Identification key for fishes from coastal streams of the Atlantic forest of southeastern Brazil

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Abstract: In recent decades, current knowledge about fish from Neotropical streams has greatly increased, but is still deficient. Here we present an identification key for fishes from coastal freshwater streams from a large conservation area of Atlantic rainforest of southeastern Brazil, including 39 species. Considering that most of these species (61.2%) are endemic to the coastal streams, this identification key will be useful not only for the species recognition of the sampled area, but also for the surrounding coastal region.

Keywords: taxonomy, endemic and endangered fishes, Neotropical streams, Juréia-Itatins Ecological Station.

Chave de identificação para os peixes de riachos costeiros da Mata Atlântica, sudeste do Brasil

Resumo: Nas últimas décadas, o conhecimento acerca dos peixes de riachos neotropicais aumentou consideravelmente, mas apesar disso ainda é deficiente. Apresentamos aqui uma chave de identificação para as 39 espécies de peixes de uma grande unidade de conservação da Mata Atlântica do sudeste do Brasil. Considerando que a maioria destas espécies (61.2%) são endêmicas dos riachos costeiros, esta chave de identificação será útil não só para o reconhecimento de espécies da área amostrada, mas também da região costeira do entorno.


Introduction

The Serra do Mar was formed from an uplift process during the Cretaceous, which originated a sequence of 1,000 km of mountains near the newly formed coast. Its current relief was shaped over millions of years by erosion and tectonic activities and currently covers the states of Rio de Janeiro to Santa Catarina (Oyakawa et al. 2006). The Atlantic forest is a complex biome that covers practically the entire Serra do Mar, and although human occupation has degraded 90% of its area, this biome harbors a significant part of the Brazilian biodiversity (Joly et al. 1999); 40% of the 2,000 vertebrate species are endemic (Oyakawa et al. 2006).

In this region, there are mountain streams with clear and fast waters due to the high slope of the relief, low temperatures and high concentration of dissolved oxygen, and the lowland streams that drains the less steep coastal plain forming meanders with black, slower, turbid and acidic waters with higher temperatures, lower dissolved oxygen concentration and sandy bottom (Por 2004). Due to the altitudinal gradient, coastal streams rise with waters typical of mountain streams that change when they reach the plains and with the proximity of the mouth in the sea (Gonçalves & Braga 2012).

These and other habitat characteristics influence the ichthyofauna of coastal streams (Abilhoa et al. 2011, Barrella et al. 2014, Gonçalves et al. 2015). The conservation of riparian forest is important since deforestation negatively impacts the survival of fish due to silting, increased sunlight incidence and decreased invertebrate fauna, among other impacts (Lorion & Kennedy 2009, Leite et al. 2015). This can lead to drastic consequences such as changes in reproductive and feeding behaviors of many species (Menezes et al. 2007, Ferreira et al. 2012, Lobón-Cerviá et al. 2016).

The Juréia-Itatins Ecological Station is a conservation unit on the south coast of the state of São Paulo with streams that protects several endemic species (and some endangered) of the Atlantic forest (Gonçalves & Braga 2013, Gonçalves et al. 2016, Gonçalves & Pérez-Mayorga 2016). Characiformes and Siluriformes are predominant, but other orders such as Cichliformes...
and Gobiiformes (sensu Betancur-R et al. 2017), Synbranchiformes, Cyprinodontiformes, and Gymnotiformes are also present (Gonçalves & Pérez-Mayorga 2016), as well as primarily marine families (Sabino & Silva 2004). Fish occupy different stream reaches according to their feeding habits and swimming capacity, varying between rapids, marginal backwaters or position in the water column (Sabino & Silva 2004). In the freshwater streams of the Jureia-Itatins Ecological Station, fish feed primarily on resources provided by riparian forest, such as terrestrial insects and vegetable debris (also consumed by immature forms of aquatic insects that will feed aquatic insectivorous fish), stressing the importance of legally protected areas in Atlantic forest (Gonçalves et al. 2013). The small size of most species of these coastal streams and the scarcity of keys can make it difficult to identify the fish of this region. The objective of this paper is to provide an identification key for fishes from coastal streams of Jureia-Itatins Ecological Station.

**Material and Methods**

The material used in this study was collected every three months between April 2009 and February 2010, and once in June 2013 (cf. Gonçalves & Braga 2012, 2013, Gonçalves & Pérez-Mayorga 2016) at the Jureia-Itatins reserve, an Atlantic rainforest pristine area with 79,240 ha on the south coast in the State of São Paulo, Brazil (24°18', 24°32' S and 47°00', 47°30' W). Average annual rainfall and temperature are 2,277 mm and 21.4 °C, respectively. A hot and rainy season occurs from October to April, and the less rainy season from May to September (Marques & Duleba 2004). Altitudes vary from sea level at alluvial plains to 1,240 m a.s.l. at steep mountains (Por 1986, Souza & Souza 2004). Due to this, local hydrography is influenced by the different vegetation types of dense ombrophilous forest found at different elevation: black waters (rich in humic substances with pH ca. 4) drains the alluvial dense ombrophilous forest and the lowland dense ombrophilous forest (also known as restinga forest), and clear waters (nutrient poor with pH ca. 6) drains the submontane dense ombrophilous forest and the montane dense ombrophilous forest (Por 1986, Por & Lopes 1994, Por 2004). Fish were sampled at 73 locations, using electrofishing, fishing nets, traps, and sieve (Gonçalves & Pérez-Mayorga 2016). Specimens were anesthetized with benzocaine, fixed in 10% formalin, and then kept in 70% ethanol until the analysis. Counts were taken on the left side of specimens as proposed by Fink & Weitzman (1974). The identification key provided was based on easily recognizable external morphological characters in most cases. The fishes classification followed Betancur-R et al. (2017). Voucher specimens (Table 1) are deposited in the fish collections of Universidade Estadual Paulista “Júlio de Mesquita Filho” (UNESP/DZSJRP), Câmpus São José do Rio Preto, and Museu de Zoologia of Universidade de São Paulo (MZUSP), São Paulo, Brazil.

### Table 1. The thirty-nine fish species registered in the coastal freshwater streams from Jureia-Itatins Ecological Station, a large conservation area of Atlantic rainforest of southeastern Brazil. (1) endemic to the Atlantic forest (Menezes et al. 2007), (2) endangered fish (State Decree Nº 60.133 07/02/2014), (-) voucher not available.

<table>
<thead>
<tr>
<th>Order/Family</th>
<th>Species</th>
<th>Voucher</th>
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<tbody>
<tr>
<td>CHARACIFORMES</td>
<td>Curimatidae</td>
<td>Cyphocharax santacatarinae (Fernández-Yépez, 1948)</td>
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<td></td>
<td>Crenuchidae</td>
<td>Characidium lanei (Regan, 1913)</td>
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<td>Characidium pterostictum (Gomes, 1947)</td>
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<td>Characidium schubarti (Travassos, 1955)</td>
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<td>Characidae</td>
<td>Astyanax ribeirae (Eisenman, 1911)</td>
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<td>Deuterodon iguape (Eisenman, 1909)</td>
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<td>Hollandichthys multifasciatus (Eisenman &amp; Norris, 1900)</td>
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<td>Hyphessobrycon greimii (Hoedeman, 1957)</td>
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<td>Hyphessobrycon boulengeri (Eisenman, 1909)</td>
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<td>Mimagoniates microlepis (Steindachner, 1877)</td>
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<td>Oligosarcus heptetus (Cuvier, 1829)</td>
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<td>Erythrinidae</td>
<td>Hoplias cf. malabaricus (Bloch, 1794)</td>
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<td>SILURIFORMES</td>
<td>Ariidae</td>
<td>Genidens genidens (Lacepède, 1803)</td>
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<td></td>
<td>Callichthyidae</td>
<td>Scleromystax barbatus (Quoy &amp; Gaimard, 1824)</td>
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<td></td>
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<td>Scleromystax macropterus (Regan, 1913)</td>
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<td>Scleromystax priodontos (Nijssen &amp; Isbrücker, 1980)</td>
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<td>Loricariidae</td>
<td>Kronichthys heylandi (Boulenger, 1900)</td>
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<td>Pseuodothrybus obtusus (Miranda Ribeiro, 1911)</td>
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<td>Rineloricaria sp.</td>
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<td>Schizolecis guntheri (Miranda Ribeiro, 1918)</td>
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<td></td>
<td>Pseudopimelodidae</td>
<td>Microclarias cf. parahybae (Steindachner, 1880)</td>
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<td>Heptapteridae</td>
<td>Acentronichthys leptos (Eisenmann &amp; Eigenmann, 1889)</td>
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<td>Pimelodella transitoria (Miranda Ribeiro, 1907)</td>
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<td>Rhamdia aff. quelen (Quoy &amp; Gaimard, 1824)</td>
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<td>Rhamdioiganis transfasciatus (Miranda Ribeiro, 1908)</td>
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<td>GYMNOTIFORMES</td>
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<td>Gymnotus paniherinus (Steindachner, 1908)</td>
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<td>CYPRINODONTIFORMES</td>
<td>Aplocheilidae</td>
<td>Atlantirivulus santensis (Köhler, 1906)</td>
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<td>Phalloceros harpagos (Lucinda, 2008)</td>
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<td>Phalloceros reisi (Lucinda, 2008)</td>
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<td>Poecilia vivipara (Bloch &amp; Schneider, 1801)</td>
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7'. Conspicuous sexual color dimorphism, males more colorful than females; pelvic fin of the mature males posteriorly displaced, its origin near the anal fin origin; females without developed urogenital papilla, and normally without spot in flank ........................................ Phalloceros vivipara

8. Female urogenital papilla approximately rectilinear along the mid-ventral line, between the anus and the base of first anal fin ray; border of the anal aperture separated from the first anal fin ray by the urogenital papilla .......... Phalloceros harpago...

9. Jaw teeth present, even if small; humeral spot present or absent and/or spot in the caudal peduncle normally absent; when present restricted to the medial portion of the caudal peduncle ........................................ Characidium schubarti

10'. Adipose fin present; forked caudal fin ........................................ 11

11'. Canine and conical jaw teeth; lateral line with more than 45 perforated scales; wide mouth opening, extending to the vertical that passes through the origin of the orbit ........................................ 12

12. Anal fin with less than 10 branched rays; dark band between snout and the orbit present; premaxillary with conical or tricuspid teeth ................. Characidium ........................................ 13 (Characidae)

12'. Anal fin with more than 10 rays; dark band between snout and the orbit absent; premaxillary teeth with four or more cusps ...................... 15

13. Dark longitudinal stripe on flank with relatively irregular borders, with spots projecting dorsally and/or ventrally ........................................ 14

13'. Dark longitudinal stripe on flank with approximately straight edge, with small spots (not covering one scale size) below the dark longitudinal stripe ........................................ Characidium schubarti

http://www.scielo.br/bn
14. Caudal and adipose fins hyaline; dark spots below the dark longitudinal stripe not extending to pelvic fin origin ........................................ Characidium lankei

14’. Caudal fin with dark spots; blackened adipose fin; dark spots below the dark longitudinal stripe extending to pelvic fin origin .................................................. Characidium pterostictum

15. Lateral line complete .......................................................... 16

15’. Lateral line incomplete .......................................................... 17

16. Large mouth opening, extending to the vertical that passes through the nostrils origin, teeth of the inner row of the premaxillary with up to nine cusps; mature males without bony hooks in anal fin; 3-4 (mode 3) maxillary teeth.......................................................... Deuterodon iguape

16’. Small mouth opening, distinctly anterior to the vertical that passes through the nostrils origin, teeth of the inner row of the premaxillary with up to seven cusps; mature males with bony hooks in anal fin; 1-3 (mode 2) maxillary teeth.......................................................... Astyanax ribeirae

17. Flank with a dark stripe or absent stripes; humeral blotch present .... 18

17’. Flank with several black stripes, usually forming a zigzag pattern; humeral blotch absent................................................. Hollandichthys multifasciatus

18. One humeral spot; spot in caudal peduncle present ...................... 19

18’. Two humeral spots; spot in caudal peduncle absent ...................... Hypheosbycon grieni

19. Narrow longitudinal stripe on flank, covering less than one scale in longitudinal series; origin of the dorsal fin vertically passing before the origin of the anal fin; flank scales with reticulated pattern; anal fin with 15-22 branched rays ........................................ Hyphessobrycon boulengeri

19’. Relatively wide longitudinal stripe on flank, covering two or more longitudinal series of scales; origin of the dorsal fin distinctly posterior to the vertical that passes before the origin of the anal fin; flank scales hyaline or with sparse chromatophores; anal fin with 26-31 branched rays .......... Mimagoniates microlepis

20. Body covered with bony plates .................................................. 21

20’. Body naked, i.e., covered by thick skin ........................................ 27

21. Body covered with two longitudinal rows of bone plates, plain (without lateral keels), subterminal mouth (not modified into a sucking disk) ........................................................................ 22 (Callichthyidae)

21’. Body covered with four or more longitudinal rows of bone plates, normally with small lateral keels; inferior mouth, modified into a sucking disk ............................................. 24 (Loricariidae)

22. Longitudinal stripe faded or absent on flank; blotches projecting dorsally and/or ventrally on flank; dark stripe below longitudinal stripe extending from the pelvic fin to the anal fin absent; uniformly colored head, with chromatophores uniformly scattered ............................................. 23

22’. Median dark longitudinal stripe conspicuous on flank, followed below by a narrow dark stripe extending from the pelvic fin to the anal fin absent; blotches projecting ventrally on flank absent; head with dark coloration, and small golden spots ........................................ Scleromyxstax barbatus

23. Three or four vertical dark blotches on the flank, caudal fin with dark narrow stripes .................................................. Scleromyxstax macropterus

23’. Blotches on flank absent, with chromatophores uniformly scattered in the caudal fin ........................................ Scleromyxstax prinonotos

24. Adipose fin absent .................................................................. 25

24’. Adipose fin present .............................................................. Kronicthys heylandi

25. Caudal peduncle rounded, without conspicuous lateral keels ........ 26

25’. Caudal peduncle depressed, with two conspicuous lateral keels ........... Pseudotobythys obtusa

26. Pectoral girdle totally exposed, posterior portion of the supraoperciplate with well-developed odontodes in adults ................................ Schizolecis guinari

26’. Pectoral girdle covered by skin, exposed only posteriorly, posterior portion of the supraoperciplate without odontodes in adults ............... Schizolecis guinari

27. Gill membranes are free to each other and to the isthmus; adipose fin origin anterior to anal fin origin .................................................. 28

27’. Gill membranes joined to each other and to the isthmus; adipose fin origin at vertical or posterior to anal fin origin .................................................. 28

28. Free orbital margin, i.e., eyes not covered by skin; hyaline dorsal fin or with sparse chromatophores, evenly distributed; flank with longitudinal dark stripes ........................................ 29 (Heptapteridae)

28’. Orbital margin not free, i.e., orbital margin covered by skin; dorsal fin with conspicuous dark blotches; flank with vertical dark stripes ................. Microglanis cf. parahybe

29. Dorsal fin origin distinctly ahead at vertical through pelvic fin origin; adipose fin not extending to caudal fin origin (free caudal peduncle dorsally) .................................................. 30

29’. Dorsal fin origin proximately at vertical through pelvic fin origin; adipose fin elongate, extending to caudal fin origin (covering the caudal peduncle area) .................................................. Acentronichthys leptos

30. Maxillary barbell short, not extending to anal fin origin; flank with longitudinally conspicuous dark stripe or dorsally dark stripes; adipose fin origin at vertical through posterior base of pelvic fin .................................................. 31

30’. Maxillary barbell long, extending to anal fin origin; flank uniformly colored; adipose fin origin at vertical through middle base of pelvic fin....... Acentronichthys leptos

31. Long supraoperciplate process, reaching the dorsal fin origin; longitudinal dark stripe extending at vertical through dorsal fin origin to caudal peduncle end; maxillary barbell long, surpassing the pelvic fin origin .................................................. 31

31’. Short supraoperciplate process, not reaching the dorsal fin origin; longitudinal dark stripe absent; albeit with dorsal dark stripes; maxillary barbell short, not reaching the pelvic fin origin .................................................. 31

32. Single dorsal fin, i.e., undivided; lateral line divided into two portions: upper dorsal and inferior ventral ........................................ 33 (Cichliformes)

32’. Dorsal fin divided into two parts; single lateral line, undivided ...... 34

33. Dark longitudinal stripe extending from eye to caudal peduncle; preopercular posterior margin serrated; rounded spot in the upper portion of caudal fin beginning; first Gill arch without lobe in its upper portion .................................................................................. Crevcichla tingui

33’. Humeral spot rounded in the medial portion in flank; preopercular posterior margin smooth; dark spot in caudal fin absent; first Gill arch with developed lobe ........................................ 33 (Cichliformes)
Identification key for coastal stream fishes

34. Caudal fin not bifurcated, i.e. emarginated, truncated, tapered or rounded; yellowish brownish flank, with dark blotches or concentrated chromatophores; small sized body, less than 60 cm in total length .......................... 35 (Gobiiformes)

34'. Caudal fin bifurcated; silver flank, without dark blotches, and blackened lateral line; mid-sized body - ca. 70 cm in total length ................................... 37 (Centropomidae - Incertae Sedis in Carangari)

35. Terminal or slightly superior mouth; free pelvic fins or with attached bases, but not forming an adhesive disk ............................. 36 (Eleotridae)

35'. Slightly inferior mouth; pelvic fins attached by a membrane, forming an adhesive disk ........................................ 37 (Gobiidae)

36. Dark stripe below the eye extending to the dentary; 25-35 scales along longitudinal series; preopercular spine absent ............... Dormitator maculatus

36'. Dark stripe below the eye absent; more than 40 scales in a longitudinal series; preopercular spine present ............................................ Eleotris pisonis

37. Scales on flank beginning at the vertical through the end of the opercular bone; a pair of anterior interorbital pores present; two or three dark stripes on the nostril ................................................................. 38

37'. Scales in the superior portion of the head extending until at vertical through preopercule; normally a single anterorbital pore; dark stripes on the nostril absent ................................................................. Bathygobius soporator

38. Caudal fin truncated or slightly rounded; two dark stripes between the orbit and the nostril; gill rakers present in the upper portion of the first branchial arch .............................................. Awaunos tajasica

38'. Posteriorly tapered caudal fin; three dark stripes between the orbit and the nostril; gill rakers in the upper portion of the first branchial arch absent ............................................................... Ctenogobius shufeldtii

Results

Seven orders, 17 families, and 39 fish species were identified (Table 1). Siluriformes were the most representative order (five families and 13 species), followed by Characiformes (four families and 12 species), Gobiiformes (two families and five species), and Cyprinodontiformes (two families and four species). Gymnotiformes and Synbranchiformes were represented by one species, each one. Twenty-four species (61.5%) are endemic to the Atlantic forest, and three are endangered (Table 1). An identification key for fishes from coastal streams of Juréia-Itatins Ecological Station is provided.

Discussion

In recent decades, current knowledge about fish from Neotropical streams has increased but is still deficient, even in better-exploited regions as southeastern Brazil. Juréia-Itatins Ecological Station represents an important refuge for the conservation of stream fishes, especially Characidium schubarti, Scleromystax macropterus, and S. proionotos that are threatened with extinction in the state of São Paulo since 2014 (State Decree 60.133), as well as Pseudocorynopoma heterandria, Hoplias lacerdae, and Brachyhypopomus jureiae, sampled during other studies (Sabino & Silva 2004, Oyakawa et al. 2006). The main threat to species found in lowland streams such as S. macropterus is the deforestation of restinga (Gonçalves et al. 2016). Furthermore, the studied area has a great regional diversity of fishes, since the high diversity of aquatic environments (e.g. mountain streams with clear waters, lowland streams with black waters, and estuarine rivers with brackish waters), allows a greater diversity of species (Gonçalves & Braga 2012, Ferreira et al. 2014).

An identification key for Atlantic forest fish was published by Oyakawa et al. (2006), but only mentioned 16 of the 39 species reported by us in Juréia-Itatins Ecological Station streams. The present identification key will be useful for the recognition of species in the studied area, especially if used jointly with the color guide available online for free (Gonçalves 2014), which contains 38 photos of the Juréia-Itatins Ecological Station fish. Considering that most of these species are endemic to the coastal streams, this identification key will be useful not only for the species recognition of the sampled area, but also for the surrounding coastal region.

Acknowledgments

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Author Contributions

Cristina da Silva Gonçalves: substantial contribution in the concept and design of the study; contribution to data collection; contribution to data analysis and interpretation; contribution to manuscript preparation and critical revision.

Fernando Rogério Carvalho: substantial contribution in the concept and design of the study; contribution to data analysis and interpretation; contribution to manuscript preparation and critical revision.

Maria Angélica Pérez Mayorga: contribution in the concept and design of the study; contribution to data analysis and interpretation; contribution to manuscript preparation and revision.

Isadora Francesconi de Oliveira: contribution to data analysis and interpretation; contribution to manuscript preparation and revision.

Conflicts of interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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