The Fishery, Diversity, and Conservation of Ornamental Fishes in the Rio Negro Basin, Brazil - A review of Project Piaba (1989-99).

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ABSTRACT

The goal of Project Piaba is to investigate the diversity of fishes in the middle Rio Negro basin, providing a scientific basis for an ornamental fishery at commercially and ecologically sustainable levels. The project has focused on the diversity and ecology of fishes, and on the socio-economic implications of the fishery, generating information for resource management, biological conservation, and business opportunities for the ornamental fish industry. Major findings include: (1) the cardinal tetra *(Paracheirodon axelrodi*) is the indicator species for the ornamental fishery, and changes in its numbers can significantly alter the socio-economic situation of riverine communities in the region, (2) species richness of the floodplain fishes is much greater than previously recorded (more than 400 species have been identified for the middle Rio Negro Basin), and the importance of the river channel as a barrier and refuge for floodplain fishes is evident, (3) climatic events such as El Niño can significantly alter fish diversity and affect the ornamental fishery of the floodplain (low water during the Pleistocene glacial period might be an important mechanism of speciation in the Neotropical region), (4) problems of fish health and live fish transport have been identified, but the issues cannot be solved by technology alone, (5) training local people and involving the ornamental fish industry, hobbyists, and regulatory agencies in the conservation of ornamental fishes has proceeded rapidly. The limitations of Project Piaba are lack of stability in human and financial resources. Therefore, an integrated assessment of the ecological and socio-economic systems of the fishery is still lacking. The next phase of Project Piaba takes a holistic approach with the intention of generating and integrating scientific data on aquatic biodiversity and other resources, and setting practical strategies for a sustainable ornamental fishery. User groups of the ornamental fish industry (aquarium suppliers, hobbyists, and public aquariums) should take more responsibility in aquatic conservation.

RESUMO

A meta do projeto Piaba é investigar a diversidade dos peixes na bacia do rio Negro, fornecendo uma base científica para manter a pesca de peixes ornamental em níveis sustentável tanto comercialmente como ecologicamente. O projeto focalizou na diversidade e ecologia dos peixes, e nas implicações sócio-econômicas da pesca de peixes ornamentais. Informações foram geradas visando manejar os recursos, conservação aquática, e as oportunidades de negócio para a indústria de peixes ornamentais. Os principais resultados são: (1) cardinal tetra (*Paracheirodon axelrodi*) é uma espécie indicadora para pescaria de peixes ornamentais, e variações em sua abundância pode alterar a situação socio-econômica das comunidades ribeirinhas da região, (2) a riqueza de espécie dos peixes das planícies inundáveis é bem maior do que previamente registrada (mais de 400 espécie foram identificadas na bacia média do rio Negro), e a importância das calhas dos rios como uma barreira e refúgio para peixes de planícies inundáveis é evidente, (3) eventos climáticos como El Niño pode alterar bruscamente a diversidade dos peixes, e afeta pescaria de peixes ornamentais nas planícies inundáveis, (4) os

problemas associados a saúde e transporte dos peixes vivos foram identificados, mas os problemas não podem ser resolvidos somente pela tecnologia, (5) treinamento. de técnicos locais, envolvimento da indústria de peixes ornamentais, aquariófilos, e as agências reguladoras na conservação de peixes ornamentais está progredindo rapidamente. As limitações do Projeto Piaba são falta a estabilidade em recursos humanos e financeiros. Conseqüentemente, uma avaliação integrada dos sistemas ecológica e sócio-econômica da pesca está ainda faltando. A próxima fase do projeto Piaba terá uma aproximação holística com a intenção de gerar e integrar dados científicos sobre biodiversidade aquática e outros recursos, além de sugerir estratégias práticas para uma pescaria de peixe ornamental sustentável. Os usuários da indústria dos peixes ornamentais (fornecedores, aquariófilos, e aquários públicos), devem tomar maior responsabilidade na conservação aquática.

INTRODUCTION

This review documents the data obtained during the last ten years (1989-1999). The first part gives the background of the study area: the Amazon basin, Rio Negro, and Barcelos, and conceptual frameworks, and perspectives of the Project Piaba. In the second part, I review the fishery process and statistics of the ornamental fish trade in the Rio Negro basin, and comment on the fishery as influenced by El Niño events of the 1982-83 and 1997-98 fishing seasons. In the third part, I report baseline biological data from our study on fish diversity and ecology and explore the question of why so many species of fishes exist in the Amazon basin, and how this diversity might be conserved.

PART I. THE BACKGROUND.

Amazon Basin, Rio Negro, and Barcelos.

The Amazon basin drains an area of 7 million km^2 (~ 2.7 million square miles). Its freshwater discharge amounts to 175,000 m^3 /sec (~46 million gallons/sec or 5.5 x 10^{12} m^3/yr) into the Atlantic, and carries about 20% of the total world freshwater runoff into the oceans (Sioli, 1984). The tectonic uplift of the Andes (at least 9 Ma) provoked a dynamic change in the drainage systems of South America. Räsänen et al (1995) believed that an interior seaway might have connected the Caribbean with the South Atlantic during the late Miocene (8-10 Ma). The present west to east flow, the principal drainage systems of the Amazon, flanked by the northern Guiana Shield, southern Central-Brazil Shield, and the western Sub-Andean foreland, was probably established during the late Miocene (Putzer, 1984; Lundberg, et.al. 1999).

Based on differences in chemical and physical properties of the water, Sioli (1984) identified three types of rivers in the Amazon basin: whitewater, clearwater, and blackwater. The Rio Negro is a “classic” blackwater river characterized by its dark tea-colored water, high content of humic acids and high acidity (pH 3.5 - 5.5), and low concentration of dissolved nutrients and major elements (hardness <2 mg/l, electric conductivity ~20 *u*S). The floodplains of the Rio Negro are less extensive than the *várzeas* of the Amazon-Solimões Rivers, a whitewater river system.

The Rio Negro is the largest tributary of the Amazon basin in terms of annual discharge (1.4 x 10^{12} m^3/yr, three times of the Mississippi). Its basin covers an area 0.75 million km^2 and extends more than 1,700 km from its mouth to its northwest headwaters in pre-Andean Colombia, and about 1,500 km to its northeast headwaters on the high Guyana Shield via the

Rio Branco. Goulding et al. (1988) provided general information on geomorphology, limnology, flora and fauna of the basin, and qualitative descriptions of the trophic relationships and organization of its fishes.

To date, deforestation in the upland forest of the Barcelos area has been minimal, due in part to the infertile sandy soils that are unsuited to large-scale agriculture and low human population densities, typical of the blackwater areas of Amazonia. Perhaps more important, the local people are largely engaged in horticultural or extractive activities such as collecting ornamental fishes and *piassava* (palm fibers), which generate enough cash or credit to supply basic foods and necessities (Prang, in this volume).

The study area of Project Piaba extends from the mouth of the Rio Negro (Manaus) to Tapuruquara (600 km upriver), including the lower Rio Branco and Rio Demini, mostly in the municipality of Barcelos (Fig. 1). Barcelos (pop.~16,000; area 122,490 km^2) is the self-proclaimed ornamental fish capital of the Rio Negro. Annual precipitation in Barcelos is about 2,100 mm. The monthly average is above 230 mm from April to July, but less than 130 mm from September to December (Salati & Marques, 1984). The high water season is between June and August and the low water season is usually from December to March (Fig. 2). At Barcelos, the maximum difference in water levels is about 7 m, and 4 m on the floodplain. The high fishing season usually coincides with the low water level from October to February.

To Fish or Not to Fish?

The impact of deforestation in Amazonia has been well documented and linked to broader environmental concerns such as global warming, climate change, and rapid loss of species diversity (Sioli, 1984; Prance & Lovejoy, 1985; Bunker, 1985; Fernside, 1986; Cowell, 1990; Anderson, 1992; Robison & Redford, 1993). Fishes and aquatic systems are often overlooked in these processes, yet of the probably 6,000 freshwater fish species of South America (Böhlke et al. 1978), some 3,000 might exist in the Amazon basin. Of Amazonian species, those of the inundated forest (*igapó*) and forest stream (*igarapé*) have been little studied, although many are exploited as ornamental fishes in the middle Rio Negro basin (Goulding et al.1988; Chao, 1992a,b).

Concepts of sustainability inevitably reflect societal choices at the local, regional, and global levels. Balancing ecological with economic and other considerations is the fundamental problem in defining sustainability (Toman, 1992). Biological inquiry alone will not satisfy the need of a sustainable ornamental fishery. Thus, Project Piaba has gradually evolved from a fish biology study into a community based, interdisciplinary project that aims to understand the ecological and social-cultural systems of the middle Rio Negro basin, and to conserve and maintain the live ornamental fishery resources at commercially feasible and ecologically sustainable levels (Chao, 1992a, 1992b, 1993,1995/96; Prang, 1996; Chao & Prang, 1997).

We are anxious to develop a sustainable use model for wild ornamental fishes and apply it to a comparative situation elsewhere. Implementation of the second phase of Project Piaba is to understand the relationships among processes from the individual, the population, the ecosystem, the socio-economy of Amazonia, and the globe. We are also exploring fundamental theoretical problems in species diversification, phylogeography, ecosystems, and natural/social communities across geographic scales and across systems to examine other sustainable resources. Eventually the integrated and synthesized information will be available to all levels of inquiry, an understanding that is meaningful and useful to managers and decision- makers.

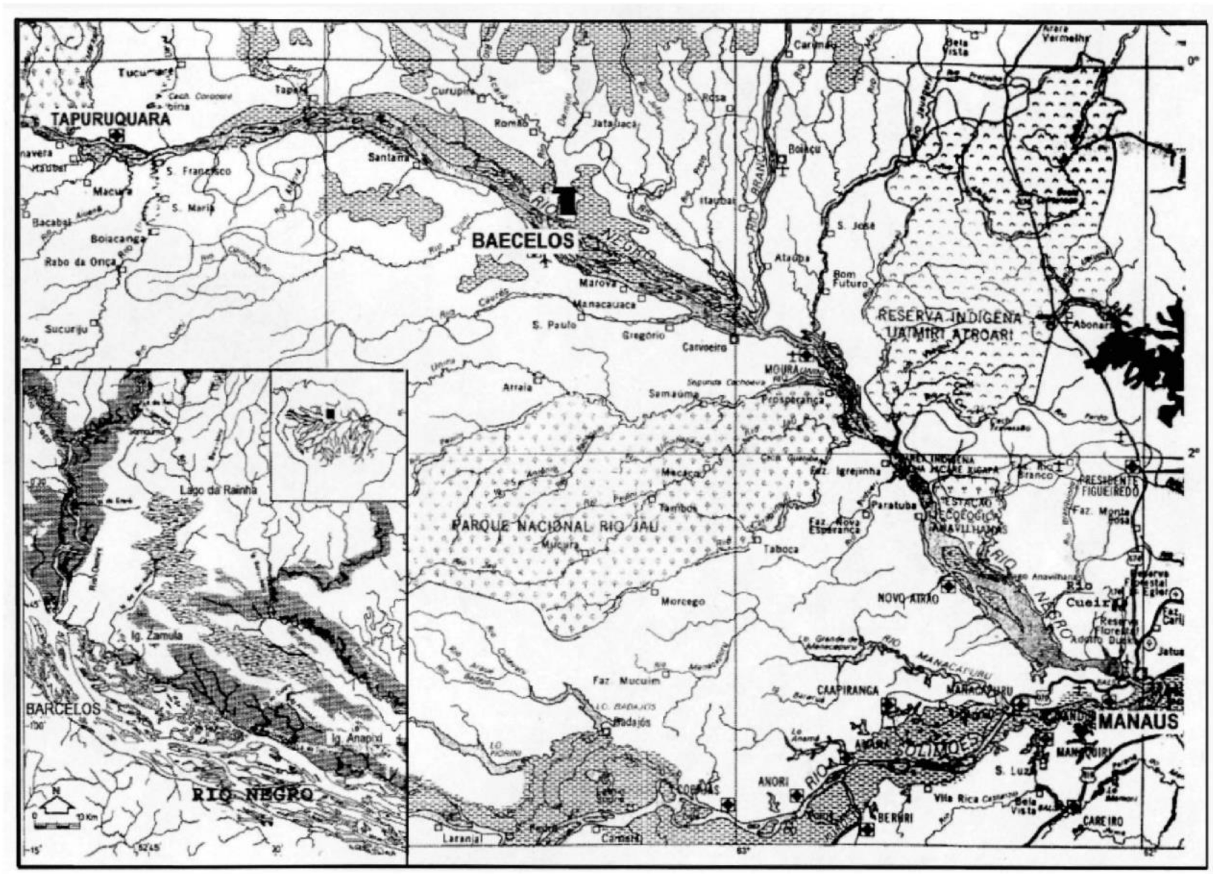


Figure 1. Study area of project Piaba extends from the mouth of Rio Negro near Manaus to Tapuruquara (Santa Isabel do Rio Negro). Insert shows floodplain near Barcelos.

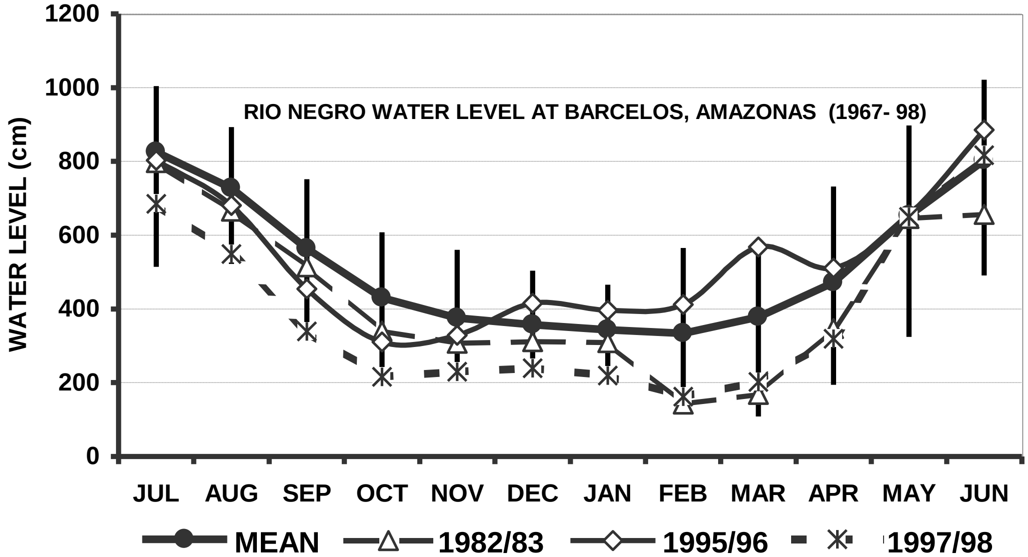


Figure 2. Relative mean water levels and monthly variations at Barcelos, mid-Rio Negro basin (1967-1998).

Part II. ORNAMENTAL FISHERY OF THE RIO NEGRO

The potential fishery yield of the Amazon basin is an estimated 320,000 to 350,000 t/yr (Junk, 1984). Whitewater rivers and floodplain lakes (*várzeas*) provide 90% of the 25,000-30,000 t/yr in food fishes offered in Manaus (Bayley & Petrere, 1989). Blackwater floodplains, *igarapés* (floodplain rainforest streams), and *igapós* (inundated lowland forests) supply 90% of the 20 million ornamental fishes exported from the State of Amazonas, Brazil (Fig. 3). The 1998 export revenue was US$2,216,620 (IBAMA report). At least 10,000 Amazonians take in part this venture, including more than 1,600 fishers from the riverine communities of the middle Rio Negro (Prang, in this volume).

THE FISHERY

The principal fishing area for ornamental fishes includes most tributaries of the middle and upper Rio Negro, from the mouth of the Rio Branco to the first major cataract below São Gabriel da Cachoeira, an approximate river distance between 300 and 800 km from Manaus (Fig.1). For economic reasons, the main fishing areas are within 200 km of Barcelos, or two days by riverboat. A typical fishing trip lasts 2 weeks. Fishers first travel aboard a 15-18 m wooden riverboat powered by a 15 to 30-hp diesel engine to the mouth of an *igarapé*. They proceed into the *igarapé* by dugout looking for schools of cardinal tetras (*Paracheirodon axelrodi*), which are readily identifiable by their metallic blue stripes in the flooded forests. Fishers use a specially designed dip net (*rapiché*) to scoop up the target species (Fig. 4B). A baited fixed trap (*cacurí*, Fig. 4C) is also commonly used in the slow flowing *igarapés*. When it rains, fishing activity idles.

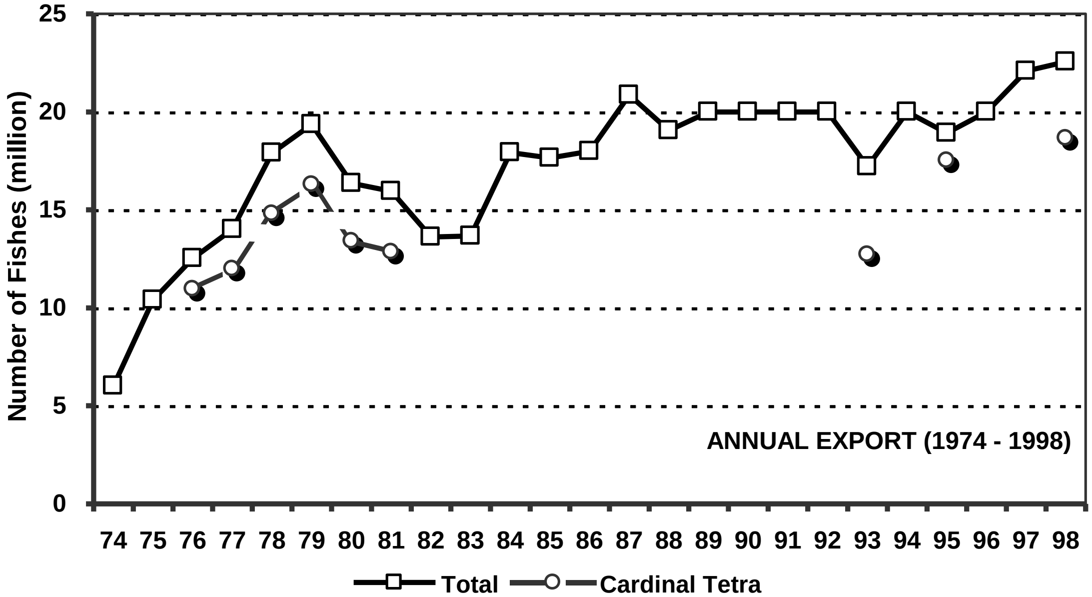


Figure 3. Ornamental fish exported from Manaus, Amazonas (also see Table 1).

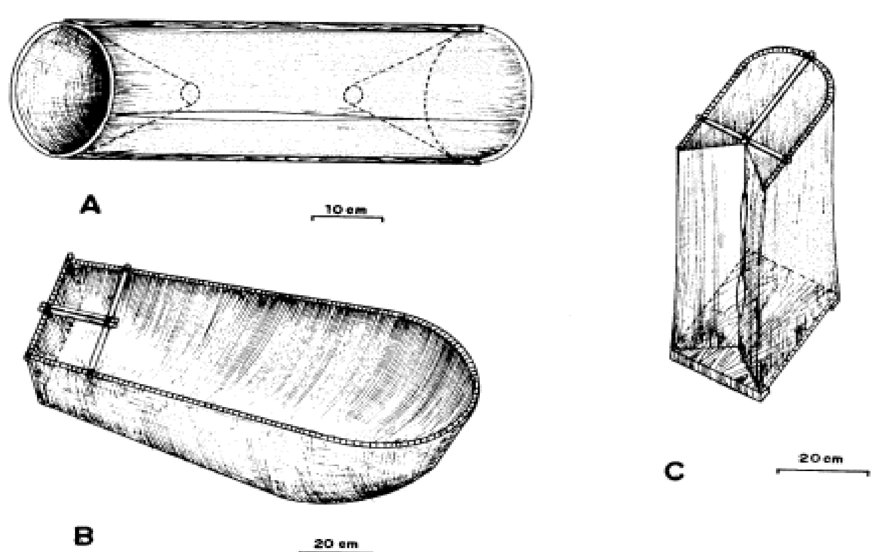


Figure 4. Fishing gear used by ornamental fishers and Project Piaba in Rio Negro. A. Collapsible minnow-trap;B. rapiché dip-net; C. Cacurí trap.

The ornamental fisher is an artisan, and his impact on the environment is minimal. During a three-hour fishing trip from the campsite, only 20-30 minutes are spent actually dipping *rapiché* in the water. The remaining time is spent searching and cruising the *igarapés*. Fishers also take food fishes and gather Brazil nuts and wild fruits. Some also hunt wildlife: turtles, waterfowl, howler monkeys, pacas, and tapirs are favored. At times, these animals are the principal source of food during a poor fishing season. Thus, difficulties in the ornamental fishery transfer even greater hardship to threatened wildlife of the region.

Before being shipped to Manaus, fishes are sorted, counted, and loaded into rectangular plastic tubs (54 x 36 x 20 cm) containing about 12-15 L of water. Each tub holds a few to 1,000 live fishes, depending on species and size. To hinder bacterial infections, fishers often apply industrial grade tetracycline to the shipping tubs (Chao, 1993).

Data on export of Amazon ornamental fishes are fragmented and inconsistent (Table 1). Since 1974, export statistics for 27 to 34 categories of fishes under local names were registered with IBAMA (Corrêa, 1984; Chao, 1995-1996). Among these, cardinal tetras *(Paracheirodon axelrodi*) averaged 80% of the total number of fishes export from Manaus (Fig. 3). From 1982 to 1988, the only export registers were made by Banco do Brazil, which did not include specific statistics for cardinal tetras or other fishes. This database consists of numbers of fishes, shipping weights (mostly water and packaging), FOB values in US and Brazilian currencies, ports of exportation, and destination countries.

In the late 1970s, official statistics have consistently reported that approximately 20 million ornamental fishes are exported from Manaus, including all species from Amazonas state and transshipped from other states. Different estimates by casual observers have also estimated the annual catch at 40 to perhaps 150 million. These discrepancies have often been attributed to the greater than 50% mortality rate (Chao, 1992a; Woeltjes, 1995). Since 1995, our studies on shipping mortality have shown less than 5% average mortality during transport between Barcelos and Manaus (also see Waichman in this volume).

We conducted a survey of ornamental fishes exported from Barcelos over two fishing seasons: from October/95 to April/96 (Table 2, Fig. 5) and from May/98 to April/99 (Table 3, Fig. 6). In 1995, two weekly shipments left Barcelos for Manaus on weekend passenger boats. At present, two additional boats have been added on Friday and Monday, and not all passenger boats carry live fishes. Weekly samples in Barcelos included species, number of shipping tubs, number of fishes in each tub, fishing tributaries, and the names of fishers and buyers.

Some local people believe that half the fish shipments by-pass Barcelos either on passenger boats from towns upstream and downstream or on boats owned by exporters. Our data from Barcelos show that in 1995/96 almost 19 million fishes were shipped in eight months (Table 2, 1995-96), and in 1998/99 about 22.5 million were exported in 11 months (Table 3, 1998-99). Official statistics of the same years on fishes exported from Manaus were fewer (Table 1).

El Niño Effects

The sharp decline in ornamental fishes exported in 1982 and 1983 (Fig. 3) coincided with a major El Niño-Southern Oscillation (ENSO, Richey et al. 1989). The unusually intense drought during peak fishing months of 1983 (Fig. 2, January/February) might have caused the low fish yield and interrupted later recruitment, but the fishery recovered within two years (Chao & Prada-Pedreros, 1995). The high fishing season in Barcelos is usually between October and April. For example, the shipments of fishes from Barcelos in 1995/96 season (Fig. 5) had two peaks, the November one constituted larger fishes catered for the holiday season sales, and the February peak were mostly smaller young-of-the-year recruits. Whereas in the El

Niño year, in the beginning of the 1997/98 fishing season, the water level in Barcelos was 2m lower than average (Fig. 2, September/October), and the low water persisted for the ensuing six months to March/98. Still, there was no reduction in ornamental fish export of 1998 (Fig. 3). Later, we learned that in October-November 1997, as a result of the El Niño-induced drought, fishers could not reach the headwater fishing areas in their dugouts. Consequently, fewer fishes were shipped from Barcelos. However, the yield peaked in August 1998 and March 1999 when the water level rose and exporters in Manaus were overstocked with cardinal tetras (Fig. 6).

Low water might have prohibited fishers from reaching the fishing areas, which in turn protected the breeding stocks in the headwater swamps and lakes, resulting in a bumper harvest a few months later. There is probably a threshold water level that affects the fishery. El Niño and long-term climatic change would have a direct effect on the aquatic ecosystem, but the ornamental fishery of the Rio Negro is probably depend more directly on the market demand.

Part III. DIVERSITY AND CONSERVATION OF ORNAMENTAL FISHES

More than 2,000 species of fishes have been catalogued from the Amazon basin, but the final count may be 3,000-5,000 (Roberts, 1972; Géry, 1977; Böhlke, et al, 1978). Of the Amazonian fishes, those of the inundated forests (*igapós*) and streams (*igarapés*) have been little studied, although many are exploited as ornamental fishes in the middle Rio Negro basin (Chao, 1995/96). Deep river channel fishes have not been sampled until recently (Barletta, 1995, Garcia, 1995, Cox-Fernandes, 1995, Souza, 1999).

About 1,000 species are known to occur in the Rio Negro basin (Table 4). Despite this species richness, freshwater Neotropical fishes belong to relatively few higher taxonomic categories. Lundberg, et al. (1999) suggested that the modern fish fauna at higher clades (supra-generic levels) are practically unchanged since the late Miocene (~7 My). Bush (1994) suggested that Quaternary climate events may have droved the speciation pump in the Amazon.

We have collected about 450 species/forms from the mouth of the Rio Negro to the middle Rio Negro basin, including the lower Rio Branco. Although many identifications are still pending, however our lists added at least 200 new records (some undescribed) to the list of 450 species of Rio Negro fishes reported by Goulding, et al. (1988).

Descriptive taxonomy and baseline ecological studies are needed in this region (Menezes, 1992). These information are fundamental to understand the processes governing speciation, fishery, the ecosystem conservation and the socioeconomic development. Here I summarize the results of work on diversity (species richness and composition), fishery ecology, and natural history of certain Rio Negro fishes. These studies have been made with my students and collaborators; only a small portion of the results has been published (see Literature Cited section).

Table 1. Statistics on ornamental fish exported from Amazonas State, Brazil. Total number of fishes, and the number and proportion (%) of cardinal tetra exported are listed.

Year	Total Fishes	Cardinal	in %	Source
1974	6,021,140			SUDEPE
1975	10,403,084			SUDEPE
1976	12,527,800	10,961,240	87.50%	SUDEPE
1977	14,001,097	11,988,199	85.62%	SUDEPE
1978	17,903,479	14,801,455	82.67%	SUDEPE
1979	19,363,569	16,296,298	84.16%	SUDEPE
1980	16,363,569	13,407,992	81.94%	SUDEPE
1981	15,951,624	12,847,806	80.54%	SUDEPE
1982	13,621,001			BB
1983	13,664,279			BB
1984	17,919,743			BB
1985	17,642,720			BB
1986	17,984,184			BB
1987	20,859,874			BB
1988	19,048,432			BB
*1989	20,000,000			IBAMA
*1990	20,000,000			IBAMA
*1991	20,000,000			IBAMA
*1992	20,000,000			IBAMA
1993	17,207,088	12,722,395	73.94%	IBAMA
*1994	20,000,000			IBAMA
1995/96	18,910,419	17,506,800	92.58%	PIABA
1996	20,000,000			IBAMA
1997	22,079,892	14,091,973	63.82%	IBAMA
1998	16,295,909	8,611,501	52.84%	IBAMA
1998/99	18,500,457	16,387,100	88.58%	PIABA
1999	30,481,330	26,798,400	87.92%	PIABA

Data sources: BB: Banco de Brasil - CACEX , extinct sector of international trade.; IBAMA: Instituto do Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (* no data listing); PIABA: fish shipment survey in Barcelos by Project Piaba (also see Tables 2 & 3); SUDEPE -Superintendência do Desenvolvimento da Pesca (agency merged with IBAMA)

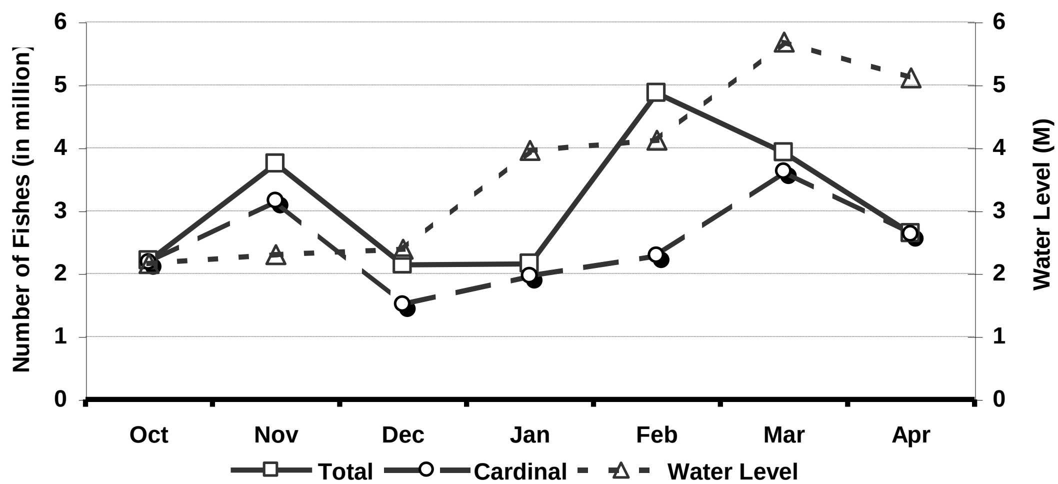


Figure 5. Weekly survey of ornamental fish shipments of Barcelos (October 1995 to April 1996).

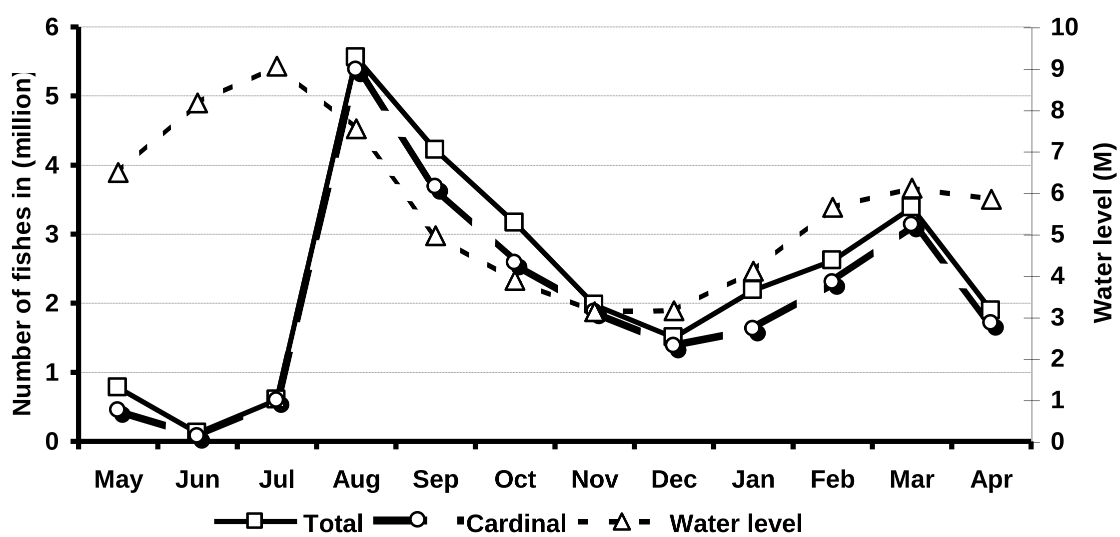


Figure 6. Weekly survey of ornamental fish shipments of Barcelos (May 1998 to April 1999).

Table 2. Weekly survey of ornamental fishes shipped from Barcelos (1995/1996).

Local names	**Scientific names**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MAR**	**APR**	**Total**
Cardinal Tetra	*Paracheirodon axelrodi*	2,179,000	3,157,400	1,510,000	1,962,200	2,284,200	3,622,800	2,624,400	17,340,000
Acará Disco	*Syphysodon discus*	315	515	222					1,052
Acará Bandeira	*Pterophyllum sp.*			25					25
Apistogramma	*Apistogramma sp.*		6,600		500			10,500	17,600
Aracuzinho	*Leporinus sp.*		168						168
Arraia	*Potamotrygon sp.*		105	105					210
Anostomus	*Anostomus sp.*		1,200	1,060	1,800				4,060
Azulão	*Heros sp.*		300	8					308
Boborleta	*Carnigells sp.*	2,600	16,000	71,250	13,800				103,650
Bodó	Loricariidae sp.	2,930	8,978	4,665					16,573
Bodo-seda	*Ancistrus sp.*		1,920	24	2,400				4,344
Bodó percote	*Peckoltia sp.*		12	200					212
Bodó Pedra	Loricariidae sp.		296	8					304
Bodó cutia	Loricariidae sp.			100					100
Bodó praia	Loricariidae sp.		112						112
Bodó amarelo	Loricariidae sp.		360						360
Buarú	*Uaru amphiaacanthoides*			200					200
Cara de mapa	*Hypselacara sp.*			100					100
Chidona	*Chilodus sp. ?*				720				720
Corydoras	*Corydoras spp.*	1,500	7,500	2,225	39,600		27,000	26,400	104,225
Farowella	*Farowella sp.*			300					300
Lapis	*Nannostomus sp.*		3,600	5,000			3,600		12,200
Leopadinae	*Pseudoacanthicus leopardus*			100					100
Leporinus	*Leporinus sp.*			1,900					1,900
Leporinus Jamesi	*Leporinus sp.*		400						400
Leporinus desmotes	*Leporinus sp.*		250						250
Loricaria	*Loricarias sp.*		152	300	1,440				1,892
Nannostomo	*Nannostomus sp.*		770	300					1,070
Peixe faca	Gymnotiformes			144	750				894
Pingo de sangue	Characidae		188,200	720					188,920
Rodostomo	*Hemigrammus rodostomus*	4,800	185,300	9,600	90,800		84,600	153,200	528,300
Rosaceu	*Hyphessobrycon spp.*	10,800	169,300	125,150	4,000				309,250
Trifasciatus	*Nannostomus trifaciatus*		2,480	176,400	2,600				181,480
Unifaciata	*Nannostomus unifaciatus*				5800				5,800
Xadrez	*Dicrosus sp.*	2,250	46,550	30,200	3,500				82,500
Xilôdo	*Chilodus sp.*		600	240					840
Total Number of Fishes		2,204,195	3,799,068	1,940,546	2,129,910	2,284,200	3,738,000	2,814,500	18,910,419
Total Number of Taxa		8	24	27	14	1	3	4	39
Relative Water level in Barcelos (cm)		**216**	**230**	**239**	**396**	**412**	**568**	**511**	
All Species									
Number of sample days.		5	7	6	4	4	4	5	35
Number of lots.		9	83	39	16	10	14	14	185
Number of tributaries explored.		5	7	9	4	4	5	7	41
Number of fish tubs in shipments.		4,332	9,839	5,220	2,051	8,112	7,297	6,704	43,555
Cardinal Tetra									
Number of sample days.		5	7	6	3	3	5	6	35
Number of lots.		4	25	24	14	8	9	10	94
Number of tributaries explored.		5	7	10	6	4	6	5	43
Number of fish tubs in shipments..		4,035	4,486	2,503	2801	3,807	6,038	5,448	29,118
Cardinal Tetra in % of total Fishes		**98.86**	**83.11**	**77.81**	**92.13**	**100**	**96.92**	**93.25**	**91.70**

Table 3. Weekly survey of ornamental fishes shipped from Barcelos between April 1998 and April 1999.

Local names	**Scientific names**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MAR**	**APR**	**Total**
Cardinal	*Paracheirodon axelrodi*	450,000	76,000	592,200	5,380,800	3,682,200	2,584,800	1,878,600	1,382,500	1,625,700	2,303,700	3,134,400	1,708,500	24,799,400
Acará Disco	*Symphysodon discus*	20					96							116
Acará Bandeira	*Pterophyllum altum.*							455	1,428	2,815	504			5,202
Apistogramma	*Apistogramma* spp					21,600	2,400			45,400	39,400	10,200	24,000	143,000
Arraia	*Potamotrygon* spp.	126			40	276	2,516	532	308	397	62	147	20	4,424
Amblydoras	*Amblyodoras hancocki*									600				600
Aspidoras	*Aspidoras* sp.							2,800						2,800
Bagre	Pimelodidae							1,080						1,080
Beltoecs	**Biotecus sp. ?**					1,050								1,050
Boborleta	*Carnegiella* spp.	9,400		2,800	2,800	70,800	108,800	31,200	40,800	107,600	85,000	59,200	31,200	549,600
Bodó	Loricariidae sp.											240	4,620	4,860
Bodó-seda	*Ancistrus* sp.						1,080	5,700	2,000	3,450				12,230
Bodó percote	*Peckoltia* sp.	300				600		1,590						2,490
Bodó Pedra	Loricariidae sp.								40				100	140
Bodó zebra	*Peckoltia sp.*						4,680	2,880						7,560
Bodó cutia	Loricariidae sp.									2,400			500	2,900
Bodó onça	*Lisomadoras oncinus*									500				500
Bodó Jauarí	Loricariidae sp.												2,000	2,000
Copeina	*Copeina guttata*										18,000		9,000	27,000
Corydoras	*Corydoras* sp.												3,800	3,800
Cruzeiro	*Hemiodopsis?*												1,000	1,000
Farowella	*Farowella* sp.					480	1,800							2,280
Jacundá	*Cichlasoma* spp.										300			300
Lápis	*Nannostomus* spp.	13,400	7,400		19,800	40,400	99,200	2,000		30,000			31,000	243,200
Loricaria	*Loricaria sp.*						2,070							2,070
Marginata	*Nannostomus marginatus*	18,600				14,400	35,600	3,000						71,600
Mandi	Pimelodidae sp.							350						350
Orelinha	Siluriformes										3,050	500		3,550
Papa-terra	Geophagus sp.								3,570					3,570
Rodóstomo	*Hemigrammus rodostomus*	3,600		3,200	139,600	332,400	163,600	30,400		234,800	79,000	132,400	7,200	1,126,200

Table3 (continues)

Local names	Scientific names	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	Total
Rosaceu	*Hyphessobrycon spp.*	272,800	36,000	600		4,800	83,600	8,800	61,600	107,600	86,600	46,400	66,800	775,600
Sarapó	Gymnotoformes							360				72		432
Trifasciatus	*Nannostomus trifasciatus*						34,600		4,800					39,400
Tuim-cavalo	*Apteronotus albifrons*						480	480						960
Unifaciata	*Nannostomus unifasciatus*	8,250			13,200									21,450
Xadrez	Dicrosus sp.					44,800	34,800	2,400	6,400	26,800			700	115,900
Xilôdo	Chilodus gracilis						360	600						960
Total Number of Fishes		**776,496**	**119,400**	**598,800**	**5,556,240**	**4,213,806**	**3,160,482**	**1,973,227**	**1,503,446**	**2,188,062**	**2,615,616**	**3,383,559**	**1,890,440**	**27,979,574**
Total Number of Taxonomic Groups		**10**	**3**	**4**	**6**	**12**	**17**	**18**	**10**	**13**	**10**	**9**	**15**	**40**
Relative Water level in Barcelos (cm)		**649**	**817**	**905**	**754**	**496**	**388**	**313**	**315**	**411**	**565**	**611**	**584**	

All Species	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MAR**	**APR**	**Total**
Number of sample days.	11	4	7	12	6	5	3	1	9	10	8	9	68
Number of transactions.	49	7	14	58	35	37	19	1	66	51	47	64	337
Number of tributaries explored.	12	2	8	13	8	10	6	1	9	11	8	7	80
Number of fish tubs in shipments.	2,548	407	1,040	9,860	5,010	5,804	2,880	2,976	5,518	6,300	7,492	5,219	42,343
Cardinal Tetra													
Number of sample days.	8	2	7	12	6	2	3	1	7	9	7	8	57
Number of transactions.	19	2	11	41	9	6	5	1	10	19	22	20	123
Number of tributaries explored.	8	1	7	14	1	1	1	1	8	15	19	15	57
Number of fish tubs in shipments.	896	190	1007	8,963	4,523	2,581	2,215	1,975	2,126	1,234	6,001	3,425	25,710
Cardinal Tetra in % of total Fishes	**57.95**	**63.65**	**98.90**	**96.84**	**87.38**	**81.78**	**95.20**	**91.96**	**74.30**	**88.07**	**92.64**	**90.38**	**88.63**

Table 4. Freshwater fish diversity of South America, Amazon and Rio Negro basin that can be legally exported from Brazil (IBAMA), non-food uses in North American (AFS, 1991), species that found in the hobby and public aquariums.

ORDERS No. of Species	South American	Amazon Basin	Rio Negro Basin	IBAMA Permitted	AFS N. American	Aquarium & Hobbyists
Petromyzontiformes	3	0	0	0	2	0
Carcharhiniformes	1	1	0	0	0	0
Rajiformes	22	14	6	4	0	6
Lepidosireniformes	1	1	1	0	1	1
Osteoglossiformes	3	3	1	0	3	3
Clupeiformes	19	14	3	0	0	2
Characiformes	1,233	740	400	97	71	180
Salmoniformes	6	0	0	0	1	0
Silouriformes	1,380	828	300	45	105	127
Gymnotiformes	96	58	40	3	7	7
Batrachoidiformes	2	1	0	0	0	0
Atheriniformes	8	0	0	0	0	0
Beloniformes	16	4	2	0	0	2
Cyprinidontiformes	178	107	50	7	18	18
Symbranchiformes	4	2	1	0	1	1
Cichlidae	275	250	120	22	52	46
Other Perciformes	52	26	20	2	9	2
Pleuronectiformes	6	2	1	2	0	2
Tetradontiformes	2	2	1	2	0	2
TOTAL	3,303	2,052	946	184	272	399

* Numbers of nominal species were extracted from various sources (Chao, 1998)

MATERIALS AND METHODS

Two categories of sample habitat are included: floodplains and deep river channels. All samples were stratified by habitat or channel depth. At least two replicates were made for each sample unit when possible in both temporal and spatial scales.

Since 1989 we have made periodic expeditions to the floodplains near Barcelos (Chao & Prada-Pedreros, 1995, Chao et al. unpublished data). The floodplain fish surveys were made across the river from Barcelos, an area of about 1,100 km^2 at the confluence of the Rio Negro and Rio Demini (Fig.1, insert). This region is a mix of lowland inundation forests and rainforest streams, with intermittent floodplains, swamps, and lakes. The rainforests of the area are mostly undisturbed and uninhabited by human beings.

Floodplain samples were taken with cylindrical minnow traps (50 cm height x 25 cm diameter), seines of various sizes and dip nets (Fig. 4). Fishing efforts of trapping are quantitatively compatible, but the use of other gear depends on the skill of each student-fisher and thus varies. Therefore, the relative percentage of individuals per species was used for comparative purpose (Tables 5 & 6).

In 1992 we also initiated a bottom trawl study of deep river channel fishes at the confluence of the Rio Negro, Solimões, and Amazonas (Barletta, 1995). From 1993 to 1998, we have made trawl surveys in various parts and tributaries of the Rio Negro, especially at its confluence with the Rio Branco (Souza, 1999). We relied heavily on boats supplied by aquarist expeditions (see Dowd in this volume).

Bottom fishes were sampled with a 16-ft otter trawl fitted with a 1/4-inch cod-end liner. Each trawl was towed from an outboard canoe at a speed of 4.5 and 6 km/hr for 10 minutes, and then the trawl area was calculated at 1,350 m^3 or 1,800 m3, respectively. Relative abundance (%) and frequency of capture (FC) were used to compare data sets from different areas (Table 7).

RESULTS AND DISCUSSION

Floodplain fishes

We have collected and identified 178 species of floodplain fishes from the mid-Rio Negro basin using rapiché and minnow traps (Fig. 4A, Table 5,). Most fishes were less than 8 cm total length. Samples taken in the floodplain of igarapés (1989-92) have shown that the cardinal tetra (*Paracheirodon axelrodi*) is most abundant (21%), followed by *Hemmigramus analis* (14%). Among 131 species, 20 constituted more than 80% of the total fish assemblage (Table 6). In the lower reach of Igarapé Zamula (1993-98), where cardinal tetras were not collected with our gear (Table 5), the most abundant species was *H. analis* (22%) and the dwarf cichlid genera *Apistogramma*, *Crenicara*, *Crenicichla*, and *Dicrosus* (>25%). The genus "*Hemigrammus*" was the most speciose with 35 species/forms (here it may include other genera of characins), composing more than 30% of the total number of fishes. Among the dwarf cichlid genera, *Apiatogramma* composed more than 15% of the total catch, and *A. petensis* was the most abundant (>10%).

Forty or so larger fishes caught by gill net, cast net, spear, and hook and line in the study areas have been recorded. The common ones were larger ornamental cichlids (*Pterophyllum altum, Symphysodon discus,* species of *Crenicichla, Satanoperca,* and *Geophagus*), the freshwater stingrays (*Paratrygon aireba*, *Potamotrygon motoro*), electric eel *(Electrophorus electricus*) and a few armored catfishes (Loricariidae). Food fishes (> 20cm TL) were mainly piranhas and pacus (Serrasalminae), trairas (*Hoplias, Erythrinus*), black aruwana

(*Osteoglossum ferreri*), freshwater croakers (*Plagioscion* species.), tucunarés (*Cichla temensis*, *C. orinocansis*) and large pimelodid catfishes.

River Channel Fishes

About 300 bottom trawl samples were taken from the mouth of the Rio Negro to the Rio Demini, including the lower reaches of Rio Branco, we have identified 277 species/forms (Table 7). Among them, 141 were catfishes (Siluriformes) and 61 were knifefishes (Gymnotiformes); only 29 were characins (Characiformes). The families Doradidae (44), Pimelodidae (43), and Apteronotidae (37) were the most speciose. Number of the predominant Characiformes and Cichlidae of the floodplain (Table 5) were much reduced in the river channel. Most characins were caught from the shallower river bed (< 5 m depth) from the lower Rio Branco and middle Rio Negro (Table 7, Souza, 1999).

Temporal and spatial variations of benthic fish communities at the confluence of the Negro, Solimões, and Amazonas Rivers were described by Barletta (1995). Species richness (diversity) remains constant through out the year, and rarefaction analysis pridicted that every 200 randomly collected fishes yield 30 to 35 species (Fig. 7). However, other data showed that the number of fishes caught per trawl haul was significantly higher in the low water seasons (Barletta, 1995).

Twenty trawls made in two days a week apart at the mouth of the Rio Cueiras (Table 7) yielded 48 species (Fig. 8). Species richness increased sharply on the second sample day (Fig.8, trawls 12 to 20) when the water level in the study area dropped a meter. The additional species were predominantly characins and Cichlidae. This may indicate that floodplain fishes use river channels as a temporary refuge during times of lower water.

Climatic events such as El Niño can significantly affect fish diversity in river channels and in the floodplains (see part 2 above). Pleistocene glaciations and water-level fluctuations in the Amazon basin could have been a mechanism for rapid speciation in Neotropical floodplains. Floodplain fishes perhaps took refuge in the deeper river channels during periods of low water, potentially enhancing the genetic mix. When water levels rose, the fishes dispersed back into their upstream habitats, especially the headwaters. At such times, allopatric speciation would prevail. These processes might have contributed significantly to the great diversity of Amazon fishes.

Table 5. Species richness and relative abundance of floodplain fishes in the mid-Rio Negro basin.

		Mid-Rio Negro Streams (1989 - 1992)		Igarapé Zamula (1993 - 1998)	
	Orders & Species	**Number of fish & relative abundance (%)**			
	RAJIFORMES				
1	*Paratrygon aiereba*			1	0.05%
2	*Potamotrygon motoro*	2	0.01%	3	0.14%
3	*Potamotrygon sp.*	3	0.01%	3	0.14%
	CLUPEIFORMES				
	Engraulidae				
4	*Lycengraulis* sp.	358	1.77%		
	ATHERINIFORMES				
5	*Hemiramphidae* sp.	7	0.03%		
	CYPRINODONTIFORMES				
	Poeciliidae				
6	*Fluviphylax pigmaeus*	81	0.40%		
7	*Rivulus sp.1*	15	0.07%	1	0.05%
8	*Rivulus sp.2*	1	0.00%		
	CHARACIFORMES				
	Anostomidae				
9	*Copella cf. compta*	27	0.13%		
10	*Copella nattereri*	1,746	8.65%		
11	*Copella* sp 1	188	0.93%		
12	*Pseudanos gracilis*			1	0.05%
	Characidae				
13	*Acestrorhynchus heterolepis*	1	0.00%		
14	*Acestrorhynchus minimus*	3	0.01%		
15	*Acestrorhynchus* sp.1	1	0.00%		
16	*Acestrorhynchus* sp.2	1	0.00%		
17	*Asiphonichthys condei*	52	0.26%		
18	*Astyanax paucidens*	5	0.02%		
19	*Boulengerella lateristriga*	2	0.01%		
20	*Boulengerella maculata*			1	0.05%
21	*Brittanichthys axelrodi*	36	0.18%		
22	*Bryconops humeralis*			2	0.09%
23	*Catoprion mento*	9	0.04%		
24	*Characidium* sp.1	6	0.03%		
25	*Chilodus punctatus*			11	0.52%
26	*Crenuchus spilurus*	143	0.71%	45	2.13%
27	*Elachocharax junki*	4	0.02%		
28	*Gnathocharax steindachneri*	91	0.45%		
29	*Hemigrammus analis*	2,742	13.59%	466	22.07%
30	*Hemigrammus arbovittatus*	244	1.21%	5	0.24%

Table 5 (continued)

	Orders & Species	Mid-Rio Negro Streams		Igarapé Zamula	
		Number of fish & relative abundance (%)			
31	*Hemigrammus bellottii*	670	3.32%	30	1.42%
32	*Hemigrammus coerulus*	6	0.03%		
33	*Hemigrammus guianensis*	5	0.02%		
34	*Hemigrammus microstomus*			8	0.38%
35	*Hemigrammus hyanuary*	120	0.59%	58	2.75%
36	*Hemigrammus schmardae*			24	1.14%
37	*Hemigrammus stictus*	281	1.39%	105	4.97%
38	*Hemigrammus vorderwinkleri*	1,081	5.36%		
39	*Hemigrammus* sp.1			32	1.52%
40	*Hemigrammus* sp.2	2	0.01%	63	2.98%
41	*Hemigrammus* sp.4	5	0.02%	6	0.28%
41	*Hemigrammus* sp.4	5	0.02%	6	0.28%
42	*Hemigrammus* sp.5	9	0.04%		
43	*Hemigrammus* sp.6	136	0.67%	10	0.47%
44	*Hemigrammus* sp.8	6	0.03%		
45	*Hemigrammus* sp.9	134	0.66%		
46	*Hemigrammus* sp.11	2	0.01%		
47	*Hemigrammus* sp.13			3	0.14%
48	*Hemigrammus* sp.14			1	0.05%
49	*Hemigrammus* sp.15	116	0.57%	15	0.71%
50	*Hemigrammus* sp.16	3	0.01%	5	0.24%
51	*Hemigrammus* sp.18	5	0.02%		
52	*Hemigrammus* sp.19	5	0.02%		
53	*Hemigrammus* sp.20	12	0.06%		
54	*Hemigrammus* sp.21	430	2.13%	29	1.37%
55	*Hemigrammus* sp.22	3	0.01%		
56	*Hemigrammus* sp.24	15	0.07%		
57	*Hemigrammus* sp.27	1	0.00%		
58	*Hemigrammus* sp.28	38	0.19%		
59	*Hemigrammus* sp.29	15	0.07%		
60	*Hemigrammus* sp.30	7	0.03%		
61	*Hemigrammus* sp.31	8	0.04%		
62	*Hemigrammus* sp.32	236	1.17%		
63	*Hemigrammus* sp.34	1	0.00%		
64	*Heterocharax macrolepis*			13	0.62%
65	*Heterocharax macrolepis*	11	0.05%		
66	*Hoplerythrinus unitaeniatus*	1	0.00%		
67	*Hoplocharax goethei*	250	1.24%	1	0.05%
68	*Hyphessobrycon* sp.4	31	0.15%	21	0.99%
69	*Hyphessobrycon* sp.5			121	5.73%
70	*Hyphessobrycon* sp.6	1	0.00%	20	0.95%

Table 5 (continued)

Orders & Species		Mid-Rio Negro Streams		Igarapé Zamula	
		Number of fish & relative abundance (%)			
71	*Hyphessobrycon* sp.7			52	2.46%
72	*Hyphessobrycon* sp.8	1	0.00%		
73	*Hyphessobrycon* sp.9	2	0.01%	3	0.14%
74	*Hyphessobrycon* sp.10	10	0.05%		
75	*Hyphessobrycon* sp.11	61	0.30%		
76	*Iguanodectes adujai*	48	0.24%		
77	*Iguanodectes spirulus*			1	0.05%
78	*Iguanodectes* sp.1	28	0.14%		
79	*Klausewitzia aphanes*	218	1.08%		
80	*Klausewitzia* sp.1	19	0.09%		
81	*Klausewitzia* sp.2	28	0.14%		
82	*Klausewitzia* sp.3	4	0.02%		
83	*Klausewitzia* sp.4	1	0.00%		
84	*Leporinus friderici*	1	0.00%		
85	*Moenkhausia collettii*	87	0.43%	1	0.05%
86	*Moenkausia copei*			1	0.05%
87	*Moenkhausia cotinho*	6	0.03%		
88	*Moenkhausia* sp.2	1	0.00%		
89	*Paracheirodon axelrodi*	4,264	21.14%		
90	*Petitella georgiae*	2	0.01%		
91	*Poecilocharax weitzmani*	70	0.35%		
92	*Serrasalmus* sp.			1	0.05%
93	*Tetragonopterinae* sp.1	2	0.01%		
93	*Tetragonopterinae* sp.1	2	0.01%		
94	*Tetragonopterinae* sp.2	3	0.01%		
	Curimatidae				
95	*Curimatopsis crypticus*	21	0.10%		
96	*Curimatopsis evelynae*	1,202	5.96%	45	2.13%
97	*Curimatella immaculata*			9	0.43%
98	*Curimatopsis macrolepis*	5	0.02%		
99	*Curimatopsis* sp.1	14	0.07%		
100	*Curimatopsis* sp.2	433	2.15%		
101	*Curimatopsis* sp.3	71	0.35%		
102	*Curimatopsis* sp.4	5	0.02%		
103	*Curimatopsis* sp.6	12	0.06%		
	Erythrinidae				
104	*Erythrinus erythrinus*	21	0.10%		
105	*Hoplias malabaricus*	126	0.62%		
	Gasteropelecidae				
106	*Carnegiella marthae*	701	3.47%	1	0.05%
107	*Carnegiella strigata*	228	1.13%		
	Hemiodontidae				
108	*Hemiodopsis gracilis*			1	0.05%

Table 5 (continued)

	Orders & Species	Mid-Rio Negro Streams		Igarapé Zamula	
		Number of fish & relative abundance (%)			
	Lebiasinidae				
109	*Nannostomus digrammus*	163	0.81%	2	0.09%
110	*Nannostomus eques*	67	0.33%	37	1.75%
111	*Nannostomus marginatus*	302	1.50%	8	0.38%
112	*Nannostomus marilynae*	181	0.90%		
113	*Nannostomus trifasciatus*			30	1.42%
114	*Nannostomus unifasciatus*	146	0.72%	33	1.56%
115	*Nannostomus* sp.1	8	0.04%		
116	*Nannostomus* sp.2	7	0.03%		
117	*Nannostomus* sp.3	3	0.01%		
118	*Nannostomus* sp.4	49	0.24%		
119	*Nannostomus* sp.5	41	0.20%		
120	*Nannostomus* sp.6	45	0.22%		
121	*Nannostomus* sp.7	104	0.52%	11	0.52%
122	**Pyrrhulina laeta**	31	0.15%		
123	*Pyrrhulina stoli*	8	0.04%		
	SILURIFORMES				
	Aspredinidae				
124	*Bunocephalus coracoides*			3	0.14%
125	*Bunocephalus verrucosus*	1	0.00%		
	Auchenipteridae				
126	*Auchenipterichthyes dantei*			1	0.05%
127	*Trachelyichthys decaradiatus*			1	0.05%
	Cetopsidae				
128	*Cetopsis* sp.	2	0.01%		
	Doradidae				
129	*Amblydoras hancocki*			13	0.62%
130	*Astrodoras asterifrons*			1	0.05%
	Loricariidae				
131	*Acestridium discus*	7	0.03%		
132	*Ancistrus* sp.				
	Loricariidae				
131	*Acestridium discus*	7	0.03%		
133	*Dolichancistrus* sp.				
	Pimelodidae				
134	*Calophysus macropterus*			1	0.05%
135	*Microglanis poecilus*			1	0.05%
136	*Phreatobius* sp.1	47	0.23%		
137	*Pseudopimelodus raninus*			1	0.05%
138	*Rhamdella* sp.			1	0.05%
	Scoloplacidae				
139	*Scoloplax dolicholophia*	68	0.34%		
	Trichomycteridae				
140	*Glanapteryx* sp.1	29	0.14%		

Table 5 (continued)

	Orders & Species	Mid-Rio Negro Streams		Igarapé Zamula	
		Number of fish & relative abundance (%)			
141	*Vandellia* sp.			3	0.14%
	GYMNOTIFORMES				
142	*Brachyhypopomus brevirostris*			19	0.90%
143	*Eigenmannia macrops*			9	0.43%
144	*Gymnotus carapo*	1	0.00%		
145	*Gymnotus* sp.1	2	0.01%		
146	*Hypopomus* sp.1	13	0.06%		
147	*Microsternachus bilineatus*			3	0.14%
148	*Sternopygus* sp.1	7	0.03%		
	SYNBRANCHIFORMES				
149	*Synbranchus marmoratus*	12	0.06%	1	0.05%
	PERCIFORMES				
	Cichlidae				
150	*Aequidens tetramerus*			13	0.62%
151	*Apistogramma agassizii*	8	0.04%		
152	*Apistogramma gibbiceps*	219	1.09%	10	0.47%
153	*Apistogramma hippolytae*	13	0.06%	5	0.24%
154	*Apistogramma paucisquamis*	679	3.37%	83	3.93%
155	*Apistogramma pertensis*	248	1.23%	226	10.71%
156	*Apistogramma* sp.			2	0.09%
157	*Biotodoma cupido*			38	1.80%
158	*Cichla* sp.	1	0.00%		
159	*Cichla monoculus*			3	0.14%
160	*Cichlasoma amazonarum*	1	0.00%		
161	*Crenicichla notophthalmus*	69	0.34%	154	7.30%
162	*Crenicichla* sp.1	17	0.08%	13	0.62%
163	*Crenicichla* sp.2	6	0.03%	101	4.78%
164	*Dicrossus filamentosus*	337	1.67%	8	0.38%
165	*Heros severum*			10	0.47%
166	*Laetacara cf. orangeflossen*	24	0.12%		
167	*Laetacara* sp.1	4	0.02%		
168	*Mesonauta insignis*	8	0.04%		
169	*Satanoperca* sp.1			33	1.56%
	Eleotridae				
170	*Microphilypnus* sp.1	81	0.40%	7	0.33%
171	Microphilypnus sp.2	1	0.00%		
	Nanidae				
172	*Monocirrhus polyacanthus*	5	0.02%	1	0.05%
	Total Number of Samples	**20,174**		**2,111**	
	Number of species sampled	**138**		**78**	

Table 6. Distribution of 20 most abundant fishes in three floodplain habitats from mid-Rio Negro basin (Chao & Prada-Pedrero, 1995).

HABITATS		Igapó	Igarapé	Lago	Total	Cumulative
Distribution by habitats (%)		Flooded	Stream	Swamp	Number of	Abundance
Species ranking by abundance		forest	margin	lake	fishes	%
1	*Paracheirodon axelrodi**	15.0	76.7	8.3	4,264	21.05
2	*Hemigrammus analis*	55.8	16.3	27.9	2,738	34.57
3	*Copella nattereri* *	52.6	46.8	0.6	1,746	43.20
4	*Curimatopsis evelynae* *	3.4	79.1	17.5	1,209	49.17
5	*Hemigrammus vorderwinkleri*	42.4	17.9	39.7	1,081	54.50
6	*Carnegiella marthae* *		99.9	0.1	701	57.96
7	*Apistogramma paucisquamis*	1.0	93.4	5.6	679	61.32
8	*Hemigrammus cf. bellottii* *	0.4	74.5	25.1	670	64.63
9	*Curimatopsis sp.2*		10.9	89.1	433	66.76
10	*Hemigrammus sp.21*		31.9	68.1	430	68.89
11	*Lycengraulis sp.1*		100.0		358	70.65
12	*Dicrossus filamentosus* *		87.8	12.2	337	72.32
13	*Nannostomus marginatus* *	58.3	29.5	12.3	302	73.81
14	*Hemigrammus cf. stictus* *		29.9	70.1	281	75.20
15	*Hoplocharax goethei* *	0.4	90.0	9.6	250	76.43
16	*Apistogramma pertensis* *	0.8	77.8	21.4	248	77.66
17	*Hemigrammus cf. arbovittatus*	84.4	13.9	1.6	244	78.86
18	*Hemigrammus sp.32*	70.8	13.6	15.7	236	80.03
19	*Apistogramma gibbiceps* *	10.0	80.4	9.6	219	81.11
20	*Klausewitzia aphanes*	6.9	82.6	10.6	218	82.18
	All the rest species.	25.4	54.0	20.7	3,608	100
	Number of fishes	5,100	11,314	3,838	20,252	
	Distribution by Habitats	25.18%	55.87%	18.95%		
	Number of species	68	103	65	131	

Table 7. Bottom trawl fish diversity of the Rio Negro basin and lower Rio Branco. (N: total number of fish sampled; %, relative abundance in the catch; FC, frequency of capture in trawl hauls)

		Lower Rio Negro			Rio Cueiras			Mid-Rio Negro			Mid-Rio Negro			Lower Rio Branco			Lower Rio Branco		
		(Barletta, 1992-93)			(Chao, 1992)			(Chao,1996)			(Souza, 97-98)			(Chao, 1996)			(Souza 96-97)		
	SPECIES	**N**	**%**	**FOC**	**N**	**%**	**FOC**	**N**	**%**	**FOC**	**N**	**%**	**FOC**	**N**	**%**	**FOC**	**N**	**%**	**FOC**
	RAJIFORMES																		
	Potamotrygonidae																		
1	*Plesiotrygon iwamae*	2	0.0%	2															
2	*Potamotrygon constellata*	2	0.0%	2															
3	*Potamotrygon motoro*	1	0.0%	1															
4	*Potamotrygon shroederi*				1	0.1%	1												
5	*Potamotrygon sp.*	1	0.0%	1															
	CLUPEIFORMES																		
	Engraulidae																		
6	*Anchovia sp.*										60	1.6%	6	6	0.3%	1	187	10.3%	3
7	*Anchoviella sp.*				1	0.1%	1												
8	*Lycengraulis sp.*				4	0.3%	1				55	1.4%	7	22	1.1%	2	2	0.1%	1
9	Engraulidae sp.	59	1.3%	19															
	Pristigsteridae																		
10	*Pristigaster cayanus*	4	0.1%	2							129	3.3%	2				11	0.6%	3
	Clupeidae																		
11	*Ilisha amazonica*																1	0.1%	1
12	*Pellona flavipinis*	2	0.0%	1															
	CHARACIFORMES																		
	Hemiodontidae																		
13	*Argonectes longiceps*																1	0.1%	1
14	*Hemiodus cf. termetzi*										1	0.0%	1						
15	*Hemiodus imaculata*										1	0.0%	1						
	Curimatidae											0.0%							
16	*Anostomoides laticeps*																1	0.1%	1
17	*Anostomoides sp. New*										1	0.0%	1						
18	*Curimata incompta*										21	0.5%	4				15	0.8%	2
19	*Curimata vittata*										12	0.3%	4						
20	*Curimatella meyeri*										2	0.1%	2				27	1.5%	3
21	*Steindachnerina planiventris*										4	0.1%	2				1	0.1%	1

Table7 (continued)

	SPECIES	Lower Rio Negro			Rio Cueiras			Mid-Rio Negro			Mid-Rio Negro			Lower Rio Branco			Lower Rio Branco		
		N	%	FOC	N	%	FOC	N	%	FOC	N	%	FOC	N	%	FOC	N	%	FOC
	Anostomidae																		
22	*Caenotropus labyrinticus*										3	0.1%	2				4	0.2%	2
23	*Laemolyta varia*										1	0.0%	1						
24	*Leporinus fasciatus*										2	0.1%	1						
25	*Rhytiodus argenteofuscus*																3	0.2%	2
	Characidae																		
26	*Acestrophalus sardina*										1	0.0%	1				1	0.1%	1
27	*Characidae sp. 1*										13	0.3%	5				82	4.5%	11
28	*Characidae sp. 2*										76	2.0%	14				45	2.5%	7
29	*Characidae sp. 3*										121	3.1%	7				25	1.4%	9
30	*Characidae sp. 4*										63	1.6%	7				12	0.7%	5
31	*Characidae sp. 5*										94	2.4%	7				500	27.6%	11
32	*Characidae sp. 6*										3	0.1%	3				1	0.1%	1
33	*Characidae sp. 7*										1	0.0%	1				2	0.1%	2
34	*Characidae sp. 8*										1	0.0%	1				5	0.3%	1
35	*Characidae sp. 10*										13	0.3%	2				1	0.1%	1
36	Eucynopotamus biserialis	4	0.1%	1															
37	*Hyphessobrycon sp.*				2	0.1%	1												
38	*Leporhinus sp1*	1	0.0%	1	1	0.1%	1												
39	*Lonchogenys ilisha*										3						2		
40	*Moenkausia sp1*	1	0.0%	1			1												
41	*Roeboides dayi*										37	1.0%	5				6	0.3%	2
42	*Serrasalmus sp. 1*										3	0.1%	2				1	0.1%	1
43	*Serrasalmus sp. 2*										2	0.1%	2						
44	*Serrasalmus sp. 3*										1	0.0%	1				1	0.1%	1
45	*Serrasalmus sp. 4 (larva)*										3	0.1%	1						
46	*Tetragonopterus chalceus*										2	0.1%	2						
	Cynodontidae																		
47	*Hydrolycus scomberoides*	3	0.1%	2													1	0.1%	1
48	*Rhaphiodon gibbus*	47	1.0%	20							9	0.2%	2						
	Curimatidae																		
49	*Potamorhina sp1*	5	0.1%	1															
	GASTEROPELECIDAE																		
50	*Canegiella sp.*				1	0.1%	1												

	Silouriformes																		
	Ageneiosidae																		
51	*Ageneiosus mamoratus*				2	0.1%	1												
52	*Ageneiosus ucayalensis*										9	0.2%	4						
53	*Ageineiosus vittatus*	1	0.0%	1	3	0.2%	1												
54	*Ageineiosus walshi*							3	2.0%	1				2	0.1%	2			
55	*Ageineiosus sp1.*	52	1.1%	26	54	3.9%	11												
56	*Ageneiosus sp. 2*	5	0.1%	5				1	0.7%	1	3	0.1%	1						
57	*Ageneiosus sp. 3*	2	0.0%	3							2	0.1%	2						
58	*Ageneiosus sp. 4*							1	0.7%	1									
59	*Pseudepapterus sp1.*	39	0.9%	14															
	Aspredinidae																		
60	*Bunocephalus sp1*	5	0.1%	5										1	0.0%	1			
61	*Bunocephalus sp2*	2	0.0%	1															
62	*Petacara labichurus*													2	0.1%	1			
63	*Petacara sp.*										1	0.0%	1						
	Auchenipteridae																		
64	*Auchenipterus nuchalis*										3	0.1%	1						
65	*Auchenipterus sp1*	5	0.1%	6															
66	*Centromochlus heckeli*	6	0.1%	4							22	0.6%	2						
67	*Pseudopapterus cucuhyensis*							3	2.0%	2	7	0.2%	2						
	Cetopsidae																		
68	*Cetopsis sp.*										3	0.1%	2						
69	*Cetopsis sp1.*	20	0.4%	18															
70	*Cetopsis sp2*	10	0.2%	5															
71	*Orthosternarchus tamandua*	2	0.0%	2															
72	*Pseudocetopsis oliverai*	5	0.1%	4															
	Doradidae																		
73	Anduzidoras sp1	2	0.0%	1	1	0.1%	1												
74	Acanthodoras sp1	2	0.0%	3															
75	*Astrodoras asterifrons*										12	0.3%	5						
76	*Astrodoras sp.1*													2	0.1%	2			
77	Centrochir crocodili	1	0.0%	1															
78	Centrodoras brachiatus	6	0.1%	6	40	2.9%	5												
79	*Hassar notospilus*																1	0.1%	1
80	*Hassar orestis*													2	0.1%	1			
81	*Hassar sp. 1*	4	0.1%		4	0.3%	1							4	0.2%	3			

82	*Hassar sp. 2*							4	2.7%	2	32	0.8%	11	11	0.5%	3	13	0.7%	4
83	*Hassar sp. 3*							1	0.7%	1				1	0.0%	1			
84	*Hassar sp. 4*													1	0.0%	1	3	0.2%	2
85	*Hassar sp. 5*										23	0.6%	3						
86	*Hassar sp. 6*										1	0.0%	1						
87	*Hemidoras stenopeltis*										84	2.2%	11				15	0.8%	1
88	*Hemidoras morrisi*	1	0.0%	1	4	0.3%	4												
89	*Hoplodoras sp1*	1	0.0%	1															
90	*Leptodoras acipenserinus*							1	0.7%	1				39	1.9%	3			
91	*Leptodoras jurensis*	2	0.0%	2															
92	*Leptodoras linnelli*										8	0.2%	4	23	1.1%	4	23	1.3%	8
93	*Lithodoras sp.1*				1	0.1%	1												
94	*Megalodoras irwini*	1	0.0%	1															
95	*Megalodoras libertati*													1	0.0%	1			
96	*Megalodoras uranocefus*													1	0.0%	1			
97	*Megalodoras sp.1*				1	0.1%	1												
98	*Nemadoras leporhinus*										36	0.9%	10	9	0.4%	1	2	0.1%	1
99	*Nemadoras trimaculatus*	45	1.0%	14							32	0.8%	6	62	3.0%	3	7	0.4%	1
100	*Nemadoras sp.1*													17	0.8%	5			
101	*Nemadoras sp.2*													1	0.0%	1			
102	*Nemadoras sp.3*													1	0.0%	1			
103	*Opsodoras humeralis*	2	0.0%	2															
104	*Opsodoras leporhinos*	5	0.1%	4															
105	*Opsodoras stuebeli*				51	3.7%	4				27	0.7%	2						
106	*Opsodoras trimaculatus*				39	2.8%	2												
107	*Opsodoras sp3*	122	2.7%	35	378	27.6%	9												
108	*Opsodoras sp5.*	34	0.7%	8															
109	*Peterodoras lentiginosus*										1	0.0%	1						
110	*Pterodoras sp1*	1	0.0%	1															
111	*Rhincodoras sp. 1*													1	0.0%	1	1	0.1%	1
112	*Scorpiodoras sp.1*													3	0.1%	2			
113	*Stenodoras microstomus*	194	4.2%	27	274	20.0%	6	3	2.0%	1	1040	27.0%	20	184	9.0%	2	5	0.3%	3
114	*Stenodoras sp.1*													35	1.7%	1			
115	*Stenodoras sp.2*													86	4.2%	2			
116	*Stenodoras sp.3*													45	2.2%	1			
	Hypophthalmidae																		
117	*Hypophthalmus edentatus*	500	10.9%	47	23	1.7%	5				1	0.0%	1						

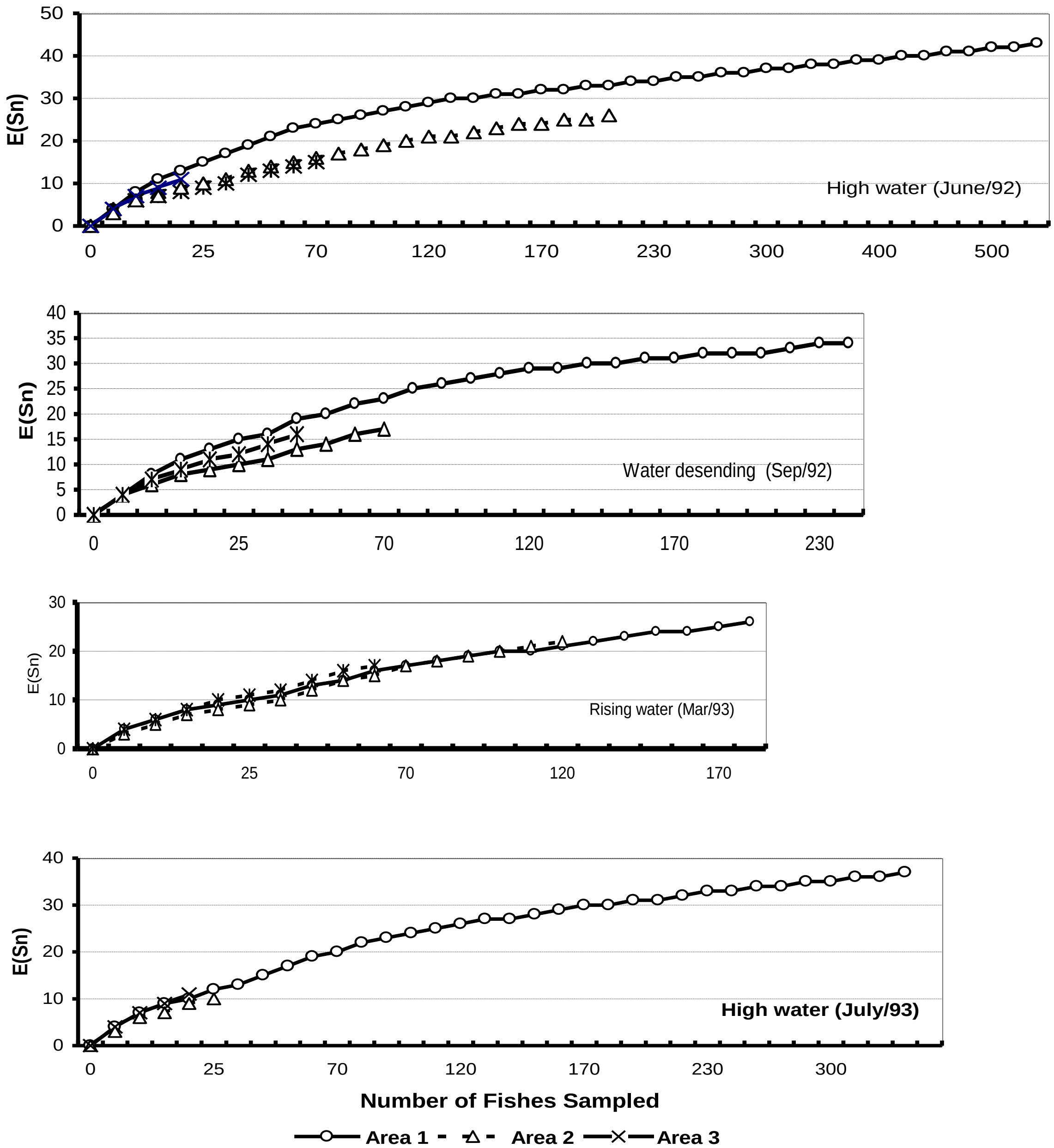
118	*Hypophthalmus fimbriatus*	37	0.8%	11	39	2.8%	4												
119	*Hypophthalmus marginatus*	97	2.1%	32	34	2.5%	5												
120	*Hypophthalmus* sp. (larvae*)*	174	3.8%	23															
	Loricaridae																		
121	*Acanthicus sp1*	2	0.0%	2															
122	*Apistoloricaria sp.*										1	0.0%	1						
123	*Furcodontichthys novaesi*										1	0.0%	1						
124	*Hemiodontichthys aciperserinus*	3	0.1%	3										8	0.4%	4			
125	*Hypostomus micropunctatus*										4	0.1%	3				1	0.1%	1
126	*Hypostomus sp.1*													1	0.0%	1			
127	*Limatulichthys punctatus*										6	0.2%	3	28	1.4%	5	2	0.1%	2
128	*Loricaria cf. cataphracta*										3	0.1%	2				1	0.1%	1
129	*Loricaria sp. 1*	1	0.0%	1							1	0.0%	1	1	0.0%	1	3	0.2%	2
130	*Loricaria sp. 2*										1	0.0%	1						
131	*Loricaria n.sp. (spiny)*										2	0.1%	2						
132	*Loricariichthys sp.1*	1	0.0%	1															
133	*Pecklotia platyrhnyca*				1	0.1%	1												
134	*Pecklotia vittata*				1	0.1%	1												
135	*Pecklotia sp. 1*																1	0.1%	1
136	*Pecklotia sp. 2*																1	0.1%	1
137	*Planiloricaria sp1*	5	0.1%	4															
138	*Pseudoloricaria laeviscula*										1	0.0%	1	1	0.0%	1			
139	*Reganella depressa*	70	1.5%	16							9	0.2%	5	14	0.7%	2	3	0.2%	2
140	*Ricola sp. 1*										1	0.0%	1						
141	*Ricola sp1.*	61	1.3%	20															
142	*Rineloricaria gr. phorocephala*										1	0.0%	1						
143	*Rhineloricaria sp.*													8	0.4%	3			
144	*Sturisoma nigrirostrum*													9	0.4%	2			
145	*Sturisoma sp.*										1	0.0%	1						
146	*Sturisoma sp1*													3	0.1%	2			
147	*Loricaridae*	23	0.5%	18													1	0.1%	1
	Pimelodidae																		
148	*Brachyplatystoma filamentosusm*	19	0.4%	18	1	0.1%	1				2	0.1%	2						
149	*Brachyplatystoma vaillanti*	22	0.5%	12															
150	*Brachyplatystoma juruensis*	1	0.0%	1															
151	*Bathypotamicthys sp.*										72	1.9%	9						
152	*Bathypotamichtys sp1*	74	1.6%	27															

153	*Cheirocerus goeldi*	32	0.8%	6							85	4.7%	2						
154	*Calophysus macropterus*	2	0.1%	2										1	0.0%	1			
155	*Duopalatinus malarmo*	4	0.1%	2							1	0.1%	1						
156	*Duopalatinus peruanus*	1	0.0%	1															
157	*Exallodontus aguanai*	37	0.8%	20															
158	*Gaeldiella eques*													2	0.1%	1			
159	*Goslinea platinema*	39	0.9%	21															
160	*Hemisorubim playtyrhynchos*													1	0.0%	1			
161	*Hepapterus sp1*	1	0.0%	1															
162	*Imparfinis sp1*	2	0.0%	1															
163	*Megalonema sp.*										32	0.8%	8				86	4.8%	13
164	*Microglanis sp. 1*																1	0.1%	1
165	*Phractocephalus hemiliopterus*	1	0.0%	1															
166	*Pimelodella cristata*	3	0.1%	3															
167	*Pimelodella cristata*			2							3	0.1%	3				2	0.1%	2
168	*Pimelodella sp.1*													87	4.3%	4			
169	*Pimelodella sp.2*													3	0.1%	2			
170	*Pimelodella sp.3*													7	0.3%	2			
171	*Pimelodina flavipinnis*	28	0.6%	13	32	2.3%	2				7	0.2%	4				1	0.1%	1
172	*Pimelodus altissimus*	388	8.5%	64							52	1.3%	10				21	1.2%	3
173	*Pimelodus blochii*	19	0.4%	14	46	3.4%	3				58	1.5%	9	417	20.5%	7	62	3.4%	4
174	*Pimelodus sp. 1*										38	1.0%	7	17	0.8%	6	123	6.8%	11
175	*Pimelodus sp. 2*													66	3.2%	3			
176	*Pimelodus sp. 3*													3	0.1%	1			
177	*Pinirampus pirinampus*	20	0.4%	15							1	0.0%	1						
178	*Platystomatichthys sturio*	4	0.1%	4	1	0.1%	1												
179	*Platystomatichthys sp.*		,								2	0.1%	1				1	0.1%	1
180	*Pseudopimelodus sp. 1*				1	0.1%	1												
181	*Pterosturisoma microps*	3	0.1%	2															
182	*Pimelodidae n. sp.1(Bathy)*		,								4	0.1%	3						
183	*Pimelodidae n. sp.2 (Bathy)*										1	0.0%	1						
	Trichomycteridae		,																
184	*Plectrochillus sp.1*													1	0.0%	1			
185	*Stegophilus sp1*	6	0.1%	6															
186	*Stegophilus sp2*	2	0.0%	1															
187	*Stegophilus sp3*	1	0.0%	1															
188	*Stegophilus sp4*	1	0.0%	1							3	0.1%	2	1	0.0%	1			

189	*Stegophilus sp5*	1	0.0%	1															
190	*Vandelia sp1*	1	0.0%	1															
191	***Siluroidei (larvas)***	6	0.1%	4															
	GYMNOTIFORMES																		
	Apteronotidae																		
192	*Adontosternarchus baleanops*							8	5.3%	2									
193	*Adontosternarchus clarkae*	37	0.8%	16	4	0.3%	4				31	0.8%	3						
194	*Adontosternarchus sachsi*	2	0.0%	3	2	0.1%	2	1	0.7%	1									
195	*Adontosternarchus sp.*							6	4.0%	1	17	0.4%	5						
196	*Apteronotus albifrons*													2	0.1%	1			
197	*Apteronotus bonapartii*	90	2.0%	35							60	1.6%	11						
198	*Apteronotus macroleps*	4	0.1%	2															
199	*Apteronotus sp1*	5	0.1%	3				3	2.0%	1									
200	*Apteronotus sp2*	4	0.1%	3										1	0.0%	1			
201	*Apteronotus sp4*	2	0.0%	1															
202	*Magosternarchus duccis*										1	0.0%	1						
203	*Orthosternarchus tamandua*										7	0.2%	4						
204	*Platyuosternachus macrostomus*													2	0.1%	2			
205	*Porotergus compsus*										5	0.1%	2						
206	*Porotergus sp.*										31	0.8%	9						
207	*Porotergus sp1.*	11	0.2%	4															
208	*Porotergus sp. 2*	2	0.0%	2							5	0.1%	3				3	0.2%	2
209	*Porotergus sp. 4*							6	4.0%	1									
210	*Sternarchaella orthos*	156	3.4%	41	195	14.2%	5												
211	*Sternarchella schotti*							4	2.7%	1	5	0.1%	4						
212	*Sternarchella terminalis*	32	0.7%	25							1	0.0%	1						
213	*Sternarchogiton nattereri*	81	1.8%	31	1	0.1%	1	5	3.3%	1	32	0.8%	6				5	0.3%	1
214	*Sternarchogiton porcinum*	41	0.9%	15	7	0.5%	2				116	3.0%	7						
215	*Sternarchogiton sp1*	15	0.3%	11	2	0.1%	1												
216	*Sternarchogiton sp2*				3	0.2%	2												
217	*Sternarchogiton sp3*				1	0.1%	1												
218	*Sternarchorhamphus muelleri*	79	1.7%	30	19	1.4%	4				4	0.1%	2				1	0.1%	1
219	*Sternarchorhynchus curvirostris*	1	0.0%	1							2	0.1%	1						
220	*Sternarchorhynchus oxirhynchus*	19	0.4%	0.19							19	0.5%	4						
221	*Sternarchorhynchus mormyrus*	2	0.0%																
222	*Sternarchorhynchus sp1*	1	0.0%	1							1	0.0%	1	36	1.8%	2			
223	*Sternarchorhynchus sp2*	2	0.0%	1										2	0.1%	1			

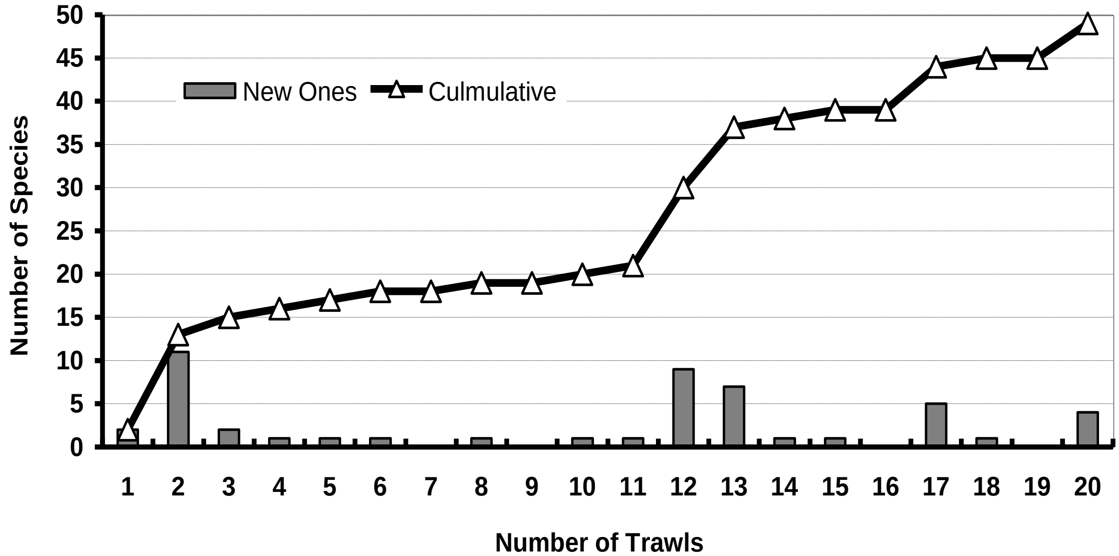
224	*Sternarchorhynchus sp3*	1	0.0%	1															
225	*Sternarchorhynchus sp4*	2	0.0%	1															
226	*Sternarchorhynchus sp5*	2	0.0%	1															
227	*Apteronotidae (gen. nov. 1)*	14	0.3%	7															
228	*Aptronotidae (gen. nov. 2)*	2	0.0%	3															
	Hypopomidae																	0.0%	
229	*Steatogenys elegans*	250	5.5%	38	46	3.4%	3	22	14.7%	1	67	1.7%	13				1	0.1%	1
230	*Steatigenys duidae*				1	0.1%	1												
	Rhamphichthydae																		
231	*Gymnorhamphichthys hypostomus*										3	0.1%	2						
232	*Gymnorhamphichthys rondoni*							3	2.0%	2				3	0.1%	2			
233	*Gymnorhamphichthys sp. (larvae)*										1	0.0%	1						
234	*Gymnorhamphichthys sp1*													2	0.1%	1			
235	*Gymnorhamphichthys sp2*	2	0.0%	2										5	0.2%	2			
236	*Rhamphichthys marmoratus*										1	0.0%	1	1	0.0%	1	1	0.1%	1
237	*Rhamphichthys sp. 2*																1	0.1%	1
	Sternopygidae		,																
238	*Distocyclus conirostris*	119	2.6%	30	23	1.7%	5	2	1.3%	1	4	0.1%	2						
239	*Eigenmannia macrops*	1	0.0%	1							505	13.1%	15				49	2.7%	9
240	*Eigenmania humbolditii*	14	0.3%	4															
241	*Eigenmannia virescens*	64	1.4%	18							9	0.2%	4				3	0.2%	1
242	*Eigenmannia sp. 1*							62	41.3%	3				136	6.7%	6			
243	*Eigenmannia sp. 2*							3	2.0%	1				132	6.5%	3			
244	*Eigenmannia sp. 3*													309	15.2%	4			
245	*Eigenmannia sp. 4*													13	0.6%	4			
246	*Rhabdolichops caviceps*		,					3	2.0%	1	14	0.4%	2	5	0.2%	1	1	0.1%	1
247	*Rhabdolichops eastwardi*	146	3.2%	17				2	1.3%	2	10	0.3%	3	28	1.4%	3	4	0.2%	2
248	*Rhabdolichops electrogrammus*	107	2.3%	5							24	0.6%	7				23	1.3%	4
249	*Rhabdolichops stewardi*													4	0.2%	2			
250	*Rhabdolichops troscheli*	55	1.2%	10							1	0.0%	1						
251	*Rhabdolichops sp.1*							3	2.0%	2				47	2.3%	4			
252	*Sternopygus macrurus*										2	0.1%	2						
	PERCIFORMES																		
	Cichlidae																		
253	*Apistogramma sp.*				2	0.1%	1												
254	*Biotodoma cupido*	1	0.0%	0.01	2	0.1%	1				1	0.0%	1	1		1			
255	*Biotoecus opercularis*	1	0.0%	0.01							1	0.0%	1						

256	*Crenicichla johanna*	1	0.0%	1															
257	*Crenicichla sp.*				8	0.6%	2												
258	*Crenicichla sp.1*													1	0.0%	1			
259	*Crenicichla sp.2*													6	0.3%	2			
260	*Crenicichla sp.3*	1	0.0%	0.01													1	0.1%	1
261	*Crenicichla sp.4*	1	0.0%	0.01							1	0.0%	1						
262	*Geophagus proximus*										170	4.4%	11	49	2.4%	2	102	5.6%	10
263	*Geophagus sp1*	253	5.5%	5															
	Sciaenidae																		
264	*Pachypops fourcroi*	32	0.7%	0.32	3	0.2%	1				12	0.3%	3				20	1.1%	4
265	*Pachipops trifilis*	68	1.5%	12	2	0.1%	1												
266	*Pachypops adspersus*	1	0.0%	1															
267	*Pachyurus schomburgkii*	1	0.0%	1							49	1.3%	9				117	6.5%	13
268	*Pachyurus sp. A*										35	0.9%	7				10	0.6%	3
269	*Plagioscion squamosissimus*	126	2.8%	34															
270	*Plagioscion sp.*										130	3.4%	16				61	3.4%	10
271	*Plagioscion sp1. (pos-larva)*	129		39	11	0.8%	4							7	0.3%	2			
272	*Plagioscion sp2 (pos-larvae)*	32	0.7%	14	1	0.1%	1												
273	*Sciaenidae (larvae)*	2	0.0%	2															
	PLEURONECTIFORMES																		
274	**Achiridae**																	0.0%	
275	*Hypoclinemus mentalis.*	2	0.0%	2							2	0.1%	2	4	0.2%	1	3	0.2%	2
	TETRADONTIFORMES																		
	Tetraodontidae																		
276	*Colomesus asellus*										1	0.0%	1						
	Number of Fishes	**4,575**	1		**1,370**	1		**150**	1		**3,858**	1		**2,037**	1		**1,810**		
	Total Weight (g)	**63,750**			**N/A**			**777**			**14,820**			**10,220**			**7,017**		
	Number of species	**120**			**48**			**23**			**122**			**96**			**71**		
	Number of trawls.	**194**			**20**			**7**			**35**			**10**			**24**		



E(Sn)
High water (June/92)
Water desending (Sep/92)
Rising water (Mar/93)
High water (July/93)
Number of Fishes Sampled
Area 1
Area 2
Area 3

Figure 7. Rare faction analyses: spatial and temporal variations of the expected number of species E (Sn) from the bottom trawl samples at the confluence of Rio Negro



(Area 1) with Rio Solimões (Area 2) and Rio Amazonas (Area 3).

Figure 8. Bottom trawl species diversity influenced by water level at the mouth of Rio Cueiras, lower Rio Negro. Water level was 1m lower during sample 12 to 20.

LIFE HISTORY TRAITS

Most floodplain fishes have short life spans and reproduce annually. Their life histories are well adapted to hydrological cycle and shifting habitats. The rainforests and aquatic systems of the middle Rio Negro region are largely intact. Deforestation has been moderate. There is no evidence that fish diversity has been threatened, but the catch might decrease with increased fishing pressure in certain river tributaries and *igarapés.*

The cardinal tetra (*Paracheirodon axelrodi*) is of particular concern to the fishery and the ecosystem, and thus has been chosen as the principal indicator species. The cardinal tetra has a life span of a year or so in the floodplain, although some may live more than 5 years in captivity. At capture, cardinal tetras are 12-35 mm SL (Standard Length). Length frequency distribution is unimodal at about 18 mm SL, with few specimens larger than 25 mm SL (Fig. 9). Cardinal tetras bear a few large eggs (300 to 500), the largest approximately 0.55 mm in diameter. Egg size distribution is bi-model (Fig. 10), perhaps indicating multiple spawning during step-ward water rising *(repiquete)*. They probably die after spawning in the wild, but smaller individuals reared in the captivity may live much longer in the captivity, over four years, not be able to spawn. More field and laboratory studies are needed to determine the relationship of live span and spawn. Other aspects of the biology and ecology of the cardinal tetra have been reported by Chao & Prada-Pedreros (1995).

Life history studies on balck aruwana (*Osteoglossum ferreiri*), dwarf cichlid (*Apistogramma petenses*), Rommy nose (*Hemigrammus rodostom*), bleeding-heart tetras *(Hyphyessobrycon* spp.) are on going student projects.

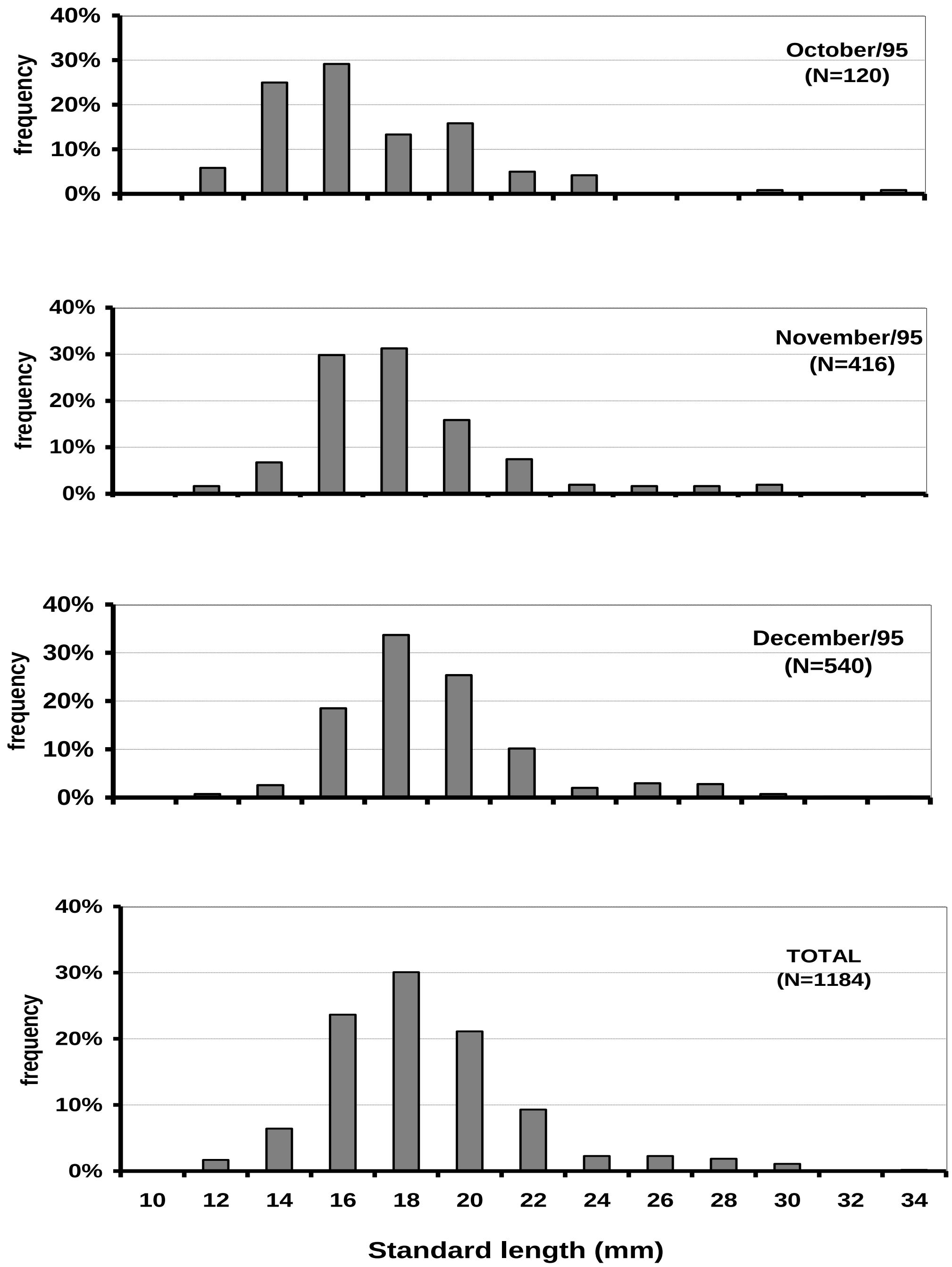


Figure 9. Length frequency distribution of Cardinal tetra between October 1995 and January 1996.

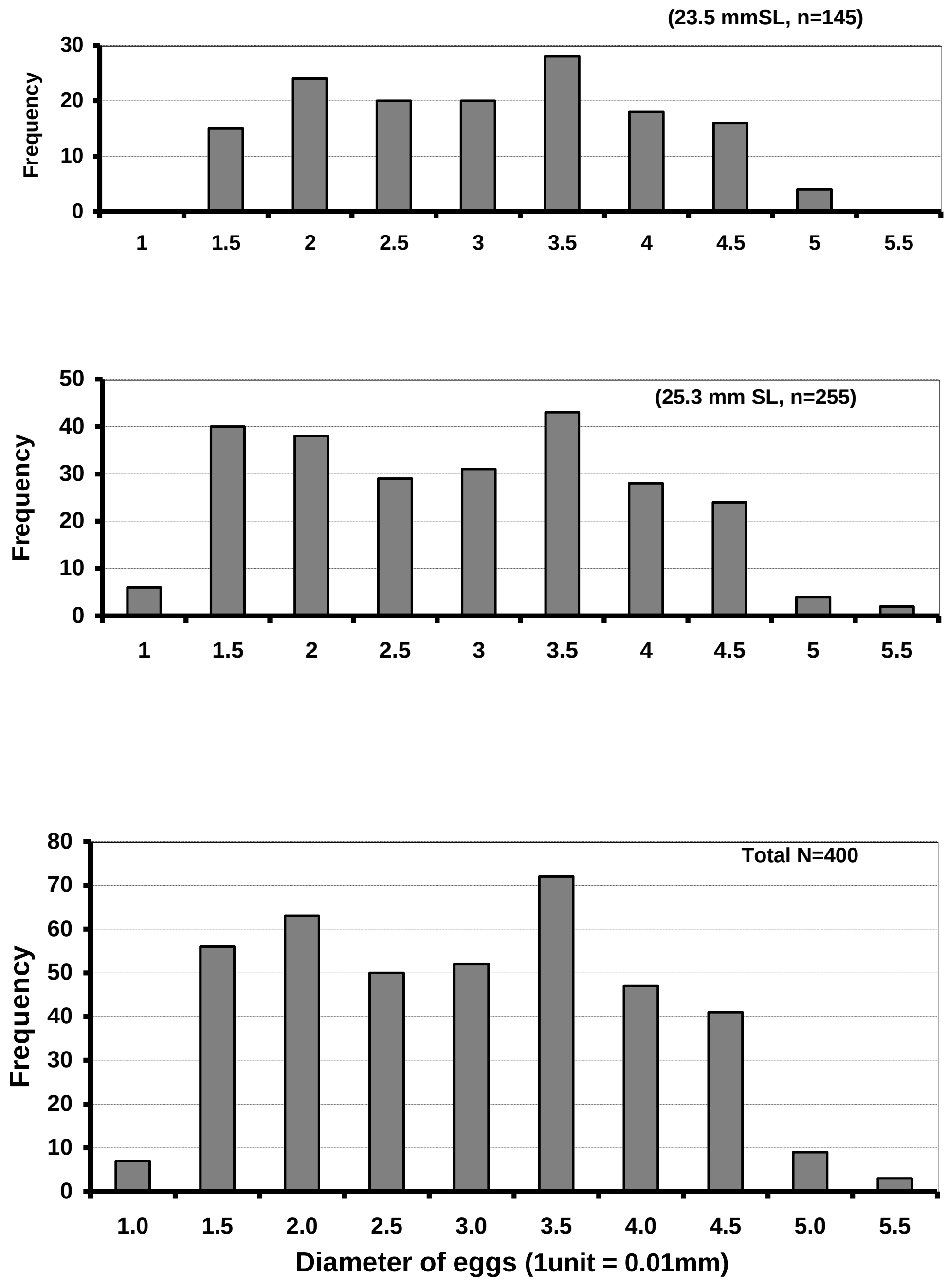


Figure 10. Egg size distribution of two Cardinal tetra, *Paracheirodon axelrodi* (23.5 and 25.3 mm SL) from Igarapé Anapixi, Barcelos, Mid- Rio Negro. May 1990.

CONSERVATION

Probably half the ornamental fishes taken from natural habitats in Amazonas are not included in the official export registers. Of the 30-40 million caught in middle Rio Negro tributaries, only 20 million are exported officially from Manaus. This may only reflect the market demand for ornamental fishes. Can the ecosystem sustain this level of exploitation?

Bayley and Petrere (1989) stated, “Intensive fishing has caused commercial extinction of discus, *Symphysodon* spp. in the lower R. Negro and the cardinal, *Paracheirodon axelrodi* in the middle R. Negro region (M. Goulding, pers. comm.).” This information was later cited by Andrew (1990) to assess conservation issues of ornamental fishes. Cardinal tetras make up more than 80% of ornamental fishes exported from the State of Amazonas (Fig. 6). Its commercial extinction would destroy not only the local ornamental fish trade and economy, but also the social structure of riverine communities of the region. Fortunately, this has not happened (also see Prang in this volume).

Persistent economic turmoil in the region makes subsistence fishing even harder. Some have shifted to slash and burn agricultural to survive; others have moved to urban slums in Manaus. Can a managed fishery lessen the environmental and socio-economic burdens?

Brazil’s environmental and natural resource agency, IBAMA (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis), has regulated the ornamental fishery by permitting only 200 species for exportation (Chao, 1995/96). The agency also prohibits export of any food species as ornamentals, but grants permits to export catfish filets. IBAMA and Amazon Ornamental Fish Exporter Association (ACEPOAM) have tried to protect the cardinal tetra fishery by prohibiting fishing and trading during the spawning season (May to July). Although IBAMA has good intentions, the ambiguity of the regulations and the lack of enforcement have caused many irregularities.

The ornamental fishery of the Rio Negro is potentially threatened by large-scale aquaculture outside the region. Captive-bred neon tetras (*Paracheirodon innesi*) from Asia have already replaced wild-caught neon tetras from Colombia in the hobby trade. Hundreds of strains of highly prized discus (*Symphysodon* spp.) are bred in Asia, Europe, and North America, and even sold back to South American fish hobbyists and breeders. Captive-bred fishes are often healthier and more appealing to consumers than wild-caught specimens. Although aquarium enthusiasts around the world have obsessive demands for new fishes and forms, many countries have tightened their import restrictions on exotic wildlife, including fishes. Furthermore, accidental or intentional release of exotic fishes in non-native waters has caused significant damage worldwide. The ornamental fish industry and hobbyists must be organized to address these issues, or face more difficulty ahead.

Locally, improved techniques in fish care and handling would reduce captive mortality and thus pressure from over fishing. Some long-term remedies include broadening species diversity of the fishery, setting export ceilings for some species, and enhancing the natural stocks with on-site captive breeding programs. Establishing protocols on quarantine would make the ornamental fish trade more environmentally responsible.

Conservation of the Rio Negro ornamental fishery is not a simple ecological issue, nor can fishery scientists alone address it. A comprehensive conservation strategy requires collaboration among all sectors of industry and government. The ornamental fish industry links the subsistence of Amazonian fishers to hobbyists throughout the world. Public aquariums play a significant role in environmental education and conservation. We believe that the people involved in the industry and hobby could take active roles in the conservation of tropical fishes and their natural habitats.

ECOTOURISM

Ecotourism is often viewed as effective in promoting the conservation of biodiversity (endangered species) and habitats in developing countries. Bookbinder, et al. (1998) reported that ecotourism in Royal Chitwan National Park (Nepal), as currently structured, provides little employment potential, has a marginal effect on household income, and offers few benefits for local people. They also urged that conservation biologists press for legislation that permits a percentage of the profit to be spent on local community development.

Ecotourism in Barcelos is mainly based on few sport-fishing operators, and the Ornamental Fish Festival in January each year. These tour operations have provided modest seasonal employments and profit for local businesses. There are complaints that some fishing operators, and town officials wanted to leave large peacock-bass (*Cichla* species) for anglers by prohibiting locals fishing for food. The ornamental fish festival have brought thousands tourists from Amazon towns. The festival is very positive by involving over a thousand children to prepare dance competition between two rival groups during school holidays. The festival has also brought in alcoholic and sexual abuses upon minors. How to evaluate the economic benefits and the socio-cultural cost of the "ecotourism" is a big challenge for the community leaders.

ACKNOWLEDEMENTS

Local "prophets" always say "*Vai com Deus*" - go with God. To start and insist on a long-term research-conservation project in the Amazon is almost foolish. I often face challenges beyond my cultural, financial and intellectual comprehesion, but I have been blessed with supports of my family and friends. I thank my sister Polly Ching Chao, and Dr. Herbert and Mrs. Evelyne Axelrod, their generous donations to Bio-Amazonia Conservation International have kept the Project Piaba going for a decade. The Manaus based Associação de Criadores e Exportadores de Peixes Ornamentais do Amazonas (ACEPOAM) and Brazilian National Research Council (CNPq), have also provided additional scholarship and research funds to keep a public aquarium and programs in Barcelos running. Mr. John Dawes of the Ornamental Fish International has made constant efforts to promote Project Piaba worldwide. Otherwise, we were unable to establish genuine partnership with affluent public aquariums, pet industry or green organizations. However, simple folks like John Licoski, a retired US Navy Chief, David Less of the Boston Aquarium Society, Frank Magalan of Oregon Piranha & Exotic Fish Exhibit, plus two hundred tropical fish hobbyists and volunteers have helped us in the field studies, fund raising and managing the web site for the Project Piaba. Numerous colleagues, students and fishers have participated, contributed and benefited from the Project Piaba. I am most grateful to Greg Prang, Paulo Petry and Scott Dowd for their unconditional and persistent loyalty to the Project Piaba, and for the hard times that we have suffered together. I want to thank piabeiros and Barcelenses, especially to Mayor Valdeci Raposo e Silva (1992-96). Among fish exporters, Ascher Benzaken and Raimundo Ribeiro (Turkys Aqurium), Sebatião Periera Corrêia (Aquário Corydoras) and Jayro Bononi (Prestige Aquarium) have been most helpful to project piaba. Steve Spotte, University of Connecticut and Karsten Hartel, Harvard University reviewed drafts of this paper. I also thank the lessons that I have learned from those who had taken advantages of the project. Sure, I want to make a difference, but I still won't admit the price that I paid was too high for my long absence from my family. Local "prophets" will say "*Deus quem sabe*" - God knows.

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