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Population structure and weight-length relationship of *Hyphessobrycon bifasciatus* Ellis 1911 in a dammed stream

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ABSTRACT. The species *Hyphessobrycon bifasciatus*, also known as the 'lemon tetra', is a small characin fish distributed in coastal rivers from the southern state of Bahia to the state of Rio Grande do Sul, and also in the upper Paraná river basin, found in small rivers and lagoons. Its diet varies between small invertebrates and plant debris. They are oviparous animals that lay their eggs on the bottom or in groups of plants, which hatch approximately two days after fertilization. In light of this, the present study aimed to describe the population structure of *H. bifasciatus* in terms of feeding and length-weight relationship in a dammed neotropical stream located in the municipality of São Roque, SP, Brazil. Specimens of *H. bifasciatus* were captured in two collection campaigns (November 2021 and July 2022). The fish were collected using a three-meter-long trawl net, with a 1 cm mesh and a sampling effort of 30 minutes at each point. Subsequently, they were transported to the laboratory, where their length and standard weight were recorded, along with their stomach contents. A total of 101 specimens were analyzed, 41 females and 60 males. The species had an average body length of 2.5 ± 0.46 cm and an average total weight of 0.33 ± 0.19 g for females, and 2.8 ± 0.60 cm and 0.45 ± 0.27 g for males. We obtained a length-weight relationship of $y = 0.4317x - 0.7574$, $R^2 = 0.9393$ for males, and $y = 0.3413x - 0.5237$, $R^2 = 0.8704$ for females. The size range varies from the 1.6-2.0 centimeter class to the 3.6-4.0 centimeter class. The main food items were plant material and filamentous algae, abundant in both sexes. Finally, it is concluded that this species forms large schools near macrophytes, exhibits peaceful behavior, and feeds mainly on plant items.

Keywords: Condition factor; habitat; dam; trophic guild; stomach content.

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Introduction

Small fish are dominant in tropical rivers, being found mainly in marginal regions associated with aquatic vegetation, where a complex habitat structure composed of leaves, stems and roots provides adequate shelter and food (Moreira, Peressin, & Pompeu, 2023). Small fish require a limited area to complete their life cycle. They are sensitive to small-scale environmental changes, rather than broader spatial factors. This mean they react to subtle changes in the immediate environment, such as water quality or food availability, and not to wider geographical or regional factors (Fernandes et al., 2021). Small fish species are those with 15 cm or less in standard length (SL) when adults, which correspond to approximately 70% of the diversity of freshwater fish species in the Neotropical region (Castro & Polaz, 2020).

The order Characiformes currently includes 2,334 valid species (Toledo-Piza et al., 2024) and forms one of the dominant groups among South American freshwater fish, consisting of very distinct lineages. This favors the diversification of their families, tending to the complexity of the individuals that make up the family. Characiformes is a large and diverse order of freshwater fish with many genera and species, the majority being found in South and Central America and Africa, belonging to the huge and widely distributed superorder Ostariophysi (Menezes et al., 2007). They are characterized by having well-developed teeth, an adipose fin usually present, a body almost always covered in scales, a pelvic fin present, a short to moderately long anal fin, and a lateral line usually curvilinear, sometimes incomplete. They have a non-protrusible upper jaw, and pharyngeal teeth are often present.

Characidae is the family with the greatest diversity of species among the Characiformes, even after the progressive dismemberment of groups of species that, during the last three decades, became part of other

families. Most species are small, known in Brazil as lambari, pequira, piaba, and matupiri (Buckup, 2021). *Hyphessobrycon* Durbin, 1908, is one of the most species-rich genera of Characidae, currently comprising approximately 150 valid species (Guimarães, Brito, Feitosa, Carvalho-Costa, & Ottoni, 2018).

Hyphessobrycon bifasciatus Ellis, 1911, popularly known as lambari, inhabits clear water streams and their backwaters, small and medium-sized rivers, small lakes and ponds, feeding on algae, zooplankton, terrestrial and aquatic insects. It is a small species, reaching 4.4 cm in males and 3.7 cm in females. It presents peaceful behavior and is found in benthopelagic environments, with pH between 5.8 and 8.0 and temperatures of 20 to 25°C (Gonçalves, Souza, Ferreira, Peressin, and Braga, 2013).

Dams, one of the oldest forms of human impact on the environment, cause several changes in ecosystems. The main change is the loss of habitats, which occurs when the area that was previously land is flooded to create the dam's reservoir. Additionally, dams alter the body of water, changing its flow, temperature and quality, which can lead to loss of biological diversity (Agostinho & Gomes, 1997; Tundisi, 1999). Given this scenario, the objective of this study was to investigate the ecology and diet of the fish species *H. bifasciatus* in a stream that was blocked by a dam. Furthermore, the study also analyzed the relationship between the weight and length of fish of this species.

Material and methods

Specimens of *H. bifasciatus* (Figure 1) were captured in a first-order dammed stream, surrounded by pine, eucalyptus, and grass, located in the Sorocaba River Basin, in the municipality of São Roque (23K290845 7388995), state of São Paulo, Brazil (Figure 2). The fish were collected in four collection campaigns, between the months of November 2021 and July 2022, using a three-meter-long trawl net, with a 1 cm mesh, and a sampling effort of 30 minutes at each point. The specimens were placed in plastic bags identifying the location and date. The collected specimens were fixed in 10% formalin, subsequently preserved in 70% alcohol, and deposited in the fish collection of the USP Zoology Museum (MUZUSP 127796). Sampling was carried out under In Situ Management Authorization DEFAU/CMFS-IS 301/2021.

For environmental characterization, we carried out measurements of depth, width, type of substrate, and the chemical parameters of the water (temperature, dissolved oxygen, pH, electrical conductivity, and total dissolved solids), which were obtained using an OAKTON PCD650 multiparameter probe.

Figure 1. *Hyphessobrycon bifasciatus*. Adult male, 12 mm Standard length. Photo: Welber Senteio Smith, Nov/2022.

For each specimen, the standard length and weight were obtained, followed by dissection to remove the digestive tract. Sexing was done by macroscopic observation of the anal fin and pelvic fin of the individuals (Pastana, & Ohara, 2016). The analysis of population structure data in terms of size was verified through the frequency distribution of classes for both sexes, thus obtained using the Sturge rule (Vieira, 1980). The ratio between weight and standard length was obtained for the individuals, being expressed by the equation:

$K_{2=} Wt/Lt^{b}$ $(allometric\ condition\ factor)$

Where:
Wt = total weight of the individual;
Lt = total length of the individual;
b = angular coefficient of the regression between Wt/Lt.
Thus, to estimate the value of the coefficient b, the expression used is:

$$Wt = a\ Lt^b$$

The value of b is the relative growth constant, and tends to assume values close to 3, when growth is isometric (Vazzoler, 1981). The differences in the average values of parameter b between males and females were evaluated using the Student's t-test, considering that the values presented a normal distribution according to the Shapiro-Wilk test. Means were evaluated using the t-test, and confidence limits were compared to identify differences.

For stomach content analyses, only stomachs from adult individuals were used, thus avoiding compromising data due to ontogenetic changes in the diet (Abelha, Goulart, Kashiwaqui, & Silva, 2006). To analyze the importance of the identified foods, the Kawakami and Vazzoler (1980) Food Index was calculated, using data on Frequency of Occurrence (Fi) and Volume (Vi) in percentage, with the formula:

$$IAi = \frac{Fi * Vi}{\sum_{i=1}^{n} * (Fi * Vi)}$$

Where:
IA = Food Index proposed by Kawakami and Vazzoler (1980);
i = 1,2, ... n = certain food item;
Fi = Frequency of Occurrence (%) of the item;
Vi = Volume (%) of the given item.
All tests were carried out using Past 3.26 software (Hammer, Harper, & Ryan, 2001).

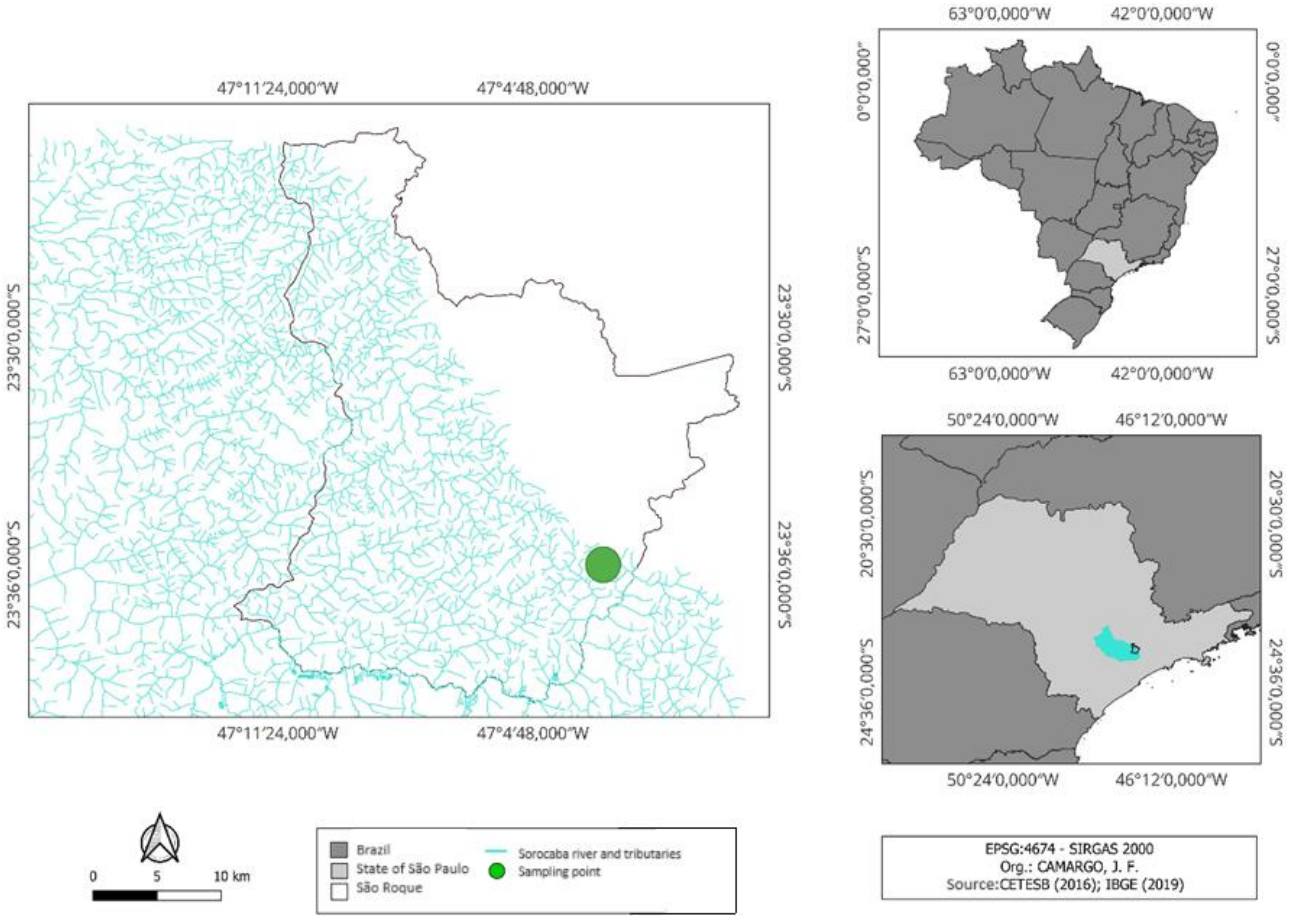

Figure 2. Location of sampling points on the dammed stream, São Roque, São Paulo, Brazil.

Results

The dammed stream had a temperature between 19.5ºC and 25.5ºC. The pH values remained close to 7. The maximum width of the studied point was 40 meters, and the minimum was 30 meters. A sandy/silty substrate was observed throughout its extension, as well as the presence of several macrophytes (Table 1).

Table 1. Average values of environmental variables in the dammed stream, São Roque, São Paulo, Brazil. Temp: temperature, Cond: Conductivity, TDS: total dissolved solids. Presence=1; absence=0.

Variables	
pH	6.9±0.4
TDS (ppm)	30.61±9.48
Cond. (µs)	56.73±9.31
Temp. (ºC)	21.8±2.5
Average Width (m).	36.6±31.7
Average Depth (m).	1.2±0.7
Herbaceous Veg. %	30%
Debris grids	0%
Ravine Width	1
Fine Substrate %	40%
Wood %	10%
Riparian Veg. %	30%
Silty Substrate	1
Sandy Substrate	1
Rocky Substrate	0
Clay Substrate	0
Organic matter %	20%
Roots %	10%
Presence of pools	1
Water flow	Low
Presence of fast	No
Presence of slow flow and pools	1
Canopy density %	40%
Human influence	1

In total, 101 specimens were analyzed, 41 females and 60 males. Females had an average weight of 0.33 ± 0.17 g and males 0.45 ± 0.27 g. Size ranged from class 1.6 - 2.0 centimeters to class 3.6 - 4.0 centimeters. The modal values were equal between the sexes, with both sexes being more abundant in the 2.1-2.5 cm length class (Figure 3).

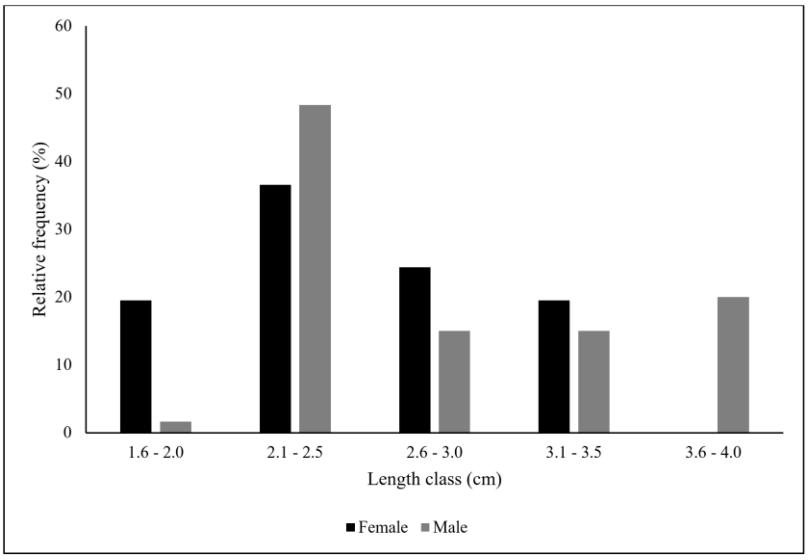

Figure 3. Relative frequency distribution by length class of females and males.

The weight-length relationship and their mathematical expressions are shown in Figure 4. The value of parameter b was 2.5565 for females and 2.6901 for males, both demonstrated negative allometry, and the

values found do not include significant differences, indicating that the condition factor values between female and male are equal ($t = 1.98$; $p > 0.05$).

The species' diet was composed of 6 food items: Inorganic material, plant material, *Mychosystis*, *Closterium*, filamentous algae, and zooplankton. Five food items were sampled for each sex (Females did not feed on inorganic material, and males did not feed on *Closterium*). The predominant item for both sexes was plant material, demonstrating a pattern for the species; however, females feed more on filamentous algae and zooplankton compared to males (Figure 5).

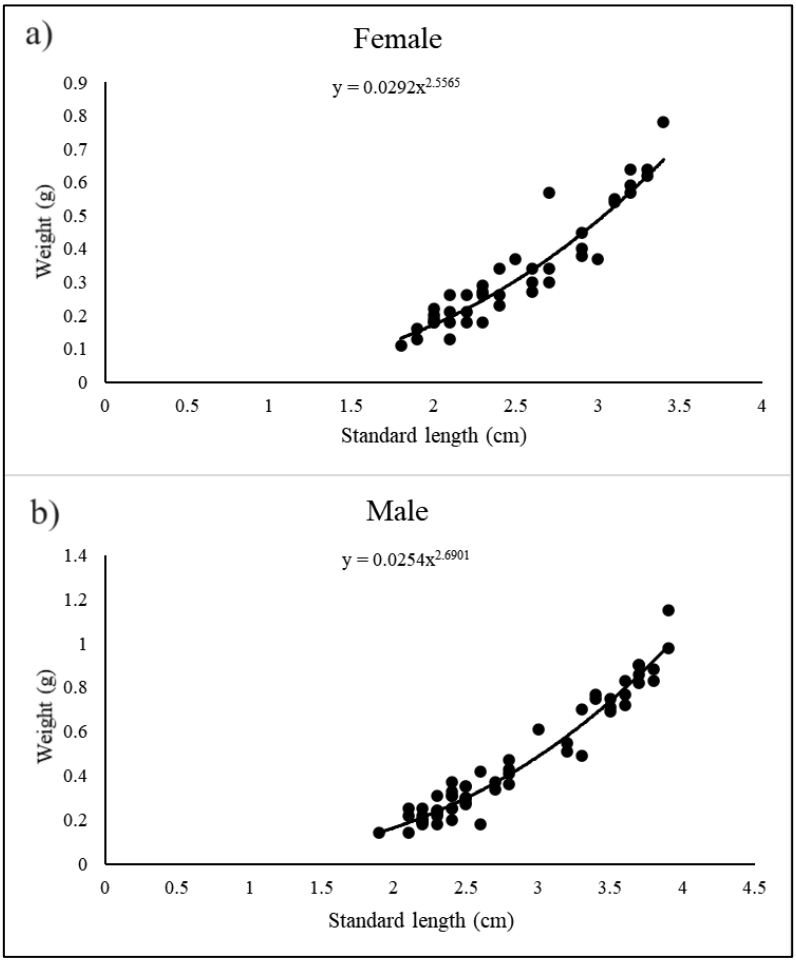

Figure 4. Weight-length relationship for females and males of *Hyphessobrycon bifasciatus*.

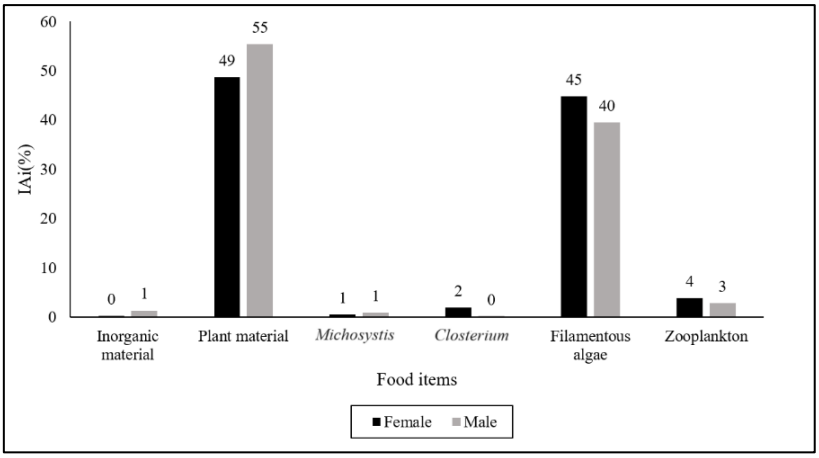

Figure 5. Food Index of items found in *Hyphessobrycon bifasciatus*.

When analyzing the feeding index of females in different classes, a preference for plant material is noticeable in the first and third classes, while the second class demonstrates a preference for filamentous

algae. The third class showed the highest preference for zooplankton compared to the others, and the same could be observed for *Closterium* in the fourth class. No food items were found in the last class (Figure 6).

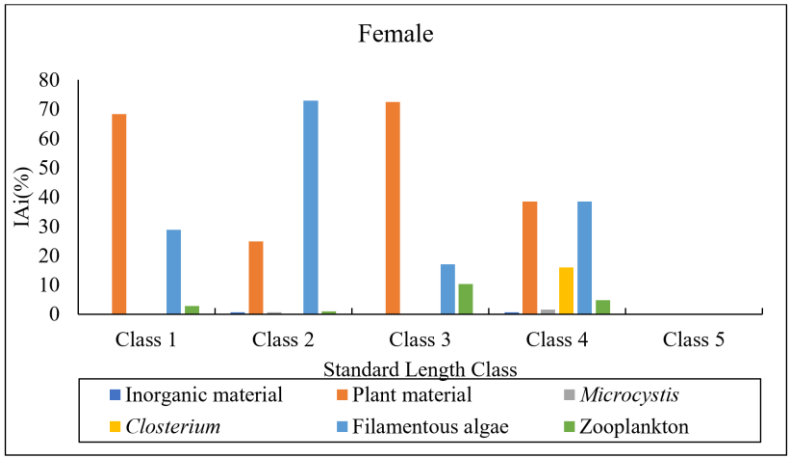

Figure 6. Food Index of length classes of females of the species *Hyphessobrycon bifasciatus*.

For the feeding index of males, no food items were found in fish from the first class; however, unlike what was found for females, the second class exhibited a preference for plant material, while the third class showed a preference for filamentous algae. For the fourth and fifth classes, plant material becomes dominant again. It is also noted that zooplankton is more frequent in the third and fourth classes, but it is not found in the fifth class (Figure 7).

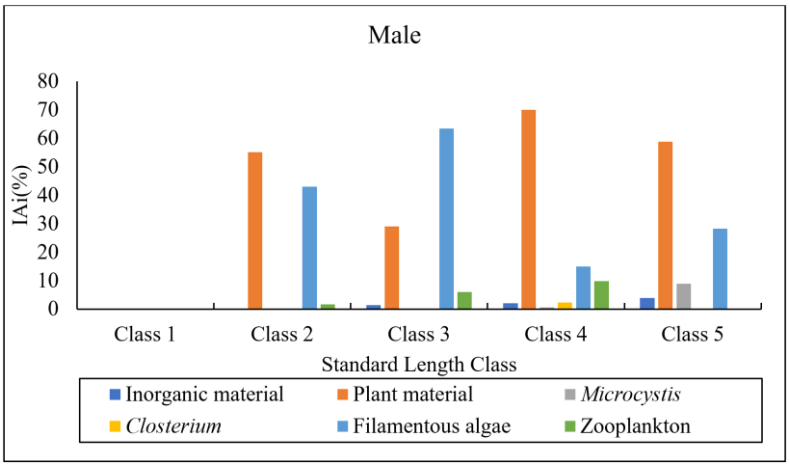

Figure 7. Food Index of length classes of males of the species *Hyphessobrycon bifasciatus*.

Discussion

Water bodies often end up being dammed to make better use of water resources, however, this leads to a change in their morphology and heterogeneity in the environment (Zhang, Nakagawa, & Mizutani, 2012; Agostinho, Luiz, Natália, Jean, & Fernando, 2016). Fish that are found in these environments derive from a reorganization of the community that was previously found in that same location before the changes (Alegretti, Ferreira, Burstin, & Flynn, 2016).

The study site has several macrophytes, sandy/silty substrate, low shading rate, and little riparian forest. The lack of riparian forests represents a problem for the environment, as its presence reduces the negative effects caused by dams (Townsend, Begon, & Harper, 2009). However, the presence of macrophytes helps the ichthyofauna in different areas, serving as a microhabitat, food source, and shelter against predators (Smith & Barrella, 2000; Santana, De Souza, Ribeiro, & Abílio, 2009).

In works such as Gonçalves, Souza, Ferreira, Peressin, and Braga, (2013) with *H. bifasciatus*, the standard length found was 3.1 cm for males and 3.0 cm for females, with no significant variation in length between the sexes. Jonsson and Toledo (1993) also worked with the species and observed adult individuals with an average

length of 4.2 cm and an average weight of 0.73 g. Differing from the results of the present work, the females had an average weight of 0.33 ± 0.17 g and the males 0.45 ± 0.27 g, with most individuals in the length class of 2.1-2.5 cm for both sexes, being smaller than those found in the literature. Therefore, environmental factors seem to have the power to influence the length and weight of individuals, since the studies mentioned above were carried out in natural environments such as marginal lakes in a conservation unit and unpolluted lakes, unlike the current study, where the collection is located in an urbanized environment with the presence of a dam, altering the aquatic structure where the species lives. Gonçalves, Souza, Ferreira, Peressin, and Braga, (2013) also observed the weight-length relationship with both sexes, where they obtained a b parameter of 2.85 for *H. bifasciatus* individuals, demonstrating a negative allometry, however, this value is still closer to 3 (isometry) than that obtained in our study (2.55 for females and 2.69 for males), demonstrating a more favorable environment.

Coutinho, Aguiaro, Branco, Albuquerque, and Souza Filho, (2000) in a study in Cabiúnas Lagoon, Macaé, RJ with *H. bifasciatus* separated food items into 5 classes: Algae, zooplankton, invertebrate larvae, other invertebrates and miscellaneous items. According to the authors, the diet of *H. bifasciatus* is associated with its standard length, indicating that individuals larger than 2.24 cm feed on larger items, such as plant remains and filamentous algae, and individuals smaller than 2.23 cm feed on smaller items, such as zooplankton. The availability of some food items can also influence the species' diet, as several macrophytes were observed in the study area, accompanied by high consumption. Therefore, it is understood that there was greater use of plant items (macrophytes and algae) than other items.

Conclusion

Studies of population structure and weight-length relationship for ichthyofauna are important to understand and conserve aquatic biota. However, most of these works occur in natural environments, with low impacts. Anthropogenic impacts alter the availability of food and habitats within the ecosystem, influencing the community. Therefore, the approach of a dammed stream may demonstrate unique characteristics for the species *Hyphessobrycon bifasciatus*.

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