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LATERAL MIGRATION OF FISHES ON A FLOODPLAIN SYSTEM IN THE CENTRAL AMAZON (CAREIRO ISLAND, LAKE OF REI) AM, BR. PRELIMINARY ANALYSES

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RESUMEN

Las áreas inundadas a lo largo del río Solimões-Amazonía en la Amazonía Central son fundamentales para la pesca regional. Muchas especies de peces presentan una estrategia migratoria adaptada para grandes variaciones en el medio ambiente acuático relacionadas con fluctuaciones en el nivel del agua.

Para el estudio de migración lateral de peces en el sistema de "várzea" en la isla del Careiro, fueron adaptados varios métodos de investigación: observaciones directas, pescas experimentales, datos de pesca comercial, de subsistencia y datos biológicos. Al inicio de aguas bajas, en septiembre, los peces efectúan una migración lateral del lago de "várzea" en dirección al lecho principal del río Amazonas, huyendo de los predadores y buscando mejores condiciones de agua y de alimento. Al comienzo de la inundación, en diciembre, se observa otra migración lateral también del lago en dirección del río, donde las especies presentan un desarrollo gonadal bastante avanzado. Después del desove, los peces adultos retornan dispersos para la "várzea". Los factores unidos a este patrón de migración son discutidos.

SUMMARY

Floodplain areas along the Solimões-Amazon river in the Central Amazon are essential to the regional fisheries. Many fish species present a migratory strategy adapted to the great variations in the aquatic environment related to fluctuations in water level. To study the lateral migration of fish in the floodplain system of Careiro island, four kinds of data were used: direct observations, experimental capture, subsistence and commercial data and biological observations.

In September, at the beginning of the low-water period, many fish species make a lateral migration from the lake in direction of the main channel of the river Amazon, thus escaping from predators an from adverse conditions in water quality an food supply.

Another lateral migration takes place at the very beginning of the rising waters in December. The movement was also from the lake in direction of the river and the specimens showed a high level of gonadal maturity pattern. After spawning, adults fishes disperse and return to the "várzea".The factors associated to this migratory pattern are discussed.

INTRODUCTION

Floodplain areas are the most productive areas in the tropics and as such support large-scale fisheries in tropical regions of the world. Since fish is the main source of animal protein in the Amazon, the importance of floodplain fisheries is obvious. Most of the flooded areas in the Amazon are located along the white (turbid) waters of the Solimões-Amazonas and 90% of the commercial fishes caught in the Amazonas state are from these areas (Junk, 1984).

Many important food fishes of the Central Amazon flooded areas are migratoy and move periodically in large schools from one place to another. Fish species present a migratory strategy adapted to the great variations in the aquatic environment related to fluctuations in water level.

The term migration has many definitions. Dingle (1980) defines migration as the act of moving from one spatial unit to another. To Smith (1985) migration would be adaptative, long distance movements that presumably occurs in the life cycle of the species. In this paper we followed Gauthreaux's (1980) definition who considers migration as a specialized behavior evolved to allow the displacement of individuals in space. In this sense accidental or occasional movements are excluded and specialized behavior is considered.

The freshwater fishes in the tropics (South America, Africa and Asia) are subject to alterations of the environment, such as deoxygenation, food scarcity and high predation pressure. The migratory movements seem to be correlated with these alterations and apparently occur in order to minimize their effects. In this respect migrations contribute to increase growth, survival, abundance and consequently the productivity of the migratory species.

Daget (1958) characterized two main types of migration for African fishes which are applicable to movements of fishes in any seasonally flooded river. Longitudinal migration occurs up and down along the main river channel. Lateral migrations are those which whereby fish leave the main channel and distribute themselves over the floodplain (Welcome, 1979) and vice versa.

Migrations of fishes in the Amazon have been mentioned or described by Lowe-McConnell (1987), Godoy (1979), Worthman (1981), Goulding (1979, 1980, 1983), Ribeiro (1983), Zaniboni Filho (1985) and others, but in spite of being mentioned and defined, lateral migration was never studied in detail.

Based on the study of migratory movements of fishes of the Lago do Rei System, it was possible to characterize and propose a general hypothesis about patterns of lateral migration in the area. We hope the results obtained in this paper can contribute to a better understanding of lateral migration in the Amazon.

STUDY AREA

This work was carried on Ilha do Careiro, a floodplain island located near the meeting of the blackwater of Río Negro with the whitewater of Río Solimões (about 3°05' - 3°12'S and 59°35' - 59°50'W). The island is washed to the north by the Río Amazonas and to the south by the Paraná do Careiro (Figs. 1- 2). It has an area of 470 km² (Anonymus, 1988).

The Lago do Rei System is formed by the lakes and flooded areas which are connected with the main "trunk" formed by the Lago do Rei and Paraná do Rei. Paraná do Rei is the largest feeding channel to the system; it never dries out even during the dry season. There is an intensive movement of fishing boats, canoes and people through it and during some months the current is very strong carrying large quantities of organic material (logs, floating madows, etc.) either from lago do Rei or from the Amazon itself. Annibal (1983) has described Paraná do Rei as an ecologically unstable environment characterized by large scale variations in the rate of motion and direction of the current. He also emphasized the variations of the limnological characteristics and the strong interaction with allochthonous detritus that exists in the Paraná due to its connection with the peripheral surroundings. As the principal connecting channel between the main river (the Amazonas) and the lake (Lago do Rei) it is expected that the fishes use the Paraná for their lateral migrations.

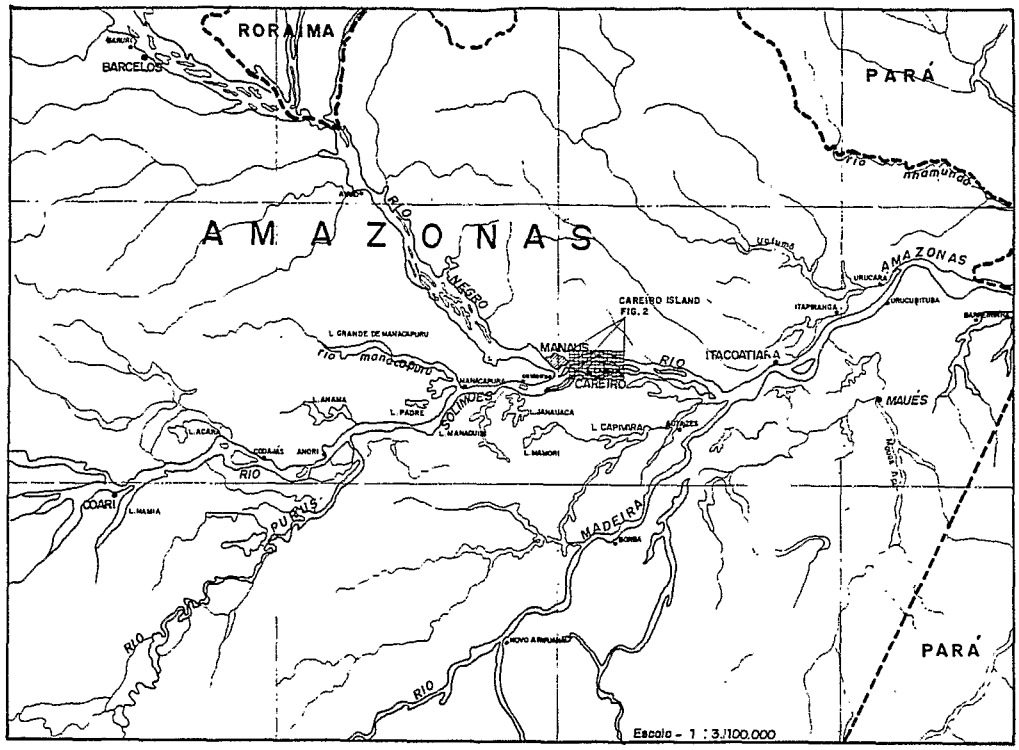

Figure 1
Location of Careiro Island

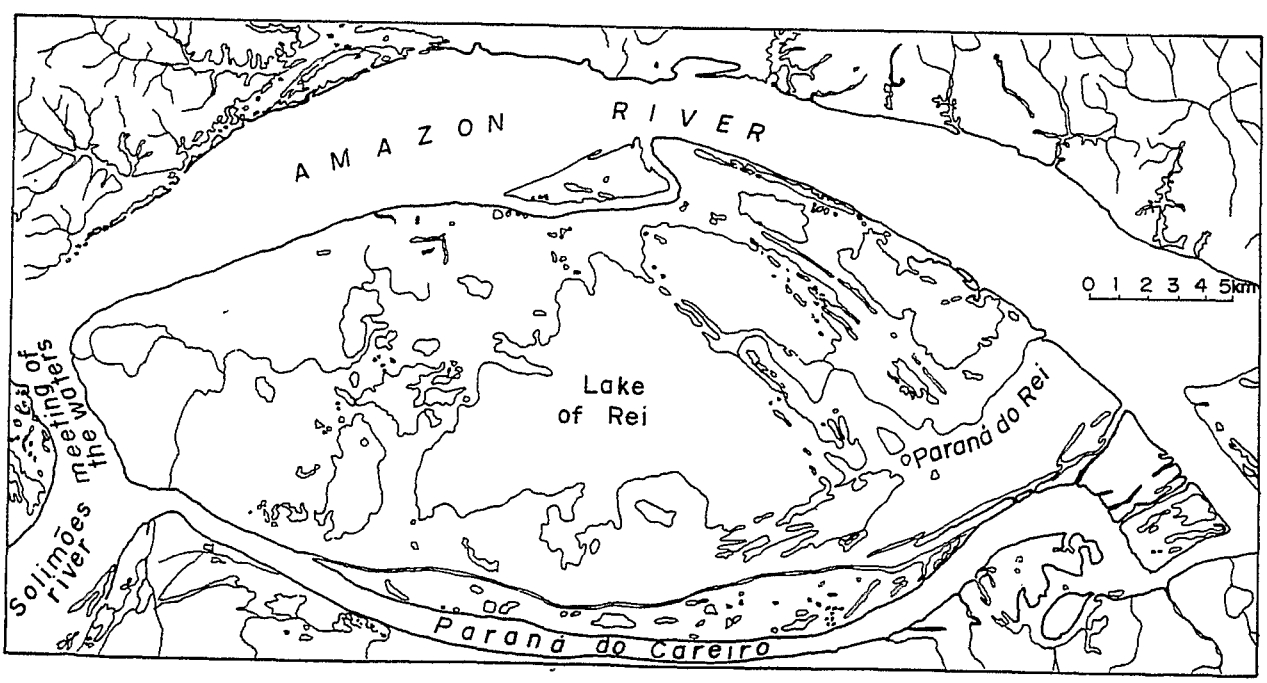

Figure 2
Careiro Island and main localities

In this paper the main migratory pelagic species of the Lago do Rei System are identified, their biological conditions evaluated and the results tentatively associated and used in connection with ecological factors to characterize lateral migration.

METHODS AND MATERIALS

Experimental fisheries

Tagging methods have not been used in this study. Attempts to carry on tagging experiments in the Amazon have not been successful (Godoy, 1979; Worthman, 1982; Carvalho, 1983). The very low percentage of recaptures (Petrere, 1985) is due to many factors of which high mortality rates and the vastness of the area (which facilitates dispersal) play an important role. In addition, low and irregular population densities make the contact with fishermen extremely difficult and their cooperation in returning tagged fishes is almost impossible.

Following the advice of the fishermen, traps and other fishing artifacts were not used due to unfavorable local conditions (traffic of fishing boats, strong currents and presence of logs on the bottom).

For the purposes of this work we concluded that conventional fishing methods would give the best results and decided to use "drifting gillnets" which were stretched across the waterbody and maintained by two canoes (one at each end) in such a way that it could be drifted downstream following the direction of the current. Using this type of gillnet it was possible to determine the direction at which the fishes were moving by the time they were captured. Gillnets are very useful devices in shallow water and specially efficient to catch migratory fishes which become entangled when they move through the meshes (von Brant, 1984).

Cast nets were used to sample along the edges in parts where aquatic plants (macrophytes) were usually abundant. The common type was used during the low water period, but "ring" cast nets were used only during the flooded period.

A total of 27 field trips were made from August, 1985 to September, 1986. All the samples were obtained in the first third of the Paraná near the Río Amazonas. A series of gillnets (meshsizes 40, 60, 80 and 110 mm between opposed knots) were used and each one was left in the water for 15 minutes. When any gillnet was taken out of the water all entangled fishes were identified by their common names and had their positions in the net marked.

To express capture per unity of effort (CPUE) per fishing gear we "balanced" the area of the four different gillnets to 100 m². To evaluate the

evolution of the fishing gear and to calculate the curve representing CPUE per species, the effort was estimated on the basis of number of specimens caught per hour.

The tendency of movements of the fishes was obtained from their recorded position at the time they were removed from the gillnets. Two main directions have been established: (1) leaving the Lago do Rei System and (2) entering the system toward Lago do Rei.

The fisheries have been considered as independent replicas and graphically represented in terms of absolute abundance por month. Each month was statistically tested. Willcoxon's prove was the non-parametric method used and the probability varied according to the number of replicas per month (Siegel, 1985).

A representative collection of all the species was kept for identification purposes. The standard lenght (cm) and the weight (g) of all specimens captured were recorded. A random sample of 20 specimens of each species was used for sex recognition and sexual maturation. The specimens were partially dissected through an incision on the abdominal wall and sexual maturity was macroscopically determined in the field according to the following table (based on Nykolsky, 1963).

0 -IMMATURE - mating has never occurred; the gonads are small, thin and transparent.

1 -NON-MATURE - gonads thicker; but still poorly developed; sex recognition still difficult at this stage.

2 -MATURING - gonads enlarged; testes white, ovaries orange and ovules not yet visible to the naked eye.

3 -MATURE - ovules opaque and visible to the naked eye.

4 -PRESPAWNING - ovules translucent; sperm flows out when pressure applied.

5 -SPENT or POST-SPAWNING - ovaries long, usually folded but still occupying a large portion of the abdominal cavity; only scattered remains of reproductive cells.

The spawning period of the species was determined according to the method described by Vazzoler (1982).

Subsistence fisheries

Information on subsistence fisheries was obtained from data collected every day from July 1985, through June, 1986 in the Paraná do Rei. The data were analysed with a microcomputer Kaypro IV using the TURBO PASCAL

program. The total monthly production expressed in number of individuals is graphically represented (Fig. 5).

Commercial fisheries

Data from commercial fisheries are used only as additional information to the data obtained through experimental and subsistence fisheries. They were obtained from commercial catches arriving in the Manaus market (Merona & Bittencourt, in press). Water level data were obtained from Boletim Fluviométrico where daily information on the Río Amazonas water level at Ilha do Careiro are recorded. Average as well as minimum and maximum water level fluctuation every fifteen days were used. Information that could be useful to this study such as movement of fishing boats, presence of aquatic plants, birds, etc., were recorded as well as direct observation on fish migrations.

RESULTS

Evidence of lateral migration

During this study August and September corresponded to the period in which the water level dropped continuously and October and November to the low water period (Fig. 3). In December and January the water started rise and by the end of January there was a short stop, the water level stabilized

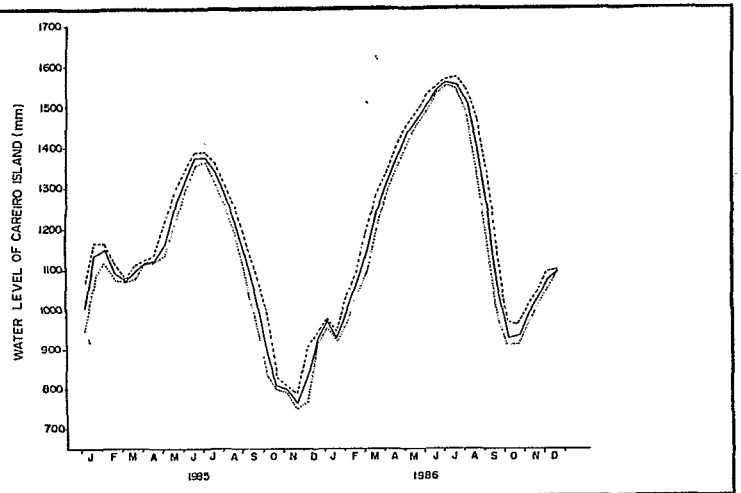

Figure 3
Maximum, minimum and mean monthly fluctuations of the water level of Careiro Island in 1985 - 1986

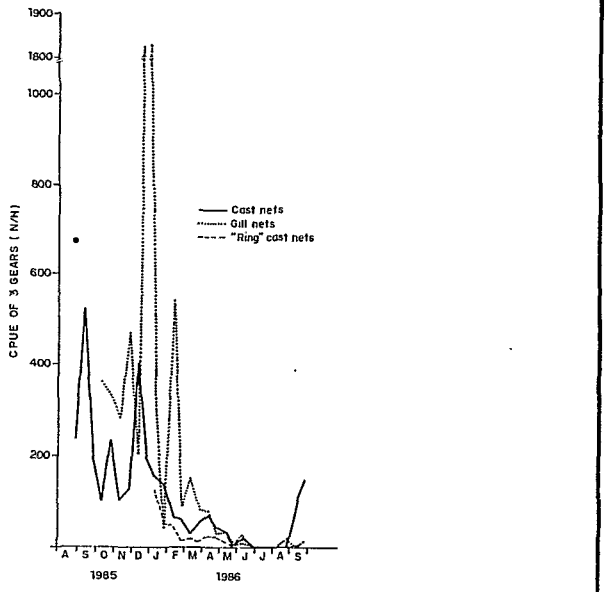

Figure 4
Evolution of the captures by the unit of effort from experimental fishing with 3 different gears

and dropped a little before rising again in February. This interruption of rising water is locally known as "repiquete". The peak flood level corresponds to July, closing the annual water level fluctuation in the area. Two peak floods can be recognized (Fig. 3): one in September and the other from the end of November to February.

We started our field work in August 1985 but it was possible to use the complete set of gillnets only in October. In August we used only one type of gillnet (mesh size 60 mm) and the total catch was significant. Since there is a good correlation among the catches produced by the different gillnets, it seems reasonable to extrapolate with some confident that a significant catch would have resulted from the utilization of a complete set of gillnets.

In December and January the CPUE reached its maximum peaks which corresponded to the period of rising water (Fig. 4). At the end of February the CPUE drastically decreased and became meaningless during the flooded period (May and July). Catches started rising again in August and September 1986 in connection with the beginning of another low water season.

In spite of the initial problems to collect the data to evaluate subsistence fisheries during the beginning of the first year, these data indicate highest

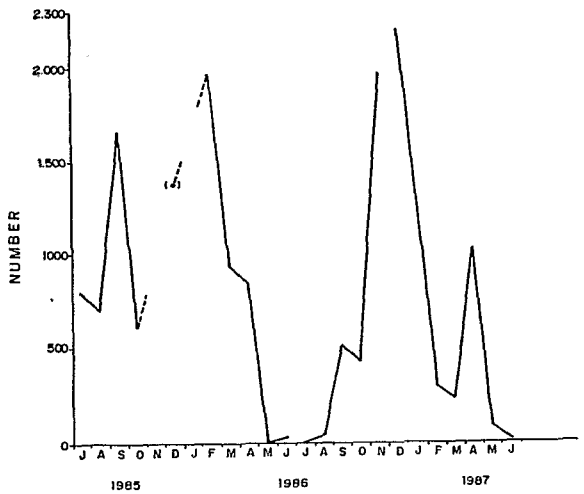

Figure 5
Monthly total production on number of individuals from fishing subsistence on the Paraná do Rei.

catches (represented by number of individuals) in September and in the period ranging from November 86 to January 87. These two peaks coincide with maximum peaks of CPUE (Fig. 5) indicating maximum abundance of fishes at certain times of the year in the Paraná.

The evolution (and evaluation) of fisheries in the Lago de Rei System with the use of gillnets and seine nets from 1984 to 1987 are shown in Figure 6. Catches obtained with seine nets are from Paraná do Rei where natural conditions favor the use of this fishing gear. It can be seen that in 1985 seine nets were responsible for highest catches in August and September and a little less in November and December.

The catches of the two main groups of fishes (sedentary and migratory) from Lago do Rei landed in the Manaus market from October 1984 to February 1987 are plotted in Figure 7. Data of curimatã was plotted separately because it is the most representative migratory species throughout the period. When Figures 6 and 7 are compared and superimposed it can be seen that the peak of utilization of the seine nets coincides with the peak of catches of the migratory species.

In 1986/87 the curves representing total landings are different from those of the proceding period clearly indicating that the behavior of the migratory species changes. It is important to emphasized that although

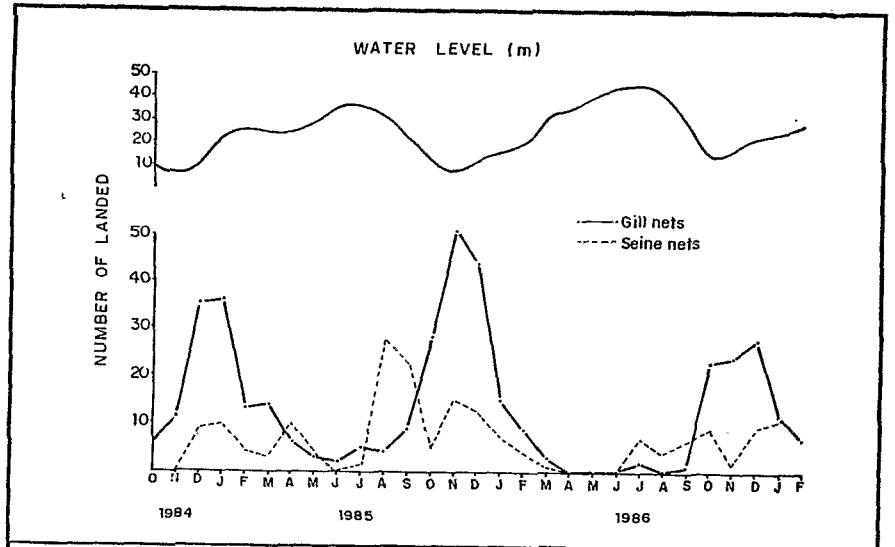

Figure 6
Utilization frequency evolution of gill nets and seine nets between October, 1984 and February, 1987. From Merona B. de, and Thery M., 1988. Etude de la pêcherie. In "Project Careiro", Rapport Terminal, Msc 375 p.

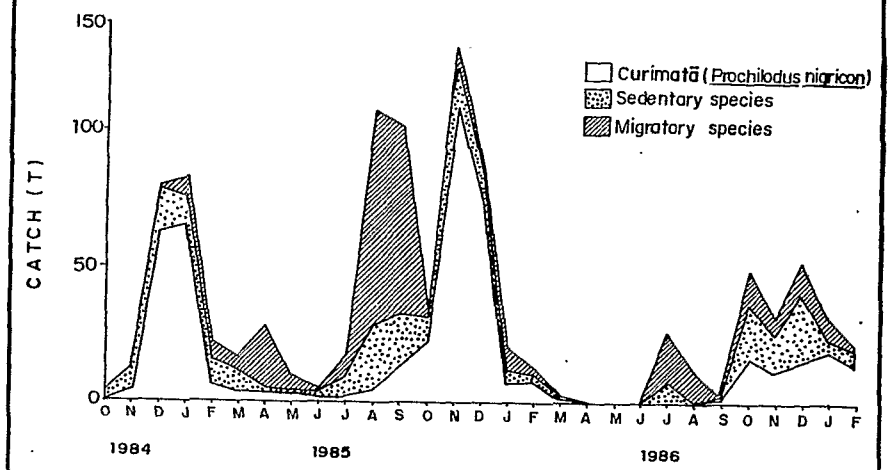

Figure 7
Evolution of capture on the lake of Rei landed at the Municipal Market of Manaus between October, 1984 and February, 1987. From Merona B. de, and Thery M., 1988. Etude de la pêcherie. In "Project Careiro", Rapport Terminal, Msc 375 p.

experimental fisheries have not been carried out every day, data derived from them can be considered accurate enough to be taken as representative of fish movements in the Lago do Rei System. The resulting catches of commercial fisheries corroborate the seasonality of migrations even though nothing can be said about exact time and regularity of occurrence during the year. This kind of information could perhaps be obtained only after some more years of study.

The main migratory species

During the experimental fisheries a total of 3724 specimens belonging to 80 species were caught. 18 species accounted for 88% of the total and were always represented by at least 30 specimens in every catch. Our study is primarily based on these species which are listed below according to the family they belong to.

Prochilodontidae: *Semaprochilodus taeniurus* and *Prochilodus nigracans.*

Curimatidae: *Potamorhina latior, Psectrogaster amazonica, Psectrogaster rutiloides* and *Curimata cyprinoides.*

Anostomidae: *Schizodon fasciatus* and *Leporinus trifasciatus* (the two species have been considered together).

Ageneiosidae: *Ageneiosus ucayalensis.*

Pimelodidae: *Pimelodus blochii.*

Hemiodontidae: Eigenmannina *melanopogon.*

Characidae: *Roeboides myersi, Triportheus albus* and *Triportheus angulatus.*

Cynodontidae:*Rhaphiodon vulpinus.*

Serrasalmidae: *Mylossoma aureum* and *Mylossoma duriventris.*

Pristigasteridae: *Pellona castelnaeana* and *Pellona flavipinnis.*

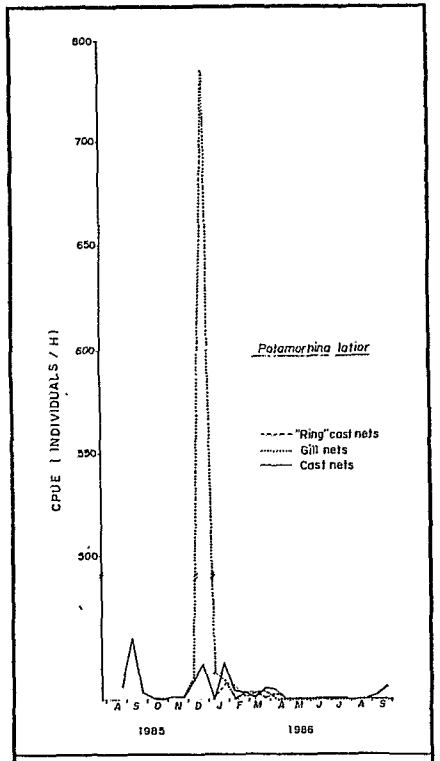

Figure 8
Capture evolution per unit of effort of *Potamorhina latior* captured from August, 1985 to September, 1986

The results of CPUE for each species reveal that two groups of species with different behavior patterns can be recognized. In the first group, represented by the species of the families Prochilodontidae, Curimatidae, Anostomidae, Ageneiosidae and Hemiodontidae, two peaks corresponding to maximum catches are always evident. In the second group no definite general pattern in discernible because the species included in it either shows only one peak or no definite peak at all.

Potamorhina latior (Vari, 1984) is perhaps the best representative of the first group. It is the most abundant species in the Lago do Rei System, it moves in large schools and for this reason was easily caught. The results of CPUE for this species (Fig. 8) shows a first peak of high catch in September, the castnet being responsible for catching the largest number of individuals per hour. The set of gillnets was incomplete (only the 60 mm mesh size used), but a slight elevation of catches with gillnets in noticeable in August. Direct observation of fish movements at the time revealed that this species migrated from Lago do Rei to the Río Amazonas. Large schools of *Potamorhina latior* were easily spotted moving on the surface of the water. The second major peak corresponds to the month of December and both the castnet and the gillnet accounted for its occurrence. The study of the tendency of movements of this species (Fig. 9) revealed that the schools left Lago do Rei and moved to Río Amazonas.

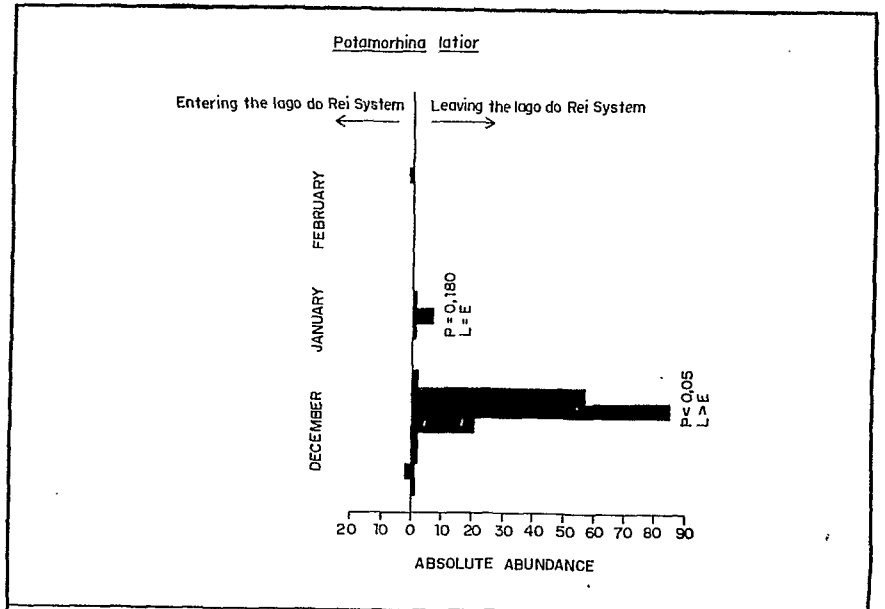

Figure 9
Tendency of the movements of *Potamorhina latior*

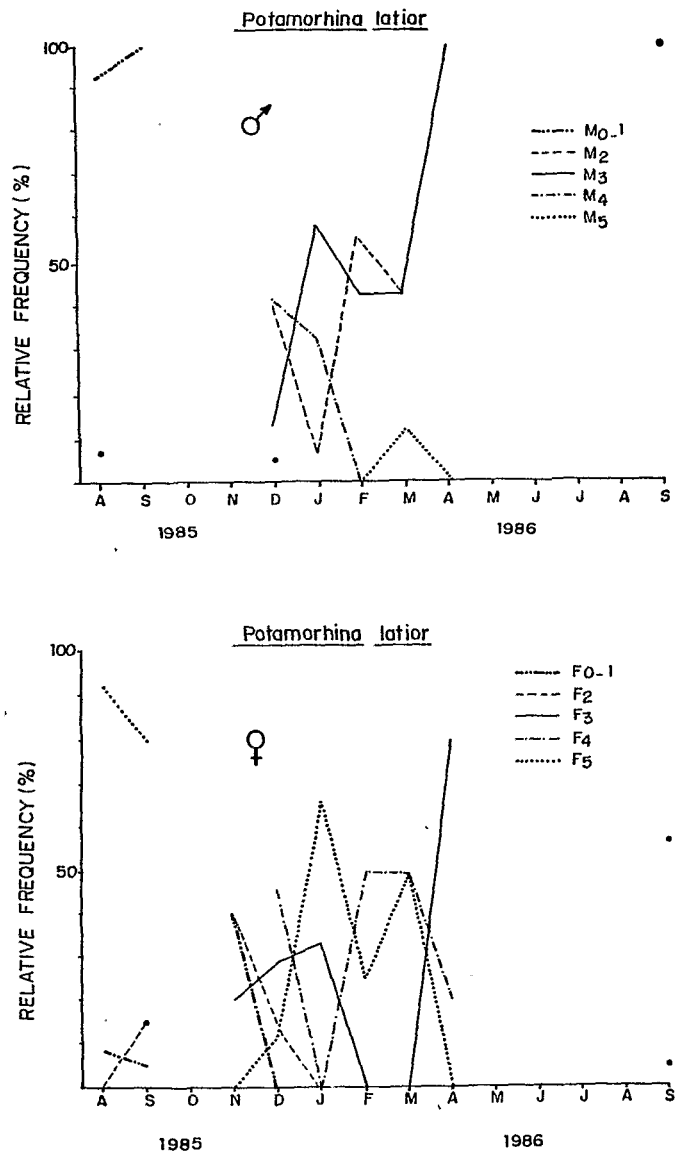

Figure 10
Monthly frequency distribution of the maturity stages for females and males of *Potamorhina latior*

The analysis of frecuency of stages of maturity of male and female gonads of *Potamorhina latior* based on the examination of 138 males and 94 females suggests that the spawning period of this species was between December and March (Fig. 10).

The combined results of catches, movements and reproductive behavior of *Potamorhina latior* obtained in this work indicate that it can be considered a typical migratory species with two main peaks of abundance in the Lago do Rei System.

The second group includes species of the families Cynodontidae, Pimelodidae, Pristigasteridae, Characidae and Serrasalmidae and although some differences with respect to the species of the last two families have been observed, the analysis of CPUE of *Pellona flavipinnis* (Whitehead, 1985) can be taken as representative of the main pattern for the group. The possible presence of a different pattern in species of Characidae and Serrasalmidae will be analysed in connection with other studies of "Projeto Careiro" which also involves fish communities.

Pellona flavipinnis was represented in almost all the samples obtained during the period the study was carried on. The analysis of CPUE for this species (Fig. 11) shows a peak of maximum catch in November. However, the species was regularly caught in Paraná do Rei from January through May.

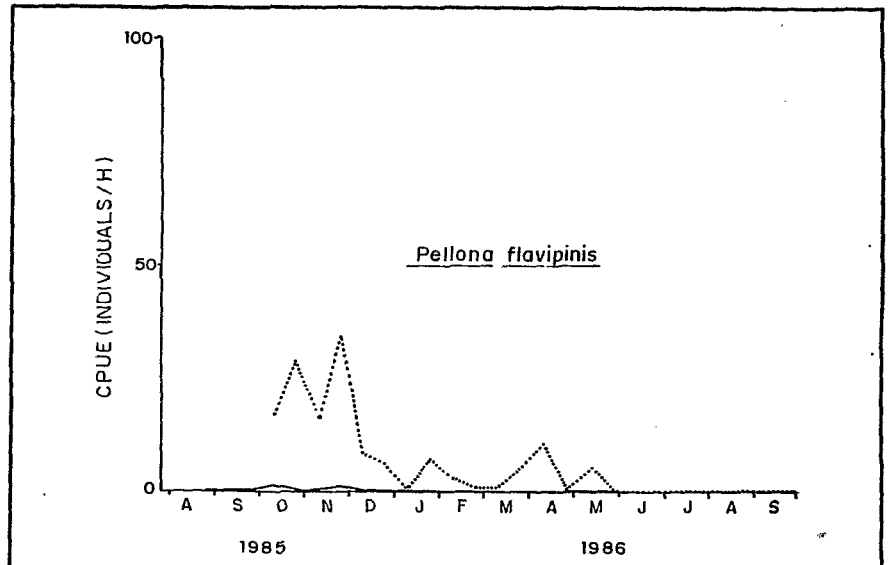

Figure 11
Evolution of the capture per unit of effort of *Pellona flavipinnis*

The study of tendency of movements (Fig. 12) revealed a statiscally significant difference in November, indicating that more fishes were moving in than going out of Lago do Rei. In the other months no significant differents were obtained.

Data obtained from the examination of 46 females and 25 males did not provide useful information on the spawning period and other reproductive aspects of *Pellona flavipinnis*. We could only suggest that spawning probably occurs outside the area and in this case a peculiar migratory pattern would be involved.

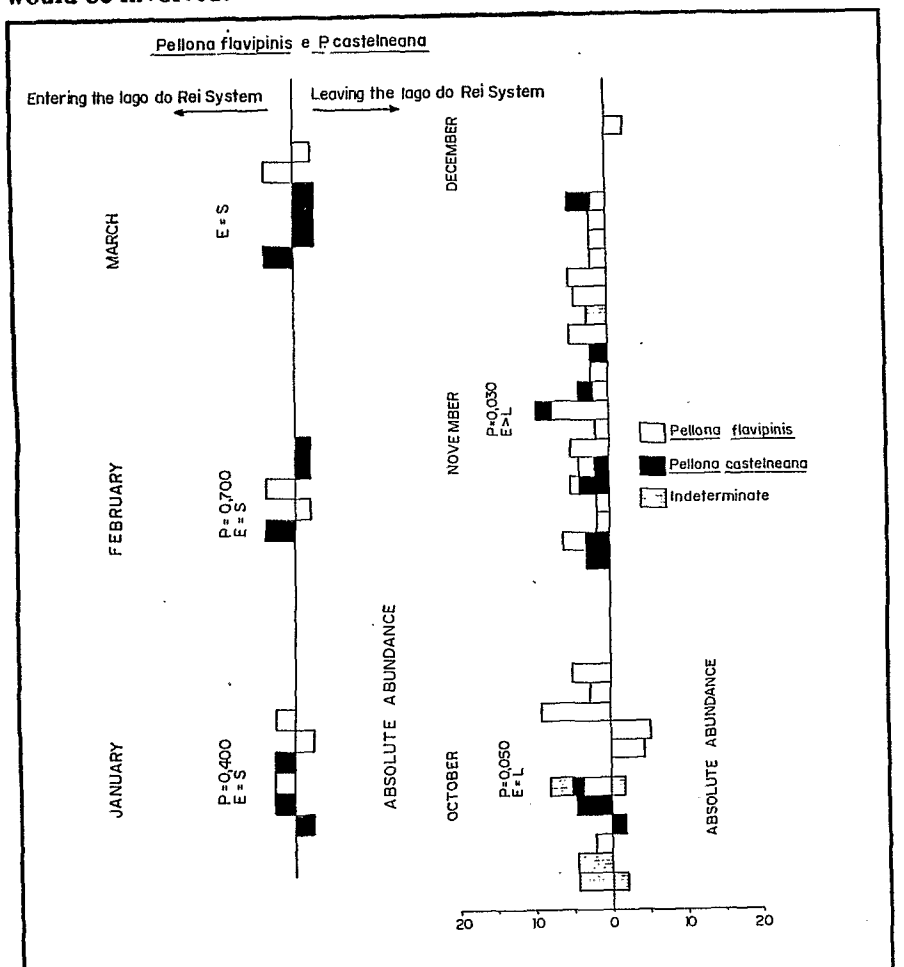

Figure 12
Tendency of the movements of *Pellona flavipinnis* and *Pellona castelnaeana*

DISCUSSION

The evaluation of fish movements in the Lago do Rey System derived from direct observation and also through the utilization of indirect methods (catches with drifting gillnets, data from commercial and subsistence fisheries and reproductive behavior of the species involved), was made having in mind that the individual inadequacy of each method would be compensated by their complementary contribution.

Bonetto *et al.* (1981) pointed out that the migratory movements of characiform fishes occur mostly through the middle and upper layers of the water and Harden Jones (1966) suggests that direct observation should be restricted to shallow-water rivers where movement of fishes near the surface could be easily detected. This method has been used in the Amazon in the study of migratory movements of *Semaprochilodus insignis* and *S. taeniurus* (Ribeiro, 1983), *Brycon cephalus* (Zaniboni Filho, 1985) and several species of the Río Madeira (Goulding, 1979). According to Petrere (1985) references to lateral and longitudinal migrations only through direct observation are made by some authors.

Even though we used data from direct observation of fish movements in Paraná do Rei, it was not possible to rely solely on this method because the water in the Paraná was turbid most of the year. Schools of fishes moving through the water surface were easy to detect but the species could never be accurately identified and the use of gillnets and other complementary methods seemed to be the only alternative.

With respect to indirect determination of fish movements through the position they were found in the meshes at the time thery were caught Harden Jones (1966) calls attention to the fact that strong winds may change the position of the boats during the catches and consequently the previously established position of the gillnets. This method, however, seems to be useful and was used by some authors (Johansen, 1927, 1964; Huntsman, 1936; Larkins, 1964; Bernaby, 1952; cited by Harden Jones, 1966) in the study of salmon and herring sea migrations.

In the Paraná do Rei the winds are not strong enough to affect boat and gillnet positions and the Paraná itself is relatively narrow (maximum width=100m). Thus, the results obtained with drifting gillnets can be considered satisfactory and the tendency of movements of the most migratory species could be accurately determined.

The results of our study indicate that there are two main migratory movements of species in the Lago do Rei System. The first one occurs during the falling water level and is characterized by the movement of migratory species from the floodplain to the main channel, the schools leaving Lago

do Rei toward the Río Amazonas. This migratory pattern is comparable to the upstream migration. Goulding (1980) characterized as "piracema" migration in the Río Madeira. The schools leaving the Paraná enter the Río Amazonas and move usptream in it, starting a typical longitudinal migration. We followed part of the upstream migration along the coast of Ilha do Careiro (coast of Marimba and Terra Nova) and suspect the schools move into the Amazonas in order to find temporary suitable conditions in the upper reaches of Río Solimões.

Some hypotheses have been proposed to explain similar movements of fishes out of lakes and other waterbodies in the Amazon. Santos (1978) studying limnological conditions in Lago Janauacá admits that a migratory movement of fishes that occurred in the area was caused by lack of space and food due to the lowering water level. According to him the migrations occur during the waxing moon. These informations, however, should be taken with precaution because they are not based on experimental work and as such may lead to erroneus conclusions. Our own observations indicate that during falling water the fishes are quite fat and shortage of food might not be a limiting factor. Junk (1984) stated that in floodplain areas during the low water season the fishes partially depend on fat stored during the flooded period and are forced to seek more open waters due to the decrease of suitable areas.

Others factors may influence fish movements out of floodplain areas. Odinetz-Collart and Moreira (in press) found minimum values for the oxigen content of the water in Lago do Rei System (station 1 in the Paraná and 2 in the lake) at the end of August and begining of September, 1987. The low oxygen rate in the water of the lake does not allow high densities of fishes and our observations indicated that on that period the fishes were not reproductive actively and had high fat storage which would enable them to undertake long migrations. If migrations do not ocurr high mortality rates are expected during the low water period and this has occurred in lakes and channels in tropical regions (Mago-Leccia, 1970). Lateral migration is certainly very important for the survival of fishes and we believe in addition to the above mentioned factors others have to be considered to understand the phenomenon. However, the reasons why the fishes leave Lago do Rei and how far up they move in the Solimões are beyond the scope of this work.

The second main migratory movement occurred during the rising water level in December and January involving species of the families Prochilodontidae, Curimatidae, Anostomidae, Agenciosidae and Hemiodontidae. We characterized it as reproductive or spawning lateral migration since the species examined were ripe. Since during the studied period the species that left Lago do Rei during the dry period were not seen coming back up into the system, we concluded that the species which remained in the lake completed gonodal development and started the spawning migration when the water

started rising. Junk (1985) found the lowest fat contents for *Triportheus elongatus*, *Semaprochilodus insignis*, *Mylossoma duriventris*, *Potamorhina latior* and *Potamorhina altamazonica*, exactly during this period. The route to Río Amazonas during the spawning migration was again Paraná do Rei but we found no evidences to determine the spawning area. Petry (personal communication) believes that in Paraná do Rei the ichthyoplankton is represented by precocious larvae originated by multiple stocks of species that breed above the "mouth" of the Paraná. Apparently then the main spawing area would be above the "mouth" of Paraná. Spawning migrations associated with the beginning of the flooded period were described by Goulding (1979) in the Río Madeira, Santos (1978) in Lago Jutaí near the Solimões and Junk (1984) in floodplain areas of Amazonian rivers. The migratory movements of fishes in these areas are from tributaries or lakes into the main rivers where the spawning areas are located and always start when the water level is rising. The association between spawning period and rising water is important to the passive movement of larvae from the spawning areas to the nursery grounds of the different waterbodies (lakes, tributaries, etc.). In the Lago do Rei System the first movements of ripe fishes occurred in December at the beginning of rising water level and in August/September the fishes started moving out of the system when the water level started falling, clearly indicating a direct relationship between migration and water level fluctuation.

In our study area, during the spawning migration period, sounds were emitted particularly by the curimatid species and although Junk (1985) suggests that sounds are useful to get the schools together it was not possible to determine their precise meaning.

The large amount of spent fishes in the Paraná is a good indication that after spawning they return to feed in the floodplain areas as indicated by Goulding (1980), Lowe McConnell (1987), and Villacorta Correa (1987).

It is during the flooded period that the fishes feed heavily to store fat to be used again during another migratory period.

The main migratory patterns we observed in the Lago do Rei System corroborate what is known in the literature about migrations of fishes in the Amazon. There are fishes that seem to react almost instanty to water level alterations moving to avoid unsuitable environmental conditions and others that are adapted to withstand such conditions.

Although certain aspects of fish migration have been clarified others remain a mistery. Strong rains and lunar rhythms seem to represent important stimuli for schooling of *Semaprochilodus insignis* and *S. taeniurus* during their spawning season (Ribeiro, 1983). To Araújo-Lima (1984) rain and lunar rhythms are apparently not related to spawning migration of fishes but the rapid rise of the water would trigger the spawning process. In the Lago

do Rei the migratory movement of fishes out of the lake coincided with maximum flood peak which ocurred between the new moon and the full moon; the movement started again in January during the first quarter moon phase. However, no clear long-term association of fish movement with lunar rhythms was detected.

To us it seems evident that fish movements in floodplain areas start with a lateral migration that is strongly influenced by water level fluctuation. However, we feel much experimental work is necessary before we can fully understand all aspects related with fish migration in these areas.

Migration or migratory aspects of fishes in the Amazon have been considered by many authors, some of them entirely based on occasional observations. We consider all the available literature information useful and important as a first step, but think that only long-term studies based on experimental work can provide the needed data for comparative purposes. These studies are urgently needed especially in areas where environmental changes are a big threat.

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