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FISHERIES ECOLOGY IN THE LOWER AMAZON: A TYPICAL ARTISANAL PRACTICE IN THE TROPICS

Mauro Luis Ruffino [1], Victoria Judith Isaac [2] & Ana Milstein [3]

[1] Projeto IARA/IBAMA-GOPA/GTZ, Av Tapajós, 2267 –Cep. 68.040-000 Santarém, PA, Brazil
[2] Museu Paraense Emílio Goeldi, CP 399, Cep. 66.017-970 Belém, PA, Brazil
[3] Fish & Aquaculture Research Station, MP Hof HaCarmel 30820, Israel

Resumo. Dados de captura e esforço pesqueiro da produção desembarcada na cidade de Santarém, Brasil, em 1993 foram estudados através de análise estatística paramétrica e através do Modelo Linear Geral (GLM) usado como análise de co-variância. Os dados mostram que os desembarques seguem um padrão bimodal, com um pequeno pico em Maio, quando o nível da água é alto e um pico maior durante a estação seca, entre Agosto e Outubro. A captura total foi de 4.280 t oriunda de 7.689 viagens de pesca. Os peixes são capturados por pequenas canoas e transportados aos mercados em pequenos barcos motorizados que servem como base das operações de pesca. Esses barcos podem ser classificados de acordo à sua função e tipo de contrato com os pescadores. As viagens duram em média de 4 a 5 dias e envolvem 4 a 5 pescadores. Malhadeira é a arte de pesca mais freqüentemente utilizada, mas uma variedade de outras artes também são empregadas. A captura por unidade de esforço foi de 14 kg/homem/dia e a atividade ocupou diretamente cerca de 3.610 pescadores. Um grande número de espécies diferentes ocorreram nos desembarques, porém apenas dez espécies correspondem a mais de 85% do total desembarcado. O grupo de espécies mais abundantes nos desembarques foram os peixes-liso (Siluriformes), mas várias espécies de Characiformes e pescadas (Sciaenidae) também foram importantes. Os resultados das análises descritivas indicam que a pesca regional depende das variáveis ecológicas e econômicas, segundo dois distintos padrões: i) uma atividade de pequena escala, desenvolvida durante todo o ano para suprir o mercado local, e ii) uma pesca mais especializada orientada à exportação de peixes-liso a outros estados do Brasil. Um Modelo Linear Geral incluindo variáveis continuas e categóricas (regressão múltipla e ANCOVA) foi estimado para a captura/viagem. O modelo indicou que o número de pescadores explica a maioria da variabilidade no rendimento, seguido pela época do ano, consumo de gelo e combustível, e tipo de embarcação utilizada.

Abstract. Data on catch effort and fish landings in the town of Santarém, Brazil, were collected during 1993. Landings follow a bimodal pattern, with a small peak in May when water level is high and a higher peak during the dry season between August and October. Total catch was 4,280 t from 7,699 fishing trips. Fish are caught by small canoes, and transported to markets in relatively small motorized boats that serve as the bases for fishing operations. These boats can be classified according to their function and the kind of contract made with fishers. Fishing trips average four to five days and involve four to five fishermen. Gill-nets are the most frequently used fishing gear, but a variety of other gear is also used. Average catch per unit effort was 14 kg/fisher/day and the activity directly occupied an average of 3,610 fishers. The number of species caught was very high, but ten species made up more than 85% of the total yield. Catfish (Siluriformes) were the most abundant species group in the landings, but several species of characiforms and freshwater drums (Sciaenidae) were also important. A General Linear Model – GLM – including continuous and class variables (multiple regression and ANCOVA) was estimated for the catch/trip. This indicated that the number of fishermen explain most of the variability in yield, followed by season, ice and fuel consumption, and type of vessel used. The results indicate that the regional fishery depends on ecological and economic variables, following two distinct patterns: (1) a small-scale activity, conducted year-round to supply local markets, and, (2) a more specialized fishery directed towards the export of catfish products to other Brazilian states. *Accepted 31 August 1998.*

Key words: Fishery assessment, fishery ecology, multivariate mathematical model, Brazilian Amazon.

INTRODUCTION

The Amazonian ecosystem is dominated by the marked periodicity of precipitation and by the snow-melt from the Andean peaks. Flood seasonality imposes a rhythm that explains most of the adaptations of aquatic and semiaquatic flora and fauna, as well as those of human activities in the region. For most of the basin the rainy season begins in November or December and continues through the following four or five months (Salati & Marques 1984). The water level in the Amazon river varies according to place and time of year. In general the pattern is unimodal with an annual amplitude of 5 to 10 m (Hanek 1982).

Periodically inundated floodplains play a significant role in the local economy. The fertile soils and the high concentration of fish and other aquatic vertebrates explain why the floodplains sustain some of the highest population densities in the basin (Meggers 1971, McGrath *et al.* 1993a). Richness in nutrients, aquatic macrophytes, fruits, leaves and seeds have made floodplain lakes and flooded forests extremely important for aquatic life (Goulding 1980, Rai & Hill 1980).

Bayley & Petrere (1989) suggest that fish stocks are underexploited and that fishing effort could be increased. However, due to lack of data, stock assessments are not available for most of the exploited fish species. Amazon freshwater fish production potential has been estimated at between 217,000 tons/year (Bayley 1981) and 902,000 tons/year (Merona 1993), and that of the Amazonian estuary at over 385,000 tons/year (Dias Neto & Mesquita 1988).

The present yield is unknown and relatively little data on catch and effort are available for the Brazilian Amazon. Estimates of fish production based on the size of the flooded area indicate values of 200,000 tons/year for the entire Amazonian basin (Bayley & Petrere 1989). Petrere (1978a, 1978b, 1985), Goulding (1979), Smith (1979), and Merona & Bittencourt (1988) have described fisheries in Belém, Porto Velho, Itacoatiara and Manaus based on data collected only over a few years. However, there is no available information on other regions of the basin. It is only recently, through the implementation of "Projeto IARA – Management of the Natural Resources of the Lower Amazon: States of Pará and Amazonas" (IBAMA 1995), that the systematic collection of data and an analysis of the fisheries has begun in the Lower Amazon (Ruffino & Isaac 1994, Isaac *et al.* 1996, Isaac & Ruffino, in press a).

This paper presents some of the preliminary results of "Projeto IARA." The objective of this project is to improve the understanding of fishing activities in the region and their ecological and socioeconomic relationships. The first part of the paper describes the main characteristics of the Lower Amazon fisheries and the second presents a General Linear Model, including continuous and class variables (multiple regression and ANCOVA), for predicting local catch per fishing trip.

MATERIAL AND METHODS

Fishermen were interviewed daily at the major landing points in the town of Santarém throughout 1993. Names of boats were recorded, with the exception of fishing canoes without identification. Recorded information included data on catch and effort, such as catch per species, number of fishermen, type of boat, type and number of fishing gear, fishing sites, duration of trip, and landing site. Additional information on ice and fuel consumption, market and average first hand price of fish were also noted. The average catch per unit effort (kg/fisher/day) was estimated using those landings for which the information on fisheries effort was complete (controlled landing).

A data matrix was constructed in which individual fishing trips were represented by rows and their respective descriptive variables as columns. The SAS statistical package (documented in SAS 1987) was used to estimate parameters of a General Linear Model, including continuous and class variables (multiple regression and ANCOVA). The effect of different fishing characteristics was examined by fitting a General Linear Model (GLM) to the data (e.g., Milstein *et al.* 1993). The logarithm of the catch (kg/trip) was used as the dependent variable, with the following numerical explanatory variables: duration of trip (days), number of fishermen, quantities of diesel oil and ice consumed per trip (liters). Categorical variables were: distance from fishing ground to landing site (four ranks), type of boat, type of gear, landing site and market, and period of day when fishing. Catches obtained with harpoon, trident and arrow, as well as all lines, were grouped into one category due to their low frequency of occurrence. All numerical variables were logarithmically transformed for normalization, and 1 was added to the quantities of diesel oil and ice consumed to avoid zeroes. Results of the GLM are of two types: an ANCOVA, which indicates the significance and relative importance of each of the effects tested, and a multiregression equation with coefficients for the continuous variables and for each category of the categorical variables. In addition, differences between geometrical averages of categorical variables, taken independently from each other, were tested with Duncan's multiple comparison test ($P \leq 0.05$).

RESULTS

General features. The fisheries in the Lower Amazon region are strictly artisanal. The local boats can be classified according to their functions and the type of contract established between the owner and the fishermen, canoe, motor canoe, fishing boat buyer boat, mixed boat, and cargo or ferry boat. All of the

Fishing grounds. The catches landed at Santarém originated from 14 municipalities along the Amazon River, from Prainha just above the mouth of the Xingú River (in the state of Pará) upstream to Manaus and the Solimões river (in the state of Amazonas) (Fig. 2). Over 78% of the fishing operations took place on fishing grounds near the town of Santarém, followed by the neighboring municipalities of Alenquer and Monte Alegre. Duration and yield of fishing trips were related to the distance of the fishing grounds from Santarém. Voyages to localities farther away, such as those in the state of

TABLE 2. Descriptive summary of the most common types of fishing gear in the Lower Amazon (modified from Barthem 1995)

Name of gear	Description	Usage
malhadeira (gill-net)	Multifilament nylon gill-net, mesh size varying according to target species, with floats on the upper edge and weights on the bottom edge	Commonly used in still waters, especially in flooded areas; usually fixed and employed as a fence net (passive gear), but also as a dragnet at the water's edge
miqueira (monofilament gill-net)	Monofilament nylon gill-net with varying mesh size, floats on the upper edge and weights on the bottom edge	Used in lakes and river margins as a fence net
bubuia or rede à deriva (drift-net)	Large and deep net set adrift in the middle of the river, tied to a boat on one side	Used to catch large catfish
tarrafa (cast-net)	Funnel-shaped net with lead weights around its mouth	Used on shallow waters with little or no vegetation, or to catch pelagic species in schools in river canals
linha-de-mão (baited handline)	Long nylon handline with a medium-size hook at one end; depending on the target-species, it can carty a float or a sinker	Used for various pelagic species (e.g., aruanã) or demersal (e.g., catfish), with different throwing techniques for each case
curumim or rapazinho (handline with one baited hook)	Long handline tied to a tree or to some fixed point on the river bank, with a medium-size hook on the other end	Used for various species
caniço (stick, line and baited hook)	Long stick with line and hook, sometimes also with a float or a sinker	Used mainly in the rainy season for small fish such as sardinha and matrinchã
espinhel (longline with several baited hooks)	Long line with many medium- or large-size hooks, one or both ends tied to some fixed point	Used to catch catfish in the river canal
arpão or haste (harpoon)	Wooden spear with a sharp metallic head	Specialized gear for arapaima and other large fish
zagaia (trident)	Wooden spear with a two- or three-pronged metallic head	Used with a flashlight for night fishing, aiming at cichlids, anuanã, etc.
flecha (arrow with or without bow)	Hollow shaft with an arrowhead propelled by hand or by means of a bow	Used for fish swimming just below to the surface
matapi (trap)	Simple cylindrical trap made of wooden sticks, with a funnel on each end and an access hatch	Used to catch freshwater shrimp

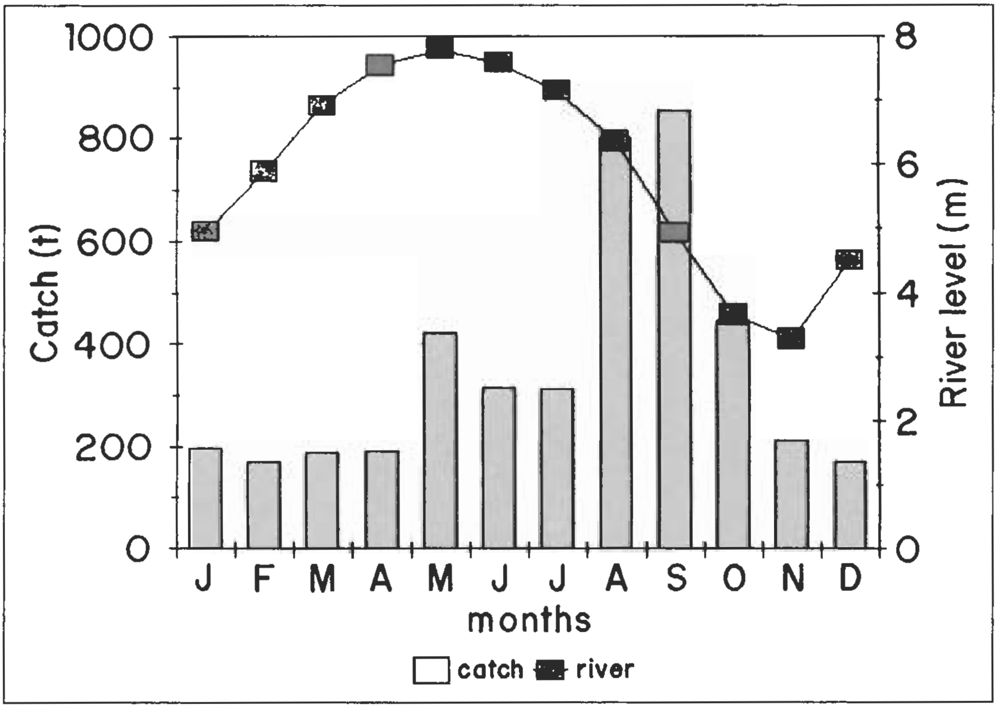

FIG. 1. Total yield and river level in the town of Santarém, 1993.

Amazonas, varied between 12 and 23 days and resulted in a higher yield per trip, accounting for 27% of the catch in weight but only 1.4% of trips. Fishing trips to nearer districts, such as Alenquer, Óbidos, Monte Alegre, or even Santarém, took 4 or 5 days and were less productive.

The main fishing grounds are located on the Amazon, Tapajós, Curuá-Una, and Solimões rivers, and in the floodplain lakes. The main floodplain lakes are Lago Grande de Franca/Curuai, Lago Grande de Monte Alegre, Lago Jauari/Dos Botos, and Lago do Pacoval, located in the municipalities of Santarém, Alenquer, Monte Alegre, Óbidos, and Juruti.

The main species caught in the municipality of Santarém included "dourada," "mapará," "pescada," "surubim" and anostomids. The most important species in Alenquer were "mapará," "dourada," "pescada" and "tambaqui." Óbidos accounted mainly for catfishes such as "dourada," "mapará," "surubim" and "piramutaba," while the catch from Monte Alegre consisted of "pescada," "acarí" *Liposarcus pardalis* (Loricariidae) and "tambaqui." The main species from Prainha were "curimatá" and "dourada." Parintins, in the state of Amazonas, was the most important municipality for catfish such as "dourada," "surubim" and "filhote." The catch from the Manaus region consisted primarily of "jaraqui" and "curimatá." Other important species from municipalities in the state of Amazonas included catfish, "jaraqui," "pirapitinga" *Piaractus brachypomus* (Characidae) and "cujuba" *Oxydoras niger* (Doradidae).

Vessel types. Of the five types of fishing vessel described earlier (Tab. 1), "barco pescador" fishing boats were the most numerous, accounting for 50% of all fishing trips and 79% of the catch by weight. They were followed in order of importance by "barco comprador" buyer boats (7.3% of catch), "barco de linha ou carga" ferry or cargo boats (5.8%) and "barco mixto" mixed boats (4.5%). Owners of "canoas" canoes fishing independently were interviewed by us in the ports but accounted for only 3% of the catch.

TABLE 3. Monthly catch, fishing effort and catch per unit of effort (CPUE) of landings at Santarém in 1993.

Month	N° trips	Days	N° of fishers	Monitored landing (t)	Total landing (t)	Fishers/ trip	Days/ trip	CPUE (kg/trip)	CPUE (kg/fisher/ day)
Jan	509	2,915	2,031	161	195	3.99	5.73	316	11.92
Feb	410	2,014	1,722	114	170	4.20	4.91	277	12.62
Mar	517	2,443	2,086	136	189	4.03	4.73	264	11.96
Apr	581	2,597	2,045	157	191	3.52	4.47	271	11.91
May	626	2,790	2,563	378	423	4.09	4.46	604	11.99
Jun	472	2,386	2,114	271	316	4.48	5.06	574	11.08
Jul	563	2,628	2,458	179	312	4.37	4.67	317	10.39
Aug	971	4,126	4,285	451	800	4.41	4.25	465	18.99
Sep	992	4,265	4,522	501	854	4.56	4.29	506	18.28
Oct	828	3,495	3,676	282	446	4.44	4.22	340	14.15
Nov	703	2,879	2,862	175	213	4.07	4.10	249	12.84
Dec	517	1,833	2,116	117	171	4.09	3.55	226	14.50
Average						4.19	4.53	367	14.03
Sum	7,689	34,371	32,480	2,922	4,280				

It was also noted that while fishing boats were active more or less continuously throughout the year, vessels of other types, mixed, buyer, cargo and ferry boats, were most active during the dry season, particularly between August and November. Buyer and mixed boats had the best catch per trip; fishing boats showed a significantly better yield than vessels in the categories cargo and ferry boats, or canoes (Table 6).

Different types of boat differed in fishing effort. On average, fishing boats went out on six-day trips with a six-man crew, while mixed and buyer boats carried about seven people on week-long trips. Canoes usually took two men on two-day fishing trips (Table 9). Typically, small scale fisheries used fishing boats and canoes, while the most powerful buyer boats landed principally at the ice-packing plants.

Fisheries ecology. Nylon nets are certainly the most important fishing gear in the Lower Amazon. Drift-nets and gill-nets were the most productive (Table 6). "Malhadeira" (multifilament nylon nets) accounted for 39% of the catch and were used in 28% of all fishing trips. These nets are mainly used as fixed gill-nets or as mobile encircling seines, principally in the state of Amazonas. Multifilament nets were followed, in order of decreasing importance, by "miqueira" monofilament nylon fixed gill-nets (25% of catches by weight, 23% of landings), "bubuia" drift gill-nets (17% and 6%), "espinhel" longlines (1.8% and 8%) and "tarrafa" cast-nets (less than 1% and 7%). Other kinds of gear, harpoon, arrow, trident, handline, hook and line, single-hook longline, beach trawl and trap, were responsible for only 1% of the catch. The use of many different kinds of gear on the same trip was a common practice, occurring in almost 25% of all operations and accounting for 15% of the annual catch.

A seasonal pattern in the choice of fishing gear was observed, correlating with water level variation. At the start of the rainy season and throughout the flood season, multifilament nylon gill-nets were the preferred gear. Use of monofilament nylon gill-nets started with the first rains, peaked when the water level was at its highest and continued until the ebbing period. The dry season brought greater variety in the choice of gear: longlines, drift-nets and cast-nets were then introduced. Nevertheless, the practice of using a combination of different methods occurred all year around (Fig. 3).

Multifilament nylon gill-nets were used for *P. nigricans*, *Plagioscion* spp., *C. macropomum*, *Pseudoplatystoma* spp., *B. flavicans*, anostomids, and armored catfishes. Purse seines were used mainly to capture schools of "jaraqui." Drift-nets were mostly used for large catfish such as "dourada," "surubim," "filhote," and "piramutaba." Monofilament nylon gill-nets were used mainly to catch 'mapará', drums and anostomids.

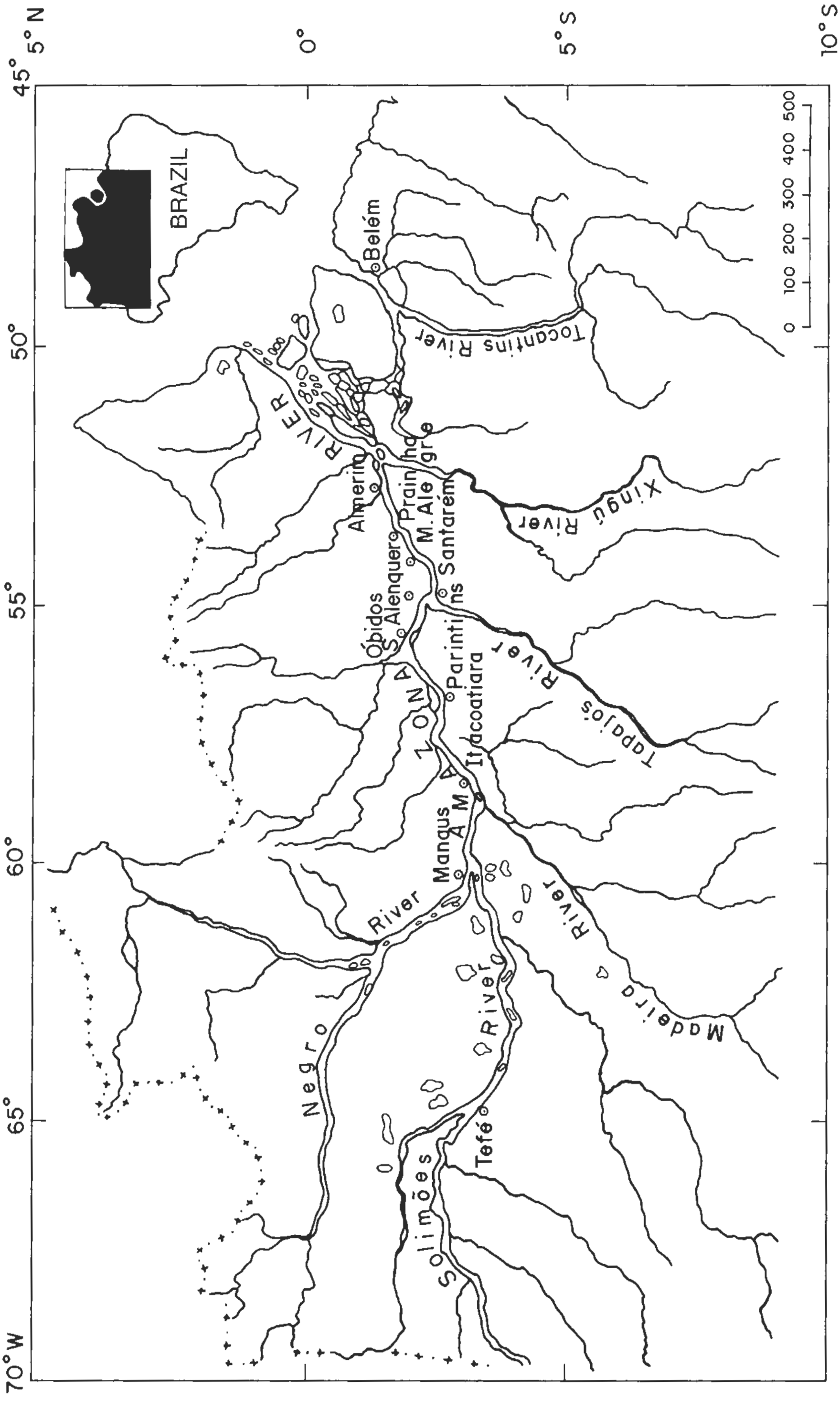

FIG. 2. Map of the Amazon River and its principal tributaries in the studied region.

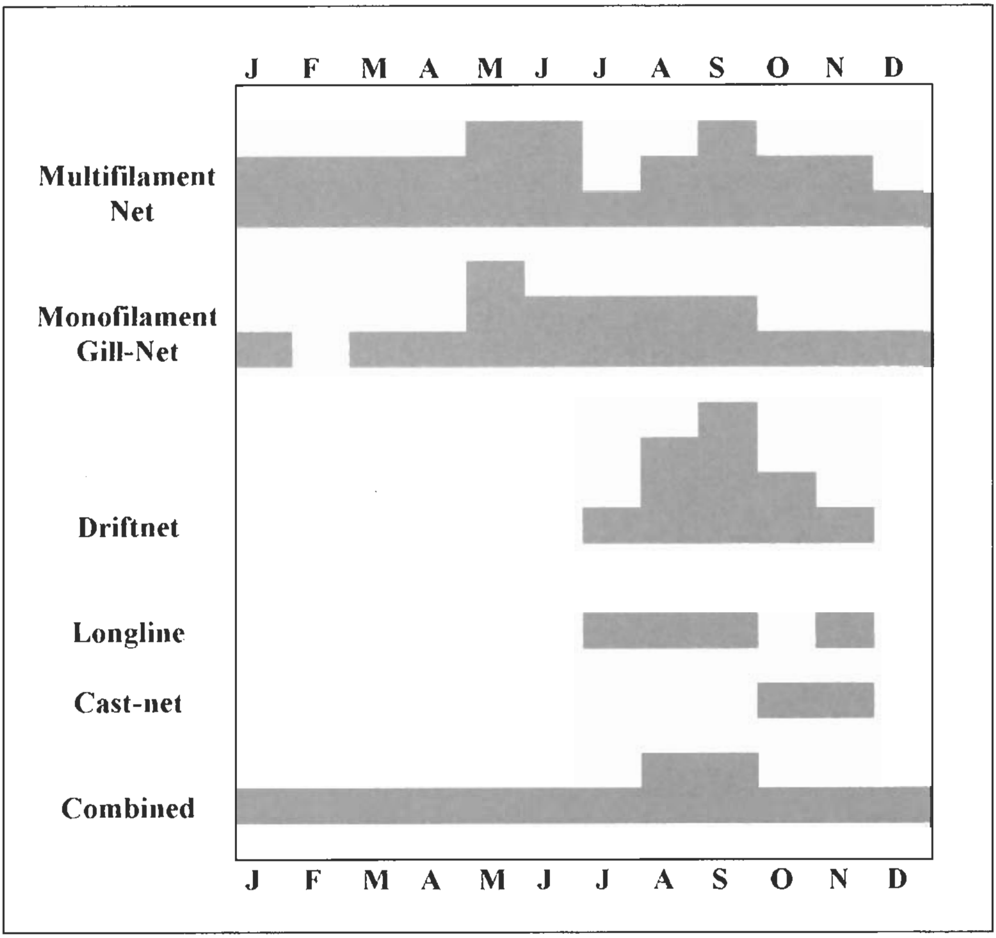

FIG. 3. Pattern of seasonal use of main fishing gears in the Lower Amazon.

Fishing in the Lower Amazon was carried out to the same extent in both lakes (50% by weight) and rivers (49%) of the region. The remaining 1% of the catch was taken in other environments such as flooded forests, streams, sand bars, etc. When considering the total catch, productivity was higher in lakes (Table 6). These habitats were exploited all year round but their catch diminished somewhat during the falling and low water periods, precisely when rivers were more intensively exploited. Catch in the rivers peaked twice: once at the beginning of the high water season, and again between August and October, the driest months of the year.

Most species caught in lakes were sedentary or migratory scale fish which spend the flood season in lakes. Some catfish such as "mapará," "surubim," "dourada," and the non-migratory "acarí" were caught during the flood season in the lakes. In the rivers, catfish were the most important species (mainly "dourada," "surubim," and "piramutaba"), followed by characiforms such as "jaraqui," "curimatá," "pacu," *Myleus* spp, *Metynnis* spp., and *Mylossoma* spp., caught in rivers during dry season upstream migrations.

Catch prediction: General Linear Model (GLM). A general linear model was fitted to the data. The results

TABLE 4. Fish species landed at Santarém, state of Pará, Brazil.

Family	Scientific name	Vernacular name
Potamotrygonidae	*Potamotrygon* spp.	Arraia
Clupeidae	*Pellona castelnaeana*	Apapá-amarelo
	Pellona flavipinnis	Apapá-branco
Arapeimidae	*Arapaima gigas*	Pirarucu
Osteoglossidae	*Osteoglossum bicirrhosum*	Aruanã
Anostomidae	*Leporinus fasciatus*	Aracu-amarelo
	Leporinus friderici	Aracu-cabeça-gorda
	Schizodon fasciatus	Aracu comum
Characidae	*Triportheus elongatus*	Sardinha comprida
	Triportheus flavus	Sardinha papuda
Curimatidae	*Psectrogaster amazonica*	Branquinha cascuda
	Potamorhina latior	Branquinha comum
	Potamorhina altamazonica	Branquinha lisa
Cynodontidae	*Cynodon gibus*	Saranha
	Rhaphiodum vulpinus	Peixe cachorro
Erythrinidae	*Hoplias malabaricus*	Traíra
Hemiodontidae	*Hemiodus* spp.	Charuto
Prochilodontidae	*Prochilodus nigricans*	Curimatã
	Semaprochilodus taeniurus	Jaraqui escama fina
	Semaprochilodus insignis	Jaraqui escama grossa
Serrasalmidae	*Colossoma macropomum*	Tambaqui
	Mylossoma spp.	Pacu comum
	Myleus spp.	Pacu jumento
	Metynnis spp.	Pacu marreca
	Myleus spp.	Pacu olhudo
	Pygocentrus nattereri	Piranha caju
	Serrasalmus splilopleura	Piranha mafurá
	Serrasalmus rhombeus	Piranha preta
	Piaractus brachypomus	Pirapitinga
Ageneiosidae	*Ageneiosus* spp.	Mandubé
Callicthydae	*Hoplosternum litoralle*	Tamuatá
Doradidae	*Lithodoras dorsalis*	Bacu pedra
	Pterodoras lentiginosus	Bacu liso
	Oxydoras niger	Cujuba
Hypophthalmidae	*Hypophthalmus* spp.	Mapará
Loricaridae	*Liposarcus pardalis*	Acarí-bodó
Pimelodidae	*Calophysus macropterus*	Piracatinga
	Brachyplatystoma filamentosum	Filhote
	Brachyplatystoma flavicans	Dourada
	Brachyplatystoma vaillanti	Piramutaba
	Goslinia platynema	Barbado
	Leiarius marmoratus	Jandiá
	Paulicea luetkeni	Jaú
	Phractocephalus hemioliopterus	Pirarara
	Pimelodina flavipinnis	Fura calça
	Pimelodus spp.	Mandí
	Platynematichthys notatus	Cara de gato
	Pseudoplatystoma fasciatum	Surubim lenha
	Pseudoplatystoma tigrinum	Surubim tigre
Cichlidae	*Astronotus crasipinis*	Acará-açu
	Cichla sp.	Tucunaré-açú
	Cichla temensis	Tucunaré-pinima
	Cichla monoculus	Tucunaré-tatu-comum
Sciaenidae	*Plagioscion* spp.	Pescada
	Plagioscion auratus	Pescada preta
	Pinirampus pirinampu	Piranambú

showed good agreement with the model, which explained over 80% of the variation in total catch per fishing trip. All variables considered were significant (Table 7) and the residuals are evenly distributed on both sides of the x-axis (Fig. 4).

The analysis of covariance demonstrates that most of the variation in yield is due to the number of active fishermen (19.6% of the total squared deviations). Month of capture, amount of ice transported, type of vessel, and amount of fuel are other important sources of variance in the model. Other variables, although significant, have less influence on the final result (Table 7).

A regression model allowed the estimation of coefficients for the numerical variables, as well as for each level of categorical variables, to predict yield per fishing trip. The resulting equation is:

$$\log_{10} \text{Catch} = 1.07 + 0.25 \log_{10}(\text{Ice}+1) + 0.32 \log_{10}(\text{Fuel}+1) + 0.20 \log_{10}(\text{Day}) + 0.52 \log_{10}(\text{Fishers}) + k_1(\text{Month}) + k_2(\text{Boat type}) + k_3(\text{Period}) + k_4(\text{Environment}) + k_5(\text{Gear}) + k_6(\text{Distance}) + k_7(\text{Market}) + \varepsilon$$

where the values of the coefficients k_1 to k_7 are presented in Table 8.

The intercept represents the mean log catch when all other terms are zero. Or in other words, the exponential of the intercept represents the geometric and not the arithmetic mean catch in any particular scenario. That is, for one fisherman in a single day, using no fuel and no ice, and for the reference level of each categorical variable. That reference level is: fishing in December, with motorized canoe, during the night, in the river channel, using various types of fishing gear, in fishing grounds far from Santarém, and landing in the Uruara market. The corresponding catch in this scenario is approximately 12 kg of fish. For other situations, the corresponding values of the continuous variables and coefficients of each categorical variable, when significantly different from zero, should be substituted in the formula.

Economics. Catch transported to Santarém was sent mainly to the three town markets (63.6%) and to the town's most important packing plant (36.4%). This fish-packing plant sells frozen fish products to other regions of Brazil. The diversity of fish was lower (39 species) in the fish-packing plant than in the local markets, although volumes were higher. Most of the species processed in the plant were catfish, including large pimelodids and doradids. The catch landed at the Santarém markets was more diversified, and consisted primarily of prochilodontids, sciaenids, and anostomids, but also included the catfish "mapará" *Hypophthalmus* spp.

Price of fish at first sale depended on three factors: species, market and season. The price per kilogram varied between US$ 0.13 and US$ 1.42, with an average value of approximately US$ 0.50/kg. Considering the total annual catch and the average price, the gross income generated in 1993 by the Santarém-based fisheries was approximately US$ 2 million. Average gross income per trip was US$ 179, with an average consumption of 676 kg of ice and 57 liters of fuel. However, gross income per trip varied according to the type of vessel used. Buyer-

TABLE 5. Composition of catch landed at Santarém in 1993.

Scientific name	Vernacular name	Landing (t)	(%)
Brachyplatystoma flavicans	Dourada	836	19.5
Hypophthalmus spp.	Mapará	810	18.9
Pseudoplatystoma spp.	Surubim	498	11.6
Semaprochilodus spp.	Jaraqui	339	7.9
Plagioscion spp.	Pescada	286	6.7
Brachyplatystoma vaillanti	Piramutaba	238	5.6
Prochilodus nigricans	Curimata	185	4.3
Brachyplatystoma filamentosum	Filhote	156	3.6
Leporinus spp., *Schizodon fasciatus*	Aracú	152	3.6
Colossoma macropomum	Tambaqui	123	2.9
Other species		657	15.4
Total		4,280	100

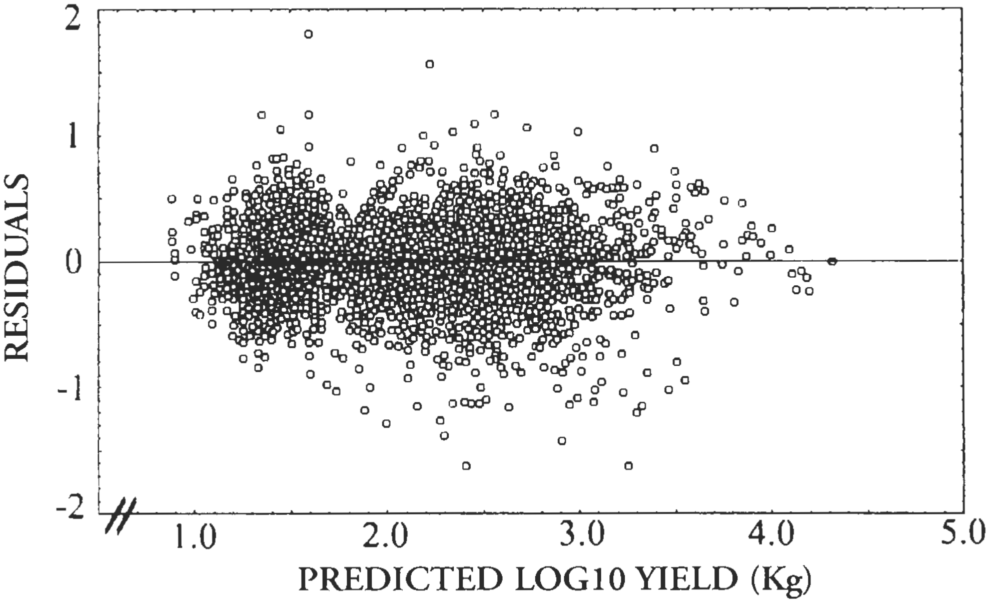

FIG. 4. Plot of predicted logarithm of yield versus regression residuals.

boats generated the highest income (Tables 9), averaging more than US$ 1,000 per trip.

DISCUSSION

This work confirms the importance of fishing to the Lower Amazon region, particularly Santarém. In addition to returns of over US$ 2 million from sales in Santarém, the fisheries employed more than 3,600 persons directly, and a much larger number indirectly in supply (nets, fuel, ice, food, etc.) and in fish processing and marketing.

From the quantitative point of view, the GLM allows us to predict total landings per trip, taking account of the wide range of facilities (vessels and gear) and environments involved in the Amazonian fisheries. Qualitatively, two fisheries can be distinguished. On the one hand, some fishing activities were pursued all year round, principally on lakes, and mainly for sale in local markets, while on the other, fishing for catfish and characoids in the river channel during the dry season was more intense during the migration period of the target species (as the water level starts to drop), particularly in the dry season. This fishery is oriented towards export to other Brazilian states and its value is increased through processing in Santarém. These conclusions, confirmed in other works, have important consequences for the management of fishery resources in the region (Isaac *et al.* 1996).

In addition, fishing power proved to be clearly correlated with number of fishermen and the physical characteristics of the iceboats. Greater yields per trip require greater financial investments, ensuring better fishing conditions (boats with greater ice capacity, larger gill-nets, larger number of fishers, etc.). These conditions are more commonly found in rhe fishing fleets of the larger towns in the region, predominately in the vessels engaged by the ice-packing plant of Santarém.

In the 1960s, the appearance in the Amazon of a class of itinerant full-time fishermen coincided with a gradual increase in fishing effort and the search for ever more productive fisheries. Decline of other resources such as rubber and jute, and the increase in urban demand for fish, were probably the socio-economic causes for this transformation. The introduction of nylon-fiber nets, now widely used, and diesel engines, in addition to the establishment of cold storage plants, provided the technical support for this change (Furtado 1993). Technological innovations increased fisheries productivity, while at the

TABLE 6. Results of the comparison of mean yield (geometric) for each variable category. Different letters indicate significant differences ($\alpha = 0.05$) between averages; A>B>C> etc. (Distance = distance between fishing *município* and Santarém; 1 = Santarém, Alenquer, Monte Alegre; 2 = Aveiros, Óbidos, Prainha, Terra Santa; 3 = Parintins, Oriximiná, Nhamundá, Trombetas; 4 = Manaus, Itacoatiara, others in the state of Amazonas).

Effect	N° trips	Log_{10} (Yield (kg/trip))	Differences						
Month									
Jan	415	2.1410	A	B					
Feb	341	2.1629	A						
Mar	441	2.0629			C				
Apr	502	1.9108					E		
May	555	1.8351						F	
Jun	405	1.9636				D			
Jul	469	1.9519				D			
Aug	840	2.1540	A	B					
Sep	873	2.1193		B					
Oct	737	2.0655			C				
Nov	607	1.9717				D			
Dec	417	1.9425				D	E		
Vessel Type									
Buyer boat	90	2.6943	A						
Mixed boat	283	2.6241		B					
Fishing boat	3313	2.4555			C				
Line/Cargo boat	108	2.1680				D			
Motor canoe	61	2.0769					E		
Canoe	2747	1.4313						F	
Period									
Day and Night	2158	2.2898	A						
Day	3527	1.9896		B					
Night	912	1.5839			C				
Fishing gear									
Drift-net	491	2.6153	A						
Multifilament Gill-net	1756	2.3859		B					
Combined gears	1449	2.0471			C				
Harpoon/Trident/Arrow	15	1.9149				D			
Monofilament Gill-net	1524	1.9077				D			
Longline	648	1.5933					E		
Cast-net	527	1.4282						F	
Handlines	192	1.3116							G
Market									
Modelo	1661	2.5019	A						
Edifrigo	938	2.4630		B					
M2000	633	1.8002			C				
Uruará	3367	1.7233				D			
Fishing environment									
Lake	3706	2.0941	A						
River	2804	1.9620		B					
Creek	48	1.8953		B					
Flooded forest	44	1.3636			C				
Distance									
1	5988	1.9535				D			
2	508	2.6942			C				
3	71	3.2200		B					
4	27	3.8029	A						

same time the increase in urban demand allowed the absorption of surplus yield (McGrath *et al.* 1993a). These transformations were associated with increasing social conflicts resulting from disputes disputes between rural and urban fishers over the appropriation of fishery resources. Community police agents, police departments and IBAMA (the Official Brazilian Environmental Agency) offices have received many complaints about physical aggression and net-burning reprisals (Ruffino & Isaac 1994, Isaac *et al.*, in press b).

An increasing number of riparian communities, worried about the diminishing fishery resources resulting from the increased effort, are organizing themselves to develop fishing agreements. These agreements establish informal rules for fishing in order to decrease fishing effort and create reserves in floodplain lakes, in the belief that these actions will help maintain the productivity of the environment. The rules generally involve at least one of some of the following restrictions (seasonal or for an indeterminate period of time): banning entry of motorized boats to lakes, banning commercial fishing, banning the use of gill-nets, or banning the catch of certain species (McGrath *et al.* 1993b, Ruffino, in press).

McGrath *et al.* (1993a) present estimates of fishing yield in two lakes near Santarém, one managed and the other not. In the managed lake, the use of gill-nets is prohibited all year round. Impact of management on yield is especially positive in the case of arapaima (*Arapaima gigas*), a sedentary species. Results also show differences between the two lakes, with 25% to 100% higher catches in the managed lake for *Cichla* spp., *C. macropomum*, and *Plagioscion* spp.

However, the mobility of most of the species caught by the fishermen makes the creation of individual fishery territories impractical. The same populations of migratory fish are probably exploited by residents in different localities, and in general each fisherman's yield affects the yield of all other fishermen in the system. Although the land along lake and river banks belongs to individual proprietors, the water environment is considered "common property" and so its control, whenever it exists, must be collective, involving all fishermen in the community. In this context, the feasibility of lake reserves depends not only on rules but also on the participation of fishermen in the fishing agreements defined by the

TABLE 7. ANCOVA of regression model of the dependent variable $\log_{10}$ (catch), measured in Kg/trip. DF = degrees of freedom. SS = sum of squares. SS% = percentage of total sum of squares. All effects are significantly different from zero at $\alpha = 0.0001$, except the last which is significant at $\alpha = 0.05$.

General			
R^2		0.81	
Degrees of freedom		38	
Geometric average of Log10 (Catch (kg/trip))		2.032	
Number of observations		6,601	
Explanatory variables	d.f.	SS	SS %
$\log_{10}$ (fishers)	1	35.15	19.61
Month	11	34.42	19.21
$\log_{10}$ (Ice)	1	33.65	18.78
Vessel type	5	29.26	16.33
$\log_{10}$ (Fuel)	1	22.84	12.74
Gear type	7	7.31	4.08
$\log_{10}$ (duration of fishing trip (days))	1	7.58	4.23
Landing site and market	3	4.64	2.59
Fishing environment	3	2.23	1.24
Distance to fishing ground	3	1.66	0.93
Fishing period	2	0.48	0.27
Total	32		100

TABLE 8. Regression model of the dependent variable $\log_{10}$ (catch), measured in kg/trip. Last category of each categorical variable is the reference level to which the other categories of the variable are compared (significance test). Coefficients significantly different from zero (continuous variables) or from reference level (categorical variables) for $\alpha = 0.05$ are in bold.

		Regression Parameters		
Variable	Category	Coeficient	Std. Error	Significance
Intercept		1.070	0.080	0.0001
Fishers		0.520	0.020	0.0001
Ice		0.250	0.010	0.0001
Fuel		0.320	0.020	0.0001
Duration		0.200	0.020	0.0001
Month	**Jan**	**-0.009**	0.020	0.648
	Feb	**0.005**	0.021	0.825
	Mar	**-0.031**	0.019	0.120
	Apr	-0.058	0.019	0.003
	May	-0.134	0.019	0.000
	Jun	-0.131	0.020	0.000
	Jul	-0.070	0.019	0.000
	Aug	0.128	0.017	0.000
	Sep	0.093	0.017	0.000
	Oct	0.020	0.018	0.000
	Nov	**0.026**	0.018	0.257
	Dec	0	-	-
Vessel	**Buyer**	**0.030**	0.050	0.536
	Mixed	-0.091	0.042	0.029
	Fishing	**-0.016**	0.037	0.662
	Cargo/Line	**-0.080**	0.046	0.080
	Motor canoe	0	-	-
	Canoe	0.496	0.044	0.000
Period	**Day/Night**	**0.001**	0.014	0.928
	Day	**-0.019**	0.013	0.147
	Night	0	-	-
Gear	**Drift-net**	**-0.018**	0.018	0.327
	Longline	-0.038	0.016	0.016
	Line	-0.225	0.025	0.000
	Harpoon/Arrow	**-0.026**	0.074	0.724
	Gill-net	-0.022	0.011	0.046
	Monof. gill-net	-0.023	0.011	0.036
	Cast-net	-0.066	0.016	0.000
	Mixed	-0.229	-	-
Market	**Modelo**	**0.003**	0.012	0.813
	Edifrigo	-0.055	0.015	0.000
	M2000	-0.087	0.013	0.000
	Uruará	0	-	-
Environment	Lake	-0.046	0.009	0.000
	River	0	-	-
	Creek	**-0.079**	0.041	0.057
	Flooded forest	**-0.061**	0.044	0.166
Distance	1	-0.255	0.060	0.000
	2	-0.229	0.059	0.000
	3	-0.186	0.065	0.004
	4	0	-	-

Note: Distance = distance between fishing *município* and Santarém; 1 = Santarém. Alenquer. Monte Alegre; 2 = Aveiros. Óbidos. Prainha. Terra Santa; 3 = Parintins. Oriximiná. Nhamundá. Trombetas; 4 = Manaus. Itacoatiara, others in the state of Amazonas).

TABLE 9. Average economic yield per trip and vessel type in Lower Amazon fisheries.

Vessel type	N	Fishers/trip	Duration of trip (days)	Ice (kg/trip)	Fuel (l/trip)	Income/trip (US$)
Canoe	-	2	2	3	0	20
Motor canoe	11	3	4	232	22	89
Fishing Boat	565	6	6	1130	94	274
Buyer Boat	18	7	8	4250	194	1188
Mixed Boat	30	7	8	1491	107	324
Cargo/Line Boat	98	5	4	266	46	130
Average		5	5	676	57	179
Sum	722					

community (McGrath *et al.* 1993a, Câmara 1996).

On the other hand, as indicated by our results, more than 80% of the catches are obtained through the use of some kind of net (monofilament fixed gill-net, multifilament fixed gill-net, or drift-net), exactly the fishing methods that are not permitted by some communities. In addition, as noted earlier, the main fishing power lies with the large-scale commercial fleets, which are responsible for the major portion of the fish caught in the river channel (though not in floodplain lakes, from which they are excluded). Community-based management controls the small-scale fishing that supplies local markets in the towns, but it has limited fishing power and productivity.

Therefore it is clear that a community management strategy by itself will not be enough to produce a sustainable and balanced use of the Amazon fishery resources. A combination of various measures will be necessary, particularly in order to regulate professional fishing activities and those with a greater, capital-intensive fishing power, which, because of their techniques, will be little affected by lake fish reserves (Câmara 1996).

In the marine environment there are examples of fisheries cooperatively managed (or co-managed) by representatives of industry, fishing communities, and government, to ensure that multiple social interests are met and an integrated exploitation of the environment is achieved (King 1995). In an attempt to improve management strategies, IBAMA officers have begun to revise regional fishing regulations and to decentralize the decision-making process from the federal to the state level. Through Project IARA, IBAMA has started a partnership with municipal governments, fishermen associations and communities to provide effective legal support for fishery agreements. Such actions should allow the consolidation of a basic management plan adapted to local circumstances, where the state could play an important role in authorizing the implementation of co-management and, more importantly, in monitoring the performance of various management strategies and providing technical assistance to local social organizations.

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REFERENCES

Barthem, R.B. 1995. Development of commercial fisheries in the Amazon Basin and consequences for fish stocks and subsistence fishing. Pp.175–204 *in* Clüsener-Godt, M., & I. Sachs (eds.). Brazilian perspectives on sustainable development of the Amazon region. UNESCO, Man and the Biosphere Series 15.

Bayley, P.B. 1981. Fish yield from the Amazon in Brazil: Comparisons with African river yields and management possibilities. Trans. Am. Fish. Soc. 110: 351–359.

Bayley, P.B., & M. Petrere, Jr. 1989. Amazon fisheries: Assessment methods, current status, and management options. Pp. 385–398 *in* D.P. Dodge. (ed.). Proceedings of the International Large River Symposium. Can. Spec. Publ. Fish. Aquat. Sci. 106.

Câmara, E.P.L. 1996. Implicações do padrão de utilização dos recursos da várzea amazônica na sustentabilidade da reserva de lago. Master Thesis. UFPA, MPEG. Belém.

Dias Neto, J., & J.X. de Mesquita 1988. Potencialidade e explotação dos recursos pesqueiros do Brasil. Ciência e Cultura 40: 427–441.

Furtado, L.G. 1993. "Reservas pesqueiras", uma alternativa de subsistência e de preservação ambiental: Reflexões a partir de uma proposta de pescadores do médio Amazonas. Pp. 243–276 *in* Furtado, L., Mello, A.F., & W. Leitão. (eds.). Povos das águas realidade e perspectiva na Amazônia. Belém.

Goulding, M. 1979. Ecologia da pesca do rio Madeira. Manaus.

Goulding, M. 1980. The fishes and the forest: explorations in Amazonian natural history. Berkeley.

Hanek, G. 1982. La pesqueria en la Amazonia peruana: presente y futuro. Documento Técnico de Pesca, FAO, FI: DP/PER/76/022.

IBAMA. 1995. Projeto IARA – Administração dos Recursos Pesqueiros do Médio Amazonas: Estados do Pará e Amazonas. IBAMA. Coleção Meio Ambiente. Série Estudos de Pesca. Brasília (15).

Isaac, V.J., & M.L. Ruffino. In press a. A estatística pesqueira no Baixo Amazonas: Experiência do Projeto IARA. IBAMA, Coleção Meio Ambiente. Série Estudos Pesca. Brasília.

Isaac, V.J., & M.L. Ruffino. In press b. Informe estatístico do desembarque pesqueiro na cidade de Santarém, PA: 1992–1993. IBAMA.·Coleção Meio Ambiente. Série Estudos Pesca. Brasília.

Isaac, V.J., Milstein A., & M.L. Ruffino. 1996. A pesca artesanal no Baixo Amazonas-Análise multivariada da captura por espécie. Acta Amazonica 26: 185–208.

King, M. 1995. Fisheries biology, assessment and management. London.

McGrath, D.G., Castro, F., Futemma, C., Amaral B.D., & J. Calabria. 1993a. Fisheries and evolution of resource management on the Lower Amazon floodplain. Human Ecology 21: 167–195.

McGrath, D.G., Castro, F., & C. Futemma. 1993b. Reservas de lago e o manejo comunitário da pesca no Baixo Amazonas: Uma avaliação preliminar. Pp. 389–402 *in* D'Incao, M.A., & I.M. Silveira (eds.). Amazônia e a crise da modernidade. Belém.

Meggers, B.J. 1971. Amazon: Man and culture in a counterfeit paradise. Chicago.

Merona, B. 1993. Pesca e ecologia dos recursos aquáticos na Amazônia. Pp. 159–185. *in* Furtado, L.G., Mello, A.F., & W. Leitão (eds.). Povos das águas realidade e perspectiva na Amazônia. Belém.

Merona, B., & M.M. Bittencourt. 1988. A pesca na Amazônia através dos desembarques no mercado de Manaus: Resultados preliminares. Memoria da Sociedade de Ciencias Naturales La Salle 48: 433–453.

Milstein, A., Goldman, A., & G. Hulata. 1993. Multiple regression analysis of fish yield and profit in commercial fish farms in Israel. Pp. 161–177 *in* Prein, M., Hulata G., & D. Pauly. (eds.). Multivariate methods in aquaculture research: case studies of tilapias in experimental and commercial systems. ICLARM Studies and Reviews 20.

Petrere, M., Jr. 1978a. Pesca e esforço de pesca no estado do Amazonas. I. Esforço e captura por unidade de esforço. Acta Amazonica 8: 439–454.

Petrere, M., Jr. 1978b. Pesca e esforço de pesca no estado do Amazonas. II. Locais e aparelhos de captura e estatística de desembarque. Acta Amazonica 8: Suplemento 2: 1–54.

Petrere, M., Jr. 1985. A pesca comercial no tio Solimões-Amazonas e seus afluentes: análise do pescado desembarcado no Mercado Municipal de Manaus (1976–1978). Ciência e Cultura 37: 1987–1999.

Rai, H., & G. Hill. 1980. Classification of central Amazon lakes on the basis of their microbiological and physicochemical characteristics. Hydrobiol. 72: 85–99.

Ruffino, M.L. In press. Desenvolvimento pesqueiro no Baixo Amazonas. *In* Padoch, C., Aytes, J.M., Henderson, A., & M. Pinedo-Vasquez. (eds.). The diversity, development and conservation of the Amazon floodplain. Advances in Economic Botany.

Ruffino, M.L., & V.J. Isaac. 1994. The fisheries of the Lower Amazon: Questions of management and development. Acta Biologica Venezuelica 15: 37–46.

Salati, E., & J. Marques. 1984. Climatology of the Amazon region. Pp. 85–126 *in* Sioli, H. (ed.). The Amazon, limnology and landscape ecology of a mighty tropical river and its basin. Dodrecht.

SAS. 1987. SAS user's guide: statistics. Version 6. SAS Inst. Inc., Cary, NC.

Smith, N.J.H. 1979. A pesca no rio Amazonas. Manaus.