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Reproductive aspects of *Schizolecis guntheri* (Loricariidae: Hypoptopomatinae), in an Atlantic Forest stream, Southern Brazil

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Abstract. *Schizolecis guntheri* is a small loricariid (maximum total length (TL), 50 mm) from the subfamily Hypoptopomatinae, which inhabits the streams of the threatened Atlantic Forest in Brazil. This study aimed to investigate the biological aspects of *S. guntheri* regarding the species' reproductive period and the gonadal maturation. We used macroscopic analysis of testis and ovary to describe the gonadal development, analyzed the seasonal changes of gonadosomatic index (GSI) and maturation stages in both sexes, and estimated the length of first maturation (L_{50}) for the species. Sampling was performed once every month from September 1999 to August 2000, on the Morato river inside the Salto Morato Natural Reserve. Three stages of gonadal development were recorded in females and four stages were recorded in males. The chronological variation in GSI and the gonadal development of *S. guntheri* showed a pronounced spring–summer activity, which also correlated with higher temperature and pluviosity records; whereas, the size at first maturity, proved to be close to the individuals' maximum length (L_{50} = 37 mm TL; Max. TL = 41 mm).

Keywords: *Cascudinho*, Coastal stream, Ecology, Fresh water, Reproduction strategy

Resumo. Aspectos reprodutivos de *Schizolecis guntheri* (Loricariidae: Hypoptopomatinae), em um riacho da Mata Atlântica, Sudoeste do Brasil. *Schizolecis guntheri* é um pequeno loricarídeo (comprimento total (CT) máximo 50 mm) da subfamília Hypoptopomatinae, que habita riachos da ameaçada Mata Atlântica brasileira. O objetivo do presente estudo foi investigar aspectos biológicos de *S. guntheri* relacionados ao período reprodutivo e amadurecimento gonadal da espécie. Nós utilizamos análises macroscópicas do testículo e ovário para descrever o desenvolvimento gonadal, analisamos mudanças sazonais do índice gonadossomático (IGS) e estádios de maturação para ambos sexos e estimamos o comprimento de primeira maturação (L_{50}) para a espécie. As amostras foram realizadas mensalmente de Setembro de 1999 a Agosto de 2000, no Rio Morato dentro da Reserva Natural do Salto Morato. Três estádios de maturação gonadal foram registrados para as fêmeas e quatro estádios para os machos. A variação cronológica no IGS e no desenvolvimento gonadal mostrou uma pronunciada atividade no período Primavera-Verão, também correlacionados com registros de altas temperaturas e pluviosidade, enquanto que o tamanho de primeira maturação, se mostrou aproximado ao comprimento individual máximo registrado no estudo (L_{50} = 37 mm CT; CT Máx. = 41 mm).

Palavras-chave: Água doce, *Cascudinho*, Ecologia, Estratégia reprodutiva, Riacho costeiro

Introduction

Brazil's Atlantic Forest represents one of the richest biomes in the world, contributing to 7% of all plant and animal species (Myers *et al.* 2000). Simultaneously, this wildlife paradise represents one of the most threatened environments, for which the acreage as of now is limited to forest fragments in distinct conservational stages, leaving only 7% (~92,000 km²) of its original area (~1.2 million km²) (Gascon *et al.* 2000, Ribeiro *et al.* 2009).

Due to this diminished biomes, the streams of the Atlantic Forest reflect richness and peril with high endemism of fish species and by anthropogenic pressures, respectively. Besides pollution and introduction of alien species (Gomiero & Braga 2006, Oyakawa *et al.* 2006) the loss of riparian vegetation damages these highly sensitive environments (Menezes *et al.* 2007, Miranda 2012) and directly affects the fish fauna (Lobón-Cerviá *et al.* 2016).

The streams of Atlantic Forest shelter small sized fish species, such as the loricariid Schizolecis guntheri (Miranda Ribeiro, 1918) (Menezes *et al.* 2007). Occurring mainly in coastal rivers of the Atlantic Forest in southeastern and southern Brazil (Schaefer 2003), *S. guntheri* has a length (from the snout until the end of caudal fin) restricted to ~55 mm standard length (SL) (São Thiago 1990, Esteves & Lobón-Cerviá 2001). This species is usually found near the water surface and is associated with structured sites such as riverbank vegetation or in the bottom, between leaves, rocks, and branches (Buck & Sazima 1995, Schaefer 2003, Barreto & Aranha 2005). At these sites, the individual species perform a grazing behavior, foraging on periphyton (Buck & Sazima 1995, Esteves & Lobón-Cerviá 2001).

The knowledge of such characteristics is intrinsic to conservation management; however, besides the records of *S. guntheri*'s ecology, the species' reproductive biology is less researched (São Thiago 1990). Therefore, this study aimed to investigate the reproduction period and gonadal maturation of *S. guntheri* from an Atlantic Forest Natural Reserve.

Material and Methods

The Morato river is located inside the Salto Morato Natural Reserve (25° 10' S 48° 18' O; Fig. 1), considered as one of the most significant extent of the Ombrophilous Dense Forest, which is derived from the Atlantic Forest (SOSMA 1998). The Morato river is about 10 km long; it begins at the east slope of Serra do Mar, runs through the coastal plain, and finally joins the Guaraqueçaba river, near to the Guaraqueçaba Bay mouth (FBPN 1995). The section of the Morato river studied (~4 km) comprises a third order stream (Suguio & Bigarella 1990), with fresh crystal clear waters (Barreto & Aranha 2005).

Distributed in altitudes from 25 to 930 m, the environment presents rainfall rates with more than 2000 mm per year, of which the summer months (December, January, February) receive the heaviest rainfall and the temperatures vary from 10 °C to 30 °C (IAPAR 1978, FBPN 1995) (Figure 2).

The sampling was performed from September 1999 to August 2000, once every month. The individual species of *S. guntheri* were captured with both beach seine net and strainers. The fish were initially fixed in 10% formalin, and were then transferred to 70% alcohol. The specimens were identified based on the guidelines of Reis & Schaefer (1998) and comparisons with reference individuals from Capão da Imbuia Natural History Museum (MHNCI). Fish collecting and handling was done following the ethical procedures and environmental legislation. Voucher specimens were deposited in the ichthyological collection of the Departamento de Zoologia of the Universidade Federal do Paraná, under code DZUP-PX10 to DZUP-PX40 (Barreto & Aranha 2005).

Laboratory measurements were performed for the weight (g) and length (mm) (fork and total) of each individual fish. Furthermore, they were dissected through incisions at the abdomen, esophagus, and anal opening. After the extraction of viscera, the gonads were analyzed under a stereomicroscope (up to 20× magnification) to examine four characteristics: the gonadal position inside the coelomic cavity (ventral, dorsal, and dorsoventral), the gonadal shape (sacciform, thread-like, and fringed thread-like), sex typing (male, female), and the maturity stage (immature, maturing process, mature, empty, and resting). Each gonad was also weighed with a precision of 0.001 g and the lighter ones were recorded with 0.0001 g to allow the following calculations.

The gonadossomatic index (GSI), representing the proportion of gonadal weight in relation to the fish total weight, was obtained through the equation:

$$GSI = \frac{W_g}{W_f} 100$$

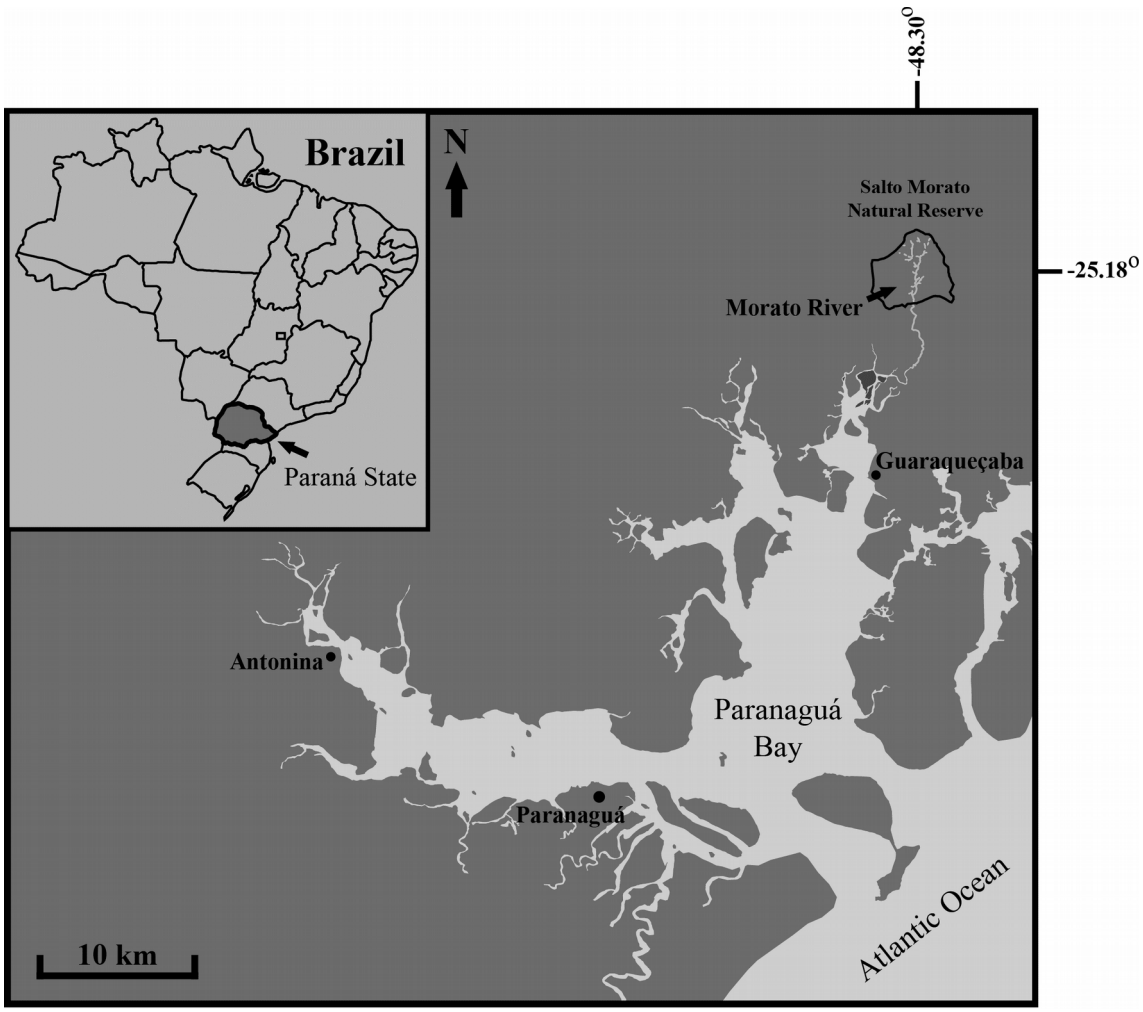

Figure 1. Location of Salto Morato Natural Reserve and the Morato river (sampling site), also highlighted at a larger scale on the map of Brazil (arrow).

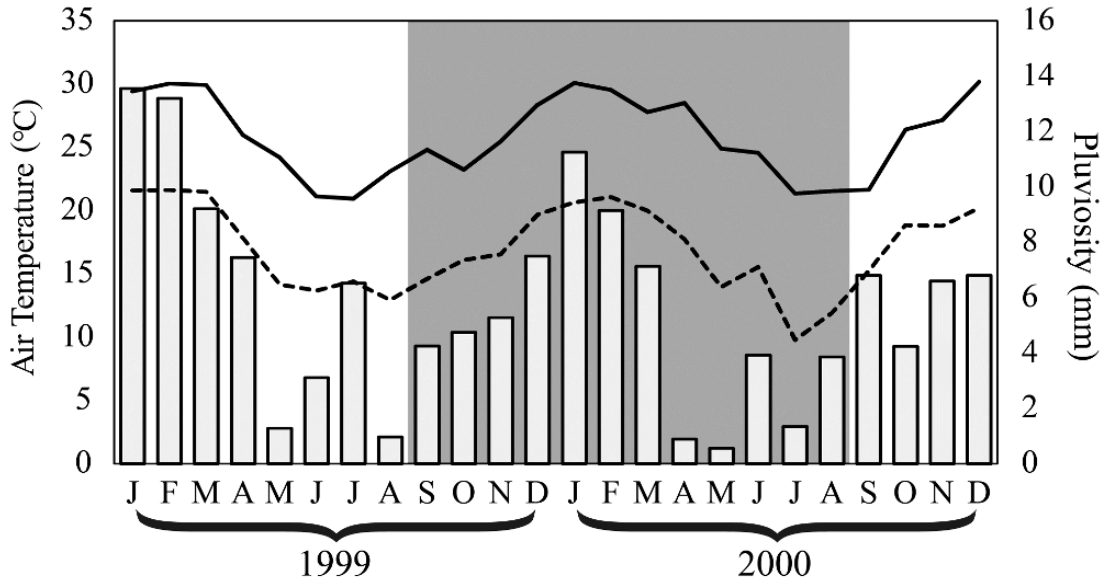

Figure 2. Abiotic data of Guaraqueçaba municipality (PR, Brazil). Monthly means of maximum temperatures (solid line), monthly means of minimum temperatures (dashed line), and mean pluviosity per month (columns). The gray background concerns the fish sampling period of the present study. Data were provided by the Instituto Agronômico do Paraná (IAPAR).

where, W_g is the gonadal weight and W_f is the fish weight. Both GSI and gonadal stage frequency were analyzed, for each sex, through time in a monthly variation (Vazzoler 1996). The length at first maturation (L_{50}) was calculated, with the following logistic equation:

$$F = \frac{100}{1 + e^{-a(TL-L_{50})}}$$

where, F is the fraction of mature individuals (male and female grouped) for each class of total length (TL), while a and L_{50} are the parameters obtained from the adjustment of least square using the Solver tool of Microsoft Excel®.

Results

A total of 113 individuals (female = 65, male = 29, immature = 19) were analyzed. The TL varied from 27 to 43 in female individuals, from 29 to 41 mm in male individuals, and from 19 to 38 mm in the immature individuals in whom the sex identification was not possible (Fig. 3).

All gonadal development features were important for classification of different maturity stages. The ovary position in females differed from dorsal in maturing individuals, to dorsoventral in mature ones; however, the ovary shape remained sacciform throughout the development. The analysis of testis showed distinct shapes; initially, a thread-like form while maturing, and a fringed thread-like form when mature or empty.

The maturation analysis identified three stages of gonadal development in females: *in maturation*, with oocytes varying from small translucent to larger opaque ones and accounting for 20% (mean) of coelomic cavity; *mature*, with homogeneous and large oocytes, which, accounted for 60% (mean) of coelomic cavity (until 80%) and presenting a lateroventral expansion of abdomen noticed before dissection; and *empty*, presenting flaccid ovaries with few oocytes characterized as atretic. The maturation analysis of males also identified three stages of gonadal development: *in maturation*, presenting moderate development of testis with small fringes (15% of coelomic cavity); *mature*: showing an increased volume of testis (27% of coelomic cavity), opaque white and highly fringed; and *empty*: besides the presence of fringes, the testes were translucent and flaccid. Immature individuals were also recorded, showing transparent small gonads, accounting for less than 10% of coelomic cavity. Despite the thread-like form of these gonads (similar to males), the sex typing was not accurate; therefore, they were disregarded.

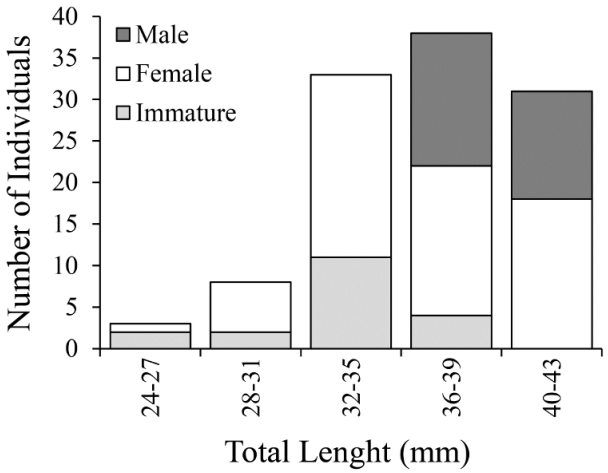

Figure 3. Number of individuals by total length classes (mm) of *Schizolecis guntheri* (female, male, and immature contributions) captured in Morato river, Southern Brazil.

Despite the lack of individuals from both sexes in October 1999 and March 2000, the monthly variation of maturation stages and GSI mean values allowed the description of *S. guntheri*'s reproductive progress (Figs. 4 and 5). Initially, the GSI analysis recorded a remarkable difference of gonadal income for fish weight, which was 2.07% of GSI for males and 15.3% of GSI for females. The narrower variation in males' GSI values associated with a fewer number of individuals restricted the comprehension of its maturing process (Fig. 4).

Alternatively, the female analysis presented an intended development of ovaries, with the transition of individuals from *mature processing* in winter–spring to the stages *mature* and *empty* in summer (Fig. 5). Furthermore, during reproductive analysis, the estimated size at first maturity (L_{50}) of *S. guntheri* (male and female grouped) was 37 mm in TL (Fig. 6).

Discussion

The reproductive period is one of the major traits of species biology, once the timing is appropriate for the offspring's fitness (Wootton & Smith 2015). Food availability, photoperiod, temperature, and pluviosity represent some environmental seasonal features, which affect the reproductive behavior of fish (Helfman *et al.* 2009). Due to the linkage between such features, its effect on reproductive biology is overlapped, requiring specific analysis for accurate addressment. Although, the correlation of spawn with broader features as temperature and pluviosity serve as

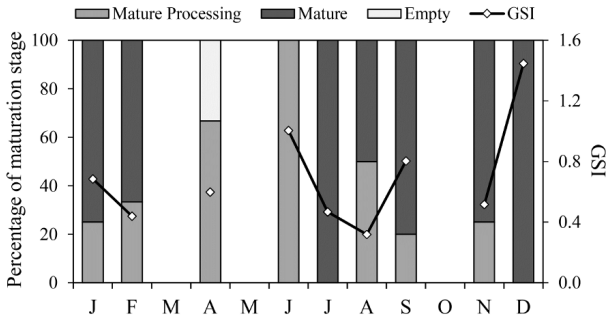

Figure 4. Representativeness of mature stages and gonadossomatic index variation per month for *Schizolecis guntheri* male individuals, captured in Morato river, Southern Brazil.

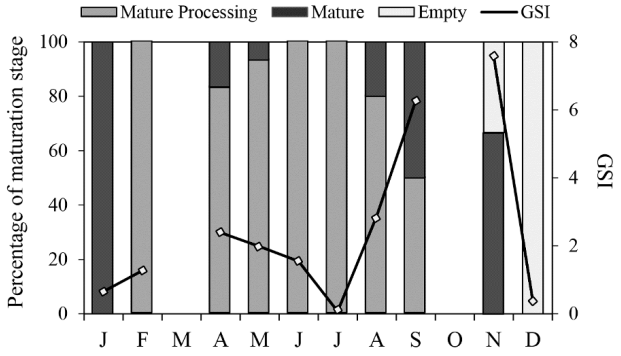

Figure 5. Representativeness of mature stages and gonadossomatic index variation per month of *Schizolecis guntheri* female individuals, captured in Morato river, Southern Brazil.

useful ecological proxies (Crawshaw & Podrabsky 2011).

The chronological variation in GSI and the gonadal development of *S. guntheri* provided a suitable overview of its reproductive period, displaying a pronounced spring–summer activity (Figures 4 and 5). Furthermore, these records correlate the higher temperatures and pluviosity data (Figure 2) with the species' offspring period. This pattern embraces the inherited life traits such as large eggs, low fecundity, and parental care (Menezes *et al.* 2000), supported by an amalgam of adaptations in the environmental conditions (Vila-Gispert *et al.* 2002) and followed by other related species. *Hemiancistrus* sp. Bleeker 1862, also present higher values of GSI in the spring–summer period (Ramos & Konrad 1999), the same applies to *Loricariichthys platymetopon* Isbrücker & Nijssen 1979, which presents such correlation with environmental conditions, featured by longer photoperiod, higher temperatures and greater rainfall

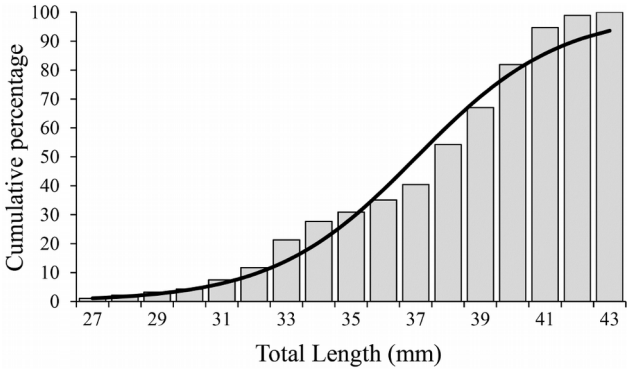

Figure 6. Cumulative percentage of mature individuals by total length (mm) for both sexes of *Schizolecis guntheri* grouped. Black line represents the logistic function of data adjusted by the least square method.

(Bailly *et al.* 2011, Querol *et al.* 2004). Moreover, the results found for *S. guntheri* in this study differ from the long reproductive period (all year round) proposed by São Thiago (1990), who analyzed the species reproduction based on a method where both *mature* and *in maturation* individuals (adults) were considered reproductively active; however, ignoring the seasonal variation in the stage frequency.

The macroscopic characteristics of *S. guntheri*'s testes and ovaries described in this study are highly related to those of *Pseudotothyris obtusa* (Miranda Ribeiro 1911) (Menezes *et al.* 2000), another Hypoptopomatinae resident of Atlantic Forest streams (Menezes *et al.* 2007). Menezes *et al.* (2000) suggested a partial spawning to *P. obtusa*, due to the record of half-empty individuals (only microscopically).

Although, Menezes *et al.* (2000) highlight the drawbacks of the spawning strategy assessment based solely on gonadal development data. In this sense, both species, *S. guntheri* and *P. obtusa*, need further investigations for a broader understanding of their spawning strategies, as chronological variation of fecundity data (Holden & Raitt 1974, Vazzoler 1996).

Considering the gonadal examination, the GSI values observed in males and females of *S. guntheri* (Figures 4 and 5) demonstrated a higher representativeness of ovaries to the fish weight than the testis. This difference between genders was also evident in *Loricariichthys castaneus* (Castelnau 1855) (Duarte *et al.* 2007), which, likewise *S. guntheri*, presented low range of testis weight between empty and mature stages (narrower GSI), and considering the small size of individuals, evidenced female's GSI as a better reproductive descriptor.

The last reproductive characteristic of *S. guntheri* analyzed in this study was the size at first maturity (L_{50} = 37 mm TL), which revealed a small interval of the individuals maximum length (Max. TL = 41 mm). Besides its main application on fishery biology, by restricting the capture size (Cochrane 2002), the L_{50} can add information to examine broader life history strategies.

In this sense, the small catfishes need to be further researched for environmental interaction, phylogenetic history, and reproductive strategies (Weitzman & Vari 1988, Bruton 1996). The need for future investigations as well as the present discoveries regarding *S. guntheri* become more essential when we consider the threatened streams of Atlantic Forest. Such knowledge is intrinsic to manage and protect fish species, which in turn supports the conservation of the environment.

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