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PENSOFT

Fishes from the Tirimbina Biological Reserve, La Virgen de Sarapiquí, Heredia, Costa Rica

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Abstract
The Tirimbina Biological Reserve (TBR), located in La Virgen de Sarapiquí, Heredia Province, Atlantic versant (Sarapiquí river basin), Costa Rica, is a private wildlife refuge established as "a place of absolute conservation" and for scientific research. An annotated and illustrated catalog of the fish species known to occur within the limits of the TBR, as well as an identification key to and descriptions of all species listed, is presented. A total of 29 species, 23 genera, 9 families and 6 orders were recorded from 13 localities regularly sampled between December 2009 and December 2016. The conservation status of the species and major threats also are briefly discussed. This contribution will serve as a scientific and educational tool to researchers and conservationists, as well as to the public, interested in knowing and working with the fish fauna of the TBR and surrounding areas.

Key words
Ichthyofauna; Neotropical freshwater fishes; diversity; identification key; photographic album.

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Introduction

The Tirimbina Biological Reserve (TBR) is a 345 ha private wildlife refuge located in La Virgen de Sarapiquí, Heredia Province, Atlantic slope (Sarapiquí river basin), Costa Rica. It is one of the most biologically diverse and relatively well-studied areas of the country (McDade et al. 1993, TBR 2010). The TBR was formally established in 1960, by Dr Robert Hunter, to become "a place of absolute conservation" and for scientific research (TBR 2010). Between 1960 and 1998 the TBR stood out because of the development of several crops that were new to the area (e.g. cacao, pepper, vanilla, and nutmeg) which promoted several research projects, mainly related to the cultivation of cacao, developed by foreign institutions as well as by the Costa Rican Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) (TBR 2010). Before 1999, the TBR adopted a strategic operational plan, which remains in effect today, where incomes from ecotourism are directly invested in conservation through environmental education and scientific research. As a result, the environmental education program is currently considered the "heart" of the TBR, promoting work within the community and local schools (Schmidt 2012).

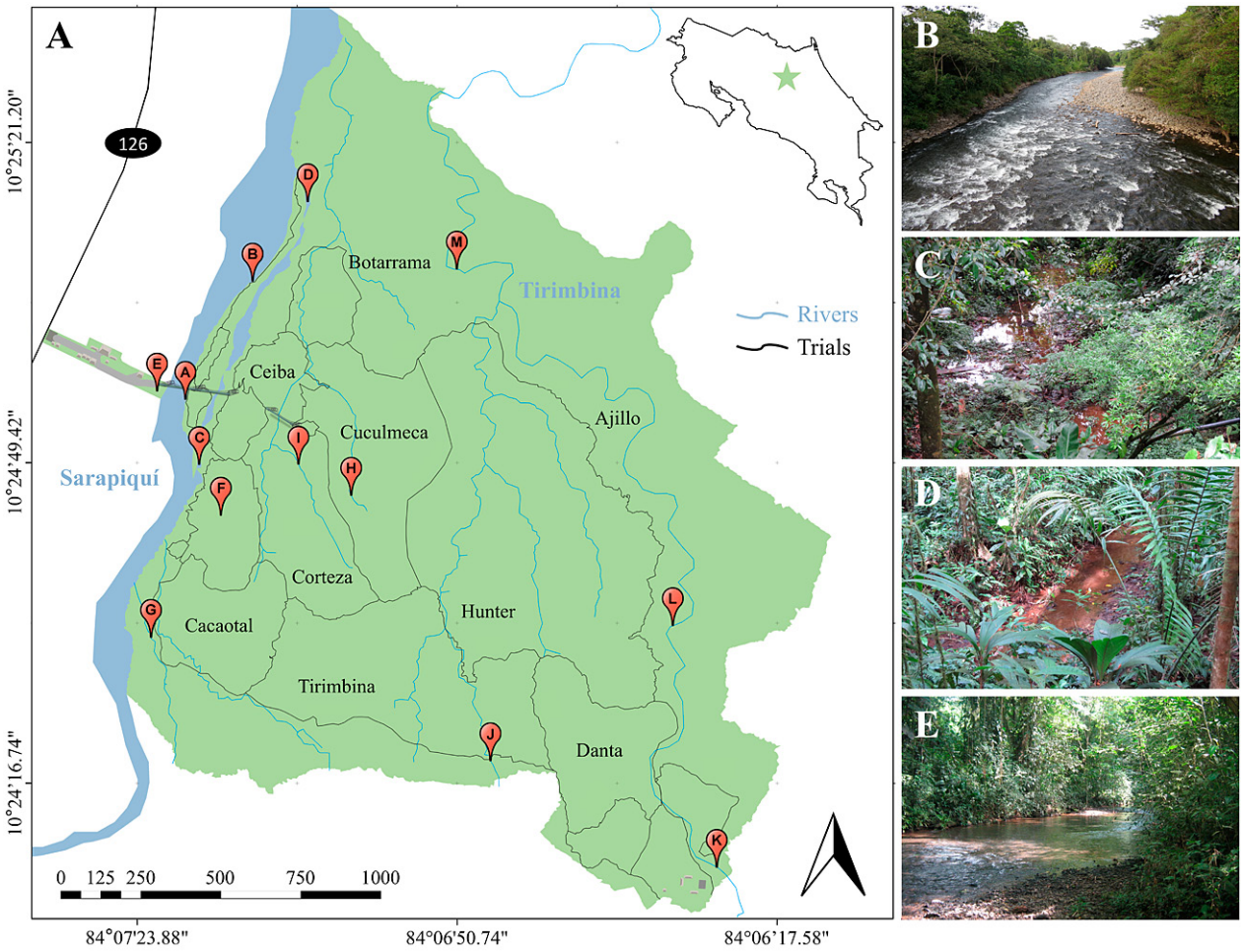

Figure 1. A. Map of the TBR showing the main trails and water bodies with the different sampled localities marked in red (see Table 1 for localities data). **B.** Sarapiquí River, main branch (sampling locality A). **C.** Sarapiquí River small tributary, swamp (sampling locality E). **D.** "Cuculmeca" Creek, tributary of Sarapiquí River (sampling locality H). **E.** Tirimbina River, upper portion (sampling locality K), photo by Carlos Garita.

As part of its scientific research program, the TBR has permanent researchers studying mammals, birds, butterflies, and plants, among other groups. This program has resulted in dozens of newly recorded species and species new to science (e.g. Grishin 2012, Angulo and Gracian-Negrete 2013, Silva and Lapinski 2014). In addition, many external research projects also have been developed at the TBR, including long-term studies and undergraduate and graduate theses from both national and foreign institutions (Finegan and Camacho 1999, TBR 2010, Grøtan et al. 2014); for more information please visit the TBR website at http://www.tirimbina.org/. Based on the above, the TBR is currently considered one of the most important educational, scientific, and ecotourism destinations in Costa Rica.

As in most of the Costa Rican Atlantic lowlands, the TBR is crossed by several rivers and small creeks (Fig. 1). The Sarapiquí River borders the western edge of the reserve for approximately 2.5 km while the Tirimbina River crosses the reserve for roughly 3 km, entering by the southeast corner and leaving it by the reserve's northwesternmost portion (Fig. 1). The whole reserve is currently under protection with almost 100% of forest cover; however, the area surrounding the TBR is highly deforested with most land used for agriculture (mainly banana and pineapple plantations) and cattle (Shaver et al. 2015). Given this, the TBR can be considered as a "purifier", "source", and "reservoir" of the rivers and other water bodies in the area. Besides deforestation, overfishing, introduction of exotic species, and the proliferation of hydroelectric dams represent the main actual threats for the aquatic ecosystems in the area (Anderson et al. 2008). Biological and chemical analyses have been done annually for the last 10 years in the main 2 rivers of the reserve (Sarapiquí and Tirimbina) and indicate relatively good quality levels (Quirós-Sanabria 2017); however, comprehensive studies regarding the health state of these rivers as well as of the aquatic populations in the area are still scarce.

Since 2009, the TBR fish fauna has been extensively sampled by both national and foreign biologists as part of several research projects. Part of the results of these research projects are herein presented under the format of an annotated and illustrated catalog, the first comprehensive study of the fish fauna of the TBR. An identification key to and descriptions of all species listed are also included to provide a tool to help with the identification of the fish species within the TBR, as basis for future inventories

Table 1. Sampling localities within the TBR. ID = locality identification, see also Figure 1 and Table 2.

ID	Sampling localities	Latitude (N)	Longitude (W)	Altitude (m)	General description
A	Sarapiquí River, main branch N1	10°24′56″	084°07′18″	149	Current very strong (40–75 cm/seg); maximum depth about 1.5 m; maximum width about 40 m; mainly rocky substrate with very little organic matter; canopy cover scarce; periphyton present, submerged vegetation absent; emergent vegetation absent; floating vegetation absent.
B	Sarapiquí River, main branch N2	10°25′06″	084°07′12″	148	Current strong (25–75 cm/seg); maximum depth about 1.8 m; maximum width about 60 m; mainly rocky substrate with very little organic matter; canopy cover scarce; periphyton present; submerged vegetation absent; emergent vegetation absent; floating vegetation absent.
C	Sarapiquí River, secondary branch N1	10°24′50″	084°07′16″	167	Current slow to moderate (5–25 cm/seg); maximum depth about 1.5 m; maximum width about 6 m; mainly rocky substrate with sand and little organic matter; canopy cover about 75%; periphyton present; submerged vegetation absent; emergent vegetation absent; floating vegetation absent.
D	Sarapiquí River, secondary branch N2	10°25′16″	084°07′05″	152	Current slow (5–15 cm/seg); maximum depth about 1.2 m; maximum width about 5 m; mainly rocky substrate with sand and organic matter; canopy cover about 75%; periphyton present; submerged vegetation absent; emergent vegetation scares (mainly on the margin); floating vegetation absent.
E	Sarapiquí River small tributary, swamp1	10°24′57 "	084°07′20″	149	None to very slow current (0–10 cm/seg); maximum depth about 0.5 m; maximum width about 3 m; mainly muddy substrate with sand and abundant organic matter; canopy cover about 60%; periphyton absent; submerged vegetation present; emergent vegetation abundant; floating vegetation scarce.
F	Sarapiquí River small tributary, swamp2	10°24′45″	084°07′14″	189	None to very slow current (0–10 cm/seg); maximum depth about 0.8 m; maximum width about 6 m; mainly muddy substrate with sand and abundant organic matter; canopy cover about 85%; periphyton absent; submerged vegetation present; emergent vegetation present; floating vegetation scarce.
G	Sarapiquí River tributary	10°24′33″	084°07′22″	168	Current strong to moderate (15–50 cm/seg); maximum depth about 2.2 m; maximum width about 15 m; mainly rocky substrate with very little organic matter; canopy cover about scarce; periphyton present; submerged vegetation scarce; emergent vegetation present (mainly at the margin); floating vegetation absent.
H	"Cuculmeca" Creek, tributary of Sarapiquí River	10°24′34″	084°07′01″	199	Current slow to moderate (5–25 cm/seg); maximum depth about 0.6 m; maximum width about 3 m; mainly muddy substrate with abundant organic matter; canopy cover about 90%; periphyton absent; submerged vegetation absent; emergent vegetation scarce (mainly at the margin); floating vegetation absent.
I	"Corteza" Creek, tributary of Sarapiquí River	10°24′49″	084°07′07″	186	Current slow to moderate (5–25 cm/seg); maximum depth about 0.5 m; maximum width about 4 m; mainly muddy substrate with abundant organic matter; canopy cover about 90%; periphyton absent; submerged vegetation absent; emergent vegetation scarce (mainly at the margin); floating vegetation absent.
J	"Hunter" Creek, tributary of Tirimbina River	10°24′18″	084°06′47″	198	Current slow to moderate (5–25 cm/seg); maximum depth about 0.4 m; maximum width about 2 m; mainly muddy substrate with sand and organic matter present; canopy cover about 60%; periphyton absent; submerged vegetation absent; emergent vegetation scarce (mainly at the margin); floating vegetation absent.
K	Tirimbina River, N1	10°24′07″	084°06′24 "	198	Current strong to moderate (15–50 cm/seg); maximum depth about 1.2 m; maximum width about 6 m; mainly rocky substrate with very little organic matter; canopy cover about 60%; periphyton present; submerged vegetation scarce; emergent vegetation present (mainly at the margin); floating vegetation absent.
L	Tirimbina River, N2	10°24′32″	084°06′28″	193	Current strong to moderate (15–50 cm/seg); maximum depth about 1.5 m; maximum width about 6 m; mainly rocky substrate with very little organic matter; canopy cover about 80%; periphyton present; submerged vegetation scarce; emergent vegetation present (mainly at the margin); floating vegetation absent.
M	Tirimbina River, N3	10°25′08″	084°06′50″	164	Current strong to moderate (15–50 cm/seg); maximum depth about 1.5 m; maximum width about 8 m; mainly rocky substrate with very little organic matter; canopy cover about 75%; periphyton present; submerged vegetation scarce; emergent vegetation present (mainly at the margin); floating vegetation absent.

and applied works, both at local and regional scale. This contribution will serve as a scientific and educational tool to researches and conservationist, as well as to the public, interested in knowing and working with the fish fauna of the TBR and surrounding areas.

Methods

Field sampling was performed between December 2009 and December 2016. Thirteen localities (Table 1; Fig. 1) were regularly sampled during that period (about 1–5 times per year). Sampling gear included seines, cast nets, and backpack electrofishers; visual censuses also were carried out using mask and snorkel. Collection and research permits (152-2009-SINAC, 181-2010-SINAC, 157-2012-SINAC, 007-2013-SINAC, 004-2015-ACCVC-PI and SINAC-SF-145-2016) were issued by the Costa Rican Ministerio de Ambiente Energía y Telecomunicaciones (MINAET) and the Sistema Nacional de Áreas de Conservación (SINAC). Voucher specimens fixed in about 10% formaldehyde and preserved in about 70% ethanol were deposited at the fish collections of the Museo de Zoología of the Universidad de Costa Rica (UCR), the Museum of Natural Science of the Louisiana State University (LSUMZ) and the Universidad Michoacana de San Nicolás de Hidalgo (CPUM). Species by sampled

Table 2. Fish species recorded within the TBR, by family, order (in parenthesis) and sampling locality (also see Figure 1 and Table 1), with relative abundances (RA) and voucher specimens.

	Sampling localities (see Table 1)														
Family/species	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**RA**	**Voucher**
Characidae (CH) 2/4															
Astyanax bransfordii			X	X			X							UC	UCR 03197
Astyanax nicaraguensis	X	X	X	X	X	X	X				X	X	X	AB	LSUMZ 14731
Eretmobrycon scleroparius	X	X	X	X		X	X				X	X	X	VC	LSUMZ 14732
Roeboides bouchellei			X	X	X	X	X				X	X	X	CO	CPUM 12762
Bryconidae (CH) 1/1															
Brycon costaricensis	X	X	X	X			X				X	X	X	CO	UCR 02936
Heptapteridae (SI) 1/3															
Rhamdia guatemalensis	X	X	X	X		X	X				X			CO	UCR 03197
Rhamdia laticauda	X		X			X					X			CO	UCR 03197
Rhamdia nicaraguensis	X	X				X								CO	UCR 03197
Atherinopsidae (AT) 1/1															
Atherinella hubbsi			X	X			X				X		X	UN	CPUM 12754
Poeciliidae (CY) 6/6															
Alfaro cultratus			X	X	X	X	X				X		X	VC	UCR 03197
Brachyrhaphis parismina				X			X		X		X			UC	UCR 03197
Phallichthys amates			X	X		X	X	X	X	X	X	X	X	VC	LSUMZ 14734
Poecilia gillii	X	X	X	X		X	X	X	X	X	X	X	X	AB	CPUM 12759
Priapichthys annectens			X	X	X	X	X	X	X	X	X		X	CO	UCR 03197
Xenophallus umbratilis				X			X							UC	UCR 03197
Synbranchidae (SY) 1/1															
Synbranchus marmoratus					X									RA	UCR 02614
Mugilidae (PE) 2/2															
Agonostomus monticola	X	X		X			X				X	X		CO	CPUM 12749
Joturus pichardi	X													RA	UCR 02257
Cichlidae (PE) 6/9															
Amatitlania septemfasciata	X	X	X	X	X	X	X				X	X	X	VC	CPUM 12770
Amatitlania siquia	X		X	X	X	X	X				X	X	X	VC	CPUM 12771
Cribroheros alfari	X	X	X	X	X	X	X				X		X	CO	UCR 03197
Hypsophrys nicaraguensis				X			X				X			UC	CPUM 12767
Neetroplus nematopus	X	X	X	X			X				X	X		CO	CPUM 12761
Parachromis dovii			X	X		X	X				X		X	UC	UCR 02540
Parachromis loisellei				X			X				X			RA	UCR 03197
Parachromis managuensis							X							RA	UCR 03197
Tomocichla tuba	X	X	X	X			X				X	X		CO	LSUMZ 14729
Gobiidae (PE) 2/2															
Awaous banana	X						X							UC	UCR 03197
Sicydium altum	X	X					X					X		CO	CPUM 12776

locality and catalog numbers for voucher specimens are listed in Table 2.

The catalog is arranged phylogenetically at the ordinal and familial levels following Eschmeyer and Fong (2017). Genera and species within each family are arranged in alphabetical order. Number of species (S), genera (G) and families (F) are indicated for each more inclusive taxon. Valid species names, their authorities and year of publication follow Eschmeyer et al. (2017). When available, common English (En) and Spanish (Sp) names are provided after the species name following Bussing (1998), Angulo (2013), and Froese and Pauly (2017). Synonyms, after Angulo et al. (2013), are also listed. Identifications were carried out following Bussing (1998). Diagnosis, coloration pattern and maximum body length (standard length: SL; in mm) are provided for each species according to Bussing (1998), Froese and Pauly (2017), the original diagnosis of the species and to information collected by us in the field. Finally, since no standardized samplings were feasible given the use of different sampling gears according to the conditions of each sampled locality, relative abundances (Table 2) were defined by us considering the number of specimens captured during the entire sampling period [i.e. rare (R) species were those for which we captured less than 5 individuals; uncommon (UC) were those with 5–20 captures; common (CO) were those with more than 20 to about 75 captures; very common (VC) were those with more than 75 to about 150 captures; and abundant (AB) were those with more than 150 captures].

Results

A total of 29 species, 23 genera, 9 families and 6 orders were recorded. The orders represented are (in order of species richness): Perciformes (PE; 3 F/10 G/13 S),

Cyprinodontiformes (CY; 1 F/6 G/6 S), Characiformes (CH; 2 F/4 G/5 S), Siluriformes (SI; 1 F/1 G/3 S), Atheriniformes (AT; 1 F/1 G/1 S), and Synbranchiformes (SY; 1 F/1 G/1 S). The families represented are (in order of species richness): Cichlidae (6 G/9 S), Poeciliidae (6 G/6 S), Characidae (3 G/4 S), Heptapteridae (1 G/3 S), Gobiidae (2 G/2 S), Mugilidae (2 G/2 S), Atherinopsidae (1 G/1 S), Bryconidae (1 G/1 S) and Synbranchidae (1 G/1 S).

Four species were listed as rare, 6 as uncommon, 11 as common, 5 as very common, and 2 as abundant. Sampling localities were usually dominated by *Poecilia gillii* (Poeciliidae) and/or *Astyanax nicaraguensis* (Characidae), with exception of the sites H, I, and J in which only 3 or 4 species of poeciliids (*Brachyrhaphis parismina*, *Phallichthys amates*, *Poecilia gillii*, and *Priapichthys annectens*) were recorded. The site G was the most diverse with 25 species recorded, followed by the sites D and L with 22 and 21 species, respectively.

According to their supposed tolerance to salinity (see Myers 1949), only 8 species (27.5%) are primary or obligate freshwater, while the vast majority (21 species; 72.5%) are secondary freshwater. All species herein listed are native from Costa Rica and the Sarapiquí river basin, i.e. no exotic and/or invasive species were recorded. All species with exception of *Agonostomus monticola* are classified as Data Deficient according to the International Union for Conservation of Nature (IUCN) Red List categories and criteria (IUCN 2016). *Agonostomus monticola*, with a postulated distribution ranging from southeast United Stated to Venezuela (both versants, Pacific and Atlantic), including the Cocos and Galapagos Islands (Bussing 1998), is classified as Least Concern, showing stable populations trends.

Order Characiformes (2 F/4 G/5 S)
Family Characidae (3 G/4 S)

(1) ***Astyanax bransfordii*** (Gill 1877: 190); Longjaw tetra (En), Sardina picuda (Sp)
Figure 2A
Bramocharax bransfordii (Gill 1877): 190—Angulo et al. (2013): 991.

Body elongate and moderately deep; snout length about equal or usually larger than eye diameter; both jaws of equal length, usually elongate; premaxillary teeth unicuspid and enlarged; nape usually convex or straight; fins without strong spines; a single dorsal fin; adipose fin present, its base shorter than the base of the dorsal fin; caudal fin forked; general coloration white silvery, darker dorsally, usually olive gray, and paler, usually white, ventrally, with a gray lateral band; caudal blotch black and rhomboid, mainly on peduncle and caudal fin base; fins usually transparent, in some specimens, the anal fin can be (partially) light red or rose and the caudal fin orange or red with the middle rays black; maximum body length ca 150 mm SL.

(2) ***Astyanax nicaraguensis*** Eigenmann and Ogle 1907: 23; Nicaraguan tetra (En), Sardina (Sp)
Figure 2B
Astyanax aeneus (Günther 1860): 319—Angulo et al. (2013): 991, in part.

Body elongate and moderately deep; snout length usually shorter than the eye diameter; both jaws of equal length, not enlarged; premaxillary teeth multicuspid, usually not enlarged; nape usually convex or straight; fins without strong spines; a single dorsal fin; adipose fin present, its base shorter than the base of the dorsal fin; caudal fin forked; general coloration white silvery, darker dorsally, usually greenish brown, and paler, usually pearl white, ventrally, with a gray lateral band; humeral blotch dark and vertically elongate; caudal blotch black and rhomboid, mainly on peduncle and caudal fin base; fins usually transparent with little dark pigment, in some specimens, the anal fin can be (partially) red, orange and/or yellow; maximum body length ca 140 mm SL.

(3) ***Eretmobrycon scleroparius*** (Regan 1908: 455); Creek tetra (En), Sardina de quebrada (Sp)
Figure 2C
Bryconamericus scleroparius (Regan 1908): 455—Angulo et al. (2013): 992.

Body elongate and moderately deep; snout length usually shorter than the eye diameter; both jaws of equal length, not enlarged; teeth multicuspid, usually not enlarged; nape usually convex or straight; fins without strong spines; a single dorsal fin; adipose fin present, its base shorter than the base of the dorsal fin; caudal fin forked; general coloration white silvery, darker dorsally, usually moss green, and paler, usually pearl white (orange or red in mature specimens), ventrally, with a diffuse violet spot present on the opercle, in live specimens, and a silvery yellow lateral band; humeral blotch dark and vertically elongate; caudal blotch black and rhomboid, mainly on peduncle and caudal fin base; fins usually orange-yellow with little dark pigment; maximum body length ca 110 mm SL.

(4) ***Roeboides bouchellei*** Fowler 1923: 25; Crystal tetra (En), Sardinilla (Sp)
Figure 2D

Body moderately elongate and moderately deep, strongly compressed; snout length usually shorter than the eye diameter; both jaws of equal length, not enlarged; 2 pairs of external teeth on premaxillary; nape concave; fins without strong spines; a single dorsal fin; adipose fin present, its base shorter than the base of the dorsal fin; anal fin very long with 42–50 rays; caudal fin forked; general coloration yellowish silver to almost transparent, darker dorsally, usually greenish yellow-green, and paler, usually pearl white, ventrally; fins usually transparent, yellowish (or light orange) in some specimens, and with black margins; maximum body length ca 105 mm SL.

Family Bryconidae (1 G/1 S)

(5) ***Brycon costaricensis*** Angulo and Gracian-Negrete 2013: 258; Machaca (En/Sp)
Figure 2E

Body elongate, robust, fusiform; snout length usually shorter than the eye diameter; upper jaw in advance of

Figure 2. Species of the Characiformes in the TBR. **A.** *Astyanax bransfordii* (Gill, 1877, upper: adult specimen, about 105 mm SL, lower: detail of the snout (elongate and with unicuspid teeth). **B.** *Astyanax nicaraguensis* Eigenmann & Ogle, 1907, upper: adult specimen, about 100 mm SL, lower: adult specimen, about 80 mm SL. **C.** *Eretmobrycon scleroparius* (Regan, 1908), upper: adult specimen, about 65 mm SL, lower: adult specimen, about 95 mm SL. **D.** *Roeboides bouchellei* Fowler, 1923, upper: juvenile specimen, about 42 mm SL, middle: adult specimen, about 85 mm SL, lower: adult specimen, about 93 mm SL. **E.** *Brycon costaricensis* Angulo & Gracian-Negrete, 2013, upper: juvenile specimen, about 120 mm SL, middle: adult specimen, about 190 mm SL, lower: detail of the snout (upper jaw in advance of lower jaw).

lower jaw; upper jaw with 3 or 4 rows of teeth; premaxillary teeth multicuspid, usually not enlarged; nape usually convex or straight; fins without strong spines; a single dorsal fin; adipose fin present, its base shorter than the base of the dorsal fin; caudal fin forked; general coloration silvery, olive dorsally (more prominent in larger specimens) and white ventrally; fins usually transparent, pinkish or yellowish in some specimens (specially the dorsal and caudal fins); maximum body length ca 500 mm SL.

Order Siluriformes (1 F/1 G/3 S)
Family Heptapteridae (1 G/3 S)

(6) ***Rhamdia guatemalensis*** (Günther 1864: 122); Catfish (En), Barbudo (Sp)
Figure 3A

Body very elongate; 3 pairs of barbels, maxillary barbels relatively long (usually extending beyond the pectoral fin origin, sometimes passing the caudal fin origin); scales absent; fins with strong spines; serrations present on both margins of the pectoral fin spine; a single dorsal fin; adipose fin present, its base larger than the base of the dorsal fin and occupying about 75% or more of the distance between the dorsal fin insertion and the origin of the caudal fin; caudal fin forked; general coloration brownish gray, darker dorsally, usually dark gray to tan, and paler, usually white, ventrally; the dorsal and caudal fins are dusky and the paired and anal fins are almost transparent or white; maximum body length ca 270 mm SL.

(7) ***Rhamdia laticauda*** (Kner 1858: 420); Catfish (En), Barbudo (Sp)
Figure 3B

Body very elongate; 3 pairs of barbels, maxillary barbels not extending beyond the pectoral fin origin; scales absent; fins with strong spines; serrations present only on the inner (posterior) margin of the pectoral fin spine, or absent; a single dorsal fin; adipose fin present, its base larger than the base of the dorsal fin and occupying about 50% of the distance between the dorsal fin insertion and the origin of the caudal fin; caudal fin forked; general coloration brownish gray, darker dorsally, usually dark gray to tan, and paler, usually yellowish white or almost white, ventrally; fins usually gray, white or almost transparent; maximum body length ca 225 mm SL.

(8) ***Rhamdia nicaraguensis*** (Günther 1864: 125); Catfish (En), Barbudo (Sp)
Figure 3C

Body very elongate; 3 pairs of barbels, maxillary barbels usually extending beyond the dorsal fin origin up to the pelvic fin insertion; scales absent; fins with strong spines; serrations present only on the inner (posterior) margin of the pectoral fin spine, or absent; a single dorsal fin; adipose fin present, its base larger than the base of the dorsal fin and occupying about 75% or more of the distance between the dorsal fin insertion and the origin of the caudal fin; caudal fin forked; general coloration brownish gray, darker dorsally, usually dark gray to tan, and paler, usually yellowish white or almost white, ventrally; the dorsal and caudal fins are dusky and the paired and anal fins are almost gray, transparent or white lightly pigmented; maximum body length ca 260 mm SL.

Order Atheriniformes (1 F/1 G/1 S)
Family Atherinopsidae (1 G/1 S)

(9) ***Atherinella hubbsi*** (Bussing 1979: 400); Silverside (En), Pejerrey (Sp)
Figure 3D

Body very elongate and compressed; 2 dorsal fins; anal fin spine weak and flexible; caudal fin forked; general coloration light yellowish (almost transparent), darker dorsally, usually yellowish olive, and paler, usually white, ventrally, with a conspicuous silver stripe (usually black or dark brown bordered) along the mid-side of the body in both live and preserved specimens; fins usually transparent or light yellow (generally the dorsal and the caudal fins); maximum body length ca 90 mm SL.

Order Cyprinodontiformes (1 F/6 G/6 S)
Family Poeciliidae (6 G/6 S)

(10) ***Alfaro cultratus*** (Regan 1908: 458); Knife livebearer (En), Olomina (sp)
Figure 3E

Body elongate, moderately deep and deeply compressed; lateral line reduced to a series of individual pits along side of body; fins without spines; a single dorsal fin; males with anal fin modified into a short gonopodium not extending beyond the dorsal fin insertion; ventral margin of the caudal peduncle sharp and compressed, scales forming a sheathed keel; caudal fin rounded; general coloration yellowish gray or pale yellow (almost transparent in some specimens) with metallic blue/green flashes in the abdomen and a thin dark line running along the entire length of the body; fins transparent or yellow; maximum body length ca 65 mm SL.

(11) ***Brachyrhaphis parismina*** (Meek 1912: 86); Parismina livebearer (En), Olomina (Sp)
Figure 3F

Body elongate and moderately deep; lateral line reduced to a series of individual pits along side of body; fins without spines; a single dorsal fin; males with anal fin modified into a long gonopodium usually extending beyond the dorsal fin insertion; caudal fin rounded; general coloration yellowish gray with a fine black line along the mid-side of the body; fins usually transparent or yellowish with few dark pigmentation; anal fin with a black blotch mainly covering it antero-basal portion; maximum body length ca 40 mm SL.

(12) ***Phallichthys amates*** (Miller 1907: 108); Merry widow (En), Olomina (Sp)
Figure 4A

Body moderately elongate and deep, almost rhomboid, moderately compressed; lateral line reduced to a series of individual pits along side of body; fins without spines; a single dorsal fin; males with anal fin modified

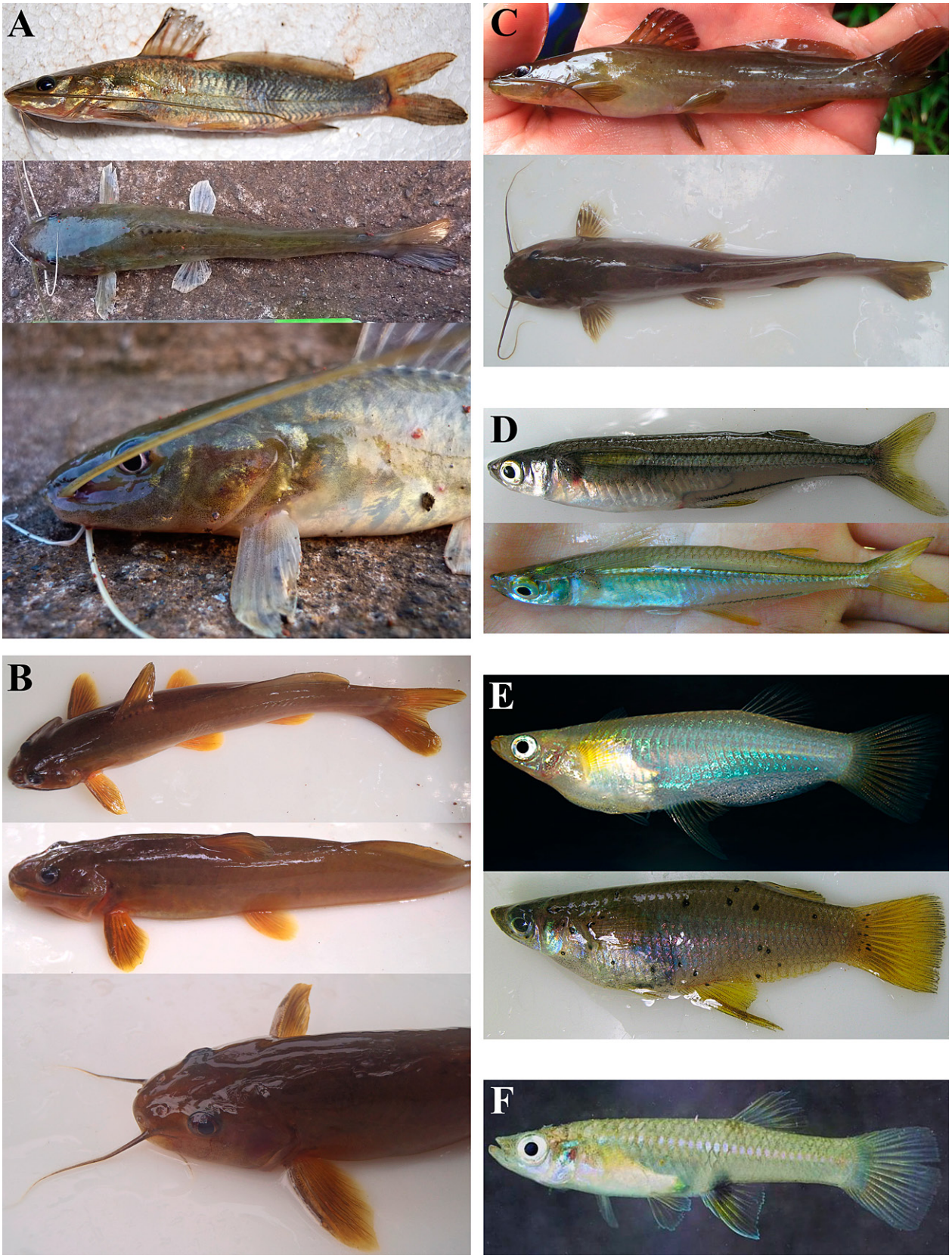

Figure 3. Species of the Siluriformes, Atheriniformes and Cyrpinodontiformes (in part) in the TBR. **A.** *Rhamdia guatemalensis* (Günther, 1864), upper: adult specimen, about 160 mm SL, middle: adult specimen, about 142 mm SL, dorsal view, lower: detail of the head. **B.** *Rhamdia laticauda* (Kner, 1858), upper: adult specimen, about 98 mm SL, dorsolateral view, middle: adult specimen, about 98 mm SL, lower: detail of the head, dorsolateral view. **C.** *Rhamdia nicaraguensis* (Günther, 1864), upper: adult specimen, about 115 mm SL, lower: adult specimen, about 100 mm SL, dorsal view. **D.** *Atherinella hubbsi* (Bussing, 1979), upper: adult specimen, about 78 mm SL, lower: adult specimen, about 90 mm SL. **E.** *Alfaro cultratus* (Regan 1908), upper: adult specimen, about 55 mm SL, female, lower: adult specimen, about 60 mm SL, male (parasite by the trematode *Uvulifer* ambloplitis encysted in skin). **F.** *Brachyrhaphis parismina* (Meek, 1912), adult specimen, about 38 mm SL.

into a long gonopodium extending to the caudal fin origin; caudal fin rounded; general coloration yellowish gray or pale yellow (almost transparent in some specimens) with bluish or purplish highlights; in some specimens, scales bordered by black, giving a cross-hatch pattern to the body (this pattern is more intensive along the mid-line of the flanks and sometimes resembles a series of X's along the body); females usually with prominent black or purple blotch covering base of pelvic and/or anal fins; fins usually transparent or yellowish; maximum body length ca 70 mm SL.

(13) ***Poecilia gillii*** (Kner 1863: 224); Molly (En), Olomina panzona (Sp)
Figure 4B

Body elongate and moderately deep, robust; lateral line reduced to a series of individual pits along side of body; fins without spines; a single dorsal fin; males with anal fin modified into a short gonopodium not extending beyond the dorsal fin insertion; caudal fin truncate to rounded; general coloration yellowish gray or pale yellow, darker dorsally, usually yellowish or grayish brown, and paler, usually yellowish white or almost white with bluish or greenish highlights, ventrally; sides with 6–8, usually 7, rows of yellow dots (1 per scale); fins usually transparent or yellow, red, principally the dorsal fin, in a few specimens); in some males the dorsal and caudal fins have black spots or blotches on the base; maximum body length ca 100 mm SL.

(14) ***Priapichthys annectens*** (Regan 1907: 259); Livebearer (En), Olomina (Sp)
Figure 4C

Body elongate and moderately deep; teeth conical and well fixed in the jaws; jaw bones firmly united; lateral line reduced to a series of individual pits along side of body; fins without spines; a single dorsal fin; males with anal fin modified into a long gonopodium extending beyond the dorsal fin insertion; caudal fin rounded; general coloration grayish yellow, darker dorsally, usually brownish yellow, and paler, usually yellowish white or almost white with bluish or purplish highlights, ventrally, and with 6–12, usually 6–8 dark bars on the sides; the scales are conspicuously bordered with black, giving a cross-hatch pattern to the body (this pattern is more intensive along the mid-line of the flanks and sometimes resembles a series of X's along the body); fins usually transparent, yellowish or orange in some specimens, with membranes of the dorsal fin base with elongate black blotches and the distal portion usually orange; maximum body length ca 60 mm SL.

(15) ***Xenophallus umbratilis*** (Meek 1912: 390); Livebearer (En), Olomina (Sp)
Figure 4D

Body elongate and moderately deep; lateral line reduced to a series of individual pits along side of body; fins without spines; a single dorsal fin; males with anal fin modified into a long gonopodium extending beyond the dorsal fin insertion; gonopodium asymmetric, either dextral or sinistral; caudal fin rounded; general coloration grayish yellow, darker dorsally, usually brownish yellow, and paler, usually yellowish white or almost white ventrally; juveniles and adult males with 5–10 black bars on the flanks; fins usually transparent or yellowish, the dorsal fin have the first ray black and a wedge-shaped black base, usually with a dusky posterior margin (in males, the remaining fin is usually brilliant yellow); maximum body length ca 45 mm SL.

Order Synbranchiformes (1 F/1 G/1 S)
Family Synbranchidae (1 G/1 S)

(16) ***Synbranchus marmoratus*** Bloch 1795: 87; Marbled swamp eel (En), Anguila de pantano (Sp)
Figure 4E

Body elongate, eel-like; scales absent; pectoral, pelvic and caudal fins absent; dorsal and anal fins vestigial (reduced to a rayless ridge); general coloration grayish brown or yellowish brown, darker dorsally and paler ventrally, usually with dark speckles of variable size ventrally; maximum body length ca 1500 mm SL.

Order Perciformes (3 F/10 G/13 S)
Family Mugilidae (1 G/2 S)

(17) ***Agonostomus monticola*** (Bancroft 1834: 367); Mountain mullet (En), Tepemechín (sp)
Figure 5A

Body elongate, robust, fusiform; mouth about terminal; fins with strong spines; 2 dorsal fins; second dorsal fin rays 9; anal fin rays 10; caudal fin forked; general coloration gray olive, darker dorsally, and paler, usually yellowish white ventrally; dark scale edges form crisscross lines on upper body; fins usually yellowish; maximum body length ca 300 mm SL.

(18) ***Joturus pichardi*** Poey 1860: 263; Bobo mullet (En), Bobo (Sp)
Figure 5B

Body elongate, robust, fusiform; mouth ventral (below a tumid, fleshy and projecting snout); fins with strong spines; 2 dorsal fins; second dorsal fin rays 10 or rarely 11; anal fin rays 11; caudal fin forked or lunate; general coloration silvery to grey green or green olive in adults, and silvery white, with dark stripes on dorsal, anal and caudal fins in juveniles; fins usually transparent, pinkish in some adult specimens; maximum body length ca 700 mm SL.

Family Cichlidae (6 G/9 S)

(19) ***Amatitlania septemfasciata*** (Regan 1908: 461); Seven stripe cichlid (En), Mojarra (Sp)
Figure 5C

Cryptoheros septemfasciatus (Regan 1908): 461—Angulo et al. (2013): 1005.

Body moderately elongate and deep; predorsal profile of head slightly curved, snout relatively short and convex, usually ca 33–43% of head length; mouth terminal, rarely inferior, relatively short, usually <30% of head length;

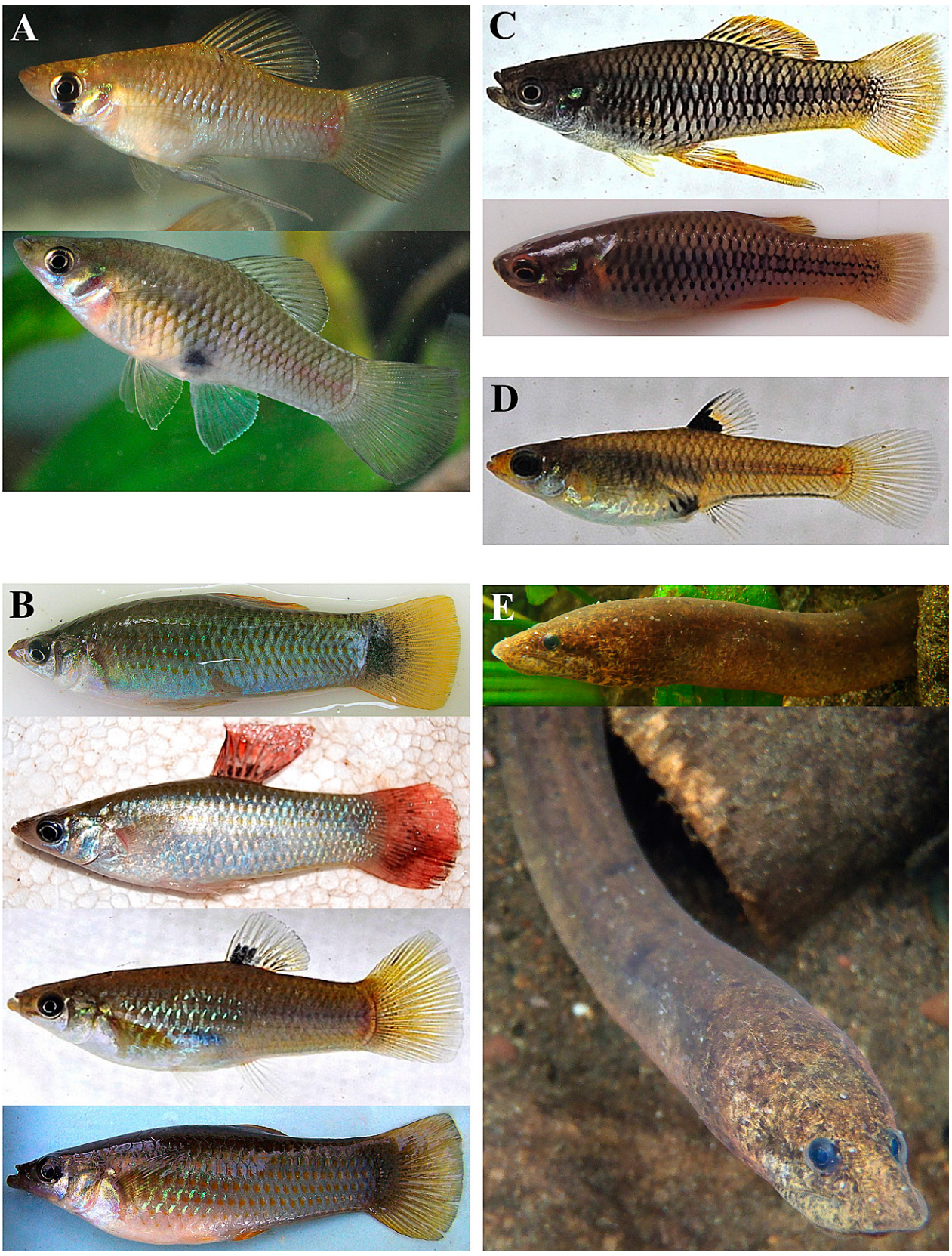

Figure 4. Species of the Cyprinodontiformes (continuation) and Synbranchiformes in the TBR. **A.** *Phallichthys amates* (Miller, 1907), upper: adult specimen, about 60 mm SL, male, lower: adult specimen, about 58 mm SL, female. **B.** *Poecilia gillii* (Kner, 1863), upper: adult specimen, about 75 mm SL, male, yellow fins form, middle-upper: adult specimen, about 78 mm SL, male, red fins form, middle-lower: adult specimen, about 60 mm SL, female; lower: adult specimen, about 70 mm SL, female. **C.** *Priapichthys annectens* (Regan, 1907), adult specimen, about 42 mm SL, male, lower: adult specimen, about 38 mm SL, female. **D.** *Xenophallus umbratilis* (Meek, 1912), adult specimen, about 35 mm SL, female. **E.** *Synbranchus marmoratus* Bloch, 1795, juvenile specimen, about 320 mm total length.

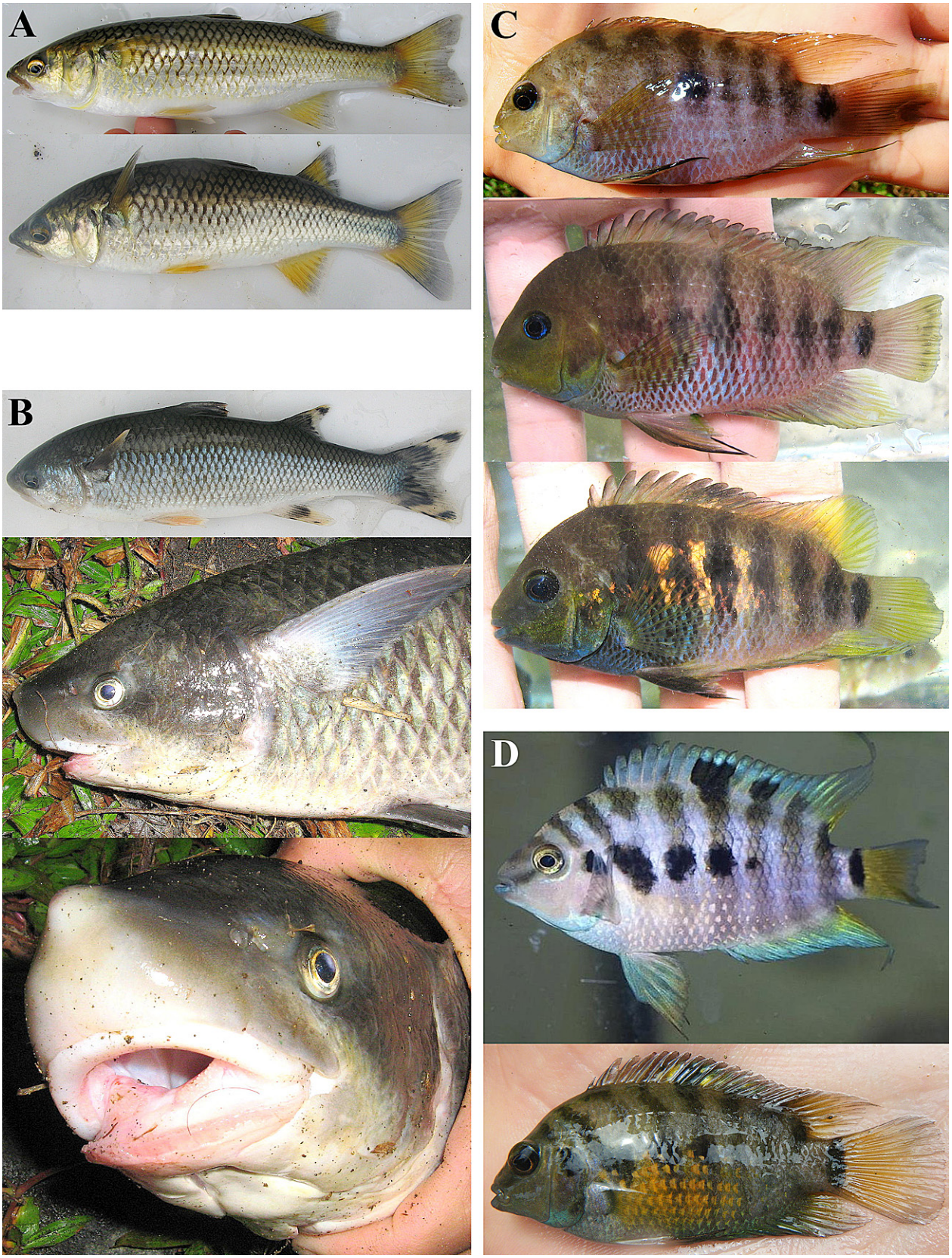

Figure 5. Species of the Perciformes (Mugilidae and Cichlidae, in part) in the TBR. **A.** *Agonostomus monticola* (Bancroft, 1834), upper: adult specimen, about 140 mm SL, lower: adult specimen, about 155 mm SL. **B.** *Joturus pichardi* Poey, 1860, upper: juvenile specimen, about 135 mm SL, middle: detail of the head (mouth ventral, below a tumid, fleshy and projecting snout), lower: detail of the mouth. **C.** *Amatitlania septemfasciata* (Regan, 1908), upper: adult specimen, about 66 mm SL, female, middle: adult specimen, about 75 mm SL, male, lower: adult specimen, about 70 mm SL, mature female. **D.** *Amatitlania siquia* Schmitter-Soto, 2007, upper: adult specimen, about 64 mm SL, mature female, lower: adult specimen, about 53 mm SL, mature male.

maxillary not extending to below the eye; jaws of equal length; teeth conical and cylindrical, somewhat enlarged, but no large canines; lateral line conspicuous, divided in 2 straight overlapping sections; fins with strong spines; a single dorsal fin; caudal fin truncate; general coloration maroon-brown (males) or grayish brown (females), darker dorsally and paler ventrally; iris bluish; opercular blotch absent; flanks usually with 6 diffuse black vertical bars, the third usually more prominent and forming an oval blotch; first vertical bar not Y-shaped; median fins solid maroon brown and pelvic fins dusky; caudal blotch mainly on caudal peduncle; during the reproductive season, the females becomes bluish gray on the lower half of the head and the abdomen, a large golden/orange area appears on the middle of the side, the median fins change to gray, the spinous dorsal fin shows a long black blotch with golden edges and the anal fin acquires blue tints; maximum body length ca 100 mm SL.

(20) ***Amatitlania siquia*** Schmitter-Soto 2007: 54; Honduran red point cichlid (En), Mojarrita (Sp)
Figure 5D

Body moderately elongate and deep; predorsal profile of head usually straight or slightly curved, relatively short and convex, usually ca 33–43% of head length; mouth terminal, rarely inferior or ventral, relatively short, usually <30% of head length; maxillary not extending to below the eye; jaws of equal length, rarely upper jaw in advance of lower jaw; teeth conical and cylindrical, somewhat enlarged, but no large canines; lateral line conspicuous, divided in two straight overlapping sections; fins with strong spines; a single dorsal fin; caudal fin truncate; general coloration tan or brownish purple, darker dorsally and paler ventrally; iris usually golden or yellowish; opercular blotch present; flanks usually with 6–8 relatively well defined black vertical bars; first vertical bar Y-shaped; fins pale, with the dark bars extending partially onto the dorsal and anal fins; caudal blotch mainly on caudal fin base; during the reproductive season, in the females, the striped pattern is intensified, the lower part of the head in darkened and a golden coloration appears on the scales of the lower half of the sides; maximum body length ca 100 mm SL.

(21) ***Cribroheros alfari*** (Meek 1907: 148); Pastel cichlid (En), Mojarra (Sp)
Figure 6A
Amphilophus alfari (Meek 1907): 148—Angulo et al. (2013): 1004.

Body moderately elongate and deep; predorsal profile of head usually straight or slightly curved, snout relatively long, pointed, straight and produced, usually ca 43–53% of head length; mouth terminal, rarely inferior or ventral, relatively short, usually <30% of head length; maxillary not extending to below the eye; jaws of equal length, rarely upper jaw in advance of lower jaw; teeth conical and cylindrical, somewhat enlarged, but no large canines; lateral line conspicuous, divided into 2 straight overlapping sections; fins with strong spines; a single dorsal fin; caudal fin truncate; general coloration olive brown, darker dorsally and paler, usually reddish white, ventrally, with a dark band between eye and lateral line, and 3–5 brown vertical bars, separated by paler spaces, on posterior portion of the flanks; head and body with irregular iridescent blue spots or vermiculations; median fins tan, in some specimens the dorsal and caudal fins are covered with evenly distributed blue dots; edge of the dorsal fin bicolored (margin red with a submarginal blue line below) and edge of anal fin olive brown; pectoral and pelvic fins usually transparent, gray, yellowish, or reddish; maximum body length ca 150 mm SL.

(22) ***Hypsophrys nicaraguensis*** (Günther 1864: 153); Butterfly cichlid (En), Moga amarilla (Sp)
Figure 6B

Body moderately elongate and deep; predorsal profile of head usually curved, snout convex, rarely pointed; mouth inferior, usually ventral; teeth of outer rows compressed antero-posteriorly (incisors), at least at the tip; lateral line conspicuous, divided into 2 straight overlapping sections; fins with strong spines; a single dorsal fin; anal fin spines 6–9; caudal fin truncate; general coloration grayish yellow, with the mid-body usually with a large black blotch on the mid-side crossed or not by a dark lateral stripe; upper portion of the snout usually yellowish or in some adult specimens grayish blue-green, without black stripes joining the eyes; iris usually yellowish; fins usually grayish yellow; maximum body length ca 165 mm SL.

(23) ***Neetroplus nematopus*** (Günther 1867: 603); Poor man's tropheus (En), Moga (Sp)
Figure 6C
Hypsophrys nematopus (Günther 1867): 603—Angulo et al. (2013): 1005.

Body elongate and moderately deep; predorsal profile of head usually curved, snout convex, rarely pointed; mouth inferior, usually ventral; teeth with flattened or truncate tips; lateral line conspicuous, divided in 2 straight overlapping sections; fins with strong spines; a single dorsal fin; caudal fin truncate; general coloration grayish brown or grayish olive, usually with 7 dark bars on the flanks in juveniles and a broad dark bar on the mid-body in adults and some juveniles (during breading season this pattern is reversed, that is, a white bar appears on a dark gray background); median fins brown; pectoral fins clear and pelvic fins dusky; iris usually bluish, silvery in a few specimens; maximum body length ca 140 mm SL.

(24) ***Parachromis dovii*** (Günther 1864: 154); Rainbow bass (En), Guapote lagunero (Sp)
Figure 6D

Body elongate, greatest body depth smaller than head length; predorsal profile of head usually straight or slightly curved, snout usually pointed; mouth terminal, relatively large, usually ca 30–40% of head length; maxillary extending to below eye; lower jaw usually in advance of upper jaw; teeth enlarged, caniniform; posterior edge of opercle almost straight; total gill rakers 9–13; lateral

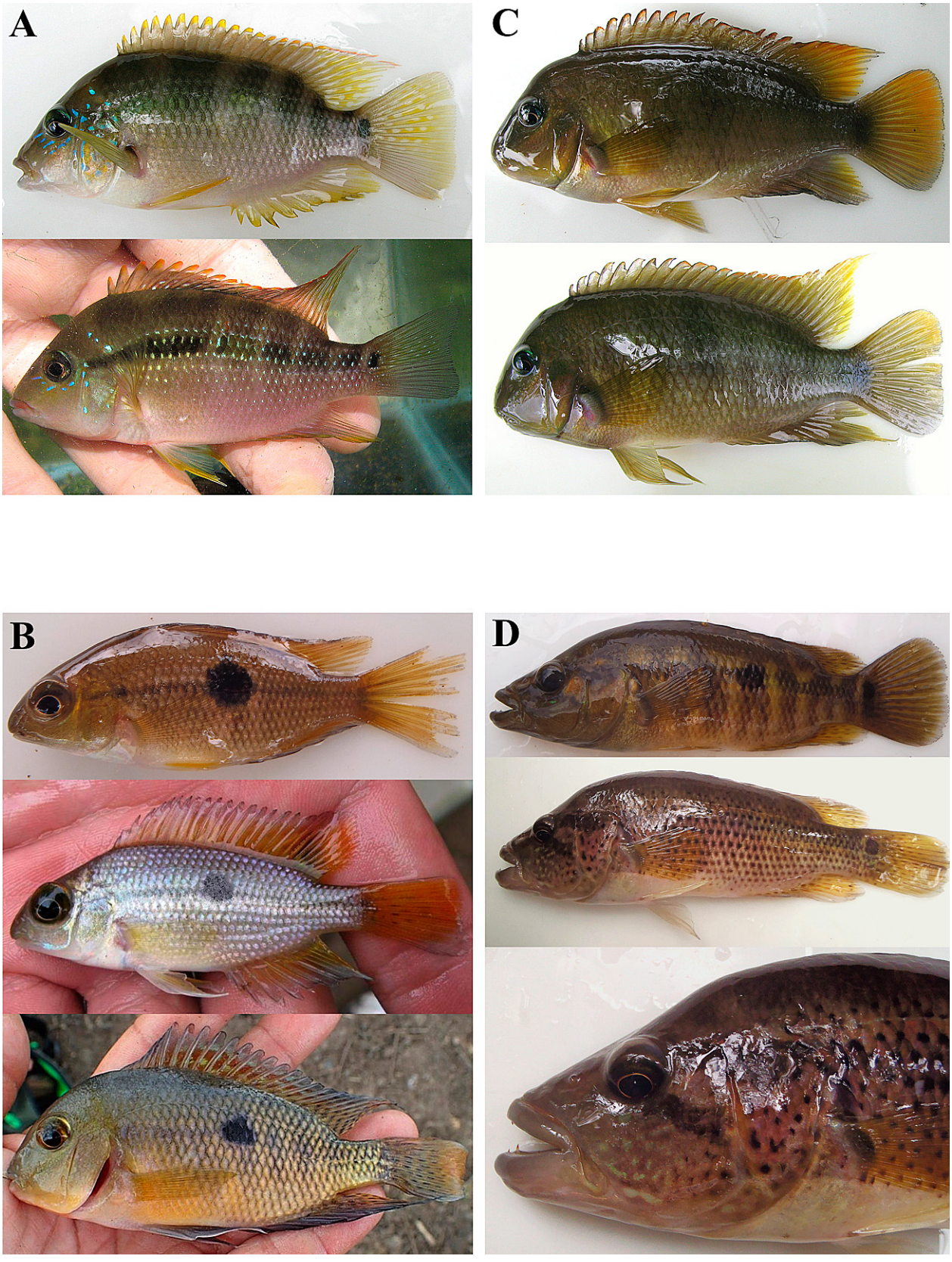

Figure 6. Species of the Perciformes (continuation: Cichlidae, in part) in the TBR. **A.** *Cribroheros alfari* (Meek, 1907), upper: adult specimen, about 70 mm SL, lower: adult specimen, about 75 mm SL. **B.** *Hypsophrys nicaraguensis* (Günther, 1864), upper: juvenile specimen, about 52 mm SL, middle: juvenile specimen, about 55 mm SL, lower: adult specimen, about 106 mm SL. **C.** *Neetroplus nematopus* (Günther, 1867), upper: juvenile specimen, about 68 mm SL, lower: adult specimen, about 112 mm SL. **D.** *Parachromis dovii* (Günther, 1864), upper: juvenile specimen, about 75 mm SL, middle: adult specimen, about 118 mm SL, lower: detail of the head (mouth terminal, relatively large, maxillary extending to below the eye, lower jaw usually in advance of upper jaw, teeth enlarged, caniniform).

line conspicuous, divided into 2 straight overlapping sections; longitudinal scales 31–34; fins with strong spines; a single dorsal fin; caudal fin truncate; general coloration grayish brown or grayish olive (light golden, yellowish, or bluish gray in some adult specimens), darker dorsally and paler, usually yellowish white, ventrally, with a black band between eye and caudal fin and another band between eye and margin of preopercle, 6 or 7 pale bars on flanks and a dark blotch on the base of caudal fin; males usually covered by tiny black spots from head to caudal fin; fins grayish brown or yellowish brown; maximum body length ca 700 mm SL.

(25) ***Parachromis loisellei*** (Bussing 1989: 153); Loiselle's cichlid (En), Guapote Amarillo (Sp)
Figure 7A

Body elongate, greatest body depth equal to or greater than head length; predorsal profile of head usually straight or slightly curved, snout usually pointed; mouth terminal, relatively large, usually ca 30–40% of head length; maxillary extending to below eye; lower jaw usually in advance of upper jaw; teeth enlarged, caniniform; posterior edge of opercle almost straight; total gill rakers 9–13; lateral line conspicuous, divided into 2 straight overlapping sections; longitudinal scales 27–31; fins with strong spines; a single dorsal fin; caudal fin truncate; general coloration grayish brown, brownish golden or yellowish brown, darker, usually grayish brown with or without golden iridescence, dorsally, presenting the most intense colors below lateral band dark band (which is formed by a series of irregular black or dark brown squares); there is another dark oblique band between eye and lower opercle; fins gray brown; males distinguished by having black spots on median fins and a reticulate pattern on body; maximum body length ca 185 mm SL.

(26) ***Parachromis managuensis*** (Günther 1867: 602); Jaguar guapote (En), Guapote pinto (Sp)
Figure 7B

Body elongate, greatest body depth smaller than head length; predorsal profile of head usually straight or slightly curved, snout usually pointed; mouth terminal, relatively large, usually ca 30–40% of head length; maxillary extending to below eye; lower jaw usually in advance of upper jaw; teeth enlarged, caniniform; posterior edge of the opercle with a conspicuous lobe at its lower angle; total gill rakers 14 or 15; lateral line conspicuous, divided into 2 straight overlapping sections; longitudinal scales 32–36; fins with strong spines; a single dorsal fin; caudal fin truncate; coloration grayish brown, brownish golden, golden green, or grayish purple, darker, usually moss green, dorsally, and paler, usually gray, ventrally, with a characteristic black spotted pattern on the body and fins, a lateral band dark band (which is formed by a series of irregular black or dark brown squares) and a dark oblique band between eye and lower opercle; iris usually reddish; fins usually brownish gray maximum body length ca 220 mm SL.

(27) ***Tomocichla tuba*** (Meek 1912: 73); Tuba (En), Vieja (Sp)
Figure 7C

Body elongate; predorsal profile of head usually curved, snout convex; mouth inferior, usually ventral; teeth spatulate with rounded tips; lateral line conspicuous, divided into 2 straight overlapping sections; fins with strong spines; a single dorsal fin; anal fin spines 4 or 5; caudal fin truncate; general coloration dark gray with olive-green and/or pink-red tones above and on the sides, changing to white on abdomen and lower portion of head; upper portion of snout usually gray olive and with 2 black stripes joining the eyes; iris usually yellowish or reddish; mid-body black blotch absent, in turn, some specimens present 7–10 incomplete dark bars on the flanks; fins usually gray with or without dark blotches or stripes; maximum body length ca 280 mm SL.

Family Gobiidae (2 G/2 S)

(28) ***Awaous banana*** (Valenciennes 1837: 103); River goby (En), Chupapiedras (Sp)
Figure 7D

Body elongate; teeth conical, 2 or 3 rows of teeth on both jaws; gill rakers present; fins without strong spines; pelvic fins united into an oval (longer than width) adhesive disc; 2 dorsal fins; caudal fin truncate to rounded; general coloration yellowish brown, darker dorsally, usually with greenish hues and irregular black blotches on back and upper flanks as well as 4 or 5 diagonal dark bars on the flanks, and paler, usually yellowish uniform, ventrally; a dark band between upper margin of opercle and base of pectoral fin; dorsal and caudal fins transparent with squarish black blotches forming several diagonal stripes; maximum body length ca 180 mm SL.

(29) ***Sicydium altum*** Meek 1907: 149; River goby (En), Chupapiedras (Sp)
Figure 7E

Body elongate; 2 rows of teeth on both jaws, minute and compressed in the upper jaw, recurved and conical in lower jaw; gill rakers absent; fins without strong spines; pelvic fins united into an almost circular or oval (wider than long) adhesive disc; 2 dorsal fins; caudal fin rounded; general coloration greenish gray, darker dorsally, usually with 5 black bars on the back and the flanks, and paler, usually yellowish white, ventrally; dorsal and anal fins dark or transparent with free edges of spines pink or reddish, anal and caudal fins usually transparent, with external borders pink or reddish; maximum body length ca 140 mm SL.

Identification key to the fishes from the Tirimbina Biological Reserve, La Virgen de Sarapiquí, Heredia, Costa Rica

1 Body eel-like; scales absent; pectoral, pelvic and caudal fins absent; dorsal and anal fins vestigial, reduced to a rayless ridge (Synbranchidae) ..... *Synbranchus marmoratus* (Fig. 4E)

1′ Body not eel-like; scales present (absent in

Figure 7. Species of the Perciformes (continuation: Cichlidae, in part, and Gobiidae) in the TBR. **A.** *Parachromis loisellei* (Bussing, 1989), upper: juvenile specimen, about 67 mm SL, brown form, middle: adult specimen, about 78 mm SL, brown form, lower: adult specimen, about 92 mm SL, yellow form. **B.** *Parachromis managuensis* (Günther, 1867), upper: juvenile specimen, about 82 mm SL, middle: juvenile specimen, about 84 mm SL, lower: adult specimen, about 230 mm SL. **C.** *Tomocichla tuba* (Meek, 1912), upper: juvenile specimen, about 76 mm SL, lower: adult specimen, about 110 mm SL. **D.** *Awaous banana* (Valenciennes, 1837), upper: juvenile specimen, about 82 mm SL, lower: dorsal view. **E.** *Sicydium altum* Meek, 1907, upper: adult specimen, about 72 mm SL, middle: adult specimen, about 78 mm SL, lower: adult specimen, about 74 mm SL, detail of the pelvic fins.

members of Heptapteridae); all fins present and well developed 2

2(1′) Pelvic fins united into an adhesive disc (Gobiidae) 3

2′ Pelvic fins separated, not in form of an adhesive disc 4

3(2) 2 or 3 rows of teeth on both jaws, conical; gill rakers present; pelvic adhesive disc oval, longer than width; general coloration yellowish brown ..... *Awaous banana* (Fig. 7D)

3′ 2 rows of teeth on both jaws, minute and compressed in upper jaw, recurved and conical in lower jaw; gill rakers absent; pelvic adhesive disc almost circular, or if oval, wider than long; general coloration greenish gray ..... *Sicydium altum* (Fig. 7E)

4(2′) 3 pairs of barbels; scales absent; adipose fin present, its base larger than base of dorsal fin (Heptapteridae) 5

4′ Barbels absent; scales present; adipose fin absent, if present (in members of Characidae and Bryconidae), its base shorter than base of dorsal fin 7

5(4) Maxillary barbels relatively long (usually extending beyond pectoral fin origin, sometimes passing caudal fin origin); serrations present on both margins of pectoral fin spine ..... *Rhamdia guatemalensis* (Fig. 3A)

5′ Maxillary barbels relatively short (usually not extending beyond pectoral fin origin, or if passing, not passing pelvic fin insertion; serrations present only on inner (posterior) margin of pectoral fin spine, or absent 6

6(5′) Maxillary barbels usually extending beyond dorsal fin origin up to pelvic fin insertion; adipose fin base relatively long, occupying ca ≥75% of distance between dorsal fin insertion and origin of caudal fin . *Rhamdia nicaraguensis* (Fig. 3C)

6 Maxillary barbels not extending beyond pectoral fin origin; adipose fin base relatively short, occupying ca 50% of distance between dorsal fin insertion and origin of caudal fin ..... *Rhamdia laticauda* (Fig. 3B)

7(4′) Adipose fin present; general coloration silvery (Characiformes) 8

7′ Adipose fin absent; general coloration variable, usually not silvery (except in Atherinopsidae) 12

8(7) Body strongly compressed; 2 pairs of external teeth on premaxillary; nape concave; anal fin very long with 42–50 rays ..... *Roeboides bouchellei* (Fig. 2D)

8′ Body robust, not strongly compressed; no external teeth on premaxillary; nape convex or straight; anal fin relatively short, usually with <42 rays 9

9(8′) Body usually very elongate; upper jaw in advance of lower jaw; upper jaw with 3 or 4 rows of teeth; maximum body length ca 500 mm SL (Bryconidae) .... *Brycon costaricensis* (Fig. 2E)

9′ Body usually not very elongate; both jaws of equal length; upper jaw with 1 or 2 rows of teeth; maximum body length ca 150 mm SL 10

10(9′) Snout length about ≥ eye diameter; jaws usually elongate, teeth unicuspid, and enlarged ..... *Astyanax bransfordii* (Figure 2A)

10′ Snout length usually < eye diameter; jaws not elongate; teeth multicuspid, usually not enlarged 11

11(10′) Body usually less robust and elongated; third infraorbital less deep and not in contact with lower limb of preopercle, yields on pressure by dissecting needle; no spots on opercle; caudal peduncle usually thin … *Astyanax nicaraguensis* (Fig. 2B)

11′ Body usually more robust and elongated; third infraorbital deep and in contact with lower limb of the preopercle, does not yield when depressed; a diffuse violet spot present on opercle in live specimens; caudal peduncle usually thick ..... *Eretmobrycon scleroparius* (Fig. 2C)

12(7′) 2 dorsal fins (first dorsal fin small and usually inconspicuous in Atherinopsidae); caudal fin forked or lunate 13

12′ A single dorsal fin; caudal fin truncate or rounded 15

13 Body very elongate and compressed; eye size ca 40% of head length; anal fin spine weak and flexible; a silver stripe present along mid-side of body in both live and preserved specimens; maximum body length ca 70 mm SL (Atherinopsidae) ..... *Atherinella hubbsi* (Fig. 3D)

13′ Body not very elongate and compressed, robust; eye size ca 25% of head length; anal fin spines (2) strong; no silver stripe along mid-side of body; maximum body length ca 700 mm SL (Mugilidae) 14

14(13′) Mouth about terminal; second dorsal fin rays 9; anal fin rays 10; general coloration gray olive, darker dorsally, and paler, usually yellowish white ventrally; dark scale edges form crisscross lines on upper body; fins usually yellowish ..... *Agonostomus monticola* (Fig. 5A)

14′ Mouth ventral; second dorsal fin rays 10 or rarely 11; anal fin rays 11; general coloration silvery to grey green in adults, silvery white, with dark stripes on dorsal, anal and caudal fins in juveniles; fins usually transparent, pinkish in some adult specimens ..... *Joturus pichardi* (Fig. 5B)

15(12′) Body elongate and moderately deep; lateral line reduced to a series of individual pits along side of body; fins without spines; males with anal fin modified into a gonopodium; caudal fin usually rounded; maximum body length ca 105 mm SL, usually less than 60 mm SL (Poeciliidae) 16

15′ Body moderately elongate and deep; lateral

line conspicuous, divided into 2 straight overlapping sections; fins with strong spines; males without gonopodium; caudal fin usually truncate; maximum body length ca 700 mm SL, usually >60 mm SL (Cichlidae) 21

16(15) Body deeply compressed; ventral margin of the caudal peduncle sharp and compressed, scales forming a sheathed keel ..... *Alfaro cultratus* (Fig. 3E)

16′ Body not deeply compressed; ventral margin of caudal peduncle rounded with a series of scales along mid-line 17

17(16′) Anal fin with a black blotch mainly covering it antero-basal portion; males with an moderately long gonopodium, usually 27–29% of SL ..... *Brachyrhaphis parismina* (Fig. 3F)

17′ Anal fin clear or dusky, without a black blotch covering antero-basal portion; males with relatively long gonopodium, usually >29% of SL, or a relatively short gonopodium, usually <27% of SL 18

18 Males with asymmetric gonopodium, either dextral or sinistral; dorsal fin with first ray black and with wedge-shaped black base, usually with dusky posterior margin, in males the remaining fin is brilliant yellow; juveniles and adult males with 5–10 black bars on flanks ..... *Xenophallus umbratilis* (Fig. 4D)

18′ Males with symmetric gonopodium; dorsal fin not as described above; no black bars on sides 19

19(18′) Teeth conical and well fixed in jaws; jaw bones firmly united; scales conspicuously bordered in black, giving a cross-hatch pattern to body (this pattern more intensive along mid-line of flanks and sometimes resembles a series of X's along body); membranes of dorsal fin base with elongate black blotches; distal portion of dorsal fin usually orange ..... *Priapichthys annectens* (Fig. 4C)

19′ Teeth compressed and not firmly fixed in jaws; jaw bones weakly united; scales usually not as described above (cross-hatching pattern present in some specimens of *Phallichthys amates*); dorsal fin without marks, or if present, not as described above 20

20(19′) Body moderately elongate, deep, almost rhomboid, moderately compressed; males with a long gonopodium, usually extending to caudal fin origin; sides usually uniformly colored, without rows of yellow dots; dorsal fin usually without spotting; females usually with a prominent black or purple blotch covering base of pelvic and/or anal fins; caudal fin usually not profusely spotted, even on its base ..... *Phallichthys amates* (Fig. 4A)

20′ Body elongate and moderately deep, robust; males with a short gonopodium, rarely extending beyond dorsal fin insertion; sides with 6–8, usually 7, rows of yellow dots (1 per scale); dorsal fin usually with black spots and/or a black blotch on its base; females usually without a dark blotch covering base of pelvic and/or anal fins; caudal fin profusely spotted on base, often on entire fin ..... *Poecilia gillii* (Fig. 4B)

21(15′) Predorsal profile of head usually curved, snout convex, rarely pointed; mouth inferior, usually ventral; teeth of outer rows compressed anteroposteriorly (incisors), at least at the tip 22

21′ Predorsal profile of head usually straight or slightly curved, snout usually pointed or convex; mouth terminal, rarely inferior or ventral; teeth of outer rows sharp, conical and cylindrical ... 24

22(21) Teeth with flattened or truncate tips; iris usually bluish, silvery in a few specimens; mid-body with a broad dark bar, on a grayish brown background (during breading season pattern reversed, that is, a white bar appears on a dark gray background ..... *Neetroplus nematopus* (Fig. 6C)

22′ Teeth spatulate with rounded tips; iris usually yellowish or reddish; mid-body dark bar absent 23

23(22′) Anal fin spines 6–9; upper portion of the snout usually yellowish or in some adult specimens grayish blue-green, without black stripes joining the eyes; iris usually yellowish; mid-body usually with a large black blotch on mid-side crossed or not by a dark lateral stripe ..... *Hypsophrys nicaraguensis* (Fig. 6B)

23′ Anal fin spines 4 or 5; upper portion of the snout usually gray olive and with 2 black stripes joining the eyes; iris usually reddish; mid-body black blotch absent, in turn, some specimens present 7–10 incomplete dark bars on flanks ..... *Tomocichla tuba* (Fig. 7C)

24(21′) Mouth relatively large, usually ca 30–40% of head length; maxillary extending to below the eye; lower jaw usually in advance of upper jaw; teeth enlarged, caniniform; maximum body length about 700 mm SL 25

24′ Mouth relatively short, usually <30% of head length; maxillary not extending to below eye; jaws of equal length, rarely upper jaw in advance of lower jaw; teeth somewhat enlarged, but no large canines; maximum body length ca 150 mm SL 27

25(24) Posterior edge of opercle usually with a conspicuous lobe at its lower angle; total gill rakers 14 or 15 ... *Parachromis managuensis* (Fig. 7B)

25′ Posterior edge of opercle almost straight; total gill rakers 9–13 26

26(25′) Greatest body depth < head length; longitudinal scales 31–34; maximum body length ca 700 mm SL ..... *Parachromis dovii* (Fig. 6D)

26′ Greatest body depth ≥ head length; longitudinal scales 27–31; maximum body length ca 185 mm

SL ..... *Parachromis loisellei* (Fig. 7A)

27(24′) Snout relatively long, pointed, straight and produced, usually ca 43–53% of head length; head and body with irregular iridescent blue spots or vermiculations; posterior portion of the flanks usually with 3–5 brown vertical bars separated by paler spaces; maximum body length ca 150 mm SL ..... *Cribroheros alfari* (Figure 6A)

27′ Snout relatively short and convex, usually ca 33–43% of head length; no iridescent blue spots or vermiculations on head or body; flanks usually with 6–8 diffuse or well defined black vertical bars; maximum body length ca 100 mm SL 28

28 (27′) Iris bluish; opercular blotch absent; first vertical bar not Y-shaped; caudal blotch mainly on caudal peduncle ..... *Amatitlania septemfasciata* (Fig. 5C)

28′ Iris usually golden or yellowish; opercular blotch present; first vertical bar Y-shaped; caudal blotch mainly on caudal fin base ..... *Amatitlania siquia* (Fig. 5D)

Discussion

Angulo and Garita-Alvarado (2013) and Angulo et al. (2013) listed a total of 60 fish species in the Sarapiquí river basin; in this contribution we list a total of 29 species, which represents about 50% of the total of species expected. On the other hand, Bussing (1993) listed 43 fish species to the Puerto Viejo River, a tributary of the Sarapiquí River, at La Selva Biological Station (a private reserve located about 10 km east of the TBR). All species listed herein were recorded by Bussing (1993), which corresponds to about 68% of the number of species listed by this author. The dominance of certain types of environments and habitats within the TBR (i.e. swift waters over rocky bottoms with depths usually < 1 m; see Table 1), in combination with the relatively high environmental diversity and heterogeneity found in neighboring water bodies and areas within the basin (see Bussing 1993, 1994) could explain this relatively low diversity in the studied area.

The families Cichlidae, Poeciliidae, and Characidae, comprising usually small to medium-sized species (150 mm or less), were dominant in the TBR, as in La Selva (Bussing 1993, 1994), and in most water bodies and areas of Costa Rica (Bussing 1998, Angulo and Garita-Alvarado 2013, Angulo et al. 2013). On the other hand, *Astyanax nicaraguensis* and *Poecilia gillii*, the most widespread and abundant fish species in Costa Rica (Bussing 1998) also were the most frequent and abundant species within the TBR. The sites G, D, and K have the greater heterogeneity of habitats and environments (Table 1), and as expected, showed the highest values of diversity, measured as the total number of species (Table 2). These environments, characterized by having swift waters over rocky bottoms and grassy margins with series of pools (Table 1), favors relative fast swimmers (e.g., *Astyanax*, *Agonostomus*, *Brycon*, *Eretmobrycon*, *Joturus*, *Tomocichla*, and *Neetroplus*) and bottom dwellers that fixate to rocks with adhesive discs (e.g. *Awaous* and *Sicydium*), as well as relatively small fishes that use the grassy margins as refuge, protection and foraging areas (e.g. *Amatitlania*, *Parachromis*, *Poecilia*, *Rhamdia*, etc.). The sites H, I, and J, in contrast, characterized by having clay substrates, slow waters, high concentration of organic matter, and consequently acid waters with little dissolved O_2 (Table 1), showed the lowest values of diversity; these environments were dominated by highly tolerant fish species such as *Poecilia* and *Priapichthys* (Bussing 1998). These results are consistent with the patterns described by Bussing (1993, 1994) and Angulo and Garita-Alvarado (2013) in environments that share, in general terms, such physical, chemical and structural characteristics.

No exotic species were recorded in this study despite that (1) the zone of La Virgen de Sarapiquí has several small-scale tilapia [*Oreochromis niloticus* (Linnaeus 1758)] farms, one of them, quite close to the limits of the TBR, and (2) other exotic species, beside to *O. niloticus* [e.g. the armored catfishes *Pterygoplichthys pardalis* (Castlenau, 1855) and *Hypostomus aspidolepis* (Günther 1867), among others], have been reported in neighboring water bodies and areas (Bussing 1998, Angulo and Garita-Alvarado 2013, Angulo et al. 2013). The absence of ideal conditions for the establishment of such species (i.e. the dominance of swift waters over rocky bottoms with depths usually <1 m) could explain their absence in the sampled localities. Both *Oreochromis* and *Pterygoplichthys*/*Hypostomus* usually prefer calm waters, on sandy or muddy bottoms, steep edges, depths usually greater than 1 m, low concentrations of dissolved oxygen and presence of submerged and/or floating vegetation (Page and Robins 2006, Zambrano et al. 2010, Wakida-Kusunoki and Amador-del Ángel 2011). Additional sampling and monitoring is necessary to corroborate this, and, in the case of confirm the presence of such (and another) exotic species in natural water bodies of the area, to assess their possible impacts on the native fauna.

Very few Costa Rican freshwater fish species have been assessed for their conservation status and/or risk of extinction. About 97% of the species herein listed (all except *A. monticola*) were classified under the IUCN Data Deficient category. Moreover, the information required to develop red lists of the freshwater fishes of the area (and Costa Rica in general) is still meager or in many instances unavailable. Filling gaps in the data is necessary for fish species conservation in many Costa Rican basins because the increased damming of rivers, water diversion, inappropriate land-use, waterway construction, contamination, and introduction of exotic species, among others. Of the species herein listed, at least 4 (*Joturus pichardi*, *Parachromis dovii*, *P. managuensis*, and *Brycon costaricensis*, in order of importance) are subject of (intensive) sport and artisanal fishing, which

has led to a decline in their populations during the last 20 years (Bussing 1998, Masís-Calvo, M. unpublished data, personal observation of authors). Other species (i.e. *Alfaro cultratus*, *Amatitlania* spp., *Cribroheros alfari*, *Parachromis loisellei*, *Priapichthys annectens*, *Xenophallus umbratilis*, among others) are of importance in the aquarium hobby and industry (Bussing 1998, Angulo and Garita-Alvarado 2013, Angulo 2014), which could lead to unregulated extraction for local and international trade (not verified in this study). In this regard, further research is strongly recommended for the application and improvement of the IUCN regional criteria based on better socio-ecological information.

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Authors' Contributions

AA drafted the first version of the manuscript. All authors collected data and contributed in the construction and improvement of the manuscript. AA and BNE verified the specimens. AA made part of the map. AA and JMLL took most of the pictures (otherwise the photographic credit is indicated). AA edited the figures.

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