POPULATION DYNAMICS OF *Prochilodus nigricans* CAUGHT IN MANACAPURU LAKE (AMAZON BASIN, BRAZIL)*

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ABSTRACT

Prochilodus nigricans, called curimatã in the Amazon Basin, is the most exploited fish species by commercial fishing fleets of Amazonas state. Were studied its population dynamics using length and weight data from fish caught at Manacapuru Lake, a large *ria* lake located along the lower reach of the Solimões River. Were sampled 1,178 *P. nigricans* individuals with lengths between 20 and 33 cm and weights between 195 and 875 g. The estimated length-weight relationship was $W = 0.0636\ L^{2.72}$, and the parameters of the von Bertalanffy growth curve were $k = 0.44.year^{-1}$ and $L\infty = 34.6$ cm. The rate of fishing exploitation varied between 27.97% and 69.23% depending on the method employed to estimate the natural mortality.

Keywords: Curimatã; growth; length-weight relationship; mortality rate

DINÂMICA POPULACIONAL DE *Prochilodus nigricans* CAPTURADA NO LAGO MANACAPURU (BACIA AMAZÔNICA- BRASIL)

RESUMO

Prochilodus nigricans, conhecido como curimatã na bacia Amazônia, é uma das espécies de peixes mais exploradas pela frota pesqueira comercial do estado do Amazonas. Sua dinâmica populacional foi estudada usando dados de comprimento e peso de peixes capturados no Lago Manacapuru, um grande lago de *ria* localizado no trecho inferior do rio Solimões. Foram amostrados 1.178 indivíduos de *P. nigricans* com comprimento entre 20 e 33 cm e peso variando de 195 a 875 g. A relação peso comprimento foi $W = 0{,}0636\ L^{2{,}72}$ e os parâmetros da curva de crescimento de Von Bertalanffy foram $k = 0{,}44$ ano^{-1} and $L\infty = 34{,}6$ cm. A taxa de explotação pesqueira variou entre 27,97% e 69,23% dependendo do método empregado para estimar a mortalidade natural.

Palavras-chave: Curimatã; crescimento; relação peso-comprimento; taxa de mortalidade

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INTRODUTION

Detritivorous fishes are the most abundant group in the floodplains of South America, making up almost 40% of the fish fauna (ARAÚJO-LIMA *et al.*, 1995). This dominance is reflected in the fishery landings at Amazonian cities over the last five decades (PETRERE Jr., 1978; MERONA and BITTENCOURT, 1993; ISAAC and BARTHEN, 1995; BATISTA, 2003; BATISTA *et al.*, 2012). The Prochilodontidae are specialized detritivorous fishes with 13 species distributed in all South American countries except Chile (CASTRO and VARI, 2003). Some of these fish species are highly important for the Amazonian commercial and subsistence freshwater fisheries.

Prochilodus nigricans, regionally called curimatã, is distributed in the Amazon and Tocantins river basins (CARVALHO and MERONA, 1986; CASTRO and VARI, 2003). During the last two decades, it has been the predominant species landed at Amazonian cities (BATISTA *et al.*, 2012). Its population dynamics have been study previously in Amazonian rivers in Bolivia (LOUBENS and PANFILI, 1992) and Ecuador (SILVA and STEWART, 2006). In the Brazilian Amazon, the ecology and population dynamics of *P. nigricans* have been studied in the lower reach of the Amazon River (RUFFINO and ISAAC, 1995) and in the Central Amazon (OLIVEIRA, 1997). However, population parameters, such as growth and mortality rates, are influenced by environmental and anthropogenic conditions. Thus, these parameters vary spatially and temporally and must be continuously evaluated to provide a useful baseline for fisheries management.

Manacapuru Lake is a large floodplain lake that is highly important as a fishing ground for the commercial fishing fleet located at Manacapuru City. In this floodplain lake, *P. nigricans* has been exploited for several decades, and no biological information is available to support the development of fisheries management strategies. This paper presents the results of a study on the *P. nigricans* population exploited by the Manacapuru fishing fleet to provide baseline data for future stock assessments.

MATERIAL AND METHODS

Study Area

Manacapuru Lake is situated along the left bank of the Solimões River (Figure 1). It is a large *ria* lake composed of a vast floodplain depression on the Manacapuru River, which is hydraulically barred by the Solimões River. This lake is deeply influenced by the hydrological cycle and exhibits four marked seasons: rising waters, flood, receding waters, and drought. Manacapuru Town is located on its eastern shore and has approximately 80,000 inhabitants (IBGE, 2010). Manacapuru harbor is home to the fourth-largest fishing fleet in the Amazon Basin (BATISTA *et al.*, 2012). This fleet consists mainly of motorized fishing boats from 12 to 22 meters long and small-motorized boats (GONÇALVES and BATISTA, 2008). There is another and smaller harbor called as Panairzinha that concentrate the landings for fisheries done at the Manacapuru Lake by small boats, while the main harbor close to the Solimões River receive fish from more distant areas, including the Solimões River itself and the lower stretch of the Purus River.

Data Sampling

Data from fish landings were collected at Panairzinha Harbor, the primary landing site for the small-scale fishing fleet at Manacapuru City, from February 2007 to January 2008. Besides the use of several fishing gear, the gillnets were the main fishing gear employed by this fishing fleet. The data included measurements of standard length (cm) and total weight (g) for approximately 200 fish per month.

Data Analysis

From the length distribution, were estimated the minimum (Lmin), median (Lmed) and maximum (Lmax) lengths of the catches. The length-weight relationship was estimated using a non-linear procedure, assuming the exponential relation of $W = a L^b$, where W is the weight, L is the length, a is the condition factor and b is the allometric coefficient. The growth type was evaluated by t-test, assuming isometric growth if $b = 3$ or allometric growth if $b \neq 3$ (ZAR, 1999). All statistical analyses were performed using the R statistical software (R DEVELOPMENT CORE TEAM, 2012).

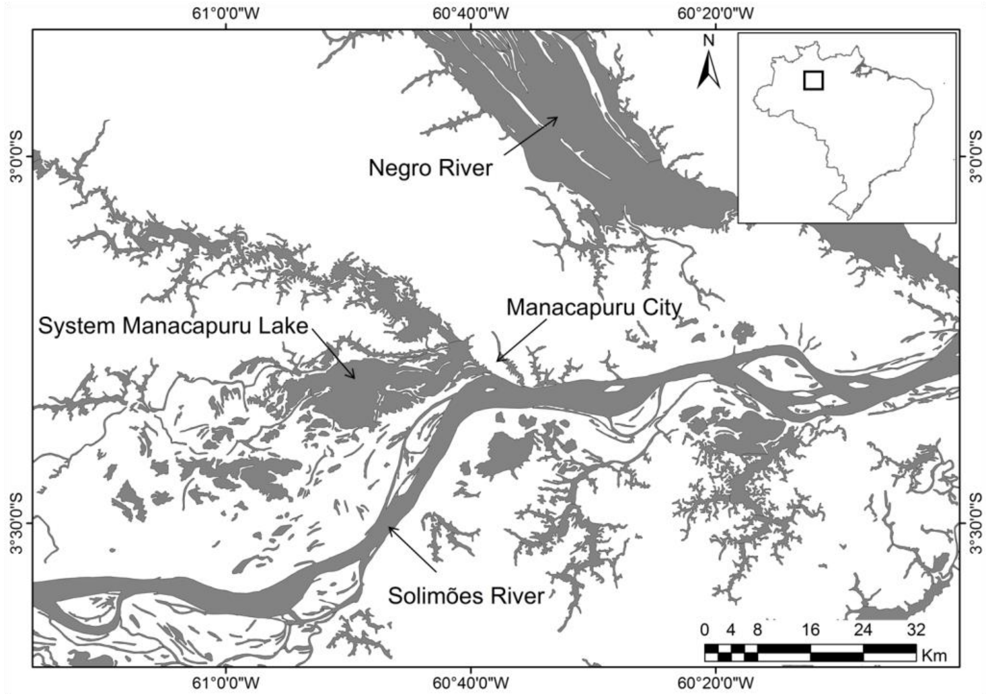

Figure 1. Manacapuru Lake system on the left bank of the Solimões River, with Manacapuru Town near its confluence with the Solimões River.

The routine ELEFAN I, part of the FAO-ICLARM Stock Assessment Tools, FISAT software (GAYANILLO *et al*., 1996) was employed to estimate the parameters $L\infty$ and k from the von Bertalanffy growth equation $Lt = L\infty[1\text{-}e\text{–}k(t\text{-}to)]$. We estimated the natural mortality M using two procedures: first, applying the equation: $[-\ln(1\text{-}0.95)/A_{0.95}]$ (TAYLOR, 1958), using the longevity estimate $A_{0.95}$ obtained from the equation ($A_{0.95} = t_0 + 2.996/k$); second, using the equation (PAULY, 1980):

$$\ln M = -0.0152 - 0.279 \ln L\infty + 0.6534 \ln k + 0.463 \ln T,$$

where: $L\infty$ and k are the parameters from the von Bertalanffy equation, M is the natural mortality rate and T is the average temperature measured at the water surface, here assumed to be 28 °C. Also we calculated the total mortality Z using the equation proposed by KING (1995), employing the linearized catch curve and assuming that the stock density diminishes proportionally with the age of the fish. Thus, were obtained two estimated rates of fishing mortality using the difference between the total and natural mortality rates, F = Z – M. Finally, the rate of fishing exploitation was estimated as E = F / Z.

RESULTS

Were sampled 1.178 *P. nigricans* individuals with lengths between 20 and 33 cm and weights between 195 and 875 g. The mean length was 26.5 cm, but approximately 70% of the sampled fish had lengths less than this value. The most frequent length classes were 24, 25, and 26 cm (Figure 2). The length-weight relationship was $W = 0.0626\ L^{2.72}$ ($R^2 = 0.77$; $p<0.001$), the allometric coefficient was statistically different than 3 (t = 20.42, $p = 0.031$) indicating allometric growth.

FISAT identified three cohorts (Figure 3). The estimated specific growth rate k and asymptotic growth $L\infty$ were 0.44 year^{-1} and 34.6 cm, respectively. The longevity $A_{0.95}$ was 6.8 years.

The total mortality Z was 1.43 year^{-1}. According to the Taylor equation, the natural mortality M was 0.44 year^{-1}, resulting in a fishing mortality F of 0.99 year^{-1}. According to Pauly's equation, the natural mortality M was 1.03 year^{-1}, and the fishing mortality was 0.40 year^{-1}. Thus, the rate of fishing exploitation varied from 27.97% to 69.23% depending on the method employed to estimate the natural mortality.

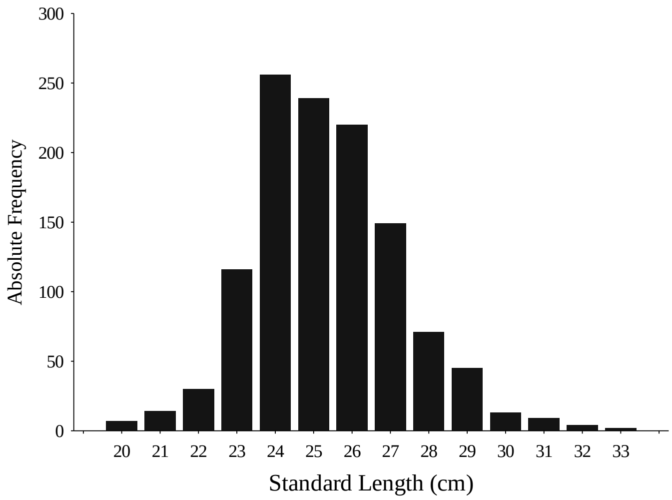

Figure 2. Length distribution for *Prochilodus nigricans* caught at Manacapuru Lake.

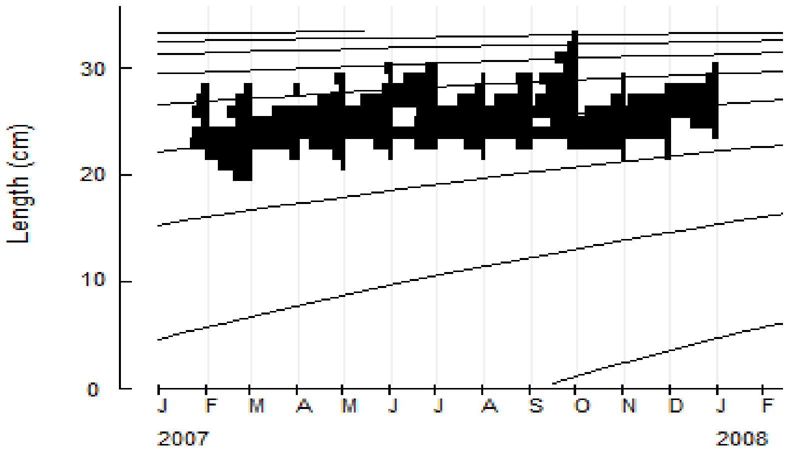

Figure 3. Monthly length distributions of *Prochilodus nigricans* caught at Manacapuru Lake from January 2007 to February 2008.

DISCUSSION

The mean size of caught fish provides preliminary insight on the status of an exploited fish species, especially if a historical data series is available. Comparisons to values obtained in previous studies are also useful, especially for widely distributed populations, as *P. nigricans*. In the present study, approximately 70% of the captured fish had standard lengths less than 26.5 cm, a markedly lower estimate than the 35.4 cm reported from the same geographical area ten years ago (MOTA and RUFFINO, 1997). However, the most frequent length class was similar to that observed by OLIVEIRA (1997). Nevertheless our results could be associated with the data collection procedure, since there is a selectivity inherent for each fishery. However we believe that this is not a substantial source of bias because the Amazonian small-scale fisheries employ a great diverse of fishing gear (GONÇALVES and BATISTA, 2008; FERNANDES *et al.*, 2009), which improve the size reach in the landings.

The fishing-recruitment length of 20 cm was similar to that estimated by RUFFINO and ISAAC (1995) for fisheries along the lower reaches of the Amazon River (21 cm), and by MOTA and RUFFINO (1997) for fisheries along the middle reach of the Solimões River (also with 21 cm). These data indicate that the *P. nigricans* fisheries are similar throughout the Brazilian portion of the Amazon Basin. In contrast, LOUBENS and

PANFILI (1995) reported that this species begins to be recruited at 27.0 cm in the Bolivian portion of the basin. This difference may be associated with fishing gear because this species is fished using several types of fishing gear and under various environmental conditions, depending on the stage of the hydrological cycle (MOTA and RUFFINO, 1997; FREITAS *et al*., 2007). The L_{50} estimated by RUFFINO and ISAAC (1995) based on fishing landings data from the lower reach of the Amazon River was 35 cm, and an analysis of a temporal series also derived from landings data indicated that the fishery was concentrated on adult fish (SANTANA and FREITAS, 2013). However, the L_{50} values estimated for other areas of the Amazon Basin are consistently lower. LOUBENS and PANFILI (1995) estimated a value of 27 cm for the Bolivian Amazon, and MONTREUIL *et al*. (2001) calculated a value of 23.8 cm for the Peruvian Amazon. The L_{50} estimated by OLIVEIRA (1997) for fish from the Central Amazon was 26.2 cm, larger than the recruitment length. Besides the effects of environmental factors, KÖSTER *et al.* (2013) studied 22 stocks of North Atlantic stocks of cod and observed that maturation patterns are related to growth potential and surplus production. We haven’t data to test the hypothesis of the effect of environmental factors or fishing intensity on the estimated L_{50}, however the floodplain lakes of the Central Amazon have been heavily exploited for several decades and is possible the occurrence of compensatory mechanisms as those described by TRIPPEL, 1995.

Allometric growth was observed for *P. nigricans* in Bolivian rivers (LOUBENS and PANFILI, 1995), but isometric growth was detected for fish in the lower reach of the Amazon River (RUFFINO and ISAAC, 1995) and in rivers of the Central Amazon (OLIVEIRA, 1997). The growth rate of 0.44 $year^{-1}$ found here is similar (but lower) to the growth rates estimated by RUFFINO and ISAAC (1995) in the lower Amazon River (0.50 $year^{-1}$ and 0.47 $year^{-1}$ for males and females, respectively), by OLIVEIRA (1997) in the Central Amazon (0.46 $year^{-1}$), and by LOUBENS and PANFILI (1995) in the Bolivian Amazon (0.52 $year^{-1}$). However, our estimate is substantially higher than that reported in Ecuador (0.18 $year^{-1}$) based on fish scales and 0.28 $year^{-1}$ based on otoliths (SILVA and STEWART, 2006). Several authors have been studying the response of growth to environmental factors and fishing (CONOVER and ROSS, 1982; NICIEZA and METCALFE, 1997), and some studies have been proposing the existence of compensatory mechanisms to improve the growth rate when the environmental conditions are favorable (NICIEZA and WOOTTON, 2003). However, the asymptotic length obtained in the present study is the lowest reported for this species. RUFFINO and ISAAC (1995) obtained 68 and 58 cm for males and females, respectively. OLIVEIRA (1997) calculated an asymptotic length of 41.6 cm, while SILVA and STEWART (2006) estimated 39.8 and 45.7 cm for males and females, respectively. In general, a high growth rate and a low asymptotic length are associated with disadvantageous conditions caused by environmental or fishing pressure. The estimated longevity calculated here is slightly greater than that calculated by OLIVEIRA (1997) for *P. nigricans* in the same geographic area. Besides there are no confidence intervals associated with the estimates generated by FISAT, we believe that these results could be first insights to understand the *P. nigricans* growth in the Central Amazon.

The estimated total mortality of 1.43 $year^{-1}$ is higher than that estimated by SILVA and STEWART (2006) for *P. nigricans* in Amazonian rivers in Ecuador but approximately three times lower than that observed for this species in the lower Amazon River by RUFFINO and ISAAC (1995). The estimated natural mortality varied widely depending on the methods employed to estimate this parameter. These variations influenced the estimated rate of fishing exploitation. Using the most conservative method, the rate of fishing exploitation is almost 70%. Combined with the other analyzed parameters, such as the recruitment length, this finding highlights the need to evaluate the status of *P. nigricans* stocks in Manacapuru Lake and to develop strategies to improve the management of this species.

CONCLUSION

The estimated population-dynamics parameters for *Prochilodus nigricans* caught at Manacapuru Lake suggested that this population have been heavily exploited. Besides there were no indications that this population was already altered by fishing.

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