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ECOLOGICAL MONITORING OF FISH ASSEMBLAGES DOWNSTREAM OF A HYDROELECTRIC DAM IN FRENCH GUIANA (SOUTH AMERICA)

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ABSTRACT

Dam impacts on the downstream section of dammed rivers are known to be important for fish because of changes in the physical and chemical river characteristics. However, the available data seem to be insufficient to draw general conclusions regarding the transformation of fish communities. A hydroelectric dam was built on the Sinnamary River in French Guiana and closed in January 1994. From December 1991 to December 1996 fish collections were made from the downstream section. The results show a rapid decrease in fish abundance in the middle downstream course immediately after dam closure. This low abundance was observed until the end of the filling phase, when the flow was maintained at a minimum level. Afterwards, abundance returned to a level comparable with that prior to dam closure. Fish collection in different zones showed that the decrease in abundance was probably due to the escape of fish to shelter areas. Another marked effect was the reduction of sample diversity due to a decrease in species richness, as well as in the regularity of the distribution of species' relative abundance. Examination of biological traits of species suggests that under these conditions feeding strategies could have been the most important factor affecting the abundance of populations. Copyright © 1999 John Wiley & Sons, Ltd.

KEY WORDS: fish abundance; fish assemblages; fish diversity; neotropics; river damming

INTRODUCTION

Dam construction on a river course causes multiple and dramatic impacts on the downstream environment (Bernacsek, 1984; Junk and Nunes de Mello, 1987; Ligon *et al.*, 1995). The nature and amplitude of these transformations depend on numerous factors, such as the characteristics of the river and the dam, and the climatic conditions where the work site is located. Nevertheless, a certain number of general tendencies have been documented in the literature. Certain effects are linked to the chemical properties of the water, such as depletion of dissolved oxygen, particularly during the filling and the stabilisation phase of the reservoir (see SCOPE, 1972 for a description of phases in setting a reservoir) and presence of toxic gases, such as H_2S and NH_4, in downstream water during the first few years following closure. There are also hydrological changes as a result of dam installation and these account for other effects that have been observed. During reservoir filling, the annual flood is suppressed and afterwards the flow regime is seriously disrupted. Generally, the extent of flooding is reduced, low flows are sustained and erratic variations of flow rate due to massive water releases are common. The consequences of these alterations are the diminution of seasonal flooded areas, structural changes of the river bed, a progression upstream in the salt water intrusion in the estuary, etc. (Baxter, 1977; Ligon *et al.*, 1995).

Naturally, such disturbances affect fish assemblages both directly and indirectly. Migratory movements are blocked by the barrage, the food chain is modified and the structure of fish communities is altered as it is particularly sensitive to changes in hydrological parameters (Schlosser, 1985; Poff and Ward, 1989;

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Travnichek *et al.*, 1995). For example, reducing the magnitude of floods decreases the expanse of spawning areas for certain species and the destruction of the natural flow regime affects the spawning process (Ponton and Vauchel, 1998).

Because of the wide range of fish trophic level, including the highest level occupied by top predators, the structure of a fish assemblage is a good indicator of the quality of the aquatic environment (Karr, 1981; Karr *et al.*, 1986; Harris, 1995; Shields *et al.*, 1995). When considering that the downstream portions of rivers are usually the most productive and are the most densely populated, studying the quality of these areas in dammed rivers takes on particular importance.

Paradoxically, there have been very few studies of downstream fish assemblages in dammed rivers, especially in tropical environments. Numerous syntheses point out the possibility of a decrease in biodiversity because of dams (Baxter, 1977; Welcomme, 1979; Bernacsek, 1984; Moyle and Leidy, 1992). Such a decrease has been demonstrated in the Nile (Ishak, 1981), but other observations have shown that species numbers can be rapidly restored when the flow is regulated (Travnichek *et al.*, 1995). Results concerning the global abundance of fish downstream of dams are also contradictory. It has been established that fisheries production was considerably depressed downstream from a dam when large flood zones were present (Welcomme, 1979; Bernacsek, 1984). On the other hand, the tailrace of the barrage has in some cases been proven to be an area with a high fish population density (Sagua, 1978; Obeng-Asamoa, 1979). This short review of data concerning downstream impacts of dams on fish communities demonstrates the need for additional data in this area.

The present research intends to (1) globally describe the temporal evolution of fish assemblages found in a middle zone of the downstream portion of the Sinnamary in French Guiana, which was dammed in 1994; (2) describe the spatial heterogeneity of these assemblages in the downstream course, 1 year after total filling of the reservoir; and (3) compare the results obtained with a similar study that was performed in the Tocantins River, Amazon Basin, dammed in 1984 (Mérona *et al.*, 1987).

MATERIAL AND METHODS

Study site

The Sinnamary is a medium sized river with a basin area of 6565 km^2 and is approximately 260 km in length. It flows from south to north and is located in the centre of French Guiana. In January 1994 a hydroelectric dam located in the downstream part of the river was closed. This area is referred to as 'Petit-Saut' and is situated approximately 60 km from the estuary. The dam flooded more than 350 km^2 of primary forest. The downstream part of the river flows through the coastal plain, which is mostly covered by primary forest (Figure 1). For the entire duration of the filling process (from January 1994 to May 1995), the rate of downstream flow was maintained at approximately 100 m^3 s^{-1}, except for brief hydrological episodes. From May 1995 onwards, the normal flow regime was restored, although with a greater variability in mean monthly discharge than in the pre-dam situation (Figure 2).

Sampling

Sampling was conducted by the use of monofibre gillnets (25 × 2 m). The sampling unit consisted of a battery of ten nets with increasing mesh size (10, 15, 20, 25, 30, 35, 40, 50, 60 and 70 mm between knots). The nets were set along the river banks in zones relatively free of obstacles and with very little or no current.

Two series of samplings were conducted:

- one series was conducted in the middle of the downstream part of the river, about 30 km from the dam (Vénus station, Figure 1). Sampling was started in December 1991 and continued until December 1996. The chronology of sampling is indicated in Figure 2. Only one battery of nets was used until February 1995 and from then on two batteries were used. The results are expressed in catch per battery. The nets are placed near the banks in the main part of the river where the bottom is muddy and the current varies daily in response to the tides and seasonally with the discharge.

- the other series was conducted at four supplementary stations, spread out along the downstream section of the river but excluding the zone of salt water intrusion. From the dam to the estuary these stations were:
  - dam: a large basin situated at the foot of the dam wall. The bottom is rocky and there was practically no current during fishing. The nets crossed the basin. Sampling was conducted at this station at 3-month intervals from February to December 1996.
  - Kérenroch: located along the main part of the river at about 8 km from the dam. The bottom is rocky and sandy and the current varies with the discharge. Samples were taken at 3-month intervals from November 1995 to December 1996.
  - Saulnier: located along the main part of the river about 40 km from the dam. The bottom is muddy and the current varies with the discharge. Sampling was done twice in November and December 1996.
  - Saulnier creek: a small tributary of the river's left bank. The mouth is located approximately 42 km from the dam. Nets were placed a few km upstream from the creek's mouth. The river bottom is muddy and full of plant debris. The station was sampled at 3-month intervals from November 1995 to December 1996.

The nets were positioned at around 17:00 h and were taken up the next day from 07:00 h onward. Additional information from fishing during the day proved insignificant.

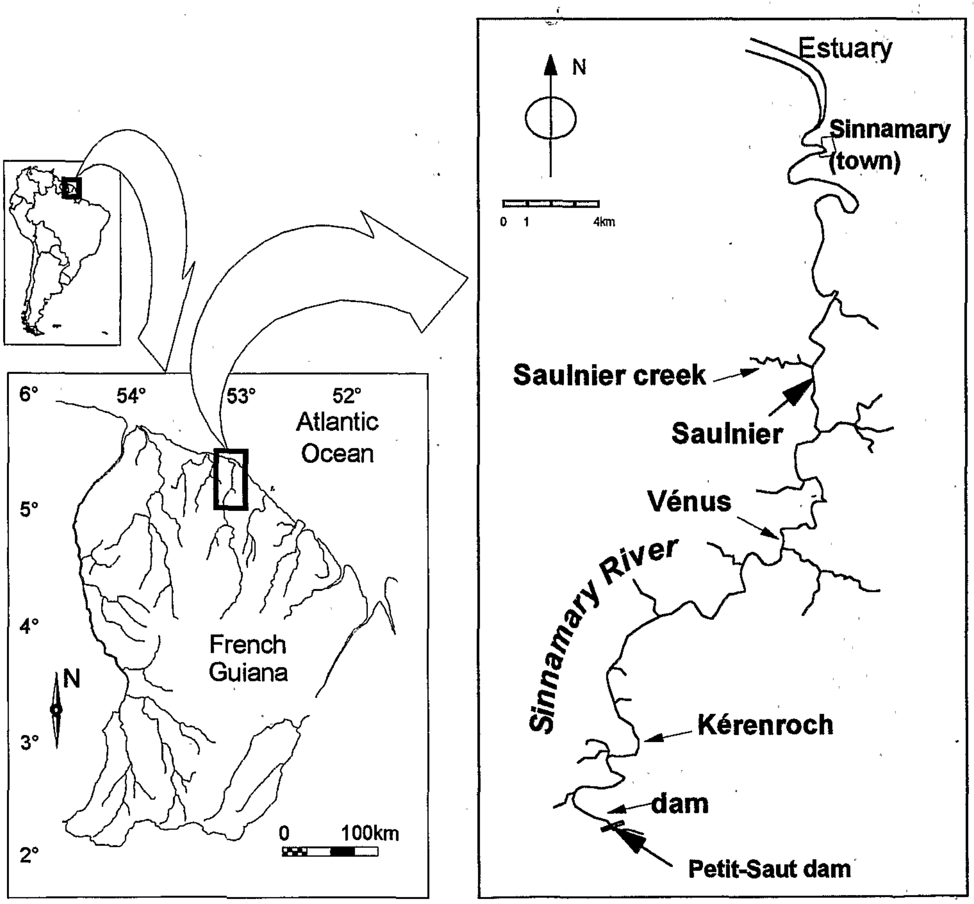

Figure 1. Geographical situation of the sampling area and position of stations

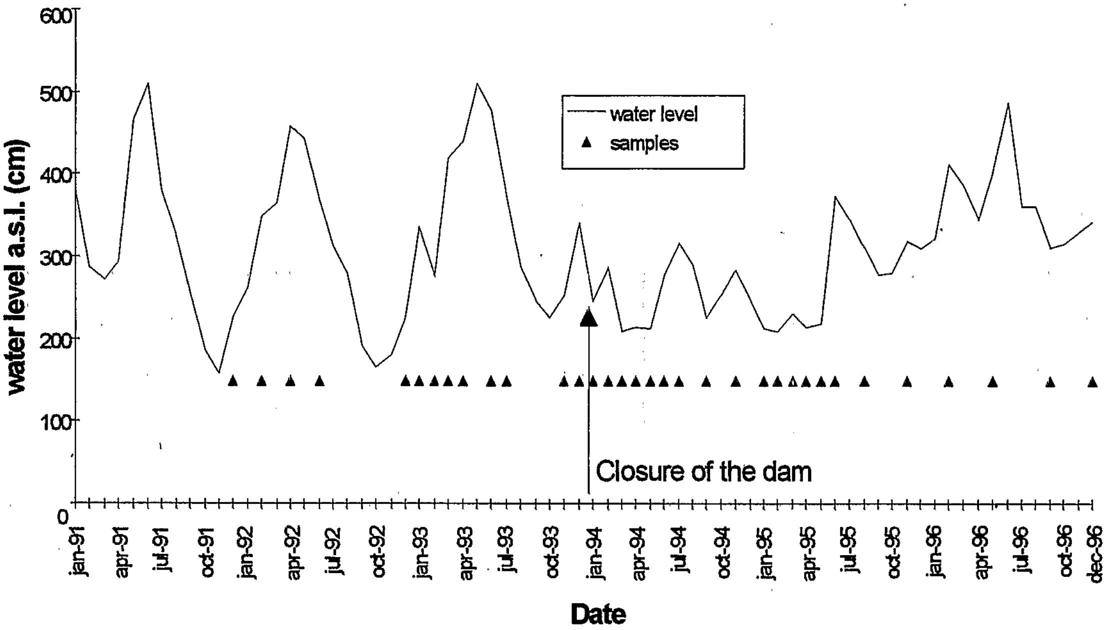

Figure 2. Mean monthly water level at the limnimetric station of Petit-Saut below the dam, and position of the sampling periods at Vénus station in the Sinnamary

Fish measurement

Each captured fish was identified to species, measured (standard length to the nearest mm) and weighed (in case there was a large number of specimens of the same species in the same net, only a random subsample was weighed individually). The number of fish captured, the species richness and the total weight were determined for each sample.

Data processing

Four series of independent data were used for data processing:

- total number of individual fish captured per battery and per night fishing,
- total weight per battery and per night fishing. Total weight is largely influenced by total number of individual fish ($n = 34$; $r^2 = 0.674$; $P < 0.001$). In order to isolate the effect of individual weight, the authors used the residual of the regression of total weight on total number computed from data normalised by natural logarithmic transformation;
- species richness or total species number in the sample taking into account the sampling intensity. The probability of capturing a species not already recorded increases with sample size (Magurran, 1988). After normalisation of the data by a natural logarithmic transformation, the linear regression of species number in the sample on total number of specimens caught has been calculated. The regression is highly significant ($n = 34$; $r^2 = 0.445$; $P < 0.001$). Therefore, the residuals of the regression were used for further processing;
- evenness given by the equitability:

$$E = -\sum p_i \cdot (\log_2 p_i / \log_2 N),$$

where p_i is the relative frequency of species i and N is the species number in the sampling.

This value varies from 0 to 1. When all the species except one are represented by a single specimen, the regularity is at a minimum and equitability near 0. Conversely, if all species have equal abundance, regularity is at a maximum and equitability equals to 1.

A LOWESS function, a technique for smoothing data based on locally weighted robust regression, has been included in order to visualise the general evolution of the data series (Cleveland, 1981). Comparisons between periods are made using a t-test adapted to samples of unequal variance (Scherrer, 1984), or in the case of high variances, by a non-parametric Kolmogorov–Smirnov (K–S) test.

An index of dominance applied to fish families is calculated according to the formula:

$$I = \arcsin(N_i/N_t),$$

where N_i is the number of specimens of species i in the sample and N_t is the total number of specimens in the sample. The arcsine transformation is used to normalise the data.

Statistic processing was carried out by using SysStat® 7.0 for Windows (Wilkinson *et al.*, 1996).

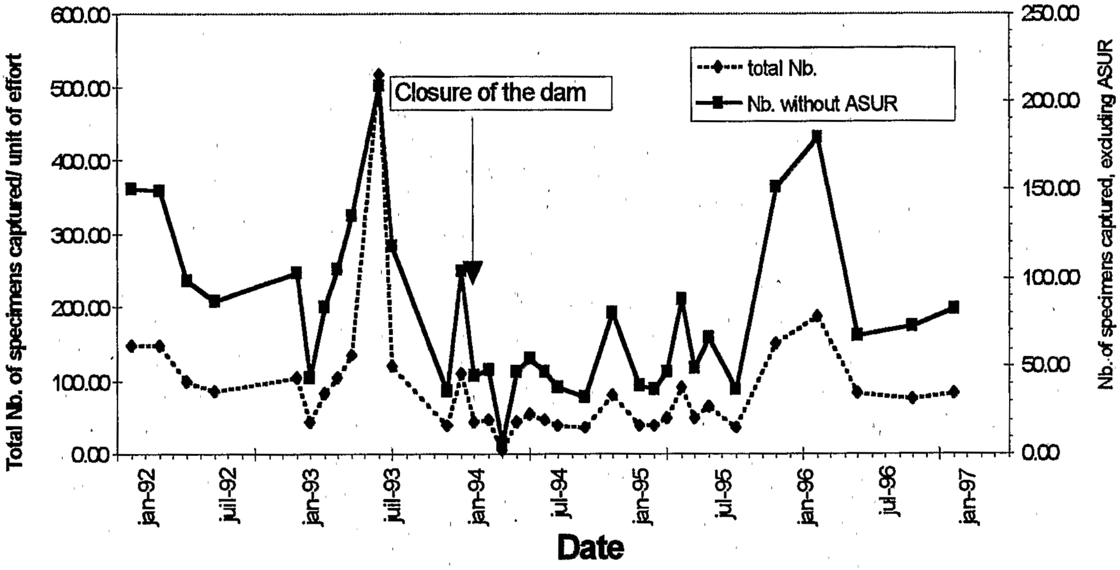

Figure 3. Variations of captures in the Sinnamary at Vénus station in the period December 1991–December 1996. The unit of effort is the night fishing with a battery of ten nets. ASUR, *Anchovia surinamensis*

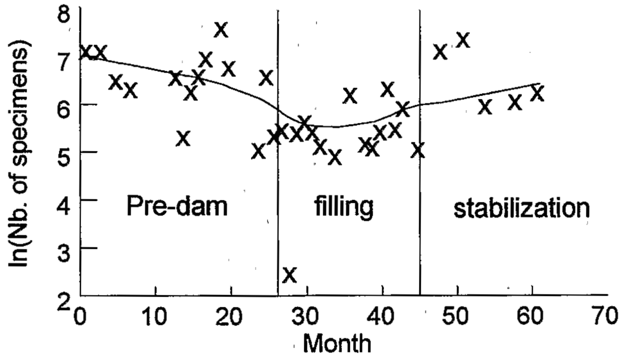

Figure 4. Variations of the number of specimens captured at Vénus station (data log transformed). The plain line is a smooth by the function LOWESS (see text)

Table I. Comparison of mean number of fish captured in the different periods using a t-test

	December 1991–December 1993	January 1994–August 1995	November 1995–December 1996
n	13	16	5
Mean	109.23	47.34	110.70
S.D.	45.72	18.95	51.52
January 1994–August 1995	$t = 4.572$, $P = 0.000$		
November 1995–December 1996	$t = 0.102$, $P = 0.902$	$t = 2.694$, $P = 0.000$	

S.D., standard deviation.

RESULTS

Temporal analysis in the middle part of the main course: Vénus station

Number of captured fish. The evolution of the number of fish captured shows a sharp peak in June 1993 (Figure 3). This peak is mostly due to high catches of a single species (*Anchovia surinamensis*), which is rare in other samples. This species has been eliminated from subsequent processing of data where fish number is involved; thereby not conferring too much importance to this accidental capture (Figure 3).

Two effects of dam closure are apparent: first, a decrease in the number captured and second, a reduction in the variations observed before dam closure. From November 1995 on, which corresponds to the return of the seasonal cycle of water level, variations comparable with those observed before the dam can be seen.

Smoothing the data by the LOWESS function confirms these tendencies: first the decrease right after dam closure, then an increase around the month of August 1995 (Figure 4).

A t-test was used to compare the average capture in three different periods defined by hydrological conditions. These periods are from December 1991 to December 1993, from January 1994 to August 1995 and from November 1995 to December 1996 (Table I). The significant difference in capture level during the filling phase (January 1994 to August 1995) as compared with the two other phases is evident. There was a distinct decrease in captures for the whole filling phase during which a minimum rate of flow at 100 $m^3 s^{-1}$ downstream was maintained. During the final year of observation, captures returned to a level comparable with the pre-closure phase.

Weight. The mean weight of fish followed a seasonal cyclical evolution during the 2 years before the dam: it was maximal at the beginning of the flood in February–March and minimal at the end of the low water season. This cycle disappeared after the closure (Figure 5). However, on a yearly basis, the evolution of mean weight shows no trend over the period. The comparisons of the values in each of the

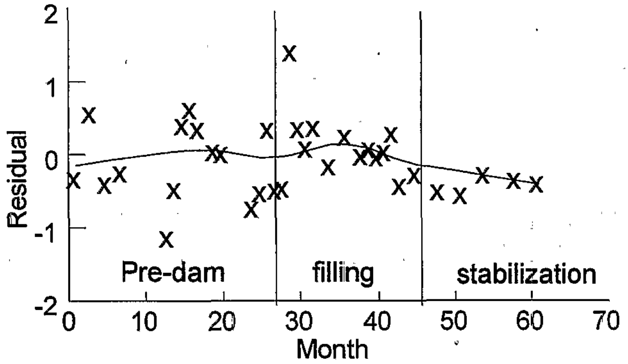

Figure 5. Variations of the residual of the linear relation between total weight and number of specimens captured at Vénus station (data log transformed). The plain line is a smooth by the function LOWESS (see text)

Table II. Comparison of mean individual weight in the different periods using a Kolmogorov–Smirnov test

	December 1991–December 1993	January 1994–August 1995	November 1995–December 1996
n	13	16	5
Mean	−0.030	0.093	−0.219
S.D.	0.541	0.302	0.083
January 1994–August 1995	$D_{\max} = 0.436$, $P = 0.100$		
November 1995–December 1996	$D_{\max} = 0.421$, $P = 0.538$	$D_{\max} = 0.642$, $P = 0.094$	

Weight is the residual of the linear regression total weight vs. number captured. S.D., standard deviation; $D_{\max}$, maximum difference.

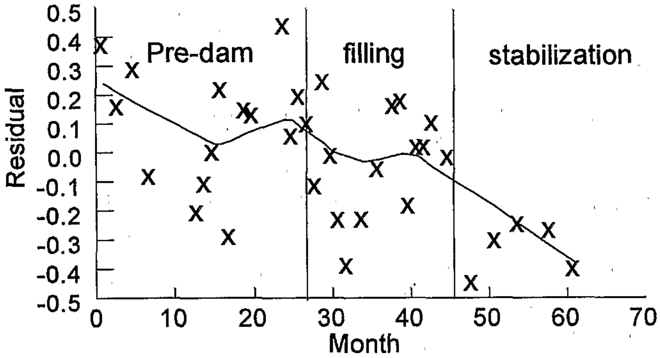

Figure 6. Variations of the residual of the linear relation between the number of species and the number of specimens captured at Vénus station (data log transformed). The plain line is a smooth by the function LOWESS (see text)

defined periods are made by using the non-parametric test of K–S because of high variances. The results show no significant difference between periods (Table II).

Species richness. Species richness seems to decline over time (Figure 6). The smoothed data have a stepped progression. During the pre-closure phase there is an initial decrease followed by a rise; at closure there is another significant decrease interrupted by a brief compensation, and finally a decline until the end of sampling. The comparison of species richness between periods indicated that the most significant decrease occurred in the third period (Table III).

That decrease in richness shown by the use of residuals is confirmed by the declining number of species in the samples. The 13 samples obtained before the dam (from December 1991 to December 1993) contained 54 species as compared with the 12 final samples (from December 1994 to December 1996)

Table III. Comparison of mean species richness in the different periods using a Kolmogorov–Smirnov test

	December 1991–December 1993	January 1994–August 1995	November 1995–December 1996
n	13	16	5
Mean	0.109	0.007	−0.303
S.D.	0.220	0.187	0.070
January 1994–August 1995	$D_{\max} = 0.264$, $P = 0.621$		
November 1995–December 1996	$D_{\max} = 0.882$, $P = 0.003$	$D_{\max} = 0.829$, $P = 0.010$	

Richness is the residual of the linear regression number of species vs. number of specimen captured. S.D., standard deviation; $D_{\max}$, maximum difference.

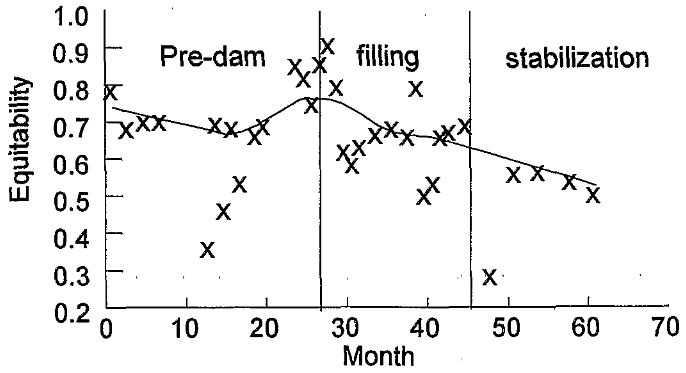

Figure 7. Variations of the equitability of the samples at Vénus station. The plain line is a smooth by the function LOWESS (see text)

which contained 47. There are 34 species common to both, 20 species present before the dam but not after, and 13 not found before the dam but captured after.

Evenness. There are large variations in equitability from one sample to another. The equitability is relatively high right after dam closure but has the tendency to decline afterward (Figure 7). The comparison of average values from the three phases reveals a significant difference between the period immediately following dam closure when equitability is high, and the recuperation phase from August 1995 onward, when it is low (Table IV). This indicates dominance of a small number of species in the sample during the final period.

Specific composition. Three families of fishes seem to have been stimulated after dam closure: the Curimatidae, the Sternopygidae (Figure 8A) and the Cichlidae. These three families include a small number of species in the assemblages of the Sinnamary River, seven, two and three, respectively (Table V). For the Curimatidae, the main species is *Curimata cyprinoides*, which was immediately dominant in the assemblages after the closure of the dam. When richness increased, the dominance of this species decreased but the number of individual fish remained high. The main Sternopygidae species was *Eigenmannia virescens*, whose abundance and dominance increased around the 35th month, or about 1 year after closure. Cichlids were not captured before closure and only appeared in the samples in small numbers at the end of the first year of filling. The dominant species here was *Geophagus surinamensis*.

Two families apparently suffered a negative impact under the new environmental conditions: the Engraulidae and the Characidae (Figure 8B). The Engraulidae were mostly represented by *Pterengraulis atherinoides*, whose periodic abundance before the closure of the dam was probably influenced by the tides. After closure, practically no specimen was present in the samples. The second family contained 20 species. The most important, *Triportheus rotundatus*, was practically absent from the samples after the dam closure, whereas it was common and very abundant before.

Table IV. Comparison of mean equitability in the different periods using a Kolmogorov–Smirnov test

	December 1991–December 1993	January 1994–August 1995	November 1995–December 1996
n	13	16	5
Mean	0.678	0.702	−0.505
S.D.	0.138	0.110	0.118
January 1994–August 1995	$D_{max} = 0.260$, $P = 0.643$		
November 1995–December 1996	$D_{max} = 0.728$, $P = 0.040$	$D_{max} = 0.829$, $P = 0.010$	

S.D., standard deviation; D_{max}, maximum difference.

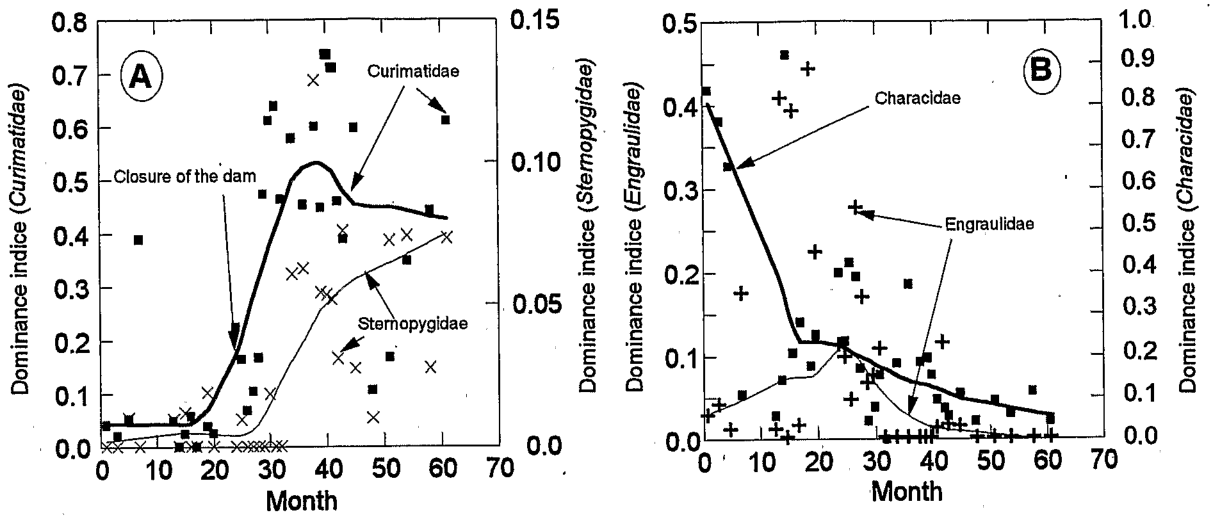

Figure 8. Variations of dominance of four families of fishes in the samples at Vénus. The plain lines are smoothes by the function LOWESS (see text). A, Curimatidae and Sternopygidae; B, Characidae and Engraulidae

Two families did not appear to have been influenced particularly by the dam. These were the Auchenipteridae and the Serrasalmidae. In the Auchenipteridae, 87.6% of the individual fishes belong to the species *Auchenipterus nuchalis* and about the same is true for the Serrasalmidae with the species *Myleus ternetzi*. Both have alternating periods of great abundance and near absence in the assemblages.

Spatial analysis

Examination of the distribution of captures from November 1995 to December 1996 in five stations situated between the dam and the limit of salt water intrusion reveals a certain number of distinct tendencies (Figure 9):

- a great accumulation of fish at the dam's tailrace, sampled from February 1996,
- the increase in number of captured fish was also noticeable, although with a much lower intensity at the same period in middle stations, Kérenroch and Vénus,
- the opposite situation occurred in the Saulnier creek station,

Table V. Main fish families and dominant species found in the samples from Vénus station

Family	Number of species	Total number of specimens	% of dominant species	Dominant species
Anostomidae	4	136	87.50	*Leporinus friderici*
Auchenipteridae	4	1072	87.69	*Auchenipterus nuchalis*
Characidae	20	730	41.10	*Triportheus rotundatus*
Cichlidae	3	30	86.67	*Geophagus surinamensis*
Curimatidae	7	868	93.32	*Curimata cyprinoides*
Engraulidae	5	259	86.10	*Pterengraulis atherinoides*
Erythrinidae	3	22	86.36	*Hoplias aimara*
Hemiodidae	3	27	62.96	*Hemiodopsis quadrimaculatus*
Sternopygidae	2	94	63.83	*Eigenmannia virescens*
Loricaridae	4	24	54.17	*Loricaria cataphracta*
Pimelodidae	5	11	36.36	*Pimelodella gracilis*
Serrasalmidae	4	56	83.93	*Myleus ternetzi*

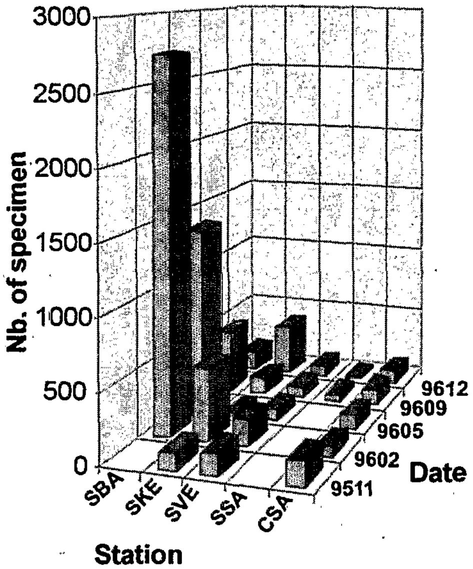

Figure 9. Distribution of captures in the Sinnamary River downstream form Petit-Saut dam in the period November 1995–December 1996. SBA, dam station; SKE, Kérenroch station; SVE, Vénus station; SSA, Saulnier station; CSA, Saulnier creek station

- fish densities decreased at the dam's tailrace from February to December 1996 and reached values comparable with those observed throughout the rest of the river.

Moreover, species richness is generally low in all the samples except in the Saulnier creek station in September and December 1996 (Figure 10).

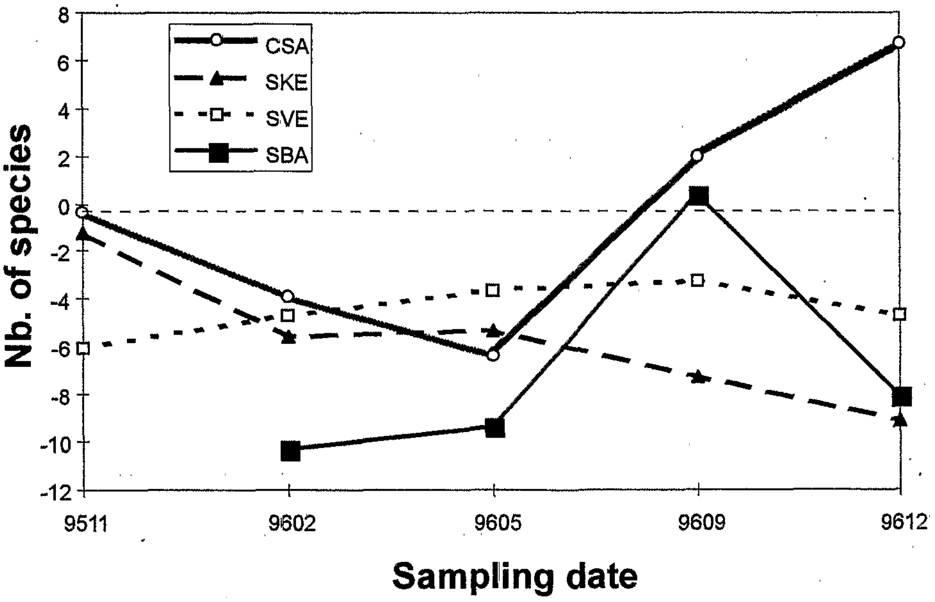

Figure 10. Deviation from the linear relation between species number and number of specimens in Vénus station, in samples from the different stations downstream of the dam. SBA, dam station; SKE, Kérenroch station; SVE, Vénus station; SSA, Saulnier station; CSA, Saulnier creek station

Table VI. Result of the Generalised Linear Model with the number of specimens captured as dependent variable and the period of sampling and the mean monthly water level as independent variables

Dependent variable: number of specimens captured
$N = 34$, multiple $R = 0.685$, $R^2 = 0.469$

Analysis of variance

Source	df	F	P
Period	2	3.717	0.036
Water level	1	2.940	0.097

Data of number of specimens are log transformed and data of water level are square root transformed for normalisation.

DISCUSSION AND CONCLUSIONS

Effect on the catch

The results clearly show that dam closure has had weighty consequences on fish yield in the middle zone of the river. Low catch levels persisted until November 1995, about a year and a half after the dam closed. To interpret this phenomenon, several hypotheses were explored: (1) change in gillnet sampling efficiency, (2) massive fish mortality, (3) lowering and/or loss of recruitment and (4) escape of fish toward shelter areas.

Hypothesis (1) is supported by the degradation of water quality in the downstream river soon after the closure of the dam. Organic debris coming from algae decomposition were transported along the river and eventually accumulated in the nets. However, although there was no improvement of water quality over time, the catch returned to pre-dam values in the stabilisation phase. In a comparable situation, in the Tocantins River, Mérona *et al.* (1987) were able to verify that low catch was not due to lower efficiency of gillnets. Another question related to sampling bias is the apparent relationship between catches and water level (see Figures 3 and 4). In order to verify the importance of this factor, a generalised linear model was developed that relates the number of specimens captured to the period and to the water level. The results show no significant effect of water level (Table VI). Thus, the decrease in catches observed during the 2 years of the reservoir filling cannot have been due to bias induced by the sampling.

Fish mortality (hypothesis (2)) due to a massive release of deoxygenated water from the turbines usually occurs after the closure of hydroelectric dams (El Moghraby, 1979; Obeng-Asamoa, 1979; Mérona *et al.*, 1987). Two brief episodes of fish mortality have been reported in the Sinnamary, 50 km downstream of the dam. There was no accurate evaluation of the number of dead fishes but, according to witnesses, a few hundred fish could have been killed. It is doubtful that these events could have had a considerable influence on the whole downstream area. A model proposed by Welcomme (1979) relating the potential commercial catch to the length of rivers in Africa, if applied to the Sinnamary River, gives the estimation of 55 metric tons for the 50 km downstream of the dam.

Lack or loss of recruitment (hypothesis (3)) in the 2 years of filling of the reservoir was suggested by the observations of Ponton and Vauchel (1998). However, as gillnets catch mainly adult fish, this phenomenon could not have had an influence on the low catches in the first year after dam closure.

The last hypothesis, escape of fish toward shelter zones, might be the most probable for explaining the low catches in the medium part of the downstream section of the Sinnamary River. This hypothesis is supported by several arguments. The great concentration of fish at the foot of the dam during the month of February 1996 (Figure 9) suggests that this area was likely to have been one of the refuge areas for the fish. A high fish population density was observed there shortly after closure (Cerdan, personal communication). In the Tocantins River, barred by the Tucurui dam, Mérona *et al.* (1987) noticed a greater density of fish close to the dam rather than further downstream, where fish abundance was severely depressed.

This observation was confirmed by the analysis of the commercial landings at one of the area's markets (Odinetz-Collart, 1991), which shows that aside from a few migration episodes, the commercial landing, coming from the downstream area, was insignificant during several years after closure. In the Sinnamary River, studies have revealed a phenomenon of oxygen consumption due to chemical oxygen demand along the course of the river (Gregoire, personal communication). This phenomenon provokes a progressive decrease in the dissolved oxygen downstream of the dam to the limit of the salt intrusion zone, and suggests that the fish swim upstream following the oxygen gradient until they reach the basin located at the tailrace below the flood gates, where the water is saturated with dissolved oxygen. As a result, fish accumulate at the tailrace. In some countries, this phenomenon has even allowed the development of commercial fisheries (see Bernacsek, 1984 for a review). Finally, escape from adverse conditions by swimming upriver could be reinforced by natural upstream movements linked to reproduction. This migratory behaviour was observed several times during the whole observation period in the rapids at the beginning of the flood (Mérona, unpublished data). Supporting this hypothesis is the high condition of the principal species and their high rate of maturation noticed in February 1996 at the tailrace of the dam (Mérona, unpublished data).

Effects of closure on mean weight of fish

The only noticeable effect of the dam closure on mean weight of fish was the elimination of the natural seasonal cycle for this variable. Increase in individual weight might be associated with growth and improvement of individual fish condition both favoured by the flood. On the other hand, decrease in individual weight at the community level may have various origins: a reduction of individual fish condition due to the liberation of sexual products, the recruitment into the experimental fishery of the young 0^+ fish, or death of the larger fish. In the Sinnamary, downstream of the dam, the interruption of the flood during two consecutive years apparently broke this natural cycle. Most probably, growth was slower and recruitment of many species did not occur. Unfortunately, the scarcity of fish in the samples did not permit the checking of these hypotheses.

Effects of closure on assemblage diversity and composition

After dam closure, both species richness and equitability of the assemblages greatly diminished. This decrease continues to be observed after the normal hydraulics are restored. The cause of the disappearance or scarcity of species has been researched by observing reproduction strategies adopted by each species (Ponton and Mérona, 1998). There appears to be no common reproduction strategy among the most affected species. However, individually, certain characteristics might have led to the observed decrease in their abundance. For example, Characiformes, whose young use the flooded areas at the creek borders, have been most likely put at a disadvantage because of the increased scarcity of surface area in these particular zones during the 2-year filling stage (Ponton and Copp, 1997). Another example is that of the Engraulidae, which have developed a one-time-only egg laying strategy at the beginning of the flood. On the other hand, certain feeding traits of species might explain their different reaction to the disturbance. The species that were the most affected all have pelagic or surface feeding behaviour, whereas the species that were at an advantage with respect to the others have a benthic feeding behaviour (Merona, unpublished data). The deterioration of the quality of water filled with organic debris and the diminishing of flooded side zones, which are rich in exogenous foods, are both factors that could have limited the maintenance and the development of pelagic or surface feeders.

General Conclusions

Three years after closure of the Petit-Saut dam it appears that the only detectable effects on fish communities downstream are those of a diminution of species richness and evenness and changes in the relative abundance of species. The observed dramatic decrease in overall fish abundance in the middle part of the downstream river course is most probably an artefact linked to the escape of fish to shelter zones. However, it is likely that the situation will change over the next few years as suggested by the erratic variations in the samples observed throughout the end of the study. A long-term survey has been initiated to verify the tendencies observed in this short-term study.

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