Acta Scientiarum
http://periodicos.uem.br/ojs
ISSN on-line: 1807-863X
Doi: 10.4025/actascibiolsci.v46i1.69946
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Aspects of the ecology of *Leporinus striatus* Kner 1858 as a support for its conservation in a Federal Conservation Unit

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ABSTRACT. This work describes aspects of the ecology and feeding of *Leporinus striatus* to fill the gap in information about the species in Brazilian rivers. The study area is in the Ipanema National Forest, Iperó/São Paulo, with the Ipanema River as the place where the specimens were collected in its middle and lower reaches. The size ranged from class 9.0 - 9.5 cm to class 11.5 - 12.0 cm, with females being found in all classes. Class 10 - 10.5 was the one with the highest relative frequency, with males being most abundant in the 9.5-10.0 cm length class and females in the 10-10.5 cm length class. The species' diet was composed of autochthonous species, with the most frequent items being insect fragments and plant material. Based on this information, the species was classified as omnivorous. Underwater observations made it possible to verify that the species is gregarious, inhabiting the water column between midwater and the bottom, preferring stretches with currents and rocky substrate. It performs foraging by leaning its body close to the substrate and biting food on solid surfaces. Small groups made up of at least six individuals shared the areas between rocks and branches. We conclude that, to guarantee the preservation of the species, it is crucial to recognize the significant role played by Conservation Units. However, given the aquatic nature of the species studied, its life cycle is intrinsically linked to stretches that extend beyond the limits of the UC. Additionally, the ecological analyses presented in this study reveal that the species relies on the preservation of a healthy river environment that transcends the boundaries of the conversational unit.

Keywords: natural diet; Ipanema National Forest; behavior; habitat use.

Received on October 24, 2023
Accepted on March 15, 2024

Introduction

Created in 1992 by Federal Decree No. 530 (*Ministério do Meio Ambiente* [MMA], 2003), the Ipanema National Forest covers an area of 5,069.73 hectares (Souza & Martos, 2008), with relevant biodiversity preserved in remnants of the Atlantic Forest and Cerrado (Dagnino, 2014). The Ipanema River, from which the studied species was collected, is the main river in the conservation unit, and a tributary of the Sorocaba River, belonging to the Upper Paraná River Basin (Silva, Sales, Albuquerque Filho, & Lourenço, 2016).

The Ipanema River and its affluent are important tributaries of the Sorocaba River basin, and much of the fish diversity is attributable to small and medium-sized species (Smith, Halcsik, Biagioni, Pinheiro, & Stefani, 2021). These same authors inventoried 89 species of fish for the Ipanema National Forest, indicating the importance of the UC for the conservation of fish fauna. The importance of these territories for the conservation of fish fauna is undeniable, however, considerations regarding freshwater fish are still scarce in the conservation scenario, unlike other vertebrates (Sarmento-Soares, Mazzoni, & Martins-Pinheiro, 2007). Considering the drainage basin and fish species when defining conservation areas is an important step (Cetra, Sarmento-Soares, & Martins-Pinheiro, 2010) to expand the role of UCs in this process. Furthermore, basic information is necessary to guide the species management plan, and it is essential to intensify studies on the biology and ecology of species (Assumpção, Silva, Makrakis, & Makrakis, 2017).

Leporinus striatus Kner, 1858, is a species popularly known as the striped knife, which has a standard length of up to 12 cm. It is widely distributed throughout the Paraná basin, in addition to the Rio da Prata Basin, drainages of the Uruguay River, and the Paraguay River. Additionally, it can be found in at least three river systems in western South America, including the Rio Atrato, Rio Magdalena and Rio Sinu, in Colombia (Birindelli & Britski, 2013). The species has a fusiform and low body, being straight in the region where the anal fin is inserted, and it features four longitudinal stripes along the lateral line: two above it, one along the

back, and one below it (Krinski & Miyazawa, 2013). Furthermore, it has a small red spot in its mouth while alive, its mouth is small in width, like other individuals of the genus, and it possesses three teeth in the premaxilla and four in the dentary (Garavello & Britski, 2003; Birindelli & Britski, 2013).

It presents short-distance reproductive migratory behavior, with external fertilization and without parental care (Araya, Flores, & Hirt, 2018). The reproductive strategy involves several spawning events during winter and summer, that is, they reproduce throughout the year, being a continuous process (Portella, Arsentales, Cavallari, & Smith, 2021). Studies have demonstrated a diversity of items present in their diets, suggesting that the species is omnivorous, and that the food base is mainly composed of Chironomida larvae and filamentous algae (Zardo & Behr, 2018; Arnhold, Penha, Peoples, & Mateus, 2019). Thus, this work aimed to expand information about aspects of the ecology of *L. striatus*, in a neotropical river located in a conservation unit.

Material and methods

The environmental characterization of the sampled sections was carried out in four sampling campaigns. We carried out measurements of the structural variables obtained through the application of the Rapid Assessment Protocol (RAP), adapted from Callisto, Goulart, and Moretti (2001). The chemical parameters of the water (temperature, pH, electrical conductivity and total dissolved solids) were obtained using an OAKTON PCD650 multiparameter probe. Specimens of *L. striatus* (Figure 1) were captured at four collection points along the Ipanema River, the main river in the Ipanema National Forest (Figure 2 and Table 1).

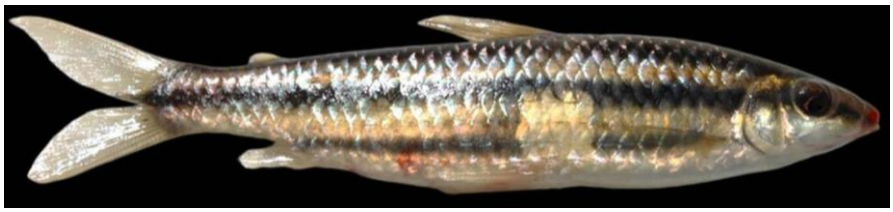

Figure 1. *Leporinus striatus*. Adult male, 12 cm Standard length.

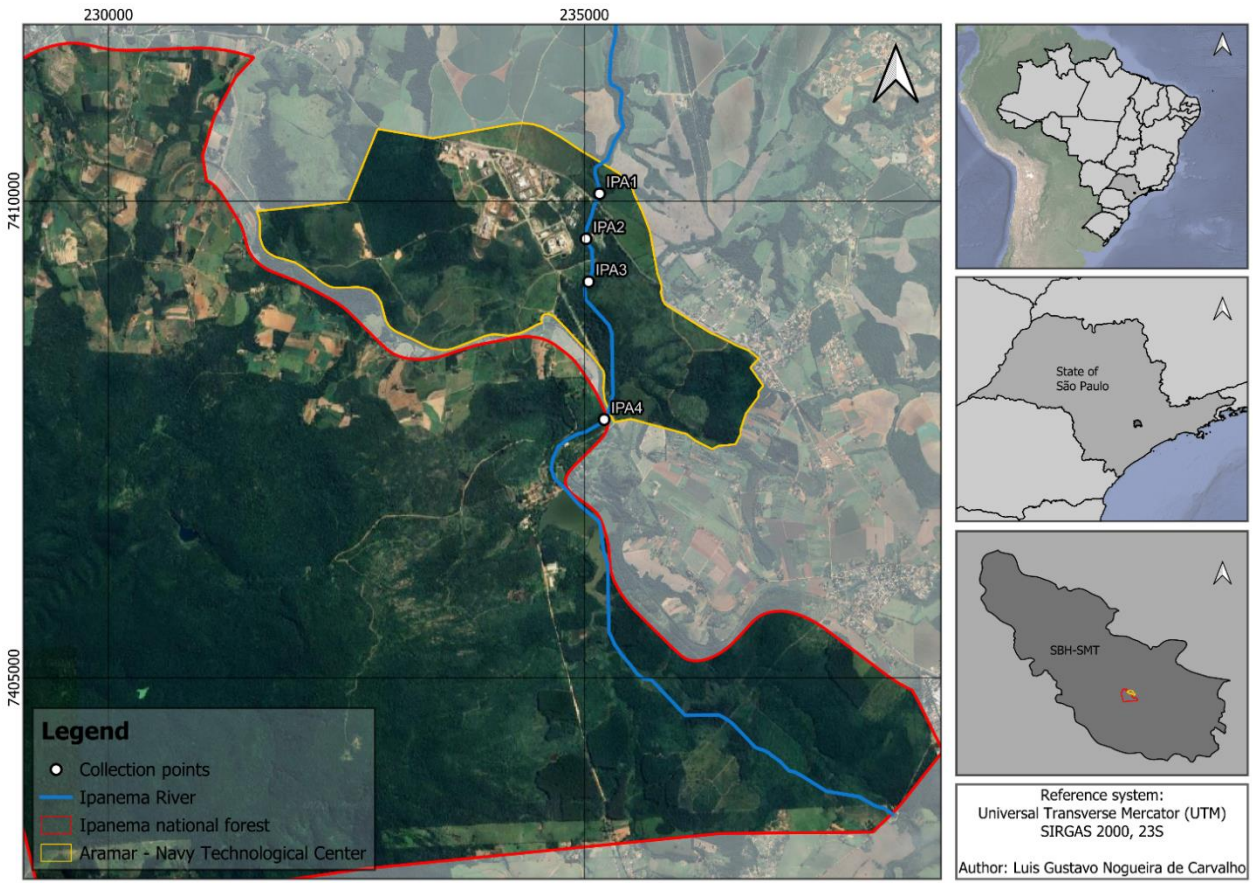

Figure 2. Location of sampling points on the Ipanema River, Ipanema National Forest, São Paulo, Brazil.

Table 1. Characteristics of the sampled locations on the Ipanema River.

Section	Location	Dominant vegetation	Geographical coordinates
IPA1	Wooden bridge	Little riparian vegetation	23° 25' 4.20" S 47° 35' 25.08" O
IPA2	ETA-CEA	Riparian vegetation	23° 24' 15.93" S 47° 35' 28.27" O
IPA3	Ipanema River Outside CEA	Riparian vegetation	23° 23' 52.33" S 47° 35' 27.98" O
IPA4	Ipanema River -CEA	Dense riparian vegetation	23° 24' 12.46" S 47° 35' 29.25" O

Four collection campaigns were carried out between the months of October 2020 and February 2021. The fish were collected with a three-meter-long trawl net, with a 1 cm mesh size, and a sampling effort of 30 min. at each point, and also with a stationary net, with mesh sizes of 4, 6, 8, and 10 cm, which remained in place for 12 hours. Then, the captured specimens were anesthetized with Benzocaine, fixed in 10% formalin, and preserved in 70% alcohol. Specimens were deposited in the fish collection of the USP Zoology Museum (MUZUSP 127797). Sampling was carried out under licenses nº 24151-1 and nº 75101-1 granted by the Brazilian Institute of Environment and Renewable Natural Resources (Ibama) and Biodiversity Information and System Authorization (Sisbio), respectively and with the certificate from the Ethics Committee on the Use of Animals (CEUA n° 2914270122).

Underwater observations were made ('snorkeling', Sabino, 1999; Barker, Forsyth, & Wood, 2014) in the 4 stretches studied, totaling 100 hours of diving (during the day - between 8:00 and 12:00), using ad libitum and focal animal techniques (Lehner, 1996). The visual census was used to determine constancy of occurrence, spatial distribution, foraging tactics and spatial position maintenance strategies. Observations on spatial distribution were stratified both horizontally (well, rapids and riverbank) and vertically (surface, midwater and bottom).

For each specimen, the standard length and weight were obtained. Afterwards, the individuals were dissected to remove the digestive tract. Sexing was done by macroscopic observation of the individuals' gonads (Vazzoler, 1982). For the analysis of stomach contents, only stomachs from adult individuals were used, thus avoiding compromising the data due to ontogenetic changes in the diet (Abelha, Agostinho, & Goulart, 2001). To analyze the importance of the identified foods, the frequency of occurrence method was used, which evaluates the percentage of stomachs in which a given food occurs. As well as frequency (F%) and relative volume (V%), which were combined to form the dietary index (IAi%) (Kawakami & Vazzoler, 1980).

The trophic guild was identified based on the food index, checking the frequency of occurrence and volume of each food item. Among the various criteria used to classify trophic guilds (for example, Mérona, Santos, & Almeida 2001; Delariva, Hahn, & Kashiwaqui, 2013), the guild was determined considering an intermediate value (60% of the diet composed of a certain food group) to what is mentioned in the literature. Therefore, we classify *L. striatus* as Herbivores - species that feed mainly on higher plants, such as leaves and seeds; Invertivores - species that explore the river bed, selecting benthic organisms, such as microcrustaceans, small mollusks, and arachnids; Insectivores - species that predominantly ingest aquatic and terrestrial insects at different stages of development; Omnivores - species that consume two or more food categories in similar proportions, with no predominance ($\geqslant$ 60%) of any of them; Piscivores - species that mainly consume fish, eggs and scales; Algivores – species that consume algae; and Detritivores - species that consume an abundance of detritus.

Results

The Ipanema River had a temperature between 23 and 27ºC, with pH values remaining close to 7. The maximum width of the river, at the points studied, was 10 meters, and the minimum was 4 meters. Throughout its extension, rocky/stony/sandy substrates were observed to be predominant, as well as the presence of a large amount of plant material, such as branches and trunks (Table 2). There were no human interventions such as deforestation, sewage, or other impacts on the stretches studied.

In total, 33 specimens were analyzed, 18 females and 15 males. Females had an average weight of 24.5 g and males 22.2 g. The size ranged from class 9.0 - 9.5 centimeters to class 11.5 - 12.0 centimeters, for both sexes. The modal values were different between the sexes, with males being more abundant in the 9.5-10.0 cm length class and females in the 10-10.5 cm length class (Figure 3).

Table 2. Mean values and standard deviation of environmental variables in the Ipanema River, São Paulo State, Brazil. Temp: temperature, Larg Med: Average width; Prof. med: medium depth, Cond. (µs): Conductivity, TDS: total dissolved solids. Presence = 1; absence = 0.

Environmental variables	Points			
	IPA1	IPA2	IPA3	IPA4
pH	6.75 ± 0.1	6.9 ± 0.14	6.9 ± 0.27	6.68 ± 0.32
TDS (ppm)	64.13 ± 36.47	76.44 ± 3.88	80.32 ± 14.03	70.16 ± 27
Cond. (µs)	113.52 ± 63.44	132.82 ± 18.82	142.5 ± 22.03	129.3 ± 51.2
Temp. (ºC)	22.55 ± 2.08	24.42 ± 3.96	22.47 ± 2.04	22.9 ± 3.13
Larg. Med.	6.46 ± 4.27	4.4 ± 0.54	5 ± 0.24	3.58 ± 0.99
Prof. Med.	0.74 ± 0.33	1.5 ± 0.38	1 ± 0.57	1.19 ± 0.22
Herbaceous vegetation%	0	0.2 ± 0.07	0.5 ± 0	0.43 ± 0.12
Large debris	1	1	1	1
Width Gully	1 ± 0	1.15 ± 0	1 ± 0	1 ± 0
Fine substrate %	1 ± 0	0.15 ± 0	1 ± 0	1 ± 0
Wood %	0.5 ± 0	0 ± 0	75 ± 0	0.75 ± 0
Riverine vegetation %	0.5 ± 0	0.75 ± 0	0.75 ± 0	0.75 ± 0
Muddy Substrate	0	0	0	0
Sandy substrate	1	1	1	1
Rocky substrate	1	1	1	1
Loamy substrate	1	1	1	1
Organic matter %	1	1	1	1
Roots %	0.15 ± 0	0.15 ± 0	0.5 ± 0	0.25 ± 0
Presence of wells	1 ± 0	1 ± 0	1 ± 0	1 ± 0
Flow	moderate to fast	moderate	light	light
Presence of rapids	1	1	1	1
Presence of slow Flow and pools	1	1	1	1
Canopy density %	0.25 ± 0	0.25 ± 0	0.25 ± 0	0.75 ± 0
Human influence	absent	absent	absent	absent

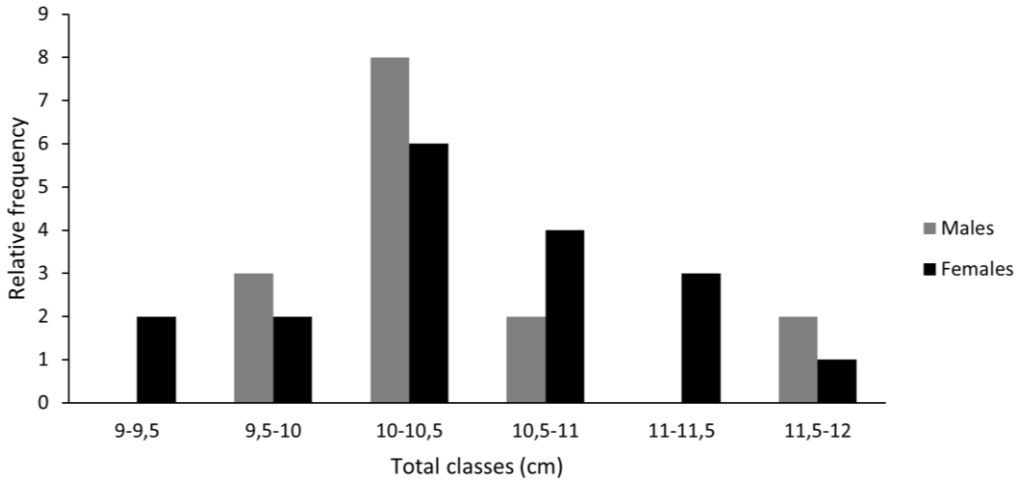

Figure 3. Relative frequency distribution by length class of males and females.

The species presented a broad dietary spectrum, being basically composed of 10 food items, one allochthonous item (Hymenoptera) and nine autochthonous items (plant material, mollusks, fragments of insect larvae, such as Trichoptera, Coleoptera, Diptera, Odonata and Lepidoptera, in addition to gastropods). The most frequent items were: Trichoptera, Diptera, fragments of unidentified insects and plant material (Figure 4). Based on this information, the species was classified as omnivorous.

We observed the activity of *L. striatus* specimens during the day, swimming from mid-water to the bottom of the water column (nektonic species) and foraging, leaning their body close to the substrate biting food on solid surfaces. Small groups formed by at least six individuals shared the areas between rocks and branches (Figure 5).

Discussion

The Ipanema River presented excellent environmental conditions and can be considered one of the most preserved rivers in the Sorocaba River basin, as reported by Smith and Petrere Jr. (2000), Oliveira, Apone, Birindelli, and Garavello (2013) and Smith, Biagioni, and Halcsik (2013). This river has standard

characteristics of second and third order watercourses, shaded by the riverside forest with less solar incidence, in addition to having a wealth of preferred habitats for the species object of the present study. Reinforcing this finding, this river also contains endangered species, as documented by Oliveira et al. (2013) and Smith et al. (2021). Another aspect was the record of *L. striatus*, only in the Ipanema River, considering secondary data from the Sorocaba river basin (Smith & Petrere Jr., 2000; Smith et al., 2013; Smith et al., 2021), which demonstrates the privileged situation of this river in environmental terms, and the need for its conservation in order to maintain these species.

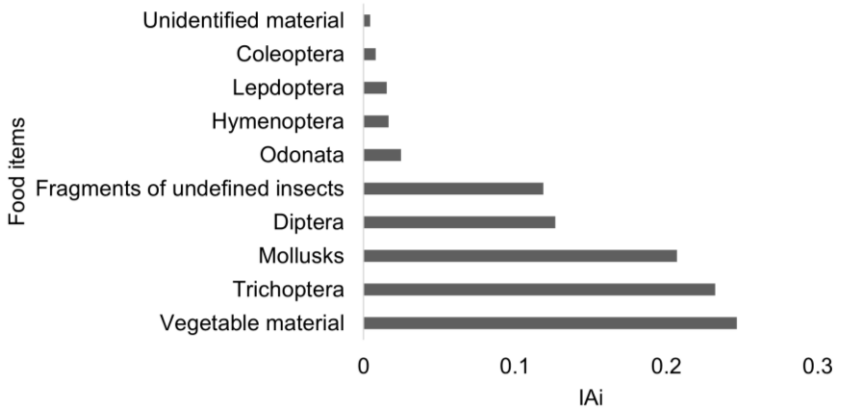

Figure 4. Composition of food resources used by *Leporinus striatus*. Food Index (IAi).

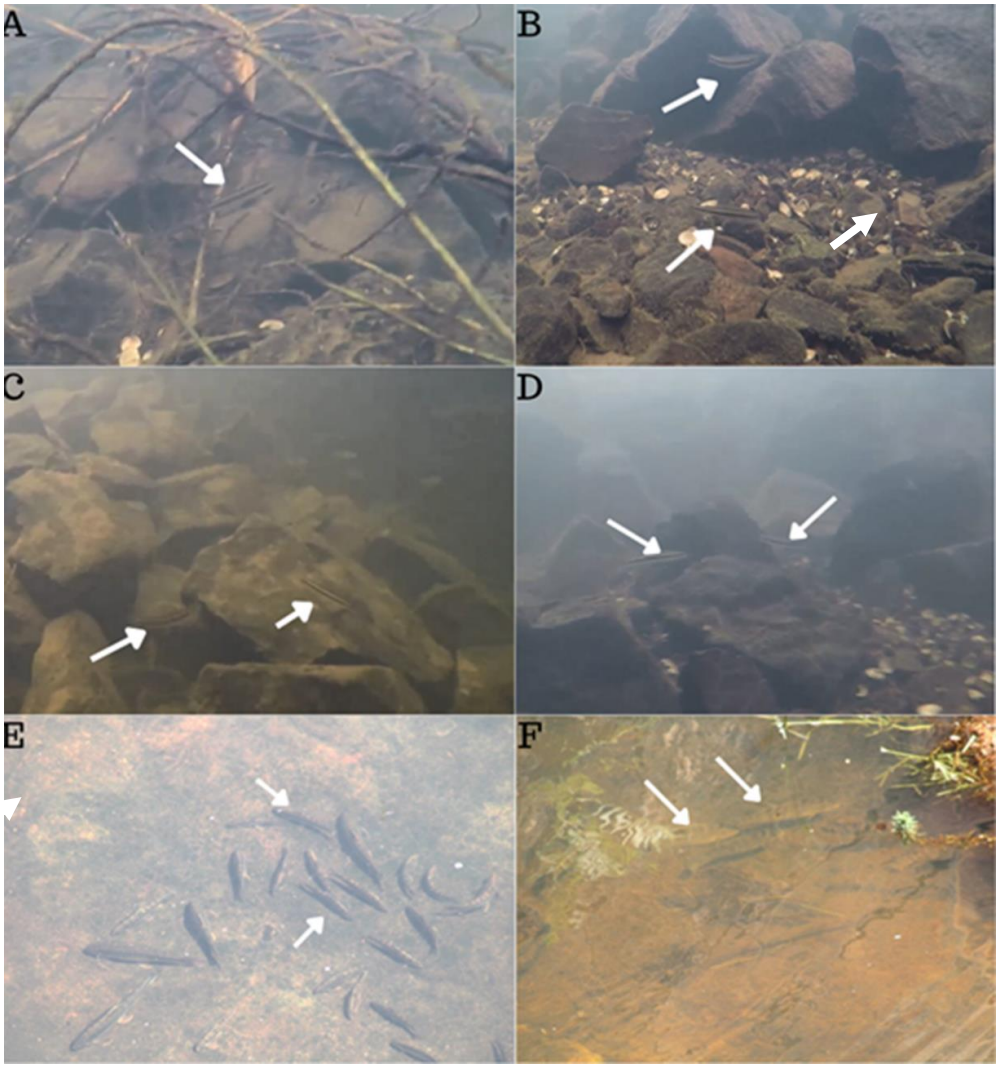

Figure 5. Habitat and photographs of *Leporinus striatus*. (A) Group of adult *L. striatus* foraging near the substrate; (B) *L. striatus* swimming near rocks. (C) Individuals of *L. striatus* sheltering under bottom rocks. (D) Individuals of *L. striatus*, foraging near branches and rocks.

Through analyzes of the stomach contents of *L. striatus* specimens, it was possible to verify that the predominant items in the species' diet come from the river itself, which demonstrates the importance of autochthonous items, even with the exuberant riparian vegetation in the stretches studied. The presence of larvae from the orders Diptera, Trichoptera and Coleoptera in the analyzed stomachs makes it possible to state that this portion of the Ipanema River has good environmental condition, because these larvae are bioindicators of environments with low environmental impact and good oxygenation, as indicated by LaSalle and Gauld (1993) and Merrit, Cummins, and Berg (2008). These abundant food resources play an important role for the species studied.

The omnivorous diet of the species was also verified by Andrian, Dória, Torrente, and Ferretti (1994), Durães, Pompeu, and Godinho (2001), Balassa, Fugi, Hahn, and Galina (2004) and Smith et al. (2021). Balassa et al. (2004) stated that such an omnivorous diet is due to the subterminal position of the mouth, which favors the feeding of insects such as chironomids, bottom debris, and filamentous algae. However, in our analysis, the presence of filamentous algae was not identified. The functional characteristics described in the literature for *L. striatus* are in agreement with those observed during dives, where the species practices foraging tactics consistent with the structure and position of its mouth, with gregarious behavior or not. Severo-Neto, Brejão, and Casatti (2023) named *L. striatus* as 'nibblers', a behavior verified in the present study, as individuals of this species feed by picking and biting food on solid surfaces (substrates), as also observed by Sazima (1986). Severo-Neto et al. (2023), as well as in the present study, found that individuals of *L. striatus* move alone or in groups, exploring the bottom and banks while collecting invertebrates from the riverbed.

The distribution and relative frequency of length classes observed in this study confirm what was described by Araya et al. (2018), that *L. striatus* is a small species and can be found with sizes from 4 to 16 cm. The environmental conditions of the studied area allow the species to carry out its entire life cycle, including its reproductive strategy, with partial spawning of the synchronous type, occurring cyclically and seasonally (Smith et al., 2021). However, we have concluded that there is a need for more specific studies to assess water quality and monitor not only this species, but also others in the aquatic environment. This is crucial for the protection and conservation of the entire Ipanema River, not solely the portion within the Conservation Unit.

As pointed out by Cetra et al. (2010), the limits of the river basins must be considered, as they meet the needs of fish species. To maintain the ichthyofauna, it is necessary to establish goals for the preservation of the living environments of these animals, as is the case of *L. striatus*, which uses the entire length of the Ipanema River for its life cycle, part of which is found in the conservation unit area and part in the buffer zone. Therefore, to strengthen the management plan as well as alert to the criteria for zoning and creation of UCs, it is necessary to consider ecological and biological information on fish species (Sarmento-Soares et al., 2007). Among these species, the one examined in this study emerges as an excellent indicator of environmental quality. Therefore, the destruction of habitats caused by human actions, such as urbanization and agricultural activities observed in the study area, as well as the construction of small dams on rural properties, reduce lotic environments and interfere with the reproductive success of the studied species. The maintenance of lotic stretches and rapids, as well as the preservation of the riparian forest, are extremely important for the reproduction and life cycle of *L. sriatus*.

Conclusion

The important findings about the species *L. striatus* presented here highlight its importance as relevant information for functional ecology studies in fish. Furthermore, we conclude that to guarantee the preservation of the species, it is crucial to recognize the role played by Conservation Units. However, given the aquatic nature of the studied species, its life cycle is intrinsically linked to stretches that extend beyond the limits of the UC and, additionally, the ecological analyzes presented in this study reveal that the species depends on the maintenance of a healthy river environment, including stretches that go beyond those protected.

Acknowledgments

To the Laboratory of Structural and Functional Ecology of Ecosystems, *Universidade Paulista*/Unip, Sorocaba campus, for logistical support; the Vice-Rector of Postgraduate Studies and Research for granting the Scientific Initiation Scholarship to the first author. We thank ICMBio and the Ipanema National Forest

for logistical support, Luciano Fogaça de Assis Montag and José Sabino for suggestions and critical reading of the manuscript, and Lucio Pinheiro for preparing the map.

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