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**Short Communication**

# Length-weight relationship and condition factor for *Prochilodus lineatus*, an important commercial fish, in contrasting water-quality environments of the middle Tietê River basin, Southeast Brazil

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***Abstract:*** This work was carried out in order to provide the length-weight relationship (LWR) and the allometric condition factor (Ka), as well as its correlation with limnological variables, for *Prochilodus lineatus* from the middle Tietê River basin. Fish were collected using gill nets in two rivers with contrasting environmental conditions, totaling 46 specimens in the highly polluted Tietê River, and 37 in the Peixe River, a relatively well-conserved tributary. Environmental measures were obtained concomitantly to the fish capture. The results showed an isometric growth ($b$ = 3.00) for the fish from Tietê River and a positive allometric growth ($b$ = 3.23) for the fish from Peixe River. The mean value of Ka was unexpectedly higher for the main river (Ka = 2.63) when compared to its tributary (Ka = 2.42), being statistically different from each other. This can be explained by the much higher availability of organic sediments in the main river, resulting from a long-term eutrophication process. Nevertheless, the positive and statistically significant correlations with dissolved oxygen, for both rivers, as well as significant negative correlations with electric conductivity, nitrogen and chlorophyll *a* for Tietê River, indicate the negative effects of the water quality deterioration on the fish condition factor. The work contributes to the expansion of knowledge about *P. lineatus*, the most important commercial fish of the middle Tietê River basin, which is severely impacted by unsustainable human actions.
***Keywords:*** *Animal welfare; Body growth pattern; Curimbatá; Water pollution.*

# Relação peso-comprimento e fator de condição para *Prochilodus lineatus*, um importante peixe comercial, em ambientes contrastantes em qualidade da água da bacia do médio rio Tietê, sudeste do Brasil

***Resumo:*** Este trabalho foi realizado com o objetivo de fornecer a relação peso-comprimento (LWR) e o fator de condição alométrico (Ka), bem como sua correlação com variáveis limnológicas, para *Prochilodus lineatus* da bacia do médio rio Tietê. Os peixes foram coletados com redes de espera em dois rios com condições ambientais contrastantes, totalizando 46 espécimes no altamente poluído rio Tietê, e 37 no rio do Peixe, um tributário relativamente bem conservado. Medidas ambientais foram obtidas concomitantemente à captura dos peixes. Os resultados mostraram um crescimento isométrico ($b$ = 3,00) para os peixes do rio Tietê e um crescimento alométrico positivo ($b$ = 3,23) para os peixes do rio do Peixe. O valor médio de Ka foi, inesperadamente, maior para o rio principal (Ka = 2,63) quando comparado ao seu afluente (Ka = 2,42), sendo estatisticamente diferentes entre si. Isso pode ser explicado pela disponibilidade muito maior de sedimentos orgânicos no rio principal, resultante de um longo processo de eutrofização. No entanto, as correlações positivas e estatisticamente significativas com o oxigênio dissolvido, para ambos os rios, bem como correlações significativas negativas com a condutividade elétrica, nitrogênio e clorofila *a* para o rio Tietê, indicam os efeitos negativos da deterioração da qualidade da água sobre o fator condição dos peixes. O trabalho contribui para a expansão do conhecimento sobre *P. lineatus*, o peixe de maior importância comercial da bacia do médio rio Tietê, severamente impactada por ações humanas não-sustentáveis.
***Palavras-chaves:*** *Bem-estar animal; Curimbatá; Padrão de crescimento corpóreo; Poluição das águas.*

## Introduction

The length-weight relationships (LWR) are very useful tools in ecological studies. This parameter, associated with the condition factor, is considered an excellent indicator of animal welfare. Its application is particularly important in the management of fisheries resources and in the development and implementation of environmental monitoring programs, especially for fish from degraded ecosystems (Froese 2006, Gubiani et al. 2009, Freitas et al. 2017), allowing comparisons between populations living in diversified environments and feed conditions (Salaro et al. 2015).

In this context, the objective of this study was to provide the LWR, the condition factor, as well as its correlation with limnological variables, for specimens of *Prochilodus lineatus* (Valenciennes 1837) from contrasting environments in terms of water quality in the middle Tietê River basin. This species, popularly named curimbatá, is widely distributed (Langeani et al. 2007) and constitute the most important and abundant fishery resource in this basin (Novaes & Carvalho 2013, Urbanski et al. 2020). Our hypothesis was to find a lower condition factor for individuals from the Tietê River, due to the strong environmental degradation of this river that receives most urban and industrial effluents of the São Paulo metropolis (Buckeridge & Ribeiro 2018, Tundisi 2018).

## Material and Methods

The study was carried out in the Tietê River (22°47'31.0" S 48°05'48.8" W) and in its tributary, Peixe River (22°49'42.8" S 48°06'01.5" W). Both sampling areas are located in the municipality of Anhembi, State of São Paulo, Southeast of Brazil, and, despite their proximity, the environments exhibit contrasting water quality conditions.

Fish were collected (IBAMA/SISBIO permanent sampling license to MGN: 13794-1) in four seasonal samplings using gill nets, between December 2016 and October 2019. Morphological identification was made based on specialized bibliography (Britski 1972, Graça & Pavanelli 2007, Ota et al. 2018) and the parameters total weight (WT) and standard length (SL) measured in grams (precision of 1g) and in centimeters (precision of 0.1cm), respectively, immediately after the capture of the specimens. Sex was not discriminated against.

To determine the LWR, linear regression was used (logWT = log $a$ + $b$ logSL) with the removal of outliers using a length-weight graph with a logarithmic scale (Froese 2006). The LWR parameters were compared with the Bayesian predictions according to Froese et al. (2014), available in the FishBase (2022).

The allometric condition factor (Ka) was obtained through the expression $Ka = 100*WT/SL^b$, where $b$ is estimated by the equation of the length-weight relationship (Froese 2006). Mean Ka values were compared between rivers using a Student's T-test with a 95% confidence interval.

Finally, a normality test was performed and later a Spearman's correlation test was applied to verify the influence of the limnological variables on the obtained condition factor values. The limnological variables used for this analysis were: dissolved oxygen (DO), electrical conductivity, and hydrogenic potential (pH), measured in situ using a Horiba U-5000 multiparameter probe, previously calibrated; and total phosphorus (TP) (Strickland & Parsons 1960), total nitrogen (TN) (Mackereth et al. 1978) and chlorophyll *a* (Talling & Driver 1963), analyzed in the laboratory in rivers surface water samples. All measurements and collection of environmental samples were carried out concomitantly to the capture of fish.

## Results

Forty-six specimens from the Tietê River and 37 from the Peixe River were analyzed. The results indicated an isometric growth pattern for fish from the main river ($b$ = 3.00) and a positive allometric growth pattern for those from its tributary ($b$ = 3.23), the latter value being higher than those calculated for *Prochilodus lineatus* in the Bayesian predictions of FishBase (2022) (Table 1, Figure 1).

The specimens from the Tietê River showed mean values of the allometric condition factor (Ka = 2.63) higher when compared to those calculated for the specimens from the Peixe River (Ka = 2.42). The condition factors between the rivers are statistically different (T-test; $p < 0.0002$).

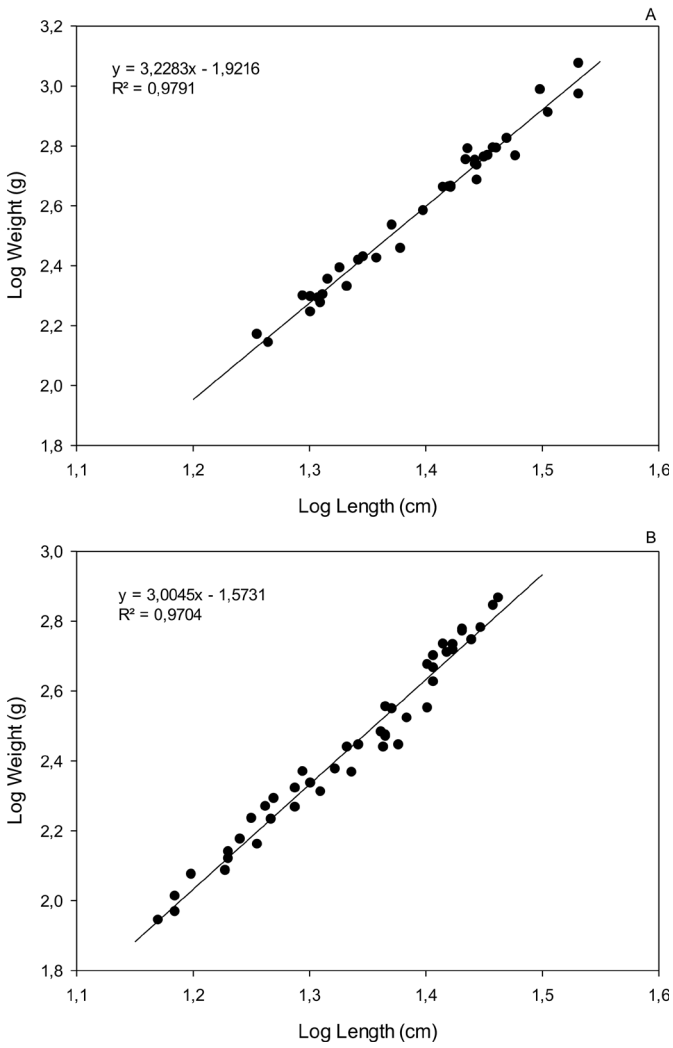


**Figure 1.** Length–weight relationship for *P. lineatus* in Peixe River (A) and in Tietê River (B).

**Table 1.** Descriptive statistics and estimated parameters of length–weight relationship for *P. lineatus* in the middle Tietê River basin, Brazil.

| Local | Species | n | SL range | WT range | a | Cl a (95%) | b | Cl b (95%) | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|
| **Peixe River** | *Prochilodus lineatus* | 37 | 18,0 – 34,0 | 139 – 1189 | 0,0120* | 0,0071 – 0,0202 | 3,2283* | 3,0667 – 3,3900 | 0,979 |
| **Tietê River** | *Prochilodus lineatus* | 46 | 14,8 – 29,0 | 88 – 735 | 0,0267* | 0,0163 – 0,0437 | 3,0045 | 2,8450 – 3,1639 | 0,970 |

*LWR parameter values different from Bayesian LWR predictions in FishBase (2022).

Sample size (n), length and weight range by species; estimated *a* and *b* values with confidence limits (95%), determination coefficient ($R^2$).

**Table 2.** Mean values and standard derivations of the environmental variables measured at the sampling sites.

| Campaign | Date | Local | DO | pH | Conductivity | TN | TP | Chlorophyll *a* |
|---|---|---|---|---|---|---|---|---|
| **1** | DEZ/2016 | Peixe River | 5.43 (±0.02) | 6.77 (±0.22) | 86.00 (±0.00) | 1.13 (±0.00) | 0.11 (±0.00) | 20.60 (±0.00) |
| | | Tietê River | 1.17 (±0.12) | 6.62 (±0.26) | 289.33 (±0.47) | 7.51 (±0.00) | 0.23 (±0.00) | 23.20 (±0.00) |
| **2** | AGO/2017 | Peixe River | 4.40 (±0.46) | 7.57 (±0.21) | 91.50 (±0.50) | 0.76 (±0.00) | 0.04 (±0.00) | 4.00 (±0.00) |
| | | Tietê River | 2.25 (±0.09) | 7.20 (±0.03) | 377.00 (±0.63) | 13.00 (±0.00) | 0.64 (±0.00) | 12.00 (±0.00) |
| **3** | ABR/2019 | Peixe River | 5.47 (±0.10) | 6.21 (±0.11) | 92.29 (±0.45) | 0.85 (±0.02) | 0.04 (±0.00) | 10.26 (±4.14) |
| | | Tietê River | 0.53 (±0.21) | 6.45 (±0.16) | 409.80 (±0.40) | 7.02 (±0.17) | 0.26 (±0.01) | 50.27 (±0.00) |
| **4** | OUT/2019 | Peixe River | 3.25 (±0.30) | 6.61 (±0.23) | 124.00 (±0.00) | 0.67 (±0.04) | 0.03 (±0.00) | 1.81 (±0.08) |
| | | Tietê River | 0.59 (±0.76) | 7.05 (±0.20) | 557.71 (±1.28) | 14.49 (±0.53) | 0.58 (±0.04) | 96.37 (±3.83) |

**Table 3.** P value and Spearman's correlation coefficient for Peixe River allometric condition factors and limnological variables.

| | | DO | pH | Conductivity | TN | TP | Chlorophyll *a* |
|---|---|---|---|---|---|---|---|
| **Ka** | Correlation Coefficient | 0.476 | –0.331 | 0,207 | –0,207 | –0.207 | –0.207 |
| | P Value | 0,00308 | 0,0458 | 0,217 | 0,217 | 0,217 | 0,217 |

**Table 4.** P value and Spearman's correlation coefficient for Tietê River allometric condition factors and limnological variables.

| | | OD | pH | Conductivity | TN | TP | Chlorophyll *a* |
|---|---|---|---|---|---|---|---|
| **Ka** | Correlation Coefficient | 0.512 | –0.0314 | –0.419 | –0.419 | –0.0314 | –0.512 |
| | P Value | 0.000304 | 0.835 | 0.00396 | 0.00396 | 0.835 | 0.000304 |

The means and standard derivations of the limnological variables obtained in the four campaigns are shown in Table 2. Spearman's correlation analysis demonstrated the existence of relations between the Ka values and the variables measured in this study (Tables 3 and 4).

The Ka values for Peixe River show significant positive correlation with the limnological variable dissolved oxygen ($p = 0.0031$) and significant negative correlation with pH ($p = 0.0458$) (Table 3).

The Ka values for the Tietê River show significant positive correlation with the limnological variable dissolved oxygen ($p = 0.0003$) and significant negative correlation with the variables conductivity ($p = 0.0039$), total nitrogen ($p = 0.0039$) and chlorophyll *a* ($p = 0.0003$) (Table 4).

## Discussion

The *b* values in the length-weight body ratio for fish vary between 2.50 and 4.00 (Le Cren 1951). For curimbatá, the analysis of different populations distributed in distinct Brazilian river basins, showed a tendency to isometric body growth pattern, with values close to 3.00 for non-sexed animals (Silveira et al. 2015), as observed in this study for specimens of the Tiete River. This was also reported by Nuñer & Zaniboni-Filho (2009) with $b = 3.06$, Batista-Silva et al. (2015) with $b = 3.08$, Nobile et al. (2015) with $b = 2.99$, Silveira et al. (2015) with $b = 3.05$, and Freitas et al. (2017) with $b = 3.06$. Values of *b* equal to or higher than those calculated for specimens from the Peixe River in this work (3.23) were not found in the literature.

This difference in the types of body growth, comparing Tietê and Peixe Rivers, should be related to the distinctiveness of the environmental conditions. However, other factors such as sample size, seasonality, and sex (Le Cren 1951, Froese 2006), the latter not differentiated in the study, also influence this parameter.

For the condition factor, unexpectedly, the specimens from Peixe River had a lower mean value compared to those from Tietê River. Probably, this can be explained by the huge amount of organic matter deposited in the bottom sediments of the main river. The noticeable accumulation of organic sediments in the Tietê River is due to the

long-term huge organic waste discharges (domestic effluents), over more than a century, especially from the São Paulo megalopolis (Tundisi 2018). Therefore, this resource is much more available for consumption by detritivorous and iliophagous fish, such as *Prochilodus lineatus*, in the Tietê River when compared to the tributary.

The target species has a wide displacement capacity, being a long-distance migrator (Castro & Vari 2004). Therefore, considering that fish from the Rio do Peixe analyzed in this study were collected only a few kilometers upstream from the mouth, possibly they also feed in the Tietê River. However, it is important to take into account that the water quality differences between rivers, may influence the fish displacement between both environments. As a result, fish from the Peixe River may spend more time in the tributary, where the sediments are poorer in organic matter and, consequently, would have less accumulation of fat and a lower condition factor than the fish from the Tietê River.

This assumption is supported by statistically significant negative correlation values between conductivity, nitrogen and chlorophyll *a* concentrations and condition factors values for the Tietê River and by positive and significant correlations with dissolved oxygen, for both rivers. This indicates the negative effects of the water quality deterioration on the fish condition factor.

Finally, *Prochilodus lineatus*, proves to be an animal extremely resistant to adverse environmental conditions, including plastic contamination (Urbanski et al. 2020), which is very interesting and needs to be better explored in further studies (e.g. morphological and eco-physiological approaches).

Our results contribute to the expansion of knowledge on *Prochilodus lineatus*, the fish of higher interest for fishermen of the middle Tietê River basin, an environment severely impacted by unsustainable human actions.

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## Author Contributions

Bruna Q. Urbanski: Substantial contribution in the concept and design of the study; Contribution to data collection; Contribution to data analysis and interpretation; Contribution to manuscript preparation and Contribution to critical revision, adding intellectual content.

Eduardo M. Brambilla: Substantial contribution in the concept and design of the study; Contribution to data collection; Contribution to data analysis and interpretation and Contribution to critical revision, adding intellectual content.

Marcos G. Nogueira: Substantial contribution in the concept and design of the study; Contribution to data collection; Contribution to manuscript preparation and Contribution to critical revision, adding intellectual content.

## Conflicts of Interest

The author(s) declare(s) that they have no conflict of interest related to the publication of this manuscript.

## Ethics

This study did not involve human beings and/or clinical trials that should be approved by one Institutional Committee.

## Data Availability

The datasets generated during and/or analyzed during the current study are available at: https://doi.org/10.48331/scielodata.HIFTCJ

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