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Community structure of fish in urban and natural streams in the Central Amazon

by

Cláudia P.D. Silva

M.Sc. Cláudia Pereira de Deus e Silva, Instituto Nacional de Pesquisas da Amazônia, Caixa Postal 478, 69011-970 Manaus/AM, Brasil.

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Abstract

A community of fish from the Quarenta stream were shown to have been affected by urban pollution (domestic drains and industrial effluents). The structure of the community, number of individuals, richness of species, index of diversity and the degree of stability were significantly different from those of the Candiru stream, which is still in a natural state. The low concentration of dissolved oxygen and the low diversity of habitats are the principal factors that are influencing the fish community of the Quarents stream.

Keywords: **Fish community, freshwater fish, environmental change, pollution.**

Resumo

A comunidade de peixes do igarapé do Quarenta tem sido afetada pela poluição urbana (esgotos domésticos e efluentes industriais). A estrutura da comunidade, número de indivíduos, riqueza de espécies, índice de diversidade e o grau de estabilidade foram significativamente diferentes daqueles do igarapé do Candirú, o qual ainda apresenta características naturais. A baixa concentração de oxigênio dissolvido e a baixa diversidade de habitats são os principais fatores que estão influenciando a comunidade de peixes do igarapé do Quarenta.

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Introduction

During the last few decades researchers have shown a growing interest in the effect of pollution on the environment (JONES 1964; WARREN 1971; HART & FULLER 1974). This fact results from the continuing increase in the level of pollution in certain parts of the world caused by an accelerated growth of the human population and increased industrial development. Rivers and streams are sometimes used as drains for untreated industrial effluents and domestic waste.

Biological communities reflect the conditions of the environment (KARR 1981). Various investigations of aquatic ecosystems have recorded alterations in the distribution and abundance of fish caused by domestic and industrial effluents (KATZ & GAUFIN 1953; TSAI 1973; OSBORNE et al. 1981; REASH & BERRA 1987).

In the Amazon, there are still few studies that address the problems of urban pollution. Earlier studies have investigated limnology (FITTKAU 1967; BRINKMAN & SANTOS 1973) and pollution in the main drainage basins of streams (BRINGEL 1986), without relating them with the local flora and fauna.

In this study, the fish communities of the two streams are compared. The Quarenta stream, located in the urban area of Manaus and subject to the emptying of urban and industrial effluents is compared to the Candirú stream, located in a natural forested area. The effects of environmental alterations on the fish community from the Quarenta stream were evaluated. The physico-chemical parameters were measured to compare the environments and identify the factors that influence the fish community.

Description of the study area

The Quarenta stream, and the Candirú stream (Fig. 1) are located above tertiary sediments of the Central Amazon, in the lower sedimentary plateau, the so called "Formação Barreira". There is a predominance of yellow distrophied latosoil (CHAUVEL 1981). Both are classified as 3rd order streams, based on HORTON'S hierarcheal system (apud. VANNOTE et al. 1980).

The Quarenta stream is situated within the city of Manaus. The study site is located at 3°7'S and 59°58'W. This stream is approximately 9 km long, with a mean width of 8 m and a mean depth of 70 cm (during the rainy season). There are three major types of microhabitats, namely: the banks of aquatic macrophytes (*Hymenachne amplexicaulis*); the clay bed and open water. This stream drains part of the industrial district of Manaus, receiving great quantities of industrial effluents daily. The water is clay coloured and contains elevated loads of suspended solids. In the dry season, the depth is about 20 cm. The margins, flooded during the rainy season, dry out almost completely and only a narrow channel remains.

The Candirú stream is 7 km long, with a mean width of 9 m and mean depth of 1.5 m. The study site is located at 2°45'S and 59°52'W. The marginal vegetation is typical of primary tropical forest. The water is clear but appears slightly brown during the rainy season due to the entry of humic substances. In some stretches, the canopy is more open and sunlight penetrates to the river bed. The increased light causes the development of banks of Cyperaceae and Eriocaulaceae macrophytes (which constitute two of the seven types of existing habitats). The other major habitat types are: shaded margins with the bottom covered by leaves; flooded marginal areas with Gramineae, with an average size of 20 cm; sandy bottom, submerged trunks and open water, in which the velocity of the current is 0.1 $m \cdot s^{-1}$.

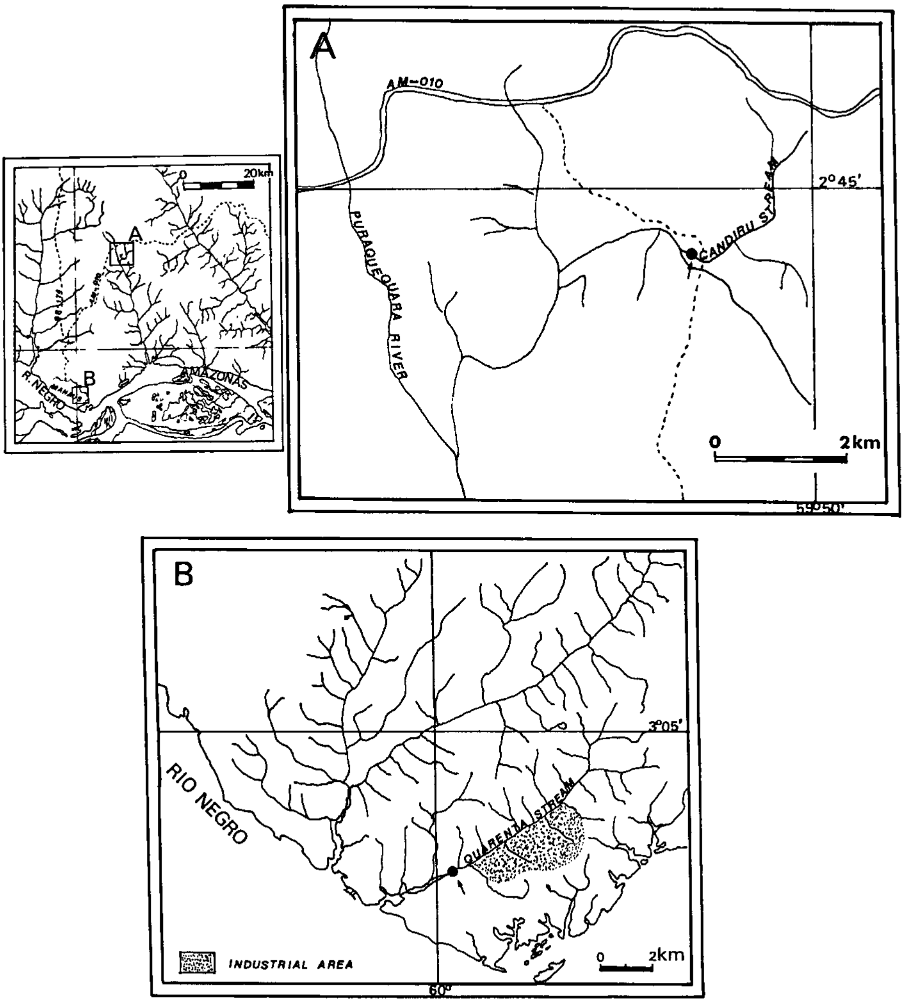

Fig. 1:
Map of study area showing the collection sites.

Material and methods

Seven collections were taken from each stream during 1990 and 1991. Four were made during the rainy season (December - May), three during the dry season (June - November). In December, during the rainy season of 1990, only water samples were taken from the Quarenta stream.

Collection and physico-chemical analysis of the water

Each collection and analysis of water was repeated whenever possible. Dissolved oxygen (O_2) and biological oxygen demand (BOD_5) were measured using WINKLER's method modified by GOLTERMAN & CLYMO (1971). The samples of BOD_5, taken from the Quarenta stream, underwent a period of aeration for 10 minutes before the incubation phase, due to the high speed of oxygen consumption (less than five days).

For the analysis of alkalinity (ALC), total suspended solids (TSS) and nitrogen compounds (NH^+_4, NO_2 and NO_3), samples were collected in polyethylene flasks, and taken to the laboratory in polystyrene boxes with ice. The alkalinity analysis were realized according to GOLTERMAN & CLYMO (1971. For TSS the methodology used was from APHA-AWWA-WPCF (1985) and NH^+_4, NO_2 and NO_3 were analyzed according to STRICKLAND & PARSON (1972).

Temperature and pH were measured *in situ* with a thermometer and a Schott-Mainz pH meter (model CG 718). To measure conductivity (COND), water samples were collected in polyethylene flasks and the measurements were taken immediately after arrival at the laboratory with a conductivity meter (WTW LF 191) with a temperature conversion to 20 °C.

Collection and selection of fish

A drag net and electrofishing gear were used as the principal methods for collection of fishes and a hand net was utilized as an auxiliary device. Based on earlier collections, it was observed that certain species could only be captured in certain types of habitats. Because of this it was decided to use all of the existing habitats in the area as sample units. Each habitat was combed twice or more depending on its extent. The catch was always made by three people. The minimum capture time was stipulated from a curve of capturability made previously for each stream. At Candirú this time was 60 minutes and at Quarenta 45 minutes.

The fish, after death, were fixed in a 10% formalin solution and subsequently preserved in 70% alcohol. Each individual was weighed and measured after being fixed.

Analysis of the data from the fish communities

The diversity index (H') was calculated for each collection using Shannon's equation:

$$H' = -\sum_{i=1}^{S} (n_i /n) \ln (n_i /n)$$

where S is the number of species in the sample and n is the total number of individuals of one species in one sample.

The number of individuals, number of species and Shannon's index from the two communities were compared testing the significance of the results with Student's test (t). Kendall's coefficient of concordance (W) was calculated for each place in relation to the number of individuals and its biomass (wet weight), to determine the persistence of the communities. This made it possible to test whether or not the composition of communities remained the same during a period of time. In the Candirú stream, there were ten most abundant species which were used in the calculation. In the Quarents, however, there were 7 most abundant species that were used in this test. The others species were of sporadic occurrence. This difference in the number of species did not invalidate the test, because calculations were done independently and in a separate manner, and based on number of most abundant species of the community. The calculation was based on SIEGEL (1975),

$$W = \frac{S}{\frac{1}{12}K^2(N^3 - N)}$$

where S is the total of the square deviations of the means of R_j. R_j is the total of the ranking values, in abundance increasing order, for each species in each month. K is the number of species observed, N is the number of months observed and 1/2 is a constant.

Results

Physico-chemical analysis of the water

The physico-chemical parameters varied in time and between the streams (Tab. 1). The concentration of dissolved oxygen in the Candirú stream was always high, whereas much lower values were observed in the Quarenta stream during the dry season (August - September) and the beginning of the rainy season (December) and the highest were observed in the months of highest precipitation. BOD_5 was constantly low in the Candirú stream; during most months consumption was lower than 1.5 $mgO_2 \cdot l^{-1}$. In the Quarenta stream O_2 consumption was rapid and always occurred during a few hours (Fig. 2), and the values from the table were always calculated from previously aired samples.

Temperature and the pH did not vary during the study. The values of these parameters were always higher in the Quarenta stream, however. The average concentration of TSS, in the Quarenta stream was 17 times higher than the concentration in Candirú.

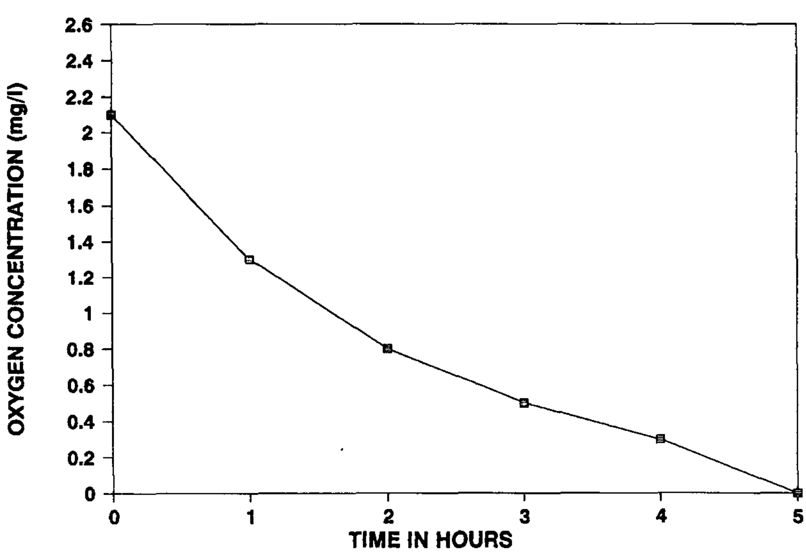

Fig. 2:
Oxygen concentration in Quarenta stream.

Table 1: Physical and chemical variables in seven samples (S) on Candirú and Quarenta streams. Values are means ± standard error.

STREAM	S	DO(mg/l)	TSS(mg/l)	T(°C)	pH	Cond(μS/cm)	BOD_5(mg/l)	ALC(mg/l)	NH_4^+(μg/l)	NO_3(μg/l)	NO_2(μ/l)
Candirú	MAR	6.3±0.09	ND*	25.5±0.07	5.0	8.9±2.47	0.4±0.40	ND*	ND*	ND*	ND*
	MAY	8.8±0.03	2.1±2.40	24.9±0.07	4.1±0.00	9.5±0.70	0.4±0.10	30.5±0.32	7.0±1.40	0	177.9±6.90
	JUL	9.5±0.04	1.1±0.98	24.5±0.14	5.7±0.07	6.0±0.00	0.3±0.10	15.7±0.10	ND	1.3±0.07	58.4±1.80
	SEP	10.4±0.05	1.8±0.70	25.0±0.07	5.1±0.07	6.2±0.21	1.2±0.10	19.8±4.03	77.0±2.80	0	29.8±0.90
	OCT	11.4±0.40	0.3±0.14	24.9±0.70	4.9±0.07	12.0±1.41	0.9±0.23	14.4±1.90	24.0±1.40	2.0±0.70	343.0±15.50
	DEC	11.9±0.05	3.2±0.36	25.0±0.07	4.9±0.07	6.3±0.70	0.8±0.15	13.2±0.07	14.0±2.80	2.0±0.50	339.0±16.90
	FEB	14.6±0.30	3.3±0.98	25.1±1.27	5.0±0.07	5.9±0.10	2.2±0.96	16.8±0.14	ND*	ND*	ND*
Quarenta	APR	7.2±0.10	32.0±4.20	28.2±0.03	6.0±0.03	56.5±0.70	11.6±0.30	44.65±0.12	1297.5±139	19.0±2.80	386.6±9.30
	MAY	5.3±0.10	52.0±8.40	27.0±0.14	6.0±0.00	65.5±0.03	7.2±0.12	61.6±2.40	974.5±3.50	10.2±1.80	460.6±0.80
	JUN	6.3±0.20	24.5±0.70	27.8±0.13	6.4±0.07	74.0±1.41	13.1±0.30	74.1±1.30	1158.0±60.80	6.3±2.40	52.1±1.50
	AUG	2.2±0.02	39.5±0.70	27.4±0.30	6.2±0.03	85.0±2.80	15.6±1.80	54.1±2.30	1225.0±31.10	0	0
	SEP	2.7±0.05	25.0±4.20	28.0±0.04	6.1±0.07	97.0±0.00	16.9±1.70	67.9±0.90	1220.3±14.20	0	2.1±0.10
	DEC	2.6±0.20	ND*	27.9±0.07	6.2±0.00	98.0±0.00	12.0±1.41	82.9±0.50	1443.0±3.21	54.0±5.90	36.9±3.40
	FEB	7.3±0.40	54.5±4.90	26.1±0.07	6.3±0.00	99.0±1.41	15.3±0.21	66.8±2.60	ND*	ND*	ND*

* Not determined

The conductivity of the Quarenta stream was always greater than that observed in Candirú and it gradually increased from April to February. Alkalinity was also higher in Quarenta stream with a peak in the month of December. Nitrogen compound concentrations in the Candirú stream were stable, and highest concentrations of nitrogen were in the form of nitrate (NH_3), nitrite (NO_2) and lower concentrations were in the form of ammonium (NH^+_4). In Quarenta stream the concentration of ammonium was always higher than 500 $\mu g \cdot l^{-1}$. In December it reached its highest concentration, which coincided with the period of low DO and the presence of dead fish in the area.

The fish communities

There were marked differences between the fish communities of Candirú and Quarenta streams. The number of individuals ($P < 0.05$), Shannon's index ($P < 0.05$) and the number of species ($P < 0.05$) were significantly higher in the Candirú stream (Fig.3). In the Candirú stream the number of individuals and the biomass were more stable over time (Tab. 2).

Table 2: Results of Kendall's Coefficient of Concordance (W). Total of the Square Deviations (S) and Probability (P).

	Number of individuals			Biomass		
Stream	W	S	P	W	S	P
Candirú	0.2888	808.5	<0.05	0.2484	695.4	<0.05
Quarenta	0.0257	20.0	*	0.1454	113.0	*

* Not determined

At Candirú, 3,735 individual fish belonging to 44 species, 34 genera and 17 families were collected (Tab. 3). The best represented order was the Characiformes (47.7 % of the total of species). Apart from having a certain tendency to capture more individuals during the rainy season, the number of individuals collected between the rainy and dry seasons was not significantly different ($P > 0.05$). Nine species (20.4 % of the total) were always present in the samples and "Piaba" (*Hyphessobrycon* sp.) was the most abundant species, representing 22.7 % of the total of individuals followed by "Piabinha" (*Hemigrammus* sp. 2) and "Cará" (*Aequidens pallidus*) representing 21.1 % and 17.9 % respectively.

In Quarenta stream 271 individuals belonging to 12 species, 12 genera and 8 families were captured (Tab. 4). The dominant order was Siluriformes (33.3 % of the total). There was no significant difference between the number of individuals in the rainy and dry seasons ($P > 0.05$). "Acará" (*Cichlasoma* sp.) and "Tamoatá" (*Hoplosternum littorale*) appeared in all of the collections. *H. littorale* was the most abundant species representing 65 % of all the individuals captured. All of the other species represented less than 15 % of the total. "Traíra" (*Hoplias malabaricus*), "Acará" (*Mesonauta insignis*) and "Muçum" (*Synbranchus marmoratus*) were collected in both streams.

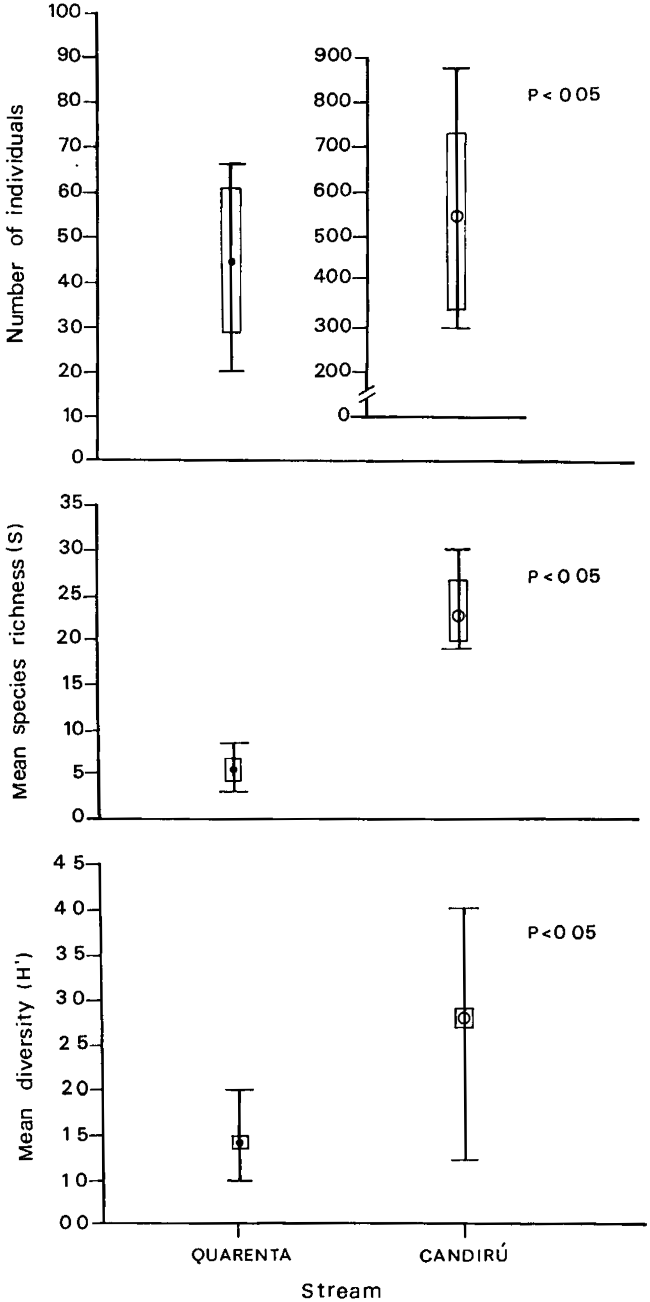

Fig. 3:
Mean, standard error and range of number of individuals (top), species richness (middle) and species diversity (Shannon Diversity - bottom) of fishes collected from Quarenta and Candirú stream.

Table 3: Fish species and total number of individuals caught in seven samples on Candirú stream. For each sample, the percentage of community contribution by species is given in parenthesis.

Species	MAR	MAY	JUL	SEP	OCT	DEC	FEB
Characidium pteroides	12(2.1)	19(2.2)	49(16.4)	43(13.6)	59(8.9)	49(10.7)	50(9.2)
Characidium fasciatum	7(1.2)		5(1.7)				4(0.7)
Ammocryptocharax sp.		3(0.3)	8(2.7)	6(2.0)	6(0.9)	2(0.4)	1(0.2)
Elachocharax sp.			1(0.3)				
Copella nattereri	16(2.8)		39(13.0)	4(1.3)	1(0.2)	1(0.2)	46(8.5)
Pyrrhulina laeta	2(0.3)		3(1.0)			1(0.2)	2(0.4)
Pyrrhulina brevis							3(0.6)
Nannostomus marginatus	5(0.9)	2(0.2)	9(3.0)	14(4.4)	22(3.3)	8(1.7)	12(2.2)
Crenuchus spilurus			14(4.7)	2(0.6)	1(0.2)		
Carnegiella strigata			18(6.0)		2(0.3)		1(0.2)
Gnathocharax steindachneri	10(1.7)		1(0.3)	2(0.6)			5(0.9)
Acestrorhynchus falcatus		2(0.2)					
Hyphessobrycon sp.	442(76.6)	27(3.1)	20(6.7)	74(23.4)	80(12.0)	174(38.0)	32(5.9)
Hemigrammus sp.1	1(0.2)						2(0.4)
Hemigrammus sp.2	28(4.8)	734(83.8)	12(4.0)	2(0.6)	1(0.2)		11(2.0)
Hemigrammus sp.3				49(15.5)	11(1.6)	1(0.2)	
Hemigrammus sp.4					1(0.2)	1(0.2)	
Iguanodectes geisleri	6(1.0)	3(0.3)	17(5.7)	46(14.6)	53(7.9)	24(5.2)	20(3.7)
Bryconops melanurus			2(0.7)				93(17.1)
Bryconops caudomaculatus		9(1.0)	2(0.7)			6(1.3)	
Hoplias malabaricus	1(0.2)	2(0.2)	2(0.7)		1(0.2)		1(0.2)
Aequidens pallidus	9(1.6)	12(1.4)	19(6.3)	42(13.3)	355(53.3)	129(28.1)	103(19.0)
Apistogramma sp.	2(0.3)		1(0.3)				1(0.2)
Apistogramma regani	1(0.2)	1(0.1)	14(4.7)	8(2.5)	12(1.8)	3(0.7)	14(2.6)
Apistogramma agassizi	1(0.2)		4(1.3)	1(0.3)		1(0.2)	
Crenicichla johanna					1(0.2)		
Crenicichla saxatilis		3(0.3)		1(0.3)		1(0.2)	2(0.4)
Mesonauta insignis				1(0.3)			
Hypselecara coryphaenoides					1(0.2)	2(0.4)	38(6.9)
Monocirrhus poliachantus		1(0.1)		1(0.3)			
Farlowella sp.	13(2.3)	23(2.6)	20(6.7)	5(1.6)	21(3.1)	24(5.2)	21(3.9)
Rineloricaria sp.	5(0.9)	12(1.4)	16(5.4)	6(2.0)	17(2.6)	24(5.2)	12(2.2)
Ancistrus sp.1	2(0.3)	2(0.2)	2(0.7)	2(0.6)	11(1.6)	3(0.7)	6(1.1)
Callichtys sp.			1(0.3)				
Brachyglanis sp.		1(0.1)		1(0.3)			
Rhamphichthys marmoratus		2(0.2)	1(0.3)	1(0.3)			
Gymnotus sp.		1(0.1)	1(0.3)				1(0.2)
Hypopygus lepiturus		1(0.1)	3(1.0)	1(0.3)	1(0.2)		1(0.2)
Steatogenys duidae		6(0.7)	2(0.7)		2(0.3)		1(0.2)

Table 3: Continuation

Species	MAR	MAY	JUL	SEP	OCT	DEC	FEB
Eigenmannia virensis							5(0.9)
Rivulus urophthalmus	14(2.4)	4(0.5)	8(2.7)				21(3.9)
Rivulus ornatus		6(0.7)		3(0.9)	2(0.3)	5(1.1)	16(2.9)
Synbranchus marmoratus			5(1.7)		4(0.6)		18(3.3)
Belonidae				1(0.3)			
No. of species	19	23	30	24	23	19	30
No of individuals	577	876	299	316	665	459	543

Table 4: Fish species and total number of individuals caught in six collections on Quarenta stream. For collection, the percentage of community contribution by species is given in parenthesis.

Species	APR	MAY	JUN	AUG	SEP	FEB
Ctenobrycon hauxelianus	6(13.0)	19(34.5)	3(4.5)			
Astyanax sp.		2(3.6)				
Cichlasoma sp.	1(2.2)	5(9.1)	13(19.7	12(22.6)	2(10.0)	4(12.9)
Mesonauta insignis				1(1.9)		
Crenicichla sp.	1(2.2)					
Hoplias malabaricus	1(2.2)	1(1.8)	1(1.5)			
Hoplosternum littorale	37(80.4)	24(43.6)	46(69.7)	34(64.2)	14(70.0)	121(67.7)
Cataphractops sp.		1(1.8)		1(1.9)		4(12.9)
Ancistrus sp.2				1(1.9)		
Gymnotus carapo		1(1.8)	2(3.0)	3(5.7)		
Synbranchus marmoratus		2(3.6)	1(1.5)		4(20.0)	2(6.5)
Poeciliidae				1(1.9)		
Total no. species	5	8	6	7	3	4
Total no. individuals	46	55	66	53	20	31

In Candirú, some species were collected in only one of the seven habitats (Tab. 5). In Quarenta, with only three types of habitats, most of the species were captured in more than one of them (Tab. 6).

Table 5: Presence of fish species in habitats in the Candirú stream.
1 = bank of Cyperaceae; 2 = sandy bottom; 3 = open water; 4 = flooded marginal area;
5 = shaded bank with bottom with leaves; 6 = bank of Eriocaulaceae; 7 = submerged trunk.

Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Characidium pteroides		+					
Characidium fasciatum		+					
Ammocryptocharax sp.	+				+		
Copella nattereri				+			
Pyrrhulina laeta				+			
Pyrrhulina brevis				+			
Nannostomus marginatus				+			
Crenuchus spilurus				+			
Carnegiella strigata			+	+			
Gnathocharax steindachneri			+	+			
Acestrorhynchus falcatus			+				
Hyphessobrycon sp.			+				
Hemigrammus sp.1			+				
Hemigrammus sp.2			+				
Hemigrammus sp.3			+				
Hemigrammus sp.4			+				
Iguanodectes geisleri			+				
Bryconops melanurus			+				
Bryconops caudomaculatus			+				
Hoplias malabaricus					+		
Aequidens pallidus			+!	+*			
Apistogramma sp.			+	+			
Apistogramma regani				+		+	
Apistogramma agassizi			+	+			
Crenicichla johana					+		
Crenicichla saxatilis				+	+		
Mesonauta insignis				+			
Hypselecara coryphaenoides					+		
Monocirrhus poliachantus					+		
Farlowella sp.	+						
Rineloricaria sp.	+						
Ancistrus sp.1	+						+
Callichthys sp.				+			
Brachiglanys sp.				+			
Ramphichthys marmoratus	+					+	
Gymnotus sp.						+	

* Young individual
! Adult individual

Table 5: Continuation

Species	1	2	3	4	5	6	7
Hypopygus lepiturus	+					+	
Steatogenys duidae	+					+	
Eigenmannia virensis	+		+				
Rivulus urophthalmus				+			
Rivulus ornatus				+			
Synbranchus marmoratus				+*		+!	
Belonidae			+				

* Young individual
! Adult individual

Table 6: Presence of fish species in habitats in the Quarenta stream.
1 = open water; 2 = bank of aquatic macrophytes; 3 = clay bed.

Species	1	2	3
Ctenobrycon hauxellianus	+		+
Astyanax sp.	+		+
Hoplias malabaricus	+		+
Cichlasoma sp.	+		+
Mesonauta insignis	+		+
Crenicichla sp.	+		
Ancistrus sp.2			+
Hoplosternum littorale		+	+
Cataphractops sp.		+	+
Gymnotus carapo		+	+
Synbranchus marmoratus		+	
Poeciliidae	+		

Discussion

Urban pollution and habitat degradation have affected fishes in Quarenta stream. Compared to Candirú stream, community structure, species richness and diversity, and persistence indicate that the community of Quarenta stream is under stress. The low concentration of oxygen is probably one of the principal factors influencing this community. However, a number of environmental alterations is present in the Quarenta stream. The removal of trees on the banks of the stream causes an increase in the sediment load (as measures by TSS), a consequent reduction in the depth and a physical alteration in the hydrology of canal. The removal of riparian vegetation also brings about an increase in water temperature. In addition to these alterations, SILVA (1992) found contamination by heavy metals (principally copper and zinc) in this stream. The same author suspected the presence of mercury as well since this metal is used as a catalizer in the manufacture of plastics. In spite of the fact that the concentrations of these heavy metals were not presented here, it is possible to state that these alterations can result in the elimination of the more sensitive species and the proliferation of exotic ones.

In Candirú, the community is composed mostly of Characiformes which is in accordance with patterns observed by other authors that have worked in natural streams in the Amazon region (KNÖPPEL 1970; SAUL 1975; SOARES 1979) and in the West-Central region of Brazil (VIANA 1989). Community structure in Quarenta was dominated by Siluriformes, and this differs from the general pattern observed in this region. Species of this order (*H. littorale, S. marmoratus, Gymnotus carapo* and *Ancistrus* sp.), possess accessory organs for air breathing (KRAMER et al. 1978) which allows them to survive in hypoxic conditions. Species of the Characidae, Poeciliidae and Cichlidae families have so far been studied, even though they are commonly captured in areas with oxygen deficiencies. LOWE-McCONNELL (1969) observed that the stomachs of "jacundá" (*Crenicichla* sp.) and "acará" (*Cichlasoma bimaculatum*) have well developed vascularization in the walls, and this type of stomach could serve as an accessory respiratory organ.

Poeciliids, in general, are also captured in inhospitable environments (ROSEN & BAILEY 1963). *H. littorale*, the dominant species in the Quarenta stream, was not observed in the Candirú nor in other natural streams of the Amazon, except in floodplains of the Solimões River. Its distribution may be restricted to water with high sediment loads (Jan H.A. MOL, pers. commun.). Because Quarenta stream has degraded conditions, it may permit colonization by *H. littorale*. The abundance of food, available habitat, absence of competing species, and accessory air breathing (part of the stomach is adapted as an air breathing accessory) are favourable to successful colonization of the system. In Candirú, nine species were dominant, which may reflect greater community stability or at least a more uniform distribution of individuals between the species.

Many of the species collected in the Candirú stream are also common in other undisturbed streams, or in other words, those that have not yet suffered anthropogenic impacts. Dissolved oxygen is one of the main physico-chemical parameters that influence species abundance and distribution. In Quarenta, oxygen consumption is high. There is a large quantity of organic material deriving from residential waste, industrial effluent and decomposition of aquatic macrophytes. Because of this, the oxygen concentration is constantly low and only species adapted to hypoxic conditions survive.

The richness of species and Shannon's diversity for Candirú stream contrast with values for Quarenta stream. The large number of species at Candirú is typical of tropical streams (LOWE-McCONNELL 1964; FITTKAU 1967; ANGEMEIER & KARR 1984; GARUTTI 1988; HENDERSON & WALKER 1986, 1990). The small number of species encountered in Quarenta, apart from the physico-chemical conditions, may be due to low habitat diversity. Increases in diversity of habitat are often proportional to increases in animal diversity (GORMAN & KARR 1978; HORWITZ 1978). In Quarenta, the habitat diversity is low due to the lack of riparian vegetation, which causes an increase in the sediment load, and a consequent reduction in depth (vanishing pools), leveling of the bed (vanishing riffles) and increasing water temperature.

The stability observed in the Candirú community suggests that it may be regulated by deterministic factors (biological interactions) (GROSSMAN et al. 1982). The annual regime of rainy and dry seasons in this region is cyclic, and predicted so that fish populations probably can respond to environmental variation in a density-dependent manner. ROSS et al. (1985) stated that stability can also occur through the resistance of the community, or, its ability to withstand environmental changes. In Quarenta, apart from dealing with the annual cycle of rainy and dry seasons, the greatest pressure on the community comes from the unpredictable physico-chemical conditions created by pollution. Studies that examine persistence in the fish communities should be performed over a relatively long period of time, covering more than one generation of the species (GROSSMAN et al. 1982; MOYLE & VANDRACEK 1985). The amount of time that Quarenta stream has been polluted is quite relative to the observation time of this study, so it is difficult to affirm that the community has been destabilized.

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References

ANGERMEIER, P.L. & J.R. KARR (1984): Fish communities along environmental gradients in a system of tropical streams. - In: ZARET, Z.M. (ed.). Evolutionary ecology of neotropical freshwater fishes: 39-58. W. Junk Publ., The Hague.

APHA-AWWA-WPCF (1975): Standard Methods for the Examination of Water and Wastewater. - Washington DC: 1268 pp.

BRINGEL, S.R.B. (1986): Estudos do nível de poluição nos igarapés do Quarenta e do Parque Dez de Novembro. Relatório Técnico. - Instituto de Tecnologia da Amazonia - UTAM.

BRINKMAN, W.L.F. & A. SANTOS (1973): Natural water in Amazonia. VL. Soluble calcium properties. - Acta Amazonica 3(3): 33-40.

CHAUVEL, A. (1981): Contribuição para o estudo da evolução dos latossolos amarelos, distróficos, argilosos na borda do platô, na região de Manaus: mecanismos de gibbsitização. - Acta Amazonica 11(2): 227-245.

FITTKAU, E.J. (1967): On the ecology of Amazonian rain-forest streams. - Atas do Simpósio Sobre a Biota Amazonica 3: 97-108.

GARUTTI, V. (1988): Distribuição longitudinal da ictiofauna em um córrego da região noroeste do estado de São Paulo, bacia do rio Paraná. - Rev. Brasil. Biol. 48(4): 747-759.

GOLTERMAN, H.C. & R.S. CLYMO (1971): Methods of Chemical analysis of freshwater. - IBP Handbook No 8. Blackwell, Scientific Publications, Oxford: 172 pp.
GORMAN, O.T. & J.R. KARR (1978): Habitat structure and stream fish communities. - Ecology **59**: 507-515.
GROSSMAN, G.D., MOYLE, P.B. & O. WHITAKER, Jr. (1982): Stochasticity in structural and functional characteristics of an Indiana stream fish assemblage: a test of community theory. - Am. Nat. **120**: 423-454.
HART, C. & L.H. FULLER (1974): Pollution ecology of freshwater invertebrates. - New York, Academic Press: 389 pp.
HENDERSON, P.A. & I. WALKER (1986): On the leaf litter community of the Amazonian blackwater stream Tarumãzinho. - Journal of Tropical Ecology **2**: 1-17.
HENDERSON, P.A. & I. WALKER (1990): Spatial organization and population density of the fish community of the litter banks within a central Amazonian blackwater stream. - Journal of Fish Biology **37**: 401-411.
HORWITZ, R.J. (1978): Temporal variability patterns and distributional patterns of stream fishes. - Ecol. Monogr. **48**: 307-321.
JONES, J.R.E. (1964): Fish and River Pollution. - London, Butterworths: 203 pp.
KARR, J. (1981): Assessment of biotic integrity using fish communities. - Fisheries **6**: 21-27.
KATZ, M. & A.R. GAUFIN (1953): The effects of sewage pollution on the fish population of a midwestern stream. - Trans. Am. Fish. Soc. **82**: 156-165.
KNÖPPEL, H.A. (1970): Food of Central Amazonian fishes. Contribution on the nutrient ecology of Amazonian rain-forest streams. - Amazoniana **2**(3): 257-353.
KRAMER, D.L., LINDSEY, C.C., MOODIE, E.E. & E.D. STEVENS (1978): The fish and the aquatic environment of Central Amazon basin, with particular reference to respiratory patterns. - Can. J. Zool. **56**(4): 717-729.
LOWE-McCONNELL, R.H. (1964): The fishes of the Rupununi savana district of British Guiana, Pt 1. Grouping of fishes species and effects of the seasonal cycle on the fish. - Journal of Linnean Society (Zoology) **45**: 103-144.
LOWE-McCONNELL, R.H. (1969): The cichlid fishes of Guyana, S. America, with notes on their ecology and breeding behavior. - Zoological Journal of the Linnean Society **48**: 225-302.
MOYLE, P.B. & B. VANDRACEK (1985): Persistence and structure of the fish assemblage in a small California stream. - Ecology **66**: 1-1-13.
OSBORNE, L.L., IREDALE, D.R., WRONA, F.J. & R.W. DAVIES (1981): Effects of chlorinated sewage effluents on fish in the Sheep River, Alberta. - Trans. Am. Fish Soc. **110**: 536-540.
REASH, R.J. & T.M. BERRA (1987): Comparison of fish communities in a clean-water stream and an adjacent polluted stream. - Am. Midl. Nat. **118**(2): 301-322.
ROSEN, D.E. & R.M. BAILEY (1963): The Poeciliid fishes (Cyprinodontiformes), their structure, zoogeography and systematics. - Bull. Am. Mus. Nat. Hist. **126**(1): 1-176.
ROSS, S.T., MATHEUS, W.J. & A.A. ECHELE (1985): Persistence of stream fish assemblage: effects of environmental changes. - Am. Nat. **126**: 24-40.
SAUL, W.G. (1975): An ecological study of fishes at a site in upper Amazonian Equador. - Proceedings of Academy of Natural Sciences of Philadelphia **127**(12): 93-134.
SIEGEL, S. (1975): Estatística Não-paramétrica. - McGraw Hill, São Paulo: 350 p.
SILVA, C.P.D. (1992): Influência das modificações ambientais sobre a comunidade de peixes de um igarapé da cidade de Manaus (Amazonas). - MSc-thesis, INPA/FUA, Manaus, Brasil: 112 p.
SOARES, M.G.M. (1979): Aspectos ecológicos (alimentação e reprodução) dos peixes do igarapé do Porto, Aripuanã, MT. - Acta Amazonica **9**(2): 325-352.
STRICKLAND, J.D.H. & T.R. PARSONS (1972): A Pratical Handbook of Seawater Analysis. - Fish. Res. Board Can. Bull. **167**: 1-130.
TSAI, C. (1973): Water quality and fish life below sewage outfalls. - Trans. Am. Fish. Soc. **102**: 281-292.

VANNOTE, R.L., MINSHALL, G.W., SEDELL, J.R. & C.E. CUSHING (1980): The river continum concept. - Can. J. Fish. Aquat. Sci. 37: 130-137.
VIANA, J.P. (1989): Estrutura de Comunidades dos Peixes do Ribeirão Sant'Ana (Brasília - DF) ao Longo de Gradientes Ambientais. - MSc-thesis, Universidade de Brasília, Brasil: 115 p.
WARREN, C.E. (1971): Biology and water pollution control. - Philadelphia, W.B. Saunders: 434 pp.