Graellsia, 79(2): e197
julio-diciembre 2023
ISSN-L: 0367-5041
https://doi.org/10.3989/graellsia.2023.v79.378

ICHTHYOFAUNA OF THE URBAN SUB-BASIN OF THE OCOA RIVER, UPPER META RIVER DRAINAGE, ORINOCO BASIN, COLOMBIA

Hernando Ramírez-Gil[1], Miguel Ángel Cortés-Hernández[2,*] & Rosa Elena Ajiaco-Martínez[3]

[1,2,3] Grupo de investigación Evaluación, Manejo y Conservación de Recursos Hidrobiológicos y Pesqueros Unillanos, Facultad de Ciencias Básicas e Ingenierías, Universidad de los Llanos, Villavicencio, Meta, Colombia.

[2] Grupo de Investigación Cuencas, Fundación Neotropical Cuencas, Arauca, Colombia.
[2] Grupo de Ictiología, Instituto de Biología, Universidad de Antioquia, Medellín, Colombia.

* Corresponding author: miguel.cortes@unillanos.edu.co – ORCID iD: https://orcid.org/0000-0002-0219-4684
[1] Email: hernando.ramirez@unillanos.edu.co – ORCID iD: https://orcid.org/0000-0002-0166-3047
[3] Email: reajiaco@gmail.com – ORCID iD: https://orcid.org/0000-0001-6407-7806

ABSTRACT

The ichthyofauna of the upper reaches of the Meta River, one of the main tributaries of the Orinoco, is still poorly known. This paper presents the first list of fishes recorded for the Ocoa River, based on 51 901 individuals sampled in 15 localities during the 2014 hydrological cycle, including urban areas in the municipality of Villavicencio. Records of 88 species were obtained, distributed in 21 families and 5 orders, corresponding to 12% of the freshwater species reported for the Colombian Orinoquia. The estimated sampling coverage (SC) for the Ocoa River was 99.9%, with an observed species richness representing 93.6% of the expected richness. Among the species collected, 13 are reported only for Colombia, 43 have fishery use and four species are introduced (*Caquetaia kraussii*, *Oreochromis niloticus*, *Poecilia reticulata* and *Poecilia* cf. *caucana*). The latter dominate in disturbed sites with low oxygen levels. This study constitutes the first approximation to the knowledge of the ichthyofauna of one of the most important sub-basins for the municipality of Villavicencio.

Keywords: Colombia, biodiversity, inventory, freshwater fish, water quality, invasive species.

RESUMEN

Ictiofauna de la subcuenca urbana del río Ocoa, drenaje superior del río Meta, cuenca del Orinoco, Colombia

El conocimiento acerca de la ictiofauna de los tramos altos del río Meta, uno de los principales afluentes del Orinoco, es aún poco conocida. En este trabajo se presenta el primer listado de peces registrados para el río Ocoa, a partir de 51 901 individuos muestreados en 15 localidades durante el ciclo hidrológico de 2014, incluidas zonas urbanas en el municipio de Villavicencio. Se obtuvieron registros de 88 especies, distribuidas en 21 familias y 5 órdenes, lo que corresponde al 12% de las especies de agua dulce reportadas para la Orinoquia colombiana. La cobertura de muestreo (SC) estimada para el río Ocoa fue del 99.9%, con una riqueza de especies observada que representa el 93.6% de la riqueza esperada. Entre las especies recolectadas, 13 están reportadas solo para Colombia, 43 tienen uso pesquero y cuatro especies son introducidas (*Caquetaia kraussii*, *Oreochromis niloticus, Poecilia reticulata* y *Poecilia* cf. *caucana*). Estas últimas dominan en sitios alterados con bajos niveles de oxígeno. Este estudio constituye la primera aproximación al conocimiento de la ictiofauna de una de las subcuencas de mayor importancia para el municipio de Villavicencio.

Palabras clave: Colombia, biodiversidad, inventario, peces de agua dulce, calidad del agua, especies invasoras.

Recibido/*Received*: 26/10/2022; **Aceptado/*Accepted***: 5/06/2023; **Publicado en línea/*Published online***: 03/10/2023

Cómo citar este artículo/*Citation*: Ramírez-Gil, H., Cortés-Hernández, M.A. & Ajiaco-Martínez, R.E. 2023. Ichthyofauna of the urban sub-basin of the Ocoa River, Upper Meta River drainage, Orinoco Basin, Colombia. *Graellsia*, 79(2): e197. https://doi.org/10.3989/graellsia.2023.v79.378

Introduction

The Meta River is one of the largest tributaries of the Orinoco River, with a basin that covers 10830.4 km^2 (Machado-Allison *et al.*, 2010), sheltering a richness of 577 fish species (Usma *et al.*, 2016), equivalent to 79.3% of the native species of the Orinoco (DoNascimiento, 2021). Previous studies have documented the fish fauna of tributaries originating in the foothill part of this basin, with 115 species reported for the Cusiana, 96 for the Cravo Sur River, 49 for the Túa River, 45 for the Upía River and 10 for the Guachiría River (Urbano-Bonilla *et al.*, 2009), and 113 species in the Orotoy River (Ramírez-Gil *et al.*, 2011), 180 for the Pauto River (Maldonado-Ocampo *et al.*, 2013), 241 for the Cusiana River (Urbano-Bonilla *et al.*, 2018) and 180 for the Casanare River (Zamudio *et al.*, 2017). However, there are still information gaps for some drainages and small streams in the upper Meta River (Zamudio & Maldonado-Ocampo, 2021), an area highly impacted by changes in land use (e.g., deforestation, agriculture, livestock, hydrocarbon exploitation, and urbanization), and biodiversity loss (Machado-Allison *et al.*, 2010).

The Ocoa River, a tributary of the Guatiquia River, is one of the most important watersheds for the municipality of Villavicencio, providing water resources for human consumption, as well as for agricultural, forestry and mining uses of rural settlements (Osorio-Ramírez *et al.*, 2015). In addition, it provides food resources (e.g., fishing for consumption) for the most vulnerable communities (Ramírez-Gil pers. obs.). However, the Ocoa River is the main recipient of more than 100 discharges from the urban center, serving as a sink for 80% of urban wastewater (Osorio-Ramírez *et al.*, 2015), promoting degradation and ecological loss of the riverbed (Aguilera-Giraldo *et al.*, 2019; Rojas-Peña *et al.*, 2021).

Faced with this panorama of anthropic intervention, we conducted surveys to characterize the fish fauna subsisting in this river and document key areas for native species. With the knowledge of the ichthyic biodiversity of the Ocoa River, we also contribute to the knowledge of the ichthyofauna of the Orinoco River basin.

Material and methods

Study site

The Ocoa River is a lotic ecosystem of the second order, located in the piedmont of the Eastern Cordillera of the Andes, with a basin of 282.2 km^2 and 68.55 km in length, of which 17 km run through the urban area of the municipality of Villavicencio, a city with an estimated population of 451 212 inhabitants (Departamento Administrativo Nacional de Estadísticas - DANE, 2018). It originates in the southwest of the municipality, in the Samaria village at 1155 m a.s.l., and flows into the Guatiquia River between the Guamo and Indostán villages at 225 m a.s.l. (Osorio-Ramírez *et al.*, 2015). The annual hydrological cycle of the Ocoa River is unimodal, with minimum rainfall between December-March and a rainy period between April and November with maximum precipitation during April-July (Instituto de Hidrología, Metereología y Estudios Ambientales - IDEAM, 2022). The average temperature range is 15.5–33.5 °C and average annual rainfall is 2700–5000 mm (Osorio-Ramírez *et al.*, 2015).

Data collection and treatment

To obtain samples of the fish community assemblages, spatial and temporal collections were made in the Ocoa River during the 2014 annual hydrological cycle. A total of 15 locations were sampled, eight along the main channel and seven in the micro-basins that are tributary to the main channel (Fig. 1); four samples were taken in each site (Table 1). Stations 3 to 6 correspond to the river's transit through the urban zone of Villavicencio. The fish were captured by electric fishing, following the methodology proposed by Ramírez-Gil *et al.* (2011). Simultaneously, some environmental variables were recorded *in situ*, including water temperature (ºC), pH, dissolved oxygen (mg/l) and electrical conductivity (µS/cm) using multiparametric equipment.

Table 1.– Temporal distribution of sampling sessions in the fifteen localities sampled.

Tabla 1.– Distribución temporal de los muestreos realizados en las quince localidades estudiadas.

Month	Sampling sites														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
February	1	1	1	1					1	1			1		
March					1	1	1	1			1	1		1	1
May	1		1	1	1	1	1		1	1	1	1	1	1	
June								1							1
August	1		1	1	1	1	1	1	1			1			
September										1	1		1	1	1
November	1		1	1	1	1	1	1	1	1	1	1	1	1	1

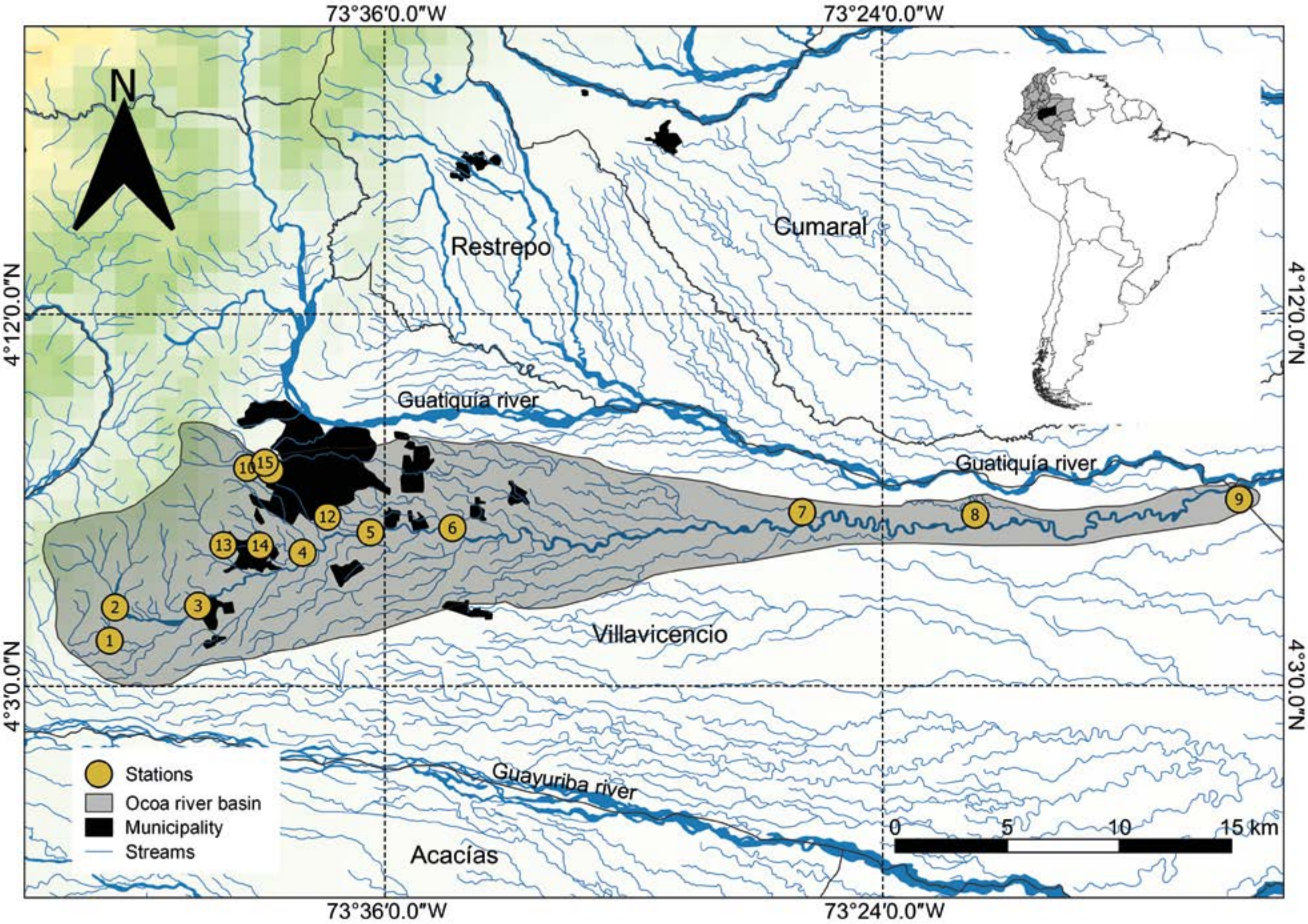

Fig. 1.– Map of the Ocoa River drainage with the distribution of the sampling stations.

Fig. 1.– Mapa de la subcuenca del río Ocoa con la distribución de las estaciones de muestreo.

The captured fish were anesthetized and sacrificed in a clove oil solution (Eugenol 300 mg/l), fixed in 10% formaldehyde, and preserved in 70% ethanol. For species identification, specialized taxonomic keys, original descriptions, and taxonomic revisions were used (e.g., Eigenmann & Fisher, 1916; Eigenmann, 1917, 1922; Myers, 1927; Schultz, 1944; Nijssen & Isbrücker, 1980; Mees, 1988; Vari, 1991; Lasso & Machado-Allison, 2000; Mago-Leccia *et al.*, 2001; Taphorn, 2003; Londoño-Burbano *et al.*, 2011, 2018; Ballen & Vari, 2012; Ballen *et al.*, 2016; Marinho & Menezesm 2017; Armbruster *et al.*, 2018; Kullander *et al.*, 2018; Urbano-Bonilla *et al.*, 2018; Urbano-Bonilla & Ballen, 2021; Lima, 2022). The taxonomic status of species was validated in Eschmeyer's Catalog of Fishes (Fricke *et al.*, 2022), and to verify the presence of these species in the national territory, the list of freshwater fish species of Colombia (DoNascimiento *et al.*, 2021), was reviewed. Later, the lots of collected specimens were deposited in the ichthyological collection of the Unillanos Natural History Museum - MHNU-I.

Statistical analyses

To calculate the interpolation and extrapolation of the species richness in the Ocoa River drainage, an analysis of the effective number of species was carried out based on the first number of the Hill series (q = 0) as suggested by Jost (2006) and Jost & González-Oreja (2012). In addition, the completeness of the sampling coverage (SC) was calculated, which allows the evaluation of the sampling effort (Chao & Jost, 2012; Chao *et al.*, 2014). All these analyses were carried out in the iNEXT package (Hsieh *et al.*, 2020) in R (R Development Core Team, 2022).

Results

In total, 51 901 specimens were collected, grouped in five orders, 21 families, 61 genera, and 88 species (Table 2). The most representative orders in captures were Siluriformes, with eight families, 26 genera and 38 species, followed by Characiformes, with seven families, 24 genera and 37 species (Table 3). The families with the greatest richness and abundance were Characidae (26 species, 29.5%; n = 20058, 38.6%), Loricariidae (17 species, 19.3%; n = 1327, 2.6%), Heptapteridae (10 species, 11.4%; n = 836, 1.6%), and Cichlidae (7 species, 8.0%; n = 2087, 4.0%) (Fig. 2). The Poecilidae family was the most representative,

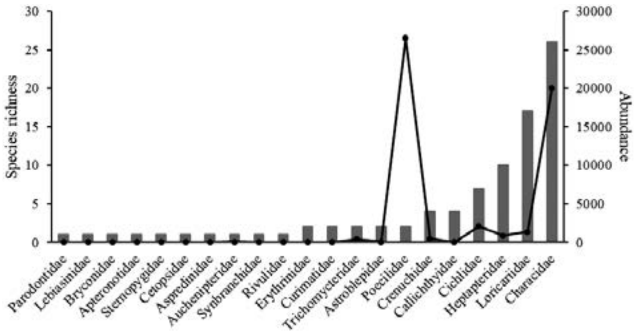

Fig. 2.– Abundance and richness of species of the family collected in the Ocoa River.

Fig. 2.– Abundancia y riqueza de especies de las familias recolectadas en el río Ocoa.

with an abundance of 26 501 individuals (51.1%), with *Poecilia reticulata* (n = 3717) and *Poecilia* cf. *caucana* (n = 22 784) being the most abundant species of all samples.

Among the captured species, 12 are endemics to the Orinoco River basin. In addition, 33 species are used in ornamental fishing and ten in consumption fishing. *Cetopsis orinoco*, *Moenkhausia oligolepis* and *Salminus hilarii* are migratory species (DoNascimiento *et al.,* 2021) and four species are introduced to the Orinoco River basin (*Caquetaia kraussii*, *Oreochromis niloticus, Poecilia* cf. *caucana* and *Poecilia reticulata*). *Poecilia reticulata* and *Poecilia* cf. *caucana*. were more abundant (n > 700 individuals) on stations 5 and 6, the sites with

Table 2.– Species captured during the hydrological cycle of 2014 in the Ocoa River, with their abundance (n) and catalog number of the ichthyological collection of the Museo de Historia Natural Unillanos. Abbreviation: * species endemic to Colombia; ** migratory species; + introduced species; Or - species of ornamental use; Fi - species consumed as food.

Tabla 2.– Especies capturadas durante el ciclo hidrológico de 2014 en el río Ocoa, con su abundancia (n) y número de catálogo de la colección ictiológica del Museo de Historia Natural Unillanos. Abreviatura: * especie endémica de Colombia; ** especies migratorias; + especies introducidas; Or - especies de uso ornamental; Fi - especies que se consumen como alimento.

Order/family/species	n	Use	MHNU-I
Characiformes			
Crenuchidae			
Characidium cf. *boavistae* Steindachner, 1915	10		1140
Characidium steindachneri Cope, 1878	19		2734
Characidium zebra Eigenmann, 1909	250	Or	2665
Characidium sp.	159		2666
Erythrinidae			
Hoplerythrinus unitaeniatus (Spix & Agassiz, 1829)	1	Or/Fi	3082
Hoplias malabaricus (Bloch, 1794)	30	Or/Fi	1884
Parodontidae			
Parodon apolinari Myers, 1930	1	Or	2152
Curimatidae			
Steindachnerina argentea (Gill, 1858)	5		1481
Steindachnerina guentheri (Eigenmann & Eigenmann, 1889)	3		2040
Lebiasinidae			
Copella eigenmanni (Regan, 1912)	10	Or	971
Bryconidae			
Salminus hilarii Valenciennes, 1850**	1	Fi	1831
Characidae			
Aphyocharax pusillus Günther, 1868	3	Or	3084
Astyanax aff. *bimaculatus* (Linnaeus, 1758)	144		1482
Astyanax integer Myers, 1930	3		3092
Astyanax metae Eigenmann, 1914	2		980
Astyanax venezuelae Schultz, 1944	12		-
Ceratobranchia sp.	283		1074
Charax metae Eigenmann, 1922	2	Or	1934
Cheirodontops geayi Schultz, 1944	20		1261
Corynopoma riisei Gill, 1858	12	Or	3087
Creagrutus taphorni Vari & Harold, 2001	7047		2376
Ctenobrycon spilurus (Valenciennes, 1850)	1	Or	3094
Gephyrocharax valencia Eigenmann, 1920	18		3088
Hemibrycon loisae (Géry, 1964)	8634		1478
Hemibrycon metae Myers, 1930	10		1441
Hemigrammus barrigonae Eigenmann & Henn, 1914	15	Or	3224

Order/family/species	n	Use	MHNU-I
Hemigrammus marginatus Ellis, 1911	5		1488
Hemigrammus sp.	2		973
Hyphessobrycon metae Eigenmann & Henn, 1914	2	Or	2041
Knodus alpha (Eigenmann, 1914)	2		1539
Knodus cismontanus (Eigenmann, 1914)	3761		1444
Knodus sp.	3		981
Moenkhausia oligolepis (Günther, 1864)**	5	Or	2042
Moenkhausia sp.	2		1584
Odontostilbe splendida Bührnheim & Malabarba, 2007	63		1537
Paragoniates alburnus Steindachner, 1876	6	Or	3085
Roeboides dientonito Schultz, 1944	1		1259
Gymnotiformes			
Apteronotidae			
Apteronotus galvisi de Santana, Maldonado-Ocampo & Crampton, 2007*	16		1988
Sternopygidae			
Eigenmannia sp.	8		3096
Siluriformes			
Trichomycteridae			
Ochmacanthus alternus Myers, 1927	37		984
Trichomycterus cf. *knerii* Steindachner, 1882	376		956
Callichthyidae			
Corydoras melanotaenia Regan, 1912*	3		2045
Corydoras metae Eigenmann, 1914*	9		2745
Corydoras simulatus Weitzman & Nijssen, 1970*	10		2047
Hoplosternum littorale (Hancock, 1828)	1	Or/Fi	1835
Loricariidae			
Ancistrus triradiatus Eigenmann, 1918	60	Or	990
Chaetostoma chimu Urbano-Bonilla & Ballen, 2021*	11		1153
Chaetostoma dorsale Eigenmann, 1922	41	Or	988
Chaetostoma formosae Ballen, 2011*	568		1152
Chaetostoma sp.	7		1595
Dolichancistrus fuesslii (Steindachner, 1911)*	72		1323
Farlowella mariaelenae Martín Salazar ,1964	49	Or	1268
Farlowella vittata Myers, 1942	163	Or	987
Hypostomus niceforoi (Fowler, 1943)*	250	Or	1068
Hypostomus plecostomoides (Eigenmann, 1922)	13	Or/Fi	2568
Lasiancistrus tentaculatus Armbruster, 2005	6		1272
Loricariichthys brunneus (Hancock, 1828)	7	Or	1923
Nannoptopoma spectabile (Eigenmann, 1914)	21	Or	986
Otocinclus vittatus Regan, 1904	17	Or	2713
Panaqolus maccus Schaefer & Stewart, 1993	25	Or	1154
Rineloricaria eigenmanni (Pellegrin, 1908)	13	Or	1560
Spatuloricaria terracanticum Londoño-Burbano, Urbano-Bonilla, Rojas-Molina, Ramírez-Gil & Prada-Pedreros, 2018	4		Donation
Astroblepidae			
Astroblepus sp. 1	6		1324
Astroblepus sp. 2	46		958
Cetopsidae			
Cetopsis orinoco (Schultz, 1944)**	14		1157
Aspredinidae			
Bunocephalus aloikae Hoedeman, 1961	14	Or	1995
Auchenipteridae			
Duringlanis romani (Mees, 1988)	53		966
Heptapteridae			
Cetopsorhamdia cf. *insidiosa* (Steindachner, 1915)	1		1159
Cetopsorhamdia orinoco Schultz, 1944	58	Or	1160
Chasmocranus rosae Eigenmann, 1922*	284		948
Heptapteridae gen. nov.	5		1161

Order/family/species	n	Use	MHNU-I
Imparfinis microps Eigenmann & Fisher, 1916*	3		3229
Imparfinis pseudonemacheir Mees & Cala, 1989	2		992
Imparfinis cf. *guttatus* (Pearson, 1924)	16		951
Nemuroglanis mariai (Schultz, 1944)*	3		1950
Pimelodella metae Eigenmann, 1917	240		993
Rhamdia laukidi Bleeker, 1858	224	Fi	1379
Synbranchiformes			
Synbranchidae			
Synbranchus marmoratus Bloch, 1795	8	Or	1507
Blenniiformes			
Cichlidae			
Aequidens metae Eigenmann, 1922	1	Or/Fi	2397
Bujurquina mariae (Eigenmann, 1922)*	1336	Or/Fi	995
Bujurquina sp.	1		-
Caquetaia kraussii (Steindachner, 1879)+	28	Fi	1167
Crenicichla geayi Pellegrin, 1903	60	Or	994
Mikrogeophagus ramirezi (Myers & Harry, 1948)	1	Or	2758
Oreochromis niloticus (Linnaeus, 1758)+	660	Fi	1070
Rivulidae			
Rivulus tessellatus Huber, 1992*	2		2104
Poeciliidae			
Poecilia reticulata Peters, 1859+	3717	Or	2506
Poecilia cf. *caucana*+ (Steindachner, 1880)	22784		1398

Table 3.– Number and percentage of families, genera and species for each of the orders present in the Ocoa River.

Tabla 3.– Número y porcentaje de familias, géneros y especies para cada uno de los órdenes presentes en el río Ocoa.

Orders	Family	%	Genus	%	Species	%
Siluriformes	8	38.1	26	42.6	38	43.2
Characiformes	7	33.3	24	39.3	37	42.0
Blenniiformes	3	14.3	8	13.1	10	11.4
Gymnotiformes	2	9.5	2	3.3	2	2.3
Synbranchiformes	1	4.8	1	1.6	1	1.1
Total	21	100	61	100	88	100

greater anthropogenic influence, where measures of dissolved oxygen ranged from 0.3–6.3 mg/l and conductivity between 135.3–222.5 µS/cm. It is worth noting that in station 6, the one with the lowest species diversity during the dry season, only four species (three of them alien) were reported: *Poecilia* cf. *caucana*, *Poecilia reticulata*, *Oreochromis niloticus,* and the native species *Characidium zebra*, with a strong dominance of *Poecilia* cf. *caucana,* that represented 83% of the individuals collected at that site, while the native species only represented 0.6%.

The completeness of the sampling coverage (SC) for the Ocoa River was 99.9%, indicating that the sampling is representative of the local fish community. Extrapolation analyses suggest that the expected richness for the Ocoa River is approximately 94 species (95% CI = 89.5–113.7), with the observed richness representing 93.6% of the expected richness (Fig. 3).

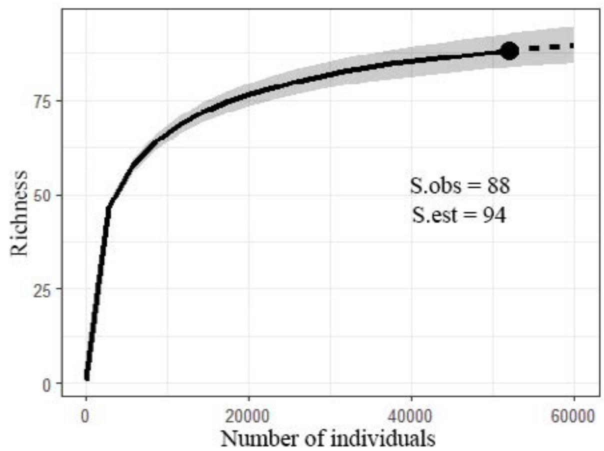

Fig. 3.– Species accumulation curve of fishes in the Ocoa River. Abbreviations: S.obs = observed richness, S.est = estimated richness.

Fig. 3.– Curva de acumulación de especies de peces del río Ocoa. Abreviaturas: S.obs = riqueza observada, S.est = riqueza estimada.

Table 4.– Physicochemical data measured in 15 sampling stations on the Ocoa River drainage. Abbreviations: Elev. – Elevation (m.a.s.l.); Temp. – Temperature (°C); DO – dissolved oxygen (mg/l); Cond.– electrical conductivity (µS/cm); * Tributaries.

Tabla 4.– Datos fisicoquímicos medidos en 15 estaciones de muestreo en la subcuenca del río Ocoa. Abreviaturas: Elev. – Elevación (m s.a.l.); Temperatura. – Temperatura (°C); DO – oxígeno disuelto (mg/l); Cond.– conductividad eléctrica (µS/cm); * Tributarios.

Stations	Elev.	Temp.	pH	DO	Cond.	Coordinates
1	451	24.0-26.3	5.6-6.3	2.7-7.3	23.0-27.5	04°04'6.1"N 73°42'38"W
2*	453	22.6-26.3	4.2-5.7	3.0-7.7	47.9-126.8	04°04'54.2"N 73°42'30.1"W
3	423	24.0-27.3	5.6-7.8	2.4-7.0	47.9-65.5	04°04'56.5"N 73°40'30"W
4	397	24.0-26.4	6.0-7.7	0.3-7.1	54.0-104.9	04°06'13.5"N 73°37'58.9"W
5	397	23.7-30.8	5.7-7.6	1.5-2.1	94.8-222.5	04°06'43"N 73°36'20.5"W
6	369	23.5-30.8	6.4-8.1	0.3-3.3	135.3-211.7	04°06'49.5"N 73°34'22.1"W
7	299	23.6-32.9	6.6-9.6	0.5-5.8	59.2-243.7	04°07'12"N 73°25'56"W
8	273	26.7-29.6	6.7-8.2	1.6-6.3	96.0-301.7	04°07'8"N 73°21'46.1"W
9	259	24.3-27.6	6.2-7.7	2.6-4.2	87.4-209.4	04°07'30.2"N 73°15'24.12"W
10*	563	16.9-24.0	6.8-10.8	3.4-7.8	50.1-199.0	04°08'16.93"N 73°39'18.88"W
11*	521	22.8-24.5	6.9-7.9	3.1-7.6	64.1-162.8	04°08'13.3"N 73°38'45.3"W
12*	395	24.5-27.2	6.5-7.2	0.5-6.3	182.4-488.0	04°07'5.84"N 73°37'23.1"W
13*	454	21.8-24.3	7.3-8.5	2.2-5.3	210.0-271.5	04°06'24.74"N 73°39'53.55"W
14*	414	21.3-24.0	6.3-8.6	1.4-6.3	196.6-241.8	04°06'24"N 73°39'0.6"W
15*	461	23.4-26.0	6.9-8.8	1.9-4.3	52.5-83.4	04°08'24.43"N 73°38'53.37"W

The physicochemical parameters recorded are summarized in Table 4. The temperature in the main channel ranged between 22.6 and 32.9 °C, and in the tributary channels between 16.9 and 27.2 °C. The pH gradient ranged from 4.2 to 7.8 in stations 1 to 5, and from 6.2 to 9.6 in the remaining stations, and in the tributaries between 4.2 and 10.8. Oxygen levels in general were between 0.3 and 7.8 mg/l, with the lowest levels found at stations 5 and 6 in the urban zone; in the tributaries, the variation was between 0.5 and 7.8 mg/l. The highest conductivity value was reported at station 12, which corresponds to a tributary.

From stations 3 to 6, corresponding to the section of the river in the urban area, the forest cover has been replaced by houses on both sides of the river, some of them with direct discharge of their domestic wastewater.

Discussion

The present study constitutes the first approximation to the knowledge of the ichthyofauna of the Ocoa River, which crosses the municipality of Villavicencio, with a species richness representing 63.7% of the species listed for the Guatiquia River (Zamudio & Maldonado-Ocampo, 2021), 15.2% for the Meta River drainage (Usma *et al.*, 2016), and 12% of those recorded in the Orinoco basin, a figure estimated at 722 species (DoNascimiento *et al.*, 2021). The extrapolation suggests that the drainage could have about 94 species, with a high percentage of the expected richness (93.6%) recovered in our surveys.

The composition of the fish assemblage of the Ocoa River was mainly dominated by Characiformes and Siluriformes, contributing 85% of the total species recorded for this drainage (Fig. 2), similarly to other drainages of the Colombian Orinoco River Basin (e.g., Urbano-Bonilla *et al.*, 2009, 2014, 2018; Ramírez-Gil *et al.*, 2011; Villa-Navarro *et al.*, 2011; Maldonado-Ocampo *et al.*, 2013; Usma *et al.*, 2016; Zamudio *et al.*, 2017) and the Neotropics (e.g., Albert & Reis, 2011; Reis *et al.*, 2016; Van der Sleen & Albert, 2018). Regarding higher taxonomic levels, our results suggest some impoverishment in the Upper Meta communities, with representatives of five of the thirteen orders registered for the Orinoquia, a figure that is usually higher (6-9) in other rivers of the region, and 20 native families out of the 50 registered for the area (Urbano-Bonilla *et al.,* 2009; Ramírez-Gil *et al.*, 2011; Maldonado-Ocampo *et al.*, 2013; DoNascimiento *et al.*, 2021).

The Poecilidae family was the most representative in terms of abundance, surpassing the Characidae and Loricariidae families (Table 2). This is probably due to the successful biological adaptations of *Poecilia* species (e.g., early reproductive maturity, sperm storage, superfetation, air-breathing ability, and high thermal tolerance), that make them highly tolerant eurytropic species (Jiménez-Prado *et al.*, 2020; López-Fuentes *et al.*, 2021), proliferating and dominating over native species, as reported by Casatti *et al.* (2009) for the São Josẽ dos Dourados and Turvo-Grande rivers in Brazil.

Four introduced species *Caquetaia kraussii*, *Poecilia* cf. *caucana*, *Poecilia reticulata* and *Oreochromis niloticus* were collected in the sites with the greatest environmental degradation, influenced by urbanization and pollution, which favors the establishment of alien species, since habitat degradation negatively affects native species and facilitates the success of invasions (Hooper *et al.*, 2005). According to Royero & Lasso (1992), *C. kraussii* was possibly introduced to the Orinoco River basin by escapes from fish farms, as reported for *O. niloticus,* which is widely distributed in 21 river basins worldwide (Agostinho *et al.*, 2021). In addition, *P. reticulata* and *P.* cf. *caucana* were possibly introduced deliberately by aquarists (Claro-García *et al.*, 2017). Previous fish assessments in foothill rivers in the region did not report introduced species (Urbano-Bonilla *et al.*, 2009, 2018; Ramírez-Gil *et al.*, 2011; Maldonado-Ocampo *et al.*, 2013; Zamudio *et al.* 2017, 2021), this being the first records of their presence, highlighting the environmental deterioration of this river to the detriment of native species.

On the other hand, our surveys also recovered individuals from 11 morphospecies (e.g., *Characidium* sp., *Ceratobranchia* sp., *Hemigrammus* sp., *Eigenmannia* sp., *Chaetostoma* sp., *Astroblepus* spp., Heptapteridae gen. nov., *Bujurquina* sp.), that possibly represent new species, which requires further, in-depth taxonomic studies to elucidate their status and present a more complete picture of the actual species diversity in the basin.

The present study was carried out during a single hydrological cycle (2014), but there is a need to continue sampling efforts in the Ocoa River; since monitoring information is important to understand how different anthropogenic activities are affecting environmental conditions and freshwater communities, allowing the design and implementation of conservation strategies for the drainage.

Acknowledgments

The authors would like to thank Universidad de los Llanos for the funding and support for this work, through the agreement 5211594 signed between Unillanos and Ecopetrol and the project "Design and implementation of an electronic prototype based on DC-AC cycle converters and photovoltaic solar energy useful for electric fishing in low conductivity waters", code C8-F02-003-2019. Also, we thank Elizabeth Aya Baquero, curator of the Unillanos Natural History Museum for the management of the biological material.

References

Agostinho, A.A., Ortega, J.C.G., Bailly, D., da Graça, W.J., Pelicice, F.M. & Júlio, H. F., 2021. Introduced Cichlids in the Americas: Distribution Patterns, Invasion Ecology, and Impacts. In: Abate, M. E. & Noakes, D.L.G. (eds.). *The Behavior, Ecology and Evolution of Cichlid Fishes*. Springer Netherlands: 313-361. https://doi.org/10.1007/978-94-024-2080-7

Aguilera-Giraldo, I.A. & Vásquez-Ramos, J.M., 2019. Distribución espacial y temporal de Elmidae (Insecta: Coleoptera) y su relación con los parámetros fisicoquímicos en el río Ocoa, Meta, Colombia. *Revista de la Academia Colombiana de Ciencias Exactas, Físicas y Naturales*, 43 (166): 108-119. https://doi.org/10.18257/raccefyn.833

Albert, J.S. & Reis, R.E., 2011. *Historical biogeography of Neotropical freshwater fishes*. Berkeley CA. University of California Press.

Armbruster, J., Van de Sleen, P. & Lujan, N. 2018. Subfamily Hypostominae. In: Van der Sleen, P. & Albert, J. (Eds). *Field guide to the fishes of the Amazon, Orinoco, and Guianas*. Princeton University Press, Princeton and Oxford: 259–286.

Ballen, G.A., Urbano-Bonilla, A. & Zamudio, J.E. 2016. *Farlowella mitoupibo*, a new species of stick catfish from the upper Guaviare River, Orinoco basin, Colombia (Teleostei: Loricariidae). *Ichthyological Exploration of Freshwaters*, 27 (4): 325-332.

Ballen, G. A. & Vari, R.P. 2012. Review of the Andean armored catfishes of the genus *Dolichancistrus* Isbrücker (Siluriformes: Loricariidae). *Neotropical Ichthyology*, 10 (3): 499-518. https://doi.org/10.1590/S1679-62252012000300003

Casatti, L., Ferreira, C. & Carvalho, F.R., 2009. Grass-dominated stream sites exhibit low fish species diversity and dominance by guppies: an assessment of two tropical pasture river basins. *Hydrobiologia*, 632: 273-283. https://doi.org/10.1007/s10750-009-9849-y

Chao, A. Gotelli, N. Hsieh, T. Sander, E. Ma, K. Colwell, R. & Ellison, A., 2014. Rarefaction and extrapolation with Hill numbers: a framework for sampling and estimation in species diversity studies. *Ecological Monographs*, 84(1): 45-67. http://doi.org/10.1890/13-0133.1

Chao, A. & Jost, L., 2012. Coverage-based rarefaction and extrapolation: standardizing samples by completeness rather than size. *Ecology*, 93 (12): 2533-2547. https://doi.org/10.1890/11-1952.1

Claro-García, A. Assega, F.M. & Shibatta, O.A., 2017. Diversity and distribution of ichthyofauna in streams of the middle and lower Tibagi river basin, Paraná, Brazil. *Check List*, 14 (1): 43-53. https://doi.org/10.15560/14.1.43

Departamento Administrativo Nacional de Estadísticas – DANE. 2018. Censo Nacional de población y vivienda 2018 Colombia. https://www.dane.gov.co/index.php/estadisticas-por-tema/demografia-y-poblacion/censo-nacional-de-poblacion-y-vivenda-2018.

DoNascimiento, C. Bogotá Gregory, J.D. Albornoz Garzón, J.G. Méndez López, A. Villa Navarro, F.A. Herrera Collazos, E.E. Agudelo Zamora, H. & Arce H, M., 2021. *Lista de especies de peces de agua dulce de Colombia / Checklist of the freshwater fishes of Colombia. v. 2.13*. Asociación Colombiana de Ictiólogos. Dataset/Checklist. https://doi.org/10.15472/numrso

Eigenmann, C.H. 1917. *Pimelodella* and *Typhlobagrus*. *Memoirs of the Carnegie Museum*, 7: 229–258, pls. 29–35. https://doi.org/10.5962/p.34485

Eigenmann, C.H. 1922. The fishes of western South America, Part I. The fresh-water fishes of northwestern South America, including Colombia, Panama, and the Pacific slopes of Ecuador and Peru, together with an appendix upon the fishes of the Rio Meta in Colombia. *Memoirs of the Carnegie Museum*, 9 (1): 1-346, Pls. 1-38. https://doi.org/10.5962/p.234839

Eigenmann, C.H. & Fisher, H.G. 1916. In: Eigenmann, C.H. New and rare fishes from South American rivers. *Annals of the Carnegie Museum*, 10 (1-2) (art. 6): 77-86, Pls. 13-16. https://doi.org/10.5962/p.328780

Fricke, R. Eschmeyer, W.N. & Van der Laan, R., 2022. Eschmeyer's Catalog of fishes: genera, species, references. Available from https://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp [accessed 10 Jul. 2023].

Hooper, D., Chapin, F., Ewel, J., Hector, A., Inchausti, P., Lavorel, S., . . . Wardle, D. A. (2005). Effects pf biodiversity on ecosystem funtioning a consensus of current knowledge. *Ecological Monographs*, 75 (1): 3-35. https://doi.org/10.1890/04-0922

Hsieh, T.C. Ma, K.H. & Chao, A., 2020. iNEXT: Interpolation and Extrapolation for Species Diversity. R package version 2.0.20. Available from http://chao.stat.nthu.edu.tw/wordpress/software_download/ [accessed 10 Jul. 2023].

Instituto de Hidrología, Metereología y Estudios Ambientales - IDEAM, 2022. Metadatos Estación 35030370. http://dhime.ideam.gov.co/atencionciudadano/

Jiménez-Prado, P., Vásquez, F. Rodríguez-Olarte, D. & Taphorn, D., 2020. Efectos de la especie invasora *Poecilia gillii* (Cyprinodontiformes: Poeciliidae) sobre *Pseudopoecilia fria* en ríos costeros de la región del Chocó, Ecuador. *Revista de Biología Tropical*, 68 (1): 122-138. https://doi.org/10.15517/rbt.v68i1.36000

Jost, L., 2006. Entropy and diversity. *Oikos*, 113 (2): 363-375. http://doi.org/10.1111/j.2006.0030-1299.14714.x

Jost, L. & González-Oreja, J., 2012. Midiendo la diversidad biológica: más allá del índice de Shannon. *Acta Zoológica Liloana*, 56 (1-2): 3-14.

Kullander, S. O., López-Fernández, H. & Van de Sleen, P. 2018. Family Cichlidae. In: Van der Sleen, P. & Albert, J. (Eds). *Field guide to the fishes of the Amazon, Orinoco, and Guianas*. Princeton University Press, Princeton and Oxford: 359–385.

Lasso, C.A. & Machado-Allison, A. 2000. *Sinopsis de las especies de peces de la familia Cichlidae presentes en la cuenca del Rio Orinoco. Claves, diagnosis, aspectos bioecologicos e ilustraciones*. Serie Peces de Venezuela. Universidad Central de Venezuela. 150 pp., 14 pls.

Lima, F.C.T. 2022. Revision of the smaller-sized dorados (*Salminus*), with comments on the monophyly of the genus and its biogeography (Characiformes: Bryconidae). *Zootaxa*, 5226 (1): 1-66. https://doi.org/10.11646/zootaxa.5226.1.1

Londoño-Burbano, A., Román-Valencia, C. & Taphorn, D. C. 2011. Taxonomic review of Colombian Parodon (Characiformes: Parodontidae), with description of three new species. *Neotropical Ichthyology*, 9 (4): 709-730. https://doi.org/10.1590/S1679-62252011000400003

Londoño-Burbano, A., Urbano-Bonilla, A., Rojas-Molina, Y., Ramírez-Gil, H. & Prada-Pedreros, S. 2018. A new species of *Spatuloricaria* Schultz, 1944 (Siluriformes: Loricariidae), from the Orinoco River basin, Colombia. *Copeia*, 106 (4): 611-621. https://doi.org/10.1643/CI-18-087

López-Fuentes, C. Velázquez-Velázquez, E. Anzueto-Calvo, M. Matamoros, W.A. & Salgado-Maldonado, G., 2021. First record of the non-native fish *Poecilia reticulata* (Cyprinodontiformes: Poeciliidae), in Chiapas, southern Mexico. *UNED Research Journal*, 13 (1): e3266. https://doi.org/10.22458/urj.v13i1.3266

Machado-Allison, A. Lasso, C.A. Usma-Oviedo, J. Sánchez-Duarte, P. & Lasso-Alcalá, O., 2010. Capítulo 7: Peces. In: C.A. Lasso, J. Usma, F. Trujillo & A. Rial (eds.). *Biodiversidad de la cuenca del Orinoco: bases científicas para la identificación de áreas prioritarias para la conservación y uso sostenible de la biodiversidad*. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, World Wide Fund Colombia, Fundación Omacha, Fundación La Salle e Instituto de Estudios de la Orinoquia (Universidad Nacional de Colombia): 217-255.

Mago-Leccia, F., Lundberd, J.G. & Baskin, J.N. 2001. The Gymnotiform fishes of the Orinoco River. Pp. 1-121.

Maldonado-Ocampo, J.A. Urbano-Bonilla, A. Preciado, J.V. & Bogotá-Gregory, J.D. 2013. Peces de la cuenca del río Pauto, Orinoquia Colombiana. *Biota Colombiana*, 14: 114-137.

Marinho, M.M.F. & Menezes, N. A. 2017. Taxonomic review of *Copella* (Characiformes: Lebiasinidae) with an identification key for the species. *PLoS ONE*, 12 (8): e0183069. https://doi.org/10.1371/journal.pone.0183069

Mees, G. F. 1988. Notes on the genus *Tatia* (Pisces, Nematognathi, Auchenipteridae). *Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen* (*Series C*, *Biological and Medical Sciences*), 91(4): 405-414.

Myers, G.S. 1927. Descriptions of new South American fresh-water fishes collected by Dr. Carl Ternetz. *Bulletin of the Museum of Comparative Zoology*, 68 (3): 107-135. Available from https://www.biodiversitylibrary.org/page/2797648 [accessed 10 Jul. 2023].

Nijssen, H. & Isbrücker I.J.H. 1980. A review of the genus *Corydoras* Lacépède, 1803 (Pisces, Siluriformes, Callichthyidae). *Bijdragen tot de Dierkunde*, 50 (1): 190-220.

Osorio-Ramírez, D., Díaz-Celis, O., Caro-Caro, C.I. & Duque-Cabrera, J., 2015. Generalidades del área de estudio. In: M.A. Torres-Mora, C.I. Caro-Caro, H. Ramírez-Gil, S.L. Parada-Guevara, J.M. Trujillo-González, R.E. Ajiaco-Martínez. & Díaz-Celis, O.D. (eds.). *Cuenca alta del río Meta: una mirada socioambiental a los ríos Guayuriba y Ocoa y al caño Quenane-Quenanito. Villavicencio, Colombia*. Villavicencio. Universidad de los Llanos: 12-65.

R Core Team, (2022). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for

Statistical Computing. Available from https://www.R-project.org [accessed 10 Jul. 2023].

Ramírez-Gil, H. Ortega-Lara, A. Ajiaco-Martínez, R.E. & Pineda-Arguello, I., 2011. *Ictiofauna del río Orotoy: distribución e importancia. Villavicencio, Colombia*. Posgrados en Gestión ambiental Sostenible. Universidad de los Llanos.

Reis, R.E. Albert, J.S. di Dario, F. Mincarone, M.M. Petry, P. & Rocha, L.A., 2016. Fish biodiversity and conservation in South America. *Journal of Fish Biology*, 89 (1): 12-47. https://doi.org/10.1111/jfb.13016

Rojas-Peña, J.I. Vásquez-Ramos, J.M. Salinas-Jiménez, L.G. Osorio-Ramírez, D.P. & Caro-Caro, C.I., 2021. Effects of physical and chemical factors on Ephemeroptera (Insecta) assemblages in an urban river of the eastern Colombian Llanos. *Papéis Avulsos de Zoologia*, 61: e20216107. https://doi.org/10.11606/1807-0205/2021.61.07

Royero, R. & Lasso, C., 1992. Distribución actual de la mojarra de río, *Caquetaia kraussii*, (Steindachner, 1878) (Perciformes: Cichlidae) en Venezuela: un ejemplo del problema de la introducción de especies. *Memoria - Sociedad de Ciencias Naturales La Salle*, 53 (138): 163-180.

Schultz, L.P. 1944. The catfishes of Venezuela, with descriptions of thirty-eight new forms. *Proceedings of the United States National Museum*, 94: 173-338, pls. 1–14. https://doi.org/10.5479/si.00963801.94-3172.173

Taphorn-B, D.C. 2003. *Manual de identificación y biología de los peces Characiformes de la cuenca del río Apure en Venezuela*. BioCentro, Guanare, estado Portuguesa, Venezuela: 1-446

Urbano-Bonilla, A. Zamudio, J. Maldonado-Ocampo, J.A. Bogotá-Grégory, J.D. Cortés-Millán, G. & López, L., 2009. Peces del piedemonte del departamento de Casanare, Colombia. *Biota Colombiana*, 10: 149-162.

Urbano-Bonilla, A. Prada-Pedreros, S. Zapata, A. Barrera-Cataño, J. & Moreno-Cárdenas, C., 2014. Composición y riqueza íctica en quebradas y ríos del piedemonte de la cuenca del río Cusiana (Orinoquia colombiana). *Biota Colombiana*, 15: 31-48.

Urbano-Bonilla, A. Ballen, G.A. Herrera-R, G.A. Zamudio, J. Herrera-Collazos, E.E. DoNascimiento, C. Prada-Pedreros, S. & Maldonado-Ocampo, J.A., 2018. Fishes of the Cusiana River (Meta River basin, Colombia), with an identification key to its species. *ZooKeys*, 733: 65-97. https://doi.org/10.3897/zookeys.733.20159

Urbano-Bonilla, A. & Ballen, G. A. 2021. A new species of *Chaetostoma* (Siluriformes: Loricariidae) from the Orinoco basin with comments on Amazonian species of the genus in Colombia. *Journal of Fish Biology*, 98 (4): 1091-1104. https://doi.org/10.1111/jfb.14640

Usma, J.S. Maldonado-Ocampo, J.A. Villa-Navarro, F.A. Ortega-Lara, A. Taphorn, D. Urbano-Bonilla, A. Zamudio, J.E. & DoNascimiento, C., 2016. Peces de la cuenca del río Meta. In: F. Trujillo, R. Antelo & J.S. Usma (eds.). *Biodiversidad de la cuenca baja y media del río Meta*. Fundación Omacha, Fundación Palmarito, WWF: 104-119.

Van der Sleen, P. & Albert, J., 2018. *Field Guide to the Fishes of the Amazon, Orinoco, and Guianas*. Princeton University Press, Princeton and Oxford. https://doi.org/10.1515/9781400888801

Vari, R.P. 1991. Systematics of the neotropical characiform genus *Steindachnerina* Fowler (Pisces, Ostariophysi). *Smithsonian Contributions to Zoology*, 507: 1-118. https://doi.org/10.5479/si.00810282.507

Villa-Navarro, F. Urbano-Bonilla, A. Ortega-Lara, A. Taphorn, D. & Usma-Oviedo, J.S., 2011. Peces del Casanare. In: J.S. Usma & F. Trujillo (eds.). *Biodiversidad del departamento del Casanare, identificación de ecosistemas estratégicos*. Gobernación del Casanare, WWF: 120-137.

Zamudio, J.E. & Maldonado-Ocampo, J.A., 2021. Prioridades para la conservación de los peces de agua dulce en la Orinoquia andina de Colombia. *Caldasia*, 44(1): 41-53. https://doi.org/10.15446/caldasia.v44n1.84798

Zamudio, J. Urbano-Bonilla, A. Preciado-Silva, V. Rodríguez-Cubillos, D. & Herrera-Collazos, E.E., 2017. Ichthyofauna of piedmont and savannah environments in the Casanare River drainage, Orinoco Basin, Colombia. *Biota Colombia*, 18(2): 199-211. https://doi.org/10.21068/c2017.v18n02a13