LIFE HISTORY, THREATS, AND CONSERVATION OF THE BRAZILIAN ANNUAL FISH *OPHTHALMOLEBIAS CONSTANCIAE* IN TEMPORARY WETLANDS

Gustavo H. S. Guedes, Antonio C. S. Silva, Francisco G. Araújo*

Federal Rural University of Rio de Janeiro, Brazil
**e-mail: gerson@ufrrj.br*

Received: 29.04.2026. Revised: 19.06.2026. Accepted: 31.07.2026.

Ophthalmolebias constanciae (Cyprinodontiformes: Rivulidae) is a Critically Endangered (CR) annual fish, endemic to the coastal plains of the state of Rio de Janeiro, Brazil. This study was aimed to provide novel data on its life-history traits (body and egg size, fecundity, sex ratio, and length-weight relationship), geographic distribution, habitat characteristics, and to assess emerging threats, including global trade and *ex-situ* maintenance, as well as changes in land use and land cover over a 22-year period (2003–2025). The species was recorded in only three temporary wetlands, characterised by acidic waters (pH 5.7 ± 0.7) and low dissolved oxygen concentrations (2.6 ± 0.6 mg/L). Total body length ranged from 33–54 mm in males and 30–45 mm in females. Batch fecundity varied from 26–69 oocytes (mean: 44 ± 12 oocytes), with oocyte diameters ranging from 0.80 mm to 1.41 mm (mean: 1.01 ± 0.13 mm). Males were significantly larger than females, and the sex ratio was biased toward females (2.1 females : 1.0 male). The species is illegally traded and maintained *ex-situ* in at least 13 countries, including regions of North America, Europe, Asia, and Oceania. Land use and cover data revealed increasing anthropogenic pressure on the species' habitats, with a loss of 25% of natural cover between 2003–2025. By combining ecological, biological, and threat data, this study strengthens the basis for evidence-based conservation of *Ophthalmolebias constanciae*.

Key words: aquarium trade, Atlantic Forest, Brazil, endangered fauna, killifish, reproduction, Rivulidae, temporary ponds

Introduction

The family Rivulidae comprises one of the most diverse groups of Neotropical fishes, currently including 497 valid species (Fricke et al., 2026), with a distribution ranging from southern Florida (USA) to the southeastern portion of the Buenos Aires Province (Argentina) (Loureiro et al., 2018; Costa & Guedes, 2026). Rivulidae are considered extremophilic species due to their evolutionary adaptations to harsh environmental conditions, including high temperatures, low oxygen concentrations, acidic waters, and intense hydrological fluctuations approaching the tolerance limits of vertebrates (Podrabsky et al., 2015; Polačik & Podrabsky, 2016). The family Rivulidae includes the only three known vertebrates exhibiting simultaneous hermaphroditism with natural self-fertilisation, *Kryptolebias marmoratus* (Poey 1880), *Kryptolebias ocellatus* (Hensel 1868) and *Kryptolebias hermaphroditus* Costa 2011, allowing a single individual to found new clonal populations (Avise & Tatarenkov, 2015; Rhee et al., 2017; Amorim et al., 2022; Berbel-Filho et al., 2022). In addition, approximately 260 species exhibit an annual life cycle and act as specialised colonisers of temporary wetlands (Guedes et al., 2025), ecosystems characterised by alternating terrestrial and aquatic phases, typically of small spatial extent and low hydrological connectivity (Calhoun et al., 2017). To survive periodic desiccation of the habitat, these fishes produce eggs that enter a state of severe metabolic depression known as embryonic diapause (Furness, 2016). This adaptation allows embryos to persist for months in dry substrates, awaiting the return of rainfall and appropriate environmental cues to hatch (Polačik et al., 2023; Weber et al., 2025). The tight synchronisation between the life cycle and rainfall regimes results in one of the shortest lifespans among vertebrates: individuals live only a few months, which has, in turn, selected for extremely rapid growth and early sexual maturation (Žák et al., 2021).

Conservation efforts are particularly urgent for Rivulidae, especially for species with an annual life cycle, given that 159 of the known species (~61%) are threatened with extinction in countries such as Brazil, Bolivia, Venezuela, Colombia, Uruguay, Mexico, and Argentina (Guedes et al., 2025). The primary threat faced by annual killifishes is habitat loss, as temporary wetlands are being destroyed due to uncontrolled urban, agricultural, and industrial expansion (Volcan & Lanés, 2018; Costa & Guedes, 2026). In addition, fire incidence in these habitats (Guedes & Araújo, 2026), microplastic pollution (Guedes et al., 2026a), and chemical contamination associated with the widespread use of agrochemicals (Gonçalves et al., 2024; Godoy et al., 2025) have been identified as additional stressors impacting an already severely threatened fauna. Furthermore, vulnerability to several other threats, such as collection and illegal trade, invasive species, and climate change, remains largely unexplored and yet poorly understood.

The coastal plains of the state of Rio de Janeiro, southeastern Brazil, constitute important hotspots for annual fish diversity (Costa, 2012), but also represent one of the regions under the greatest pressure on species and their habitats (Costa, 2009; Guedes et al., 2023a). The state of Rio de Janeiro harbours seven genera and 23 valid species, with exceptionally high endemism (21 species) and a large proportion of threatened taxa (18 species) (Guedes et al., 2026b). Among the endemic species of this region, the annual fish *Ophthalmolebias constanciae* (Myers, 1942) stands out. The genus *Ophthalmolebias* Costa, 2006 comprises six valid species, all endemic to the Atlantic Forest biome and threatened with extinction (ICMBio, 2026a; IUCN, 2026). Studies on species of the genus *Ophthalmolebias* have primarily focused on aspects such as egg morphology (Fava & Toledo-Piza, 2007), trophic ecology (Costa, 1995), and phylogenetic relationships (e.g. Costa, 2006), while significant knowledge gaps persist regarding their life history traits, as is the case for most annual fishes (Costa et al., 2025). In the absence of robust data on natural history and on the susceptibility of these populations to multiple threats, there is a real risk of underestimating key drivers of decline and failing to implement effective conservation measures. To address these knowledge gaps, this study aims to provide novel data on natural history traits (including body and egg size, fecundity, sex ratio, and length-weight relationships), as well as on geographic distribution and habitat characteristics. It also evaluates emerging threats, such as illegal global trade, *ex-situ* maintenance, and changes in land use and land cover over a 22-year period (2003–2025). By integrating new data on life-history traits and threats, this study aims to inform decision-making and strengthen conservation strategies to safeguarding ephemeral aquatic ecosystems and their uniquely adapted fauna in Brazil.

Material and Methods

Study area

The study was conducted in the River São João basin and River Una basin, located in the municipalities of Casimiro de Abreu (22.576023° S, 41.985805° W; Cod. 1 shown in Fig. 1), and Rio das Ostras (22.561034° S, 41.979307° W, Cod. 2; 22.558876° S, 41.978484° W; Cod. 4) and Cabo Frio (22.733055° S, 42.0416666° W; Cod. 3), state of Rio de Janeiro, southeastern Brazil (Fig. 1). The climate is classified as tropical seasonal, with rainy summers and dry winters (Aw climate, according to the Köppen-Geiger classification; https://koppenbrasil.github.io/). The area is situated on sandy coastal plains of Quaternary origin within the Atlantic Forest biome, including Restinga formations (Coe et al., 2007; Guimarães et al., 2024). Sampling sites are located at altitudes ranging from 4 m a.s.l. to 8 m a.s.l., with distances from the coastline varying between 30 m and 5900 m.

Biotic and abiotic samplings

Four sites with known occurrence of *Ophthalmolebias constanciae* (Fig. 2) were surveyed during April 2026 (Fig. 1). Fish were collected using hand nets (oval dip nets, 50 × 40 cm, 1 mm mesh size). After capture, specimens were anesthetised with benzocaine hydrochloride (50 mg/L), euthanised, and fixed in 10% formalin in situ. In the laboratory, fish were measured (precision = 0.01 cm; Total length) and weighed (precision = 0.001 g), and after 48 h, preserved in 70% ethanol. Biometric analyses were conducted three days after capture to avoid biases associated with long-term fixation and preservation. Specimens were identified and sexed according to Costa (2009). This study was conducted under permits issued by the Instituto Chico Mendes de Conservação da Biodiversidade (SISBio permits #10707 and #87082) and approved by the Animal Ethics Committee of the Universidade Federal Rural do Rio de Janeiro (CEUA/ICBS/UFRRJ; protocol #12.28.01.00.00.00.45, February 2023).

To assess fecundity, ovaries from spawning-capable females (N = 15) were removed from the visceral cavity, weighed, and maintained in Gilson's solution until complete dissociation of oocytes from the epithelial and ovarian tissues. Eggs were counted and measured (diameter, in µm) under a LEICA TL5000 Ergo microscope. Total fecundity (TF) was calculated as the total number of oocytes per female, regardless of the oocyte developmental stage. Batch fecundity (BF), defined as the number of eggs produced per spawning event, was estimated based on counts of vitellogenic oocytes (Rizzo & Bazzoli, 2020). Relative fecundity (RF) was determined as the number of vitellogenic oocytes per unit of body length (1 cm).

The physical and chemical water parameters, i.e. temperature (°C), dissolved oxygen (mg/L), pH, electrical conductivity (µS/cm), and turbidity (FNU), were measured using a multiparameter probe (Hanna HI9829). Water depth (cm) was measured using graduated rulers at the centre of the temporary wetland, equidistant from the opposite margins.

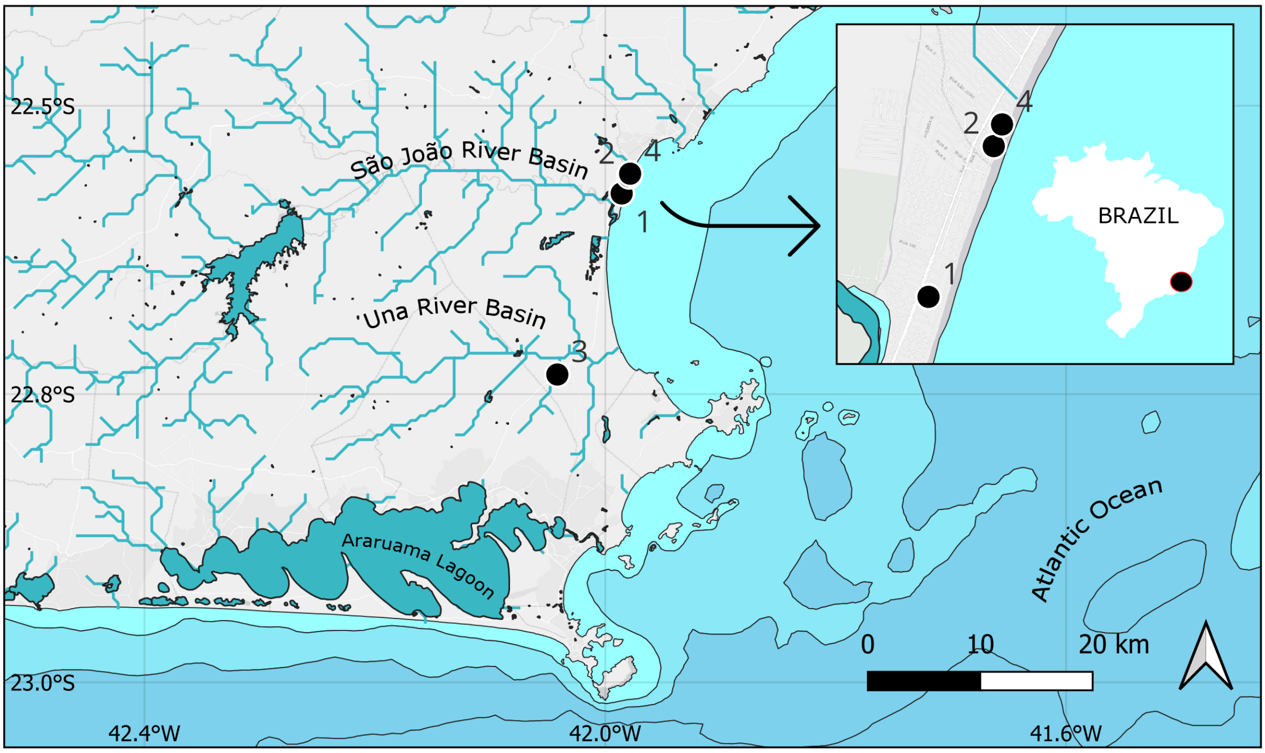

Fig. 1. Map showing the sampling sites (black circles) in the River Una basin and River São João basin, between the municipalities of Cabo Frio and Rio das Ostras, state of Rio de Janeiro, southeastern Brazil.

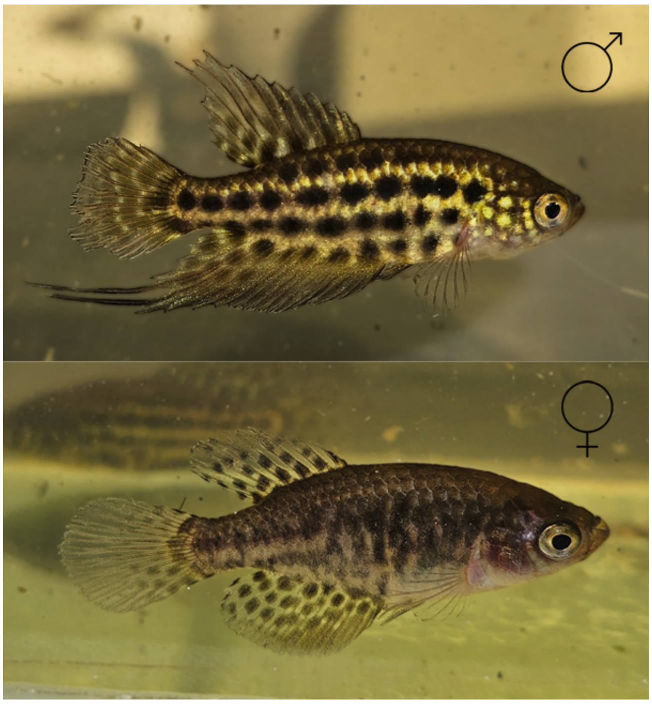

Fig. 2. Photographic records of *Ophthalmolebias constanciae* (♂, male, 48 mm TL; ♀, female, 40 mm TL) collected in the municipality of Cabo Frio, state of Rio de Janeiro, southeastern Brazil.

Land use and cover

To assess landscape changes within the fish occurrence areas, buffers with a 250-m radius were established around the centroids of the water bodies where fish were collected, totalling an analysed area of ~0.1963 km², following Guedes et al. (2023a). Within these areas, land use and land cover for the years 2003 and 2025 were analysed using imagery from Google Earth Pro (version 7.3.7.1155). Classification was performed manually due to the high spatial resolution and image clarity for the analysed years, in contrast to Brazil land use and land cover products with coarser resolution. Land use and land cover classes were manually delineated using the polygon tool, which allows measurement of areas of geometric shapes on the ground. The different classes were grouped into two categories: natural (e.g. forest formations, wetlands, restingas) and anthropogenic (e.g. urban infrastructure, pasture, roads). Subsequently, the rate (%) of progression or regression of anthropogenic cover between 2003 and 2025 was calculated.

Trade and ex-situ maintenance

To determine the existence of active trade and to identify the countries where illegal *ex-situ* maintenance of the species occurs, searches were conducted on ornamental fish sales websites (e-commerce) and social media platforms. The survey across e-commerce platforms (e.g. AquaBid) and social media (Facebook, and specialised killifish groups) was carried out in December 2025, using combinations of keywords in Portuguese and English, such as «*Ophthalmolebias constanciae*», «eggs», «sale». Facebook was selected for analysis because it is one of the most popular online platforms worldwide, where users feel comfortable sharing their experiences and photos of the species (Borges et al., 2021, 2022). The aim was to identify posts, particularly images, related to the maintenance and trade of the studied species. For each identified record, information on the publication date and the country of origin of the post author was extracted.

Statistical analysis

A potential bias in the population sex ratio was assessed by comparing the expected 1:1 proportion using a chi-square test (χ^2) at a 95% significance level. The Mann-Whitney-Wilcoxon test was applied to compare differences in the total length (TL) between males and females. The length-weight relationship ($W = a \times TL^b$) was estimated separately for males and females using linear regression on log-transformed data (Le Cren, 1951):

$$\log(W) = \log(a) + b\log(TL),$$

where W is the body weight (g), TL is the total length (cm), a is the intercept, and b is the allometric coefficient (Froese, 2006).

Differences between sexes were tested using analysis of covariance (ANCOVA), with log (TL) as a covariate and sex as a fixed factor, including their interaction to evaluate differences in slopes (i.e. allometric coefficients). When the interaction term was not significant, differences between sexes (i.e. adjusted intercepts) were assessed. All statistical analyses were performed in the R environment (R Core Team, 2026).

Results

Geographical distribution and habitats

A total of 57 specimens of *Ophthalmolebias constanciae* were collected from three of the four sampled sites, being absent only from one locality in Rio das Ostras, where the species is possibly extirpated (Cod. 2; Fig. 1). Of these, 18 specimens (4♂, 14♀) were recorded in Casimiro de Abreu (Cod. 1), 33 specimens (11♂, 22♀) in Cabo Frio (Cod. 3), and six specimens (3♂, 3♀) in Rio das Ostras (Cod. 4). The temporary wetlands where the species occurred were shallow (63 ± 36 cm depth, mean ± standard deviation), with acidic waters (pH: 5.7 ± 0.7) and high turbidity (96 ± 64 FNU) (Table 1, Fig. 3). Dissolved oxygen concentrations were generally low to moderate (2.6 ± 0.6 mg/L), while electrical conductivity indicated environments with medium to high mineralisation (1726 ± 767 µS/cm) (Table 1). The only other fish species recorded co-occurring with *Ophthalmolebias constanciae* was the Endangered species *Nematolebias whitei* (Myers, 1942), found in Cabo Frio and Rio das Ostras municipalities.

Life history

The sex ratio was 2.1 females : 1.0 male, showing a bias toward female captures according to the chi-squared test ($\chi^2 = 7.73$, $p = 0.005$). Total length ranged from 33 mm to 54 mm (mean ± SD: 48.1 ± 4.4 mm) for males, and from 30 mm to 45 mm (37.2 ± 3.0 mm) for females. The mean body size of males was significantly higher than that of females ($W = 43$, $p < 0.0001$). The length-weight relationship (LWR) was significant for both sexes ($p < 0.001$). Males were described by the equation $W = 2.7 \times 10^{-5} \times TL^{2.78}$ (n = 18), corresponding to the log-transformed model $\log10(W) = -4.57 + 2.78 \times \log10(TL)$ ($R^2 = 0.92$) (Fig. S1). The estimated allometric coefficient was b = 2.78 (95% CI: 2.36–3.20). Females were described by the equation $W = 6.7 \times 10^{-6} \times TL^{3.19}$ (n = 39), corresponding to lo g10(W) = -5.17 + 3.19 × log10(TL) ($R^2 = 0.87$). The estimated coefficient was b = 3.19 (95% CI: 2.77–3.61). Analysis of covariance (ANCOVA), however, indicated no significant difference in slopes between sexes ($p = 0.159$), suggesting similar growth patterns. However, intercepts differed significantly ($p = 0.0029$), indicating that females are heavier than males for a given length. The total number of oocytes present in the gonads (regardless of developmental stage) ranged from 30 to 138 (99.7 ± 21.3 oocytes). Batch fecundity (considering only vitellogenic oocytes in spawning-capable females) ranged from 26 to 69 (43.9 ± 12.5), corresponding to oocyte diameters between 800 µm and 1.43 mm (1.01 ± 0.13 mm). The relative fecundity (oocytes per unit body size – 1 cm) ranged from 16.7 to 34.5 (26 ± 5).

Table 1. Environmental variables (mean ± standard deviation) in the three localities where *Ophthalmolebias constanciae* was captured

Site	Depth (cm)	pH	Temp. (°C)	Turbidity (FNU)	D.O (mg/L)	Cond. (µS/cm)	Dist. sea (m)	Altitude (m a.s.l.)
Casimiro de Abreu (Cod. 1)	50	4.9 ± 0.5	22.8 ± 0.2	118 ± 29	2.1 ± 0.5	1180 ± 50	150	8
Rio das Ostras (Cod. 2)	–	–	–	–	–	–	37	8
Cabo Frio (Cod. 3)	105	5.8 ± 0.4	22.5 ± 0.1	140 ± 30	2.0 ± 0.2	1391 ± 67	5900	4
Rio das Ostras (Cod. 4)	35	6.3 ± 0.4	23.2 ± 0.2	28 ± 6	3.8 ± 0.3	2608 ± 80	30	8

Fig. 3. Aerial images of occurrence sites of *Ophthalmolebias constanciae*. Red dashed circles indicate the microhabitats where the species was recorded, currently (a, c, d) and historically (b), highlighting the strong anthropogenic influence in the municipalities of (a) Casimiro de Abreu (Cod. 1), (b) Rio das Ostras (Cod. 2), (c) Cabo Frio (Cod. 3), (d) Rio das Ostras (Cod. 4), southeastern Brazil.

Changes in land use and cover

The analysis of land use and cover in the surroundings (250-m buffer) of *Ophthalmolebias constanciae* habitats revealed a marked expansion of the anthropogenic matrix over the last two decades (2003–2025). The main driver of this transformation was the replacement of Non-Forest Natural Formations (i.e. restinga) by urbanised areas (e.g. roads, streets, and housing), with the anthropogenic matrix increasing from an average of 23.0% (± 22.9) in 2003 to 48.7% (± 28.7) in 2025 (Table S1). Changes in habitats and their surroundings, however, varied among sampling sites. In Casimiro de Abreu (Cod. 1), the anthropogenic cover increased from 56% to 77%; in Rio das Ostras, from 20% to 53% (Cod. 2) and from 10% to 50% (Cod. 4); whereas in Cabo Frio (Cod. 3) the smallest proportional increase of anthropogenic cover was observed, from 5.1% to 8.6%.

Trade and ex-situ maintenance

A total of 15 posts related to the species were recorded, of which nine posts referred to *ex-situ* maintenance in aquaria and six posts to the sale of eggs. The posts spanned the period from 2011 to 2025, with the most recent sale advertisement identified in October 2025 on the AquaBid platform, indicating the continued presence of active trade on specialised e-commerce websites (Table S2). Regarding the geographic distribution associated with *ex-situ* maintenance and trade, the species was recorded in 13 countries across various continents, including Europe (Germany, Belgium, Spain, Switzerland, Finland, France, the Netherlands, England, and the Czech Republic), Oceania (Australia), North America (United States), South America (Chile), and Asia (Japan) (Fig. 4).

Discussion

Geographical distribution and habitats

Ophthalmolebias constanciae was recorded at three of the four sampled sites and was absent from one locality (Rio das Ostras, site cod. 2), where the species has probably been extirpated due to landfilling activities conducted in September 2020, as evidenced by satellite imagery analysis in Google Earth Engine (Fig. S2). Historically, several abundant subpopulations were reported across the municipalities of Cabo Frio, Casimiro de Abreu, and Rio das Ostras; however, many have been progressively eliminated due to urban expansion, resulting in a reduction of their geographic distribution (Costa, 2009, 2012). In addition, another annual rivulid species, *Nematolebias cruzi* (Costa, 1988), previously found in syntopy with *Ophthalmolebias constanciae*, has not been recorded since 2002 and may be extinct (Pavanelli et al., 2024a), despite recurrent sampling efforts in the region, including the present study.

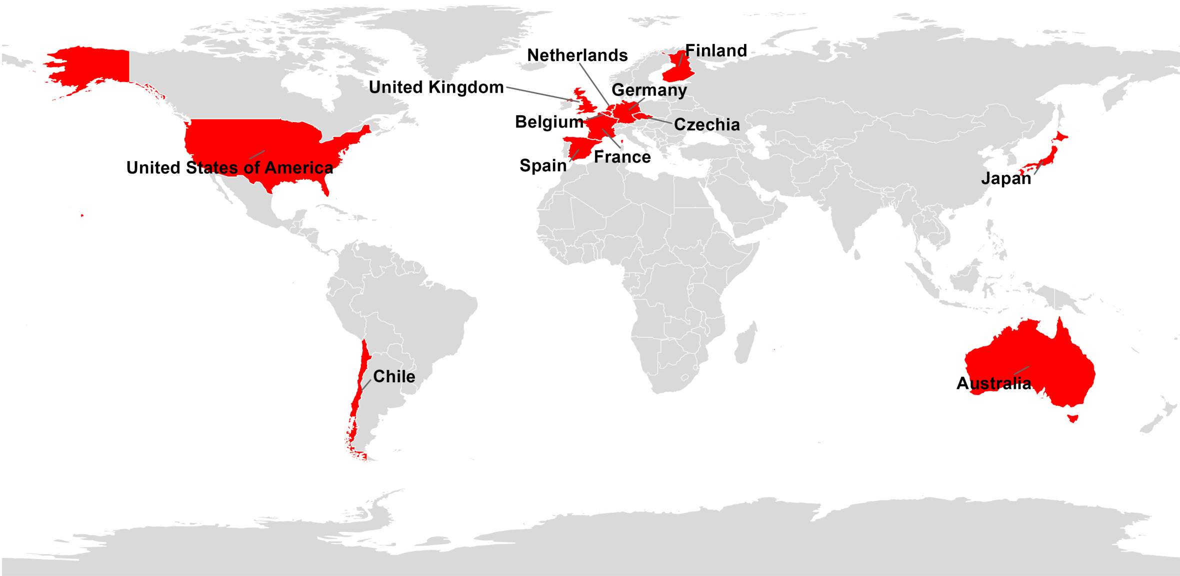

Fig. 4. Map showing the countries where trade and *ex-situ* maintenance of the annual fish *Ophthalmolebias constanciae* were recorded based on surveys of e-commerce websites and social media platforms.

Typical habitats where these species were recorded are temporary wetlands, characterised by acidic waters and low oxygen concentrations. Annual fishes have evolved to withstand extremely daily and seasonal environmental variability, including fluctuations in temperature, dissolved oxygen, salinity, pH, and water availability (Podrabsky et al., 2015; Polačik & Podrabsky, 2016; Gomes et al., 2025). However, the rapid intensification of anthropogenic pressures may be exceeding this adaptive capacity, contributing to the decline and potential local extirpation of populations.

Life history

Ophthalmolebias constanciae exhibited a female-biased sex ratio (2.1 : 1.0). In general, studies on Rivulidae fishes have reported a predominance of females in sex ratios, such as *Leptopanchax opalescens* (Myers, 1942) (Guedes et al., 2020), *Atlantirivulus riograndensis* (Costa & Lanés, 2009) (Lanés et al., 2012), and *Simpsonichthys boitonei* Carvalho, 1959 (Shibatta, 2005). In contrast, some species exhibit sex ratios close to the expected 1 : 1 proportion (e.g. *Notholebias minimus* (Myers, 1942), see Guedes et al., 2023a), and, to date, no studies have reported sex ratios with a significant males bias. However, sex ratios in Rivulidae are not static, showing temporal variation associated with population aging (Lanés et al., 2016). A plausible explanation for this pattern is differential mortality between sexes in annual fishes, with males generally facing higher predation risk due to their more conspicuous coloration, increased activity, and greater investment in courtship and territorial behaviours (Reichard et al., 2014). Additionally, epigenetic mechanisms, such as temperature-regulated DNA methylation, have been suggested to modulate sexual determination and, consequently, sex ratios in the selfing fish *Kryptolebias marmoratus* (Ellison et al., 2015). Thus, sex ratios in annual rivulids likely reflect the interaction of environmental, epigenetic, and behavioural factors associated with their life-history traits.

The body size of males was significantly larger than that of females; however, females were heavier than males for a given length. This pattern indicates sexual size dimorphism, a common feature in Rivulidae (e.g. Arenzon et al., 2001; Nascimento et al., 2012; Guedes et al., 2023a). In Rivulidae fishes, the larger male size is often associated with sexual selection, particularly through male–male competition (intrasexual selection) and courtship behaviour (intersexual selection), in which an increased body size may confer advantages in territorial disputes and enhance attractiveness to females (Passos et al., 2013). Despite this, the significant differences in the intercepts of the length–weight relationship indicate that females are relatively heavier than males at a given length. This suggests sex-specific energy allocation strategies, with females investing proportionally more in somatic condition and reproductive tissues, particularly in oocyte development (Guedes et al., 2023b). Taken together, these results highlight a trade-off between linear growth and mass allocation between sexes: males prioritise somatic growth in length, likely driven by sexual selection, whereas females allocate more energy to body mass, enhancing reproductive capacity.

Ophthalmolebias constanciae exhibits batch fecundity ranging from 26 to 69 oocytes (43.9 ± 12.5), values higher than those reported for other Rivulidae species, such as *Notholebias minimus* (24.8 ± 8.8 eggs; Guedes et al., 2023a), *Cynopoecilus melanotaenia* (Regan, 1912) (19 ± 26 eggs; Gonçalves et al., 2011), *Garcialebias nigrofasciatus* Costa & Cheffe, 2001 (21.5 ± 12.0 eggs; Volcan et al., 2011), and *Leptopanchax opalescens* (Myers, 1942) (27 ± 7 eggs; Guedes et al., 2023b), which may indicate a greater reproductive investment per spawning event. The eggs are relatively large (maximum diameter of 1.41 mm), particularly considering the spatial constraints imposed by the coelomic cavity in a small-bodied species (< 6 cm). The mean oocyte diameter of *Ophthalmolebias constanciae* (1.01 ± 0.13 mm) observed in the present study is consistent with the value reported by Fava & Toledo-Piza (2007) (1.01 mm), analysed ornamentation patterns in the external morphology of the eggs. Furthermore, these values fall within the general range of variation (0.50 mm to 2.25 mm) described for 136 Rivulidae species, in which annual species tend to exhibit smaller eggs than non-annual species (Guedes et al., 2023b).

Land use and cover

The marked increase in anthropogenic cover (~25.7 percentage points; ≈112% relative increase) in the surroundings of *Ophthalmolebias constanciae* habitats over the last two decades reflects a broader, well-documented pattern of coastal urbanisation in the Atlantic Forest biome, where natural ecosystems have been rapidly converted into urban infrastructure (Scherner et al., 2013; Pardal et al., 2024). Urban expansion in areas inhabited by *Ophthalmolebias constanciae* is more pronounced than that reported for the threatened annual fish *Notholebias minimus* (Guedes et al., 2023a). In the latter, biotopes located in protected and unprotected areas exhibited contrasting temporal trends in landscape change: unprotected areas showed a 4% increase in anthropogenic matrices, whereas protected areas experienced a 7.3% recovery of natural matrices between 1985 and 2021. For *Ophthalmolebias constanciae*, the only locality under territorial protection is situated in Casimiro de Abreu, where a small sustainable-use protected area (4842 m²) has been established to preserve the local ecosystem through land-use regulation, aiming to reconcile conservation with human activities (Pavanelli et al., 2024b). However, despite this protection status, the surrounding area has undergone a substantial increase of 36.86% in urban cover, indicating limited effectiveness in buffering external anthropogenic pressures. In the municipalities where *Ophthalmolebias constanciae* occurs (Cabo Frio, Rio das Ostras, and Casimiro de Abreu), a substantial population increase of approximately 252 200 inhabitants was recorded between 2000 and 2022, with the total population rising from 172 500 inhabitants to 424 700 inhabitants (IBGE, 2023). Annual fishes of the family Rivulidae are particularly sensitive to landscape changes due to their strict dependence on temporary wetlands and their limited dispersal ability (Volcan & Lanés, 2018; Abrantes et al., 2020; Castro & Polaz, 2020; Guedes & Araújo, 2026). Urbanisation can alter key ecological processes in temporary wetlands, including local hydrology, soil permeability, and water quality (Calhoun et al., 2017), ultimately compromising the formation and persistence of seasonal pools required for reproduction and population persistence. In summary, accelerated urbanisation surrounding *Ophthalmolebias constanciae* habitats, combined with the limited coverage of protected areas, increases the species' vulnerability to landscape changes severely.

Trade and ex-situ maintenance

This study presents, for the first time for an annual fish species (Rivulidae), a global mapping of populations maintained *ex-situ* due to the aquarium trade. The commercialisation and export of endangered species in Brazil are, in general, prohibited under current environmental legislation (SAP/MAPA Ordinance №17/2021; MMA Ordinance №148, 07.06.2022), with exceptions permitted only in specific cases, subject to authorisation by competent authorities and within the framework of Recovery Plans (MMA Ordinance №445, 17.12.2014). Currently, *Ophthalmolebias constanciae* is maintained under *ex-situ* conditions, with authorisation from Brazilian environmental authorities, in two institutions: the Aquário do Rio São Francisco (Belo Horizonte, MG), since 2018, following an emergency rescue carried out in Casimiro de Abreu (RJ); and, more recently, since 2025, at Colégio Dante Alighieri, in São Paulo (SP), where research, conservation, and environmental education activities are conducted. Considering the absence of records of past or current authorisations for the commercialisation of *Ophthalmolebias constanciae*, both domestically and for export, the trade and *ex-situ* maintenance activities identified in this study are not in compliance with the current Brazilian legislation.

The occurrence of *Ophthalmolebias constanciae* in 13 countries, including regions such as Europe, Oceania, North America, and Asia, can be interpreted from various perspectives. First, the reproductive biology of *Ophthalmolebias constanciae* favours its dispersal within the ornamental fish trade, as the mapped sales records are predominantly associated with the commercialisation of eggs. These eggs, which are small (mean: of 1.016 ± 0.130 mm), exhibit high resistance due to embryonic diapause (Furness, 2016), allowing them to be transported in dry or semi-moist substrates, which hinders their detection during inspections and control procedures. Second, from a husbandry perspective, this wide *ex-situ* distribution suggests a high degree of plasticity in the species' tolerance to captive conditions, enabling it to persist under diverse management regimes. Such variability reflects both the particular practices adopted by individual aquarists, employing different transport and maintenance protocols (Maia et al., 2025), and environmental differences among regions worldwide, including variations in temperature and photoperiod. Third, the aquarium trade represents one of the five major pathways for the introduction of non-indigenous aquatic species and has been linked to more than 150 species invading natural ecosystems worldwide (Chang et al., 2009). Notably, the annual fish *Argolebias nigripinnis* (Regan, 1912), native to South America (Brazil, Uruguay, Argentina, and Paraguay) (Calviño, 2007; Volcan et al., 2017), has already been reported as introduced into natural environments in the Philippines (Gilles et al., 2025). Fourth, the lack of information regarding the origin of individuals maintained in captivity prevents the assessment of whether current trade is sustained by *ex-situ* reproduction or relies on continuous collection from the wild. The predominance of egg-based trade, however, suggests that, at least internationally, the market may be partially supported by successive captive breeding. Nevertheless, this uncertainty represents a critical issue, as trade maintained through recurrent removal of wild individuals may increase pressure on already vulnerable natural populations, contributing to population decline and an increased risk of extinction (Borges et al., 2021, 2022).

Conclusions

Although this study provides relevant insights, some limitations should be considered. First, there is a pronounced Wallacean shortfall regarding the distribution of annual fishes, as is the case for most taxa in the Neotropical region, with occurrence records still incomplete and spatially biased (Guedes & Araújo, 2026; Costa & Guedes, 2026). Therefore, it is plausible that additional sampling efforts may reveal new occurrence localities of *Ophthalmolebias constanciae* beyond those reported here. Second, *ex-situ* maintenance data are likely underestimated, as they depend on the voluntary disclosure of species in social media and e-commerce platforms. Many hobbyists avoid sharing such information, possibly due to legal restrictions, suggesting that the actual *ex-situ* distribution of the species may be broader than identified in this study. Third, the lack of long-term population monitoring and the absence of genetic data limit more robust inferences about population dynamics and the conservation status of the species. Despite these limitations, the results provide consistent evidence of ongoing habitat loss, local extirpation, and increasing anthropogenic pressures across the species' distribution. The combination of high endemism, rapid urban expansion, limited coverage of Protected Areas, and unregulated trade outlines a critical conservation scenario in which both *in-situ* and *ex-situ* processes may simultaneously threaten and reshape the species' persistence. In this context, integrated conservation approaches («One Conservation»), in which *ex-situ* actions play a complementary role to *in-situ* conservation, have started to be discussed by the Brazilian federal environmental agency (ICMBio) since 2025 (ICMBio, 2026b). Thus, the data presented here on distribution, life history, and threats can support decision-making by regulatory agencies. Finally, future studies should prioritise long-term monitoring, genetic assessments, and the traceability of traded individuals, as well as evaluate the effectiveness of conservation strategies at both local and landscape scales. Additionally, integrating species distribution data with environmental agencies and landowners is essential to enable proactive habitat conservation measures before this critically endangered species disappears.

Acknowledgements

This study was funded by Fundo Brasileiro para a Biodiversidade – FUNBIO Conservando o Futuro, and Instituto HUMANIZE (Proc. # 028/2023), Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro (E-26/200.897/2021, E-26/210.103/2023), and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq 140.512/2022-5).

Supporting Information

Additional data for the paper by Guedes et al. (2026) may be found in the **Supporting Information**.

References

Abrantes Y.G., de Medeiros L.S., Bennemann A.B.A., de Medeiros Bento D., Teixeira F.K., Rezende C.F., Lima S.M.Q. 2020. Geographic distribution and conservation of seasonal killifishes (Cyprinodontiformes, Rivulidae) from the Mid-Northeastern Caatinga ecoregion, northeastern Brazil. *Neotropical Biology and Conservation* 15(3): 301–315. DOI: 10.3897/neotropical.15.e51738

Amorim P.F., Katz A.M., Ottoni F.P., de Bragança P.H.N. 2022. Genetic structure of the mangrove Killifish *Kryptolebias hermaphroditus* Costa, 2011 (Cyprinodontiformes: Aplocheiloidei) supports a wide connection among its populations. *Zoological Studies* 61: 4. DOI: 10.6620/ZS.2022.61-04

Arenzon A., Peret A.C., Bohrer M.B.C. 2001. Growth of the annual fish *Cynopoecilus melanotaenia* (Regan, 1912) based in a temporary water body population in Rio Grande do Sul State, Brazil (Cyprinodontiformes, Rivulidae). *Revista Brasileira de Biologia* 61(1): 117–123. DOI: 10.1590/S0034-71082001000100015

Avise J.C., Tatarenkov A. 2015. Population genetics and evolution of the mangrove rivulus *Kryptolebias marmoratus*, the world's only self-fertilizing hermaphroditic vertebrate. *Journal of Fish Biology* 87(3): 519–538. DOI: 10.1111/jfb.12741

Berbel-Filho W.M., Pacheco G., Tatarenkov A., Lira M.G., Garcia de Leaniz C., Rodríguez López C.M., Lima S.M.Q., Consuegra S. 2022. Phylogenomics reveals extensive introgression and a case of mito-nuclear discordance in the killifish genus *Kryptolebias*. *Molecular Phylogenetics and Evolution* 177: 107617. DOI: 10.1016/j.ympev.2022.107617

Borges A.K.M., Oliveira T.P.R., Rosa I.L., Braga-Pereira F., Ramos H.A.C., Rocha L.A., Alves R.R.N. 2021. Caught in the (inter)net: online trade of ornamental fish in Brazil. *Biological Conservation* 263: 109344. DOI: 10.1016/j.biocon.2021.109344

Borges A.K.M., Oliveira T.P.R., Alves R.R.N. 2022. Marine or freshwater: the role of ornamental fish keeper's preferences in the conservation of aquatic organisms in Brazil. *PeerJ* 10: e14387. DOI: 10.7717/peerj.14387

Calhoun A.J., Mushet D.M., Bell K.P., Boix D., Fitzsimons J.A., Isselin-Nondedeu F. 2017. Temporary wetlands: challenges and solutions to conserving a 'disappearing' ecosystem. Biological Conservation 211(B): 3–11. DOI: 10.1016/j.biocon.2016.11.024

Calviño P.A. 2007. Distribución geográfica de *Austrolebias nigripinnis* (Regan) (Cyprinodontiformes: Rivulidae) en Argentina, con comentarios sobre su variabilidad en el patrón de color. *Boletín del Killi Club Argentino* 12: 22–38.

Castro R.M.C., Polaz C.N.M. 2020. Small-sized fish: the largest and most threatened portion of the megadiverse neotropical freshwater fish fauna. *Biota Neotropica* 20(1): e20180683. DOI: 10.1590/1676-0611-bn-2018-0683

Chang A.L., Grossman J.D., Spezio T.S., Weiskel H.W., Blum J.C., Burt J.W., Muir A.A., Piovia-Scott J., Veblen K.E., Grosholz E.D. 2009. Tackling aquatic invasions: risks and opportunities for the aquarium fish industry. *Biological Invasions* 11(4): 773–785. DOI: 10.1007/s10530-008-9292-4

Coe H.H.G., Carvalho C.N., Souza L.O.F., Soares A. 2007. Peculiaridades ecológicas da região de Cabo Frio, RJ. *Revista Tamoios* 4(2). P. 1–20.

Costa J.H.A., Guedes G.H.S. 2026. Biodiversity knowledge and conservation shortfalls in Rivulidae fishes. *bioRxiv*. Available from https://doi.org/10.64898/2026.07.04.736495

Costa J.H.A., Zuanon J., Selinger A., Castilho A.G., Souza U.P., Duarte R.M. 2025. Diving into temporary pools: a global perspective on freshwater fish research. *Neotropical Ichthyology* 23(3): e250043. DOI: 10.1590/1982-0224-2025-0043

Costa W.J.E.M. 1995. *Pearl killifishes. The Cynolebiatinae. Systematics and biogeography of a Neotropical annual fish subfamily (Cyprinodontiformes: Rivulidae)*. Neptune City: T.F.H. Publications. 128 p.

Costa W.J.E.M. 2006. Descriptive morphology and phylogenetic relationships among species of the Neotropical annual killifish genera *Nematolebias* and *Simpsonichthys (*Cyprinodontiformes: Aplocheiloidei: Rivulidae). *Neotropical Ichthyology* 4(1): 1–26. DOI: 10.1590/S1679-62252006000100001

Costa W.J.E.M. 2009. *Peixes aploqueilóideos da Mata Atlântica brasileira: história, diversidade e conservação*. Rio de Janeiro: Museu Nacional. 171 p.

Costa W.J.E.M. 2012. Delimiting priorities while biodiversity is lost: Rio's seasonal killifishes on the edge of survival. *Biodiversity and Conservation* 21(10): 2443–2452. DOI: 10.1007/s10531-012-0301-7

Ellison A., Rodríguez López C.M., Moran P., Breen J., Swain M., Megias M., Hegarty M., Wilkinson M., Pawluk R., Consuegra S. 2015. Epigenetic regulation of sex ratios may explain natural variation in selfing rates. *Proceedings of the Royal Society B: Biological Sciences* 282(1819): 20151900. DOI: 10.1098/rspb.2015.1900

Fava D., Toledo-Piza M. 2007. Egg surface structure in the annual fishes *Simpsonichthys* (subgenera *Ophthalmolebias* and *Xenurolebias*) and *Nematolebias* (Teleostei: Cyprinodontiformes: Rivulidae): variability and phylogenetic significance. *Journal of Fish Biology* 71(3): 889–907. DOI: 10.1111/j.1095-8649.2007.01572.x

Fricke R., Eschmeyer W.N., Fong J.D. 2026. Genera/species by family/subfamily. In: *CAS – Eschmeyer's Catalog of Fishes*. Available from http://researcharchive.calacademy.org/research/ichthyology/catalog/SpeciesByFamily.asp

Froese R. 2006. Cube law, condition factor and weight–length relationships: history, meta-analysis and recommendations. *Journal of Applied Ichthyology* 22(4): 241–253. DOI: 10.1111/j.1439-0426.2006.00805.x

Furness A.I. 2016. The evolution of an annual life cycle in killifish: adaptation to ephemeral aquatic environments through embryonic diapause. *Biological Reviews* 91(3): 796–812. DOI: 10.1111/brv.12194

Gilles A.S., Bate J.M., Peralta E., Pavia R.T., Vilizzi L. 2025. Current and future risk of invasion by non-native freshwater fishes in a mega-biodiversity country (the Philippines). *Management of Biological Invasions* 16(1): 73–89. DOI: 10.3391/mbi.2025.16.1.05

Godoy R.S., Weber V., Lanés L.E.K., Castro B.D., Oliveira G.T., Arenzon A., Stenert C., Maltchik L. 2025. Early post-hatching sensitivity of a Neotropical annual killifish to glyphosate-based-herbicide. *Toxicological and Environmental Chemistry* 107(7): 1322–1338. DOI: 10.1080/02772248.2025.2527648

Gomes B.P., Sarmento-Soares L.M., Martins-Pinheiro R.F., Leite G.R. 2025. Habitat and Conservation Assessment of Annual Killifishes of the Genus *Xenurolebias* (Rivulidae: Cynolebiinae) from Coastal Floodplains, Including the First Record South of the Rio Doce, Southeastern Brazil. *Diversity* 17(9): 644. DOI: 10.3390/d17090644

Gonçalves C.S., Souza U.P., Volcan M.V. 2011. The opportunistic feeding and reproduction strategies of the annual fish *Cynopoecilus melanotaenia* (Cyprinodontiformes: Rivulidae) inhabiting ephemeral habitats on southern Brazil. *Neotropical Ichthyology* 9(1): 191–200. DOI: 10.1590/S1679-62252011000100019

Gonçalves N.M., Silveira T.L.R., Martins A.W.S., Dellagostin E.N., Blödorn E.B., Nunes L.S., Domingues W.B., Salvi L.C., Costa P.G., Bianchini A., Kütter M.T., Marins L.F.F., Volcan M.V., Remião M.H., Campos V.F. 2024. A Pilot Study of Gene Expression Modulation from Antioxidant System of Killifish *Austrolebias charrua* After Exposure to Roundup Transorb®. *Bulletin of Environmental Contamination and Toxicology* 113(2): 17. DOI: 10.1007/s00128-024-03930-w

Guedes G.H.S., Araújo F.G. 2026. Water and fire: wildfires threaten fish habitats across Brazilian biomes, and protected areas offer insufficient safeguards. *Biological Conservation* 315: 111692. DOI: 10.1016/j.biocon.2025.111692

Guedes G.H.S., Salgado F.L.K., Uehara W., Ferreira D.L., Araújo F.G. 2020. The recapture of Leptopanchax opalescens (Aplocheiloidei: Rivulidae), a critically endangered seasonal killifish: habitat and aspects of population structure. *Zoologia* 37: 1–8. DOI: 10.3897/zoologia.37.e54982

Guedes G.H.S., Luz C.H.P., Mazzoni R., Lira F.O., Araújo F.G. 2023a. New occurrences of the endangered *Nothobias minimus* (Cyprinodontiformes: Rivulidae) in coastal plains of the State of Rio de Janeiro, Brazil: populations features and conservation. *Neotropical Ichthyology* 21(3): e230013. DOI: 10.1590/1982-0224-2023-0013

Guedes G.H.S., Gomes I.D., do Nascimento A.A., de Azevedo M.C.C., de Araújo Souto-Santos I.C., Buckup P.A., Araújo F.G. 2023b. Reproductive Strategy of the Annual Fish *Leptopanchax Opalescens* (Rivulidae) and Trade-Off Between Egg Size and Maximum Body Length in Temporary Wetlands. *Wetlands* 43(4): 29. DOI: 10.1007/s13157-023-01680-9

Guedes G.H.S., Santangelo J.M., Pires A.P.F., Araújo F.G. 2025. β-Diversity Scaling Patterns Across Different Bioregionalisations for a Megadiverse Neotropical Fish Family. *Journal of Biogeography* 52(4): e15088. DOI: 10.1111/jbi.15088

Guedes G.H.S., Cordeiro L., Azeredo L.F.S.P., Araújo F.G. 2026a. Microplastics in wetlands: contrasting fish contamination between mangroves and temporary ponds in southeastern Brazil. *Wetlands Ecology and Management* 34(3): 49. DOI: 10.1007/s11273-026-10156-6

Guedes G.H.S., Lanés L.E.K., Souto-Santos I.C.A., Lira F.O., Araújo F.G. 2026b. Environmental licensing and conservation of rivulid fish (Cyprinodontiformes: Rivulidae): practical recommendations for environmental agencies and consultants [Preprint]. *Zenodo*. Available from https://doi.org/10.5281/zenodo.22088576

Guimarães G.S., Nunes-Freitas A.F., Baumgratz J.F.A. 2024. Flora and Phytophysiognomies of an Atlantic Forest remnant on the coast of Southeast Brazil. Rodriguésia 75: e00122023. DOI: 10.1590/2175-7860202475005

IBGE. 2023. *Censo demográfico 2022, Brasil*. Available from https://www.ibge.gov.br

ICMBio. 2026a. *Sistema de Avaliação do Risco de Extinção da Biodiversidade – SALVE*. Available from https://salve.icmbio.gov.br

ICMBio. 2026b. *Avaliação de Manejo Ex situ de espécies do gênero Steindachneridion e Ophthalmolebias constanciae*. ICMBio, Brasília. Available from https://www.gov.br/icmbio/pt-br/assuntos/biodiversidade/pan/pan-rivulideos

IUCN. 2026. *The IUCN Red List of Threatened Species. Version 2025-2*. Available from https://www.iucnredlist.org

Lanés L.E.K., Keppeler F.W., Maltchik L. 2012. Abundance, sex-ratio, length–weight relation, and condition factor of non-annual killifish *Atlantirivulus riograndensis* (Actinopterygii: Cyprinodontiformes: Rivulidae) in Lagoa do Peixe National Park, a Ramsar Site of Southern Brazil. *Acta Ichthyologica et Piscatoria* 42(3): 247–252. DOI: 10.3750/AIP2011.42.3.09

Lanés L.E.K., Godoy R.S., Maltchik L., Polačik M., Blažek R., Vrtílek M., Reichard M. 2016. Seasonal dynamics in community structure, abundance, body size and sex ratio in two species of Neotropical annual fishes. Journal of Fish Biology 89(5): 2345–2364. DOI: 10.1111/jfb.13122

Le Cren E.D. 1951. The Length-Weight Relationship and Seasonal Cycle in Gonad Weight and Condition in the Perch (*Perca fluviatilis*). *Journal of Animal Ecology* 20(2): 201–219. DOI: 10.2307/1540

Loureiro M., Sá R.O., Serra S.W., Alonso F., Lanés L.E.K., Volcan M.V., Calviño P., Nielsen D., Duarte A., Garcia G. 2018. Review of the family Rivulidae (Cyprinodontiformes, Aplocheiloidei) and a molecular and morphological phylogeny of the annual fish genus *Austrolebias* Costa 1998. *Neotropical Ichthyology* 16(3): 1–20. DOI: 10.1590/1982-0224-20180007

Maia C.M., Gauy A.C.S., Gonçalves-de-Freitas E. 2025. Fish Welfare in the Ornamental Trade: Stress Factors, Legislation, and Emerging Initiatives. *Fishes* 10(5): 224. DOI: 10.3390/fishes10050224

Nascimento W.S., Yamamoto M.E., Chellappa S. 2012. Proporção Sexual e Relação Peso-Comprimento do Peixe Anual *Hypsolebias antenori* (Cyprinodontiformes: Rivulidae) de Poças Temporárias da Região Semiárida do Brasil. *Biota Amazônia* 2(1): 37–44. DOI: 10.18561/2179-5746/biotaamazonia.v2n1p37-44

Pardal A., Christofoletti R.A., Martinez A.S. 2024. Urbanisation on the coastline of the most populous and developed state of Brazil: the extent of coastal hardening and occupations in low-elevation zones. *Anthropocene Coasts* 7(1): 15. DOI: 10.1007/s44218-024-00048-8

Passos C., Tassino B., Loureiro M., Rosenthal G.G. 2013. Intra- and intersexual selection on male body size in the annual killifish *Austrolebias charrua*. *Behavioural Processes* 96: 20–26. DOI: 10.1016/j.beproc.2013.01.008

Pavanelli C.S., Fukakusa C.K., Da Costa Neto F.P.S., Lira F.O., Garcia I.C.B., Zuanon J., Mattos J.L.O., Santos J.F., Netto M.R.C.B., Silva M.J., Amorim P.F., Reis R.E., Ramos T.P.A., Ruiz W.B.G. 2024a. Ficha de *Notholebias cruzi* [Dataset]. In: Datasets – Sistema SALVE –Instituto Chico Mendes de Conservacao da Biodiversidade (ICMBio). Available from https://doi.org/10.37002/salve.ficha.25002.2

Pavanelli C.S., Fukakusa C.K., Da Costa Neto F.P.S., Lira F.O., Garcia I.C.B., Zuanon J., Mattos J.L.O., Santos J.F., Netto M.R.C.B., Silva M.J., Amorim P.F., Reis R.E., Ramos T.P.A., Ruiz W.B.G. 2024b. Ficha de *Ophthalmolebias constanciae* [Dataset]. In: Datasets – Sistema SALVE –Instituto Chico Mendes de Conservacao da Biodiversidade (ICMBio). Available from https://doi.org/10.37002/salve.ficha.25007.2

Podrabsky J.E., Riggs C.L., Wagner J.T. 2015. Tolerance of environmental stress. In: N. Berois, G. García, R.O. Sá (Eds.): *Annual fishes*. Boca Raton: CRC Press. P. 160–180.

Polačik M., Podrabsky J.E. 2016. Temporary environments. In: R. Riesch, M. Plath, M. Tobler (Eds.): *Extremophile fishes*. New York: Springer. P. 217–245.

Polačik M., García D., Arezo M.J., Papa N., Schlueb H., Blanco D., Podrabsky J.E., Vrtílek M. 2023. Embryonic development of natural annual killifish populations of the genus *Austrolebias*: Evolutionary parallelism and the role of environment. *Freshwater Biology* 68(10): 1726–1738. DOI: 10.1111/fwb.14161

R Core Team. 2026. *R: A language and environment for statistical computing*. Vienna: R Foundation for Statistical Computing. Available from https://www.R-project.org

Reichard M., Polačik M., Blažek R., Vrtílek M. 2014. Female bias in the adult sex ratio of African annual fishes: interspecific differences, seasonal trends and environmental predictors. *Evolutionary Ecology* 28(6): 1105–1120. DOI: 10.1007/s10682-014-9732-9

Rhee J.S., Choi B.S., Kim J., Kim B.M., Lee Y.M., Kim I.C., Kanamori A., Choi I.Y., Schartl M., Lee J.S. 2017. Diversity, distribution, and significance of transposable elements in the genome of the only selfing hermaphroditic vertebrate *Kryptolebias marmoratus*. *Scientific Reports* 7(1): 40121. DOI: 10.1038/srep40121

Rizzo E., Bazzoli N. 2020. Reproduction and embryogenesis. In: B. Baldisserotto, E.C. Urbinati, J.E.P. Cyrino (Eds.): *Biology and physiology of freshwater Neotropical fish*. London: Academic Press. P. 287–313. DOI: 10.1016/B978-0-12-815872-2.00013-0

Scherner F., Horta P.A., de Oliveira E.C., Simonassi J.C., Hall-Spencer J.M., Chow F., Nunes J.M.C., Pereira S.M.B. 2013. Coastal urbanization leads to remarkable seaweed species loss and community shifts along the SW Atlantic. *Marine Pollution Bulletin* 76(1–2): 106–115. DOI: 10.1016/j.marpolbul.2013.09.019

Shibatta O.A. 2005. Reprodução do pirá-brasília, *Simpsonichthys boitonei* Carvalho (Cyprinodontiformes, Rivulidae), e caracterização de seu habitat na Reserva Ecológica do Instituto Brasileiro de Geografia e Estatística, Brasília, Distrito Federal, Brasil. *Revista Brasileira de Zoologia* 22(4): 1146–1151. DOI: 10.1590/S0101-81752005000400048

Volcan M.V., Lanés L.E.K. 2018. Brazilian killifishes risk extinction. *Science* 361(6400): 340–341. DOI: 10.1126/science.aau5930

Volcan M.V., Fonseca A.P., Robaldo R.B. 2011. Reproduction of the threatened Annual Killifish *Austrolebias nigrofasciatus* (Cyprinodontiformes: Rivulidae), confined in a natural environment. *Journal of Threatened Taxa* 3(6): 1864–1867. DOI: 10.11609/JoTT.o2575.1864-7

Volcan M.V., Gonçalves A.C., Lanés L.E.K. 2017. First record of blackfin pearlfish *Austrolebias nigripinnis* (Regan, 1912 (Cyprinodontiformes, Cynolebiidae) from Brazil. *Zootaxa* 4254(3): 387–390. DOI: 10.11646/zootaxa.4254.3.9

Weber V., Alonso F., Godoy R.S., Lanés L.E.K., Pires M.M., Stenert C., Gava A., Maltchik L. 2025. Hitting and Unhitting the Pause Button: Variable Hatching Patterns of Annual Killifish Embryos Over a Wetland Wet–Dry Cycle. *Ecology of Freshwater Fish* 34(1): e12816. DOI: 10.1111/eff.12816

Žák J., Vrtílek M., Polačik M., Blažek R., Reichard M. 2021. Short-lived fishes: annual and multivoltine strategies. *Fish and Fisheries* 22(3): 546–561. DOI: 10.1111/faf.12535

ЖИЗНЕННЫЙ ЦИКЛ, УГРОЗЫ И СОХРАНЕНИЕ ОДНОЛЕТНЕЙ РЫБЫ БРАЗИЛИИ *OPHTHALMOLEBIAS CONSTANCIAE* ВО ВРЕМЕННЫХ ВОДОЕМАХ

Г. Х. С. Гедес, А. С. С. Силва, Ф. Г. Араужо*

Федеральный сельский университет Рио-де-Жанейро, Бразилия
**e-mail: gerson@ufrrj.br*

Ophthalmolebias constanciae (Cyprinodontiformes: Rivulidae) – однолетняя рыба, находящаяся на грани исчезновения (Critically Endangered) и являющаяся эндемиком прибрежных равнин штата Рио-де-Жанейро, Бразилия. Данное исследование направлено на получение новых данных о характеристиках жизненного цикла вида (размер тела и икринок, плодовитость, соотношение полов и отношение между длиной и массой тела), его географическом распространении и особенностях среды обитания. Также в работе оцениваются возникающие угрозы, включая международную торговлю и содержание *ex-situ* наряду с изменениями в землепользовании и характере растительного покрова за 22-летний период (2003–2025 гг.). Вид был зарегистрирован всего в трех временных водоемах, характеризующихся кислой реакцией воды (pH 5.7 ± 0.7) и низкой концентрацией растворенного кислорода (2.6 ± 0.6 мг/л). Общая длина тела составляла 33–54 мм у самцов и 30–45 мм у самок. Порционная плодовитость варьировала от 26 до 69 ооцитов (среднее значение: 44 ± 12 ооцитов) при их диаметре 0.80–1.43 мм (среднее значение: 1.01 ± 0.13 мм). Самцы были достоверно крупнее самок, а в соотношении полов наблюдалось смещение в сторону самок (2.1 : 1.0 в пользу самок). Установлено, что *Ophthalmolebias constanciae* является предметом незаконной торговли и содержится в условиях *ex-situ* как минимум в 13 странах, включая регионы Северной Америки, Европы, Азии и Океании. Данные о землепользовании и растительном покрове выявили растущую антропогенную нагрузку на биотопы вида, при этом потеря естественного покрова в период 2003–2025 гг. составила 25%. Объединяя экологические, биологические данные и сведения об угрозах, это исследование укрепляет научно обоснованную базу для сохранения *Ophthalmolebias constanciae*.

Ключевые слова: Rivulidae, аквариумная торговля, Атлантический лес, Бразилия, временные пруды, исчезающая фауна, киллифиш, размножение