

Impoundment effects in the population of *Auchenipterus osteomystax* (Siluriformes: Auchenipteridae): a Neotropical reservoir case

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Abstract: New impoundments provide opportunities to check whether species that present enough feeding flexibility in natural conditions may take advantage of this situation and, without reproductive restriction, can occupy the most conspicuous habitat in a large reservoir (open areas) and present higher success in the colonization of the new environment. We examined variations in the abundance and feeding of *A. osteomystax* in two environments, one natural (Sinhá Mariana floodplain lake) and one dammed (Manso Reservoir), during two periods: the first year after the filling phase and three years later. Our goal was to evaluate the occupation of the new habitat (Manso Reservoir), by this species, as well as to test the hypothesis that in the reservoir, unlike the natural environment, there are remarkable changes in diet between the periods. Fish were sampled monthly in the floodplain lake and in the reservoir during two annual periods using gillnets. To evaluate the differences in abundance of *A. osteomystax* we employed the Kruskal-Wallis test, and the diet analysis was carried out using frequency of occurrence and volumetric methods. Temporal differences in the diet were tested by Kruskal-Wallis test using the scores from a detrended correspondence analysis. *A. osteomystax* was significantly more abundant in the floodplain lake, where the captures were higher than in the reservoir in almost all months analyzed, and significant variations in abundance between the two periods were not recorded in either the reservoir or the floodplain lake. The diet variation between the two periods, which had a time lag of three years between them, was much less pronounced in the natural environment, where the resource availability is essentially regulated by seasonality. Thus, our hypothesis was accepted; that is, the interannual variations in the diet of *A. osteomystax* are more relevant in an artificial environment than in a natural one. Rev. Biol. Trop. 60 (2): 699-708. Epub 2012 June 01.

Key words: pantanal, floodplain lake, feeding changes, insectivores.

Success in the colonization of new reservoirs by fish has been explained by morphological and behavioral pre-adaptations associated with the new habitat uses, diet, and reproduction (Fernando & Holcik 1991, Rodriguez-Ruiz 1998, Agostinho *et al.* 2008). The scarcity of pre-adapted species occupying the open areas in Neotropical reservoirs, which is certainly related to the absence of large lakes in the main river basins of South America, can explain the distribution of fish in such an environment, as they are concentrated

essentially in marginal areas (floodplain lakes species), and fluvial zones (rheophilic and migratory species). In general, this success is assessed by comparisons between pre- and post-impoundment (Benedito-Cecílio *et al.* 1997, Marques *et al.* 2009).

The catfish *Auchenipterus osteomystax* (Miranda Ribeiro, 1918) belongs to the restricted group of Neotropical species with morphological pre-adaptations that enable them to occupy the pelagic areas of reservoirs (body shape, orientation of mouth and eyes;

Agostinho *et al.* 1999). Abundance of the genus *Auchenipterus* in reservoirs during the first years has been reported (Ferreira 1984a, Benedito-Cecílio *et al.* 1997, Marques *et al.* 2009). Internal fertilization is a characteristic associated with its success in the occupation of impounded environments (Agostinho *et al.* 2008), besides its ability to incorporate, opportunistically, zooplankton in the diet (Mol *et al.* 2007). However, its abundance can be severely reduced after the heterotrophic period (Mol *et al.* 2007), suggesting that food availability is a key factor in this success.

Nevertheless, for a suitable understanding of the factors involved in this success we need to know the habitat and diet requirements in relation to the available resources in these environments. Reports about remarkable changes (temporal and spatial) in the diet of Neotropical fish have been frequently found in the literature (Araújo-Lima *et al.* 1995, Albrecht & Caramaschi 2003, Hahn *et al.* 2004), and they are related to the variations in the availability of food resources (Luz-Agostinho *et al.* 2006). These variations in natural aquatic systems are principally associated with the seasonality of hydrometeorological conditions (Kalk *et al.* 1979); consequently, the diet of fish in these environments is also highly seasonal (Welcomme 1979, Hahn *et al.* 2004). In natural environments, these changes are more or less predictable and gradual, allowing species to make better use of the resource thanks to their adaptations (Hahn & Fugi 2008). On the other hand, the formation of a reservoir changes the physical, chemical, and biological composition of the river, with several environmental effects (Mol *et al.* 2007, Agostinho *et al.* 2008), modifying or decreasing the seasonality to which the biota is adapted. Furthermore, the food availability changes on a plurianual scale in a reservoir as a consequence of alterations in nutrient concentrations (longitudinal and transversal stratification and exportation), productivity, biotic interaction, and dam operation. Thus, the formation of an impoundment provides excellent opportunity to test whether species that present enough feeding flexibility in natural

conditions may take advantage of this situation and, without reproductive restriction, can occupy the most conspicuous habitat in a large reservoir (open areas) and present higher success in the colonization of the new environment.

In the present study, we examined the variations in abundance and feeding of *A. osteomystax* in two distinct environments: natural (Sinhá Mariana floodplain lake) and dammed (Manso Reservoir), during two periods: the first year after the filling phase (Period I) and three years later (Period II). We intend to evaluate, through the variation in abundance, the occupation by this species of a new habitat formed by the Manso Reservoir as well as to test the hypothesis that in the reservoir, unlike the natural environment, there are remarkable changes in diet between the periods. This hypothesis is based upon the fact that reservoirs present great temporal changes in the communities and resources during the colonization (Agostinho *et al.* 1999).

MATERIAL AND METHODS

The study area is located in the watershed of Manso/Cuiabá River, Brazil, encompassing two lentic environments, an artificial one, Manso Reservoir (located in Manso River), and a natural one, the Sinhá Mariana floodplain lake, situated in the complex area of lakes and wetlands of the Pantanal of Mato Grosso (Fig. 1). The Manso Reservoir (14°32'-15°40' S and 54°40'-55°55' W) was created in November 1999 by flooding an area of 427km². About 80km downstream from the dam, the Manso River joins Cuiabazinho River, forming the Cuiabá River, which flows to lower regions, with a large catchment draining into the Pantanal of Mato Grosso, where the Sinhá Mariana floodplain lake (area=11.2km²) is located (Fig. 1).

Fish were sampled monthly in the reservoir and in the lake floodplain during two annual periods: Period I between March 2000 and February 2001 (the first year after the filling phase), and Period II between March 2003 and February 2004 (three years later). Fishes

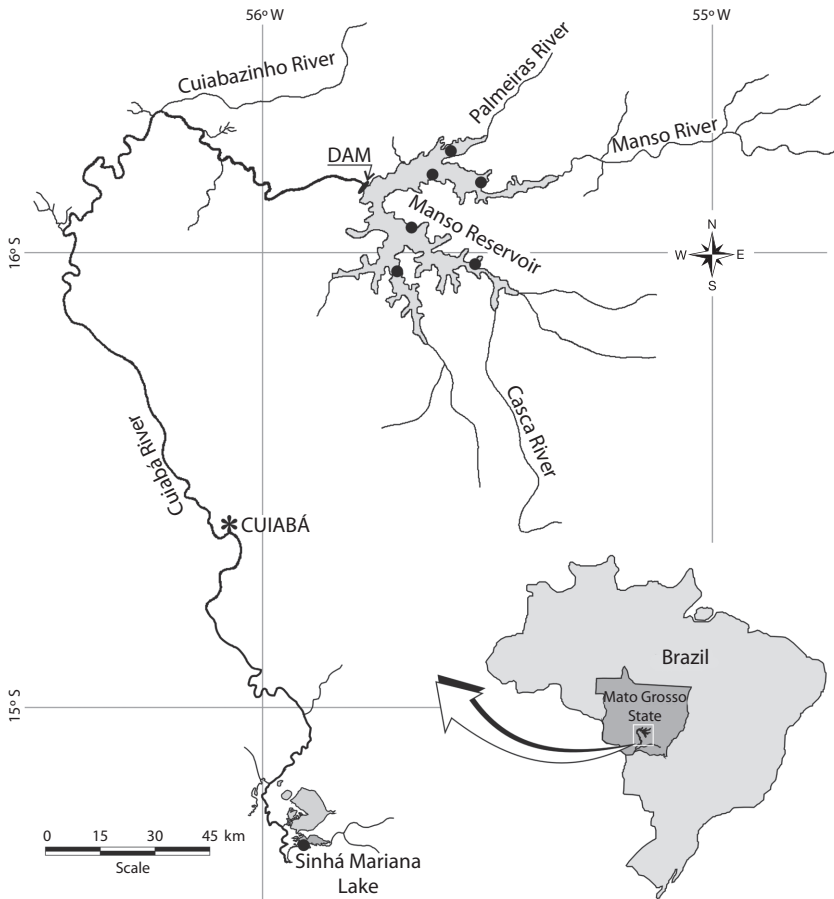


Fig. 1. Location of the sampling site (•) in the Manso reservoir and Sinhá Mariana floodplain lake, Manso/Cuiabá River, Brazil.

were sampled by a set of gillnets 10m long with different mesh sizes (12 nets; 2.4, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14 and 16cm opposite knots). Nets were set simultaneously in open areas, littoral areas, and at the bottom of the reservoir and in open and littoral areas of the lake during 24hr, and fish were removed in the morning (0800h), in the evening (1600h), and at night (2200h). Immediately after the capture, the fish were identified and measured and the stomachs were removed. The stomachs with food (n=295) were preserved in 4% formaldehyde for diet analysis. Voucher specimens were deposited at the Museum of the Universidade Estadual de Maringá, Paraná State, Nup. 928.

The abundance of *A. osteomystax* was expressed as the number of individuals captured by 1000m² of gillnet during 24hr (CPUE). In order to evaluate spatial (reservoir and floodplain lake) and temporal (Periods I and II) differences in the abundance, we employed the Kruskal-Wallis nonparametric test (Zar 1996), since the assumptions of normality and homogeneity were not reached. The evaluation of the *A. osteomystax* abundance at the surface (open areas), margin (littoral areas), and bottom was performed only for the reservoir, where the samplings were accomplished in the three habitats. The differences in captures were tested using the Kruskal-Wallis test, and when

significant differences were detected, the *a posteriori* test (multiple comparisons of mean ranks for all groups) was used. The significance level adopted was $p < 0.05$.

Stomach contents were examined, and to express the results on diet, volumetric (obtained by water displacement in graduated cylinders) and occurrence frequency methods (Hyslop 1980) were used, combined in the Alimentary Index (IA_i) proposed by Kawakami & Vazzoler (1980) and described by the equation: $IA_i = (F_i * V_i / \sum F_i * V_i) * 100$, where: $i = 1, 2, \dots, n$ food items; F_i = frequency of occurrence (%) of the item i , and V_i = percentage of volume of the item i .

With the aim of evaluating temporal differences in diet, we tested the scores of two detrended correspondence analyses carried out individually for the reservoir and floodplain lake (DCA-Hill & Gauch 1980). The matrix used in this ordination was based on the relative frequencies of the volume of food items. The scores from the DCA did not reach the assumptions of normality and homogeneity, and thus the diet differences were tested using the Kruskal-Wallis nonparametric test. The first axis of the DCAs was the only one retained for analysis, whose eigenvalues (0.65 to reservoir and 0.54 to floodplain lake) were greater than 0.20-Matthews 1998).

RESULTS

Auchenipterus osteomystax was significantly more abundant ($H = 5.97, p = 0.014$) in the floodplain lake, where the captures were higher than in the reservoir in almost all analyzed months (Fig. 2). We did not record significant variations in abundance between the two periods (I and II) in either the reservoir ($H = 1.6147, p = 0.2038$) or the floodplain lake ($H = 1.143, p = 0.285$). Nevertheless, a strong seasonal trend was observed in the floodplain lake, where *A. osteomystax* was more abundant in September and October in the two periods.

Significant differences in the abundance of *A. osteomystax* were observed between the habitats within the reservoir during both

Period I and Period II ($H = 13.73, p = 0.001$ and $H = 15.827, p = 0.0004$, respectively) (Fig. 3). The abundance was significantly higher at the surface in both periods (Period I: S and B $p = 0.0039$; S and M $p = 0.0046$; Period II: S and M $p = 0.0004$; S and B $p = 0.0005$), while the abundance of *A. osteomystax* was not different between the margin and the bottom in either period (Period I: $p = 0.9973$; Period II: $p = 0.9839$).

The diet of *A. osteomystax* was basically compounded by insects during the two study

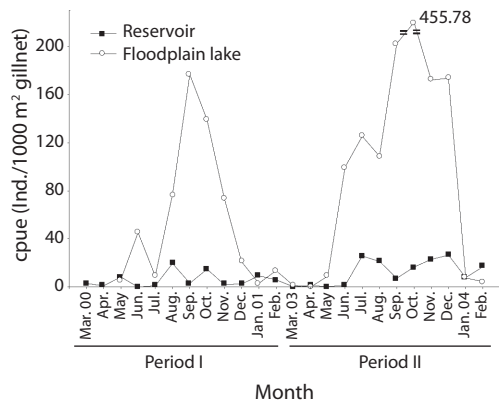


Fig. 2. Temporal variation in relative abundance (CPUE) of *A. osteomystax* in Manso Reservoir and Sinhá Mariana floodplain lake.

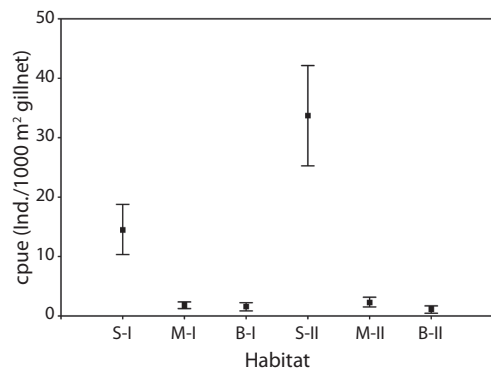


Fig. 3. Spatial variation in relative abundance (CPUE) of *A. osteomystax* in Manso Reservoir. S=surface, M=margin, B=bottom, I=Period I, and II=Period II (mean \pm standard error).

periods in both locations. Meantime, when considering inferior taxonomic levels, the similarity between the periods was observed only for the population from the floodplain lake. In relation to the population from the reservoir, besides the remarkable variation between the periods, the diet was also different from those in the natural environment (Fig. 4).

The differences in the diet between the periods were significant in the reservoir ($H=37.48$, $p=0.0001$). During Period I, Chaoboridae larvae was the dominant food ($IAi=76.1\%$), and in Period II, Chironomidae pupae, Hymenoptera, and Hemiptera were the most consumed items ($IAi=42\%$, 23% , 12.4% , respectively) (Fig. 5A, B, C). In Period II, Coleoptera and Chaoboridae were consumed in small amounts, but presented relevant occurrence in the diet (Fig. 5A). In the floodplain lake, we did not register a significant difference in the diet of *A. osteomystax* between Periods I and II ($H=0.513$; $p=0.4738$), and Ephemeroptera was predominant in both ($IAi=56.2$ and 74.2% , respectively) (Fig. 5E, F). Besides Ephemeroptera, the Chaoboridae larvae were an important food in Period I, totaling 34.8% of the diet, whereas Chironomidae pupae and microcrustaceans were important only in relation to the occurrence (30.3% and 27.3%, respectively) (Fig. 5D). Regarding Period II, there was a decrease in the consumption of Chaoboridae larvae ($IAi=3.6\%$) and

an increase in the consumption of microcrustaceans ($IAi=17.8\%$) (Fig. 5F). Chaoboridae larvae presented a lower quantitative participation in the diet during Period II; however, these organisms were an important food, occurring in 54.4% of the stomachs (Fig. 5D).

DISCUSSION

The experimental fishing carried out in Manso Reservoir reveals that the density of *A. osteomystax* was low compared to the natural lentic environment (floodplain lake), with secondary importance in the reservoir (1.3% and 7.2% of the captures, respectively; A.A. Agostinho, unpublished). The preference of *A. osteomystax* for lentic habitats and its success in the colonization of reservoirs has been reported frequently in the literature. In the Itaipu and Rosana reservoirs, which are also in the Prata River basin, this species was one of the most abundant in the first years after the impoundment (Agostinho & Zalewski 1995, Benedito-Cecílio *et al.* 1997, Agostinho *et al.* 1999), exceeding its density in natural environments. This same result was observed for a congeneric species (*A. nuchalis*) in the reservoirs of Curuá-Una (Ferreira 1984a) and Peixe-Angical (Marques *et al.* 2009). The colonization of a reservoir by the pre-existing ichthyofauna depends on both the pre-adaptations

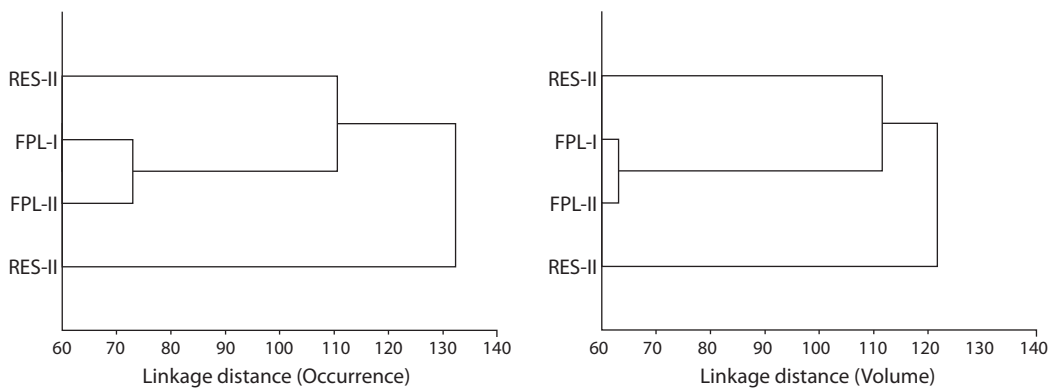


Fig. 4. Similarity in the diet of *A. osteomystax* between the locations (RES=Manso reservoir; FPL=Sinhá Mariana floodplain lake) and periods (I and II) evaluated through cluster analysis (city-block distance, single linkage) for the data of occurrence and volume of food items.

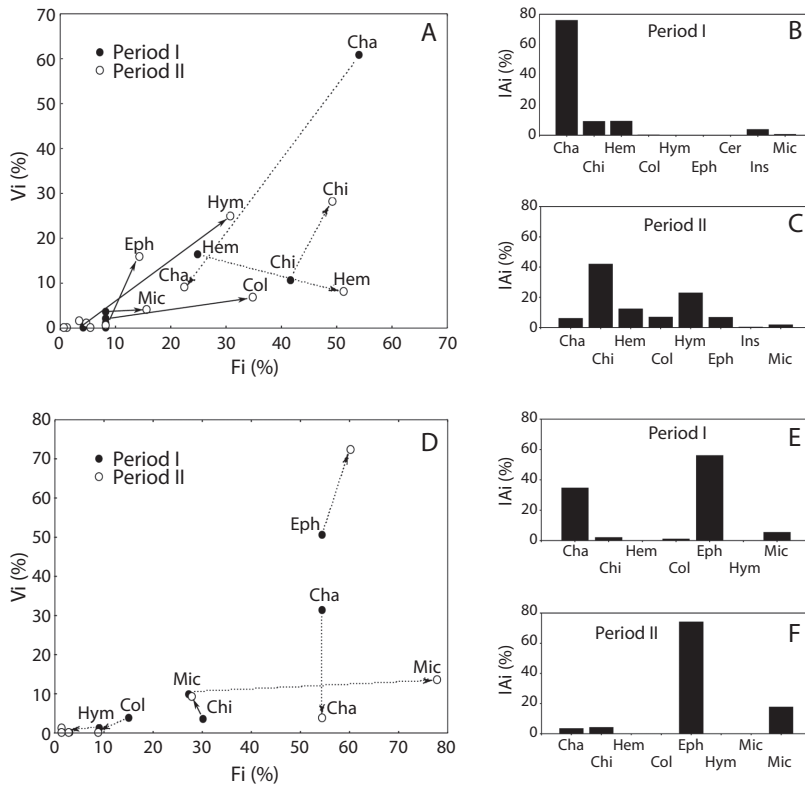


Fig. 5. Occurrence (Fi), volume (Vi) and feeding index (IAi) of the items present in the diet of *A. osteomystax* in Manso Reservoir (A, B, C) and Sinhá Mariana floodplain lake (D, E, F), during distinct annual periods. Cha=Chaoboridae, Chi=Chironomidae, Hem=Hemiptera, Col=Coleoptera, Hym=Hymenoptera, Eph=Ephemeroptera, Cer=Ceratopogonidae, Ins=other insect, Mic=microcrustaceans.

to the new environment (Fernando & Holcik 1991, Agostinho *et al.* 1999) and the number of individuals of each population in the environment that will be impounded (Agostinho *et al.* 2008). Thus, despite the absence of data on the abundance of *A. osteomystax* in the previous period, the result of low capture in the first months of the reservoir formation suggests that this species was not abundant in the dammed region. Although seasonality in the abundance of this species was evident in both locations, it was more pronounced in the floodplain lake, with high capture during the months of low water and beginning of flooding. The remarkable reduction in the water level during the drought and the displacement that this species performs towards more lotic environments in

the tributaries for reproduction (Benedito-Cecilio & Agostinho 2000) may explain this seasonality. Indeed, this species spawns between November and April in lotic areas of Manso River basin (H.I. Suzuki, unpublished), period that coincides with that of Tocantins River (Medeiros *et al.* 2009).

Many of the fish species from Neotropical reservoirs occupy the margins of these environments (Araújo-Lima *et al.* 1995, Agostinho *et al.* 1999, Mol *et al.* 2007), while the open areas are less occupied, mainly due to the absence of species pre-adapted to lacustrine conditions (Agostinho *et al.* 1999). Nevertheless, *A. osteomystax*, which has morphological adaptations to displacement and feeding in pelagic regions (Freire & Agostinho 2000), principally

occupied the reservoir surface. Furthermore, *A. osteomystax* is not considered an obligatory zooplanktivorous species since it feeds primarily on insects (mainly Ephemeroptera; Hahn *et al.* 1998), but it may be considered as facultative zooplanktivorous, that is, able to use the zooplankton that suddenly becomes abundant in newly formed reservoirs (Strictar-Pereira *et al.* 2010). Therefore, the predominance of the species in open areas of Manso Reservoir might have been favored by the ability to consume zooplanktonic organisms. A similar indication is given by the higher abundance of this species in surface water in the reservoir transition zone (Ferreira 1984a, Benedito-Cecílio *et al.* 1997), where the primary productivity and the zooplankton density are higher due to the balance between the light penetration and nutrient concentration (Kimmel *et al.* 1990, Marzolf 1990).

The success of zooplanktivorous species in new impoundments has been described (Ferreira 1984b, Agostinho *et al.* 1992, Casemiro *et al.* 2003). Although a slight increase in the occurrence of microcrustaceans was observed in the diet of *A. osteomystax* during the second period in Manso Reservoir, this species may not be classified as typically zooplanktivorous, nor did it present the expected increase in abundance after the formation of Manso Reservoir. Mol *et al.* (2007) reported that the congeneric species *A. nuchalis*, which was abundant soon after the formation of Brokopondo Reservoir, was not present during the samplings accomplished 40 years later.

The diet of *A. osteomystax* was predominantly compounded by insects independently of the location and period. Meanwhile, we verified differences in the composition and abundance of insects consumed by this species, with a higher relevance of aquatic forms in the natural environment (floodplain lake). The main change in the diet observed in the Manso Reservoir three years after its formation was a decrease in the consumption of Chaoboridae. Although this reduction was partially compensated by an increase in the consumption of other aquatic organisms (Chironomidae,

Ephemeroptera, and microcrustaceans), the terrestrial organisms Hemiptera, Hymenoptera, and Coleoptera presented more important increases, especially in occurrence. On the other hand, in the population at the floodplain lake, where the variations were less pronounced, the decrease in Chaoboridae was accompanied by a reduction in the values for terrestrial insects and increase in aquatic forms such as Ephemeroptera and microcrustaceans. The predominance of allochthonous resources, especially terrestrial insects, in the diet of *Auchenipterus* species has been discussed for other reservoirs (Mérona *et al.* 2001, 2003), rivers (Tejerina-Garro & Mérona 2010), and *várzea* lakes of the Amazon (Mérona & Rankin-de-Mérona 2004). However, the predominance of aquatic forms of insects in the diets of the same species of *Auchenipterus* is reported for the Itaipu reservoir (Hahn *et al.* 1998) and lakes of the Upper Paraná River floodplain (Hahn *et al.* 2004).

The intense proliferation of zooplankton that characterizes new reservoirs (Rocha *et al.* 1999, Bonecker *et al.* 2001) was not directly exploited by *A. osteomystax*. Nevertheless, the initial diet of Chaoboridae larvae is based on flagellate protozoans and, during final stages, on microcrustaceans (Arcifa 2000). These larvae may belong to plankton or benthos depending on the time of day and instar (Arcifa 2000, Bezerra-Neto & Pinto-Coelho 2002). The fact that the final instars develop nocturnal migrations to the surface, coinciding with the location and time of higher activity of *A. osteomystax* (A.A. Agostinho, unpublished), makes the Chaoboridae a dominant prey in the diet. Research performed in the Curuá-Una Reservoir, six years after its formation, indicates that where the congeneric species *A. nuchalis* was more abundant, the diet was clearly dominated by Chaoboridae or microcrustaceans (Ferreira 1984b).

Pupae of Chironomidae together with terrestrial insects compounded the basis of the diet of *A. osteomystax* three years after the formation of the reservoir. The Chironomidae larvae are among the principal benthic organisms (Higuti & Takeda 2002, Callisto *et al.* 2002)

and in the present study their pupae must have been consumed at the surface during the period when these insects, whose adults are terrestrial, are emerging and may be found at the surface. Besides that, the consumption of Hymenoptera by fish is frequent (Goulding *et al.* 1988); these terrestrial organisms fall into the water and are mostly consumed by fish that feed at the surface. In this way, although the diet was changing between periods, *A. osteomystax* continued to consume food available at the surface of the water column, evidencing that this layer was the foraging location in the second period too.

In contrast to what was observed in the reservoir, at the floodplain lake the diet of *A. osteomystax* did not present significant temporal differences, and Ephemeroptera was the most consumed item during both periods. The high consumption of Ephemeroptera subimagos indicates that, as occurred in the reservoir, *A. osteomystax* feeds at the surface, since at this stage of development these insects emerge at the surface and become available for capture. In lakes of the Upper Paraná River floodplain, the diet of this species was also composed of Ephemeroptera consumed at the surface (Hahn *et al.* 2004), as recorded for *A. nuchalis* in the Curuá-Una River upstream of the reservoir with the same name (Ferreira 1984b). Meanwhile, in the impounded environment of Itaipu, Ephemeroptera was also the main food item of this species (Hahn *et al.* 1998).

Therefore, we conclude that the reservoir occupation by Auchenipteridae fish presents variable chance of success, with the most successful occupation being in the superficial layer of the water column in the transition zones of these environments, where the zooplankton density is higher. The seasonality observed in the abundance and the temporal coincidence with reproductive events suggests that the species show active displacements towards waters with higher turbulence. The diet is based on aquatic forms of insects that come to the surface to emerge (Chaoboridae, Diptera, and Ephemeroptera) or terrestrial forms that fall on the surface (Hymenoptera, Hemiptera, and Coleoptera). The variation in diet between the

two periods, which had a time lag of three years between them, was much less pronounced in the natural environment (floodplain lake), where the resource availability is essentially regulated by the seasonality. The heterotrophic features of the processes during the first years of the reservoir, due to the flooding of biomass, and the unnatural fluctuations of the water level must abort successional processes that lead to biota adjustments, causing the variation in trends in food availability for fish to be random. Thus, our hypothesis was accepted; that is, the interannual variations in the diet of *A. osteomystax* are more relevant in an artificial environment than in a natural one.

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RESUMEN

Los embalses nuevos ofrecen la oportunidad de comprobar si especies que presentan suficiente flexibilidad en la alimentación en condiciones naturales pueden aprovechar esta situación y, sin restricciones de reproducción, ocupar la mayor parte del hábitat visible en un gran embalse (espacios abiertos), además, presentar un alto éxito en la colonización del nuevo entorno. Asimismo, examinamos variaciones en la abundancia y alimentación de *A. osteomystax*, en dos ambientes, uno natural (Sinhá Mariana floodplain lake) y otro alterado (Embalse Manso), durante dos períodos: el primer año después de la fase de llenado y tres años más tarde. Nuestro objetivo fue evaluar la ocupación del nuevo hábitat (Embalse Manso) por esta especie, así como probar la hipótesis de que en el embalse, a diferencia del ambiente natural, se producen cambios notables en la dieta entre los períodos. Los peces fueron muestreados mensualmente en el lago de la planicie de inundación y en el embalse durante dos períodos anuales con redes de enmalle. Para evaluar las diferencias en la abundancia de *A. osteomystax* empleamos la prueba de Kruskal-Wallis, y el análisis de la dieta se llevó a cabo con el uso de la frecuencia de ocurrencia y métodos volumétricos. Las

diferencias temporales en la dieta fueron probadas con Kruskal-Wallis, se usaron los resultados a partir de un análisis de correspondencia sin tendencia. *A. osteomystax* fue significativamente más abundante en el lago de la llanura de inundación, donde las capturas fueron más altas, que en el embalse en casi todos los meses analizados, y no se registraron variaciones significativas en la abundancia entre los dos períodos tanto en el embalse como en el lago de inundación. La variación en la dieta entre los dos períodos, en los cuales había un desfase de tres años entre ellos, fue mucho menos pronunciada en el entorno natural, donde la disponibilidad de recursos es esencialmente regulada por la estacionalidad. Por lo tanto, nuestra hipótesis fue aceptada, es decir, las variaciones interanuales en la dieta de *A. osteomystax* son más relevantes en un ambiente artificial que en uno natural.

Palabras clave: pantanal, llanura de inundación, cambios en la alimentación, insectívoros.

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