

SPATIAL AND TEMPORAL VARIATION IN THE POPULATION STRUCTURE OF THE HALFTOOTH, *Hemiodus unimaculatus*, IN THE TUCURUÍ RESERVOIR ON THE LOWER TOCANTINS RIVER IN EASTERN BRAZILIAN AMAZONIA

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ABSTRACT

The present study investigated the spatiotemporal changes in the structure of the population of the halftooth, *Hemiodus unimaculatus* (Bloch, 1794), in the area upstream from the Tucuruí hydroelectric dam on the Tocantins River, through quarterly samples obtained in 2001, 2003, 2005 and 2007. The variation in the total length and weight of the specimens was analyzed using the Kruskal-Wallis test, with a 5% significance level, while the spatiotemporal variation in population parameters was evaluated using a cluster analysis and SIMPER. A number of changes were found in the population structure of *H. unimaculatus*, with an increase in population size, a shift in the proportion of juveniles and adults, and alterations of the spatial distribution of the fish. The lack of data on the species and its occurrence in the study area reinforce the need for the development of adequate management measures to avoid overfishing in the future.

Key words: Tucuruí reservoir; populational distribution; mesh size.

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ESTRUTURA POPULACIONAL E VARIAÇÃO ESPACIAL DA JATUARANA ESCAMA GROSSA *Hemiodus unimaculatus* NA ÁREA DE INFLUÊNCIA DO RESERVATÓRIO DE TUCURUÍ NO BAIXO RIO TOCANTINS, NA AMAZONIA BRASILEIRA ORIENTAL

RESUMO

O presente estudo investigou as mudanças espaço-temporais na estrutura da população da jatuarana escama grossa, *Hemiodus unimaculatus* (Bloch, 1794), na área a montante da hidrelétrica de Tucuruí, no rio Tocantins, através de amostras trimestrais obtidas em 2001, 2003, 2005 e 2007. A variação no comprimento total e peso dos espécimes foi analisada pelo teste de Kruskal-Wallis, com nível de significância de 5%, enquanto a variação espaço-temporal nos parâmetros populacionais foi avaliada por meio de análise de agrupamento e SIMPER. Algumas mudanças foram encontradas na estrutura populacional de *H. unimaculatus* com aumento do comprimento total dos indivíduos, modificação na proporção de jovens e adultos e mudanças na distribuição espaço-temporal. A falta de dados sobre a espécie e sua ocorrência na área de estudo reforçam a necessidade do desenvolvimento de medidas de manejo adequadas para evitar a sobrepesca no futuro.

Palavras-chave: UHE Tucuruí; distribuição populacional; tamanho de malha.

Received: February 15, 2018
Approved: May 23, 2018

INTRODUCTION

The fisheries of the Tocantins River in eastern Amazonia have traditionally been an important economic activity for the local riverside populations, since long before the formation of the reservoir of the Tucuruí hydroelectric dam. This reservoir is a relatively productive source of fishery resources, providing an estimated 5 kg ha⁻¹ year⁻¹ (RIBEIRO *et al.*, 1995), in comparison with other Amazonian reservoirs, such as Balbina, where productivity is estimated at 1.2-3.1 kg ha⁻¹ year⁻¹ (SANTOS and OLIVEIRA-JÚNIOR, 1999).

CINTRA *et al.* (2007) concluded that the bulk of the fishery catches landed in the area of the Tucuruí reservoir was made up of 13 species, including the halftooth, *Hemiodus unimaculatus* (Bloch, 1794), which is known locally as the “thick-scaled” jatuarana, which accounts for a mean annual catch of 14.4 t year⁻¹ (PINHEIRO *et al.*, 2015). *Hemiodus unimaculatus* is fished in the Tucuruí reservoir throughout the year, but primarily during the ebb period of the Tocantins River (May to July), which is considered to be the local harvest period. The species is fished using hook-and-line and nets, including gillnets, block nets, and weirs (CINTRA *et al.*, 2013).

The damming of a river alters its physical and chemical characteristics, its current speed, microhabitats, and food sources, resulting in a proliferation of some fish species and the decline or even extinction of others (HAHN *et al.*, 1998; AGOSTINHO *et al.*, 2007). This process also causes profound changes in the structure and species composition of the communities of native fish (AGOSTINHO *et al.*, 1992), given that the modifications of the local aquatic ecosystems have a direct influence on the biological functions of each fish species and its interspecific relationships (MÉRONA, 1987).

The spatial and temporal patterns of fish communities are modified or readapted to the new environments created by the reservoir, which contrast with the typical seasonal dynamics of most rivers (AGOSTINHO and ZALEWSKI, 1996), and the association between biotic and abiotic factors (LOWE-MCCONNELL, 1987; PERES-NETO *et al.*, 1995). In this context, the duration of the period necessary for the fish community to establish a new equilibrium is unpredictable, and will depend on a series of factors, ranging from the degree of conservation of the original fluvial habitats

to the operational schedule of the reservoir. It is thus important to evaluate systematically the structure of fish populations to better understand the life history strategy of each species, and its allocation of energy to growth, survival, and reproduction, which reflects the environmental conditions that influence the population (BENEDITO-CECÍLIO and AGOSTINHO, 1997).

The effects of the damming of the Tocantins River on the local population of *H. unimaculatus* are still unknown, despite the importance of this information for the adequate management of its stocks, and in particular for the development of sustainable fisheries. To redress this situation, the present study investigated the structure and spatiotemporal variation of the *H. unimaculatus* population of the Tucuruí reservoir.

METHODS

The study area is located upstream from the Tucuruí dam, divided into two zones, the reservoir proper and the upstream zone (CINTRA *et al.*, 2007). The specimens were collected by the technical team of the Fishery and Ichthyofauna Program of the Central Electric Company of Northern Brazil (Centrais Elétricas do Norte do Brasil S/A – ELETRONORTE, AU N.º.: 919/2010). The samples were collected quarterly during four years, 2001, 2003, 2005, and 2007, beginning in January of each year. The fieldwork was conducted at seven sampling point (Figure 1), five located within the Tucuruí reservoir (Breu Branco, Caraipé, Funai, Maternal, and Igarapé Altamira) and two (Lourenção and Marabá) in the upstream zone.

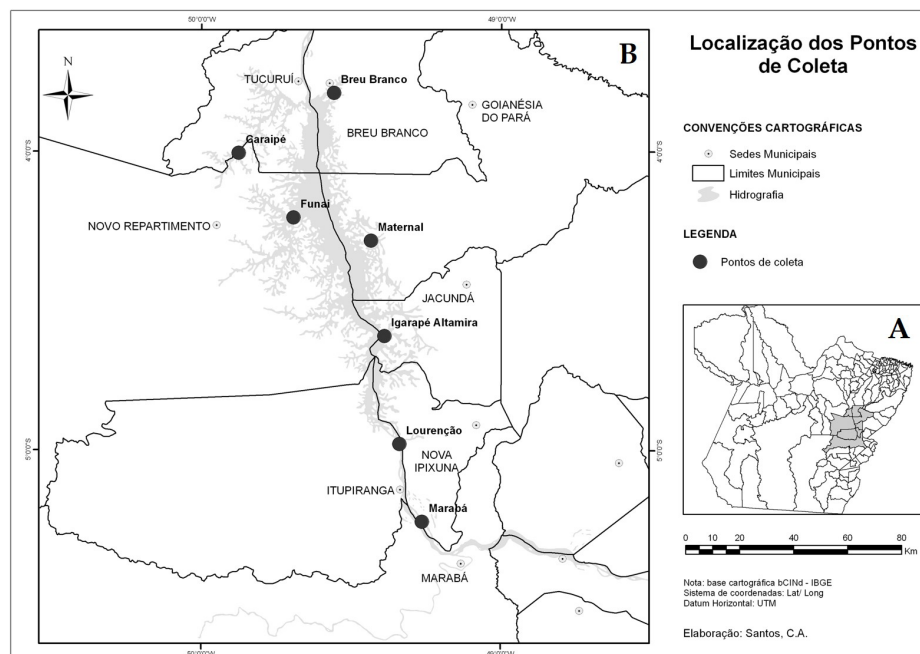


Figure 1. Location of the study area. (A) Brazilian state of Pará; (B) region upstream from the Tucuruí dam, showing the sampling points.

The specimens were collected using a battery of gillnets (50 m long and 3 m high), with meshes of 40 mm, 60 mm, 80 mm, and 100 mm, distributed at intervals of 5 m. The nets were set overnight, remaining in place for 12 hours. The fish captured were euthanized by chilling and stored in plastic bags, labelled with the sampling point, date, and mesh size, before being placed in coolers filled with crushed ice (1:1) for transportation to the laboratory for analysis.

The specimens were identified based on SANTOS *et al.* (2004) and weighed in grams (g), and their total length was measured in millimeters (mm). The sex and maturation of the gonads were determined by macroscopic examination, following the scale of four reproductive stages defined by VAZZOLER (1996).

As the samples were collected in alternating years, they were combined in two periods – 1 (2001-2003) and 2 (2005-2007) – for the analysis of temporal patterns. The data on the length and weight of the specimens (median values) were compared between sexes, zones (reservoir and upstream), and periods (1 and 2) using the Kruskal-Wallis test, with a significance level (α) of 0.05.

The two periods (1 and 2) were also analyzed using a hierarchical agglomerative cluster analysis of the abundance of fish collected at each sampling point, considering the number of individuals by their sex, stage of gonadal maturation, and total length class (40 mm intervals). As specimens were not collected in all months

at Lourenção, this sampling point was not included in this analysis. The occurrence data were first log (x+1) transformed and standardized for the preparation of the similarity matrix, based on the Bray-Curtis coefficient, with the groups being joined by the means of their similarity values – UPGMA (JOHNSON and WICHERN, 1992). A percentage similarity (SIMPER) analysis was used to identify the principal factors that contributed to the similarities found within each group, and the dissimilarities among the groups. The analyses were run in PRIMER 5.0 (CLARKE and WARWICK, 1994).

RESULTS

A total of 1401 *H. unimaculatus* specimens were collected during the present study, with 700 being collected during period 1, and 701 in period 2 (Table 1). In the upstream zone, 58 specimens (55.2% female and 44.8% male) were captured during period 1 and 178 specimens (63.5% female and 36.5% male) were captured during period 2. In the reservoir zone, 642 specimens (60.9% female and 39.1% male) were collected in period 1, and 523 (61.8% female and 38.2% male) in period 2. In the upstream zone, the females were longer than the males in both periods (Figure 2A), but were heavier only in period 1, with the males

Table 1. Number and size (total length) of *Hemiodus unimaculatus* specimens captured using gillnets with different mesh sizes during the present study in the area of the Tucuruí reservoir, in periods 1 (2001-2003) and 2 (2005-2007).

MESH (MM)	PERIOD									
	1					2				
	N	%	TOTAL LENGTH (MM)			N	%	TOTAL LENGTH (MM)		
		MÍN	MEAN ± SD	MÁX			MÍN	MEAN ± SD	MÁX	
40	489	69.9	150	193.3 ± 23.1	265	352	50.2	125	185.0 ± 39.2	370
60	209	29.9	170	230.4 ± 22.0	290	337	48.1	140	223.3 ± 23.7	350
80	1	0.1	290	290	290	10	1.4	200	244.0 ± 19.0	270
100	1	0.1	200	200	200	2	0.3	250	255.0 ± 7.1	260
TOTAL	700	100	-	-	-	701	100	-	-	-

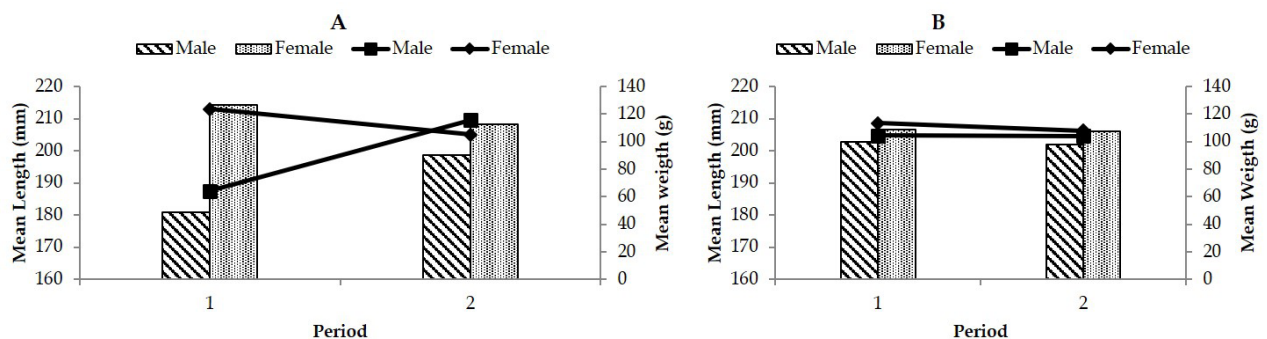


Figure 2. Mean total length of the halftooth (*Hemiodus unimaculatus*) specimens captured during the present study in the Tucuruí reservoir in Pará (Brazil) during periods 1 (2001-2003) and 2 (2005-2007). (A) upstream zone; (B) reservoir zone. The columns represent the mean length (mm) and the lines, the mean weight (g).

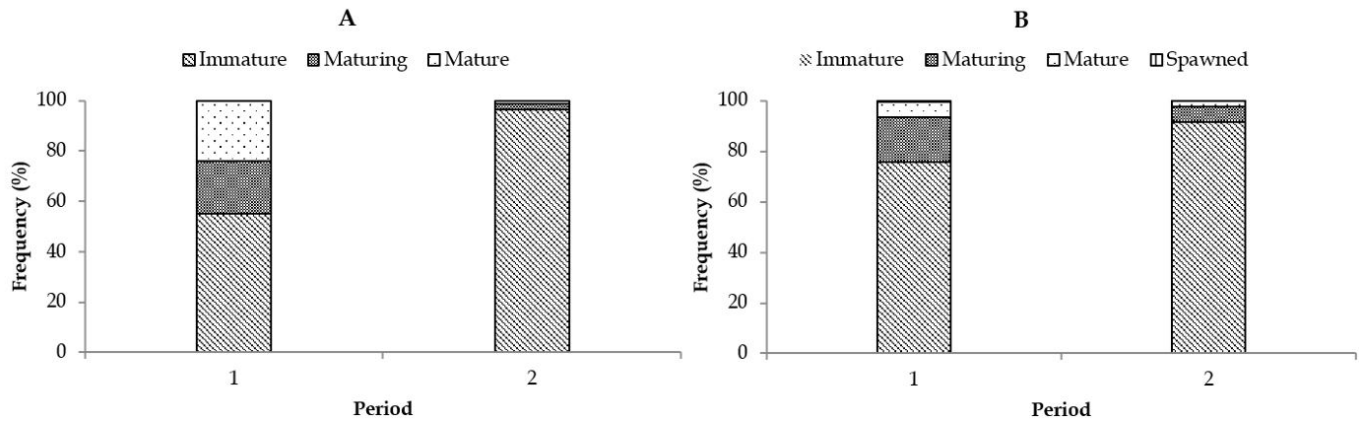


Figure 3. Relative frequency of the *Hemiodus unimaculatus* specimens of different maturation stages captured during the present study in the Tucuruí reservoir in Pará (Brazil) during periods 1 (2001-2003) and 2 (2005-2007). (A) upstream zone; (B) reservoir zone.

being heavier in period 2. In the reservoir zone, the females were larger than the males in both periods (Figure 2B).

The *H. unimaculatus* specimens captured in the upstream zone did not vary in length between periods ($H = 2.72$; $p = 0.099$), although they were significantly heavier ($H = 5.62$; $p = 0.018$) in period 2. While the females did not vary significantly between periods in either length ($H = 0.92$; $p = 0.336$) or weight ($H = 1.31$; $p = 0.252$), the males did increase significantly in length ($H = 9.79$; $p = 0.002$) and weight ($H = 20.69$; $p < 0.001$). In the reservoir zone, the specimens did not vary significantly between periods in either length ($H = 0.11$; $p = 0.735$) or weight ($H = 2.00$; $p = 0.158$). Similarly, no significant variation was found between periods in either the females (length: $H = 0.24$; $p = 0.625$; weight: $H = 2.48$; $p = 0.115$) or the males (length: $H < 0.01$; $p = 0.96$; weight: $H = 0.07$; $p = 0.789$).

In period 1, the macroscopic examination of the gonads classified 55.2% of the specimens from the upstream zone as immature ($N = 32$), 20.7% ($N = 12$) as maturing, and 24.1% ($N = 14$) as mature (Figure 3). In period 2, almost all (96.63%) the specimens ($N = 172$) were immature, with the remainder being either maturing or mature. All four maturation stages were identified in the specimens from the reservoir zone, by contrast (Figure 3). In period 1, 75.6% of the specimens ($N = 485$) were immature, 17.8% ($N = 114$) were maturing, 6.2% were ($N = 40$) mature, and 0.47% ($N = 3$) were spawned. In period 2, the vast majority of the specimens (91.6%; $N = 479$) were immature.

The cluster analysis of the data from period 1 (2001-2003) separated the sampling points into four groups, based on a minimum similarity of 70%. In this analysis, the points Caraipé (group 1), Igarapé Altamira (group 2), and Marabá (group 3) were all isolated, while Funai, Maternal and Breu Branco clustered in a single group (4), with a similarity of 75.6% (Figure 4A). The SIMPER analysis associated the similarity among the three points of group 4 with the presence of immature males and females of the 170 mm, 210 mm, and 250 mm length classes (64.1%). The dissimilarity between groups 4 and 1 was 30.5%, due to the predominance of spawned females in the 210 mm length class (11.9%) at Caraipé, while that between groups 4 and 2 was 27.9%,

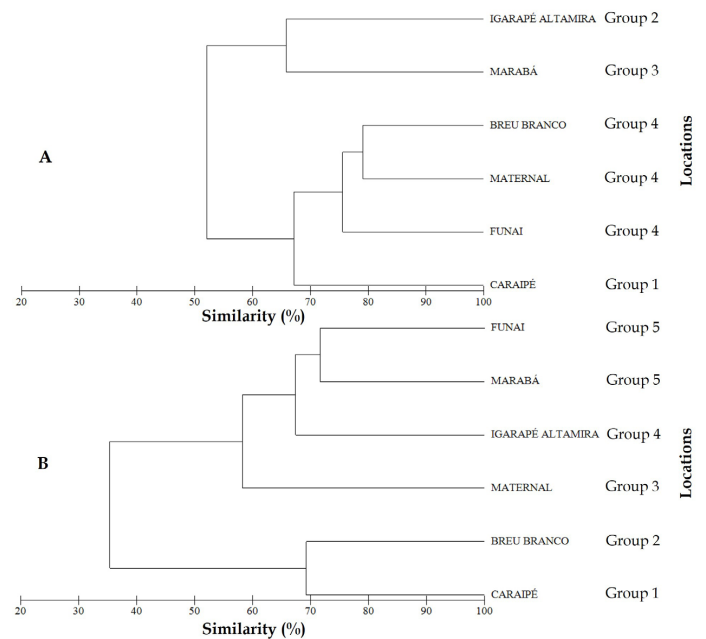


Figure 4. Clusters derived from the log-transformed and standardized abundance data on the halftooth, *Hemiodus unimaculatus*, specimens captured in the area upstream from the Tucuruí dam in Pará, Brazil. (A) Period 1 (2001 and 2003); (B) Period 2 (2005 and 2007).

related to the prevalence of immature males of 250 mm in length (13.0%) in group 4. The dissimilarity between groups 4 and 3 was 37.4%, and was related to the predominance of mature males in the 210 mm category (11.8%) at Marabá.

In period 2 (2005-2007), five groups were formed, with four isolated groups, Caraipé (group 1), Breu Branco (group 2), Maternal (group 3) and Igarapé Altamira (group 4), and a fifth group containing Marabá and Funai, with a similarity of 71.6%

(Figure 4B). The association diagnosed by the SIMPER analysis in group 5 is related to the presence of immature males and females 170 mm, 210 mm, and 250 mm in length (83.5%) and, to a lesser extent (8.3%), immature males in the 130 mm length category. The dissimilarity between groups 5 and 1 (38.2%) was related to the larger number of maturing females in the 250 mm category (16.9%) at Caraipé, and that between groups 5 and 2 (30%), to the excess (13.3%) of immature males in the 170 mm category in group 5. The dissimilarity between groups 5 and 3 (38.4%) was related to the predominance of immature males in the 250 mm category (10.4%) in group 5, and that between groups 5 and 4, to the larger number of immature females in the 130 mm category (16.3%) at Igarapé Altamira.

DISCUSSION

The structure of the *H. unimaculatus* population shifted significantly over the seven years of the study period, including an increase in the total length of the specimens and the proportion of immature specimens, and changes in the spatial distribution of the different categories. The characteristics of this population have also changed since the filling of the reservoir, with the maximum length of the specimens captured during the present study being greater than the values recorded in previous studies. Prior to the construction of the Tucuruí dam, SANTOS *et al.* (1984) recorded *H. unimaculatus* specimens with a maximum length of 180 mm, whereas 20 years later, the largest specimens had a total length of 300 mm (SANTOS *et al.*, 2004). The maximum length of 370 mm, recorded in the present study, indicates the consolidation of the population, which may be related primarily to the decomposition of the submerged plant material, the increased penetration of sunlight, and the consequent increase in the abundance of plankton and pleuston (the principal source of food of this fish species), as recorded at other Amazonian hydroelectric reservoirs (SANTOS, 1995).

The temporal shifts in body size (length and weight) observed in the present study indicate that the reservoir is an environment that supports a greater homogeneity in the population, probably related to the availability of feeding resources, which may have influenced the differences in the size of the *H. unimaculatus* specimens observed in the upstream zone. In natural environments, seasonal oscillations result in shifts in the abundance of feeding resources (HAHN and FUGI, 2007; GANDINI, 2011), in particular in lotic ecosystems, where the resources available in the water column are less abundant (LUIZ *et al.*, 1998). In this case, a probable reduction in resources in period 1 in the upstream zone, may have been modified by physical, chemical, and biological variations in the environment, resulting in an expansion in the availability of resources, and a subsequent increase in the body weight of the fish in period 2.

In period 1, the population structure was more balanced, shifting to a much greater predominance of immature individuals in period 2. The modifications of the physical-chemical environment of the study area, the variation in the annual flood pulse, and the concentrations of dissolved oxygen and phosphorus may still be affecting the

regulation of population density (MÉRONA *et al.*, 2010), and fish maturation rates. ESTEVES and COSTA (2012) concluded that environments with a marked predominance of juvenile fish may undergo a “density-dependent maturation” effect, in which few immature individuals become adults or, when there are few adults, fecundity increases, leading to the production of more offspring. The proportion of adults and juveniles is regulated by density-dependent adjustments in fecundity and reproduction until the population reaches an equilibrium.

In period 1, the differences among the sampling points were related to a predominance of mature specimens at Marabá, and of spawned individuals at Caraipé. Marabá is in the upstream zone, whereas Caraipé, while being located within the reservoir zone, is in a relatively marginal position (Figure 1). *Hemiodus unimaculatus* may use more peripheral areas of the reservoir to spawn, and more central areas to feed and grow, as observed in other *H. unimaculatus* populations. BRANDÃO *et al.* (2003) observed the species forming shoals that moved toward the river channel to spawn, while in the Luís Eduardo Magalhães reservoir, in Tocantins state, MAQUIAVELI (2006) recorded more intense feeding behavior in the area of the lake, reinforcing the conclusion that it was used primarily for feeding and growing. Overall, the trophic plasticity of the hemiodontids (SILVA *et al.*, 2008), associated with their use of space may account for the relative success of *H. unimaculatus* within the area of the Tucuruí reservoir.

In period 2, there was a shift in the distribution of the more advanced stages of maturation, with mature and spawned individuals predominating at Marabá, Funai, Caraipé and Breu Branco, which may reflect an expansion in the species’ spawning grounds. This would reinforce its chances of survival, with an increased probability of encountering feeding grounds and refuges. Overall, then, the success of *H. unimaculatus* in the Tucuruí reservoir may be related not only to the abundance of feeding resources, but also the adoption of novel breeding strategies, given that changes in the location of spawning sites may contribute to the reproductive success of the species (VAZZOLER, 1996).

CONCLUSIONS

The structure of the *H. unimaculatus* population in the Tucuruí reservoir indicates that the species is still adapting to the impacts of the damming of the Tocantins River. The predominance of juveniles in the population and the general lack of data on the species and its capacity to survive in the study area reinforce the need for the establishment of adequate management measures, in particular to avoid overfishing in the future.

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