Length-weight relationships of native and non-native fishes in a subtropical coastal river of the Atlantic Rain Forest
Relação peso-comprimento de espécies nativas e não nativas de um rio subtropical da Mata Atlântica

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Abstract: Aim: The objective was to describe the LWR of fish species of the Guaraguçu River, as well as to compare the LWR parameters of the non-native species with the parameters obtained in their native ranges, available in the literature. Methods: In this study, the LWR of 10 fish species of the Guaraguçu River, southern Brazil, were analyzed. Fish were sampled semiannually between 2004 and 2007, using different sampling techniques in the Guaraguçu River. Results: A total of 673 specimens of 10 species were captured. The LWR demonstrated a prevalence of species (six out of 10) with positive allometric growth (b > 3). The remaining species presented isometric (b = 3, two species) or negative growth (b < 3, two species). Native species exhibited the same LWR from previous studies, except Centropomus parallelus, which presented an isometric growth in this study. The non-native species Clarias gariepinus and Ictalurus punctatus showed significant differences between the LWR parameters in the Guaraguçu River and in their native distribution, but the same growth pattern. Oreochromis niloticus did not present significant differences in the allometric coefficient from its native range. Conclusions: These results indicate that different environmental conditions may not influence the growth pattern of non-native species, which explains their invasion success due to high adaptability to new environments.

Keywords: alien species; Atlantic Rain Forest; fisheries; ichthyofauna; length-weight relationships.
The Neotropical region is one of the richest regions regarding the number of fish species (Abell et al., 2008; Reis et al., 2016). Located in this region is the Atlantic Rain Forest, which harbors a high diversity of fish in a variety of habitats such as lagoons, streams, rivers, and estuaries (Abilhoa et al., 2011). This complex ecosystem is an important hotspot of biodiversity in the world, with a high rate of endemism, and at the same time presenting some of the most degraded habitats due to high human occupation rates (Myers et al., 2000; Laurance, 2009; Ribeiro et al., 2009). Several studies have reported the impact of anthropogenic actions in rivers of the Atlantic Rain Forest (Best, 2019) and one of the most prominent of these is the introduction of non-native species (Vitule et al., 2006, 2019; Faria et al., 2021).

The length-weight relationship (LWR) is a useful tool for supporting fish biology studies, because it allows to estimate the fish weight based on the length (Le Cren, 1951; Froese, 2006). This data can be applied to estimating biomass and elaborate stock and growth models (Haimovici & Canziani, 2000). Also, the LWR allows the assessment the body condition, which can provide information about fitness, such as growth, reproduction, behavior, and survival, indicating the health of fish populations (Gubiani et al., 2020). The variability in the LWR can be influenced by several factors such as the life stage, season, and environmental conditions, thus re-estimates of LWR are recommended to complement species information and allow comparisons through space and time (Froese, 2006; Possamai et al., 2020). The LWR could be helpful to evaluate the variation in exotic fish communities and the effects of control programs and management policies (Sánchez-González et al., 2020). Also, it is possible to assess the population parameters of native species co-occurring with non-native species, to investigate potential competitive interactions and changes in fitness (Irons et al., 2007).

Despite the great biodiversity of freshwater fish in the Atlantic Rain Forest (Abilhoa et al., 2011), few studies to date have described the LWR of its species. This study aims to describe the LWR of native and non-native species in the Guaraguacu River and compare the LWR parameters of non-native species to those obtained in their native distribution. The data obtained with this study will provide subsidies for future monitoring of the non-native species’ life history in recently colonized environments, unraveling important mechanisms of the invasion process itself.

Fish were sampled semi-annually in the Guaraguacu River (25°42’S - 38°31’W) between 2004 and 2007. Fish samplings were performed using trawl nets, line and hook, cast net, small funnel traps, longline, and gillnets of different mesh sizes (4, 6, and 8 cm).

All specimens were identified and had their total length (Lt, cm) and total body weight (Wt, g) recorded in the laboratory. LWR was adjusted through the following equation (Huxley, 1924):

\[ Wt = a \cdot Lt^b \]

where \( a \) is the scaling coefficient, and \( b \) is the allometric coefficient. Both coefficients were determined using the least-squares method (Carvalho et al., 2017). The allometric coefficient determines whether the body growth pattern is isometric (\( b = 3 \)) or allometric, where values larger than 3 indicate positive allometry (fish grows faster in weight than in length) and values smaller than 3 indicate negative allometry (fish grows faster in length than in weight).

The allometric coefficients obtained from the LWR of each species were compared with the null hypothesis of \( b = 3 \) (isometry) to reveal the type of growth pattern, using a \( t \)-test. To verify differences between the LWR of non-native species in the newly colonized area and their native range, the allometric coefficient of the non-native fish in Guaraguacu River was compared with the values available in the literature for their native distribution, using a \( t \)-test. All statistical analyses were performed in the software R 3.6 (R Core Team, 2015) considering a significance level of \( p = 0.05 \).

A total of 673 individuals of 10 species were captured (seven native and three non-native) belonging to nine families (Table 1). The allometric coefficient ranged from 2.61 to 3.39 (mean ± SD = 3.096 ± 0.24). Three different growth types were identified, and the coefficient of determination ranged from 0.76 to 0.99 (Table 1).

Only Gymnotus carapo and Clarias gariepinus presented negative allometric growth, as this species has an elongated body shape, growing faster in length. Centropomus parallelus and Oreochromis niloticus showed isometric growth, while all other species exhibited positive allometric growth. In total, 60% of the species showed positive allometric growth (\( b > 3, p < 0.05 \)), 20% showed negative allometric growth (\( b < 3, p < 0.05 \)), and 20% of the species presented isometric growth (\( b = 3, p > 0.05 \)) (Table 1).

The comparison of the allometric coefficient of non-native species between the Guaraguacu River and their native ranges showed significant
Table 1. Length-weight relationship parameters of ten fish species of Guarapuava River, Paraná, Brazil, sampled between 2004 and 2007. Equation parameters: scaling coefficient (a), allometric coefficient (b), and coefficient of determination (r²). Deviation from isometric growth (b = 3) was tested by a Student’s t-test. Bold values denote p < 0.05. N is a native species and NN is a non-native species.

<table>
<thead>
<tr>
<th>Family</th>
<th>Species</th>
<th>n</th>
<th>Total Length (cm)</th>
<th>Total Weight (g)</th>
<th>Equation parameters</th>
<th>t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>min</td>
<td>max</td>
<td>min</td>
<td>max</td>
</tr>
<tr>
<td>Centropomidae</td>
<td>Centropomus parallelus</td>
<td>116</td>
<td>2.2</td>
<td>40</td>
<td>0.11</td>
<td>587</td>
</tr>
<tr>
<td></td>
<td>Geophagus brasiliensis</td>
<td>56</td>
<td>2.2</td>
<td>32</td>
<td>0.15</td>
<td>710</td>
</tr>
<tr>
<td>Chilidae</td>
<td>Oreochromis nilotica (NN)</td>
<td>16</td>
<td>17</td>
<td>43.3</td>
<td>96.82</td>
<td>1,750</td>
</tr>
<tr>
<td>Claridae</td>
<td>Clarias gariepinus (NN)</td>
<td>51</td>
<td>36</td>
<td>88.5</td>
<td>365</td>
<td>4,550</td>
</tr>
<tr>
<td>Clupeidae</td>
<td>Platanichthys platara (N)</td>
<td>150</td>
<td>2.5</td>
<td>7.2</td>
<td>0.08</td>
<td>3.97</td>
</tr>
<tr>
<td>Erythrinidae</td>
<td>Hoplias malabaricus (N)</td>
<td>97</td>
<td>6</td>
<td>63</td>
<td>3</td>
<td>3,600</td>
</tr>
<tr>
<td>Gymnotidae</td>
<td>Gymnotus carapo (N)</td>
<td>10</td>
<td>11</td>
<td>43.8</td>
<td>8</td>
<td>340</td>
</tr>
<tr>
<td>Heptapteridae</td>
<td>Rhanthias quelen (N)</td>
<td>79</td>
<td>14.2</td>
<td>40</td>
<td>13</td>
<td>790</td>
</tr>
<tr>
<td>Ictaluridae</td>
<td>Ictalurus punctatus (NN)</td>
<td>20</td>
<td>27</td>
<td>66.5</td>
<td>150</td>
<td>3.35</td>
</tr>
</tbody>
</table>

Table 2. Comparison of the allometric coefficient (b) estimated for non-native species between their native range (b₁) and the recently colonized Guarapuava River (b₂). Bold values denote p < 0.05.

<table>
<thead>
<tr>
<th>Species</th>
<th>Allometric coefficient</th>
<th>t-test</th>
<th>Reference of b₁</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>b₁</td>
<td>b₂</td>
<td>t</td>
</tr>
<tr>
<td>Clarias gariepinus</td>
<td>2.84</td>
<td>2.92</td>
<td>13.7</td>
</tr>
<tr>
<td>Ictalurus punctatus</td>
<td>3.49</td>
<td>3.39</td>
<td>-13.42</td>
</tr>
<tr>
<td>Oreochromis nilotica</td>
<td>3.017</td>
<td>3.01</td>
<td>-0.014</td>
</tr>
</tbody>
</table>

The non-native species Clarias gariepinus and I. punctatus showed the same growth pattern in the Guarapuava River compared to their native distribution, despite the significant differences observed in the allometric coefficient value. Many endogenous and exogenous factors may contribute to change patterns of fish growth (Carvalho et al., 2017), such as temperature. Clarias gariepinus and O. nilotica are native from Asia and Africa and I. punctatus is native from North America (Tyus & Nikirk, 1990; De Graaf & Janssen, 1996; Naeem et al., 2010). The Guarapuava River has a lower water temperature (Weyl et al., 2016) than most African and higher temperatures when compared to North American rivers (Kaushal et al., 2010; Lawson, 2011). The same allometric coefficient of O. nilotica in the Guarapuava River and in its native range also indicates the high adaptability of the species to a wide range of conditions. Indeed, the allometric coefficient of O. nilotica is already described for many locations, frequently indicating isometric growth (Kosai et al., 2014). This consistent pattern also shows that biotic and abiotic factors have little influence in the growth of this species, which explains its successful invasions.
Although we recognize the limitations of our study, such as the different sampling methods that unbalance the samples, the predominance of juveniles and the small N for certain species, the data presented here is important as a temporal reference for comparison in future monitoring in the Guaraguaçu River. We highlight that measuring LWR parameters was not the main objective in our monitoring, but we identified its importance because for Guaraguaçu River this description was non-existent. The Guaraguaçu River is an important coastal river of the Paraná State, located in a hotspot for conservation, and that serves as a source of subsistence fishing in the region. To date, this is the first study that describes the LWR in the region and draws attention to the differences in the allometry coefficient of non-native species in the Atlantic Rain Forest and in their native ranges. The results obtained are fundamental to understanding the fish biology in the region and subside future studies on fisheries and conservation.

Acknowledgements

We are thankful to CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) for research grants provided to BMC (Process Numbers: 153090/2019-7) and JRSV (Process Numbers: 310850/2012-6; 303776/2015-3). NRM and LF are grateful for their PhD scholarships provided by CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior).

References


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