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SHORT RESEARCH NOTE

Dynamics of artisanal fisheries in two Brazilian Amazonian reserves: implications to co-management

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Abstract In this study we compare the dynamics of artisanal fishery in two adjacent reserves located in the Brazilian Amazon, Mamirauá (being managed for more than 12 years) and Amanã (initiating a management process), through the record of 485 fish landings in one fishing community in each reserve during high and low water seasons in 2003. Our goals were, first, to make a rapid and comparative assessment of some main aspects of fisheries in these two communities (fish species caught, CPUE, fishing gear and habitats exploited). Second, we used such data to evaluate if management strategies already in place in Mamirauá would be also valid for Amanã. Third, we compared fishing CPUE between the two communities, in order to check if co-management measures have contributed, at least partially, to preclude over-fishing, maintaining a higher fishing reward in Mamirauá reserve. We analyzed fisheries directed to the two most important marketable fishes in the region: the pirarucu (*Arapaimas gigas*) and the tambaqui (*Colossoma macropomum*), besides those fisheries aimed to subsistence and lower valued fishes. Our results indicated that the tambaqui was intensively fished year-round in Mamirauá, while Amanã fishers caught a higher variety of fishes, including catfishes and migratory scale fishes. Such differences might reflect differences in gear used and habitat exploited by fishers during the high water season. Mamirauá fishers caught a higher fish biomass considering both marketable and all fishes. Differences in gear used, habitats exploited and fishes caught during high water season indicate that distinct management initiatives might apply for each reserve. Notwithstanding their differences, both communities exploited the commercial fishes (tambaqui and pirarucu) in a similar way during the low water season. Therefore, the higher mean fishing yield (CPUE) observed in Mamirauá may be partially

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attributable to co-management measures, considering that Mamirauá has possibly been experiencing a higher fishing intensity than Amanã. Fishing related data are seldom available in Brazil and other tropical developing countries. We thus provided a framework of fast assessment of fishing dynamics, which may represent a first and useful step for management initiatives in the absence of more detailed data.

Keywords Co-management · Floodplain lakes · Amazonian fisheries · Mamirauá reserve · Amanã reserve · Freshwater fisheries

Introduction

Management of tropical and multi-species coastal fisheries in developing countries suffer from a scarcity of biological and fish landings data, mostly due to lack of personnel and financial resources to undertake fisheries research. The best and most feasible option to manage such fisheries in the short term would be to follow a "data-less" management approach, using whichever information available (Johannes, 1998). We believe that such approach might also be valid for tropical freshwater fisheries in remote places such as the Brazilian Amazon, where logistical constraints usually preclude the recording of long-term fish landings data on small and isolated fishing communities. Indeed, continuous monitoring of fisheries dynamics is rare in Brazilian Amazon, except for some major urban centers (Petrere, 1985). Considering the pressing needs to make management decisions (and to verify the effects of those already made), short time data series may be fairly better than no data, or even worse, no management attempts.

Small-scale artisanal fisheries are an important component to the subsistence and to the economy of Amazonian people, providing about 60% of fish landings (Bayley & Petrere, 1989). The average daily consumption of fish among Amazonian populations ranges from 38 to 55 kg/person/year (Batista et al., 1998). The floodplains of the Amazonian white water river (várzeas) are nutrient rich and have a high biological productivity, holding a high fish diversity and abundance (Lowe-McConnell, 1987; Junk et al., 1989; Henderson & Crampton, 1997; Crampton, 1999). White water floodplain lakes typically show a high fish density during the low water season, when fishes became concentrated (Henderson & Crampton, 1997; Saint-Paul et al., 2000; Silvano et al., 2000). Consequently, several small-scale artisanal fishing communities exploit such lakes for subsistence and as a source of cash (McGrath et al., 1993; Cerdeira et al., 2000; Almeida et al., 2001).

The region in the confluence between Solimões and Japurá Rivers in Central Amazon is one of the main Amazonian fishing regions, with approximately 60 small settlements and six small cities, where most inhabitants are fishers or fish consumers (Queiroz, 1999). This illustrates the importance of Solimões River floodplain to both local and regional fisheries, which has been raising concerns about fishing pressure in this region (Barthem, 1999). The Mamirauá Sustainable Development Reserve was created in 1990, with the main goal of protecting the biodiversity of this large floodplain area between the Solimões and Japurá Rivers, through a co-management initiative (Viana et al., 2004). In 1998, the Amanã Sustainable Development Reserve was created in the same region, bordering Mamirauá, and being managed by the same institution (Mamirauá Civil Society) (www.mamiraua.org.br).

Among the resource management strategies implemented in the Mamirauá Reserve, there is a fishery management plan, which includes a package of management measures, such as the zoning of lakes (establishing exploited and no-take lakes), the complete exclusion of outsiders from the fishery, an annual established quota for the pirarucu (*Arapaimas gigas*, Osteoglossidae) and the establishment of minimal sizes to commercialization of tambaqui (*Colossoma macropomum*, Serrasalmidae) (Queiroz & Crampton, 1999; Viana et al., 2004). Such fishery management scheme is a kind of co-management (Wilson et al., 2003), involving the participation of fishing communities in both the elaboration and implementation of management rules.

Although there are available studies dealing with the biology, ecology and fisheries of pirarucu (Neves, 1995; Queiroz & Sardinha, 1999; Castello, 2004) and tambaqui (Lima & Goulding, 1998;

Costa et al., 2001), there is still lack of data about the artisanal fisheries in the Mamirauá and Amanã Reserves, such as data about the composition of fish landings and about the fishing strategies adopted by fishers. Such information would be useful to evaluate, to monitor and to update current fishery management practices (Viana et al., 2004).

Although the Amanã Reserve still lacks a management plan, some fishery management strategies have been applied there, based on the previous experience in Mamirauá, considering that these two reserves are contiguous, inhabited by the same cultural group, the ‘‘caboclos’’ (descendants of Indians and Portuguese) and they are both located on the Solimões river basin. However, these two reserves also show some differences: Mamirauá is entirely located on floodplain forests, while Amanã consists mostly of upland ‘‘terra firme’’ forests. Therefore, many communities in Amanã are mainly devoted to agriculture, while fishing predominates in Mamirauá (www.mamiraua.org.br). Also, Mamirauá has a much more extensive system of floodplain lakes, which may influence the composition and quantity of fish species caught. We aim to analyze and to compare aspects of the fishery dynamics (composition and abundance of fish landings, fishing gear used and fishing grounds exploited) between two fishing communities: Jarauá, located in Mamirauá Reserve, under management for 12 years and Ebenezer, located in Amanã Reserve, where the management process is still being implemented. Therefore, a comparative survey of fishing dynamics would indicate to what extent the management rules adopted in the former would be also applicable to the latter. Such rapid assessment approach may be also useful to record and analyze data on other tropical freshwater fisheries, where similarly to the Amazon, data is needed but it is still scarce.

Methods

Study areas

The Mamirauá Sustainable Development Reserve, located in the confluence of Solimões and Japurá Rivers, has an extensive floodplain with several aquatic habitats, such as lakes, flooded

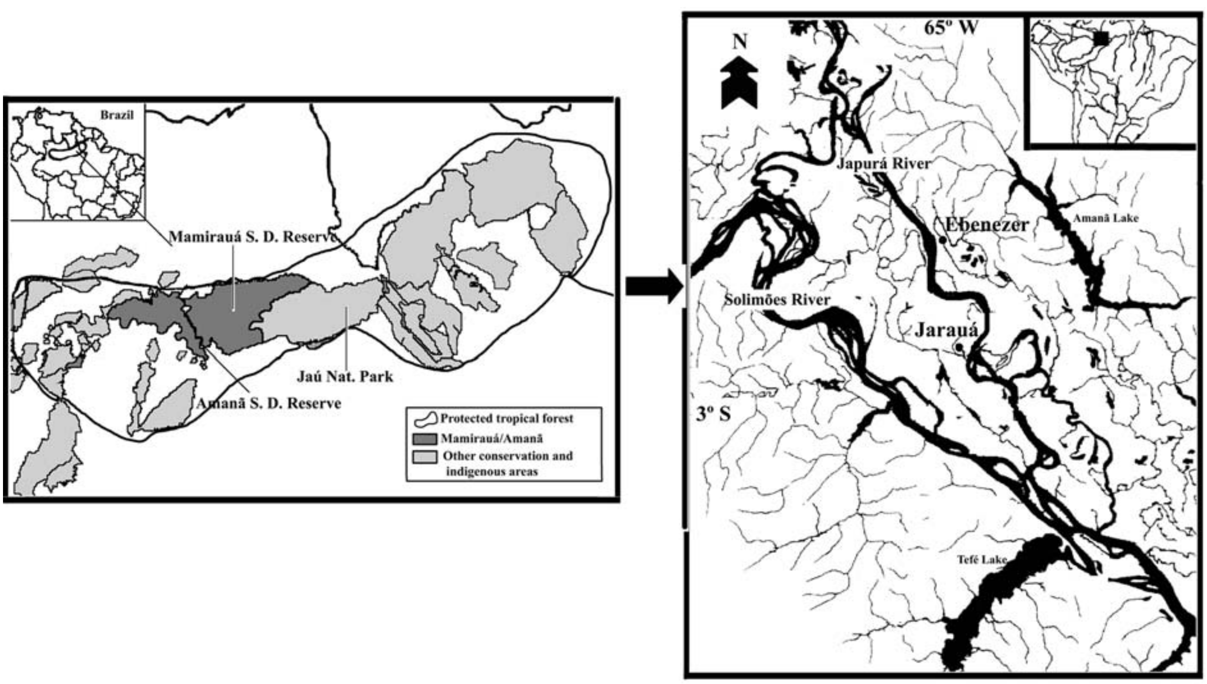

Fig. 1 Map of the study area showing Mamirauá and Amanã Reserves (adapted from Ayres et al., 2005). In detail, Ebenezer (Amanã) and Jarauá (Mamirauá) fishing communities (adapted from Henderson & Crampton, 1997)

forest, rivers and channels (Henderson & Crampton, 1997; Crampton, 1999), with a total area of 1,124,000 ha. Our survey was made with fishers from Jarauá community, (02°51′849″ S, 64°55′750″ W) (Fig. 1), one of the largest and most active fishing villages of the Mamirauá Reserve (Queiroz, 1999). Amanã Reserve has an area of 2,350,000 ha, being located between the black water Negro River and the white water Solimões and Japurá Rivers, connecting the Mamirauá Reserve to the Jaú National Park, forming the largest block of contiguous protected tropical forests in the world (www.mamiraua.org.br) (Fig. 1). In Amanã, we made our survey in the fishing community of Ebenezer (02°34′222″ S, 64°58′676″ W) (Fig. 1), located in the Coraci River banks, as this is the largest and most active fishing village in this reserve.

Sampling of fish landings

We recorded fish landings simultaneously in the two fishing communities (Jarauá and Ebenezer) in 2003, during 17 days in the high water season (June and July) and 15 days in the low water season (October and November). We interviewed fishers when they arrived from their fishing trips, recording the weight of fishes caught per species (or groups of species), fishing gear used, fishing grounds explored, crew number and time spent fishing.

During the low water season, there is an established period when the fisheries are directed to the two most important commercial fish species, pirarucu and tambaqui. Thus, in this season, fishers organize communal fishing trips managed through a system of collective fishing quotas. Both reserve managers and fishers define these quotas, which are based on the number of adult pirarucus in the lakes estimated by experienced fishers (Castello, 2004). In Brazil, only the pirarucu fished in managed areas can be commercialized, as the capture of this species is now strictly regulated (www.ibama.gov.br). All the pirarucu fished in both reserves is commercialized with the support of the reserve managers, which, as a consequence, leads to a stricter control of the amount and number of fish caught. However, fishermen did fish independently from each other, and they might not necessarily achieve their quotas, since this depends on each fisher's efficiency. In Ebenezer (Amanã), until 2003 only a few fishers took part in the communal fishing trips, keeping their regular fishing activities. In this period, we sampled the fish landings all day long at the exploited lakes (in Mamirauá) or in a boat that was collecting the commercial fishes caught in more distant lakes (in Amanã).

We collected some of the fish species from the fish landings and during a survey of fish communities in Mamirauá (R.A.M. Silvano, unpublished data), which were identified by a taxonomist (J.A.S. Zuanon) and deposited in the ichthyological collection of the Instituto de Pesquisas da Amazônia (INPA). We identified those fish species not collected by comparing their common names with available fish inventories for Mamirauá Reserve (Crampton, 1999).

Data analysis

We analyzed fish landing data separately by season, due to the seasonal differences in fisheries above mentioned. We compared the composition of fish landings between the two studied fishing communities, based on biomass of fish species (or groups of species) using Morisita–Horn similarity index. We made two comparisons: first, considering all fish species caught and second, excluding the two most important commercial fishes with established quotas, pirarucu and tambaqui.

We compared fish catches using a measure of capture by unity of fishing effort (CPUE), considering the "biomass of fish caught (kg) * number of fishers^{-1} * time spent fishing (h)$^{-1}$. Time spent fishing also includes the traveling time to and from the spots. We compared such measure of CPUE between seasons through Mann–Whitnney (U) test, considering time fishing with distinct technologies, such as spear, hand lines and gill net, in the same way. In other places, usually fishermen set gillnets in the water and return to check them after some period of time, such as overnight (Silvano & Begossi, 2001) while the spear fishing needs a constant effort on the fishing grounds. However, in Mamirauá and in many other Brazilian regions, fishermen usually stay near their gillnets during the whole fishing period, constantly checking the nets in order to avoid damaged of the nets and entangled fishes by aquatic predators (water dolphins, caimans and piscivorous fishes). We thus assumed that fishing effort as time spent fishing would be comparable among distinct fishing gears, as otherwise we would not be able to compare fishing rewards between seasons and fishing communities. We also compared the frequency of fishing trips using different fishing gear and exploiting distinct habitats between the two studied communities through χ^2 tests.

We made multiple linear regression analyses (Standard Least Square), in order to check which of these factors (independent variables) would be influencing the CPUE (dependent variable) in each season: fishing gear (gillnets, hand lines, spear, gillnets and spear together, beach seine and others), fishing community (Jarauá or Ebenezer) and habitat exploited: lakes, rivers, flooded forest (*igapós*), backwaters (*ressacas*) and small channels linking two rivers or linking rivers to lakes (*paranás*). We made this analysis considering all the fishes caught and considering only pirarucu and tambaqui. The significance of the factors were tested by the Effect Test (JMP 6.0)

Results

Comparison of artisanal fisheries

We sampled a total of 485 fish landings in the two communities: 174 in Ebenezer and 166 in Jarauá during the high water season and 41 in Ebenezer and 104 in Jarauá during the low water season. Considering all fish caught (See Electronic Supplementary Material), fish landings showed a similar composition between the two studied fishing communities: Morisita–Horn indices were of 0.81 and 0.74, respectively for high and low water seasons (Fig. 2a), with an overall similarity of 0.6, considering both seasons. However, when we excluded the two most important commercial fishes (pirarucu and tambaqui) (See Electronic Supplementary Material) from the analysis, the composition of fish landings was then remarkably different between the two communities: similarity indices were 0.08 and 0.17 respectively for high and low water seasons (Fig. 2b), with an overall similarity of 0.10. Such difference is due to a higher relative contribution of many species of catfishes and small to medium fin-fishes, such as jaraqui (*Semaprochilodus* spp.) and aruanã (*Osteoglossum bicirrhosum*) in fish landings from Ebenezer (See Electronic Supplementary Material, Fig. 2b), while Jarauá fish landings showed a higher predominance of the two most valuable commercial fishes, tambaqui and pirarucu, plus the large scale fish pirapitinga (*Piaractus brac-*

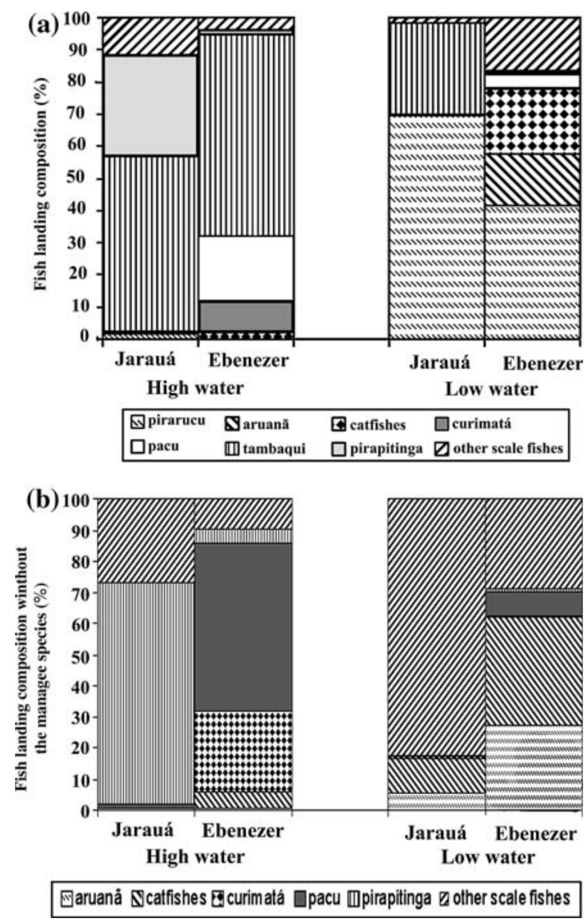

Fig. 2 (**a**) Composition (% of biomass) of fish landings including all fishes in the two studied seasons in Ebenezer (Amanã) and in Jarauá community (Mamirauá), considering fish species groups as in Electronic Supplementary Material. Catfishes include all species of Pimelodidae. (**b**) Composition (% of biomass) of fish landings not considering the two main targeted fishes (pirarucu and tambaqui) in the two studied seasons in Ebenezer (Amanã) and in Jarauá community (Mamirauá), considering fish species groups as in Electronic Supplementary Material. Catfishes include all species of Pimelodidae

hypomus, Serrasalmidae) (Fig. 2 a, b, See Electronic Supplementary Material).

During the high water season, Jarauá fishers used hand lines and Ebenezer fishers used mostly gillnets, while in the low water season we observed the prevalence of gillnets in both places, sometimes used with a spear, in order to catch pirarucu and tambaqui (Table 1). This resulted in a significant difference between the methods employed in the two communities, when considering all fish landings together ($\chi^2 = 253$, $df = 4$, $P < 0.001$). Fishers from the two communities differed also with respect to habitats exploited: Jarauá fishers used mostly lakes, while Ebenezer fishers fished mainly in the Coraci river and in the flooded forest ($\chi^2 = 173.3$, $df = 3$, $P < 0.001$) (Table 1).

The mean CPUE in the low water season was larger for Jarauá, compared to Ebenezer fish landings, while the reverse occurred during the high water season. Such pattern holds when considering only catches of pirarucu and tambaqui (Fig. 3). However, when considering all the regression factors, ''fishing community'' (if fishery was recorded in Jarauá or in Ebenezer) had a low and non-significant influence on the CPUE during the high water season, when considering all fish species, but was significant to predict the CPUE for the species with quotas (Effect Test: $F = 7.99$; $P = 0.005$) (Table 2). The only significant factor ($P < 0.05$) during this period was the type of habitat exploited for the regression considering all the species ($F = 3.69$; $P = 0.006$). The model indicated that flooded forest influenced negatively the CPUE, suggesting that this habitat demands more effort to catch fishes, either in travel time or in time spent fishing. When taking into account just the species with quotas, besides the community effect, fishing in rivers and in the small river channels also influence on the catch ($F = 2.75$; $P = 0.02$). Conversely, in the low water season, the fishing community is the sole factor influencing the CPUE, with Ebenezer showing the lower values considering all fishes caught ($F = 4.54$; $P = 0.03$). When considering only the two managed species all the factors influenced on the CPUE, resulting in the highest value for the r^2 (0.55) ($F_{community} = 18.60$, $P < 0.001$; $F_{gear} = 32.23$, $P < 0.001$; $F_{environment} = 3.60$; $P = 0.03$). In this case, fishing in the backwater had higher CPUE than fishing in the lakes (Table 2).

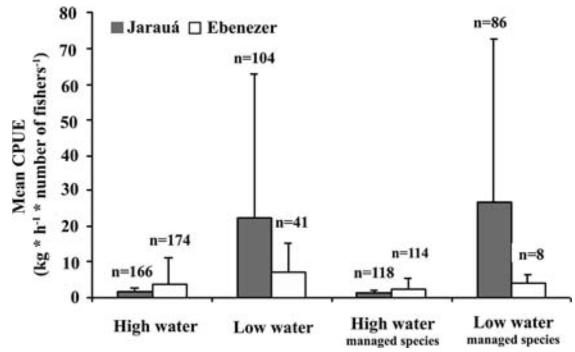

Fig. 3 Mean values for CPUE (kg * h^{-1} * number of $fishers^{-1}$) for the two communities in the two seasons, considering all fish caught and only the two main commercial fishes. All comparisons were significant through Mann–Whitney *U* test ($P < 0.001$)

Table 1 Frequency of fishing trips and of fishing gears (number of sampled fish landings) undertake by fishers from the two communities during the two seasons in five habitat categories

	Jarauá		Ebenezer	
	High	Low	High	Low
Habitats				
Lakes	130	60	18	10
Rivers	12	8	80	9
Channels	14	0	32	8
Flooded forest	7	0	39	0
Backwaters	3	37	5	7
Fishing gear				
Gillnet	0	31	149	10
Hand line	166	0	22	0
Spear	0	3	2	6
Spear + gillnet	0	67	0	9
Others[a]	0	3	4	16

The total may be different than the total of fishing lands sampled, because some fishers visited more than one place during a fishing trip

[a] It includes trap nets, beach seine, long line and trident

The fisheries of pirarucu and tambaqui

In Jarauá, pirarucu represented less than 2% of the biomass and only 1% of the fish landings during the high water season, when its fishery was restricted for consumption. On the other hand, this fish represented 70% of the biomass, being

Table 2 Parameters derived from multiple regression analyses of CPUE in the two seasons, considering all fish species and only the ones with quota

Parameter	High water—general		Low water—general		High water—quota		Low water—quota	
	Estimate (SE)	*t*-ratio	Estimate (SE)	*t*-ratio	Estimate (SE)	*t*-ratio	Estimate (SE)	*t*-ratio
Intercept	1.12 (0.11)	10.39**	1.99 (0.12)	16.69**	1.19 (0.09)	13.89**	2.95 (0.34)	8.75**
Community	0.11 (0.07)	1.63	–0.24 (0.11)	–2.13**	0.14 (0.05)	2.83**	–0.62 (0.14)	–4.31**
Gear								
Spear			–0.29 (0.29)	–1	0.19 (0.15)	1.32	4.09 (0.52)	7.94**
Hand line	–0.14 (0.13)	–1.1			–0.09 (0.08)	–1.12		
Others			0.58 (0.35)	1.64				
Gillnet	–0.09 (0.11)	–0.85	0.11 (0.18)	0.59	–0.27 (0.12)	–2.33**		
Gillnet + Spear			0.14 (0.21)	0.69			–2.02 (0.29)	–7.00**
Environment								
Lake	–0.07 (0.06)	–1.17	0.26 (0.13)	1.96	–0.02 (0.06)	–0.26	0.13 (0.20)	0.68
Flooded forest	–0.16 (0.09)	–1.86**			–0.01 (0.07)	–0.08		
Small channels	–0.08 (014)	–0.56			0.22 (0.08)	2.8**		
Backwater	0.13 (0.14)	0.93	0.10 (0.14)	0.73	0.06 (0.15)	0.38	0.54 (0.21)	2.52**
River					–0.14 (0.07)	–2.05**		
r^2	0.13		0.21		0.16		0.55	

* Significant at the level of 10%, ** significant at the level of 5%

present in 63% of all fishing landings during the low water season, when it could be either consumed or sold (See Electronic Supplementary Material). The mean CPUE for pirarucu in Jarauá was 1.65 kg/fishers/h (±0.74) and 17.25 kg/fishers/h (±13.33), during the high and low water seasons, respectively. In Ebenezer, pirarucu was present in 19% of the fishing landings, representing 42% of total fish biomass caught in the low water season (See Electronic Supplementary Material), when the mean CPUE for this fish was 3.87 kg/fishers/h (±2.75). We did not observe fishers catching this fish during the high water season, indicating that this fish was caught less frequently during that season.

In Jarauá, tambaqui represented 70% (n = 115) of fishing landings and 54% of the biomass caught in the high water season, while in the low water season it represented 20% of fishing landings (n = 20) and 28% of biomass caught (See Electronic Supplementary Material). However, in the low water season, Jarauá fishers caught almost four times more biomass of tambaqui than during the high water season. Indeed, the mean CPUE, considering only the fish landings where tambaqui was caught in Jarauá, was significantly lower in the high water season (n = 117, 1.08 kg/fishers/h ±0.86) when compared to the low water season (n = 21, 55.30 kg/fishers/h ±85.43) (U = 167; P < 0.0001). In Ebenezer, tambaqui was present in 65% of all fishing landings in the high water season, representing 62% of total biomass of landed fishes and the mean CPUE was 2.49 ± 3.07. In the low water season, tambaqui communal fishing in Ebenezer occurred during one single night, which did not coincide with our sampling period. We thus analyzed only tambaqui fisheries data for high water season in Ebenezer.

The results shown for Jarauá during the low water season represent the communal quotas fishing activities. Conversely, most fishers during the low water season in Ebenezer fished individually, not engaging in the communal quotas fishing.

Discussion

The Jarauá fishery here reported is similar to that described in 1991/1992 (Queiroz, 1999), concerning overall fishing gears used and fish species caught. For instance, pirarucu was also the main commercial species, but the catfishes had a significant participation in biomass and in frequency in fish landings. The prevalence of fishing gear during 1991/1992 agrees with the frequency of use that we observed, showing the importance of spears, hand line and gillnets (Queiroz, 1999). We observed a higher fishery production, compared to that reported by Queiroz (1999) in 1994, who observed the catch of about 0.5 *t* during the same months that we sampled in the high water period and about 3.7 *t* in the low water period (Queiroz, 1999). However, in tropical floodplain areas, the temporal comparisons of fishery production may be difficult due to annual fluctuations in the non-biotic patterns, such as frequency of rains (de Graaf, 2003).

The differences in the fish landing composition between the two studied communities, when not considering the two more important commercial species managed by a system of quotas, could be related to the differences between the fish communities in the use of fishing gear and in the habitats exploited during high water season. For example, fishers from Ebenezer exploit fishing grounds in the river using mostly gillnets, while Jarauá fishers concentrated their fishing trips in lakes, using mostly hand lines. These differences are expected, since gillnets are forbidden in Jarauá (except during the fishery of pirarucu), where there is also a wider floodplain system with several lakes (Fig. 1). Differences in fish species richness caught may be also attributed to these differences in habitat and gear. For instance, Ebenezer fishers caught more fish species, including catfishes, such as surubins (*Pseudoplatystoma* spp.) and other fishes from the Pimelodidae family, which are usually caught in the Amazonian rivers' channels (Barthem & Goulding, 1997). Furthermore, gillnets are usually less selective than hand lines with baited hooks, considering that gillnets select fishes according to their size, thus capturing several fish species with similar sizes (Saint-Paul et al., 2000; Silvano et al., 2000).

The highest total value (kg) captured in Jarauá during the low water season may be partially due to the fact that Ebenezer fishers usually devoted more time to agriculture during this season than Jarauá fishers. Considering mean CPUE as a measure of fishing productivity, Jarauá fishers caught in average more fish than Ebenezer fishers during low water season, when fishery was directed to achieve quotas of pirarucu and tambaqui, indicating a higher fish density in Jarauá lakes. In another Amazonian region in Brazil (Lower Amazon river), lakes are also the most productive environments, both in commercial and in subsistence fishery (Cerdeira et al., 2000). However, in a Peruvian reserve, the highest fishing productivity in the low water season was obtained in rivers, instead of lakes or floodplain forests (McDaniel, 1997). Although overall environmental (rivers × lakes) and gear differences might have influenced the differences in CPUE between the two studied communities, during the low water season their fisheries were similar: both caught pirarucu and tambaqui in lakes, using mainly gillnets. Furthermore, socio-economic data indicate that in Jarauá the fishing has probably been more intense, as there are more fishermen, who fish more often (Queiroz, 1999), than in Ebenezer. Therefore, we believe that the difference in fishing productivity (CPUE) during the low water season may be at least partly attributable to the ongoing fishery management in Mamirauá Reserve. In this sense, the co-management measures adopted there can be avoiding over-fishing, besides increasing Jarauá fishers' rewards. Although Ebenezer fishers caught more fish during high water season, the magnitude of the difference between the two communities was much lower then (Fig. 3), and, as shown by the multiple regressions, this may be attributed to differences in the type of habitat exploited.

Our results indicated that gillnets might be increasing the fishing productivity (CPUE) in Ebenezer during the high water season by allowing fishers to caught a greater array of fish species (Fig. 2b), as well as tambaqui. However, gillnets can cause impacts on the fish community as a whole, such as the capture of juveniles, overfishing of target species and by-catch (Costa et al., 1999). Albeit some kind of restriction on this fishing method might probably be negotiated in Amanã Reserve in the near future, total prohibition of gillnets, could reduce fishing rewards and raise conflict with fishers. Ebenezer fishers lack the complex and large system of floodplain lakes that enabled Jarauá fishers to specialize in the two most desired fishes, pirarucu and tambaqui. The use of gillnets is also prevalent in other Amazonian regions, such as in the Lower Amazon (Cerdeira et al., 2000), though the use of fishing techniques varies widely in Amazon, depending on the target species (Isaac et al., 1996). In a co-managed reserve in Peru, the community accepted restrictions on use of gillnets, since fishers are allowed to use this fishing technique as a relief mechanism in harsh moments (McDaniel, 1997). Such sort of compromise, allowing gillnets in specific places or seasons, or regulating only the gillnet mesh sizes, would probably be more effective to Amanã fisheries than the total banning of this fishing gear as adopted in Mamirauá.

Despite the observed differences in productivity, there is some evidence that the two studied communities show high levels of fish production compared to other Amazonian fisheries. In Lago Grande, at the Lower Amazon River, the overall mean fish catch per person per day is 22 kg (Cerdeira et al., 2000), which is similar to other comparable Amazonian regions, while in Jarauá and Ebenezer this value was 46.3 (±73.0) and 50.4 person per day (±70.8), respectively. However, our results indicate that the tambaqui was intensively caught year-round in Jarauá, which claims for a more intensive fishery control and regular studies of the populations of this fish, as have been done with pirarucu (Queiroz & Sardinha, 1999; Castello, 2004).

Besides being located in the same region and along the same main river (Japurá River), our results indicated that these two communities would be better suited to slightly different management measures, as they show distinct characteristics regarding habitats exploited and fishing strategies. For example, fisheries management measures in Amanã should include the migratory catfishes, as well as some small to medium sized scale fishes, such as jaraquis (*Semaprochilodus* spp.) and pacus (Serrasalmidae). The establishment of no-take lakes as fish conservation zones, as implemented in Mamirauá, would usually affect mainly the more sedentary fish species, such as pirarucus, tucunarés (*Cichla* spp.) (McGrath et al., 1993) and juveniles of tambaqui (Costa et al., 1999). However, as shown in a study realized in Mekong River, such measures have also the potential to benefit migratory fishes through a network of no-take lakes (Baird & Flaherty, 2005). Conversely, managing highly migratory catfishes (Barthem & Goulding, 1997) might demand broader actions, as the same fish stocks might be exploited by several fishing communities located all along the Solimões River.

Jarauá and Ebenezer harvested respectively 20 and 37 fish species, but both communities rely mostly on few fish species: pirarucu, tambaqui, pirapitinga and pacu comprised about 90% of the total biomass caught, contrarily to what has been observed in other Amazonian regions (Cerdeira et al., 2000; Almeida et al., 2001; Cetra & Petrere, 2001). In the Lower Amazon, commercial fisheries explore a higher diversity of fishes (up to 47 species), without a remarkable predominance of any single species (Almeida et al., 2001). In another region comprehending a huge lake also in the Lower Amazon more than 70 species were presented in fish landings, with 10 of these fishes accounting for 75% of the total catch (Cerdeira et al., 2000). The exception is a region altered by a huge reservoir in the Tocantins River, in Eastern Amazon, where about 50 fish species were marketed, but 70% of the biomass landed corresponds to only two schooling migratory fishes, *Psectrogaster amazonica* and *Semaprochilodus brama* (Cetra & Petrere, 2001). Therefore, it seems that fishermen from Mamirauá, Amanã and from the Tocantins River (Cetra & Petrere, 2001) show a relative specialization regarding fish species marketed, possibly due to different reasons. In the Tocantins River, fishermen concentrate on two smaller sized and lower valued fishes (Cetra & Petrere, 2001), which may be partially due to impacts and alterations on fish communities derived from Tucuruí reservoir (Petrere, 1996). In Mamirauá and Amanã, on the other hand, fishers specialized on the larger and more profitable fishes since these fishers have a higher abundance of fishes to choose from, which may be due to a more pristine environment and to fishery management measures adopted in Mamirauá (Queiroz & Crampton, 1999).

Co-management is a participatory and collaborative process of regulatory decision-making among different groups (Jentoft, 2003). Co-management schemes are widespread and some of them are now being evaluated (Lyver, 2005), which allowed the emergence of different factors that can affect their implementation and success of such arrangements (Pomeroy et al., 2001). Experiences involving fisheries co-management occurs in all continents, and both in marine and freshwater ecosystems (Wilson et al., 2003). Despite the many kinds of possible co-management arrangements, based on the different extent of power transfer to the community (Pomeroy, 1995), some conditions seem relevant to achieve success. These conditions can be grouped into three different categories: (1) supra-community level, which indicates conditions that are external such as government support; (2) community level, the social-environmental conditions that can influence the management; and (3) individual and household level, approaching their decision making process of individuals in the community. Although a detailed classification of the kind of co-management adopted in the studied region is beyond the scope of this study, both studied reserves seem to be involved in a highly participative co-management arrangement. Following Sen and Nielsen (1996) categories of co-management, the Sustainable Development Reserve of Mamirauá could be seen as showing mechanisms of instructive and informative processes, since there are top-down decisions, but there are also mechanisms for consulting users (Begossi & Brown, 2003). In Mamirauá, according to Viana et al. (2004), all the communities take part in the process of decision-making, aiming to reconcile the use and conservation of natural resources. Indeed, the co-management includes not only fisheries, but also freshwater turtles, game, and logging (www.mamiraua.org.br). Furthermore, other economic alternatives are being developed in Mamirauá in order to reduce the pressure over the natural resources, for example, through the aggregation of value to local products (Viana et al., 2004).

In tropical coastal fisheries in the Pacific, fishery co-management schemes emerged from common management rules and strategies that had been adopted by fishing communities for many generations, such as fishing territories, closed seasons, restrictions on species caught, among other measures (Johannes, 2002). On the other hand, co-management system in the lower Brazilian Amazon emerged only recently (after 1980) as a response to more efficient fishing gear and more intense fishing (Castro & McGrath, 2003). Such co-management schemes, named ‘‘fishing accords’’, are aimed to grant exclusive fishing rights for some fishing communities in selected lakes, but some of these fishing accords may not achieve their objectives, due to constraints imposed by their recent origin and the consequent lack of expertise of some communities in working together (Castro & McGrath, 2003). The co-management in Mamirauá was also devised recently, since the 1990s in its actual form and some decades before through the influence of the Catholic Church (Queiroz & Crampton, 1999), which also influenced the fishing accords of the Lower Amazon (Castro & McGrath, 2003). Therefore, our data could be useful to update and improve Mamiraua co-management, besides helping orient co-management still in progress in the Amanã Reserve. Co-management alternatives do not necessarily imply in successful resource conservation (Pomeroy & Carlos, 1997), which reinforces the need of constant evaluation and improvement.

Although large data series of several years and from several fishing communities may be required to devise fishery management schemes, such detailed data are rare for tropical freshwater fisheries, especially in the Amazon. However, even data gathered in shorter spatial and temporal scales, such as from one or few fishing communities and along one year or two fishing seasons, has been providing useful scientific insights to understand and to manage both freshwater (Castro & Begossi, 1996; Silvano & Begossi, 2001) and coastal (Seixas & Begossi, 2000) and coastal (Begossi, 1996, Seixas & Begossi, 2000) Brazilian fisheries. In this sense, we provided a cost-effective and rapid approach to assess basic and main aspects of fisheries dynamics, assessing the basic main points, such as CPUE, production, species caught, habitats exploited, and fishing gear used in the main seasons. Such approach may be useful to undertake a first evaluation, as well as to monitor fishery co-management practices in the studied floodplain forests and in other tropical freshwater environments in Amazon (Almeida et al., 2001; McGrath et al., 1993) and elsewhere (Baird & Flaherty, 2005; Dugan, 2005). Our approach would thus be promising to support adaptive fishery management schemes (Lee, 1999), where management rules are continuously changed according to management outcomes.

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