USING STOCK ASSESSMENT TO INVESTIGATE THE SUSTAINABLE FISHERIES OF THE YELLOW MANDI *Pimelodus maculatus* IN THE UPPER URUGUAY RIVER, SOUTHERN BRAZIL

**ABSTRACT**

The yellow mandi *Pimelodus maculatus* is a medium-sized species with a wide geographical distribution. The species is very common in the Neotropical region, representing an important share of fishing activity in several Brazilian reservoirs. Therefore, the objective of this study was to evaluate the current situation of the yellow mandi fish stock in the Itá reservoir, located in the Upper Uruguay River. Data collected from January 2004 to December 2016 were used to estimate growth, mortality, and fish recruitment rates. In addition, a stock assessment was performed, and the results were used to verify the status of the fishery. The mean of the population parameters were: total length (*L*) = 55.65 cm; length at which 50% of fish are vulnerable to capture (*L*_c) = 23.08 cm, growth rate (*k*) = 0.260 year^{-1}, growth performance index (*Ø*) = 3.047, natural mortality rate (*M*) = 0.537, fishing mortality rate (*F*) = 0.413, total mortality rate (*Z*) = 0.95, exploitation rate (*E*) = 0.434, maximum age (*T*_max) = 6.68 years. The growth curve obtained via ELEFAN I revealed that fishing operates on eight of the eleven cohorts of the population. Yellow mandi stock assessment did not show signs of fish overexploitation or any risk of depletion.

**Key words:** Growth; mortality; fish stock; Uruguay River

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INTRODUCTION

Inland fishing, performed both in rivers and in reservoirs, stands out as an activity of great social and economic importance (Junk, 2007). In many Brazilian regions, fishing is the main source of income and food supply for local population, as well as being an important recreational activity (Junk, 2007; Schork et al., 2013).

Characterized as having a small scale and dispersed activity with little or no landing control, inland fisheries are difficult to manage, largely due to the difficulty of obtaining consistent data (Penha and Mateus, 2007; Agostinho et al., 2016). Nevertheless, understanding population structure and dynamics of fish stocks is essential to ensure the sustainability of fisheries (Jiménez-Badilho, 2004; Penha and Mateus, 2007; Campos and Freitas, 2014; Sá-Oliveira et al., 2015; Amarasinghe et al., 2017; Doll et al., 2017; Ellis et al., 2018; Kumari et al., 2018).

One way of studying fishing stocks is through the yield-per-recruit model (Munyandorero, 2018), which facilitates the estimation of the biomass that is being replaced in the population, to ensure an equilibrium condition. In this model, fishing catch data, species growth, and natural mortality are related to estimate the maximum fishing mortality (F_{max}) that guarantees the maximum yield-per-recruit for the renewal of the species stock, i.e., the maximum sustainable yield. However, in many situations, the maximum sustainable yield is only investigated when the population is already overfished (Mateus and Penha, 2007). Thus, Biological Reference Points (BRPs), which contain additional information to assess the current status of a fish stock, are usually selected depending on the type of data available about the target species.

In several Brazilian regions, different sizes of pimelodid species have been important for fishing activities (Doria et al., 2012; Sant’Anna et al., 2014). The yellow mandi \textit{Pimelodus maculatus} Lacepede, 1803 is a medium-sized species with a wide geographical distribution, found from the north of South America to Argentina, in the La Plata River Basin (Godoy, 1967). In Brazil, this species is very common in the main rivers and their tributaries, as well as in reservoirs (Bizzoto et al., 2009). It is a moderate migratory species that performs small movements during its reproductive period. According to some studies on the species life cycle in the Upper Uruguay River, the adults leave the main river towards the tributaries to carry out their spawning (Cassini, 1998; Zaniboni-Filho and Schulz, 2003). The yellow mandi’s reproductive period occurs mainly between October and March (Vazzoler et al., 1997; Sabinson et al., 2014), coinciding with a period of high rainfall. The species is omnivorous, with a wide adaptability with regard to diet (Menin and Mimura, 1992; Lolis and Andrian, 1996), and is considered as an opportunistic species, because it takes advantage of abundant food resources in short periods of time (Ramos, 2009).

The yellow mandi represents an important share of the fishing activity in several Brazilian reservoirs, mainly in the Paraná River Basin, where the species rank fourth among the most captured in biomass (Agostinho et al., 2007). In the Upper Uruguay River, Schork et al. (2012, 2013) also identified the yellow mandi among the most captured species in Machadinho and Itá reservoirs. However, the yellow mandi is more susceptible to fish mortality events due to hydroelectric dam operations (Loures and Pompeu, 2012); its population confined in reservoirs is at constant risk. Therefore, the aim of this study was to evaluate the current situation of the fishing stock of the yellow mandi \textit{P. maculatus} in the Itá reservoir, based on data collected over a 15-year study.

MATERIAL AND METHODS

Study area

Itá reservoir is located in the Upper Uruguay River, between the border of Santa Catarina and Rio Grande do Sul states. The reservoir has a perimeter of approximately 800 km and a total area of 141 km², covering eight municipalities. Machadinho Dam is located around 6 km upstream the end of the reservoir.

Sampling and data processing

Total length (Lt, cm) and total weight (Wt, g) data were measured from yellow mandi specimens captured as part of continuous seasonal (4 per year) scientific fishing surveys in the Itá reservoir, between January 2004 and December 2016, totaling 52 collections. A voucher specimen was deposited in the Ichthyological Collection of the Universidade Estadual de Londrina, Brazil (MZUEL n° 09590). Additionally, monthly yellow mandi fishing catch data between 2004 and 2016 were obtained from artisanal fishermen, which used mainly drift nets, lines, and longlines as fishing gear.

Length data were grouped into classes determined in number and range using the Sturges’ rule (Sokal and Rohlf, 1981). Subsequently, as described by Sparre and Venema (1997), fishing catch data were grouped and weighted according to the length classes defined by scientific data.

Growth

The length-weight relationship was estimated using the model $W_t = a \times L_t^b$, where $W_t$ is the total weight (g), $L_t$ is the total length (cm), and $a$ and $b$ are the linear equation coefficients, obtained through the least squares method.

Then, the von Bertalanffy Growth Function (VBGF) (Bertalanffy, 1938) was used to adjust the growth curve for length data: 
$L_t = L_\infty \left[ 1 - e^{-k \cdot (t-t_0)} \right]$, where $t$ corresponds to age (year), $L_t$ is the total length of the individual at age $t$ (cm), $L_\infty$ is the asymptotic length or the maximum theoretical length, $k$ is the individual growth coefficient (year$^{-1}$), and $t_0$ is the theoretical age (years) in which the length is zero. $t_0$ was estimated using Pauly’s empirical equation (Pauly, 1979): $\log_{10} (t_0) = -0.392 - 0.275 \times \log_{10} L_\infty - 1.038 \times \log_{10} k$.

The parameters considered in VBGF – $L_\infty$, $k$, $C$ (degree of oscillation $= 0$), $WP$ (‘winter point’ $= 0$), SS (sum of squares $= 2$), and $SL$ (standard length $= 25.50$ cm) – were determined using the FISAT II program (FAO-ICLARM Stock Assessment Tools; Gayanilo Júnior et al., 2005) using the ELEFAN I methodology (Eletronic Length-Frequency Analysis) (Pauly and David, 1981),
which consists of the identification of peaks and adjustment of growth curves according to length-frequency histograms.

Longevity

The population longevity was calculated using the equation proposed by Taylor (1958): $t_{\text{max}} = t_0 + 2.996 \times k^{-1}$. The number of cohorts (1 cohort = 1 year) generated using the VBGF model was observed in order to confirm the estimated longevity values.

Growth performance index

The growth performance index ($O'$) provides information that allows a comparison of the estimated parameters with parameters of other phylogenetically related species or groups (Gayanilo Júnior and Pauly, 1997). It is expected that population parameters estimated correctly would present similar values among related species (Gayanilo Júnior and Pauly, 1997). In this study, $O'$ was calculated as proposed by Pauly and Munro (1984): $O' = \log_{10} k + 2 \times \log_{10} L_\infty$.

Recruitment

The number of recruitment pulses per year was obtained using both the frequency distribution of length classes and the estimated growth parameters for the species. The same was used to evaluate the relative importance of these pulses. These analyses were performed through the ELEFAN I routine, included in the FISAT software (Gayanilo Júnior and Pauly, 1997).

Mortality

The instantaneous natural mortality rate (M) was estimated based on the empirical relationship between $L_\infty$, $k$, and the mean annual temperature (T) of the environment (21 °C). For the determination of the temperature in freshwater environments, it is considered that the average annual water surface temperature corresponds to the average annual air temperature for the same area (Pauly, 1980). The model proposed by Pauly (1983) was used for the calculation of the aforementioned empirical relation: $\ln M = 0.0066 - 0.279 \times \ln L_\infty + 0.6543 \times \ln k + 0.4643 \times \ln T$.

The instantaneous total mortality rate (Z) was obtained through the linearized length-converted catch curve (Pauly, 1983). First, data were converted to age using the inverse equation of VBGF: $t = t_0 - k^{-1} \times \ln [(1-L) \times L_\infty^{-1}]$, then, total mortality was calculated using the equation: $\ln [C (t, t + \Delta t) / \Delta t] = c - Z \times (t + \Delta t / 2)$.

The instantaneous fishing mortality rate (F) was calculated as the difference between $Z$ and $M$, i.e., $F = Z - M$.

Exploitation rate

The exploitation rate (E) indicates the fishery status of a stock, and can be determined using the coefficients of mortality $F$ and $Z$, based on the relationship $E = F / Z$. This value allows estimating the other $F$ values ($F_{\text{max}}$; $F_{0.1}$; $F_{0.5}$) using the following expression: $F = M \times E \times (1 - E)^{-1}$.

Biological Reference Points

The biological reference points (BRPs) were estimated based on the instantaneous fishing mortality ($F$), being defined as:

1) $F_{\text{max}}$ – fishing mortality rate that maximizes the yield-per-recruit without considering whether the spawning stock is conserved to maintain recruitment in the future, estimated from the $E_{\text{max}}$;
2) $F_{0.1}$ – rate at which the slope of the yield-per-recruit curve falls to 10% of its origin value, estimated from $E_{0.1}$;
3) $F_{0.5}$ – fishing mortality rate in which the slope of the yield-per-recruit curve falls to 50% of its original value while retaining a safety margin to maintain future recruitment rates, estimated at $E_{0.5}$.

Yield-per-recruit

The yield-per-recruit was calculated using the equilibrium yield model of Beverton and Holt (1966), represented by the expression:

$$\frac{Y}{R} = F \times e^{-M \times (T_c - T_r)} \times W_\infty \times \left[ Z^{-1} - 3H \times (Z + k)^{-1} + 3H^2 \times (Z + 2k)^{-1} - H^3 \times (Z + 3k)^{-1} \right]$$

where $Y/R$ is the yield-per-recruit; $H = e^{-k \times (T_c - t_0)}$; $k$ = growth coefficient; $t_0$ = parameter of the VBGF Model; $T_c$ = age of first capture; $T_r$ = age of recruitment; $W_\infty$ = asymptotic weight from the growth model; $F$ = fishing mortality; $M$ = natural mortality; $Z$ = total mortality.

RESULTS

In 798 specimens captured as part of scientific fishing surveys from 2004 to 2016, length ranged from 15 to 53 cm. The most abundant length frequency was 22-33 cm, with class of 27 cm being the most frequent (Figure 1). The length growth curves obtained using ELEFAN I showed that fishing was operating on eight $P. maculatus$ cohorts, with the highest catches occurring mainly on five cohorts. Additionally, it was possible to observe...
the presence of a higher number of individuals captured from different cohorts during the winter season (Figure 2).

Length-weight relationship parameters for *P. maculatus* were calculated as: \(a = 0.0077, b = 3.0695\), with \(R^2 = 0.8621\) (Figure 3), which is similar to those obtained by Nuñer and Zaniboni-Filho (2009) studying the same region.

The highest recruitment frequencies of specimens to the fishing area in the Itá reservoir occurred between April and August (Figure 4).

For the period between 2004 and 2016, the mortality rates calculated using the linearized length-converted catch curve showed the following coefficients: \(Z = 0.95, M = 0.537, F = 0.413,\) and \(E = 0.434\) (Figure 5). It was observed that the \(F\) was below the two biological parameters \(F_{\text{max}}\) and \(F_{0.1}\), and above \(F_{0.5}\) (Figure 6). The yield-per-recruit curve showed values of 128 g for the mortality rates found in the present study.

The estimated parameters of \(t_0\), growth performance index, longevity, and \(L_{50}\) are presented in Table 1. Table 2 shows the growth parameters \(L_{\infty}, L_c,\) and \(k\), in addition to the exploitation rates.

### Table 1. Population parameters estimates for *Pimelodus maculatus* stock in the Itá reservoir: age at zero size \((t_0)\), growth performance index \((\Omega')\), maximum age \((t_{\text{max}})\) and length at which 50% of fish are vulnerable to capture \((L_{50})\).

| Parameters     | Value |
|----------------|-------|
| \(t_0\) (year) | -0.39 |
| \(\Omega'\)     | 3.047 |
| \(t_{\text{max}}\) (year) | 6.68 |
| \(L_{50} = L_c\) | 23.08 |
Table 2. Estimates used for the application of the Beverton and Holt model (1966) and results of the stock assessment of *Pimelodus maculatus* in the Itá reservoir between 2004 and 2016.

| Inputs  | Outputs |
|---------|---------|
| L∞ (cm) | 55.65   | E       | 0.434   | F       | 0.413   |
| Lₜ (cm) | 21.98   | Eₘₜ     | 0.642   | Fₘₜ     | 0.963   |
| K (year⁻¹) | 0.260  | Eₜ       | 0.501   | Fₜ     | 0.539   |
| Z (year⁻¹) | 0.950  | E₀.₅     | 0.332   | F₀.₅   | 0.267   |
| M (year⁻¹) | 0.537  |         |         |         |         |

**DISCUSSION**

The results obtained in this study indicate that the stock of yellow mandi *P. maculatus* in the Itá reservoir is neither overexploited nor at risk of depletion.

Maintaining fisheries resources at sustainable and profitable levels is the main objective of most management actions (Brooks, 2013). According to Mateus and Penha (2007), it is important to consider rates of exploitation that keep the target population at acceptable levels, i.e., that allow the species stock renewal, avoiding overfishing. In the present study, the observed fishing mortality rate for yellow mandi in the Itá reservoir from 2004 to 2016 showed values lower than the maximum fishing mortality rate (Fₘₜ) calculated for the species. However, increasing fishing effort up to this maximum yield-per-recruit may be undesirable because it does not lead to a safety level of exploitation (Deriso, 1987; Sant’Anna et al., 2014).

Although the instantaneous fishing rate did not reach the BRPs Fₜ and Fₘₜ, this does not mean that the fishing effort on the species can be increased randomly without damage to the species stock renewal. The values obtained in this study were based on the existing fishing effort in the Itá reservoir, not taking into account the possible fishing effort increase applied by artisanal fishermen in the same environment during following years, nor the biotic and abiotic factors that can affect the recruitment of the species. Increased *P. maculatus* catches, such as those observed several years during the study period, 2012–2015, may result in cumulative losses and should be evaluated periodically, always considering population responses to fishing effort.

Additionally, fish stock assessments mainly take into account fishing mortality data (Ellis et al., 2018), without considering other factors, typical of river stretches under the influence of hydroelectric power plants, such as the mortality events due to the operational management of hydroelectric dams. These may increase the mortality of this species, making its stock even more vulnerable.

In this study, estimates were based on historical fishing data in the region. Therefore, they are subject to change. During the analyzed period it was possible to observe that the yellow mandi biomass captured by fishermen presented a considerable increase in the last six years (2011 to 2016), which may be related both to an increase in fishing effort as well as to an increase in the yellow mandi population. Thus, a periodical re-assessment of these data might be essential to ensure that the yellow mandi fishery in the Itá reservoir does not collapse, causing environmental, social, and economic damages to the region. It is worth remembering that the stock status is directly influenced by fishing and reflects its current conditions in relation to the estimated reference points (Brooks, 2013).

**CONCLUSIONS**

The fishing stock assessment of yellow mandi *P. maculatus* in the Itá reservoir based on data from 2004 and 2016 showed no signs of overexploitation or any risk of depletion. However, a periodical re-assessment of these data might be important to ensure a continuous yield and yellow mandi fishery in the region.

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**REFERENCES**

Agostinho, A.A.; Gomes, L.C.; Pelicice, F.M. 2007. Ecologia e manejo de recursos pesqueiros em reservatórios do Brasil. Maringá: EDUEM. 500p.

Agostinho, A.A.; Gomes, L.C.; Santos, N.C.L.; Ortega, J.C.G.; Pelicice, F.M. 2016. Fish assemblages in Neotropical reservoirs: colonization patterns, impacts and management. Fisheries Research, 173(1): 26-36. http://dx.doi.org/10.1016/j.fishres.2015.04.006

Amarasinghe, U.S.; Prabath, R.P.; Jayasinghe, K.; Moreau, J. 2017. Length-based stock assessment of *Oreochromis mossambicus* and *Oreochromis niloticus* (Actinopterygii: Perciformes: Cichlidae) in multi-mesh gillnet fisheries in reservoirs of Sri Lanka. Acta Ichthyologica et Piscatoria, 47(3): 265-277. http://dx.doi.org/10.1080/10709290.2017.1368331

Bertalanffy, L.V. 1938. A quantitative theory of organic growth. Human Biology, 10(2): 181-213. Available from: <http://www.jstor.org/stable/41447359> Access on: 17 July 2019.

Beverton, R.J.H.; Holt, S.J. 1966. Manual of methods for fish stock assessment. Part II: tables of yield function. FAO Biological Technical Paper, 38: 1-67.

Bizzotto, C.P.M.; Godinho, A.L.; Vono, V.; Kynard, B.; Godinho, H.P. 2009. Influence of seasonal, diel, lunar, and other environmental factors on upstream fish passage in the Igarapava Fish Ladder, Brazil. Ecology Freshwater Fish, 18(3): 461-472. http://dx.doi.org/10.1111/j.1600-0633.2009.00361.x

Brooks, E.N. 2013. Effects of variable reproductive potential on reference points for fisheries management. Fisheries Research, 138: 152-158. http://dx.doi.org/10.1016/j.fishres.2012.06.003

Campos, C.P.; Freitas, C.E.C. 2014. Yield per recruit of the peacock bass *Cichla monoculus* (Spix and Agassiz, 1831) caught in Lago Grande at Manacapuru (Amazonas - Brasil). Brazilian Journal of Biology = Revista Brasileira de Biologia, 74(1): 226-230. http://dx.doi.org/10.1590/1519-6984.17312

Schork et al. Bol. Inst. Pesca 2020, 46(1): e535. DOI: 10.20950/1678-2305.2020.46.1.535
Cassini, C.A. 1998. Estrutura da população e distribuição espacial de *Pimelodus maculatus* Lacépède, 1803 (Siluriformes, Pimelodidae) *Rhamaia quelen* Quoy & Gaimard, 1824 (Siluriformes, Pimelodidae) e *Schizodon aff. nasutus* Kner, 1859 (Characiformes, Anostomidae), no Alto Rio Uruguai, Brasil. Florianópolis. 75f. (Dissertação de Mestrado. Programa de Pós-graduação em Aquicultura, UFSC). Available from: <https://repositorio.ufsc.br/xmlui/handle/123456789/77658> Access on: 17 july 2019.

Deriso, R.B. 1987. Optimal F0,1 criteria and their relationship to maximum sustainable yield. Canadian Journal of Fisheries and Aquatic Sciences, 44: 339-348. http://dx.doi.org/10.1139/f87-335.

Doll, J.C.; Lauer, T.E.; Clark-Kolaks, S. 2017. Yield-per-recruit modeling of two piscivores in a Midwestern reservoir: a Bayesian approach. Fisheries Research, 191: 200-210. http://dx.doi.org/10.1016/j.fishres.2017.03.012.

Doria, C.R.C.; Ruffino, M.L.; Hijazi, N. C.; Cruz, R.L. 2012. A pesca comercial na bacia do Rio Madeira, estado de Rondônia, Brasil. Acta Amazonica, 42: 29-40.

Ellis, T.A.; Hightower, J.E.; Buckel, J.A. 2018. Relative importance of fishing and natural mortality for spotted seatrout (*Cynoscion nebulosus*) estimated from a tag-return model and corroborated with survey data. Fisheries Research, 199: 81-93. https://doi.org/10.1016/j.fishres.2017.11.004.

Gayanilo Júnior, F.C.; Pauly, P. 1997. The FAO-ICLARM Stock Assessment Tools (FISAT) reference manual. Rome: FAO. 262p. (FAO Computerized Information Series (Fisheries) 8).

Gayanilo Júnior, F.C.; Sparre, P.; Pauly, D. 2005. FAO-ICLARM stock assessment tools II (FISAT II): revised version: user’s guide. Rome: FAO. 168p. (FAO Computerized Information Series (Fisheries) 8).

Godoy, M.P. 1967. Dez anos de observações sobre periodicidade migratória de peixes do rio Mogi-Guaçu. Revista Brasileira de Biologia, 27(1): 1-12.

Jiménez-Badillo, L. 2004. Application of holistic and analytical models for the management of tilapia fisheries in reservoirs. Hidrobiológica, 14(1): 61-68. Available from: <http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S0188-8897200400100008&lng=en> Access on: 17 july 2019.

Junk, W.J. 2007. Freshwater fishes of South America: Their biodiversity, fisheries, and habitats: a synthesis. Aquatic Ecosystem Health & Management, 10(2): 228-242. http://dx.doi.org/10.1080/14634980701356733.

Kumari, S.; Sarkar, U.K.; Mandhir, S.K.; Lianthuamluia, L.; Panda, D.; Chakraborty, S.K.; Karnatak, G.; Kumar, K.; Puthiyottil, M. 2018. Studies on the growth and mortality of Indian River shad, *Gudustria chapra* (Hamilton, 1822) from Panchet reservoir, India. Environmental Science and Pollution Research International, 25: 33768-33772. http://dx.doi.org/10.1007/s11356-018-2637-9.

Lolis, A.A.; Andrian, I.F. 1996. Alimentação de *Pimelodus maculatus* Lacépède 1803 (Siluriformes, Pimelodidae), na planície de inundação do Alto Rio Paraná, Brasil. Boletim do Instituto de Pesca, 23: 187-202.

Loures, R.C.; Pompeu, P.S. 2012. Temporal variation in fish community in the tail race at Três Marias Hydroelectric Dam, São Francisco River, Brazil. Neotropical Ichthyology, 10(4): 731-740.

Mateus, A.F.; Penha, J.F. 2007. Avaliação dos estoques pesqueiros de quatro espécies de grandes bagres (Siluriformes, Pimelodidae) na bacia do rio Cutába, Pantanal norte, Brasil, utilizando alguns Pontos de Referência Biológicos. Revista Brasileira de Zoologia, 24(1): 144-150.

Menin, E.; Mimura, O.M. 1992. Anatomia funcional comparativa do estômago de três peixes Teleostei de hábito alimentar onívoros. Revista Ceres, 39(223): 233-260.

Munyandoro, J. 2018. Embracing uncertainty, continual spawning, estimation of the stock-recruit steepness, and size-limit designs with length-based per-recruit analyses for African tropical fisheries. Fisheries Research, 199: 137-157. http://dx.doi.org/10.1016/j.fishres.2017.11.017.

Nuñer, A.P.O.; Zaniboni-Filho, E. 2009. Length-weight relationships of fish species caught in the Upper Uruguay River, Brazil. Journal of Applied Ichthyology, 25: 362-364. https://doi.org/10.1111/j.1439-0426.2009.01233.x.

Pauly, D. 1979. Theory and management of tropical multispecies stocks. Manila: ICLRM Studies and Reviews. 35p.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stock. ICES Journal of Marine Science, 39(2): 175-192. https://doi.org/10.1093/icesjm/s39.2.175.

Pauly, D. 1983. Length-converted catch curves: a powerful tool for fisheries research in the tropics. (Part I). ICLRM Fishbyte, 1(2): 9-13.

Pauly, D.; David, N. 1981. ELEFAN I, a basic program for the objective extraction of growth parameters from length-frequency data. Meeresforschung Reports on Marine Science, 28: 205-211.

Pauly, D.; Munro, J.L. 1984. Once more on the comparison of growth in fish and invertebrates. ICLRM Fishbyte, 2(1): 1-21.

Penha, J.M.F.; Mateus, L.A.F. 2007. Sustainable harvest of two large predatory Catfish in the Cuiabá river basin, northern Pantanal, Brazil. Brazilian Journal of Biology = Revista Brasileira de Biologia, 67(1): 631-637. http://dx.doi.org/10.1590/S1519-69842007001000010.

Ramos, I.P. 2009. Aspectos da biologia populacional de *Pimelodus maculatus* (Teleostei: Siluriformes) sob influência de sistemas de piscicultura em tanques-rede. Botucatu. 124f. (Dissertação de Mestrado. Instituto de Aquicultura, Universidade Estadual Paulista - Unesp). Available from: <https://repositorio.unesp.br/handle/11449/99459> Access on: 17 july 2019.

Sabinson, L.M.; Rodrigues Filho, J.L.; Peret, A.C.; Verani, J.R. 2014. Growth and reproduction aspects of *Pimelodus maculatus* Lacépède, 1803 (Siluriformes, Pimelodidae) of the Cachoeira Dourada reservoir, state of Goiás and Minas Gerais, Brazil. Brazilian Journal of Biology = Revista Brasileira de Biologia, 74(2): 450-459. http://dx.doi.org/10.1590/S1519-6984200701356733.

Sá-Oliveira, J.C.; Angelini, R.; Isaac-Nahum, V.J. 2015. Population parameters of the fish fauna in a long-established Amazoniam reservoir (Amapá, Brazil). Journal of Applied Ichthyology, 31: 290-295. http://dx.doi.org/10.1111/jai.12667.

Schork, G.; Hermes-Silva, S.; Beux, L.F.; Zaniboni-Filho, E.; Nuñer, A.P.O. 2012. Diagnóstico da pesca artesanal na Usina Hidrelétrica de Machadinho, Alto Rio Uruguai – Brasil. Boletim do Instituto de Pesca, 38(2): 97-108.

Schork, G.; Hermes-Silva, S.; Zaniboni-Filho, E. 2013. Analysis of fishing in the reservoir of the Hydroelectric Power Plant of Itá in the upper Uruguay River, in the period 2004-2009. Brazilian Journal of Biology.
Sokal, R.R.; Rohlf, F.J. 1981. Biometry. San Francisco: Freeman. 877p.
Sparre, P.; Venema, S.C. 1997. Introdução à avaliação de mananciais de peixes tropicais. Parte 1: manual. Roma: FAO. 404p.
Taylor, C.C. 1958. Water temperature and Cod Growth-Rate Cod growth and temperature. Journal Du Conseil, 23(3): 366-370.
Vazzoler, A.E.A.M.; Suzuki, H.I.; Marques, E.E.; Lizama, M.A.P. 1997. Primeira maturação gonadal, períodos e áreas de reprodução. In: Vazzoler, A.E.A.M.; Agostinho, A.A.; Hahn, N.S. (Eds.). A planície de inundação do Alto Rio Paraná. Maringá: Eduem. p. 249-265.
Zaniboni-Filho, E.; Schulz, U.H. 2003. Migratory fishes of the Uruguay river. In: Carolsfeld, J.; Harvey, B.; Baer, A.; Ross, C. (Eds.). Migratory fishes of the South America: biology, social importance and conservation status. Victoria: World Fisheries Trust/ IDRC/ World Bank. p. 135-168.