BIOLOGICAL ATTRIBUTES OF *Steindachnerina insculpta* (Fernandez-Yepez, 1948) (Curimatidae) IN TWO RESERVOIRS OF MIDDLE PARANAPANEMA RIVER, BRAZIL*

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RESUMO: O objetivo deste estudo foi avaliar os atributos biológicos de *Steindachnerina insculpta* em duas represas do médio rio Paranapanema. Os peixes foram coletados com redes de espera bimestralmente em quatro áreas da represa de Salto Grande e trimestralmente em cinco áreas de Chavantes. Após a confirmação da espécie, foram obtidos os dados biométricos, comprimento padrão, peso total e o sexo. Estas informações foram utilizadas para avaliar os atributos biológicos (abundância, razão sexual, relação peso-comprimento, fator de condição e a distribuição em classes de tamanho) para cada área. Para ambas as represas a proporção sexual diferiu de 1:1 e o tipo de crescimento foi allométrico positivo. O fator de condição e as classes de tamanho variaram entre as áreas amostradas. Para as duas represas a classe de tamanho mais representativo foi entre 9,1 e 10,5 cm. Este trabalho demonstra que os atributos biológicos das populações de *S. insculpta* variam ao longo das áreas das duas represas, refletindo a capacidade de ajuste da espécie.

Palavras chave: Distribuição espacial, represa de Salto Grande, Represa de Chavantes.

ATRIBUTOS BIOLÓGICOS DE *Steindachnerina insculpta* (Fernandez-Yepez, 1948) (Curimatidae) EM DUAS REPRESAS DO MÉDIO RIO PARANAPANEMA, BRASIL

ABSTRACT: The aim of the present study was to evaluate the biological attributes of *Steindachnerina insculpta* in two reservoirs of middle Paranapanema River. Fish were collected with gillnets every two months at four sites of the Salto Grande Reservoir and quarterly at five sites of the Chavantes Reservoir. After confirmation of the species, were obtained biometric data, standard length, total weight and sex. This information was used to assess the biological attributes (abundance, sex ratio, length-weight relationship, condition factor and size class distribution) for each area. In both reservoirs, the sex ratio of the total samples differed from 1:1 and growth was positive allometric. The condition factor and length varied between sites. The most representative size class at all sites was 9.1 to 10.5 cm. This study demonstrates that the biological attributes of populations of *S. insculpta* are modified along the areas of the two reservoirs, reflecting the ability to adjust the species.

Key words: Spatial distribution, Salto Grande reservoir, Chavantes reservoir.
INTRODUCTION

The fish species *Steindachnerina insculpta* (Fernandez-Yépez, 1948) belongs to the family Curimatidae and has wide geographic distribution in South America (Reis et al., 2003). It is especially abundant in the Paranaapanema River (Dias & Garavello et al., 1998; Hoffmann et al., 2005; Britto & Carvalho, 2006; Brandão et al., 2009; Oliva-Paterna et al., 2009), and well adjusted to environments of artificial reservoir.

Artificial reservoirs are structured along a continuum beginning in the region of the influx of the river to the reservoir, with three distinct zones – the lotic, transition and lentic zones (Fernando & Holčík, 1985). These zones differ with regard to the physical, chemical and biological properties of the water (Pagioro et al., 2005) as well as the structuring of different groups of aquatic organisms (Fearnside, 2008; Naik et al., 2011).

Fish populations are subject to the operational conditions of the reservoir, which can lead to changes in the structure of the habitat and availability of resources for the ichthyofauna. Among the resident fish in artificial reservoirs, the species considered sedentary (able to complete all stages of their life cycle in the same environment), are generally, the most pre-adapted to survive in this type of environment, as observed in reservoir of Paranapanema River (Agostinho et al., 2007). Probably, this strategy is adopted by the species *S. insculpta*.

This small species is considered to have no commercial value and is only used as bait in professional and amateur fishing activities (Ratton et al., 2003; Bialetzki & Nakatani, 2004). However, small species, such as *S. insculpta*, are ecologically important as a food source for higher trophic levels, especially piscivorous fish (Bennemann & Shibatta, 2002). Thus, the presence of these species can ensure the survival of other species of larger size maintaining a relatively balanced ecosystem.

The aim of the present study was to evaluate the biological attributes (abundance, sex ratio, distribution in size classes and condition factor) of populations of *S. insculpta* and compare sites of the Salto Grande and Chavantes reservoirs, at middle Paranapanema River, Brazil.

MATERIAL AND METHODS

The Salto Grande (SG - 22° 50’ 23” S and 49° 50’ 50” W) and Chavantes (CH - 23° 07’ 50.5” S and 49° 42’ 04.8” W) reservoirs are located along the middle Paranapanema River at the border of the states of São Paulo and Paraná, Brazil (Figure 1). The two reservoir present great differences regarding size, structure and operation. The Chavantes Reservoir is 480 m above sea level, with maximal depth of 70 to 90 m, total volume of 9,410 x 106 m³ and an area of 400 km² and high residence time of water (418 days) (Duke Energy, 2002, Nogueira et al., 2006). The Salto Grande Reservoir exhibits little variation in water level, regardless of the flow, and there is no expansion of the aquatic environment, even during the rainy season. This reservoir has a maximal depth of 13 m, total volume of 42.2 x 106 m³ and an area of 12.2 km² and residence time of water of 1,5 days (Junior et al., 2005).

![Figure 1. Location of Salto Grande and Chavantes reservoirs along middle Paranapanema River, states of São Paulo and Paraná, Brazil; sampling sites indicated by arrows (Source: GoogleEarth – DigitalGlobe).](image_url)
measured (standard length in centimeters). The biologic material was collected with permanent license for zoological material (Ibama Register: 2629349).

Table 1. Surroundings of the sampling areas of in the reservoirs of the Salto Grande and Chavantes.

<table>
<thead>
<tr>
<th>Sites/Code</th>
<th>Reservoir</th>
<th>Geographical coordinates</th>
<th>Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dam (DA)</td>
<td>Salto Grande</td>
<td>S 22º54’13.2’ W 49º59’00.3’</td>
<td>Lentic</td>
</tr>
<tr>
<td>Pedra Branca (PB)</td>
<td>Salto Grande</td>
<td>S 22º 57’ 08.4’ W 49º 58’ 22.0’</td>
<td>Transition</td>
</tr>
<tr>
<td>Pardo (PA)</td>
<td>Salto Grande</td>
<td>S 22º 54’ 14.0’ W 49º 57’ 01.1’</td>
<td>Lotic</td>
</tr>
<tr>
<td>Diácu (DI)</td>
<td>Salto Grande</td>
<td>S 23º 01’ 59.2’ W 49º 54’ 52.9’</td>
<td>Lotic</td>
</tr>
<tr>
<td>Ribereño Claro (RC)</td>
<td>Chavantes</td>
<td>S 23º 14’ 28.9’ W 49º 39’ 45.5’</td>
<td>Lentic</td>
</tr>
<tr>
<td>Fartura (FA)</td>
<td>Chavantes</td>
<td>S 23º24’ 57.7’ W 49º 33’ 54.1’</td>
<td>Lentic</td>
</tr>
<tr>
<td>Paranapanema (PP)</td>
<td>Chavantes</td>
<td>S 23º08’ 03.3’ W 49º 26’ 14.6’</td>
<td>Transition</td>
</tr>
<tr>
<td>Verde (VE)</td>
<td>Chavantes</td>
<td>S 23º33’ 38.9’ W 49º 32’ 10.9’</td>
<td>Lotic</td>
</tr>
<tr>
<td>Itararé (IT)</td>
<td>Chavantes</td>
<td>S 23º36’ 11.2’ W 49º 36’ 22.9’</td>
<td>Lotic</td>
</tr>
</tbody>
</table>

Species abundance was transformed into catch per unit of effort in number of individuals (CPUEn) in order to standardize catch efforts for 1,000 m² of nets among all sites of the river: CPUEn=number×1000/area of nets (Carvalho & Silva, 1999). Analysis of the variation in standard length (Ls) and total weight (Ws) in the population was performed to compare sites in both reservoirs. After checking assumptions of normality (Lilliefors test), with the aid of the BioEstat 5.0 (Ayres et al., 2007), the statistical differences were tested using the nonparametric Kruskal-Wallis (p < 0.05) test, followed by Dunn’s test for comparing differences.

The sex of the specimens was determined in laboratory by macroscopic analysis of the gonads and the sex ratio for each site and for the reservoirs was determined using the chi-square test (χ²; p < 0.05), employing the following equation: χ² = 2 * x(Oxe), in which O is the frequency of females and males and E is the expected proportion (Ayres et al., 2007).

The length-weight relationship was calculated for males, females and total individuals, based on Le Cren (1851) and Santos (1978), as follows: Wt = φ × Ls², in which Wt is the total weight of the individual (g), φ is the parameter indicating the welfare of the fish (physiological state of the individual), Ls is the standard length (cm) and e is the parameter defining the type of growth of the species.

The condition factor (K = W/Ls³) (Vazzoler, 1996), derived from the calculation of the length-weight relationship, was based on Le Cren (1851) and Santos (1978). The K factor was calculated to populations considering the sampling areas grouped of each reservoir and each environmental compartment separately, irrespective of sex. The nonparametric Kruskal-Wallis (p < 0.05) test was performed for analysis among sites and Mann-Whitney U test was used for analysis among reservoirs. The analysis was performed in BioEstat 5.0 and STATISTICA 7 (ZAR, 1984; Ayres et al., 2007) program.

The distribution of the specimens in size classes was performed considering the sampling areas grouped of each reservoir and each environmental compartment separately, based on Sturges (1926), using the following equation: W = K × R, in which W is the weight of each size class, K is the number of classes (1 + (3.222 log N)) (N= number of individuals) and R is the full amplitude of the data (greatest Ls – smallest Ls). Classes were determined from the data of the total sample in the two reservoirs separately. The relative frequency of each size class for males and females was confirmed using the Kolmogorov-Smirnov test (p < 0.05). The analysis was performed in BioEstat 5.0 (Ayres et al., 2007).

For all statistical analyzes in this study, the differences between variables were considered significant when p <0.05. Voucher specimens were deposited at the Laboratório de Biologia e Genética de Peixes (LBP), Instituto de Biociências, UNESP Botucatu, Brazil.

RESULTS

A total of 336 individuals of S. insculpta (Voucher LBP 4823) were caught in the Salto Grande Reservoir and 525 were caught in the Chavantes Reservoir, totaling 861 specimens. The absolute abundance of fish in each site is presented at Table 2. Females were predominant at all sites, except the Itararé site (IT), where males were dominant.

The largest CPUEn in the Salto Grande Reservoir was recorded in the Pardo and the smallest catch was recorded at the Dam site. In the Chavantes Reservoir, the largest catch occurred at the Fartura site and the smallest
was recorded at the Ribeirão Claro site (Figure 2).

**Table 2.** Total absolute abundance (n), the sex ratio (SR) and Chi-square ($\chi^2$) test applied to female to male for *S. insculpta* in all sites of Salto Grande and Chavantes reservoirs (bold), Middle Paranapanema River. *Chi-square ($\chi^2$) statistically different values ($\chi^2 > 3.84$).

<table>
<thead>
<tr>
<th>Site</th>
<th>n</th>
<th>SR</th>
<th>$\chi^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salto Grande (SG)</td>
<td>336</td>
<td>03:1</td>
<td>24.36*</td>
</tr>
<tr>
<td>Dam (DA)</td>
<td>63</td>
<td>04:1</td>
<td>36.79*</td>
</tr>
<tr>
<td>Pedra Branca (PB)</td>
<td>78</td>
<td>3.5:1</td>
<td>31.64*</td>
</tr>
<tr>
<td>Pardo (PA)</td>
<td>125</td>
<td>2.9:1</td>
<td>23.78*</td>
</tr>
<tr>
<td>Diacuí (DI)</td>
<td>67</td>
<td>02:1</td>
<td>11.78*</td>
</tr>
<tr>
<td>Chavantes (CH)</td>
<td>525</td>
<td>1.5:1</td>
<td>4.0*</td>
</tr>
<tr>
<td>Ribeirão Claro (RC)</td>
<td>72</td>
<td>2.2:1</td>
<td>14.8*</td>
</tr>
<tr>
<td>Fartura (FA)</td>
<td>147</td>
<td>1.5:1</td>
<td>4.5*</td>
</tr>
<tr>
<td>Paranapanema (PP)</td>
<td>101</td>
<td>2.5:1</td>
<td>18.6*</td>
</tr>
<tr>
<td>Verde (VE)</td>
<td>84</td>
<td>2.2:1</td>
<td>14.6*</td>
</tr>
<tr>
<td>Itararé (IT)</td>
<td>121</td>
<td>1:1.4</td>
<td>3.9*</td>
</tr>
</tbody>
</table>

**Figure 2.** Catch per unit of effort (CPUEn) of *S. insculpta* populations considering sampling sites in (A) Salto Grande and (B) Chavantes reservoirs.

We observed differences in size and weight of fishes among sites. In the Salto Grande Reservoir, the longest standard lengths were observed in the lotic Pardo (PA), transition Pedra Branca (PB) and lentic Dam (DA) zones (Figure 3-A), whereas total weight presented higher values at the Pardo site (Figure 3-A and C). In the Chavantes Reservoir, the longest standard length and greatest total weight were recorded in the lentic Ribeirão Claro (RC) and transition Paranapanema (PP) zones (Figure 3-B and D).

The analyses of length-weight relationship showed that the populations of *S. insculpta* of Salto Grande and Chavantes reservoirs presented positive allometric growth (Table 3). In the sites Pedra Branca (PB) and Dam (DA), the growth type was more close to 3.0, being considered isometric.

The condition factors revealed variation between environmental compartments. Considering the total population of each reservoir separately (independently of the distribution of the populations within the environmental compartments of each reservoir), significant differences was observed among reservoirs (Figure 4A). In the Salto Grande Reservoir, statistically significant differences were found between the transition Pedra Branca (PB) and lentic Dam (DA) and lotic zones (Pardo - PA and Diacuí, DI) (Figure 4B). In the Chavantes Reservoir, the highest values were recorded in the Ribeirão Claro (lentic zone), Fartura (FA) and Paranapanema (PP) sites (transitions zones), with statistically

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**Figure 3.** Variation in standard length and weight of *S. insculpta* in Salto Grande (A and C) and Chavantes (B and D) reservoirs; Vertical lines: maximum and minimum values; box: first and third quartiles; horizontal lines: medians; Different letters indicate significant differences (Kruskal-Wallis test; p < 0.05).
significant differences between the lotic and all other sites (Figure 4C).

**Table 3.** Length-weight relationship of *S. insculpta* in the sites of Salto Grande and Chavantes reservoirs (bold). Middle Paranapanema River, Brazil. N: number of analyzed specimens, (a) = condition factor, (b) = growth type, (r²) = determination coefficient.

<table>
<thead>
<tr>
<th>Sites</th>
<th>n</th>
<th>a</th>
<th>b</th>
<th>r²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salto Grande Reservoir (SG)</td>
<td>336</td>
<td>0.0157</td>
<td>3.26</td>
<td>0.93</td>
</tr>
<tr>
<td>Dam (DA)</td>
<td>63</td>
<td>0.0023</td>
<td>3.07</td>
<td>0.96</td>
</tr>
<tr>
<td>Pedra Branca (PB)</td>
<td>78</td>
<td>0.0123</td>
<td>3.07</td>
<td>0.96</td>
</tr>
<tr>
<td>Pardo (PA)</td>
<td>125</td>
<td>0.01</td>
<td>3.44</td>
<td>0.90</td>
</tr>
<tr>
<td>Diacui (DI)</td>
<td>67</td>
<td>0.011</td>
<td>3.41</td>
<td>0.94</td>
</tr>
<tr>
<td>Chavantes Reservoir (CH)</td>
<td>525</td>
<td>0.0164</td>
<td>3.21</td>
<td>0.98</td>
</tr>
<tr>
<td>Ribeirão Claro (RC)</td>
<td>72</td>
<td>0.0142</td>
<td>3.28</td>
<td>0.98</td>
</tr>
<tr>
<td>Fartura (FA)</td>
<td>147</td>
<td>0.0205</td>
<td>3.12</td>
<td>0.94</td>
</tr>
<tr>
<td>Paranapanema (PP)</td>
<td>101</td>
<td>0.0122</td>
<td>3.34</td>
<td>0.87</td>
</tr>
<tr>
<td>Verde (VE)</td>
<td>84</td>
<td>0.0173</td>
<td>3.17</td>
<td>0.99</td>
</tr>
<tr>
<td>Itararé (IT)</td>
<td>121</td>
<td>0.0206</td>
<td>3.10</td>
<td>0.91</td>
</tr>
</tbody>
</table>

Regarding the structure of the size classes, for all sites, females and males present differences in size classes distribution (Kolmogorov-Smirnov test, p < 0.05). Most individuals at all sites in both the Salto Grande and Chavantes reservoirs were in the 9.1 to 10.5 cm class (Figures 5-A and 6-A). In the Salto Grande Reservoir, except for the Diacui (DI) site, a greater number of females in the 10.6 to 12.0 cm class were caught, whereas the most frequent class for males was 9.1 to 10.5 cm (Figures 5 B, C, D and E).

In the Chavantes Reservoir, a greater number of males in the 9.1 to 10.5 cm class were caught at the Itararé (IT), Paranapanema (PP) and Fartura (FA) sites, whereas the predominant class was 7.6 to 9.0 cm at the Verde (VE), Fartura (FA) and Ribeirão Claro (RC) sites and 12.1 to 13.5 cm at the Ribeirão Claro (RC) site. Regarding the frequency of females caught, the predominant class was 9.1 to 10.5 cm at the Itararé (IT), Verde (VE), Fartura (FA) and Ribeirão Claro (RC) sites and 10.6 to 12.0 cm at the Paranapanema site (Figures 6 B, C, D, E and F).
Figure 6. Frequency (%) of standard length of *S. insculpta* by size class in Chavantes Reservoir (A) and in the different sites: Ribeirão Claro (B), Fartura (C), Parapananema (D), Verde (E) and Itararé (F) sites.

**DISCUSSION**

The species of fish *S. insculpta* is between the most abundant species in the two reservoirs studied (Brandão et al., 2009; Vidotto-Magnoni, 2009) and is between the dominant species of fish in the Paraná River Basin (Agostinho et al., 2007). This detritivorous species plays an important role in the trophic structure of reservoirs, since the feeding of detritus by fish species is a fundamental feeding tactic, increasing the energy efficiency and productivity of the community (Araújo-Lima et al., 1995; Lowe-McConnell 1999; Alvim & Peret 2004).

In the Salto Grande reservoir, *S. insculpta* presented greatest abundance in the Pardo site, possibly due to the considerable contribution of the input of suspended material and detritus from the surrounding municipalities, which favors detritivorous species (Bennemann et al., 2000; Teixeira & Bennemann, 2007). The high abundance of detritivorous fish is expected in river stretches of reservoirs, using the detritus of the non-consolidated bottom as food resources (Hahn et al. 1998). In addition, this can also be associated with the presence of macrophytes in the littoral zone, providing organic matter and substrate for attachment of algae and periphyton (Smith et al. 2,003; Winemiller & Jepson, 1998).

In the Chavantes reservoir, the greatest abundance was recorded in the site Fartura, which may be related to the types of compartments created in the littoral zone in lentic environments. Similarly to Pardo site, this area presents high amounts of aquatic macrophytes. These areas are favorable to the development of different organisms, performing important functions, such as structural protection of the habitat, areas for breeding and the provision of food resources (Casatti et al., 2003; Pelicic & Agostinho, 2006), such as organic matter which can be used by detritivorous fish species as *S. insculpta*.

The analysis of the length pattern revealed small differences in the distribution pattern of the *S. insculpta* populations in the different areas in each Reservoir, indicating that the populations respond similarly to pressure from the environment in terms of growth. Regarding the population structure based on the length pattern, smaller differences in class sizes among females and males was found in the total population in the Salto Grande Reservoir in comparison to that in the Chavantes Reservoir, which had individuals with more diversified lengths. Moreover, all females in both reservoirs were larger than the males, demonstrating sexual dimorphism. Such differences in length pattern among individuals and the distribution of length classes in the populations in different environmental compartments can be a reflection of the environmental heterogeneity among the study sites.

The sex ratio differed from 1:1, with a greater number of females in both reservoirs. However, the sex ratio pattern was not observed, only the predominance of females. The characterization of the sex ratio and size structure are basic data for assessing the reproductive potential and estimated stock size (Vicentini & Araújo, 2004). It is likely that the predominance of females constitutes a strategy reproductive (Winemiller, 1989; Vismara et al., 2004), that are directly related to the behavior of species.

The population growth pattern in both reservoirs was positive allometric, corroborating the findings reported by Orsi et al. (2002) for the Tibagi River, which is an important tributary of the Parapananema River. This indicates that this species displays good adjustment to different environments, since the
ecosystem is constantly changing, leading populations to develop appropriate strategies for the maintenance and continuity of their life cycles.

Higher condition factor values were observed in the Salto Grande Reservoir, which may be associated with some particular feature of this environment, for example, more diversity of habitat compared with the reservoir Chavantes, allowing for the populations more alternatives to find resources (food, area for breeding and spawning) for its development. The analysis in condition factor in the populations of the longitudinal axis of this reservoir was more homogeneous. However, in the Chavantes Reservoir, major differences were observed among the sites. Differences in condition factor values can be interpreted as a variation in the amount of body fat, changes in the environment related to gonad maturation and feeding intensity (Wooton, 1990; Ribeiro et al., 2007). This variation in both the Salto Grande and Chavantes reservoirs may be due to limnological characteristics (the structuring of the habitats), reflecting the amount of available food, refuge and reproductive sites for the species.

In this study we observed that the biological attributes of populations of *S. insculpta* are modified along the areas of the two reservoirs, reflecting the ability to adjust in dammed aquatic ecosystems. It is important to emphasize that the two reservoirs differ substantially in relation to size, structure and operation. Chavantes Reservoir works as accumulation basin for the other reservoirs downstream, while Salto Grande Reservoir works almost like a natural river (retention time of water is no longer 2 days). These features probably are important in distribution and structure of all biological attributes of *S. insculpta* populations.

The natural environmental variations and operating procedures of artificial reservoir can influence the spatial distribution of fish species and their biological attributes. Unpredictable differences are associated with local events, depending on the operational procedures of the reservoir and the multiple uses of the adjacent areas.

**CONCLUSION**

This study demonstrates that *S. insculpta* has a noticeable capacity to adjust to different environments, such as the lotic, transition and lentic limnological compartments of the Salto Grande and Chavantes reservoirs.

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