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Investigations on the seasonal changes in the chemical composition of liver and condition from a neotropical characoid fish *Colossoma macropomum* (Serrasalmidae)

by

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Abstract

Annual fluctuations in the water level of the Amazon River system change the living conditions of juvenile *Colossoma macropomum.* Due to a greatly reduced food supply during the low-water periods, the fish must metabolize their reserve material to meet the energy needs, as could be demonstrated by a reduction of both, the glycogen-somatic index and the protein content of the filet. No changes in the visceral fat content were detected. With rising water level the grain of *Oryza perennis* (Gramineae) become available as food and consequentely an increase in the glycogen content of the liver was detected. A delay and a reduction in the production of *Oryza perennis* prevents the improvement in the condition of the starved fish.

Keywords: **Amazon, floodplain, fish, body composition.**

1. Introduction

In the Central Amazon Basin, a characteristic system of lakes, called várzea, borders the main river. These lakes, formed by recent alluvial deposits, are separated from the river for much of the year. Differences in the water level of as much as 15 m occur seasonally, and during the high-water period, the river overflows into the lakes, adding nutrients and greatly expanding the aquatic habitat (SIOLI 1968; JUNK 1982, 1983).

Along with *Arapaimas gigas, Colossoma macropomum*, ("tambaqui" in Brazil), make up the largest and commercially most important members of the Brazilian neotropical ichthyofauna. *C. macropomum* inhabits both the Amazon and the Orinoco River systems. At sexual maturity individuals weigh about 4 or 5 kg. A maximum weight of 30 kg can be attained.

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During high water periods, the tambaqui of the Amazon region inhabits the flooded forest of the várzea, nourishing themselves on the seeds and fruits that fall from the trees and shrubs (GOULDING 1980). As the water level falls the adult tambaqui leave the shrinking habitat and migrate into the white-water rivers where they remain until the end of the spawning season. They return to the forest when these are flooded again.

The juveniles remain in the várzea lakes for the entire year. Examinations of the stomach contents showed that these fish are adapted to the water level fluctuations by horizontal migrations. When the water level rises, they prefer to feed on the grain of *Oryza perennis* (Gramineae). During the high water period they consume the seeds and fruit of the forest plants as the adults do. While the water level is falling, zooplankton, particularly Cladocera, forms the chief component of their diet. During the low-water periods, the fish survive a hunger phase lasting several weeks (GOULDING & CARVALHO 1982; SAINT-PAUL 1982).

The goal of this investigation was to determine the extent to which the chemical composition and condition of the body reflects the seasonal dietary changes, especially in the juveniles. Special attention was given to the phase of food shortages during low-water periods.

This investigation is part of an extensive program concerned with the ecology and physiological adaptability of juvenile tambaqui, giving special attention of the oxygen concentration in the water (SAINT-PAUL 1982, 1983, 1984).

2. Material and Methods

2.1. Fish specimens

The fishes were collected from a floodplain lake, Lago Manaquiri, beside the white-water Solimões/Amazon River near Manaus (Fig. 1). Monthly excursions, lasting several days each, were made to the lake from January 1979 to July 1980 in order to catch juvenile tambaqui weighing, on the average, between 1,000 and 1,400 g. Gill nets of 4 to 10 cm mesh were used to capture the fish.

2.2. Preparation of the specimens

The standard length of each fish was measured, and total and gutted weights were determined with an accurancy of ± 0.1 g for specimens under 1,500 g, and ± 20 g for those over 1,500 g. The degree of stomach fullness was estimated and graded according to seven categories: 1, 5, 10, 25, 50, 75, and 100 %.

Immediately after capture, the livers were dissected out of the visceral mass and weighed with an accurance of ± 0.1 g. The samples were placed separately in capped glass bottles and stored on ice at + 5 to + 7 °C. The maximum storage time was three days. Immediately after the arrival of the ship in Manaus, the samples were deep frozen at -18 °C and stored until the analyses were made.

Those fishes to be used for the analyses of the filets were taken to the institute on ice for further treatment.

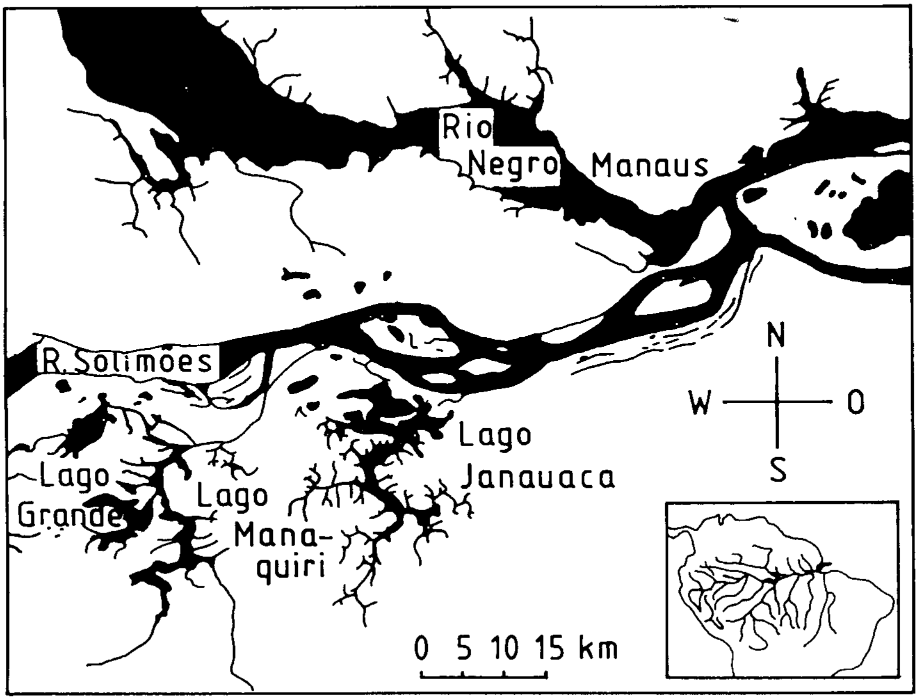

Fig. 1:
Study area

2.3. Condition factors

The Fulton Corpulence Factor (k-factor) was calculated based on isometric fish growth, as shown by the analysis of the length-weight relationship (BAGENAL 1978):

$W = 0.04 \cdot L^{3.00}$ g; with $r = 0.97$ and $N = 275$.

As total weight is included in the calculation, the k-factor is influenced not only by differences in the fat content but also by the gonad weight and degree of fullness of the digestive tract. Because the gonad weight of juvenile fishes shows no seasonal changes, only the degree of fullness of the digestive tract might mask the changes in the fat content. For this reason, CLARK (1928) proposed that a second corpulence factor be calculated based on the weight of the gutted fish. This factor was also determined for a total of 235 fishes.

The liver-somatic index (LSI) provides the percent proportion of the liver weight relative to the weight of the rest of the body. It is thus a measure of liver size. The LSI was calculated for a total of 239 fishes.

The glycogen-somatic index (GSI) is the percentage of liver glycogen by weight relative to the rest of the fish body. It was calculated for a total of 179 fishes.

2.4. Crude nutrient analyses

The parameters included in the chemical determination of the filets and livers were: protein, fat, ash, and water content. For the liver: the glycogen content was also recorded.

The nitrogen content was determined by the Kjeldahl method, and the result was multiplied by 6.25 to estimate the amount of crude protein present (DOWGIALLO 1975). The amount of crude fat present was determined by 18 hour extractions of the samples with petroleum ether in a Soxleth apparatus (PALOHEIMO 1969). To determine the dry weight, the samples were desiccated in a constant temperature oven at 110 °C for 24 hours. The ash content was recorded after combustion in a muffel oven at 540 °C. Before the analyzes, the filets were ground in a meat grinder. A total of 27 fishes were analyzed. All results are based on dry weights.

Because of the lack of suitable facilities in the field, the liver glycogen content could not be analyzed directly and was determined instead by calculation. The difference between the initial dry weight and the sum of the crude protein, crude fat, and crude ash weights was assumed to be the glycogen content (ALBRECHT 1966; ALBRECHT & BREITSPRECHER 1969).

A total of 200 samples were analyzed. All results are given as percentage of dry weight. Monthly averages were recorded from the individual values (mean ± SE).

3. Results

3.1. Condition factors

With règards to the corpulence factor, large changes in the fat content can be detected indirectly. The assumption was made that of two fishes of equal length, the heavier is in better condition because the greater weight results from a higher fat content. For this reason, it has become a common practice to call the condition factor the "fat factor" (BAGENAL & TESCH 1978).

The monthly averages for this factor based on the total and the gutted weight are shown in figure 2. For the values based on total weight, the standard deviations from the averages are also depicted. When the months of January and February 1979 are ignored, both curves run parallel to the abscissa, since the values from March to October remain generally constant, and then begin to decrease slightly.

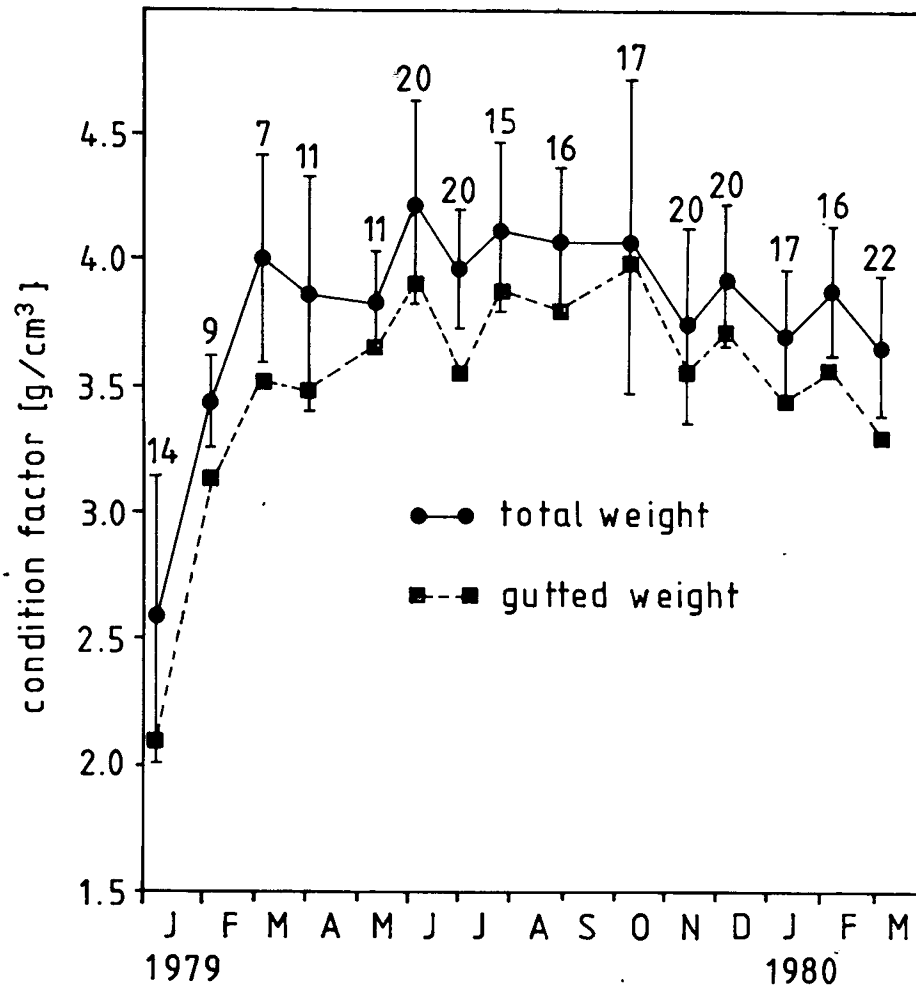

Fig. 2:
Seasonal changes in the corpulence factor of tambaqui (*Colossoma macropomum*) from Lago Manaquiri. All values given are mean ± SE. Sample sizes are indicated by numbers above the points.

The influence of the seasonal changes in visceral weight on the corpulence factor cannot be detected using this method of illustration. However, because the difference between the curves is the weight of the viscera, the percentage of this weight in the total can be calculated. The average monthly values are depicted in figure 3. The line connecting the monthly averages approximates a sine curve that obviously shows a general similarity with the curve for the water level. In order to determine whether the fluctuations were due only to the differences in the degree of stomach fullness or whether the visceral fat content was responsible, a statistical test was conducted to see if a relationship exists between the weight of the viscera and the degree of stomach fullness. It was determined that these two values are positively correlated with a probable error smaller than 0.001 %. From these results it can be assumed that the degree of stomach fullness has the main influence on the visceral weight.

An analysis of these data shows that the corpulence factor of juvenile fishes from Lago Manaquiri remains generally constant throughout the year, and that the seasonal fluctuations in the degree of stomach fullness is reflected in the percentage of the visceral weight in the total. However, the low k-values found at the beginning of 1979 show that the relationships do not remain as consistent every year.

3.2. Chemical content of the body

Analyses of the body contents revealed changes in the composition of the tambaqui filets during the period of decreasing water levels. The results are presented in table 1. While the fat and water contents remained nearly constant, a definite, steady decline in the protein content of the filets was detected. The proportion of protein decreased significantly in the course of a half year from 88.2 % in July to 72 % in January. This is a decrease of about 16 %.

Table 1: Changes in the composition of the tambaqui (*Colossoma macropomum*) filets during the period of decreasing water level.

month	n	water (%)	crude protein (% dry weight)	crude fat (% dry weight)
July (1979)	4	81.6 ± 0.6	88.2 ± 0.3	0.9 ± 0.1
August	4	88.3 ± 0.1	88.3 ± 0.1	1.1 ± 0.2
October	5	80.5 ± 3.3	80.5 ± 3.3	1.1 ± 0.2
November	5	81.6 ± 6.4	81.6 ± 6.4	1.1 ± 0.1
December	5	76.2 ± 2.2	76.2 ± 2.2	1.5 ± 0.1
January (1980)	5	72.0 ± 4.2	72.0 ± 4.2	1.2 ± 0.1

3.3. Liver composition

The monthly averages for the liver-somatic indices (LSI) are depicted in figure 4. It is apparent that the plotted values somewhat resemble a sine curve. They vary between 0.99 and 2.70 %. The minimum value was recorded in December. Thereafter, the LSI together with the water level increased, slowly at first, then more rapidly. This increase was first detected in 1979, and it repeated itself the following year. The maximum values were reached in April. There was a significant difference of the LSI between the low-water

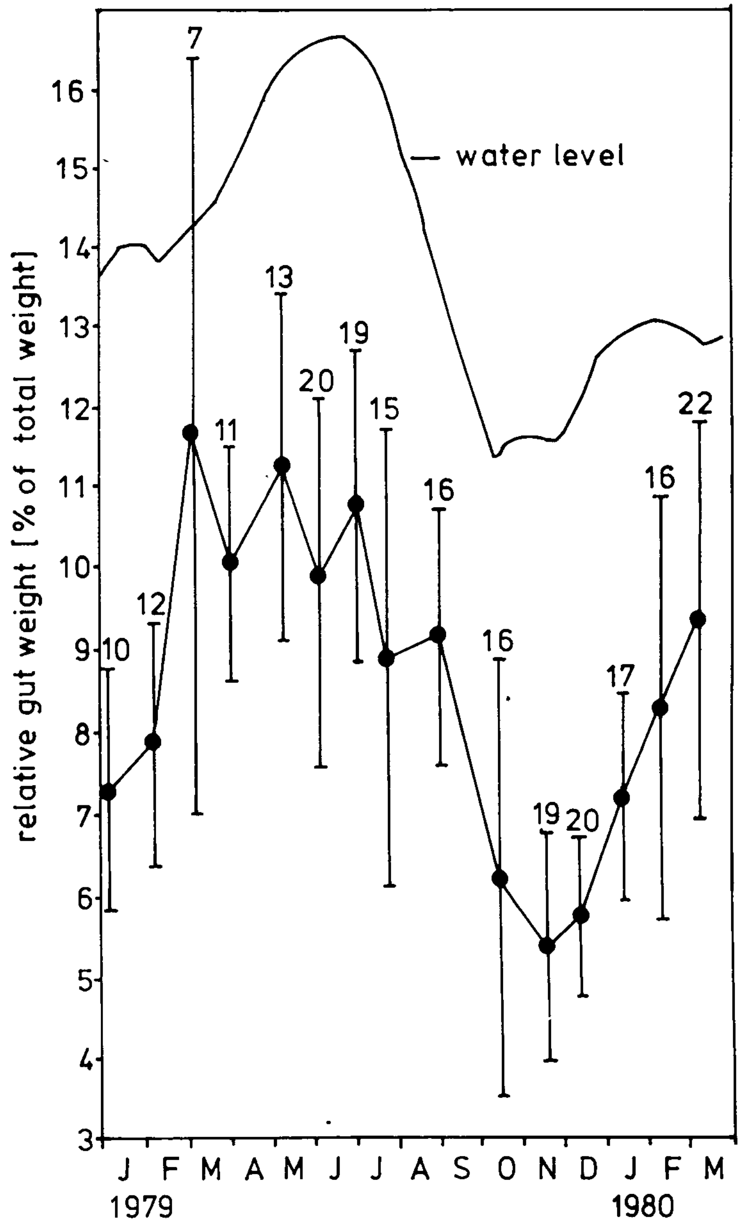

Fig. 3:
Relative gut weight of tambaqui (*Colossoma macropomum*) from Lago Manaquiri. All values given are mean ± SE. Sample sizes are indicated by numbers above the points.

(mean = 1.08, SE = 0.23) and high-water (mean = 1.87, SE = 0.54) period. It is notable that the increase in the liver mass from December to April is steady and rapid, while the decrease is slow and passes through several stages. The lowest standard deviations from the mean, and therefore the least scattering of the values, were found during the low-water period (November to January), while the LSI was decreasing (May to July). That indicates that the decrease in the LSI of all investigated fishes occurred more uniformly than its increase.

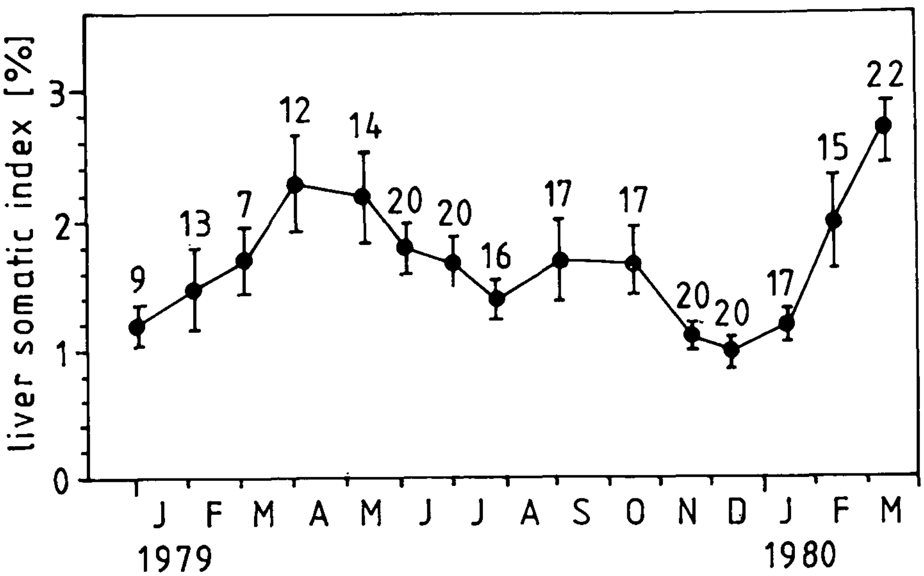

Fig. 4:
Seasonal changes in the liver-somatic index (LSI) of tambaqui (*Colossoma macropomum*) from Lago Manaquiri. The LSI is the liver weight as a percentage of the weight of the fish. The values are given in percentage of dry weight (mean ± SE). Sample sizes are indicated by numbers above the points.

The seasonal changes in the liver composition are depicted in figure 5. Considerable fluctuations were observed in the protein, the glycogen, the fat and the ash content. The glycogen content decreased from February to June, and thereafter steadily increased again. An indication that this is not a random fluctuation but rather a pattern of change that repeats itself regularly is the increase in the glycogen content at the beginning of 1979, and the repetition of this increase the following year. Opposite changes occured in the protein content.

Naturally the relationship between the liver composition and the LSI must be established. It is of fundamental importance to know how much glycogen is available as energy reserve during the hunger phase. For this reason, the glycogen-somatic index (GSI) was calculated, and its seasonal changes are illustrated in figure 6. It is apparent that the curve is very similar to that for the LSI (Fig. 4). The glycogen reserves increase from January to

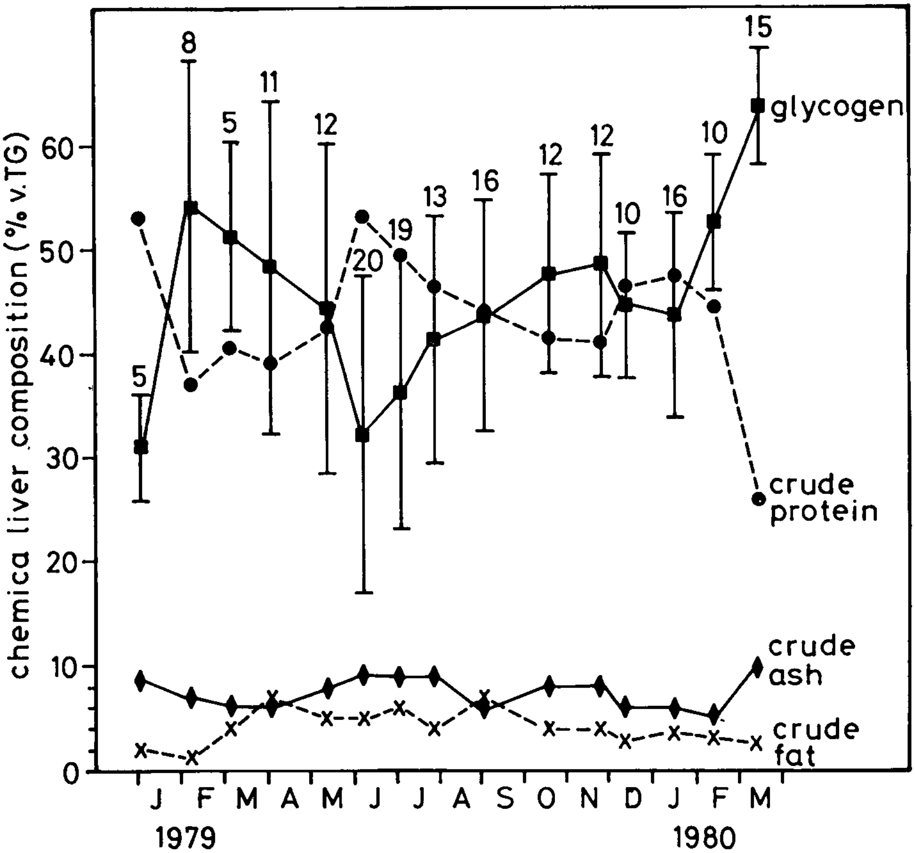

Fig. 5:
Seasonal changes in the percent composition of livers from the tambaqui (*Colossoma macropomum*) taken from Lago Manaquiri. The values (mean ± SE) are given as percentage of dry weight. Sample sizes are indicated by numbers above the points.

May. During the next two months, the values show a sharp decrease, and then, after a brief period of increase, reach their minimum in December. Thereafter, as during the previous year, the GSI increased again with the start of the new year. The differences between low-water and high-water period are significant. Thus, the changes in the LSI can be accounted for by the storage or the release of glycogen from the reserves.

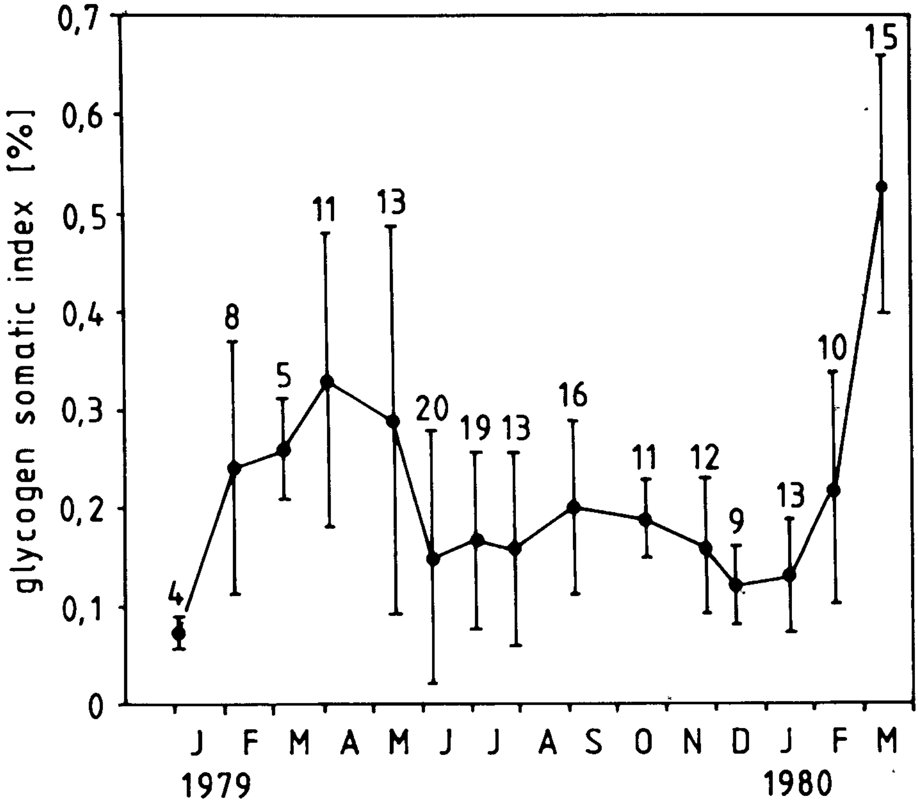

Fig. 6:
Seasonal changes in the glycogen-somatic index (GSI) of tambaqui (*Colossoma macropomum*) from Lago Manaquiri. The GSI is the glycogen content of the liver as a percentage of the weight of the fish. All values given are mean ± SE. Sample sizes are indicated by numbers above the points.

4. Discussion

The annual fluctuations in the water level of the Amazon River system change the living conditions of the ichthyofauna to an extent similar as to the climatic variations in the temperate zones (JUNK 1983). During the high-water phases terrestrial regions are converted to aquatic habitats suitable for fishes. The flooded várzea forest then provides a large food supply for frugivorous species (GOULDING 1980). The falling water level reduces the size of the habitat for fish drastically. For example, Lago Manaquiri becomes 67 % smaller (SAINT-PAUL 1982). Since only the adult tambaqui migrate into the river system, there is a considerable increase in the population density of the sexual immature fishes in the lake at this time.

These changes in the living conditions are reflected by the degree of stomach fullness and the nature of its contents, as shown by the investigations of GOULDING & CARVALHO (1982). Due to a greatly reduced food supply during the low-water periods, the fish must metabolize their reserve materials to meet their energy needs.

These observations have also been made in other tropical floodplains. The fishes in the Mekong River system consume no food during the dry season (CEVEY & LE POULAIN 1940). Similar findings were made during investigations of seasonal changes in the corpulence factor of *Tilapia zillii* (Cichlidae) and *Alestes leuciscus* (Hydrocynidae) from the Niger (DAGET 1956, 1957) and fishes from the Shire (WILLOUGHBY & TWEDDLE 1977).

The results of the present investigation corroborate only to some extent the hypothesis that the chemical composition and condition of the body reflect dietary changes in the juveniles. Nutritional investigations have shown that the low-water phases are hunger periods for these fishes (GOULDING & CARVALHO 1982; SAINT-PAUL 1982). The degree of stomach fullness decreases to 10 %, and detritus becomes the most important food item. The analysis of the condition factor, however, showed that it remains relatively constant and that there are no significant changes in the visceral fat content of the juveniles throughout the year. For adult tambaqui visceral fat concentrations of up to 10 % of the total weight are recorded (CASTELO et al. 1980). These fishes, however, have a greater energy demand at this time because the spawning season coincides with the period of low-water.

During the period of decreasing water level the fishes must have metabolized protein as a reserve material as could be shown by the steady decline in the protein content of the filets.

The results show that the liver of the tambaqui is a very important depot for glycogen, which serves as an energy source during the low-water period when there are shortages of food. The glycogen content of fish livers can reach 0.5 to 1.5 % of the total weight (SHUL'MAN 1974). The glycogen-somatic indices (GSI) found for the tambaqui were somewhat lower, ranging from 0.1 to 0.5 %. The glycogen content of the liver, on the other hand, was relatively high at 30 to 60 % of the liver weight. SHUL'MAN (1974), in his review of the significance of glycogen as a storage material in the energy metabolism, concluded that this substance is mobilized especially frequently when the energy demand is suddenly increased. In this process, glycolysis plays a special role as the means of energy release, and the significance of anaerobic metabolism in fishes was investigated by BLAZKA (1958), HOCHACHKA (1961), HEATH & PRITCHARD (1965), HOCHACHKA & SOMERO (1973), JOHNSTON (1975), and HEATH et al. (1980).

If glycogen is used by the tambaqui in this way, a decrease in the GSI could be expected during the periods when this fish lives at low oxygen concentrations, i. e. during February and March and from May to July, as shown by SAINT-PAUL (1984). According to the findings presented here, this is actually not the case. However, to prove the prevalence of one particular metabolic pathway, direct glycogen determinations together with analyses of the pyruvat-lactate relationship are necessary. Only with this the occurence of anaerobic metabolic processes can be proved.

A single plant species (*Oryza perennis*) plays a vital role in the recovery of young tambaqui after a period of hunger during the low-water period. As soon as the grain begins to ripen in January or February, the fishes start to consume it, which is reflected in the increase in the liver-somatic and glycogen-somatic indices as well. The supply of reserve materials that was reduced during the hunger period is replenished this way.

The importance of this plant in the recovery of the tambaqui is also reflected in the extremely low values of the corpulence factor in January and February 1979. Because

Oryza perennis can only develop on land from which the water has receded during the low-water period, the area on which it produced grain in 1978 was much smaller than that during the following year. The minimum water level in 1978 was 2.60 m higher than it was in 1979, and the exposed soil regions were therefore smaller. It is possible that the lower *Oryza* grain production in 1978 was responsible for the observed changes in the condition factor of the tambaqui. If there is a delay and a reduction in the production of this grass, the improvement in the condition of the starved fishes can be prevented, with fatal results.

The data presented clearly show that the young tambaqui are dependent on the flood-plain macrophytes and forest for fruits and seeds. A sufficient quantity of the grain of *Oryza perennis* seems to be especially important for the condition improvement after food shortages during the low-water period. A change in the seasonal water level fluctuations, caused by deforestations, would destroy the food sources for fruit and seed eating fish species. As there are no alternative foods, a recovery of the condition of this species would be endangered. The extinction of such a species could be a consequence.

5. Resumo

Fluctuações anuais do nível de água no sistema fluvial do Amazonas modificam as condições de vida do juvenil *Colossoma macropomum.* Devido a uma oferta extremamente reduzida de alimento nos períodos de nível baixo de água os peixes são obrigados a metabolizar suas reservas para cobrir a necessidade de energia, o que foi possível demonstrar pela redução dos dois fatores: do índice somático de glicogênio e da percentagem de proteína do filé. Na gordura visceral nenhuma alteração foi descoberta. Quando o nível de água começa aumentar, os sementes de *Oryza perennis* (Gramineae) estão a disposição para alimentação do peixe, e consequentemente foi descoberto um aumento no conteúdo glicogénico do fígado. Uma produção retardada ou reduzida de *Oryza perennis* impede um melhoramento na condição do peixe.

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