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Fishing Effort and Catch Composition of Urban Market and Rural Villages in Brazilian Amazon

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Abstract The management of small-scale freshwater fisheries in Amazon has been based usually on surveys of urban markets, while fisheries of rural villages have gone unnoticed. We compared the fishing characteristics (catch, effort and selectivity) between an urban market and five small villages in the Lower Tocantins River (Brazilian Amazon), downstream from a large reservoir. We recorded 86 and 601 fish landings in the urban market and villages, respectively, using the same methodology. The urban fishers showed higher catch per unit of effort, higher amount of ice (related to a higher fishing effort, as ice is used to store fish catches) and larger crew size per fishing trip, but village fishers had a higher estimated annual fish production. Conversely, urban and village fishers used similar fishing gear (gillnets) and the main fish species caught were the same. However, village fishers showed more diverse strategies regarding gear, habitats and fish caught. Therefore, although it underestimated the total amount of fish caught in the Lower Tocantins River region, the data from the urban market could be a reliable indicator of main fish species exploited and fishing gear used by village fishers. Monitoring and management should consider the differences and similarities between urban and rural fisheries, in Amazon and in other tropical regions.

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Introduction

Small-scale freshwater fisheries are among the main sources of animal protein and income for people in tropical developing countries (Bayley and Petrere 1989; Ticheler and others 1998; Weyl and others 2005; Navy and Bhattarai 2006; Isaac and others 2008). These fisheries are challenging to manage due to their complexity and to the lack of basic catch and effort data. Such data is difficult to obtain due to the high diversity of exploited species and fishing gears, variable fishing effort, diffuse production (multiple landing points) and remoteness of fishing sites usually found in many tropical freshwater fisheries, especially those in floodplains of large rivers (Bayley and Petrere1989; Ticheler and others 1998). Studies on catch composition and fishing effort of these fisheries have been made in urban markets or at household level, using three main methodological approaches: interviewing households or fishers about previous fishing activities (Begossi and others 1999; Camargo and Petrere 2004; Almeida and others 2001, 2009), recording actual fish landings from individual fishers (de Merona 1990; Cetra and Petrere 2001; Silvano and Begossi 2001) and data gathered by fishers themselves (participatory monitoring) (Ticheler and others 1998). Regardless of the chosen sampling method, it is necessary to consider to which extent all techniques, purposes and scales of fisheries are being addressed in fisheries surveys.

Amazonian fisheries in Brazil are typical tropical freshwater fisheries, where small scale fishers produce most of the catches and fish is usually the main animal protein being consumed by local people (Bayley and Petrere 1989; Batista and others 1998). Brazilian Amazon fisheries have been adversely affected mainly by large dams and reservoirs built in major rivers to generate electric power (de Merona 1990; Petrere 1996; Fearnside 1999) and by an increasing fishing pressure (Petrere and others 2004). The consequences to fish production of Amazon deforestation or climatic changes, such as altered precipitation patterns, are still poorly known (Malhi and others 2008). Many Amazon fisheries lack even basic knowledge about fish biology, fish production, fishing gears employed and fish species exploited (Bayley and Petrere 1989; Petrere 1996). Such knowledge would be the baseline to guide sound management practices.

In Brazilian Amazon, the main fishers' categories (not mutually exclusive) are subsistence, commercial (large or regional scale), ornamental and recreational (de Merona 1990; Petrere 1996; Almeida and others 2001; MacCord and others 2007; Silva and Begossi 2009). Amazon fisheries may also differ among fishing communities, cities or boat size categories, even in the same region (Almeida and others 2001; MacCord and others 2007; Garcia and others 2009). For example, in Lower Amazon most of the income and employment are provided by the small (0–4 t) boat operators, who should be considered in political and management decisions (Almeida and others 2001). In Brazilian Amazon, most of the fisheries management and policy decisions have been usually based on fish landings data from the major urban markets, such as Manaus, Tefé, Santarem and Belém (Costa and others 2001; Ruffino 2004; Isaac and others 2008). Conversely, most of the catch from several villages have had not reached the official statistics.

Fishers in urban markets should usually catch more fish, have a higher fishing effort and be more selective compared to fishers in villages, as has been shown by previous surveys (Bayley and Petrere 1989; Cerdeira and others 2000; Almeida and others 2001; Isaac and others 2008; de Merona and others 2010). However, to our knowledge no surveys have compared urban and village fishers simultaneously in the same region and using the same sampling methodology. We aim to compare the fishers' characteristics (catch, effort and selectivity) between an urban market and five villages in Lower Tocantins River, downstream from a large reservoir. Such comparison can improve data recording and management interventions in tropical freshwater fisheries, by showing to which extent those surveys made in urban markets reflect the characteristics of (unknown) fisheries of small villages in the same region. If small villages show a distinct fishery or do make a relevant contribution to fish production, it would be worth including those fisheries in monitoring and management programs.

Methods

Study Site: Tocantins River and the Tucuruí Reservoir

The Araguaia-Tocantins River Basin (Eastern Brazilian Amazon) has been affected by environmental changes, such as deforestation, intensification of fisheries and building of dams (Ribeiro and others 1995). The Tocantins River, which is a clear water river with 2750 km length, drains a 343,000 km^2 region. This river was impounded in 1984 by the construction of the Tucuruí reservoir, which flooded an area of 2,830 km^2. The impoundment of the Tocantins River has adversely affected fish communities and fisheries downstream from the dam through reduced productivity (retention of sediments in reservoir), alterations in hydrological cycle and interruption of spawning migrations of commercial fishes (de Merona 1990; Ribeiro and others 1995; Petrere 1996; Fearnside 1999). According to studies made in south Brazilian rivers, which have been more severely impounded than Amazon rivers, dams may impede both fish migrations upstream and dispersal of eggs and larvae downstream, therefore potentially reducing fish populations downstream from the dam (Agostinho and others 2004).

Study Site: Fishing Villages and Fisheries

In Lower Tocantins River, small-scale fishers are usually local Amazonian people culturally defined as *caboclos* (descendants from Portuguese and indigenous Brazilian), making a living off of small-scale agriculture and fishing (Ribeiro and others 1995; McGrath and others 2008). The Brazilian governmental electric company (Eletronorte) that runs the reservoir has been recording data on fish landings at urban fish markets along the Tocantins River (Eletronorte unpublished reports). According to previous surveys, Tocantins River has small-scale commercial fishers (de Merona 1990; Petrere 1996), who are similar to fishers in Amazon Basin as a whole: units of production are discrete boats, which sell fish at local markets and each boat is usually owned by a single family (Bayley and Petrere 1989). These fishers use mainly gillnets and the main fish species caught are the *curimata* (*Prochilodus nigricans)* and the *mapara* (*Hypophthalmus marginatus*) (Ribeiro and others 1995; Petrere 1996). Fisheries have been studied in more detail in Tucuruí reservoir (Camargo and Petrere 2004) and in Middle Tocantins River upstream from the dam (Cetra and Petrere 2001). Fisheries remain less studied in Lower Tocantins River, which is one of the most populated regions of the Tocantins River and that might have been more affected by impacts from the Tucuruí reservoir (de Merona 1990; Petrere 1996).

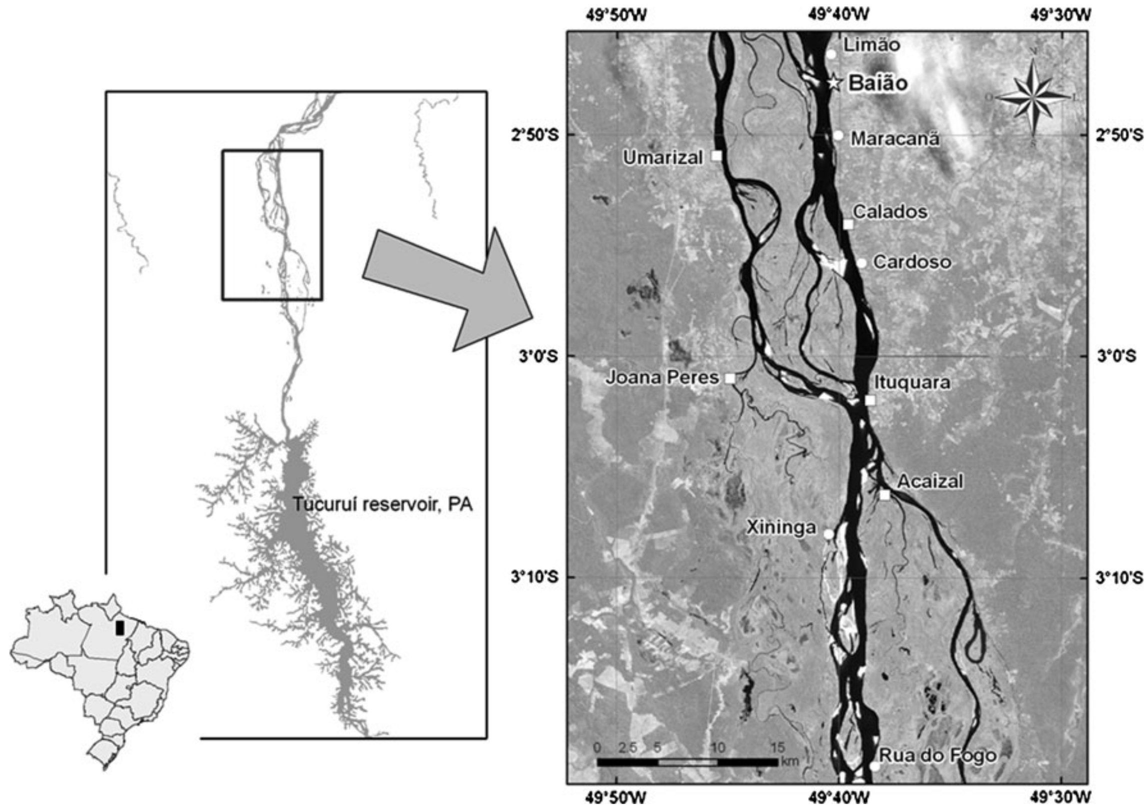

Fig. 1 Map of the studied region, showing the studied fishing villages and the city of Baião, in the Lower Tocantins River

General Interviews and Selection of Studied Villages

Interviews through standardized questionnaires were conducted with 300 fishers (243 men and 57 women) in nine villages in Lower Tocantins River (Fig. 1) in August, 2006. These nine villages were chosen following advice from Eletronorte's staff, from local fishing associations and from the city council of Baião, aiming to include fishing communities over a broad area in Lower Tocantins River region (Fig. 1) and over a large range of habitats (lakes, tributaries and the main river). Interviewed fishers were indicated by villages' leaders, which were usually members of local fishing associations. Alternatively, we used the snow-ball method: each interviewed fisher indicated others to be interviewed. These interviews, which included open ended questions about the fishers' overall socioeconomic profile (main activities, place of origin, time of residence in the region, literacy, among others), were conducted by researches to assess the fishers' main characteristics and to guide the selection of some villages, which would be studied in more detail. Detailed results from this general socio-economic survey can be found in Silvano and others (2009). After this initial stage of general interviews, five villages were selected from the former nine: Açaizal, Calados, Ituquara, Joana Peres and Umarizal. Two villages, which are in fact districts of Baião city, were excluded from the survey because fishers there landed most of their catches at the studied urban market in Baião (Silvano and others 2009). The village of Rua do Fogo was excluded because it was too far from the others to be simultaneously surveyed (Fig. 1). The village of Xininga was excluded because it was too small with only about five families. Although these five fishing villages were selected in a nonrandom and haphazard way, we believe that we were successful in including villages showing a range of relevant characteristics. Villages vary regarding size, from the smaller Açaizal with about 68 families to the larger Ituquara with about 1000 families (both data from J.A.C. Andrade, unpublished report by Eletronorte, 2003); fishing was important to the local economy of all these villages, as many of the fishers interviewed were devoted mostly to fishing (Silvano and others 2009); some of these villages, such as Ituquara, have been regarded as important centers of fish production for rural people (de Merona 1990).

A general socio-economic survey based on interviews was not made with urban fishers who land their catches at the urban market in Baião. Urban fishers are a diffuse and heterogeneous group, including people from the city of Baião, from villages and even from other cities. This makes very difficult to locate urban fishers to be interviewed, compared to the situation in villages, where we interviewed people at their houses. Therefore, the comparison between urban market and village fishers that we made in this article is restricted to fish landings data.

Sampling of Fish Landings

The survey of fishing landings was conducted in the five selected fishing villages (hereafter named villages) and at the urban market in Baião (hereafter named urban market) (Fig. 1). All the studied sites were located in Lower Tocantins River, downstream of the Tucuruí reservoir, between the coordinates of 02°50′944″S; 49°45″511″W and 03°06′210″S; 49°37′872″W in a floodplain (seasonally inundated islands and forests), which includes Tocantins River tributaries (locally called *igarapés*) and shallow floodplain lakes (locally called *lagoas*) (Fig. 1).

Fish landings were sampled in villages in five fieldtrips (67 days total) in all major hydrological seasons: flooding (11 days in December, 2006), high water (26 days in March, 2007 and in February, 2008), receding water (14 days in June, 2007) and low water (16 days in September, 2007). Fish landings were sampled all day (from 07:30 to 18:00 h, approximately), in about two to five days in each village and in each season. Villages were usually sampled in consecutive days, except for some occasions when two observers sampled two villages simultaneously. Fish landings were recorded by weighing fish according to species (or group of species) and by conducting a brief interview with fishers. This interview, which was based in a standard field questionnaire, addressed the fishing grounds exploited, fishing gears used, duration of fishing, crew size and amount of ice used (indicators of fishing effort). Fish landings were sampled at the urban market daily and all year long by Eletronorte staff, following the same procedure described above for the villages' survey. The same questionnaire was used and the same questions were asked at the urban market and in villages. Sampling at the urban market occurred in the morning, when fishers arrived to sell the fish. Because sampling at the urban market was much more extensive than that in villages, only those days where we had sampled both the urban market and villages were analyzed. This assured a complete overlap on sampling days at the urban market and in villages, thus allowing a more accurate comparison. Nevertheless, this was done at the expense of not including in analyses those days where sampling was made at the urban market, but not in the villages, thus restricting both samples to the same 67 days throughout hydrological seasons (see above). This comparative analysis of fishing effort was made using data gathered at the urban market up to 2007. The data gathered at the urban market by Eletronorte in February 2008 were not fully available at the time of our analyses: we had data on total amounts of fish caught (per species) only, during the 13 days of this month when we sampled fish landings in villages. Such urban market data from February 2008 were used to compare fish catch composition only, being excluded from the other analyses (e.g., the comparisons of CPUE, amount of ice and crew size).

During the interviews, fishers were asked to identify the fishes caught by mentioning their local names. These names were assigned to fish species based on researchers' previous knowledge concerning the commonest species and through two comparisons. First, we compared local names with common names and pictures of a fish book from the region (Santos and others 2004). Second, we compared local names with fish sampled through experimental fishing, which were identified to species level by the authors (Silvano and others 2009). Albeit we could identify most of the fish landed at least to the level of genera, we could not always establish a one to one correspondence. Therefore, we arranged some fishes in species groups, rather than in individual species.

Data Analysis

Fishing productivity was compared through a measure of catch per unit of effort (CPUE) defined as total amount of fish caught (kg) fishers^{-1} day^{-1}, which made our results comparable from other surveys (Cerdeira and others 2000; Almeida and others 2001; Cetra and Petrere 2001). We compared the mean CPUE and the median of amount of ice used (kg) and of number of fishers per fishing trip (crew size) between the urban market and the villages through Z test (means) and the non-parametric Mann–Whitney (U) test (medians). When using the Z test, we made a descriptive statistical analysis and used the calculated variances to perform the test. We checked the homogeneity of variances through the F test (variance ratio) and normality of data through the Lilliefors test (Ayres and others 2000). We log-transformed data to achieve normal distribution and homogeneous variances; when these were not achieved, we used the corresponding non-parametric test.

Frequency of fishing gear used, such as gillnets mesh sizes, was compared through Chi-square test. Diversity of fish caught was compared using the Shannon and Simpson diversity indexes, as done in other surveys (Cetra and Petrere 2001; Silvano and Begossi 2001), besides a measure of Evenness (Simpson E1/D) to assess fisheries' selectivity. We used the term diversity of fish to refer to the measures provided by diversity indexes, which consider both the number and the relative composition of species (Magurran 1988). The number of fish species, which is another measure of species diversity, has been regarded as species richness. These two measures (richness and diversity) are complimentary and are both useful: the diversity considers also information regarding dominance or rarity of species in samplings (fish landings in our case) (Magurran 1988).

Composition of fish species caught in villages and at the urban market was compared through the Morisita-Horn similarity index, based on biomass of species (or groups of species). Diversity and similarity indexes were calculated using the software Ecological Methodology (Kenney and Krebs 2000) and the other statistical tests were performed using the software BioEstat (Ayres and others 2000). To increase sample size, data from the five villages were analyzed together and we pooled the data in two main seasons: high water (high plus flooding water seasons) and low water (low plus receding water seasons).

Results

We recorded a total of 606 fish landings in the five fishing villages, which yielded a total of 6,848 kg of fish; and 118 fish landings at the urban market, which yielded a total of 10,770 kg. Five fish landings in villages were excluded from the analyses due to missing data. We excluded also 32 fish landings at the urban market (seven from the low water and 25 from the high water season): 15 of these came from the Tocantins River upstream from the dam (outside the studied region), seven caught freshwater shrimps only (427 kg or 3.8% of total landings) and 10 had missing data. Therefore, the analyses included 86 fish landings from the urban market and 601 fish landings from the villages.

Do Urban Fishers Fish More Intensely and Catch More Fish Than Village Fishers?

The mean CPUE and the median of ice used and crew size per fishing trip were higher at the urban market (Table 1), indicating that urban fishers catch more fish on average and employ a more intense fishing effort than village fishers. Indeed, urban fishers used powered motor boats in nearly all fishing trips sampled (98.8%) while village fishers used small canoes in most fishing trips (80%). However, the estimated annual fish production based on daily mean amount of fish caught was twice higher in villages compared with the urban market (Table 2).

Table 1 Comparison of the variables CPUE, number of fishers and amount of ice between fish landings recorded at the urban market ($n = 86$) and in villages ($n = 601$) at the Lower Tocantins River, in 2006–2008

Variable	Villages	Urban market	Statistical test[a]	Significance
CPUE (mean) (kg fishers^{-1} day^{-1})	5.97 (±7.24)	30.23 (±26.61)	$Z = 16.6343$	$P < 0.0001$
Number of fishers (mean)	1.68 (±0.75)	2.45 (±0.68)		
Number of fishers (median)	2 (1; 2)	2 (2;3)	$U = 11437.50$	$P < 0.0001$
Ice (kg) (mean)	4.35 (±21.51)	93.76 (±49.43)		
Ice (kg) (median)	0.0 (0.0;0.0)	80 (80;100)	$U = 1023.50$	$P < 0.0001$

The values are either (means ± S.D.) or medians (lower 25%; upper 75% quartiles); [a] The *Z* test compares means and the U test compares medians. However, we show means also because they are better comparable with previous studies. Medians were only calculated when needed to make the U test

Table 2 Sampling effort, number of fish landings and fishers, observed and estimated total annual fish catches for the five villages and for the catch commercialized in the urban market (Baião) at the Lower Tocantins River, from 2006 to 2008

Locality	Sampling days	Fish landings	Number of fishers	Fish catch (kg)	Fish catch (kg) day^{-1}	Annual Estimate of fish caught (t)[b]
Açaizal	12	94	169	1415.23	117.9	36.8
Calados	18	119	204	933.37	51.9	16.2
Ituquara	19	223	373	2532.98	133.3	41.6
Joana Peres	16	110	191	1545.64	96.6	30.2
Umarizal	8	58	80	421.14	52.6	16.4
All villages (total)	73[a]	604	1017	6848.4		141.1
Baião	55	86	211	10,770	186.6	58.2

[a] Total number of days differ from total fieldwork sampling days (67) because on some days two villages were sampled simultaneously, by different researchers; [b] Estimate based on 52 weeks a year (364 days), considering six fishing days each week (excluding Sundays or at least one resting day each week) or 312 fishing days a year, which was multiplied by the average daily catches (kg) for each villages and totals for the five villages summed

Do Catch and Effort Vary Seasonally at the Urban Market and in Villages?

The median CPUE of fish landings did not vary seasonally in villages: 3.6 (1.1 lower 25% quartile; 9.5 upper 75% quartile) kg $fishers^{-1}$ day^{-1} in low water season ($n = 275$) and 3.6 (2 lower 25% quartile; 6.2 upper 75% quartile) kg $fishers^{-1}$ day^{-1} in high water season ($n = 326$) ($U = 44546$, $P > 0.05$). The mean CPUE of fish landings at the urban market was higher in low water season (33.3 ± 24.6 kg $fishers^{-1}$ day^{-1}, $n = 46$) than in high water season (26.7 ± 28.6 kg $fishers^{-1}$ day^{-1}, $n = 40$) ($Z = 2.2$, $P < 0.05$). However, the mean amount of fish caught (not considering fishing effort) at the urban market did not differ between seasons (122.2 ± 112.9 kg in low water, $n = 46$ and 116 ± 94.4 kg in high water, $n = 40$, $Z = 0.43$, $P > 0.05$). This indicated that urban fishers maintained their catch levels in high water by increasing their fishing effort, which showed higher medians in high water season (2 fishing days, with 2 lower 25% quartile; 3 upper 75% quartile, $n = 40$) than in low water season (1 fishing day, with 1 lower 25% quartile; 2 upper 75% quartile, $n = 46$, $U = 479.5$, $P < 0.01$).

Are Urban Fishers More Selective Than Village Fishers Regarding the Fishing Gear Used, Habitats Exploited and Fish Species Caught?

Gillnets were the main fishing gear used by both urban and village fishers (Fig. 2). Urban fishers used gillnets in more than 90% of fishing trips, while village fishers used also other gears, such as hand lines (Fig. 2). However, village fishers still used gillnets more often than they used hand lines (considering all fishing landings in the two seasons) (Fig. 2, $\chi^2_1 = 58.9$, $P < 0.01$). The most often used gillnet mesh sizes (measured in cm between opposite knots) were those of 6 to 8 cm in villages and of 7 and 8 cm at the urban market (Fig. 3). Village fishers, who used also hand lines besides gillnets, can be thus regarded as less selective than urban fishers.

Fishers at the urban market and in villages exploited distinct aquatic habitats. The formers fished exclusively in the main canal of the Tocantins River, while village fishers exploited the main river canal ($n = 221$), tributary rivers (locally called *igarapés*, $n = 185$) and lenthic water habitats (lakes and seasonally inundated floodplain sites, $n = 192$). Village fishers were thus less selective than urban fishers regarding the habitats exploited.

Village fishers caught 57 fish species groups and urban fishers caught 18 fish species groups (Table 3). Diversity of fish landed measured by the Shannon index was higher in villages (H′ = 3.72) than at the urban market (H′ = 2.97), but Simpson diversity were similar in villages (1 − D = 0.87) and at the urban market (1 − D = 0.83). Evenness was higher at the urban market (E1/D = 0.32) than in villages (E1/D = 0.14), which indicated that fish species were landed in a more evenly distributed proportions at the urban market (Table 3). The urban fishers were in general more selective than the village fishers, who caught more species and a higher diversity of fish.

Did Urban and Village Fishers Catch the Same Fishes?

The two studied fisheries were very similar regarding the relative composition (in biomass) of groups of fish species caught (Morisita-Horn coefficient = 0.94), as the same fish species (or groups) were among the most caught both in villages and at the urban market: *pescada* (*Plagioscion squamosissimus), curimata* (*Prochilodus nigricans*), *mapara* (*Hypophthalmus marginatus*) and *branquinha*

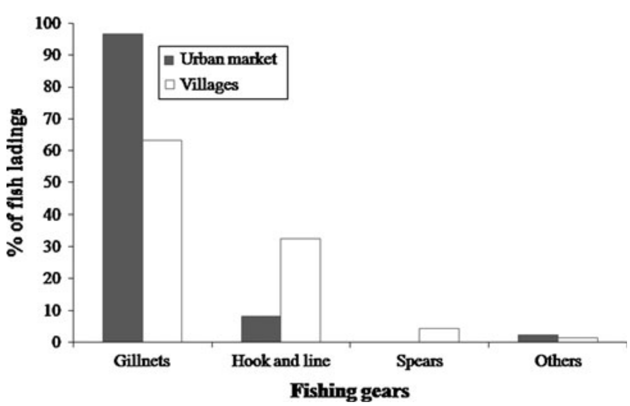

Fig. 2 Frequency (% of total fish landings) of use of fishing gears by fishers at the urban market ($n = 86$) and in villages ($n = 601$) in the Lower Tocantins River, from 2006 to 2008. Hook and line includes hand lines, fishing poles and long-lines; spears included at least four kinds of spears used underwater or from the surface; others refers to one and two fishing gears respectively at the urban market and in villages

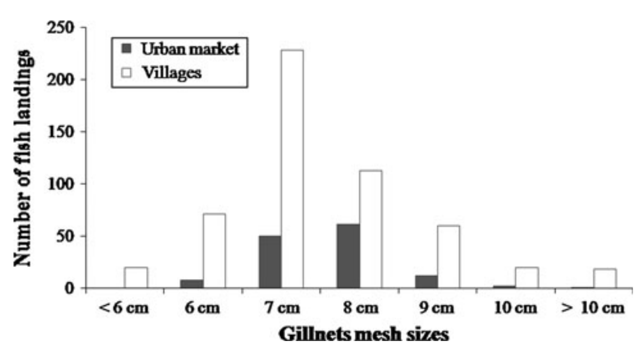

Fig. 3 Frequency (number of fish landings) of use of different mesh sizes (distance between opposite knots) of gillnets used by fishers at the urban market ($n = 86$) and in villages ($n = 601$) in the Lower Tocantins River, from 2006 to 2008

Table 3 Composition of fish landings regarding the main fish species or groups of fish species caught by commercial fishers in the urban market ($n = 86$ landings, 10,770.4 kg of fish) and by village fishers ($n = 606$ landings, 6,848.4 kg of fish) at the Lower Tocantins River, from 2006 to 2008

Common name	Family	Fish species[a]	Villages (kg)	Urban Market (Kg)
Pescada	Sciaenidae	*Plagioscion squamosissimus*	1956.3	2974
Mapará	Pimelodidae	*Hypophthalmus marginatus*	769.23	1143
Curimatá	Prochilodontidae	*Prochilodus nigricans*	729.18	1606
Branquinha	Curimatidae	Different species (*Curimata vittata, Cyphocharax* spp., *Psectrogaster essequibensis*)	577.17	1299
Tucunaré	Cichlidae	*Cichla kelberi* and *C. pinima*	383.76	138
Piau or aracu	Anostomidae	Different species (*Laemolyta* spp., *Leporinus* spp., *Schizodon vittatus*)	382.36	690
Acará	Cichlidae	Different species (*Astronotus ocellatus, A. crassipinnis, Chaetobranchus flavescens, Geophagus altifrons, G. proximus, Hypselecara temporalis, Satanoperca jurupari*)	365.98	131
Piranha	Serrasalmidae	*Pygocentrus nattereri, Serrasalmus* spp.	307.87	30
Traíra	Erythrinidae	*Hoplias malabaricus*	218.88	124
Aruanã	Osteoglossidae	*Osteoglossum bicirrhosum*	126.5	17
Jutuarana	Hemiodontidae	*Hemiodus* spp.	121.59	51.2
Apapá	Pristigasteridae	*Pellona castelnaeana*	97.55	512
Ximbé	Auchenipteridae	*Ageneiosus ucayalensis*	88.88	0
Cuiú	Doradidae	*Oxydoras niger*	88.11	0
Jacundá	Cichlidae	*Crenicichla* spp.	72.82	0
Dourada	Pimelodidae	*Brachyplatystoma rousseauxii*	67.66	346
Pacu	Characidae	Different species (*Metynnis* spp., *Myleus* spp., *Mylossoma duriventre*)	67.19	126
Mandubé	Auchenipteridae	*Ageneiosus* spp.	51.56	0
Acari	Loricariidae	Different species (*Pterigoplichthys joselimaianus, Hypostomus* spp.)	50.61	0
Pirarara	Pimelodidae	*Phractocephalus hemioliopterus*	48.2	65
Botinho	Doradidae	*Hassar wilderi, H. orestis*	43.12	0
Pirarucu	Arapaimatidae	*Arapaima gigas*	40	0
Sardinha	Characidae and Clupeidae	Different species (*Triportheus spp., Lycengraulis batesii, Anchovia surinamensis, Pterengraulis atherinoides*)	32.55	0
Jeju	Erythrinidae	*Hoplerythrinus unitaeniatus*	24.53	0
Filhote	Pimelodidae	*Brachyplatystoma filamentosum*	20.39	0
Raia	Potamotrygonidae	*Paratrygon* sp., *Potamotrygon* sp.	17.8	8
Surubim	Pimelodidae	*Pseudoplatystoma fasciatum*	14.85	92
Peixe Galinha	Pimelodidae	*Pimelodina flavipinnis*	12.56	0
Curuca	Auchenipteridae	*Trachelyopterus galeatus*	9.16	14
Ripa	Cynodontidae	*Rhaphiodon vulpinus*	8.32	0
Piramutaba	Pimelodidae	*Brachyplatystoma vaillantii*	8.09	0
Uéua	Acestrorhynchidae	*Acestrorhynchus* spp.	5.89	0
Cabeça de Pedra		Non identified	5.14	0
Mandi	Pimelodidae	*Pimelodus blochii, Megalonema platycephalum*	4.46	0
Bacu	Doradidae	Non identified	3.26	0
Corvina	Sciaenidae	*Pachypops fourcroi, Pachyurus* spp.	2.65	0
João Duro	Chilodontidae	*Caenotropus labyrinthicus*	2.49	0
Jandiá	Pimelodidae	*Pimelodella cristata*	2.44	0
Tambaqui	Serrasalmidae	*Colossoma macropomum*	2.2	0
Ituí	Rhamphichthyidae	*Rhamphichthys marmoratus*	1.94	0

Table 3 continued

Common name	Family	Fish species[a]	Villages (kg)	Urban Market (Kg)
Braço de Moça	Pimelodidae	*Hemisorubin platyrhynchos*	1.6	0
Tamatá	Callichthyidae	*Callichthys callichthys, Hoplosternum littorale, Megalechis thoracata*	1.5	0
Bagre	Pimelodidae	*Goslinia platynema*	1	0
Piracatinga	Pimelodidae	*Platynematichthys notatus*	1	0
Peixe Rei		Non identified	0.67	0
Bico de Pato	Pimelodidae	*Sorubim lima*	0.6	0
Bicuda	Ctenoluciidae	*Boulengerella* spp.	0.5	0
Aicanga	Cynodontidae	*Cynodon gibbus*	0.47	0
Guerrenche	Doradidae	*Platydoras costatus*	0.45	0
Bacurrico (Botinho)	Doradidae	*Platydoras armatulus*	0.4	0
Babaiacu	Tetraodontidae	*Colomesus asellus*	0.27	0
Candiru	Cetopsidae	*Cetopsis coecutiens*	0.25	0
Flauta		Non identified	0.2	0
Pirapitinga	Serrasalmidae	*Piaractus brachypomus*	0.16	0
Barbado	Pimelodidae	*Pinirampus pirinampu*	0.15	0
Chave	Doradidae	*Platydoras costatus*	0.15	0
Carataí	Auchenipteridae	*Auchenipterus nuchalis*	0.12	0
Matupiri	Characidae	Different species (*Bryconops alburnoides, Poptella* spp., *Tetragonopterus* spp.)	0.04	0
Jatuxi	Loricariidae	*Loricariichthys acutus*	0.03	0
Mixed fishes[b]	Non identified	Non identified	0	1403
Total (Kg)			6842.8	10770

[a] We identified fish species by comparisons with fish species sampled and identified in lakes in the region (experimental fishing) and by consulting a fish catalogue for the Tocantins River (Santos and others 2004); [b] Mixed fishes refer to juvenile of different species usually caught together and sold for a cheap price. In the urban market (Baião), despite their relative importance (in kg), these mixed fishes were not separated by fish vendors, not allowing the identification of each species

(several species of Curimatidae), which corresponded to about half of the total biomass caught (Table 3).

Discussion

Limitations of the Data Set

Our results have some limitations, as our data were gathered during 67 days in one year. Relatively few surveys have been able to record fish landings in Brazilian Amazon for more than one year (Cetra and Petrere 2001, Isaac and others 2008), but even these studies rely on short time series, of up to five years. The Brazilian government has been unable to gather a large amount of reliable fisheries data in Amazon, where fisheries are diffuse, widespread, small-scale and difficult to sample (Bayley and Petrere 1989). Therefore, fisheries in Brazilian Amazon would possible need a data less management approach, as proposed by Johannes (1998) in the context of coastal tropical fisheries. We thus considered that, although limited temporally, our data set is sufficient to compare urban and village fisheries and to analyze key aspects of these fisheries, such as catch per unit of effort (CPUE), fishing gears used, catch composition and diversity (selectivity).

Fish Catches in Villages and at the Urban Market: Implications to Monitoring

As we expected, urban fishers caught more fish and employed a higher fishing effort (boat and crew size, amount of ice) than village fishers. Although we lack information on the socioeconomic background of urban fishers, the observed differences on fishing effort indicated that most of these fishers were full time fishers or fish vendors. Other surveys in Amazon, which compare distinct categories of fishers (commercial vs. subsistence, small vs. large boats), indicate also that commercial fishers catch more fish and that these higher catches are related to a higher fishing effort (amount of ice used and number of fishers in the crew) (McGrath and others 1997; Almeida and others 2001; Cardoso and Freitas 2008; Isaac and others 2008). Our results indicated that village fishers, who are also part time farmers according to interview data (Silvano and others 2009), went fishing mostly for subsistence and local commerce, as has been observed in other Amazonian fishing villages (McGrath and others 2008; Silva and Begossi 2009). The observed differences in catch and effort may be an indicator of the general socio-economic profile of urban and village fishers in Lower Tocantins River, even in the absence of detailed interviews with the former.

The total estimated annual fish production was higher in villages, which showed more fishing trips per day and more fishers in activity than the urban market in the Lower Tocantins River (Table 2). Other surveys showed that, albeit commercial fisheries may be more productive, small scale fisheries in villages contribute substantially to fish production, employment and income generation in Amazonian rivers (Bayley and Petrere 1989; McGrath and others 1997; Almeida and others 2001; Cardoso and Freitas 2008). Indeed, subsistence fishers caught a similar amount of fish compared to commercial fishers in a lake in the Lower Amazon (Cerdeira and others 2000). Therefore, restricting monitoring of fish landings to urban markets underestimates the total amount of fish landed. Fish landings have been regularly monitored in some Amazonian villages due to co-management initiatives (Castello and others 2009), but most of the surveys addressing catch and effort in Amazonian village fisheries have been more restricted in time and place (Isaac and others 1996; Batista and others 1998; Cerdeira and others 2000; Begossi and others 1999; MacCord and others 2007; Silva and Begossi 2009). According to Bayley and Petrere (1989), interviewing households to estimate basin wide fish production would be advantageous, as such interview data are less variable than data from fish landings in major markets. Indeed, surveys comparing distinct kinds and scales of fisheries in the same region have been usually based on interviews with selected fishers (Batista and others 1998; Almeida and others 2001). Although we considered that our data were sufficient to describe village fisheries, our villages' survey can be considered as a rapid assessment approach, when compared to the more extensive (and more expensive) monitoring of fish landings by Eletronorte in Baião and other cities in Tocantins River (de Merona 1990; Cetra and Petrere 2001). Our approach of comparing village and urban fisheries in the same region, during the same time period and using the same sampling methodology could thus be a feasible way to check if these two kinds of fisheries would shown the same characteristics. This could indicate the cost-benefit of expanding the monitoring that is already made at the urban markets to villages. Rapid assessments of village fisheries could help also to know the fishers better. A second step then could be the participatory monitoring, where fishers in villages may be trained to monitor their catches (Ticheler and others 1998; Cerdeira and others 2000; Castello and others 2009). Although participatory monitoring also involves costs and qualified personnel, they could be more appropriate to more distant villages and could improve dialogue and collaboration between fishers and managers. Fish landings surveys in villages could also be useful to improve biological knowledge: catch data from commercial and subsistence fisheries provided additional information on fish lateral migrations in the Amazon River (Fernandes 1997).

Fishing Strategies and Selectivity at the Urban Market and in Villages

As expected, village fishers caught more fish species than urban fishers. This indicates that fisheries surveys at urban markets may also give incomplete information about the kinds of fish caught (catch composition). More than 30 fish species groups were only recorded in villages, where fishers caught more 'rare' fish (fish species caught in smaller amounts), as indicated by the lower evenness and higher Shannon diversity indexes. Compared to other tropical freshwater fisheries, both urban and village fishers in the Lower Tocantins River can be considered as moderately selective, as the three main fish species caught accounted for near half of the total biomass (Table 4). Considering the total number of fish species caught, Lower Tocantins village fishers were relatively less selective compared to other small scale fisheries, but urban fishers were among the most selective (18 fish species only) (Table 4). Such high selectivity of urban fishers could be related to fishing strategies, to market demands or to incomplete data collection. Although we did not make a detailed survey of fish market chains, we assumed that general market system (prices, customers, fish preferences) were the same at the urban market and in villages. People living in villages and in Baião city have the same cultural background (*caboclos*) and the main fish species caught and sold were the same (Table 3), which indicated similar fish preferences. Nevertheless, because they were more commercial, urban fishers may have discarded part of the fish caught before landing. Therefore, we consider that market demands do not fully explain why urban fishers caught less fish species.

An unknown proportion of fish landings recorded at the urban market in the Lower Tocantins River may come from fish vendors: sometimes fishers (or vendors) from villages or from other towns buy fish in villages to be sold at the

Table 4 Comparison of fisheries selectivity among several tropical freshwater fisheries (including the studied urban and village fisheries in the Lower Tocantins River), regarding the relative proportion (%) of total biomass landed corresponding to the three main fish species caught

Scale of fisheries	Region	% of the 3 main fish species caught	Number of fish species (or species group) caught	Source
Villages (small scale)	Lower Tocantins River, Eastern Brazilian Amazon	50.4	57	This study
Urban market (commercial)		54.6	18	This study
Small-scale	Middle Tocantins River, Eastern Brazilian Amazon	77.4	50	Cetra and Petrere (2001)
Mixed	Lower Amazon River, Eastern Brazilian Amazon	37	70	Cerdeira and others (2000)
Mixed[a]	Solimões River, Middle Brazilian Amazon	90	37	MacCord and others (2007)
Commercial	Madeira River, Western Brazilian Amazon	55.2	32	Cardoso and Freitas (2008)
Commercial	Amazon estuary, Eastern Brazilian Amazon[b]	82	37	Oliveira and others (2007)
Commercial	Amazon and Ucayali Rivers, Loreto Region, Peruvian Amazon	62	65	Garcia and others (2009)
Small-scale	São Francisco River, southeastern Brazil[c]	75.8	11	Camargo and Petrere (2001)
Small-scale	Piracicaba River, southeastern Brazil	62.5	43	Silvano and Begossi (2001)
Commercial[d]	Lake Malawi, Africa	40.3	107	Weyl and others (2005)
Small-scale	Malaysia	44.9	59	Ali and Lee (1995)
Subsistence	Rice-farming landscapes, Laos	40	124	Khoa and others (2005)

[a] 90% of the amount caught (in kg) consisted of four fish species (MacCord and others 2007); [b] Brackish water: the confluence between the Amazon River and the Atlantic Ocean (Oliveira and others 2007). Data from fish landings using gillnets, which are more comparable to those studied in the Lower Tocantins River; [c] Data from wet season only (Camargo and Petrere 2001); [d] Data from pair-trawl fishery (Weyl and others 2005)

urban market (G. Hallwass and R.A.M. Silvano, personal observation, 2007). The high selectivity regarding habitats exploited (e.g., the high quotation of Tocantins river as the fishing spot), fishing gear used (gillnets only) and fish species caught could be partially due to underreporting by vendors, who may not know the details of fishing activities, such as habitat and gear. Fish landings from vendors could also partially account for the higher values of CPUE, fish catches and effort (ice used) here observed at the urban market, as some of the landings were a product of the (unmeasured) effort performed by several fishers, including those in the villages. Unfortunately, data recording at the urban market did not distinguish fishers from vendors. We suggest that future and current monitoring of fish landings at urban markets identify landings from vendors, to not overestimate the amount of fish caught and fishers' selectivity. It would also be interesting to ask vendors to mention the amount of fishers who sold fish to them, to get a better idea of market chains.

Urban and village fishers also showed distinct seasonal patterns of catch and effort in the Lower Tocantins River: the CPUE of the former was higher during the low water season than during the high water season, while the CPUE of the later did not differ seasonally. Other studies on Amazon fisheries show that catches and CPUE are usually higher during the low water season, because fish are more concentrated in rivers and lakes (Fernandes 1997; Begossi and others 1999; Cerdeira and others 2000; MacCord and others 2007; Cardoso and Freitas 2008). Urban and village fishers in the Lower Tocantins River may adopt distinct strategies to deal with seasonal changes on water level: village fishers maintained their CPUE during the high water season by changing their fishing gear from gillnets to hand lines (less susceptible to variations in fish density). Seasonal rotation of fishing gear, which is also observed in other Brazilian freshwater fisheries, can potentially reduces overfishing by distributing fishing pressure among distinct fish species (Isaac and others 1996; Silvano and Begossi 2001; MacCord and others 2007). On the other hand, the studied urban fishers increased their fishing effort in high water season to maintain fish production, as observed in other Brazilian Amazon river (Cardoso and Freitas 2008).

Contrary to our hypothesis, urban and village fishers used similar fishing gear (gillnets) and did not differ regarding overall composition of the catch nor the main fishes caught (Table 3). Therefore, albeit it underestimated the total fish production, urban market data was a reliable indicator of fishing gear used and main fish species caught in the Lower Tocantins River villages. This is a relevant input to fisheries management, as some management measures will focus on gear restrictions or characteristics of the main fish species exploited (minimum size, closed seasons, among others). Previous surveys comparing distinct scales of fisheries in the same region usually do not detail the catch composition (Almeida and others 2001; Isaac and others 2008).

Catch and Effort at the Urban Market, in Villages, and in Other Freshwater Fisheries

Urban fishers showed a higher mean CPUE than village fishers in the Lower Tocantins River. A similar pattern (larger scale commercial fishers showing a higher CPUE) has been observed in other small-scale fisheries in the Brazilian Amazon (Table 5). The mean CPUE of studied village fishers was usually lower than those of other small scale subsistence or commercial fishers in the Brazilian Amazon, besides being comparable to those of subsistence fishers in more depleted Asian and African reservoirs and lakes (from 4 to 7 kg $fishers^{-1}$ day^{-1}, Table 5). This raises concerns about possible problems affecting village fisheries in Tocantins River, such as overfishing and impacts from the dam. The observed CPUE at the studied urban market was relatively high compared to other Brazilian Amazon fisheries in more productive white water rivers, such as Lower Amazon and Madeira (Table 5). This suggests that the studied fisheries may be not seriously overfished yet. However, we lack detailed surveys of temporal trends to assess the intensity of overfishing in the studied region.

Potential Reservoir Effects

Notwithstanding the monitoring efforts of Eletronorte, there are no temporal data series on fish landings in the Lower Tocantins River from before the impoundment. We compared our data gathered within one year with data from the same region, before the reservoir formation (1980 and 1981) (de Merona 1990; de Merona and others 2010), and with a recent survey in the Tocantins River upstream from the dam (Cetra and Petrere 2001). Although these comparisons should be considered with care, they could provide some insight on possible reservoirs' effects. The total

Table 5 Mean catch per unit of effort (CPUE, kg $fishers^{-1}$ day^{-1}) of several freshwater fisheries, including those studied in the Lower Tocantins River

CPUE		River	Region	Sampling method	Source
Subsistence or small-scale[a]	Commercial[b]				
6	30	Lower Tocantins	Brazilian Amazon	Fish landing	This study
5.3		Middle Tocantins	Brazilian Amazon	Fish landing	Cetra and Petrere (2001)
	17.8	Lower Amazon	Brazilian Amazon	Fish landing and interview[c]	Isaac and others (2008)
9.97	25.34	Lower Amazon	Brazilian Amazon	Fish landing and interview	Almeida and others (2001)
16	35	Lower Amazon	Brazilian Amazon	Fish landing[d]	Cerdeira and others (2000)
46.3		Japurá and Coroaci	Brazilian Amazon	Fish landing[e]	MacCord and others (2007)
50.4		Japurá and Solimões	Brazilian Amazon	Fish landing	MacCord and others (2007)
20.7	22.9	Middle Madeira	Brazilian Amazon	Fish landing and interview	Cardoso and Freitas (2007)
4			Camboja, Southeast Asia	Interview[f]	Navy and Bhattarai (2006)
6.8			Malaysia, Southeast Asia	Fish landing and interview	Ali and Lee (1995)

[a] Fisheries usually made by a crew of few fishers (two or three) in small boats or canoes; the catch is either consumed (subsistence) or sold locally. This category includes most of the village fisheries studied in Brazilian Amazon; [b] Fisheries usually made by large crews (more than four fishers) in large boats, sometimes the crew is formed by hired fishers who work for the boat's owner; the catch is always sold, usually in markets. This category includes the urban fishers studied here and most of other fishers who land their catches in markets of larger Amazon cities; [c] Average CPUE for the period 1993–2003 (Isaac and others 2008); [d] Fishers, who were trained by researchers of Project IARA/IBAMA, recorded fish landings themselves (Cerdeira and others 2000); [e] Although these fisheries can be considered small-scale, being performed by fishers in villages, they are an exception compared to others: fishers organize themselves and go fishing in groups to catch large commercial fish species (MacCord and others 2007); [f] Fisheries have been decreasing since 1990, when the CPUE was 15 kg $fishers^{-1}$ day^{-1} (Navy and Bhattarai 2006)

annual catch estimated at the urban market in this study (58.2 t) was respectively 15 and 4.3 times lower than the values recorded at urban markets in the Tocantins River upstream from the reservoir (Cetra and Petrere 2001) and in the same region before the impoundment (de Merona and others 2010). Large tropical reservoirs may affect fishers several kilometers downstream from the dam (Fearnside 1999), but these fishers are usually among the less benefited by compensatory measures.

Conclusions

Based on previous surveys, we expected that urban fishers would catch more fish, employ a higher fishing effort and be more selective compared to village fishers and our data confirm this general hypothesis in the Lower Tocantins River. We also observed similarities between urban and village fisheries regarding the overall catch composition, main fishing gear used and main fish species caught. However, the total estimated amount of fish caught annually was larger in villages, reinforcing their importance to the regional economy and food production. Previous surveys (Almeida and others 2001; Weyl and others 2005; MacCord and others 2007; Garcia and others 2009) and ours indicate the need of considering differences among distinct scales or kinds of fisheries when devising fishery management measures. We suggest that specific management measures may be needed in the Tocantins River, which can account for the apparent reduced availability of fish to village fishers, the importance of fishing to food security and the widespread use of gillnets, especially by urban fishers. Co-management, which involve local fishers in the definition and enforcement of management rules, have been a promising approach to manage Amazon floodplain fisheries, improving fishing rewards of those communities involved in co-management (MacCord and others 2007; McGrath and others 2008; Almeida and others 2009; Castello and others 2009). Co-management could be also feasible in the studied village fisheries in the Lower Tocantins River, considering their diversified resource use strategies and less intensive fishing effort. Amazon people regularly perform other resource use activities, such as small scale agriculture, gathering of non timber forest products and hunting (McGrath and others 2008; Silva and Begossi 2009). Comparing different scales of resource use in the same region, during the same time period and using the same sampling methodology would be useful to improve monitoring and management of these other activities as well.

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