Ichthyofauna of piedmont and savannah environments in the Casanare River drainage, Orinoco Basin, Colombia

Ictiofauna de los ambientes de piedemonte y sabana en el drenaje del río Casanare, cuenca del Orinoco, Colombia

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Abstract

Currently, only 20 fish species have been recorded from the Casanare River, which is one of the main tributaries of the Meta River drainage. To characterize the fish assemblages of this river, samplings were carried out at 35 collecting stations in low and high water seasons of 2015. The results obtained, raised the number of fish species of the Casanare River drainage to 180, of which 41 are exclusive to the piedmont, 83 to the savannah and 56 are shared between both units; 19 species are endemic, 11 are migratory, and three are classified in one of the national threat categories. Three species were found to be undescribed and one represents a new record for the Orinoco River Basin in Colombia. This study fills the lack of information for the Casanare River drainage, highlights its importance as a potential area for biodiversity conservation and facilitates the decision-making process related to the management planning and conservation of the hydrographic basin.

Key words. Composition. Fishes. Inventory. Neotropical ichthyology. Richness.

Resumen

Actualmente, sólo se han registrado 20 especies de peces para el río Casanare, uno de los principales afluentes de la cuenca del río Meta. Con el fin de caracterizar los ensamblajes de peces de este río, se realizaron muestreos en 35 estaciones de colecta en los períodos de aguas bajas y altas del 2015. Los resultados obtenidos incrementaron el número de especies de peces de la cuenca del río Casanare a 180, de las cuales 41 son exclusivas del piedemonte, 83 de la sabana y 56 son compartidas entre ambas unidades; 19 especies son endémicas, 11 son migratorias y tres están clasificadas en una de las categorías de amenaza nacional. Se encontraron tres especies no descritas y una representa un nuevo registro para la cuenca del río Orinoco en Colombia. Este estudio llena el vacío de información para la cuenca del río Casanare, destaca su importancia como área potencial para la conservación de la biodiversidad y facilita el proceso de toma de decisiones relacionado con la planificación de manejo y conservación de la cuenca hidrográfica.

Palabras clave. Ictiología Neotropical. Composición. Inventario. Peces. Riqueza.

Introduction

The Orinoco River Basin, with an area of 981,446 km^2, shared between Venezuela (65 %) and Colombia (35 %) (Lasso *et al*. 2016), harbors 1002 fish species (Reis *et al*. 2016), from which more than 66 % (663 spp.) are found in Colombia (DoNascimiento *et al.* 2017), in different aquatic systems of the Andean Orinoco, piedmont and savannahs natural ecoregions (Abell *et al*. 2008).

The tributaries of the Orinoco River in Colombia are the Arauca, Guaviare, Vichada, Inírida, Tomo, Bita and Meta rivers, where the sampling effort and the level of knowledge are low (scores 1 or 2 on a scale of 1 to 4) and the information gap is high (scores 3 and 4 on a scale of 1 to 4) (Lasso *et al*. 2016). The Meta River is the main Colombian Orinoco tributary with an area of 10830,4 km^2 (Machado-Allison *et al*. 2010), medium to high fish species richness and important levels of endemism (of 577 species recorded, 10 or more are endemics), and high importance for local human communities with 298 economically important species (Usma *et al*. 2016). However, part of this richness is currently threatened with 15 species classified as Endangered (Mojica *et al*. 2012), mainly as an effect of several anthropic impacts such as land conversion and habitat loss, especially in the piedmont and savannah regions (Barletta *et al*. 2010, 2016, Reis *et al*. 2016).

In the last few years, the increase in the ichthyological knowledge has been significant for the principal tributaries of the Meta River (Mojica 1999, Urbano-Bonilla *et al*. 2009, 2014, Villa-Navarro *et al*. 2011, Maldonado-Ocampo *et al*. 2013, Usma *et al*. 2016). However, there are still poorly-known drainages such as the Casanare River drainage, that currently has information gaps (Machado-Allison *et al*. 2010, Lasso *et al*. 2016), and for which only 20 fish species have been recorded (Villa-Navarro *et al*. 2011). For this reason, the ichthyological inventory of the piedmont and savannahs of the Casanare River drainage is presented here, as an effort to contribute to the knowledge of its composition and richness, and to structure a base-line of the fish species found in the hydrographic drainage.

Material and methods

Study site

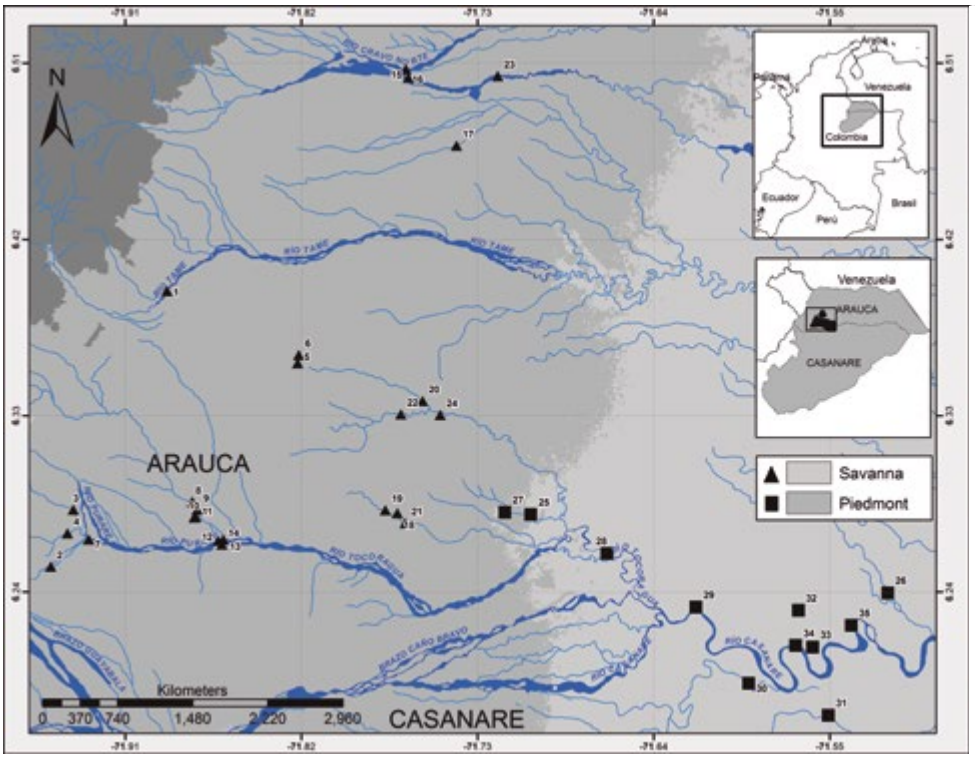
The main tributary of the Orinoco River in Colombia is the Meta River, which has an extensive system of tributaries that drain the Andes Mountains (Casanare, Ariporo, Cusiana, Cravo Sur, Pauto, Túa, Upía and Guachiría rivers). The Casanare River, with an extension of 8000 km^2, originates in El Cocuy Natural National Park at 3685 m a.s.l (06°18'N, 072°21'W), and joins with the Ariporo River at 85 m a.s.l (06°03'N, 069°53'W) (IGAC 1999). The Casanare River drainage includes several different natural habitat units (Andean mountain, piedmont and savannah or llanos areas) and aquatic ecosystems (streams, rivers, wetlands and morichales) (Garavito-Fonseca *et al*. 2011) that drain part of the territory in the departments of Boyacá, Casanare and Arauca. The annual hydrological cycle of the drainage is unimodal with maximum rainfall through June-July, and minimum during January-February. The average monthly temperature is 25,9 °C and the precipitation 298,3 mm (IDEAM 2016 http://www.ideam.gov.co/web/tiempo-y-clima/clima).

This study considered two natural units, the Andean piedmont that comprises the Andean versant above 200 m a.s.l, and the savannahs and flooded forests below 200 m a.s.l (Lasso *et al*. 2010). For the delimitation of natural units, the layer intersection tool was used (slope, geo-shape, covers and climate), available in ArcGIS ©10.2 (Figure 1).

Data Collection and Treatment

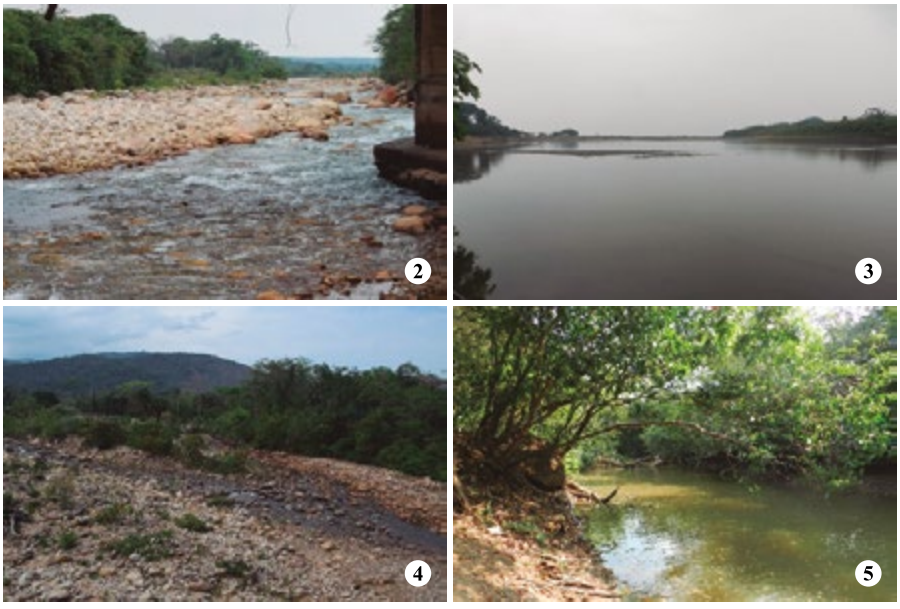
Samplings took place during two hydrological seasons: low water (March-April 2015) and high water (August-September 2015). The collections were carried out at 35 sampling localities in the Casanare River drainage including rivers, streams, lakes, floodplain lagoons and morichales, of which 24 are in the piedmont and 11 in flooded savannahs (Figures 2–11). The coordinates follow the WGS84 system.

Collection in piedmont stations was carried out with transects of 75 meters in length using an electrofishing



	Piedmont	m a.s.l
1	Río Tame	586
2	Caño La Lejía	546
3	Quebrada Aguas Negras	520
4	Quebrada La Colorada	514
5	Laguna La Vieja 2	492
6	Laguna La Vieja 1	487
7	Quebrada La Lejía	482
8	Caño 1 Tributario del río Tocoragua	421
9	Río Tocoragua 2	420
10	Caño 2 Tributario del río Tocoragua	413
11	Nacedero Morichal	411
12	Caño La Florida	395
13	Río Tocoragua 1	387
14	Río Purare	386
15	Río Cravo Norte 2	369
16	Río Culebrero	346
17	Caño Gualabao	331
18	Caño 2 Tributario del caño Caribabare	318
19	Caño 1 Tributario del caño Caribabare	302
20	Caño Totumal	285
21	Caño Caribabare	264
22	Caño Puna Puna 2	264
23	Río Cravo Norte 1	262
24	Caño Puna Puna 1	257
	Savannahs	
25	Caño Mapoy	199
26	Caño Banderita	197
27	Laguna El Vergel	192
28	Río Tocoragua	188
29	Caño Bejuquero	183
30	Caño Yaguarapo	178
31	Caño Aracal	176
32	Caño La Raya	159
33	Estero El Chenchenal	155
34	Río Casanare 1	154
35	Río Casanare 2	145

Figure 1. Spatial localization of the sampling sites in piedmont (black triangles) and savannah (black squares) in the Casanare River drainage.



Figures 2–5. Ecosystems in piedmont and savannahs in the Casanare River drainage: **2:** piedmont river (río Tame), **3:** savannah river (río Casanare 1), **4:** piedmont stream (caño Puna Puna), **5:** savannah stream (caño La Raya and caño Yaguarapo).

Figures 6–11. Ecosystems in piedmont and savannahs in the Casanare River drainage: **6:** piedmont white-water creek (quebrada La Colorada), **7:** savannah stream (caño La Raya and caño Yaguarapo), **8:** piedmont black-water creek (caño La Lejía), **9:** savannah floodplain lagoon (estero El Chenchenal), **10:** piedmont lagoon (laguna La Vieja), **11:** savannah lagoon (laguna El Vergel).

equipment (Samus 725G/550-600), complemented with six successive passes of a seine (5 m long, 2 m height and 0,1 cm mesh) and 20 throws of a cast net (3 m diameter and 2 cm mesh). In the savannah stations, sampling spanned a transect of 100 m, performing eight passes of a seine (7 m long, 2 m height and 0,1 cm mesh), 20 throws of cast net (diameter of 4 m and 2,5 cm mesh) and the installation of 20 hooks during two hours (hooks and lines of different size and bait types). Two "stationary" gillnets (23 m long, 2 m height and 5 cm mesh) were used along the main course of the Casanare River, which were installed during 4 hours and examined every half hour.

The specimens were anesthetized in-situ with benzocaine solution and fixed in 10 % formalin, and then preserved in 70 % ethanol. Specimens were identified and housed in the ichthyological collections of both the Instituto Alexander von Humboldt (IAvH-P) and the Museo Javeriano de Historia Natural Lorenzo Uribe Uribe S.J (MPUJ). Large-sized species and those under any national threat category, were identified in the field, photographed and posteriorly released in their capture site. Taxonomic identification was done at the species level using species descriptions, taxonomic revisions and specialized taxonomic keys (Lasso and Machado-Allison 2000, Vari and Harold 2001, Taphorn

2003, Armbruster 2003, 2005, Netto-Ferreira *et al*. 2009, Londoño-Burbano *et al*. 2011, Ballen and Vari 2012, Ballen and Mojica 2014, Menezes and Lucena 2014, Marinho and Langeani 2016). The list of species and the validation of the scientific names follow the classification of Eschmeyer *et al*. (2016 http://www.calacademy.org/scientists/catalog-of-fishes-classification/).

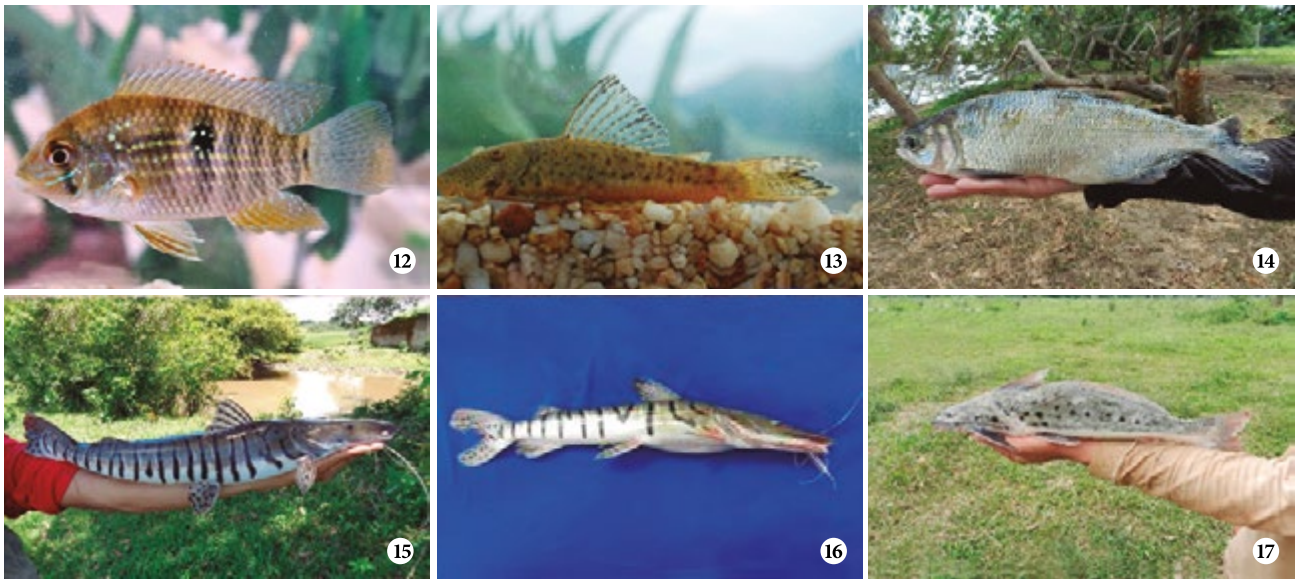
Species were categorized as endemic of Orinoco river drainage or some sub-drainage (Machado-Allison *et al*. 2010), migratory (Zapata and Usma 2013) and threatened (Mojica *et al*. 2012), in order to assess the conservation status of the fish fauna in the drainage.

Lastly, the complete dataset was uploaded to SiB Colombia's (GBIF Colombia Node) Integrated Publishing Tool in order to increase the visibility and reach of the information produced herein. The Darwin Core standard (Wieczorek *et al.* 2012) was used as the biodiversity standard to structure the complete dataset. The shared dataset is identified by a DOI, provided by SiB Colombia and is available at http://doi.org/10.15472/fjsg8q. All the results and discussion showed herein follow the version 2.2 of the published dataset.

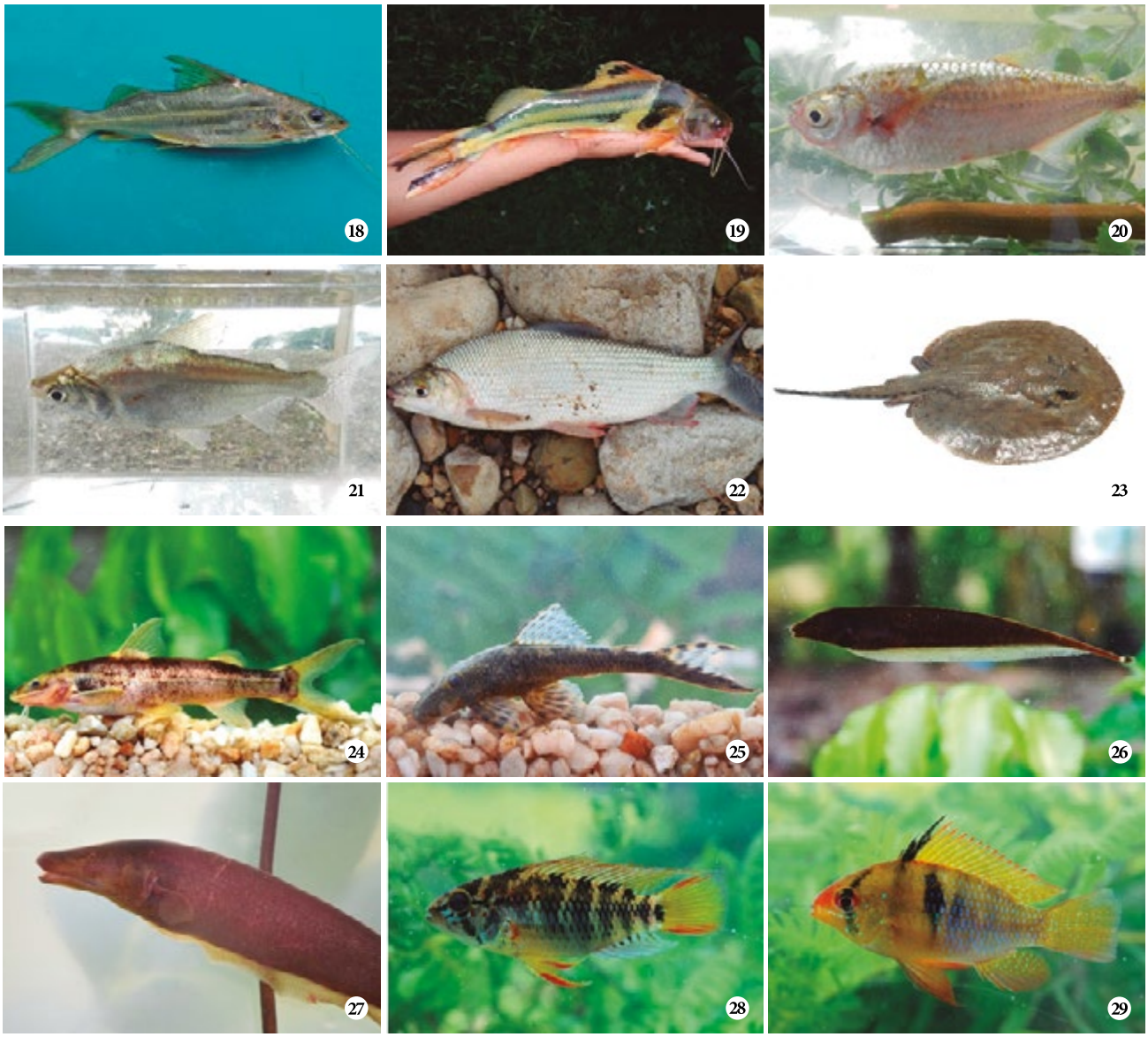
Results

We recorded 180 fish species belonging to 110 genera, 33 families and seven orders. The order Characiformes was the richest with 92 species followed by the Siluriformes with 68, Gymnotiformes with 9 and the Cichliformes with 8, while the Myliobatiformes, Synbranchiformes and Cyprinodontiformes were represented by one species each (Figures 12–65). Of these species, 41 are exclusive to the piedmont, 83 to the savannah and 56 are shared between both natural units. We found 27 species with taxonomic uncertainty that are in revision process, three are presumably undescribed species: *Andinoacara* sp. (Figure 12), *Chaetostoma* sp. (Figure 13) and an undetermined genus of Heptapteridae. *Epapterus blohmi* is herein reported as a new record for the Orinoco River Basin in Colombia.

Likewise, 19 species are endemic to the Orinoco River Basin, 11 are migratory (Figures 14–22) and three categorized as threatened: *Pseudoplatystoma metaense* (Figure 15) and *P. orinocoense* (Figure 16) are Vulnerable-VU and *Potamotrygon orbignyi* (Figure 23) is Near Threatened-NT.

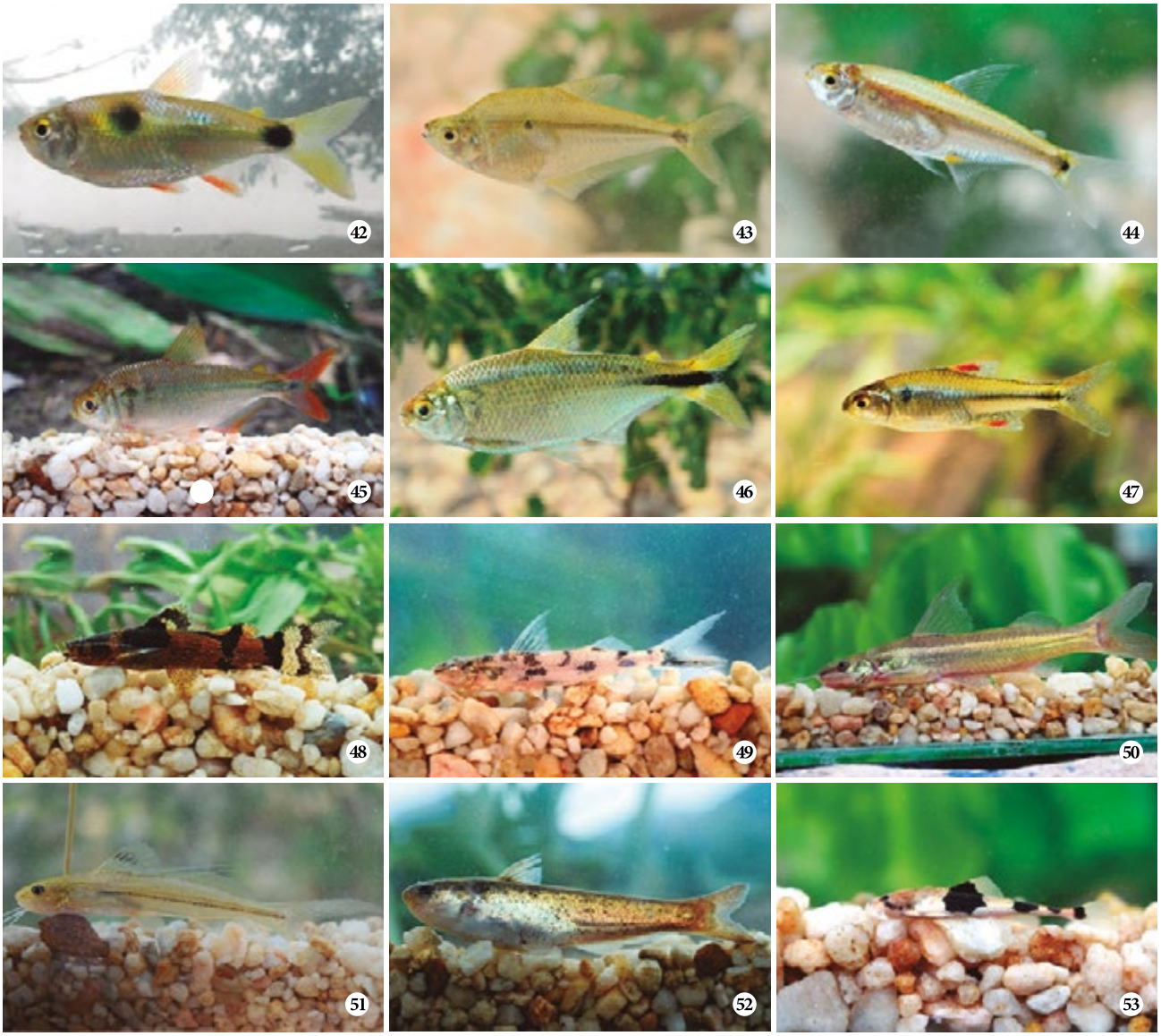


Figures 12–17. Undescribed, migratory, threatened and endemic species from the Casanare River drainage: **12:** *Andinoacara* sp., **13:** *Chaetostoma* sp., **14:** *Brycon amazonicus*, **15:** *Pseudoplatystoma metaense*, **16:** *P. orinocoense*, **17:** *Calophysus macropterus.*



Figures 18–29. Undescribed, migratory, threatened and endemic species from the Casanare River drainage: **18:** *Pimelodus blochii*, **19:** *P. ornatus*, **20:** *Triportheus venezuelensis*, **21:** *Potamorhina altamazonica*, **22:** *Prochilodus mariae*, **23:** *Potamotrygon orbignyi*, **24:** *Cetopsorhamdia* aff. *picklei*, **25:** *Lasiancistrus tentaculatus*, **26:** *Apteronotus galvisi*, **27:** *A. macrostomus*, **28:** *Apistogramma viejita*, **29:** *Mikrogeophagus ramirezi.*

Figures 30–41. Fish species recorded from the Casanare River drainage: **30:** *Parodon apolinari*, **31:** *Steindachnerina pupula*, **32:** *Serrasalmus irritans*, **33:** *Entomocorus gameroi*, **34:** *Lebiasina erythrinoides*, **35:** *Copella eigenmanni*, **36:** *Pyrrhulina lugubris*, **37:** *Gymnocorymbus bondi*, **38:** *Aphyocharax alburnus*, **39:** *Paragoniates alburnus*, **40:** *Xenagoniates bondi*, **41:** *Acestrocephalus* sp.



Figures 42–53. Fish species recorded from the Casanare River drainage: **42:** *Exodon paradoxus*, **43:** *Roeboides dientonito*, **44:** *Cheirodontops geayi*, **45:** *Astyanax integer*, **46:** *A. venezuelae*, **47:** *Creagrutus melasma*, **48:** *Microglanis iheringi*, **49:** *Imparfinis pseudonemacheir*, **50:** *Imparfinis* sp. 1, **51:** *Pimelodella metae*, **52:** *Cetopsis orinoco*, **53:** *Hoplomyzon sexpapilostoma.*

Figures 54–65. Fish species recorded from the Casanare River drainage: **54:** *Hypostomus plecostomoides*, **55:** *Hypostomus* sp. 1, **56:** *Chaetostoma joropo*, **57:** *Panaqolus maccus*, **58:** *Astroblepus* sp., **59:** *Eigenmannia virescens*, **60:** *Hypopygus lepturus*, **61:** *Electrophorus electricus*, **62:** *Synbranchus marmoratus,* **63:** *Hemisorubim platyrhynchos*, **64:** *Oxydoras sifontesi*, **65:** *Entomocorus* sp.

Discussion

The highest diversification of the freshwater fish species took place in the tropical and subtropical regions, as a result of climatic and environmental processes and ecological factors (Levêque *et al*. 2008, Winemiller 2008). Among freshwater groups, the Characiformes and Siluriformes are the most diversified and representative taxa of the Neotropical ichthyofauna (Albert and Reis 2011, Reis *et al*. 2016), which has been studied at different spacial scales (Lasso *et al*. 2004, Urbano-Bonilla *et al*. 2009, 2014, Villa-Navarro *et al*. 2011, Maldonado-Ocampo *et al*. 2013). In this study the same pattern was observed, where Characiformes and Siluriformes represent 89,1 % of recorded species.

Urbano-Bonilla *et al*. (2009) reported 15 species for the piedmont natural unit of the Casanare River drainage, while in this study the number increased to 97. This richness is higher than that found for the piedmont in other adjacent drainages such as the Pauto (58 spp.), Túa (49 spp.) and Upía river (45 spp.) (Urbano-Bonilla *et al*. 2009). This is the first contribution to the knowledge of the fishes found in the savannah natural unit in the Casanare River drainage with 139 species. These results highlight the importance of the multi-spatial and multi-temporal inventories that improve our knowledge about community composition, which can not be successfully recorded by means of isolated punctual samplings. Such approach is even more relevant for areas with highly diverse and speciose faunas such as the Orinoco River Basin (Lasso *et al*. 2016).

Villa-Navarro *et al*. (2011) found 20 fish species for the Casanare River drainage, while Usma *et al*. (2016) recorded only three species in the drainage. In this study we found 180 species, placing the Casanare River as the second drainage in species richness of freshwater fishes within the Meta River drainage, surpassed only by the Cusiana River, with 258 species (Usma *et al*. 2016). Although some patterns of fish distribution and richness have been reported for piedmont rivers (Urbano-Bonilla *et al*. 2009, 2014), savannahs (Hoeinghaus *et al*. 2004, Arrington and Winemiller 2006) and shared environments (Willis *et al*. 2005), the present contribution complements previous studies on the ichthyofauna of the Casanare River drainage. However, similar efforts are still needed in order to characterize the species composition in the upper (more than 1000 m a.s.l) and lower portions of the drainage (below 150 m a.s.l). Such biological assessment studies are important given the strong anthropogenic impact present in these areas (i.e., land conversion due to colonization, mining, agricultural and livestock), factors with a direct impact on the composition, richness and function of the fish community due to habitat loss (Machado-Allison *et al*. 2011, Barletta *et al*. 2016, Lasso *et al*. 2016, Reis *et al*. 2016, Toussaint *et al*. 2016).

Fish species richness in the Casanare River drainage represents 27,3 % of that reported for the Orinoco River Basin in Colombia, including a new record, three presumably undescribed species, 19 endemics, 11 migratory and three categorized as threatened. This information about the ichthyofauna present in the drainage is useful, considering that conservation efforts are focused on prioritized areas according to the level of knowledge about richness, endemism, threats and importance for human communities (Machado-Allison *et al*. 2010, Trujillo *et al*. 2011, Portocarrero-Aya *et al*. 2014). Therefore, our results contribute to filling some knowledge gaps on the fish communities of the Casanare River drainage, and highlight its importance as a potential area for biodiversity conservation. In addition, this information is expected to allow environmental authorities to develop and implement management plans for a series of human activities such as fishing and hydrobiological resource use in the drainage.

Conclusion

The natural eco-regions of Orinoco Piedmont and Savannahs or Orinoco Llanos, have unique attributes of resources and microhabitat availability and water types, which facilitate the refuge, dispersion and reproduction for a high number of freshwater fish species. This study highlights the importance of performing ichthyological explorations in poorly sampled environments, as it

contributes to the baseline to knowledge of biodiversity and serves as a tool for regional environmental authorities as CORPORINOQUIA, to formulate the Plan for the Management of the Casanare River drainage. In addition, this information is key to identify conservation priorities for migratory, endemic or endangered species and priority areas or drainages for conservation, in the process of selection and enactment of national protected areas in Colombia.

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Literature Cited

Abell, R., M. L. Thieme, C. Revenga, M. Bryer, M. Kottelat, N. Bogutskaya, B. Coad, N. Mandrak, S. Contreras-Balderas, W. Bussing, M. L. J. Stiassny, P. Skelton, G. R. Allen, P. Unmack, A. Naseka, R. Ng, N. Sindorf, J. Robertson, E. Armijo, J. V. Higgins, T. J. Heibel, E. Wikramanayake, D. Olson, H. L. López, R. E. Reis, J. G. Lundberg, M. H. Sabaj-Pérez and P. Petry. 2008. Freshwater ecoregions of the world: a new map of biogeographic units for freshwater biodiversity conservation. *BioScience* 58(5): 403–414.

Albert, J. S. and R. E. Reis. 2011. Historical biogeography of Neotropical freshwater fishes. Berkeley: University of California Press., 388 pp.

Armbruster, J. W. 2003. The species of the *Hypostomus cochliodon* group (Siluriformes: Loricariidae). *Zootaxa* 249: 1–60.

Armbruster, J. W. 2005. The loricariid catfish genus *Lasiancistrus* (Siluriformes) with description of two new species. *Neotropical Ichthyology* 3 (4): 549–569.

Arrington, D. A. and K. O. Winemiller. 2006. Habitat affinity, the seasonal flood pulse, and community assembly in the littoral zone of a Neotropical floodplain river. *Journal of the North American Benthological Society* 25 (1): 126–141.

Ballen, G. A. and R. P. Vari. 2012. Review of the Andean armored catfishes of the genus *Dolichancistrus* Isbrücker (Siluriformes: Loricariidae). *Neotropical Ichthyology* 10 (3): 499–518.

Ballen, G. A. and J. I. Mojica. 2014. A new trans-Andean Stick Catfish of the genus *Farlowella* Eigenmann & Eigenmann, 1889 (Siluriformes: Loricariidae) with the first record of the genus for the río Magdalena Basin in Colombia. *Zootaxa* 3765 (2): 134–142.

Barletta, M., A. J. Jaureguizar, C. Baigun, N. F. Fontoura, A. A. Agostinho, V. M. F. Almeida-Val, A. L. Val, R. A. Torres, L. F. Jimenez-Segura, T. Giarrizzo, N. N. Fabré, V. S. Batista, C. Lasso, D. C. Taphorn, M. F. Costa, P. T. Chaves, J. P. Vieira and M. F. M. Corrêa. 2010. Fish and aquatic habitat conservation in South America: a continental overview with emphasis on Neotropical systems. *Journal of Fish Biology* 76 (9): 2118–2176.

Barletta, M., V.E. Cussac, A.A. Agostinho, C. Baigún, E.K. Okada, A.C. Catella, N.F. Fontoura, P.S. Pompeu, L.F. Jiménez-Segura, V.S. Batista, C.A. Lasso, D. Taphorn and N.N. Fabré. 2016. Fisheries ecology in South American river basins. Pp: 311–348. *In*: J.F. Craig (Eds.). Freshwater Fisheries Ecology. Oxford: John Wiley & Sons Ltd.

DoNascimiento, C., E. E. Herrera-Collazos, G. A. Herrera-R, A. Ortega-Lara, F.A. Villa-Navarro, J. S. Usma-Oviedo and J. A. Maldonado-Ocampo. 2017. Checklist of the freshwater fishes of Colombia: a Darwin Core alternative to the updating problem. *ZooKeys* 708: 25–138. https://doi.org/10.3897/zookeys.708.13897.

Garavito-Fonseca, J., C.F. Suárez, A.M. Bravo, R. Vargas, L. Cuadros, M. Córdoba and J.S. Usma. 2011. Descripción del medio natural del departamento del Casanare. Pp: 50–71. *In*: J.S. Usma and F. Trujillo (Eds.). Biodiversidad del Casanare: Ecosistemas estratégicos del departamento. Bogotá D.C.: Gobernación de Casanare and WWF Colombia.

Hoeinghaus D.J., K.O. Winemiller and D.C. Taphorn. 2004. Compositional change in fish assemblages along the Andean Piedmont-Llanos floodplain gradient of the río Portuguesa, Venezuela. *Neotropical Ichthyology* 2(2): 85–92.

IGAC-Instituto Geográfico Agustín Codazzi. 1999. Casanare características geográficas. Bogotá D.C.: IGAC, Gobernación

de Casanare, Asociación Santiago de las Atalayas and Coporinoquia., 356 pp.

Lasso, C. and A. Machado-Allison. 2000. Sinopsis de las especies de peces de la familia Cichlidae presentes en la cuenca del Orinoco. Claves, diagnosis, aspectos bio-ecológicos e ilustraciones. Caracas: Publicaciones del Museo de Biología, Universidad Central de Venezuela., 150 pp.

Lasso, C.A., J.I. Mojica, J.S. Usma, J.A. Maldonado-Ocampo, C. DoNascimiento, D.C. Taphorn, F. Provenzano, Ó.M. Lasso-Alcalá, G. Galvis, L. Vásquez, M. Lugo, A. Machado-Allison, R. Royero, C. Suárez and A. Ortega-Lara. 2004. Peces de la cuenca del río Orinoco. Parte I: lista de especies y distribución por subcuencas. *Biota Colombiana* 5(2): 95–158.

Lasso, C.A., J.S. Usma, F. Trujillo and A. Rial. 2010. Biodiversidad de la cuenca del Orinoco: bases científicas para la identificación de áreas prioritarias para la conservación y uso sostenible de la biodiversidad. Bogotá, D.C.: Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, WWF Colombia, Fundación Omacha, Fundación La Salle and Instituto de Estudios de la Orinoquia (Universidad Nacional de Colombia)., 609 pp.

Lasso, C.A., A. Machado-Allison and D.C. Taphorn. 2016. Fishes and aquatic habitats of the Orinoco River Basin: diversity and conservation. *Journal of Fish Biology* 2016: 1–18.

Levêque, C., T. Oberdorff, D. Paugy, M.L.J. Stiassny and P.A. Tedesco. 2008. Global diversity of fish (Pisces) in freshwater. *Hydrobiologia* 595(1): 545–567.

Londoño-Burbano, A., C. Román-Valencia, and D.C. Taphorn. 2011. Taxonomic review of Colombian *Parodon* (Characiformes: Parodontidae), with descriptions of three new species. *Neotropical Ichthyology* 9 (4): 709–730.

Machado-Allison, A., C.A. Lasso, J.S. Usma, P. Sánchez-Duarte and O.M. Lasso-Alcalá. 2010. Peces. Pp: 217–257. *In*: C.A., Lasso, J.S. Usma, F. Trujillo and 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. Bogotá, D.C.: Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, WWF Colombia, Fundación Omacha, Fundación La Salle and Instituto de Estudios de la Orinoquia (Universidad Nacional de Colombia).

Machado-Allison, A., A. Rial and C.A. Lasso. 2011. Amenazas e impactos sobre la biodiversidad y los ecosistemas acuáticos de la Orinoquia venezolana. Pp: 62–87. *In*: C. A. Lasso, A. Rial, C. Matallana, W. Ramírez, J.C. Señaris, A. Díaz-Pulido, G. Corzo and A. Machado-Allison (Eds.). Biodiversidad de la Cuenca del Orinoco: II Áreas prioritarias para la conservación y uso sostenible. Bogotá, D.C.: Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, Ministerio del Ambiente, Vivienda y Desarrollo Territorial, WWF Colombia, Fundación Omacha, Fundación La Salle de Ciencias Naturales e Instituto de Estudios de la Orinoquia (Universidad Nacional de Colombia).

Maldonado-Ocampo, J.A., A. Urbano-Bonilla, J.V. Preciado and J.D. Bogotá-Gregory. 2013. Peces de la cuenca del río Pauto, Orinoquia colombiana. *Biota Colombiana* 14 (2): 114–137.

Marinho, M.M., and F. Langeani. 2016. Reconciling more than 150 years of taxonomic confusion: the true identity of *Moenkhausia lepidura*, with a key to the species of the *M. lepidura* group (Characiformes: Characidae). *Zootaxa* 4107 (3): 338–352.

Menezes, N.A. and C.A.S.D. Lucena. 2014. A taxonomic review of the species of *Charax* Scopoli, 1777 (Teleostei: Characidae: Characinae) with description of a new species from the rio Negro bearing superficial neuromasts on body scales, Amazon basin, Brazil. *Neotropical Ichthyology* 12 (2): 193–228.

Mojica, J. I. 1999. Lista preliminar de las especies de peces dulceacuícolas de Colombia. *Revista de la Academia Colombiana de Ciencias Exactas, Físicas y Naturales* 23 (Suplemento Especial): 547–566.

Mojica, J.I., J.S. Usma and C. Lasso (Eds.). 2012. Libro Rojo de Peces Dulceacuícolas de Colombia-2012. La serie de Libros Rojos de especies amenazadas de Colombia. Bogotá, D.C.: Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, Instituto de Ciencias Naturales de la Universidad Nacional de Colombia, WWF Colombia and Universidad de Manizales., 319 pp.

Netto-Ferreira, A.L., A.M. Zanata, J.L. Birindelli, and L.M. Sousa. 2009. Two new species of *Jupiaba* (Characiformes: Characidae) from the rio Tapajós and rio Madeira drainages, Brazil, with an identification key to species of the genus. *Zootaxa* 2262: 53–68.

Portocarrero-Aya, M., G. Corzo, A. Diaz-Pulido, M.F. González, M. Longo, L. Mesa, A. Paz, W. Ramírez and O.L. Hernández-Manrique. 2014. Systematic conservation assessment for most of the Colombian territory as a strategy for effective biodiversity conservation. *Natural Resources* 5: 981–1006.

Reis, R.E., J.S. Albert, F. Di Dario, M.M. Mincarone, P. Petry and L.A. Rocha. 2016. Fish biodiversity and conservation in South America. *Journal of Fish Biology* 89 (1): 12–47.

Taphorn, D.C. 2003. Manual de identificación de los peces Characiformes de la cuenca del río Apure en Venezuela. Guanare, Venezuela: UNELLEZ., 392 pp.

Toussaint, A., N. Charpin, S. Brosse and S. Villéger. 2016. Global functional diversity of freshwater fish is concentrated in the Neotropics while functional vulnerability is widespread. *Scientific Reports* 6: 22125.

Trujillo, A.F., C.F. Suárez, J.S. Usma, F. Trujillo, A.M. Bravo, M. Córdoba, F. Villa, C. Yara, L.T. Ayala, A. Acosta, J.P. Alfaro, L.F. Castillo, J. Garavito, A. Urbano, J. Zamudio, J. Peña, D. Vergel, R. Combariza and J. Cuéllar. 2011. Ecosistemas estratégicos del Casanare: áreas con alto valor de conservación. Pp: 24–49. *In*: J.S., Usma and F. Trujillo. (Eds.). Biodiversidad del Casanare: Ecosistemas Estratégicos del Departamento. Bogotá D.C.: Gobernación de Casanare, WWF Colombia.

Urbano-Bonilla, A., J. Zamudio, J.A. Maldonado-Ocampo, J.D. Bogotá-Grégory, G.A. Cortes-Millán and Y. López. 2009. Peces del piedemonte del departamento de Casanare, Colombia. *Biota Colombiana* 10 (1-2): 149–162.

Urbano-Bonilla, A., S. Prada-Pedreros, Á. Zapata, J.I. Barrera-Cataño and A.C. Moreno-Cárdenas. 2014. Composición y riqueza íctica en quebradas y ríos del piedemonte de la cuenca del río Cusiana, Orinoquia colombiana. *Biota Colombiana* 15 (Supl. 1): 52–69.

Usma, J. S., J. Maldonado-Ocampo, F. A. Villa-Navarro, A. Ortega-Lara, D. Taphorn, A. Urbano-Bonilla, J. E. Zamudio and C. DoNascimiento. 2016. Peces de la cuenca del río Meta. Pp: 103-119. In: Trujillo, F., R. Antelo and J. S. Usma (Eds.). Biodiversidad de la cuenca baja y media del río Meta. Bogotá, D.C.: Fundación Omacha, Fundación Palmarito, WWF Colombia.

Vari, R.P., and A. Harold. 2001. Phylogenetic study of the Neotropical fish genera *Creagrutus* Günther and *Piabina* Reinhardt (Teleostei: Ostariophysi: Characiformes), with a revision of the cis-Andean species. Washington, D.C.: Smithsonian Contributions to Zoology N° 613., 239 pp.

Villa-Navarro, F., A. Urbano-Bonilla, A. Ortega-Lara, D. Taphorn and J.S. Usma Oviedo. 2011. Peces del Casanare. Pp: 120–137. *In*: J.S., Usma and F. Trujillo. (Eds.). Biodiversidad del Casanare: Ecosistemas Estratégicos del Departamento. Bogotá D.C.: Gobernación de Casanare, WWF Colombia.

Wieczorek, J., D. Bloom, R. Guralnick, S. Blum, M. Döring, R. Giovanni, T. Robertson and D. Vieglais. 2012. Darwin Core: an evolving community-developed biodiversity data standard. *PloS one* 7 (1): p.e29715.

Willis, S.C., K.O. Winemiller and H. López-Fernandez. 2005. Habitat structural complexity and morphological diversity of fish assemblages in a Neotropical floodplain river. *Oecologia* 142: 284–295.

Winemiller, K.O., A.A. Agostinho and E. Pellegrini-Caramaschi. 2008. Fish ecology in tropical streams (Chapter 5). Pp: 107–146. *In*: D. Dudgeon (Eds.). Tropical Stream Ecology. San Diego: Elsevier/Academic Press.

Zapata, L.A. and J.S. Usma. 2013. Guía de las Especies Migratorias de la Biodiversidad en Colombia: Peces. Volumen 2. Bogotá D.C.: Ministerio de Ambiente y Desarrollo Sostenible and WWF-Colombia., 486 pp.

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Ichthyofauna of piedmont and savannah environments in the Casanare River drainage, Orinoco Basin, Colombia

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