INFLUENCE OF THE SETTING UP OF A MAN-MADE LAKE ON MERCURY LEVELS IN THE FLESH OF FISH IN A NEOTROPICAL HABITAT: THE SINNAMARY RIVER (FRENCH GUIANA)

Sandrine RICHARD[1], André ARNOUX[2], Philippe CERDAN[1], Cécile REYNOUARD[1], Véronique HOREAU[1] & Régis VIGOUROUX[1]

RÉSUMÉ

La mise en eau du barrage hydroélectrique de Petit Saut en Guyane française en janvier 1994 a entraîné des modifications de la qualité de l'eau au sein du réservoir et dans la partie aval. La stratification thermique des eaux de la retenue a pour conséquence la mise en place rapide d'un épilimnion oxygéné et d'un hypolimnion anoxique. Par ailleurs, depuis 1870, les activités minières liées à l'or sont responsables de rejets de mercure métallique dans le milieu guyanais où il s'accumule dans la chaîne alimentaire. Afin d'étudier les conséquences de la mise en eau du barrage de Petit Saut, le mercure total a été analysé dans la chair des poissons du bassin versant du fleuve Sinnamary. L'étude de 1690 individus prélevés entre 1993 et 1998 montre que les concentrations en mercure augmentent progressivement au fil du temps, l'essentiel des modifications se situant dans la zone aval de la retenue depuis la mise en eau. L'évacuation d'eaux hypolimniques semble influencer le devenir du métal dans la chaîne alimentaire. Les herbivores ne présentent pas d'évolution au fil du temps, les concentrations restant très faibles. Chez les omnivores et les carnivores, l'augmentation des concentrations est observée essentiellement au niveau du tronçon aval. Trois espèces représentatives du groupe des herbivores (*Myleus ternetzi*), des omnivores (*Leporinus friderici*) et des carnivores (*Hoplias aimara*) ont été étudiées plus particulièrement. Au niveau de la retenue, aucune augmentation significative n'est visible, mais on pourrait assister à une homogénéisation progressive de la masse d'eau, entraînant, au travers des chaînes trophiques, une pollution des poissons de la zone épilimnique.

SUMMARY

The filling of the hydroelectric dam reservoir at Petit Saut (French Guiana) in January 1994 brought about changes in the water quality in the reservoir and downstream. The thermal stratification of the waters of the reservoir has resulted in the rapid establishment of an oxygenated epilimnion and an anoxic hypolimnion. Moreover, since 1870, activities linked to gold mining are responsible for the rejection of metallic mercury into the Guianese environment where it accumulates in the food chain. In order to study the consequences of the filling of the dam reservoir at Petit Saut, the total level of mercury in the flesh of the fish in the catchment basin of the Sinnamary River was analyzed on 1,690 fish specimens sampled

[1] Laboratoire Environnement, HYDRECO, BP 823, 97388 Kourou Cedex (France), E-mail: Hydreco-labops@wanadoo.fr

[2] Laboratoire d'hydrologie et de molysmologie, Faculté de Pharmacie, 13385 Marseille Cedex (France).

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between 1993 and 1998. This study showed that mercury concentrations increase progressively over time, with most of the changes since the filling of the reservoir occurring downstream. The evacuation of the hypolimnic waters seems to influence what becomes of the metal in the food chain. Mercury concentrations in the herbivorous fish did not evolve over time, and remained very low. Among the omnivorous and carnivorous species, an increase in the concentrations was essentially observed in fish sampled downstream. Three fish species representing herbivorous (*Myleus ternetzi*), omnivorous (*Leporinus friderici*), and carnivorous (*Hoplias aimara*) species were studied in particular. No significant increase was visible in the reservoir itself, but one could observe the progressive homogenization of the mass of water that triggers, through the trophic chain, the polluting of fish in the epilimnic zone.

INTRODUCTION

Numerous studies have shown that mercury pollution in the Brazilian Amazon is particularly linked to gold-mining activities (Lacerda, 1985, 1992; Lacerda *et al.*, 1991a; Pfeiffer & Lacerda, 1988; Fernandes *et al.*, 1989; Pfeiffer *et al.*, 1989; Malm *et al.*, 1990; Aula *et al.*, 1992; Nriagu *et al.*, 1992; Akagi, 1995; Lacerda & Salomons, 1998), as metallic mercury is used to amalgamate the fine gold particles. However, this direct source of mercury is not the only one, as recent studies have shown the extent to which the erosion of soils naturally rich in mercury also plays a role. The increase in the amount of fine particles in the water influences the Hg content (Roulet *et al.*, 1998a & b). The mercury, which is deposited on the soil, vegetation, then on the sedimentary bottoms of rivers, is transformed into organic mercury through bacterial action. It is found later in the food chain where it can reach elevated concentrations in the different parts of the biosphere, notably in fish (Jackson, 1986; Lacerda & Salomons, 1998).

High mercury concentrations in fish from the recently-filled reservoirs of hydroelectric dams have been observed in Canada (Bodaly *et al.*, 1984; Boucher *et al.*, 1985; Hecky *et al.*, 1987; Jackson 1986, 1988 a & b), the United States (Babiarz & Andren, 1995; Driscoll *et al.*, 1998), Finland (Lodenius *et al.*, 1983; Porvari & Verta, 1995) and Brazil (Aula *et al.*, 1992).

In French Guiana, gold extraction has been in practice since 1854 (Huygues-Belrose & Bruleaux, 1988) at numerous localities around the Sinnamary River where a hydroelectric dam reservoir was filled at the beginning of 1994. Since 1857, if one refers both to declared gold production and to estimations of clandestine production, 175 tons of gold have been extracted (Huygues-Belrose & Bruleaux, 1988; Petot, 1993). The Regional Bureau for Industry, Research and Environment, or DRIRE (Direction Régionale à l'Industrie, la Recherche et l'Environnement), estimates that 200 to 300 tons of mercury have been disseminated into the Guianan environment (DRIRE, pers. comm.). This situation corresponds to the totality of the mercury used since the beginning of gold-mining activities, as no recycling was practiced in French Guiana. Starting a few years ago, the amount of mercury released into the environment has decreased. It is recuperated through distillation and re-used. The study of mercury levels in the different abiotic and biotic components of the waterways in French Guiana began in 1990. The survey, originally limited to the catchment basin of the Sinnamary River (Richard, 1996, 1997; Richard *et al.*, 1997), and expanded later to other Guianan rivers, has been conducted on numerous soil, sedimentary, and especially fish samples (Richard *et al.*, 2000), and has permitted the detection of elevated concentrations of mercury in some fish species, especially carnivores (up to 1.94 $\mu g\ g^{-1}$, fresh weight).

The creation of the Petit Saut reservoir has brought about numerous hydrochemical and hydrobiological changes, most notably by modifying the nutriment cycle (Richard, 1996), and primary (Vaquer *et al.*, 1997), and secondary production (Mérona, 1997; Horeau, 1996; Horeau *et al.*, 1997; 1998). From the beginning of the filling phase (January 1994), the lake became stratified with the formation of an oxygenated epilimnion measuring seven meters in 1998. The rest of the water column is characterized by the complete absence of dissolved oxygen. Temperature profiles show that the stratification is stable all year long (Richard, 1996; Richard *et al.*, 1997).

Downstream from the dam, the waters flow from the anoxic part of the reservoir. In order to maintain a concentration in dissolved oxygen compatible with aquatic life, an aeration system was set up in the outflow of the turbines. This system triggers the saturation of the waters in dissolved oxygen. Nonetheless, a residual reducing agent is apparent in the progressive consumption of dissolved oxygen whose minimum is reached between Pointe Combi and the town of Sinnamary (Galy-Lacaux, 1996; Galy-Lacaux *et al.*, 1997; Gosse, 1994; Gosse & Grégoire, 1997; Richard *et al.*, 1999). Because of their position at the end of the food chain, fishes are probably the best indicators of a possible change in the level of mercury contamination through bio-accumulation. Since the dam reservoir at Petit Saut was filled, fishes have been sampled from upstream, the reservoir itself, and downstream. The objective of this study is two-fold. The first objective is to determine the mercury concentrations in fish flesh in the catchment basin of the Sinnamary River in order to define the risk linked to the consumption of fishes originating from the reservoir and from downstream. The second objective is to determine what influence the filling of the dam reservoir has had on mercury concentrations in fish flesh (Porvari & Verta, 1995).

MATERIALS AND METHODS

STUDY STATIONS

In French Guiana, the bedrock is made up of a Pre-Cambrian insular shelf; two-thirds of the surface are occupied by granites and migmatites. Schists, green rocks (amphibolites, lava, dolerites, etc.) and detritic continental sands are also present. No rock containing the minerals of mercury, such as cinnabar, has been found in French Guiana (*Bureau de recherches géologiques et minières* [BRGM], pers. comm.).

The dam at Petit Saut was built on the Sinnamary River by the *Centre National d'Equipement Hydraulique (CNEH) d'Electricité de France*; its principal characteristics are presented in table I (Sissakian, 1997; Huynh *et al.*, 1997). The river runs through the equatorial forest from the centre of French Guiana towards the north where it spills into the Atlantic Ocean (Fig. 1). Its average flow is 267 $m^3\ s^{-1}$. The source of the Sinnamary River is situated at 150 m in altitude and 250 km from the estuary. Overall, the slope is 0.5 m per km. The filling of the dam reservoir began in January 1994 and took 18 months.

TABLE I

General characteristics of the reservoir at Petit Saut.

Size of the catchment basin	5927 km^2
Mean annual flow of the river	267 m^3 s^{-1}
Minimum flow	80 m^3 s^{-1}
Dam closed	January 1994
Date, end of the filling phase	June 1995
Maximal depth	35 m
Minimal depth**	31 m
Reservoir surface area at 35 m*	365 km^2
Reservoir surface area at 31 m*	223 km^2
Total island surface area at 35 m**	105 km^2
Tidal range surface*	142 km^2
Maximum length	60 km
Maximum width	60 km
Maximum depth	35 m
Mean depth	10 m
Residence time	6 months
Total volume	$3{,}5.10^9$ m^3
Install capacity	116 MW (4 turbines of 29MW)

** Theoretical value, as from January to April 1998, the level fell below this benchmark.
* Estimations by the remote detection laboratory (IRD Cayenne) (HUYNH *et al.*, 1997).

Since 1991, fishes were sampled throughout the catchment basin in the three principal zones: the zone situated upstream from the reservoir (from Saut Maïpouri to Saut Takari Tanté), the reservoir itself (from Saut Takari Tanté to Petit Saut), and the zone downstream from the reservoir (Fig. 1).

FISH SAMPLING AND MERCURY ANALYSIS

Fishes were captured using gill nets (mesh width of 50 to 70 mm, 25 m in length and 2 m in depth), set lines being also used. Both were checked morning and evening. The captured fishes were identified (Le Bail *et al.*, 1984a, b & c; Planquette *et al.*, 1996; Rojas-Beltran, 1984), measured (length and weight) and freezed for conservation. Their age was not determined as techniques designed to determine the age of tropical fish species are not yet available (Meunier *et al.*, 1994).

A flesh sample (approximately 100 g) was freeze-dried. The ratio fresh/dry weight was determined. After crushing and homogenization, mineralization was conducted on a one-gram trial sample with 10 ml of nitric acid (d = 1.40) at 150 °C for two hours in a Teflon® bomb placed in a stainless steel case. The product of the mineralization was then mixed with highly pure de-ionized water to 100 ml. The dosage was made through atomic absorption using the cold vapors method: after the permanganic oxidation of the trial sample and the elimination of the excess oxidant using hydroxylamine chlorhydrate, Hg^{2+} was reduced to Hg^0 through stannous chloride and transported by an air current into the cell of a Perkin-Elmer mercury analyzer. Standardization was conducted under identical conditions from

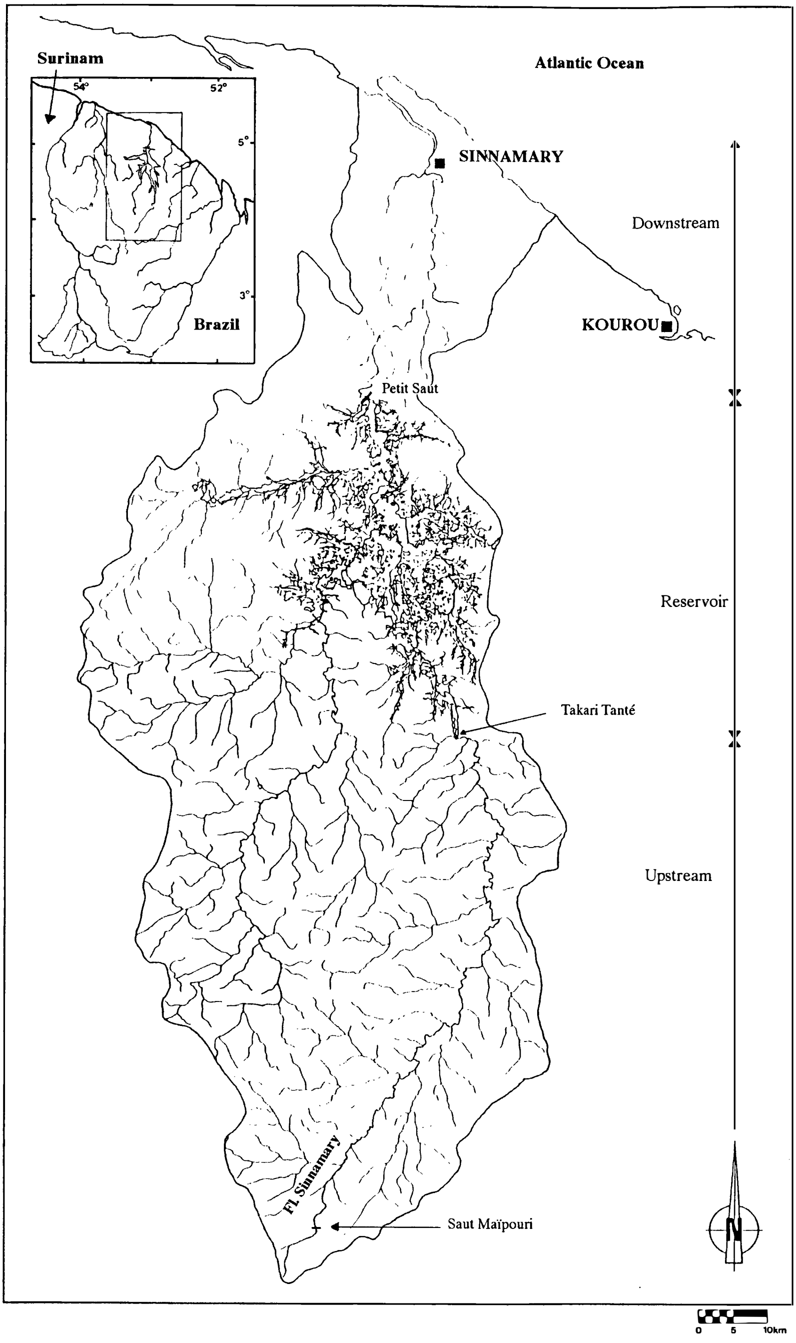

Figure 1. — Location of study stations.

successive dilutions of a stock solution of mercurial nitrate at 1 g l^{-1}. Mercury concentrations in the fish were expressed as µg Hg total g^{-1} (fresh weight). The limit for detection was 0.001 µg g^{-1}.

European standards concerning the limits of mercury concentrations in fish flesh intended for consumption are established at 0.5 µg g^{-1} for non-carnivorous fishes (omnivorous and herbivorous) and at 1.0 µg g^{-1} for carnivorous ones; the World Health Organization (WHO) has set the limit at 0.5 µg g^{-1} (fresh weight). However, studies conducted on the stomach contents of fishes originating from the neotropical region (Marlier, 1968; Knöppel, 1970; Saul, 1975; Ferreira, 1984; Boujard *et al.*, 1990, 1991), especially from French Guiana (Lecomte *et al.*, 1993; Rojas-Beltran, 1989; Horeau *et al.*, 1996, 1998), suggest the need to distinguish three fish groups: carnivorous, herbivorous and omnivorous (Richard *et al.*, 2000).

Analyses of variance (ANOVA) (Scherrer, 1984) with 3 factors of variability (year, zone and diet) were conducted to test the effects of these factors and their possible interactions. Statistical analyses were carried out using Systat® 9.0 for Windows.

RESULTS

SPECIES CAPTURED

The fish species analyzed, the number of individuals and their diets are indicated in table II. The present results correspond to the 1,690 analyses conducted between 1993 and 1998. Of these, 889 fishes were carnivorous, the rest including 432 herbivores and 369 omnivores. Several species were particularly well represented, *Leporinus friderici*, *Hoplias aimara*, *Myleus ternetzi* and *M. rhomboïdalis* representing 79 % of the sample.

MEAN CONCENTRATIONS PER YEAR AND GROUP

Total sample

We calculated the mean concentrations, in µg g^{-1} with regard to the fresh weight, from 1993 to 1998 per year and for the three fish groups (Figs. 2 and 3). The minimal concentrations are equal or close to the limit of detection and the maximal concentrations reached 1.94 µg g^{-1} (*Acestrorhyncus falcatus*, upstream zone, 1996; mean concentration = 0.79; SE = 0.38; range: 0.07-1.94; n = 79). Mercury concentrations significantly increased since the beginning of the filling phase and their was a significant effect of diet and zone (ANOVA, Table III).

Herbivores

Figure 2 describes variations in the concentrations over time for the entirety of the catchment basin. Few variations have been observed since 1993. The mean concentrations are less than 0.064 µg g^{-1}. The maximal concentration of 0.18 µg g^{-1} was observed in a *M. rhomboïdalis* specimen captured in 1998 and weighing 2 000 g. In the species *M. rhomboïdalis*, the mean concentrations are

TABLE II

Fish species, number of specimens (N) captured and diet (C: carnivorous, O: omnivorous, H: herbivorous).

Order	Family	Sub-family	*Species*	N	Diet*
Clupeiformes	Clupeidae		*Opisthonema oglinum*	20	O
			Pellona flavipinnis	8	O
	Engraulidae		*Pterengraulis antherinoides*	1	O
Cypriniformes	Anostomidae		*Leporinus fasciatus*	14	O
			Leporinus friderici	216	O
	Characidae	Bryconidae	*Triportheus rotundatus*	77	O
		Characinae	*Acestrorhyncus falcatus*	79	C
			Acestrorhyncus microlepis	5	C
		Stethagonopterinae	*Poptella orbicularis*	1	O
	Curimatidae		*Curimata cyprinoides*	17	O
	Erythrinidae		*Hoplerythrinus unitaeniatus*	2	C
			Hoplias aimara	691	C
			Hoplias malabaricus	50	C
	Hemiodidae		*Hemiodus unimaculatus*	2	O
	Serrasalmidae		*Myleus rhomboidalis*	263	H
			Myleus ternetzi	169	H
	Gymnotidae		*Gymnotus sp.*	3	O
Siluriformes	Ariidae		*Arius couma*	58	C
	Auchenipteridae		*Pseudauchenipterus nodosus*	8	O
Perciformes	Cichlidae		*Cichlidae sp.*	2	C
	Sciaenidae		*Plagioscion squamosissimus*	4	C

TABLE III

Result of the ANOVA testing for the effect of year, diet, zone and all interactions between factors on mercury concentration (µg g^{-1}). (N = 1690, multiple R = 0,833, R^2 = 0,694)

Source	df	*F*	*P*
Year	5	4.504	0.000
Diet	2	69.642	0.000
Zone	2	7.296	0.001
Diet x Year	9	5.189	0.000
Year x Zone	8	2.103	0.033
Diet x Zone	3	0.262	0.853
Year x Diet x Zone	19	1.678	0.033

0.03 ± SE 0.02 µg g^{-1} (range = 0.001-0.18; n = 263). No fish had concentrations higher than the standards. No significant difference was demonstrated between years for the concentrations (Fig. 2). In the species *Myleus ternetzi*, for example, the mean concentrations are less than 0.02 µg g^{-1}. The maximal concentration of

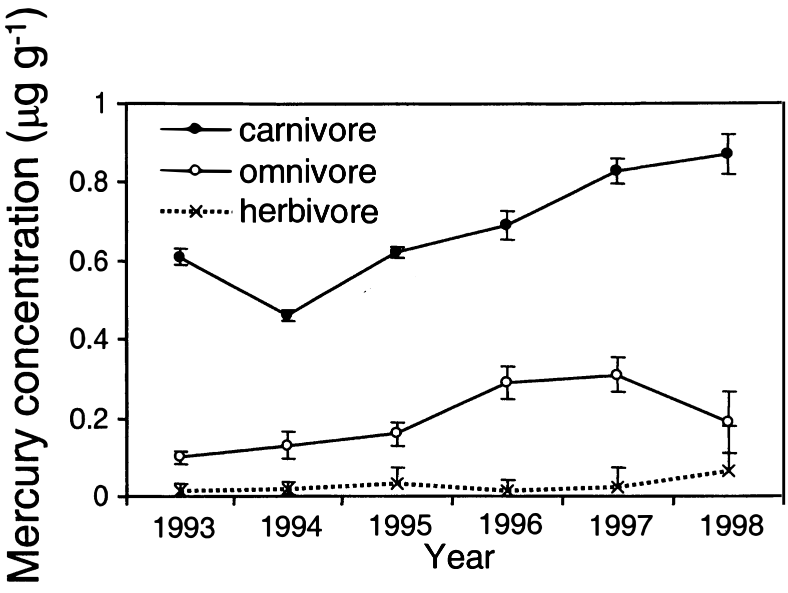

Figure 2. — Mean concentrations in mercury ($\mu g\ g^{-1}$) per year and group (error bar represents standard error).

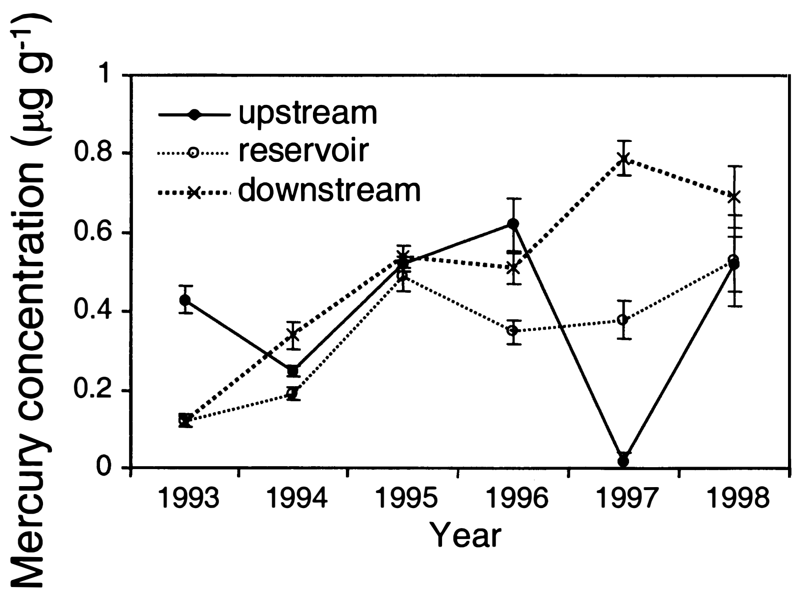

Figure 3. — Mean concentrations in mercury ($\mu g\ g^{-1}$) per year and zone (error bar represents standard error).

0.08 μg g^{-1} was observed in an individual captured in 1994 and weighing about 600 g (species mean concentration = 0.02 ± SE 0.01 μg g^{-1}; range: 0.001-0.08; n = 169).

Omnivores

The mean concentrations were less than 0.31 μg g^{-1} (Fig. 2). Amongst omnivorous fishes, 13 individuals (3 from the reservoir and 10 downstream) representating 3.6 % of samples had concentrations higher than 0.5 μg g^{-1}. The maximal concentration of 0.79 μg g^{-1} was observed in an *O. oglinum* specimen captured in 1997 and weighing 1,800 g (species mean concentration = 0.30 ± SE 0.16 μg g^{-1}; range: 0.1-0.79; n = 20). Globally, the concentrations increased progressively over time. By choosing *Leporinus friderici* as an example from the group of omnivores, one can note that this species has concentrations that are relatively high, and close, even superior, to the European standards for consumption (0.5 μg g^{-1}). Over time, the mean concentrations of mercury in the flesh of *Leporinus friderici* increase (Fig. 4 and Table IV). Thus, the increase in the concentrations observed between the period corresponding to prior to the filling of the dam reservoir and 1997 is significant (p = 0.05). The increase observed between 1994 and 1995 is also significant (p = 0.05).

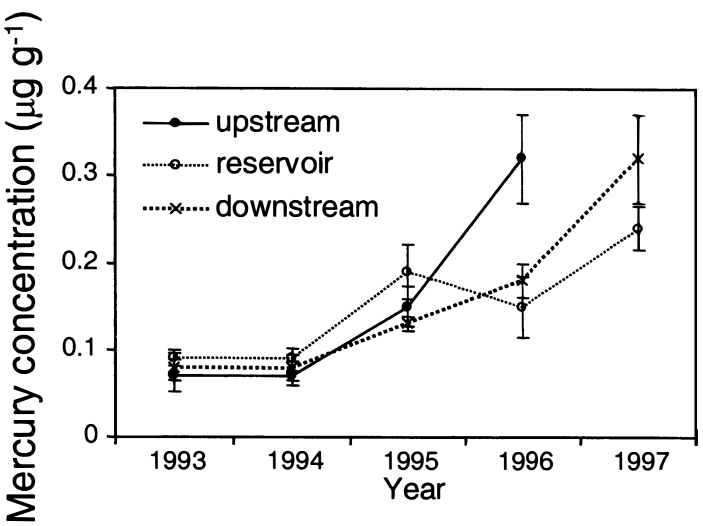

Figure 4. — Temporal variations in mercury concentrations (μg g^{-1}) in *Leporinus friderici* per zone (error bar represents standard error).

Carnivores

Sixty-five carnivorous fishes (7.8 % of total sample) corresponding to 23, 18 and 24 individuals that were captured upstream, in the reservoir, and downstream, respectively, had concentrations greater than 1 μg g^{-1} (Fig. 2). The mean concen-

TABLE IV

Result of the ANOVA testing for the effect of year and zone, and the interaction on mercury concentration (µg g^{-1}) in Leporinus friderici *(A) and matrix of pairwise comparison probabilities using Bonferroni adjustment (B). (N = 216, multiple R = 0.692, R^2 = 0.479).*

(A)

Source	df	*F*	*P*
Year	5	8.912	0.000
Zone	2	0.061	0.941
Year & Zone	8	2.245	0.026

(B)

Pairwise comparison	1993	1994	1995	1996	1997	1998
1993	1.000					
1994	1.000	1.000				
1995	0.000	0.004	1.000			
1996	0.025	0.089	1.000	1.000		
1997	0.001	0.009	0.056	0.081	1.000	
1997	1.000	1.000	1.000	1.000	1.000	1.000

trations were less than 1.0 µg g^{-1}, the maximal concentration of 1.94 µg g^{-1} being observed for a *Acestrorhyncus falcatus* specimen captured upstream in 1996 and weighing 260 g. Globally, the concentrations progressively increased over time: the increase in the mean concentrations from year to year was significant ($p = 0.05$). A total of 645 *Hoplias aimara* individuals were analyzed. This species, whose diet is strictly carnivorous, has high concentration levels (Figs. 5 and 6) close to or higher than European standards for consumption established at 1 µg g^{-1}. Individual fishes with concentrations higher than 1 µg g^{-1} represent 2.4 % of the total sample (39 specimens), or 6 % of the species *Hoplias aimara.* When considering all of the zones together, the results show that the concentrations of *H. aimara* increase over the course of time (Table V).

MEAN CONCENTRATIONS PER YEAR, BY GROUP AND ZONE

The analyses presented above were conducted zone by zone showing that mercury concentration increase mostly occurs downstream for all of the groups pooled (Fig. 7). In the upstream zone, no variation was noted among the herbivores. Among the omnivores, the year 1996 peaked due to the higher levels of concentrations, whereas the highest concentrations occurred in 1993 for carnivores. In the lacustrine zone, the variations among the herbivores were related to weak concentrations while in the omnivores and carnivores, no change was

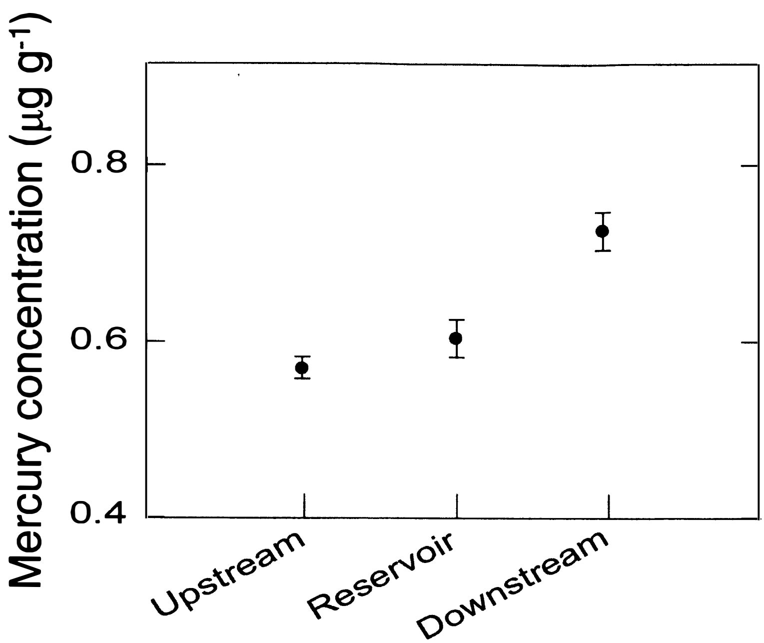

Figure 5. — Mean concentrations in mercury (µg g^{-1}) in *Hoplias aimara* per zone (error bar represents standard error).

TABLE V

Result of the ANOVA testing for the effect of year, zone and the interaction on mercury concentration (µg g^{-1}) in Hoplias aimara *(A) and matrix of pairwise comparison probabilities using Bonferroni adjustment (B). (N = 691, multiple R = 0.423, R^2 = 0.179).*

(A)

Source	df	*F*	*P*
Year	5	10.698	0.000
Zone	2	8.361	0.000
Year x Zone	9	0.087	0.126

(*B*)

Pairwise comparison	Upstream	Reservoir	Downstream
Upstream	1.000		
Reservoir	1.000	1.000	
Downstream	0.014	0.000	1.000

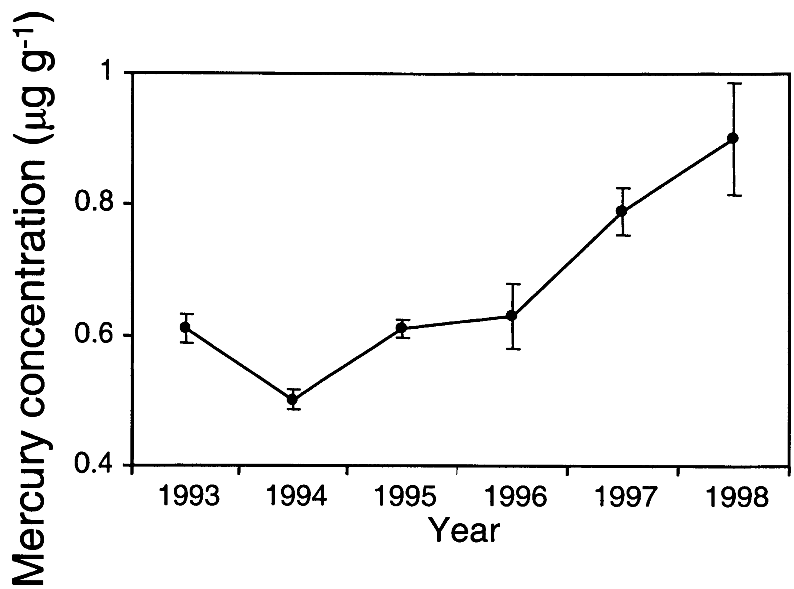

Figure 6. — Mean concentrations in mercury (µg g^{-1}) in *Hoplias aimara* per year (error bar represents standard error).

observed. The changes that occurred downstream was essentially linked to a significant increase in mercury concentration in the carnivores flesh and to a lesser extent in the omnivores one (Fig. 7).

DISCUSSION - CONCLUSION

A comparison with other regions can be made. Fernandes *et al.* (1989) pointed out mercury concentrations between 0.04 and 0.42 µg g^{-1} for herbivorous fishes and between 0.05 and 2.19 µg g^{-1} for carnivorous fishes in the Carajás (Brazil) region. Lacerda & Salomons (1991) report a value superior to 2.7 µg g^{-1} for a carnivorous fish in the Itacaiunas-Paraobedas (Carajás district) system. A more detailed study shows that the concentrations are between 0.3 µg g^{-1} and 0.91 µg g^{-1} for *Hoplias malabaricus* and between 0.01 µg g^{-1} and 1.37 µg g^{-1} for a group of 19 piranhas (Lacerda *et al.*, 1994) and the concentrations remain low for herbivores.

In the reservoir at Tucuruí in Brazil, Aula *et al.* (1992) mention a mean concentration of 2.6 µg g^{-1} for piranha (*Serrassalmus* sp.), 1.3 µg g^{-1} for the other predators, and 0.21 µg g^{-1} for non-carnivorous fishes. For carnivorous fishes in the Madeira River, the largest tributary of the Amazon, concentration level of 2.1 µg g^{-1} in a *Brachyplastitoma* sp. (20 kg) are mentioned by Malm *et al.* (1990) and concentrations higher than 2.7 µg g^{-1} are mentioned by Pfeiffer *et al.* (1989). In Jaciparana River, a tributary of the Madeira River, a *Pseudoplastitoma* sp. (685 g) shows a concentration of 2.7 µg g^{-1} (Malm *et al.*, 1990).

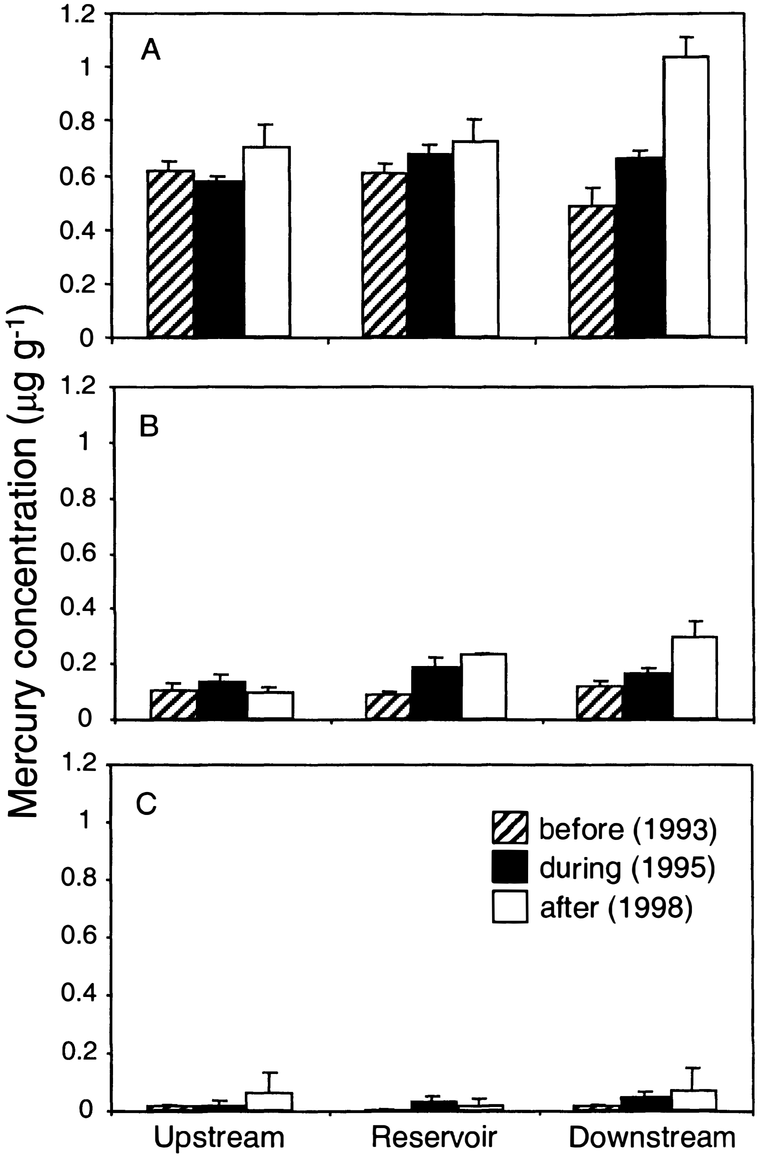

Figure 7. — Mean concentrations in mercury (µg g^{-1}) per year, zone and group (error bar represents standard error). A : Carnivores, B : Omnivores and C : Herbivores.

At the end of the filling phase, we put forth the hypothesis that the submersion of the lake zone would have for its only apparent consequence the dilution of mercury, which explains the tendency for the amounts of mercury noted in fish (Richard, 1996) to decrease. Lacerda *et al.* (1991b) attributed weak mercury concentrations (mean lower than 0.06 µg g^{-1}) for piranhas in the Poconé district in

Brazil to a similar phenomenon. They ascribed these results not only to dilution, but also to the exportation of particle matter loaded with mercury towards the flood zones, marshes, and lakes of the catchment basin as well. In the case of Petit Saut, the particle matter is partially deposited in the deep zone of the lake and can constitute in this way a reservoir of mercury that is potentially solubilizable. Thus, the processes of decomposition of the organic matter currently take place at the bottom of the lake and continue for many years (Richard, 1996). The diffusion of mercury depends directly on these processes that interact with the physico-chemical conditions of the milieu and the microbiological activity. These factors seem to influence the mobilization of the mercury currently dispersed in the different zones of the lake. The hypothesis that a process of accumulation of this metal exists, notably in the deepest layer of the lake, should be considered given the recent existence of the reservoir. The present results show that the flooding of this zone seemed to have, at first, consequences on mercury concentrations in fish in the downstream section. This section essentially receives, indeed, hypolimnic waters which are the privileged site of physico-chemical and bacteriological processes, as the evolution of mercury to methylmercury depends amongst other things on reducing conditions and on the presence of organic matter in large quantities.

During this phase of the study, measuring contamination levels in the flesh of fish from the lake allowed the greater solubilization of the mercury present in the submersion zone of the lake to be suggested. Indeed, a significant correlation between the levels of organic matter in the sediments and the mercury concentration in the water (floating or interstitial) was observed in the lakes of the Pantanal District in Brazil (Lacerda, 1992; Lacerda *et al.* 1991b; Lacerda & Salomons, 1991), which underlines the essential role that organic matter plays in the mobilization of this metal. In Canada, high levels of mercury concentrations found in the fish from the reservoirs of hydroelectric dams are related to the flooding of soils containing metallic mercury. The decomposition of the flooded organic matter by microorganisms brings about a methylation of the metallic form and facilitates its passage into the food chain (Bodaly *et al.* 1984; Hecky *et al.*, 1987). A direct relationship between the surface area of the flooded territory and the level of accumulation of mercury in fish in hydroelectric systems indicates that in addition to a process of diffusion of the submerged soils there is an inflow from the catchment basin (Lodenius *et al.*, 1983; Bodaly *et al.*, 1984; Boucher *et al.*, 1985; Jones & Saint-Onge, 1985; Hecky *et al.*, 1987; Jackson, 1988a, 1998b). Porvari & Verta (1995) demonstrated in laboratory experiments that flooded soils (humus and peat) under anoxic conditions have high diffusion levels of methylmercury. These authors link these mechanisms to the high concentrations of methylmercury that were demonstrated in the reservoirs.

The increase in mercury concentrations in fish downstream the dam of Petit Saut implies the regular follow-up of this zone, especially since the return to mining activities in the catchment basin in 2000. For the reservoir, the progressive homogenization of the water mass might bring about an increase in mercurial contamination through all of the scattered sources. Such increase might affect, first, the deep zone of the lake, second, the subjacent layers through diffusion and/or dilution, and third the fish in the superficial zone through the trophic chains in a more significant way as initially suggested by Aula *et al.* (1992) in Tucuruí. It is therefore advisable to pursue the study of this metal in the fish flesh of the reservoir.

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