery potential of the region has been estimated at between 425 and 1.500 thousand tons per year (Barthem et al., 1997), although the exact figures are unclear.

Until recently, small-scale fisheries, especially in freshwater ecosystems, have tended to attract little attention from scientists, and even less from the public authorities, which has been, at least partly, related to the inconsistencies and paucity of reliable data on the yield of these fisheries on a national scale (Bené et al., 2009; Castello et al., 2009). The available data on catches have generally been limited to a small number of urban centers over relatively short periods of monitoring (Isaac et al., 2000; Barthem and Fabré, 2004). The lack of more systematic studies is related to the unique characteristics of this activity, which is generally informal, involves a large number of fishers, exploiting vast areas, using a variety of techniques and equipment, and often disembarking their catches in small, relatively inaccessible settlements (McClanahan et al., 2009; Navy and Bhattarai, 2009; Hallwass et al., 2011). In addition, small-scale fisheries are generally run by members of economically underprivileged rural communities, which tend to be socially and politically marginalised (Pauly, 1997).

In the basin of the Xingu River in northern Brazil, fishing is a traditional activity of considerable economic and social importance to local populations. In this region, four principal modes of fishing can be differentiated: (i) the commercial harvesting of a wide range of species for local and regional markets, (ii) the commercial capture of ornamental fishes for aquarium enthusiasts, in particular on the international market, (iii) subsistence fishing by local communities, and (iv) sports fishing, a leisure activity. Commercial fishing for food species is the most important in terms of catch volume (Eletrobras, 2008), even though the harvesting of ornamental fish has become increasingly intense in recent years (Prang, 2004; Ribeiro et al., 2008).

Few scientific studies have focused on the fishery industry in the region of the Xingu River. Surveys of the commercial fishing of food species are restricted to the Environmental Impact Study for the Belo Monte hydroelectric dam (Eletrobras, 2008), the study of Camargo and Ghilardi Junior (2009), and the twice-yearly reports for the Basic Environmental Plan of the Belo Monte hydroelectric dam (2012–2015), available on the licensing site made available by the Brazilian Federal Environment Institute (IBAMA, 2012).

The construction of the Belo Monte hydroelectric dam on the lower Xingu will undoubtedly have a major impact on the use of the region's aquatic resources, and in particular the river's hydrological regime, which will have fundamental consequences for the structure and dynamics of local diverse fish communities (Junk and Mello, 1987; Camargo et al., 2004; Cunha and Ferreira, 2012). In this context, reliable data on local fishery activities and the their special and temporal dynamics will be essential, not only for the monitoring of changes following the damming of the river, but also for the development of the most effective measures for the mitigation of impacts and the management of fishery stocks under expected future scenarios. A systematic understanding of catch levels and the establishment of reference parameters are essential for the development of effective management strategies for fishery stocks (Beddington et al., 2007).

Given these considerations, the present study aimed to characterise the dynamics of the artisanal fisheries of the Xingu River, analysing practices and catch levels prior to the planned impacts on the hydrological conditions of the river. It is hopped that the data presented here will provide a sound baseline for the definition of effective measures and policies for the social, economic, and environmental development of the region following the construction of the dam.

2. Material and Methods

2.1. Study area

The basin of the Xingu River covers a total area of approximately 531,000 km^2, equivalent to 24.5% of the area of the Brazilian state of Pará. The1600 km-long Xingu is one of the principal right-bank tributaries of the Amazon River. Its headwaters are located at 15º S, in the state of Mato Grosso, some 200 km from Cuiabá, and its mouth is downriver from the municipalities of Porto de Moz and Gurupá, in the Amazon estuary. Its principal tributary is the Iriri River, which originates approximately 100 km southwest of Altamira, and the second largest is the Bacajá River, located on the Great Bend, downriver from Altamira (Eletrobras, 2008).

The Xingu runs mostly over rocky substrates, which create an enormous diversity of habitats, marked by considerable variation in current velocities, depths, and topographic features, which create a large number of waterfalls, rapids, and other characteristics, such as anastomosed channels formed among the blocks of stone. The stretch of the river just upstream of the village of Belo Monte is characterised by a sequence of five waterfalls, which form a natural biogeographic barrier that affects not only local navigation, but also the distribution of many aquatic species, most notably of fish. Downriver, the river becomes a large floodplain system, with a wide channel formed over a sedimentary bed, which has created an internal delta lined with cliffs and fluvial beaches. In addition to the annual flood pulse, this stretch of the river is affected by the semidiurnal tidal regime of the Amazon estuary (Silva and Rodrigues, 2010).

2.2. Data collection

Data on the catches landed by the artisanal fishery fleet of the Xingu River were collected between April, 2012, and March, 2014, at nine locations along the middle and lower Xingu – São Félix do Xingu, Maribel, Altamira, Belo Monte, Vitória do Xingu, Vila Nova, Senador José Porfírio, Porto de Moz, and Gurupá (Figure 1) by 21 data collectors. The landings were daily monitored, between Monday and Saturday, through interviews with every boat master for

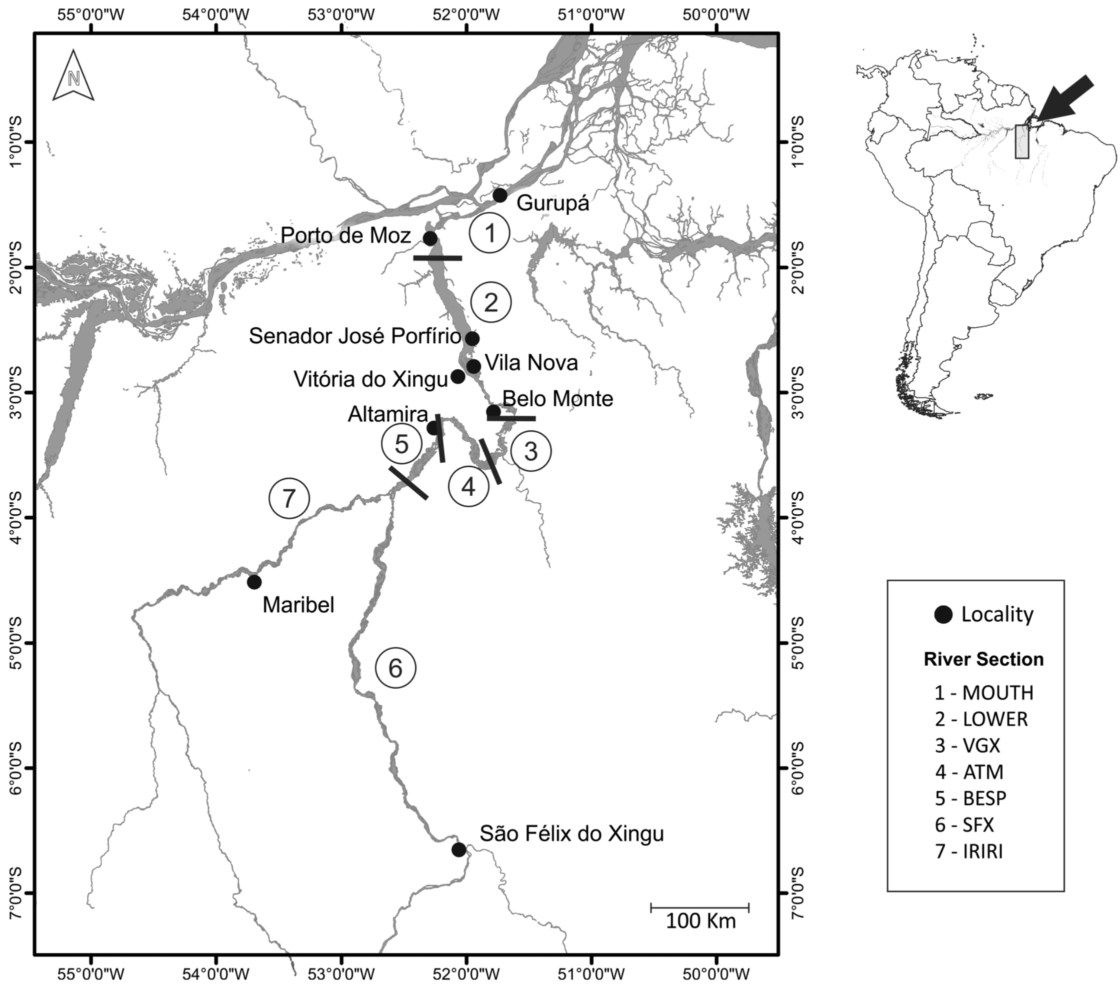

Figure 1. Map showing the location of the nine localities analyzed in the present study and the sections of the Xingu River in the Brazilian Amazon region: MOUTH: Amazon River near the mouth of the Xingu, and the Xingu itself between its mouth and the town of Porto de Moz, LOWER: the lower Xingu between Porto de Moz and the village of Belo Monte, GBX: the region of the Xingu known as the Great Bend between the waterfalls and the locality of Pimental, where the main dam is being built, ATM: Xingu River between Pimental and the town of Altamira, BESP: Xingu River between Altamira through the village of Boa Esperança to the mouth of the Iriri River, SFX: Xingu River from Iriri River to upstream of the town of São Félix do Xingu including the Fresco River, IRIRI: Iriri River between its mouth and just upstream of the village of Maribel.

each catch being disembarked. The information collected in these interviews (for each fishing trip) included the type of catch (subsistence, commercial or intermediary), the type of vessel (boat or canoe), and its propulsion (inboard or outboard motor, paddle), the number of fishers, days spent fishing and the river section of the capture, the equipment used, and the total catch (in kg) for each species. The fish species were identified by their local common names, as declared by the fishers, some of which correspond to a group of species, with distinct scientific names (see list in Table 4 for details). The vessels and their crews were also inventoried for the determination of the number of vessels and personnel involved in the region's fisheries.

Each trip was classified according to the fishing method used, which was defined based on the combination of the type of vessel and the equipment used, in order to standardise the analysis of fishery potential and the effects of selectivity. Given their relative contribution to the data, in terms of the number of catches recorded, statistical comparisons were based on the analysis of the six principal fishing methods recorded during the present study, which involved motorised canoes and motorboats each with three combinations of fishing equipment. These were MCG (motorised canoe with gillnets), MCL (motorised canoe with lines), MCG+L (motorised canoe with gillnets and lines), MBG (motorboat with gillnets), MBL (motorboat with lines), and MBG+L (motorboat canoe with gillnets and lines). For statistical analyses, paddle canoes were not considered.

For the statistical comparisons, the locations of the catch were classified according to their position on the Xingu in river sections, as (i) MOUTH: Amazon River near the mouth of the Xingu, and the Xingu itself between its mouth and the town of Porto de Moz, (ii) LOWER: the lower Xingu between Porto de Moz and the village of Belo Monte, (iii) GBX: the region of the Xingu known as the Great Bend (*Volta Grande*) between the waterfalls and the Pimental locality, where the main dam is being built, (iv) ATM: Xingu River between Pimental locality and the town of Altamira, (v) BESP: Xingu River between Altamira through the village of Boa Esperança to the mouth of Iriri River, (vi) SFX: Xingu River from the mouth of Iriri Riverto upstream of the town of São Félix do Xingu including the Fresco River, (vii) IRIRI: Iriri River between its mouth and just upstream of the village of Maribel (Figure 1).

2.3. Data analysis

The total effort and catch values were grouped by spatial and temporal criteria for the description of the region's fisheries. Fishery yield was evaluated through estimates of capture per unit effort, or the CPUE, which is calculated by dividing the total catch (kg) by effort (fishers*day). The CPUE was calculated for the main fishing method, month, and river section, considering that the variance in this variable is proportional to the fishing effort (Equation 2 in Petrere Junior et al., 2010). For the calculation of the CPUE, all records with incomplete information on effort were excluded, as well as catches landed by intermediaries or subsistence fishers.

Comparisons of CPUE values were based on the data obtained between April and December in 2012 and 2013, in order to standardise for seasonal changes. A two-way Analysis of Variance (ANOVA) was used to test the differences between years (2012 and 2013) and among months, and a one-way ANOVA was used to test differences among the different river sections, using log-transformed CPUE values. The Newman-Keuls and Scheffé tests were used to evaluate the significance of differences in the CPUE values. When the assumptions of normality and homoscedasticity were not satisfied, the nonparametric multiple comparison Kruskal-Wallis was applied, following Siegel and Castellan (1988).

3. Results

3.1. Fishing fleet and number of fishers

The artisanal fishery fleet of the Xingu River is made up of wooden vessels, which mainly use ice to conserve their catches. Two types of vessel can be identified: (i) canoes (rowed with paddles or provided with long-tailed outboard motors), and (iii) boats with inboard motors. There was a total of 2.231 vessels, of which only 8% were non- motorised canoes, 78% were motorised canoes, and 14% were boats with inboard motors (Table 1). Neither type of canoe has a cabin or hold for the storage and transportation of the catch.

Non- motorised canoes are the smallest vessels, with a mean length of 4.0 m (SD = 1.0 m) and were able to transport a mean of 13±15 kg of ice. The motorised canoes had a mean length of 7.0±1.0 m, with outboard motors of 5.5–7.5 horsepower, and were able to carry an average of 72±62 kg of ice. The motorboats are the largest vessels, with a mean length of 10.0±2.0 m, with engines of up to 90 horsepower, and a mean capacity of 197±246 kg of ice. These boats are used for fishing, as well as transporting personnel and catches. Few boats equipped with refrigerated holds – known locally as "ice packers" – are also occasionally used to transport the catches from the outlying villages to the region's major urban centers and ports.

Non- motorised canoes are mostlyfound in the small villages, such as Vila Nova and Maribel, whereas motorboats are more numerous in the larger ports such as Gurupá and Porto de Moz. The motorised canoes have a relatively homogeneous spatial distribution (Table 1).

The distribution of caches alongthe Xingu River depends on the type of boat and river section. Motorboats

Table 1. Number of fishers, vessels, and total catch (t) recorded at each fishing port on the Xingu River between April, 2012, and March, 2014.

Fishing port	Number of fishers	Total catch (t)	Number of vessels		
			Non-motorised canoe	Motorised canoe	Motorboat
Gurupá	375	195.45	21	173	110
Porto de Moz	416	159.17	4	263	93
Senador José Porfírio	301	62.12	14	185	25
Vila Nova	161	70.10	62	95	2
Vitória do Xingu	292	161.05	12	210	27
Belo Monte	111	78.64	13	135	0
Altamira	403	265.50	14	360	32
Maribel	101	215.68	31	81	22
São Félix do Xingu	191	276.46	2	240	5
TOTAL	2,351	1484.20	173	1,742	316

are almost restricted to the mouth of the river and the adjoining Amazon estuary, although some are found on the Iriri, where they are used mainly for the storage of catches bought from the local communities. The motorised canoes are the region's most important fishing units, being found along the whole of the Xingu, and accounting for 76% of all fishing trips. Non- motorised canoes are found only in the vicinity of small villages.

In the fishing ports, a total of 2,351 fishers were recorded being involved in fishery activities (Table 1), of which 93% are capturing food fish and 7% ornamental species. It was estimated that about 600 other fishers were also involved in fishery activities, but passed their catches on to partners or intermediaries rather than disembarking the fish themselves. According to the records of the region's fishery associations, however, the total number of affiliated fishers in the local municipalities is 12,777 but this number is certainly overestimated.

3.2. Catches, fishery effort and CPUE

Between April, 2012, and March, 2014, a total of 23,999 fishing trips were recorded, during which 1,484 tons of fish were caught and disembarked at the different ports. Just under one fifth (19%) of the total catch was disembarked at São Félix do Xingu, 18% at Altamira, and 15% at Maribel (Table 1).Most of the catch (1,043 t) was done by motorised canoes, followed by motorboats (416t). The accumulated effort for the whole of the study period was 52,394 days of fishing involving 23,583 men. An average trip lasted 2.18 (SD = 1.73) days, while crews ranged between one and 14 individuals.

For the period between April and December (2012 and 2013), mean catch per unit effort estimated for the commercial fisheries of the Xingu River was 18.47 kg.fisher^{-1}.day^{-1} (SD=16.50 kg). Comparing fishing methods, the mean CPUE was higher for motorised canoes, in particular those operating with nets (median = 17kg.fisher^{-1}.day^{-1}), followed by those with mixed equipment, i.e., nets and lines (median = 16.41 kg.fisher^{-1}.day^{-1}), and motorboats with mixed equipment (median = 14.58 kg.fisher^{-1}.day^{-1}). Overall, line fishing was significantly less efficient than using nets (H=850, p=<0.001) (Figure 2).

Comparing river sections differences are all significant (Table 2). The motorised canoes with nets obtained the highest mean yields upriver from the town of Altamira, with values above 25 kg.fisher^{-1}.day^{-1}. Lined fishing in motorised canoes obtained the lowest yields (<11 kg.fisher^{-1}.day^{-1}) in the streches near Altamira, but much higher values at the river mouth and upstream from this town. The motorised canoes with mixed equipment (lines and nets) returned good yields in the Great Bend section and on the Iriri River, but once again, much lower values near Altamira (Figure 3).In the case of the motorboats, the few vessels that fish on the Iriri have relatively good yields, principally those that use lines or mixed techniques. The motorboats that fish with nets obtain better yields on the lower Xingu than at the mouth of this river (Table 3)

No significant difference in yields was found between years (2012 and 2013) for most systems, except for motorised canoes used for line fishing (2012>2013) and motorboats using nets (2012<2013). With the exception of the motorboats that use mixed equipment, the yields of

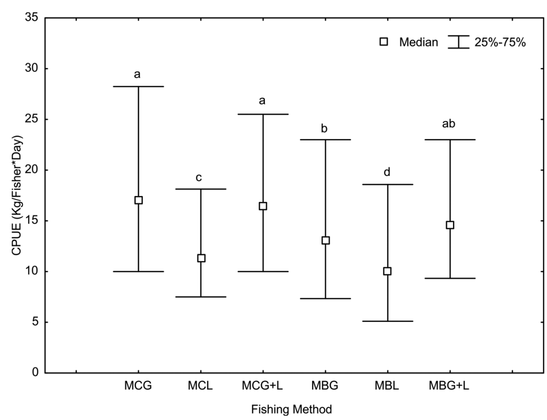

Figure 2. Comparison of the capture per unit effort (kg/fishermen^{-1}*day^{-1}) among different systems of commercial fishery on the Xingu River in northern Brazil between April and December in 2012 and 2013. Multiple comparison test: a>b>c>d; α = 0.05. MCG = Motorized canoe/gillnet; MCL = Motorized canoe/lines; MCG+L = Motorized canoe/gillnet+lines; MBG=Motorboat/gillnet; MBL = Motorboat/lines; MBG+L = Motorboat/gillet+lines.

Table 2. Results of the one-way and two-way analyses of variance for the mean yields obtained by the different fishing methods on the Xingu River between April, 2012, and March, 2014, according to the river section and the month/year.

Fishery Production System	One-way ANOVA		Two-way ANOVA					
	Fishing ground		Month		Year		Month *vs* Year	
	F	p	F	p	F	p	F	p
Motorised canoe/gillnet	22.99	0.0000	8.68	0.0000	1.73	0.1889	0.70	0.6922
Motorised canoe/lines	21.93	0.0000	8.92	0.0000	3.53	0.0602	4.17	0.0001
Motorised canoe/gillnet+lines	7.41	0.0000	3.70	0.0003	0.46	0.4967	1.28	0.2495
Motorboat/gillnet	17.46	0.0000	10.35	0.0000	15.88	0.0001	11.02	0.0000
Motorboat/lines	7.41	0.0000	2.96	0.0034	0.27	0.6018	1.49	0.1604
Motorboat/gillnet+lines	4.50	0.0048	1.12	0.3552	2.28	0.1336	0.48	0.8699

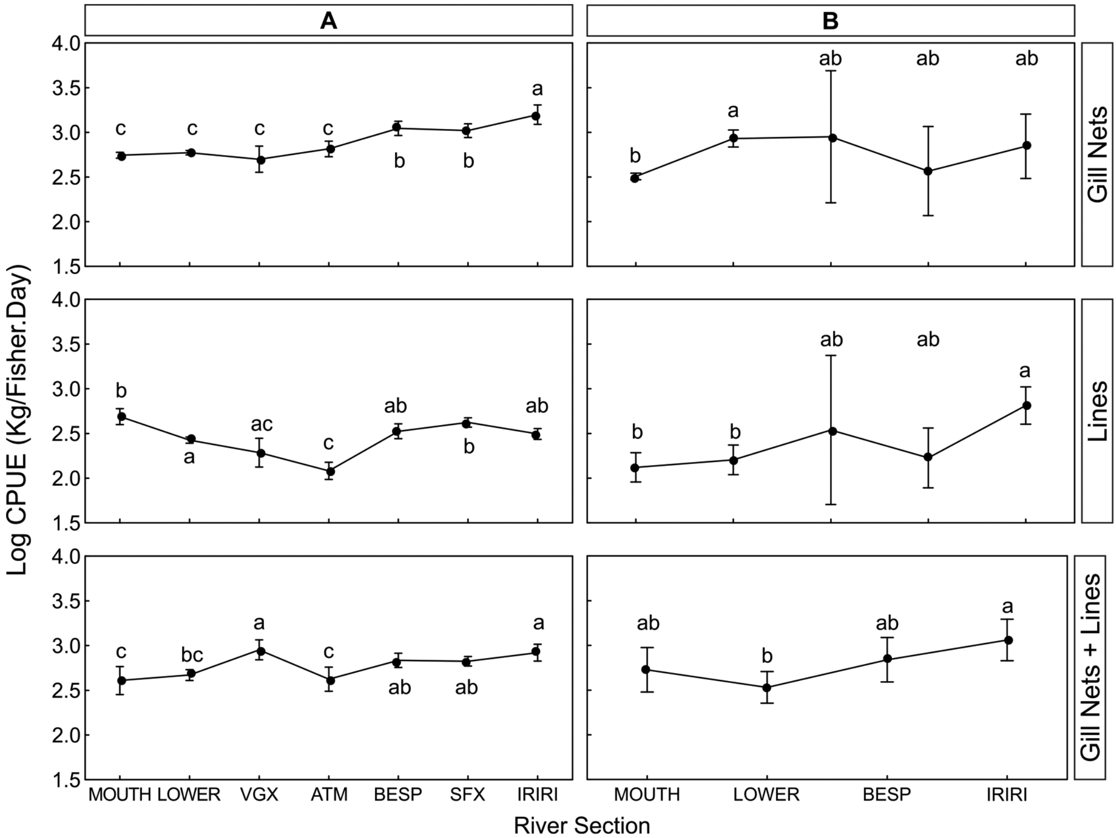

Figure 3. Comparison of the log mean capture per unit effort (kg/fishermen^{-1}*day^{-1}) among the different sections of the Xingu River monitored between April and December, in 2012 and 2013. Multiple comparison tests: a>b>c>d; α = 0.05. A- Motorized canoes; B- Motorboats.

the production systems varied considerably over the course of the year. Overall, fishing with nets generally rendered higher yields during the second half of the year, when the level of the river is relatively low, whereas line fishing tends to be more productive during the flood or receding water periods of the flood pulse (Table 2).

3.3. Species composition of catches and fishing equipment

A total of 43 different types of fish was recorded in the catches (Table 4). Some of these types are made up of a number of distinct taxa, including at least 82 different species, representing 24 families belonging to seven orders. Perciforms accounted for 43% of the total catch landed, followed by Characiforms, with 34%, and Siluriforms, with 21%. At the species level, the croakers (*Plagioscion* spp.) and peacock bass (*Cichla* spp.) each accounted for 20% of total catch, while "pacus" (a number of different Serrasalmidae species) represented 10% of the total, followed by "aracu" (various Anastomidae species) and the "curimatã" (*Prochilodus nigricans*), each with 6% of the total catch landed. These five groups of species together contributed to more than 60% of the total catch recorded during the study.

The composition and relative importance of the different species varied considerably among months and ports, presumably reflecting specific features of each river section and harvest. The catfish harvest (*Brachyplatystoma* spp) on the lower Amazon and on the mouth of the Xingu, for example, occurs during the dry season, when these fishes migrate upriver. On the lower Xingu between Porto de Moz and the waterfalls of the Great Bend, the most productive period also coincides with the migration of the catfishes – mainly *Brachyplatystoma filamentosum, Brachyplatystoma rousseauxii and Hypophthalmus* spp which enter the mouth of the river during the flood period and are captured as they migrate upstream to the waterfalls, just upriver from the village of Belo Monte. In this case, the harvest is complemented by the availability of croakers, which reach their maximum abundance during the flood period. From the waterfalls as far upstream as São Félix, the best harvests are associated with the low water period, when the migratory characiforms, such as the *Brycon* spp, *Myloplus*, and *Prochilodus nigricans*, are most abundant, together with peacock bass and croakers.The types of equipment used by artisanal fisheries for the capture of food species on the Xingu range from the most traditional, such as hand-lines, to modern and highly efficient drift nets, used in the main river channel. The nylon gillnet

Table 3. Mean catch per unit effort (kg/fishermen^{-1}*day^{-1}) by the different fishing methods according to the periods of the flood pulse on the Xingu River between April, 2012, and March, 2014.

River section	Fishing method	2012				2013				2014	
		Fooding (Apr)	High (Nov-Dec)	Low (Aug-Oct)	Receding (May-Jul)	Fooding (Feb-Apr)	High (Nov-Jan)	Low (Aug-Oct)	Receding (Feb-Apr)	Fooding (Feb-Mar)	High (Jan)
MOUTH	MCG	14.94	21.89	19.20	17.45	14.06	21.38	23.67	18.24	10.61	14.88
	MCL	51.83	16.55	28.11	34.52	14.76	11.92	21.48	18.12	8.36	9.63
	MCG+L	8.96	14.93	22.79	15.23	18.75	13.25	23.58	14.43	21.75	
	MBG	14.10	46.82	16.57	13.83	10.30	26.33	17.86	12.43	14.13	5.54
	MBL	65.00	7.59	20.63	24.98	11.25	8.44	42.17	19.17	5.15	6.59
	MBN+L	14.94	15.30	5.88	25.83	26.76	13.91	24.24	12.38	12.53	11.22
LOWER	MCG	20.86	21.74	20.31	20.72	21.41	25.50	21.44	20.61	22.89	30.42
	MCL	19.73	11.40	12.30	14.46	14.09	13.37	10.46	15.85	15.06	12.68
	MCG+L	20.59	18.73	16.07	17.94	24.10	19.43	19.55	20.29	23.90	18.58
	MBG	22.04	23.26	21.30	25.89	33.82	28.77	20.75	31.07	25.40	48.02
	MBL	9.46	9.89	12.32	10.35	14.88	8.77	13.07	10.33	11.89	22.38
	MBN+L	22.92	17.13	8.52	18.83	21.50	5.27	8.33	18.04	19.17	16.00
VOLTA GRANDE	MCG		31.15	19.12	16.09	13.63	20.42	18.08	20.94	39.40	
	MCL	13.17	18.50	10.68	9.65	11.97	16.02	9.93	15.98	4.71	5.67
	MCG+L	10.88	21.25	27.92	18.11	11.89	27.25	34.56	17.20		
	MBG										
	MBL					11.00					
	MBN+L							7.08	8.79		
ALTAMIRA	MCG	12.25	20.92	24.86	18.54	14.07	19.53	21.34	14.79	24.53	14.73
	MCL	14.55	11.46	13.76	11.05	9.61	10.08	7.46	9.04	6.73	7.38
	MCG+L	15.69	9.46	19.81	27.20	10.13	12.08	13.24	10.30	10.33	27.99
	MBG			23.44				21.96			
	MBL						11.00		13.14		12.17
	MBN+L					22.50	14.00				
BOA ESPERANÇA	MCG	28.75	27.05	35.22	23.08	26.92	19.06	24.45	24.74	20.38	37.00
	MCL	19.70	16.31	16.53	16.34	15.73	13.14	13.28	15.06	10.78	10.59
	MCG+L	23.71	18.28	23.79	20.89	15.99	20.24	16.77	19.12	17.17	19.38
	MBG		31.50	41.22			8.97	7.55	79.00	8.00	
	MBL		11.88	16.60	14.15	23.66	11.75	3.40	11.67		11.00
	MBN+L	14.54	14.00	19.38	16.92	8.80	16.67	17.43	54.36		
SÃO FÉLIX	MCG	9.64	29.73	31.97	19.33	18.36	26.74	36.93	15.15	17.31	
	MCL	17.86	18.62	16.00	17.91	14.61	14.13	22.55	16.12	16.16	14.50
	MCG+L	15.50	26.12	22.97	19.64	16.75	27.36	24.20	20.05	20.81	33.14
	MBG										
	MBL				42.59	14.80	20.33		30.60		
	MBN+L			17.63					28.13	13.33	
IRIRI	MCG	46.02	40.00	42.48	28.73	20.47	22.08	27.32	24.83		
	MCL	15.90	10.73	20.04	14.03	10.85	14.63	16.37	20.02		14.06
	MCG+L	16.33	31.72	28.06	25.61	15.05	14.63	22.46	21.85		19.50
	MBG		18.25	21.59	37.61	23.46		14.26	42.38		
	MBL		8.40	22.29	28.06	15.57	25.05	20.62	22.14		40.78
	MBN+L	20.40	17.45	34.33		21.00		24.03	20.41		

was the most important type of equipment, responsible for 42% of the total catch. The second most used type of equipment is hand-lines – known locally as "telas" – which consist of nylon lines with a hook and small lead weight baited with fish or fruit, which were responsible for 23% of the total catch. Vessels that used both nets and lines were responsible for 18% of the total catch,, while all other types of equipment, such as cast-nets, paternosters, and harpoons, were together responsible for 17% of the total catch landed during the study period.

3.4. Fishing habitats

Regional markets are supplied by fisheries on the Xingu and its main tributaries, the Iriri and the Bacajá rivers. Fishing is concentrated in the main river channel, from which 83% of the total catch is obtained, given that the Xingu sub-basin has very limited floodplain habitats

Table 4. List of the main fish species caught by artisanal fisheries in the Xingu River during the study period.

Taxon	Common name (Portuguese)
CHARACIFORMES	
Anostomidae	
Hypomasticus julii (Santos. Jégu and Lima, 1996)	Aracu
Anostomoides passionis (Santos and Zuanon, 2006)	Piau
Anostomus ternetzi (Fernández-Yépez, 1949)	Piau
Laemolyta spp	Aracu branco/Aracu flexa
Petulanos intermedius (Winterbottom, 1980)	Piau
Leporinus friderici (Bloch, 1794)	Aracu cabeça gorda
Leporinus agassizi (Steindachner, 1876)	Piau
Schizodon vittatus (Valenciennes, 1850)	Aracu
Characidae	
Brycon aff pesu (Müller & Troschel, 1845)	Matrinxã
Brycon falcatus (Müller & Troschel, 1844)	Matrinxã
Myloplus arnoldi (Ahl, 1936)	Pacu
Myloplus rubripinnis (Müller & Troschel, 1844)	Pacu
Myloplus schomburgkii (Jardine & Schomburgk, 1841)	Pacu
Ctenoluciidae	
Boulengerella cuvieri (Spix & Agassiz, 1829)	Bicuda
Boulengerella lucius (Cuvier, 1816)	Bicuda
Boulengerella maculata (Valenciennes, 1850)	Bicuda
Curimatidae	
Potamorhina latior (Spix & Agassiz, 1829)	Branquinha/Mocinha
Potamorhina spp.	Branquinha/Mocinha
Cynodontidae	
Hydrolycus armatus (Jardine & Schomburgk, 1841)	Cachorra
Hydrolycus tatauaia (Toledo-Piza. Menezes & Santos, 1999)	Cachorra
Erythrinidae	
Erythrinus erythrinus (Bloch & Schneider, 1801)	Jeju
Hoplerythrinus unitaeniatus (Spix & Agassiz, 1829)	Jeju
Hoplias aimara (Valenciennes, 1847)	Trairão
Hoplias malabaricus (Bloch, 1794)	Traira
Hemiodontidae	
Argonectes spp.	Flexeira/Erana / Charuto
Bivibranchia spp.	Flexeira/Erana / Charuto
Hemiodus spp.	Flexeira/Erana / Charuto
Prochilodontidae	
Prochilodus nigricans (Spix & Agassiz, 1829)	Curimatã
Semaprochilodus brama (Valenciennes, 1850)	Ariduia/Jaraqui/Ariru
Serrasalmidae	
Colossoma macropomum (Cuvier, 1816)	Tambaqui
Myleus rhomboidalis (Cuvier, 1818)	Pacu
Myleus setiger (Müller & Troschel, 1844)	Pacu
Piaractus brachypomus (Curvier, 1918)	Pirapitinga
Serrasalmus spp.	Piranha
Triportheidae	
Triportheus spp.	Sardinha
CLUPEIFORMES	
Pristigasteridae	
Pellona castelnaeana (Valenciennes, 1847)	Apapá/Sarda
Pellona flavipinnis (Valenciennes, 1837)	Apapá/Sarda

Table 4. Continued...

Taxon	Common name (Portuguese)
GYMNOTIFORMES	
Apteronotidae	
Apteronotus spp.	Ituí
Sternarchella sp.	Ituí
Sternarchorhynchus spp.	Ituí
Rhamphichthyidae	
Gymnorhamphichthys spp.	Ituí
Rhamphichthys spp.	Ituí
MYLIOBATIFORMES	
Potamotrygonidae	
Potamotrygon spp.	Arraia
OSTEOGLOSSIFORMES	
Arapaimidae	
Arapaima gigas (Schinz, 1822)	Pirarucu
Osteoglossidae	
Osteoglossum bicirrhosum (Curvier, 1929)	Aruanã
PERCIFORMES	
Sciaenidae	
Pachyurus junki (Soares & Casatti, 2000)	Corvina/Pescada amarela
Pachyurus schomburgkii (Günther, 1860)	Corvina/Pescada amarela
Cichlidae	
Astronotus crassipinnis (Heckel, 1840)	Acará
Caquetaia spectabilis (Steindachner, 1875)	Acará
Cichla melaniae (Kullander & Ferreira, 2006)	Tucunaré
Cichla monoculus (Agassiz, 1831)	Tucunaré
Cichla pinima (Kullander & Ferreira, 2006)	Tucunaré
Crenicichla spp.	Jacundá
Geophagus gr. altifrons (Heckel, 1840)	Acará
Retroculus xinguensis (Gosse, 1971)	Acará
Satanoperca sp	Acará
Sciaenidae	
Plagioscion squamosissimus (Heckel, 1840)	Pescada
SILURIFORMES	
Auchenipteridae	
Ageneiosus inermis (Linnaeus, 1766)	Fidalgo
Tocantinsia piresi (Miranda Ribeiro,1920)	Pocomon
Callichthyidae	
Hoplosternum littorale (Hancock, 1828)	Tamoatá
Doradidae	
Lithodoras dorsalis (Valenciennes, 1840)	Cuiu/Serrote/Cujuba / Bacu
Megalodoras uranoscopus (Eigenmann & Eigenmann, 1888)	Cuiu/Serrote/Cujuba / Bacu
Oxydoras niger (Valenciennes, 1821)	Cuiu/Serrote/Cujuba / Bacu
Loricaridae	
Hypostomus plecostomus (Linnaeus, 1758)	Acari
Pterygoplichthys pardalis (Castelnau, 1855)	Acari
Pterygoplichthys xinguensis	Acari
Pimelodidae	
Brachyplatystoma filamentosum (Lichtenstein, 1819)	Filhote
Brachyplatystoma rousseauxii (Castelnau, 1855)	Dourada
Brachyplatystoma vaillantii (Valenciennes, 1840)	Piramutaba

Table 4. Continued...

Taxon	Common name (Portuguese)
Hypophthalmus fimbriatus (Kner, 1858)	Mapará
Hypophthalmus marginatus (Valenciennes, 1840)	Mapará
Phractocephalus hemioliopterus (Bloch & Schneider, 1801)	Pirarara
Pimelodina flavipinnis (Steindachner, 1876)	Fura calça
Pimelodus blochii (Valenciennes, 1840)	Mandi
Pimelodus ornatus (Kner, 1858)	Mandi
Pinirampus pirinampu (Spix & Agassiz, 1829)	Barba chata/Piranambu
Platystomatichthys sturio (Kner, 1858)	Braço de moça
Pseudoplatystoma punctifer	Surubim
Sorubim elongatus (Littmann. Burr. Schmidt & Isern, 2001)	Bico de pato
Sorubim lima (Bloch & Schneider, 1801)	Bico de pato
Sorubim trigonocephalus (Miranda Ribeiro, 1920)	Bico de pato
Zungaro zungaro (Humboldt, 1821)	Jaú

appropriate for this activity. Streams and swamps each provided only 8% of the total catch. While fishing occurred in the main river channel throughout the year, it was most intense during the receding water and low water periods. The swamps were also fished throughout the year, although they were more productive during the flooding or rising water and high water periods, whereas the streams are fished primarily during the dry (low water) season.

The predominance of fishing in the main river channel was clear from the data collected in all the different ports, except for Porto de Moz, where 44% of the total catch was produced by fishing in flooded habitats, and 24% of that recorded at Belo Monte came from streams. The data from Vila Nova were the most diverse in terms of the habitats fished, with 46% of the total catch being obtained from the main river channel, 20% from swamps, 19% from lakes, and 16% from streams.

4. Discussion

The unique characteristics of the artisanal fisheries of the Amazon region reinforce the need for the continuous monitoring of activities and practices as a fundamental tool for fishery management, and in particular for the establishment of guidelines and formal regulations (Ruffino, 2008; Gonçalves and Batista, 2008). Such monitoring will also be essential for the assessment of changes provoked by anthropogenic impacts, which may affect breeding patterns, recruitment, and productivity, all of which can have highly deleterious consequences for a region's fishery industry (Junk et al., 1989).

The economic importance of local fisheries for the Xingu region is emphasized by the large number of fishers –approximately three thousand – known to be involved in this activity over the two years of the study period. The disparity between this estimate and the figures provided by the region's fishery associations appears to be related to the social benefits made available to affiliated members. However, the entry requirements for new associates are extremely lax, and members include many local residents that fish only occasional or as a leisure, rather than a subsistence activity (Cardoso, 2001; Braido and Caporlingua, 2013). This obviously reduces the utility of the statistics provided by these associations for the development of effective management measures.

Even so, the relative number of fishers in the region is considerable. Based on the 2010 national census, it is possible to deduce that, in the municipalities covered by the present study, one person in every 100 is a fisher, on average, in contrast with the World Bank (2008) estimate of 0.23 fisheries workforce (i.e. fishing and postharvest activities) per 100 inhabitants in Brazil. Despite this disparity, the numbers of fishers are expected to grow even more over the next few years, given the influx of migrant workers related to the construction of the dam. This implies an increasing demand for fish, which will almost certainly result in further growth in fishery effort and production, especially in the sector between Altamira and Belo Monte, which already has the lowest yields, indicating that it is already at risk of becoming overfished in comparison with less impacted sectors of the basin, such as the Iriri River. Sustainable fisheries will be important for the maintenance of food security in the region, and in particular its social stability. Guaranteeing fishery catch represents a form of maintaining the economic and social stability of the families that reside in the vicinity of the river. For this reason, the availability of fishery resources should be monitored systematically, and control measures implemented in order to avoid the interruption of supplies and loss of income from overfishing or environmental impacts.

In contrast with other regions of the Amazon basin, the fishing fleet of the Xingu is dominated by a large number of wooden canoes powered by "long-tail" outboard motors, which work independently (Cardoso and Freitas, 2007; Isaac et al., 2008; Doria et al., 2012). Larger ice packer motorboats are rare. These canoes focus primarily on the backwaters and pools of the river, reflecting its hydrological characteristics, and in particular, the many waterfalls and rapids, which hamper long-distance movements along the river. In particular, the larger motorboats equipped with more powerful motors that have a much wider range are mainly limited to the mouth of the river and neighboring areas of the Amazon estuary, where fishery practices are more similar to those of the lower Amazon or the region of Manaus, where the ice packers tow the canoes to the fishing grounds, and then transport the catch to port (Isaac et al., 2008; Bastos and Petrere Junior, 2010).This demonstrates the adaptive capacity of Amazonian fisheries, which represent the end point of the accumulation of individual and group knowledge with regard to the adequate use of resources and technologies according to the specific characteristics of each type of fishing ground and the diversity of fish species (Barthem and Fabré, 2004; Freitas and Rivas, 2006). This "social memory" (Olsson et al., 2004) is part of the region's cultural legacy and traditions, which must be preserved in order to guarantee the participative and sustainable management of its natural resources.

The diversity of fish species exploited on the Xingu is another important characteristic of the Amazon region's profile of commercial artisanal fisheries, which are typically multi-specific, exploiting an ample variety of stocks, primarily those of characiforms, siluriforms, and perciforms. The harvesting of these species is influenced by the hydrological cycle, which is the primary regulator of the whole ecosystem, and has a direct influence on yield. The target species shift according to a calendar which allows for high yields throughout practically the whole year, guaranteeing both subsistence and incomes (Batista and Petrere Junior, 2003; Barthem and Fabré, 2004; Gonçalves and Batista, 2008; Camargo et al., 2009, Doria et al., 2012).The present study revealed that more than 60% of total catches are related to the capture of five species groups, three of which (curimatã, aracu, and pacu) have periods of breeding and recruitment strictly linked to the river's flood pulse (Camargo and Lima Junior, 2007; Camargo et al., 2009). Modifications of the dynamics of this process will inevitably affect the abundance of these species in the future reservoirs, resulting in major shifts in the composition of the community. For this reason, the structure and yield of catches must be monitored throughout the process of the construction of the dam and following the formation of the reservoirs.

The mean yields recorded in this study (18.47 kg/fisher per day) are higher than the mean CPUE estimated by Isaac et al. (2004) for the lower Amazon region, i.e., 15 kg/fisher per day, a neighboring area already considered to be overfished. However, these yields are much lower than those recorded on the middle Solimões, 40-80 kg/fisher per day (Viana, 2004), the Madeira (22-65 kg/fisher per day), and the Tocantins, i.e., 30 kg/fisher per day (Hallwass et al., 2011). In the present study, in addition, the river sectionthat include the town of Altamira present the lowest yields for all fishery methods. These differences among areas and river basins presumably reflect those in the specific characteristics of each region in terms of the abundance and diversity of fishery resources, and conservation levels. While the diversity of the fish fauna of the Amazon's clear- and black-water rivers are high, the yield of fishery of its white-water rivers are much higher (Santos and Santos, 2005). This is partly a result of the relatively ample floodplains of these rivers and the presence of substantial beds of macrophytes and riparian forests, which are exploited for food by an ample diversity of fish species, enriching the whole aquatic food chain (Sánchez-Botero and Araújo-Lima, 2001).

The results of the present study reinforce the importance of maintaining the original hydrological and environmental conditions of the river as intact as possible on at least some stretches (Barthem, 1999; Batista and Petrere Junior, 2003; Isaac et al., 2004; Viana, 2004; Cardoso and Freitas, 2007), given that the main river channel is the principal fishing ground, and that the proposed dam will impact the hydrological cycle and level of the river over a stretch of more than 200 km between the town of Altamira and the Great Bend. In particular, effective conservation and management strategies for the sectors of the river upstream from Altamira must be prioritized and implemented as soon as possible, with adequate resources to ensure the effectiveness of this process. The conservation of riparian forests and island habitats, as well as the vegetation of the blocks of stone found within the main channel of the river should guarantee the productivity of the system, especially as the vast majority of the fishing on the Xingu occurs in the main river channel, and the yield of the catch of these waters depends on the maintenance of these habitats, which guarantee the input of both the allochthonous and autochthonous resources essential to support the local fish fauna (Zuluaga-Gomes, 2014).

The lack of historical data on fishery effort and yields constitute one of the principal barriers to the adequate management and sustainability of fishery activities (Almeida et al. 2001; Barthem and Fabré 2004). The control of the variation in fishers' incomes, based on catch data, is a fundamental tool for the management of resources. At the present time, the Brazilian government has cancelled practically all monitoring programmes for artisanal fisheries in its Amazon region. Additionally, there are serious limitations in the historical Brazilian statistical collection, like temporal discontinuities, lack of standardisation and poor identification of the species caught (Kalikoski and Vasconcellos, 2006). Lack of human resources to monitor fisheries catches is also recognised as a major constraint (FAO, 2003).

In fact, at the present time the only reliable data on fishery production are being provided by the companies responsible for the construction of the hydroelectric power stations, such as that at Belo Monte on the Xingu, due to the legal requirements of projects of this type with regard to the monitoring of environmental impacts. This clearly leaves the fishery stocks of the Brazilian Amazon region vulnerable to overexploitation. As research and investments are in decline, there is little perspective for the planning and implementation of adequate policies to guarantee the sustainability of the industry over the long term. The overall situation reflects the political "invisibility" of the fishery sector in the Brazilian Amazon region, totally ignoring its enormous economic, social, and cultural importance (Junk et al., 1989; Poff and Allan, 1995; Santos and Santos 2005). Ultimately, there is a clear need for consolidated investment in the continuous monitoring of fisheries by the federal authorities, which should be considered to be of the highest priority to guarantee the future sustainability of this sector.

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