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Stock assessment and population parameters for *Triportheus spp*. and *Pellona flavipinnis* in floodplain lakes, central of Amazon, Brazil

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ABSTRACT

It is essential to provide data on fish stocks, especially those that appeared more recently on fishing landings. The present study estimated growth, mortality and evaluated the fish stock of *Triportheus albus*, *Triportheus angulatus*, *Triportheus auratus*, and *Pellona flavipinnis* in floodplain lakes in central Amazon, Manaus (AM), Brazil. Samplings were carried out monthly between 2006 and 2007 and bimonthly until 2008 using gillnets. We evaluated the growth parameters ($L\infty$, k, t_0, t_achor, Ø, $A_{0.95}$), natural, total, and fishing mortality, exploitation rate, and yield per recruit. The results showed *T. auratus* had the lowest estimated current fishing mortality pressure, while *T. angulatus* and *T. albus* had the highest fishing mortality pressure. It indicates that *T. angulatus* and *T. albus* are heavily exploited commercially. Considering current fishing mortality, *T. angulatus* and *T. albus* presented values above the maximum sustainable yield, indicating that these species are being exploited in an unsustainable way. This was the first time these fisheries stocks were evaluated. Despite the data being from a few years ago, these values are the only available and may be the baseline for the fisheries management plans.

Keywords: TropfishR; Growth; Fish stocks; Mortality; Yield per recruit.

Parâmetros populacionais e avaliação de estoques de *Triportheus spp*. e *Pellona flavipinnis* em lago de várzea, Amazônia Central, Brasil

RESUMO

É fundamental gerar informações acerca dos estoques pesqueiros de importância comercial, principalmente os emergentes nos registros de desembarque. O presente estudo estimou o crescimento e a mortalidade e avaliou os estoques de *Triportheus albus*, *Triportheus angulatus*, *Triportheus auritus* e *Pellona flavipinnis* em lagos de várzea na Amazônia Central, Manaus (AM), Brasil. As amostragens foram realizadas mensalmente de 2006 a 2007 e bimestralmente até 2008 utilizando redes de espera. Avaliaram-se os parâmetros de crescimento, a mortalidade natural, total e por pesca, a taxa de exploração e o rendimento por recruta. Os resultados mostraram que *T. auritus* teve a menor pressão de mortalidade por pesca, enquanto *T. angulatus* e *T. albus* tiveram a maior pressão de mortalidade por pesca. Nesse caso, *T. angulatus* e *T. albus* são fortemente explotadas comercialmente. Considerando a mortalidade por pesca atual, *T. angulatus* e *T. albus* apresentaram valores acima do rendimento máximo sustentável, indicando um nível de explotação insustentável. Essa foi a primeira vez que esses estoques pesqueiros foram avaliados. Apesar de os dados serem de alguns anos atrás, esses valores são os únicos disponíveis e podem servir como linha de base para planos de gestão pesqueira.

Palavras-chave: TropfishR; Crescimento; Estoque pesqueiro; Mortalidade; Rendimento por recruta.

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INTRODUCTION

In the Amazon region, fishing stands out in relation to other Brazilian regions, both in inland and coastal waters (Barthem and Fabré, 2004; Barbosa et al., 2020). It is the main source of income and food for riverside communities in the Amazon River basin (Rylands et al., 2002), which is mainly artisanal, multispecies and multigear. Fishing in the central Amazon can be divided into two different systems: fishing in flooded areas (lakes and flooded forest), and in river channels (Souza, 2012). During the flood, most fish species move to regions of lakes, macrophyte stands, and flooded forests, where they find food, refuge, and protection from predators (Isaac and Barthem, 1995).

The fish fauna richness in the Amazon basin is high (Tedesco et al., 2017), accounting for the vast number of species in the neotropical region, which have remarkable strategies of adaptation to seasonal changes in the different environments they occupy (Ruffino, 2004). Species of the family Characidae stand out in the Amazon basin, due to the high number of known species with vast ecological importance and expressive commercial value (Britzke, 2011). The family Pristigasteridae contains predatory species with high abundance, especially in lowland areas (Saint-Paul et al., 2000).

In the Central Amazon, fish of the families Characidae and Pristigasteridae that previously had no commercial importance began to appear in commercial records (Ibama, 2007; Prestes et al., 2010). For example, *Triportheus albus* (Cope, 1872), *Triportheus angulatus* (Spix and Agassiz, 1829) and *Triportheus auritus* (Valenciennes, 1852), popularly known as *sardinha*, as well as *Pellona flavipinnis* (Valenciennes, 1836), known as *sardinhão*. These species are pelagic, occur in most large hydrographic basins in South America (Malabarba, 2004; Moreira-Hara et al., 2009), are medium to large (15–30 cm) (Pinna and Dario, 2003; Malabarba, 2004), with predominantly piscivorous (*P. flavipinnis*) and carnivorous feeding habits with a tendency to insectivory and frugivory (*Triportheus* spp.) (Braga, 1990; Ferreira et al., 1998; Yamamoto et al., 2004). The fact that these fish began to appear at the commercial landings demonstrates fluctuations in commercial preferences in the fishing activity, with a significant increase in commercialization (Soares and Junk, 2000). This could increase the fishing effort, causing a possible reduction in fish stocks in the region.

Studies have revealed that *Triportheus* species have a short biological cycle, high mortality, and short life expectancy, being considered r-strategist species (Prestes et al., 2010; Dieb-Magalhães et al., 2015; Barros et al., 2016). Although the growth parameters for some of these species were available a while (Prestes et al., 2010), the old-school assessment models required a lot of available data. Data-limited/data-poor approaches have gained importance nowadays and can be used with data-poor species (Jiao et al., 2011; Saldaña et al., 2017).

In this context, the present study aimed to evaluate the stocks of *T. albus*, *T. angulatus*, *T. auritus* and *P. flavipinnis* from floodplain lakes in central Amazon, using a data-limited/data-poor approach using the statistical language R. Such studies are of paramount importance to assess for the first time the state of these fisheries stocks. Despite the data being taken 14 years ago, these values are the only ones available to the new data-poor approaches. These outputs may be used as the baseline for supporting decision-making in fisheries management to aim exploitation in the long term.

MATERIAL AND METHODS

Study area

Specimens were caught monthly from July 2006 to August 2007 and bimonthly until April 2008 in Jaitêua (3’15’52.79”S and 60’42’55.91”W) and São Lourenço (3º14’28.90”S 60º44’31.88”W) lakes, located on the left bank of the Solimões River, municipality of Manacapuru, state of Amazonas, Brazil (Fig. 1). These lakes are part of a complex of Manacapuru lakes in an extensive floodplain area connected to the Solimões River.

Sample and data processing

Samplings were carried out in the open water and flooded forest with the objective of having a representative sample of the different cohorts of fish (Autorization no. 31010-1 SISBIO). For this, we used batteries of mixed gillnets (length 25 × height 2 m), with mesh sizes ranging from 20, 30, 40, 50, 60, 70, 80, 90, 100, 110 and 120 mm between opposite knots, exposed for 24 hours with inspection every 6 hours. The captured fishes were identified in the field with systematic keys (Géry, 1977; Santos et al., 1984; Ferreira et al., 1998). The date of collection, standard length (cm), and total weight (g) were recorded for each fish.

Growth

The length to weight ratio (LWR) was calculated by linear regression using the Eq. 1:

$$\mathrm{Wt} = a + b*\mathrm{lnLs} \quad (1)$$

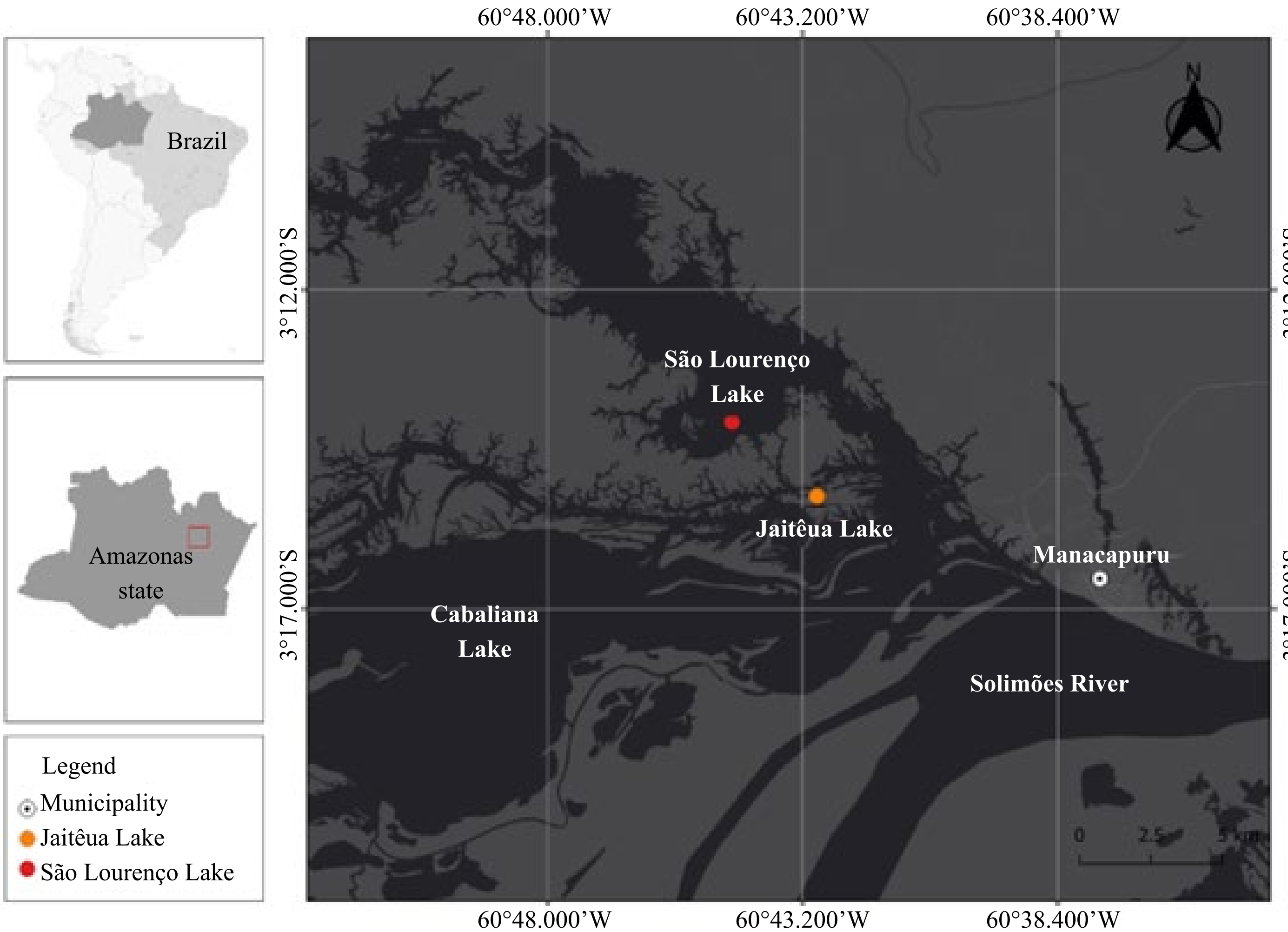

Figure 1. Location map of Jaitêua and São Lourenço lakes and Solimões River, municipality of Manacapuru, state of Amazonas, Brazil.

Where: Wt: total weight; Ls: standard length; *a*, *b* and r^2: linear regression coefficients.

The value of *b* was tested using the Student's t-test, where H_0: b = 3 (isometric growth) and H_1: b ≠ 3 (allometric growth), with the significance level of 0.05% (Le Cren, 1951). Population growth parameters–L∞: asymptotic length, k: growth coefficient, t_0: length in the time zero, t_anchor: time of cohort birth, and Ø: growth performance index–were estimated using the TropFishR package (Mildenberger et al., 2017).

This package includes traditional and updated versions of the electronical length frequency analysis (ELEFAN) method, used in growth parameters estimation, with new optimization techniques. Length frequency data was used to calculate the von Bertalanffy growth rate (k) and the asymptotic length (*L∞ Linf*) by model progression analysis using the Genetic Algorithm ELEFAN GA, which is one of the new optimization approaches ELEFAN within the TropFishR package (Mildenberger et al., 2017; Kindong et al., 2020). This algorithm uses the von Bertalanffy equation (VBGF) with and without seasonality in a growth (i.e., considering or not differences in growth velocity during the year) (Sparre and Venema, 1992). For this analysis, the best score adjustment (Rn) was always considered. The value of Rn is used to define an adequate measure of the goodness of fit of the data restructuring. The calculation of Rn is according to Eq. 2:

$$Rn = ESP/ASP \quad (2)$$

Where: ESP: the sum of explainable points; ASP: the sum of available points.

The highest value of Rn was used to determine the best quality of fit of the growth curves in ELEFAN GA.

The parameter t_0 was considered 0. The version of the equation with seasonality considers, in addition to the L∞ and k parameters, two other parameters: Cº (seasonal oscillation amplitude) and ts (summer point). The seasonal oscillation amplitude (Cº) characterizes the species growth as being slow in the winter point (Wp), equivalent to the flood period (February to May), and accelerated in the summer point (ts), equivalent to the dry period (September to November). This adaptation was based on the flood pulse of the central Amazon region (Castro et al., 2002). In ELEFAN, time is used rather than age, and the point in which the growth curve crosses length zero is referred to as the "anchor time" (t_anchor) model. This is interpreted as the time when length equals zero. Thus, t_anchor is the point in which the growth curve crosses zero length, and it estimates the birth time of the cohort. The growth performance index (Ø) was used to compare the growth curves according to the Eq. 3 (Pauly and Munro, 1984):

$$Ø = \log k + 2 * \log L\infty \tag{3}$$

Analyses were run using the R software (R Core Team, 2020).

Longevity

Longevity ($A_{0.95}$), defined as the time the individual takes to reach 95% asymptotic length, was estimated based on the formula proposed by Taylor (1958) (Eq. 4), using the Excel 2010 software from the Microsoft office suite:

$$A_{0.95} = t_0 + (2.996/k) \tag{4}$$

Mortality

For natural mortality (M), we used the method based on a meta-analysis of 201 fish species (Then et al., 2015). The length-converted catch curve allowed to estimate the instantaneous total mortality rate (Z) through the length frequency data (LFQ) and the selectivity model. The total mortality rate was estimated with a representative sample of catches for the entire year. Subtracting M from Z, it was possible to calculate the fishing mortality rate (F). The exploitation rate was defined as E = F/Z. Furthermore, the catch curve selectivity function estimated the first catch length (L_{50}) using the TropfishR package (Mildenberger et al., 2017).

Yield per recruit

Yield per recruit (Y/R) was calculated using the model by Beverton and Holt (1957), which is used to assess the status of fish stock based on biological reference points–$F_{current}$: current fishing mortality, F_{msy}: fishing mortality of maximum sustainable yield, $E_{current}$: current explotation rate, L_c: length in a 50% of fishes were caught. This analysis was performed in Excel 2010 software from the Microsoft office suite.

RESULTS

The analysis of the length class frequencies for all analyzed species tended to normality, with representative length amplitude for young and adults (Table 1). The estimated growth parameters pointed to accelerated growth (k), with relatively small asymptotic length (L∞), and high natural mortality (M), according to the growth pattern of medium-sized species in floodplain lakes in the Central Amazon (Table 1). The four species showed seasonal oscillation amplitude (Cº) in growth, and the seasonal oscillations were such that the growth rate was increased by 59–87% at the time of the peak of the flood growth and rapidly reduced by this same proportion in the drought. In the flood period, growth is faster in March (0.24), April (0.32) and May (0.42 and 0.47), according to the values of the seasonal oscillation point (ts) (Salomão, 2023).

The length-weight relationship for all species showed moderate and high r^2 values, above 0.62, with negative allometric growth for all species (b < 3) (Table 1). The values of the growth performance index (Ø) and the maximum goodness of fit (Rn) for the ELEFAN algorithm in estimating the growth parameters are listed in Table 1.

Among the species studied, *T. albus* presented the highest values of natural mortality (M) and total mortality (Z). Fishing mortality rates (F) indicated that *T. auritus* had the lowest estimated current fishing pressure, while *T. albus* had the highest fishing pressure, indicating that *T. albus* followed by *T. angulatus* are being heavily exploited commercially. The current fishing mortality ($F_{current}$) estimated was bigger than mortality at maximum sustainable yield (F_{msy}) for *T. angulatus* and *T. albus*. Values of the current fishing mortality ($F_{current}$) were below F_{msy} to *T. auritus* and *P. flavipinnis*. The estimates of the current exploitation rate ($E_{current}$) and yield per recruit (Y/R) are in Table 2.

DISCUSSION

These are the first estimates of population parameters for *P. flavipinnis* and the first data to assess fish stocks in the Amazon basin for *T. albus*, *T. angulatus* and *T. auritus*. LWR data are input information for calculating stock biomass considering the length of age groups/cohorts in fish stock assessment models. The correlation of total weight and standard length of the analyzed species indicated a strong correlation,

Table 1. Growth parameter estimates for *Triportheus albus*, *Triportheus angulatus*, *Triportheus auritus* and *Pellona flavipinnis* caught in Jaitêua and São Lourenço lakes in the 2006–2008 period, municipality of Manacapuru, state of Amazonas, Brazil.

Species	*Triportheus albus*	*Triportheus angulatus*	*Triportheus auritus*	*Pellona flavipinnis*
N	693	640	486	2.070
Lmin (cm)	8.40	7.00	6.50	6.50
Lmax (cm)	23.00	27.00	26.50	30.00
$L\infty$ (cm)	23.99	30.40	21.57	32.77
k ($year^{-1}$)	0.74	0.50	0.50	0.19
t_anchor	0.38	0.78	0.59	0.58
C°	0.87	0.64	0.79	0.59
ts	0.32	0.47	0.45	0.24
Ø	2.63	2.67	2.37	2.31
Rn	0.39	0.49	0.49	0.38
$A_{0.95}$	4.04	5.99	5.92	15.76
a	0.0358	0.0305	0.0556	0.0475
b	2.669	2.848	2.499	2.586
r^2	0.62	0.88	0.85	0.80

N: number of individuals used in the analysis; Lmin: minimum length; Lmax: maximum length; $L\infty$: maximum asymptotic length; k: growth rate; t_anchor: anchor time; C°: amplitude of growth oscillation; ts: oscillation point in the summer; Ø: growth performance index; Rn: highest score value; $A_{0.95}$: longevity; a: linear coefficient; b: coefficient of allometry; r^2: coefficient of determination.

Table 2. Estimates used to apply the model (Beverton and Holt, 1957) to data *Triportheus albus*, *Triportheus angulatus*, *Triportheus auritus* and *Pellona flavipinnis* caught in Jaitêua and São Lourenço lakes in the 2006–2008 period, in the municipality of Manacapuru, state of Amazonas, Brazil.

Species	*Triportheus albus*	*Triportheus angulatus*	*Triportheus auritus*	*Pellona flavipinnis*
N	693	640	686	2.070
M ($year^{-1}$)	1.16	0.81	0.90	0.39
Z ($year^{-1}$)	3.95	2.83	1.03	0.95
L_{50}/Lc (cm)	14.25	14.14	13.52	15.74
$F_{current}$	2.79	2.02	0.12	0.56
F_{msy}	1.50	1.50	1.50	1.30
$E_{current}$	0.70	0.71	0.12	0.59
Y/R (gr)	9.85	26.26	5.14	13.17

N: number of individuals used in the analysis; M: natural mortality; Z: total mortality; L_{50}/Lc: length in a 50% of fishes were caught; $F_{current}$: current fishing mortality; Fmsy: mortality at maximum sustainable yield; $E_{current}$: current explotation rate; Y/R: yield per recruit.

with r^2 above 0.62. The allometry coefficient (b) results were statistically different from 3, with values indicating negative growth allometry for all species analyzed in this study. Silva-Júnior et al. (2007) state that, when *b* is different from 3, the growth is allometric, and, when the value is lower than 3, it implies an increase in length greater than in weight. This pattern is expected for *sardinha* species in general, with an elongated body, and this type of growth corroborates the results found by Prestes et al. (2010).

The TropFishR package used in this study consists of new and little used methods for assessing limited data (Peixoto et al., 2020), which use LFQ. In this package, population growth parameters are estimated from VBGF with and without seasonality, and these estimates are evaluated using an effective measure of goodness-of-fit (Rn). The best fits for all the species analyzed in this study were those for VBGF with seasonality (Appendix 1). This was the first time that length-frequency analysis using a growing oscillation model gave a better fit than without oscillation.

This result is consistent with those already found oscillation in growth for *mapará* (*Hypophthalmus marginatus*) and *piracatinga* (*Calophysus macropterus* Lichtenstein) in floodplains lakes in Central of Amazonian (Cutrim and Batista, 2005; Pérez and Fabré, 2003). However, those studies were done reading growth rings in otoliths, bones, scales. They validated the rings formation and differences in the growth speed of fish with flood and drought periods of the hydrological cycle in the Central Amazon region (Cutrim and Batista, 2005; Pérez and Fabré, 2003). The better fit of the oscillation growth model using length frequency may be related to the robust methodology used, the genetic algorithm in the Rstudio software. The genetic algorithm seeks the best performance for data analysis, and one of the advantages of using ELEFAN_GA is the possibility of optimizing the VBGF parameters with and without seasonal oscillation in growth. The optimization result can be compared relatively between seasonal and non-seasonalized data, indicating the best genetic fit. Prestes et al. (2010), estimating growth and mortality parameters for sardines (*T. albus*, *T. angulatus* and *T. auritus*), did not find the oscillation in growth using the method ELEFAN without optimization algorithm in an older and less robust program, FISAT II.

According to Mildenberger et al. (2017), the genetic algorithm methods cannot estimate t_0 from LFQ data. However, this parameter does not interfere with the fish stock evaluation results based on length; therefore, t_0 is set as zero length. In the genetic algorithm, the parameter t_anchor acts as the FISAT II known starting point, which indicates the fraction of a year in which the von Bertalanffy growth curve for a given cohort crosses length = 0. However, t_anchor does not replace t0. The point at which the growth curve crosses length zero (t_anchor) ranges from April (0.38) to September (0.78) according to Fig. 2.

Values obtained for the growth index for *Triportheus* species were lower than the values presented by Prestes et al. (2010), which presented a variation from 2.70 to 2.74. This is related to the high L∞ values of Prestes et al. (2010), whose values varied from 24.68–27.83 cm. The L∞ and k for analyzed species indicated fast growth, with relatively low asymptotic length, characteristic of these medium-sized r-strategists (Barros et al., 2016) that inhabit the wetlands of the Amazon region. The results for *T. angulatus*, *T. auritus* and *T. albus* were in agreement with Prestes et al. (2010).

Natural mortality (M) is usually empirically estimated by different equations, with environmental and growth parameters. For example, Hoenig (1982) proposed an equation emphasizing maximum age (T_{max}), Taylor (1958) relates M to longevity ($A_{0.95}$), and Pauly (1980), in addition to k and L∞, considers the environmental temperature. Then et al. (2015) tested the effectiveness of empirical estimation of various equations and found a better fit for the equation that uses the T_{max} and growth parameters.

In the present study using the equation of Then et al. (2015), natural mortality was high for *T. albus*, *T. angulatus*, and *T. auritus*, except for *P. flavipinnis*, which may be related to the size that the species reach, that is, the higher the L∞, the lower the rate of M. The main factors of M are predation and diseases since smaller species are more susceptible to predation, and larger species are more exposed to diseases due to the lower use of nutritional elements (Fonteles Filho, 2011). The results of M for *T. albus*, *T. angulatus,* and *T. auritus* differed from those presented by Prestes et al. (2010), which showed lower values. However, despite this difference, the results of M found in both studies are expected for the *Triportheus* species studied here.

Based on the results obtained by recruiting and biological reference points, the stocks of *T. albus* and *T. angulatus* are under threat of overfishing. On the other hand, both *T. auritus* and *P. flavipinnis* are in a less threatening situation. According to Mateus and Penha (2007), the yield per recruit (Y/R) model considers the effect of different exploitation strategies, assuming the equilibrium state, correlating catch, growth, and fishing mortality ($F_{currentl}$). The maximum yield per recruit guarantees the replenishment of the stock (F_{msy}) to be achieved. Therefore, the relationship of equivalence between $F_{current}$ and F_{msy} was considered a biological reference point for this study.

These estimates can be used as a biological reference point for the management of fisheries for these species in the floodplain lakes of the Amazon basin, and raise a step in the discussion by implementing a period of restriction in fishing (close season) and establishing quotas for catch or monitoring, thus favoring sustainability in the use of fish stocks and avoiding fishing during the vulnerable period of the species.

Deciding whether these recommendations are feasible and which strategies are most likely to achieve them will require a broad, collaborative discussion. It is important to remember that overfishing can be avoided through sustainable fishing, which allows stocks to replenish. However, stock renewal is highly dependent on the state of the environment. Therefore, it is necessary to consider the environmental aspects that directly affect the life cycle and dynamics of fish stocks (Fonteles Filho, 2011). Thus, in areas subject to flooding, three fundamental points can be listed:

- Habitat complexity;
- Water quality;
- Flood pulse.

Given this, any activity that affects these factors will imply changes in stocks and, consequently, in fishing activity. Therefore, for fishing to be sustainable, the environment must be preserved.

CONCLUSION

In view of the results presented, the status of the fish stocks of the species *T. auritus* and *P. flavipinnis* showed sustainable levels of exploitation. However, attention should be paid to the state of the *T. albus* and *T. angulatus* stocks, which exceeded the levels of maximum sustainable yield. In addition, although these data were collected more than ten years ago, it is the first time they are used for stock assessment, demonstrating that a periodic reassessment of these species is necessary to ensure continued production and sustainable fishing in the region.

The use of the genetic algorithm in the TropfishR package allowed more robust estimates of population parameters to be obtained and, for the first time, these stocks to be assessed.

These are the most up-to-date estimates available and will serve as a basis for subsidizing fisheries management standards. It is important to note that it is necessary to resume the collection of fisheries data, and although these data are not current, they are the only data available for these species.

CONFLICT OF INTERESTS

Nothing to declare.

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AUTHORS' CONTRIBUTIONS

Conceptualization: Salomão CB, Soares MGM, **Methodology:** Prestes L, Soares MGM; **Investigation:** Soares MGM; **Data curation:** Salomão CB, Gonçalves VD, Soares JMS, Prestes L, Oliveira MSB; **Validation:** Soares MGM; **Formal Analysis:** Salomão CB, Gonçalves VD, Soares JMS, Prestes L, Oliveira MSB; **Resources:** Prestes L; **Project administration:** Prestes L; **Supervision:** Prestes L, Soares MGM; **Writing – original draft:** Salomão CB, Soares JMS, Prestes L, Soares MGM; **Writing – review & edition:** Salomão CB, Prestes L.

DATA AVAILABILITY STATEMENT

The data and analyses (script in the RStudio program) supporting the results are available at https://figshare.com/articles/dataset/Dados_e_An_lises_do_Estudo/24470701. These data were collected through the SPC&T Phase II/PPG7 Project and the Bases for Sustainability of Fishing in the Amazon (BASPA) project.

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REFERENCES

Barbosa, R.R.; Silva, D.L.; Andrade, P.F.; Aquino, L.J.M. 2020. Pesca, ambiente e apetrechos no município de Benjamin constant-AM. *Anuário do Instituto de Natureza e Cultura*, 3(1): 123-125.

Barros, N.H.C.; Lima, L.T.B.; Araújo, A.S.; Gurgel, L.L.; Chellappa, N.T.; Chellappa, S. 2016. Estudos sobre as táticas e as estratégias reprodutivas de sete espécies de peixes de água doce do Rio Grande de Norte, Brasil. *Holos*, 3: 84-103. https://doi.org/10.15628/holos.2016.3648

Barthem, R.B., Fabré, N.N. 2004. Biologia e diversidade dos recursos pesqueiros da Amazônia. In: Ruffino, M.L. (ed.). *A pesca e os recursos pesqueiros na Amazônia brasileira*. Manaus: IBAMA/ProVárzea, v. 1, p. 17-62.

Beverton, R.J.H.; Holt, S.J. 1957. On the dynamics of exploited fish populations. England: Copeia.

Braga, F.M.S. 1990. Aspectos da reprodução e alimentação de peixes comuns em um trecho do rio Tocantins entre Imperatriz e Estreito, Estados do Maranhão e Tocantins, Brasil. *Revista Brasileira de Biologia*, 50(3), 547-558.

Britzke, R. 2011. *Revisão taxonômica do grupo Moenkhausia dichroura (Kner, 1858) (Characiformes: Characidae)* [dissertation]. Botucatu: Instituto de Biociências, Universidade Estadual Paulista "Júlio de Mesquita Filho". Available at: https://repositorio.unesp.br/bitstream/handle/11449/99452/britzke_r_me_botib.pdf?sequence=1&isAllowed=y. Accessed on: Dec. 17, 2021.

Castro, P.M.G.; Cergole, M.C.; Carneiro, M.H.; Mucinhato, C.M.D.; Servo, G.J.M. 2002. Crescimento, mortalidade e taxa de explotação do goete, Cynoscion njamaicensis (Perciformes: Sciaenidae), na região Sudeste/Sul do Brasil. *Boletim do Instituto de Pesca*, 28(2): 141-153.

Cutrim, L., Batista, V.D.S. 2005. Determinação de idade e crescimento do mapará (Hypophthalmus marginatus) na Amazônia Central. *Acta Amazônica*, 35(1), 85-92. https://doi.org/10.1590/S0044-59672005000100013

Dieb-Magalhães, L.; Florentino, A.C.; Soares, M.M. 2015. Length–weight relationships and length at first maturity for nine fish species of floodplain lakes in Central Amazon (Amazon Basin, Brazil). *Journal of Applied Ichthyology*, 31(6): 1182-1184. https://doi.org/10.1111/jai.12919

Ferreira, E.J.G.; Zuanon, J.A.S.; Santos, G.M. 1998. *Peixes Comerciais do Médio Amazonas, Região de Santarém/PA*. Brasília: IBAMA, 211 p.

Fonteles Filho, A.A. 2011. *Recursos pesqueiros: biologia e dinâmica populacional*. Fortaleza: Imprensa Oficial do Ceará.

Géry, J. 1977. *Characoids of the world Neptune City*. New Jersey: T.F.H., 672 p.

Hoenig, J.M. 1982. *Compilation of mortality and longevity estimates for fish, mollusks, and cetaceans with a bibliography of comparative life history studies*. Technical Report Reference No. 82-2 p. Rhode Island: University of Rhode Island, Graduate School of Oceanography.

Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (Ibama). 2007. *Estatística da pesca 2007: Brasil, grandes regiões e unidades da federação*. Brasília: IBAMA, DIFAP, CGREP, 113 p.

Isaac, V.J.; Barthem, R.B. 1995. Os recursos pesqueiros da Amazônia brasileira. *Boletim Museu Paraense Emílio Goeldi, Série Antropologia*, 11(2): 295-339.

Jiao, Y.; Cortés, E.; Andrews, K.; Guo, F. 2011. Poor-data and data-poor species stock assessment using a Bayesian hierarchical approach. *Ecological Applications*, 21(7): 2691-708. https://doi.org/10.1890/10-0526.1

Kindong, R.; Wu, F.; Tian, S.; Zhu, J.; Dai, X.; Wang, J.; Dai, L. 2020. Biological parameters estimate for the sickle pomfret (Taractichthys steindachneri) in the west-central and eastern Pacific Ocean. *Indian Journal of Geo-Marine Sciences*, 49(3): 373-381.

Le Cren, E.D. 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (Perca fluviatilis). *Journal of Animal Ecology*, 20(2): 201-219. https://doi.org/10.2307/1540

Malabarba, M.C.S. 2004. Revision of the neotropical genus Triportheus Cope, 1872 (Characiformes: Characidae). *Neotropical Ichthyology*, 2(4): 167-204. https://doi.org/10.1590/S1679-62252004000400001

Mateus, LA.; Penha, J.M. 2007. Avaliação dos estoques pesqueiros de quatro espécies de grandes bagres (Siluriformes, Pimelodidae) na bacia do rio Cuiabá, Pantanal Norte, Brasil, utilizando alguns Pontos de Referência Biológicos. *Revista Brasileira de Zoologia*, 24(1): 144-150. https://doi.org/10.1590/S0101-81752007000100017

Mildenberger, T.K.; Taylor, M.H.; Wolff, M. 2017. TropFishR: an R package for fisheries analysis with length-frequency data. *Methods in Ecology and Evolution*, 8(11): 1520-1527. https://doi.org/10.1111/2041-210X.12791

Moreira-Hara, S.S.; Zuanon, J.A.; Amadio, S.A. 2009. Feeding of Pellona flavipinnis (Clupeiformes, Pristigasteridae) in a Central Amazonian floodplain. *Iheringia. Série Zoologia*, 99(2), 153-157. https://doi.org/10.1590/S0073-47212009000200006

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. *Journal du Conseil International pour l'Exploration de la Mer*, 39(2): 175-192. https://doi.org/10.1093/icesjms/39.2.175

Pauly, D.; Munro, J.L. 1984. Once more on the comparison of growth in fish and invertebrates. *ICLARM Fishbyte Newsletter of the Network of Tropical Fisheries Scientists*.

Peixoto, U.I.; Mesquita, E.M.; Cintra, I.A.; Klautau, A.G.; Gouveia, N.A.; Paes, E.T.; Isaac, V.J. 2020. Dinâmica populacional e sustentabilidade da pesca da lagosta (Panulirus meripurpuratus Giraldes & Smyth, 2016) na plataforma continental amazônica. *Marine and Freshwater Research*, 72(1): 99-109. https://doi.org/10.1071/MF19333

Pérez, A.; Fabré, N.N. 2003. Seleção das estruturas calcificadas para determinação da idade da piracatinga Calophysus macropterus Lichtenstein (Siluriformes: Pimelodidae) na Amazônia Central, Brasil. *Acta Amazônica*, 33(3): 499-514. https://doi.org/10.1590/S0044-59672003000300015

Pinna, M.C.C.; Dario, D. 2003. Family Pristigasteridae. In: Reis, R.; Kullander, S.O.; Ferraris Jr., C.J. (eds.). *Check List of the Freshwater Fishes of South and Central America*. Porto Alegre: Edipucrs, p. 43-45.

Prestes, L.; Soares, M.G.M.; Silva, F.R.; Bittencourt, M.M. 2010. Dinâmica populacional de Triportheus albus, T. Angulatus e T. Auritus (Characiformes: Characidae) em lagos da Amazônia central. *Biota Neotropica*, 10(3): 177-181. https://doi.org/10.1590/S1676-06032010000300020

R Core Team. 2020. *R: A language and environment for statistical computing*. Vienna: R Foundation for Statistical Computing. Available at: https://www.R-project.org/. Accessed in: July, 2022.

Ruffino, M.L. (ed.). 2004. *A pesca e os recursos pesqueiros na Amazônia brasileira*. Brasília: Ibama.

Rylands, A.B.; Mittermeier, R.A.; Pilgrim, J.; Gascon, G.; Fonseca, G.A.B.; Silva, J.M.C.; Mittermeier, C.; Brooks, T.; Rodriguez, J.V.; Singh, J. 2002. Amazonia. In: Mittermeier, R.A.; Mittermeier, C.G.; Gil, P.R.; Pilgrim, J.; Fonseca, G.; Brooks, T.; Konstant, W.R. (eds.). *Wilderness: Earth's Last Wild Places*. Mexico: Conservation International, p. 57-106.

Saint-Paul, U.; Zuanon, J.; Villacorta-Correa, M.A.; Garcia, M.; Fabré, N.N.; Bergera, U.; Junk, W.J. 2000. Fish communities in central Amazonian white and blackwater floodplains. *Environmental Biology of Fishes*, 57: 235-250. https://doi.org/10.1023/A:1007699130333

Saldaña, A.; Salas, S.; Arce-Ibarra, A.M.; Torres-Irineo, E. 2017. Operações de pesca e estratégias adaptativas de pescadores de pequena escala: percepções para a gestão da pesca em situações de escassez de dados. *Fisheries Management and Ecology*, 24(1): 19-32.

Salomão, C. B. 2023. Dados e Análises do Estudo. figshare. Dataset. https://doi.org/10.6084/m9.figshare.24470701.v1

Santos, G.M.D.; Jegu, M.; Merona, B. 1984. *Catálogo de peixes comerciais do baixo rio tocantins*. Manaus, Brazil: Projeto Tucuruí, Eletronorte, Conselho Nacional de Pesquisas Científicas e Tecnológicas/Instituto Nacional de Pesquisas da Amazônia, 83.

Silva-Júnior, M.G.; Castro, A.C.L.; Soares, L.S.; França, V.L. 2007. Relação peso-comprimento de espécies de peixes do estuário do rio Paciência da ilha do Maranhão, Brasil. *Boletim do Laboratório de Hidrobiolo*gia, 20(1). Available at: https://bit.ly/RELAÇÃOPESO-COMPRIMENTODEESPÉCIESDEPEIXESDOESTUÁRIODORIOPACIÊNCIA. Accessed on: Dec. 17, 2021

Soares, M.G.M.; Junk, W.J. 2000. Commercial fishery and fish culture of the state of amazonas: Status and perspectives. In: Junk, W.J.; Ohly, J. (eds.). *The Central Amazon Floodplain: Actual Use and Options for a Sustainable Management*. Leiden: Backhuys, p. 433-461.

Souza, A.C.B. 2012. Ambiente e vida regional ritmado pela várzea no complexo Solimões-Amazonas. *Revista Geonorte*, 2(4), 91-102.

Sparre, P.; Venema, C. 1992. *Introduction to tropical fish stock assessment*. Rome: FAO.

Taylor, C.C. 1958. Cod growth and temperature. *ICES Journal of Marine Science*, 23(3): 366-370. https://doi.org/10.1093/icesjms/23.3.366

Tedesco, P.A.; Beauchard, O.; Bigorne, R.; Blanchet, S.; Buisson, L.; Conti, L.; Oberdorff, T. 2017. A global database on freshwater fish species occurrence in drainage basins. *Scientific Data*, 4: 170141. https://doi.org/10.1038/sdata.2017.141

Then, A.Y.; Hoenig, J.M.; Hall, N.G.; Hewitt, D.A. 2015. Avaliação do desempenho preditivo de estimadores empíricos da taxa de mortalidade Natural usando informações sobre mais de 200 espécies de peixes. *ICES Journal of Marine Science*, *72*(1): 82-92. https://doi.org/10.1093/icesjms/fsu136

Yamamoto, K.C.; Soares, M.G.M.; Freitas, C.E.D.C. 2004. Feeding of Triportheus angulatus (Spix & Agassiz, 1829) in the Camaleão lake, Manaus, Amazonas state, Brazil. *Acta Amazonica*, 34(4): 653-659. https://doi.org/10.1590/S0044-59672004000400017