



Stock assessment of the peacock bass *Cichla temensis* (Humboldt, 1821), an important fishing resource from the middle Negro river, Amazonas, Brazil

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(With 2 Figures)

Abstract

Peacock bass *Cichla temensis* is an important species at the Amazon basin, since commercial, subsistence and recreational fisheries simultaneously exploit it. *Cichla temensis* is the preferred species by recreational fishers and it has been strongly exploited, mainly at the Negro river, the second largest tributary of the Amazon River. It was used data from experimental fisheries, collected at the middle stretch of Negro river, which were coupled with previously published data on its population dynamics, to run a yield per recruit model and build scenarios of sustainable fisheries. The results showed that the age of the first catch is a key variable to successful management of the peacock bass stocks at this region.

Keywords: stock assessment, simulation model, population dynamics, Amazon basin.

Avaliação de estoque do tucunaré *Cichla temensis*, um importante recurso pesqueiro do médio rio Negro, Amazonas, Brasil

Resumo

O tucunaré *Cichla temensis* é uma importante espécie de peixe da bacia Amazônica, uma vez que esta espécie é simultaneamente explorada pela pesca comercial e de subsistência. Além disso, é preferida pelos pescadores esportivos que atuam na região do rio Negro, o segundo maior afluente do rio Amazonas. Foram usados dados de pescarias experimentais, coletados no trecho médio do rio Negro. Estes dados foram vinculados a outros dados, previamente publicados, sobre sua dinâmica populacional, para executar um modelo de rendimento por recruta e, dessa forma, construir cenários para pesca sustentável dessa espécie. Os resultados mostraram que a idade da primeira captura é uma variável chave para gerenciar, com sucesso, os estoques de tucunarés nesta região.

Palavras-chave: avaliação de estoque, simulação de modelo, dinâmica populacional, bacia Amazônica.

1. Introduction

The Amazon basin hosts at least four types of fisheries: subsistence, artisanal small-scale, industrialized small-scale and recreational, which could be discriminated by noticeable characteristics, such as target species, type of vessels, type of fishers and fishing gears (Freitas and Rivas, 2006; Ruffino, 2014). Some species are simultaneously exploited by more than one fishery and the effect of the added fishing effort is difficult to address. Besides, the fishing intensities are broadly variable by species, populations, seasonality aquatic environmental and areas of the basin, but some stocks already exhibit over-fishing status (Isaac and Ruffino, 1996; Sant'Anna et al., 2014; Campos et al., 2015b).

The *Cichla* species are large piscivorous, can reach around 11 kg and more than 80 cm length (Jepsen et al., 1997; Campos et al., 2015a). They are broadly distributed

over the basin, with several species inhabiting black waters of Orinoco and Negro river basins (Kullander and Ferreira, 2006), where they are exploited for feeding and recreational proposals (Jepsen et al., 1999; Barthem and Goulding, 2007; Inomata and Freitas, 2015). At the Negro river basin, *Cichla temensis* is the most attractive species for anglers, due its aggressive behavior and large body size (Holley et al., 2008). Several studies were developed on this species, describing its geographic distribution and resource use (Jepsen et al., 1997; Winemiller et al., 1997), color patterns and hybridism occurrence (Andrade et al., 2001; Brinn et al., 2004; Reiss et al., 2012), feeding behavior (Rabelo and Araújo-Lima, 2002), reproduction (Montaña et al., 2007) and populational genetics (Willis et al., 2015). Also growth studies were done for populations of

the Orinoco River basin (Jepsen et al., 1997, 1999), and Negro river basin (Holley et al., 2008; Campos et al., 2015a) and a stock assessment was developed to *Cichla monoculus* (Agassiz, 1831) caught at the Lago Grande, a huge floodplain lake located at the left bank of the Solimões River, near to Manaus (Campos and Freitas, 2014). However, at this moment, there are no assessment studies to the stocks of *C. temensis* living at Negro river, where different fisheries have been acting on it.

Due the absence of fishing data to develop traditional stock assessment procedures, this manuscript taken data from experimental fisheries that generates growth parameters (Campos et al., 2015a) to estimate mortality parameters and simulate scenarios of sustainable fishing with different values of age at the first catch and fishing mortality. The simulation was based on a yield per recruit model and afterward some potential management strategies were discussed aiming to contribute for the sustainability of this important fishing resource.

2. Material and Methods

This study was conducted in the middle Negro river region (W 062°C56'56.1" S 00°58'00.5"), in the proximities of Barcelos municipality in the state of Amazonas, Brazil (Figure 1). This is a typical blackwater river owing to the dark color of the water, resembling black tea and its middle stretch is characterized by the Mariuá Archipelago (Latrubesse and Franzinelli, 2005).

Samples of *Cichla temensis* were obtained between October 2011 and September 2012, on a monthly basis.

Samplings were experimental fisheries performed twice a day, from 6h00 to 12h00 and from 14h00 to 18h00, in the main channel of the river, the adjacent lakes as well as in the canals of the Mariuá archipelago. Fish were kept in coolers with ice and transported to Manaus for the retrieval of biological data: standard length (cm) and total weight (g). Although experimental fisheries, these were developed with the same fishing gear and strategies developed by anglers and was supposed that it could obtain truly the parameters of the exploited population.

Campos et al. (2015a) estimated the following growth parameters of von Bertalanffy equation and using the same dataset: asymptotic length ($L_{\infty} = 68.05$ cm), growth coefficient ($k = 0.20 \cdot \text{year}^{-1}$) and longevity ($A_{0.95} = 14.0$ years). The parameter t_0 was considered zero because the initial size of the individual is negligible and because this parameter has no biological relevance.

The ages of recruitment (Tr) [Equation 1] and first catch (Tc) [Equation 2] were estimated using an adaptation of the von Bertalanffy growth equation (King, 1995; Sparre and Venema, 1997), as follows:

$$Tr = t_0 - \left(\frac{l}{k}\right) \cdot \ln \cdot \left[1 - \frac{L_t}{L_{\infty}}\right] \quad (1), \text{ and}$$

$$Tc = t_0 - \left(\frac{l}{k}\right) \cdot \ln \cdot \left[1 - \frac{L_t}{L_{\infty}}\right] \quad (2)$$

The length of the first catch and mean length of recruitment were estimated assuming that: $L_c = L_r =$ the smallest length class fully in the sampling (King, 1995; Sparre and Venema, 1997).

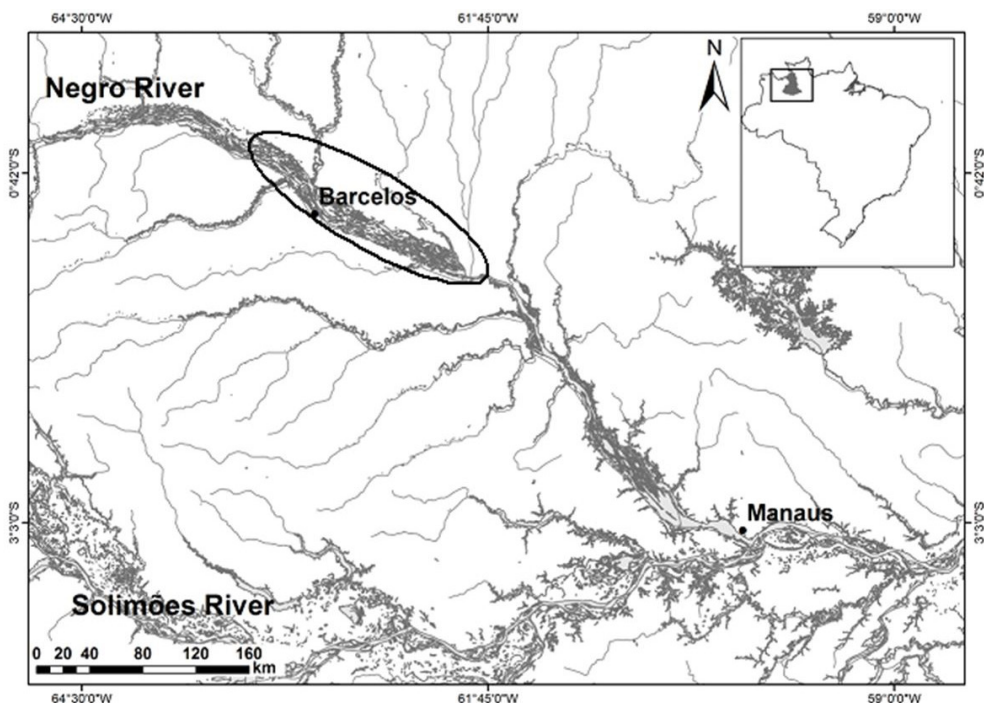


Figure 1. Middle Negro river, Amazonas, Brazil, showing the cities of Manaus and Barcelos.

The parameters a and b of the weight and length relationship, as defined by the Equation:

$$W = a \cdot L^b \quad (3),$$

where W is the total weight and L is the standard length, were estimated employing a non-linear model using the Levenberg-Marquardt procedure. The obtained equation was employed to obtain an estimate of Maximum Theoretical Weight (W_∞).

The natural mortality (M) was estimated by Equation 4 (Pauly, 1980), which estimates the natural mortality using an empiric equation that establishes a relationship between the natural mortality, growth parameters, and the temperature at the water surface.

$$\log M = -0.0066 - 0.279 \cdot \log L_\infty + 0.6543 \cdot \log k + 0.4634 \cdot \log T \quad (4),$$

where L_∞ and k = the parameters of the von Bertalanffy growth equation and T = the mean annual temperature at the water surface.

The total mortality (Z) was estimated by the linearized catch curve (King, 1995), assuming that the stock density decreases by a rate proportional to the abundance of each age class. The age (t) was estimated using the Equation 5:

$$t = \frac{-Ln \cdot \left(1 - \left(\frac{Lt}{L_\infty} \right) \right)}{k} \quad (5),$$

where Ln = natural logarithm; Lt = length at age t ; L_∞ = asymptotic length. We assumed that Z is the slope of the regression between the log-transformed values of density and age. After that, fishing mortality (F) was estimated using the Equation 6:

$$F = Z - M \quad (6)$$

Scenarios of yield per recruit for different combinations of fishing mortality (F) and age of the first catch (Tc) were done using the Beverton and Holt model, as described by Sparre and Venema (1997) according to the Equation 7:

$$Y/R = F \cdot \exp^{-M \cdot (Tc - Tr)} \cdot W_\infty \cdot \left[\left(\frac{1}{Z} \right) - \left(\frac{3S}{Z+K} \right) + \left(\frac{3S^2}{Z+2K} \right) - \left(\frac{3S^3}{Z+3K} \right) \right] \quad (7),$$

where Y/R = the yield per recruit ($g \cdot \text{recruit}^{-1}$); F = the fishing mortality; M = the natural mortality; Tr = the age of recruitment; Tc = the age of the first catch; W_∞ = the maximum theoretical weight; Z = the total mortality; $S = \exp^{-k \cdot (Tc - t_0)}$; k = the intrinsic rate of growth and t_0 = the parameter of the von Bertalanffy equation.

3. Results

A total of 250 *Cichla temensis* specimens were collected. Standard length varied between 21.5 and 53.5 cm (mean 33.30 \pm 5.34 cm). The natural mortality was calculated as 0.49 $\cdot \text{year}^{-1}$ and the total mortality (Z) as 1.24 $\cdot \text{year}^{-1}$. As consequence, the fishing

mortality was equal to 0.75 $\cdot \text{year}^{-1}$ (Table 1). The age of recruitment and the age of the first catch were assumed equal to 1.88 years, since the fish of this species became vulnerable for fishing at the same age they began to live at the adult stock.

The mean length of captured fish was 33.0 cm, which correspond to an age of 3 years. The length of the first catch (Lc), which is the lower length fully represented at the catch was assumed as 21.5 cm, based on fishing reports. Approximately 5% of the collected fish showed length smaller than 25 cm (minimum fish size of fishing defined by Brazilian law).

4. Discussion

The results showed that age of the first catch is a key variable for a successful management of *Cichla temensis* exploited by commercial, subsistence and recreational fisheries at the middle Negro river. Nowadays, the Brazilian Agency responsible by the fishing management establishes the minimum size to fish peacock bass, main commercial *Cichla* species, as 25 cm (Dias-Neto and Dias, 2015). However, as an evidence of the law inconsistency, the size of first sexual maturation (L_{50}) for *C. temensis* population of the middle Negro river was estimated in 31.1 cm, correspond to an age around 3 years old (Campos et al., 2015a). Actually, if the catches are based on individuals below 25 cm they are exploring fishes younger than 2.26 years old (Table 2).

The peacock bass *Cichla temensis* is a large equilibrium species, in the sense of Winemiller and Rose (1992), with moderate to long generation time, low reproductive effort, large body size, low batch fecundity, high investment per offspring and, in general, no migratory behavior. By this way, its yield per recruit should be highest exploring individuals

Table 1. Population parameters of *Cichla temensis* caught at in the region of the middle Negro river (Amazonas, Brazil) between 2011 and 2012.

Estimated population parameters	2011/2012
Total mortality (Z) (year^{-1})	1.24
Natural mortality (M) (year^{-1})	0.49
Fishing mortality (F) (year^{-1})	0.74
Maximum theoretical weight (W_∞) (g)	5,037.63
Age of recruitment (Tr) (year)	1.88
Age at first capture (Tc) (year)	1.88
Length at first capture (Lc) (cm)	21.5

Table 2. Criteria employed to associate length intervals (L.I.) to age intervals (A.I.) of the *Cichla temensis* caught at the middle Negro river (Amazonas, Brazil), from 2011 to 2012.

Criteria	L.I. (cm)	A.I. (years)
1 – Length $< L_{law}$ *	21.5–24.9	1.88–2.26
2 – $L_{law} < \text{Length} < L_{50}$ **	25.0–30.9	2.27–3.00
3 – Length $\geq L_{50}$	31.0–53.5	3.01–7.64

*Minimum fish size of fishing of *Cichla* spp. defined by Brazilian law. **Length at sexual maturity of *Cichla temensis*.

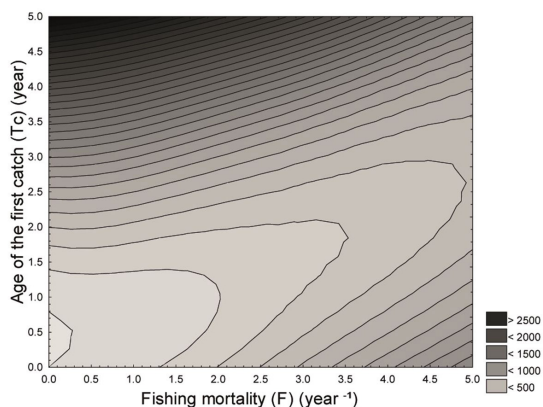


Figure 2. Simulation the yield per recruit of *Cichla temensis* for different combinations of age at first capture (T_c) and fishing mortality (F). Each isoline represents a constant yield per recruit.

older than 3 years old, which is correspondent to a length above 31 cm that is its size of first sexual maturation (Figure 2; Table 2). It is noticeable that exploiting a fishing based on an age of the first catch below 2 will not obtain yields per recruit above $0.50 \text{ g} \cdot \text{g}^{-1}$ independent of the fishing mortality coefficient (Figure 2).

The yield per recruit model is an efficient approach for fish stock assessment, consisting in an important tool to the management of fisheries (Sparre and Venema, 1997). Nevertheless, its efficacy has been criticized because recruitment and natural mortality are assumed as constant. Another constraints could arise in multispecies fisheries, as happens at the Amazon basin, since this model do not include the complex interactions among species (Pauly, 1980). Moreover, the model establishes reference points for management purposes, but none hypothesis tests are performed during the stock assessment process.

In general, the fishing effort (f) and the age of the first catch (T_c) are the viable goals for fishing management (Sparre and Venema, 1997). However, the fishing effort is a very difficult task in small-scale fisheries as performed in the Amazon basin (Bayley and Petrere, 1989; Batista and Petrere Junior, 2007; Batista et al., 2012). As the age of the first catch (T_c) is directly associated with the size of the first catch (L_c), other studies already proposed a fishing management based on it as an option for small-scale fisheries developed on the stocks of *Cichla monoculus* (Campos and Freitas, 2014), *Prochilodus nigricans* (Spix et Agassiz, 1829) (Catarino et al., 2014) and *Colossoma macropomum* (Cuvier, 1816) (Campos et al., 2015b) on the lower stretch of the Solimões river.

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