Fish diversity of a tributary of the Meta River, in the flat highlands of the colombian Orinoquia

Diversidad de peces de un tributario del río Meta, en la altillanura plana de la Orinoquia colombiana

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ABSTRACT

The distribution and abundance of fishes for the Orinoco River basin drainages are influenced by hydrometric seasonality and the structural complexity of the habitat, so understanding how fish assemblages are structured on a temporal and spatial scale is essential for biological conservation. Therefore, the purpose of this study was to describe the fish assemblage for the Mitimiti stream and test the hypothesis of spatial and temporal variation. To do this, collections were made at four sampling stations on the Mitimiti stream, during three contrasting rainfall seasons, with the help of a 10 m x 1.5 m trawl net and a 2 mm mesh eye. The diversity of fish assemblages was analyzed using Hill numbers, abundance-based dissimilarity, and a Canonical Correspondence Analysis (CCA). In total, 2,493 individuals and 115 species were recorded, where the orders with the highest dominance were Characiformes and Blenniiformes. Regarding the diversity of order q = 0, no significant differences were found between the hydrological periods and the sampling stations, however, the low water period and St3 exhibited the highest species richness. The most dissimilar

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hydrological period was the high-water season and the variables that significantly influenced fish assemblage were water temperature (p = 0.02) and dissolved oxygen (p = 0.05).

Keywords — Assemblage, Hill numbers, hydrological periods, Meta River.

RESUMEN

La distribución y abundancia de peces para los drenajes de la cuenca del río Orinoco están influenciadas por la estacionalidad hidrométrica y la complejidad estructural del hábitat, por lo que entender cómo se estructuran los ensamblajes de peces a escala temporal y espacial, es fundamental para la conservación biológica. Por lo anterior, el presente estudio tuvo como finalidad describir el ensamblaje de peces para el caño Mitimiti y probar la hipótesis de variación espacial y temporal. Para ello se realizaron recolecciones en cuatro estaciones de muestreo sobre el caño Mitimiti, durante tres temporadas pluviométricas contrastantes, con ayuda de una red de arrastres de 10 m x 1.5 m y ojo de malla de 2 mm. La diversidad de los ensamblajes ícticos se analizó mediante los números de Hill, la disimilitud basada en abundancia y un Análisis de Correspondencia Canónica (CCA). En total, se registraron 2.493 individuos y 115 especies, donde los órdenes con mayor dominancia fueron Characiformes y Blenniiformes. En cuanto a la diversidad de orden q = 0 no se encontraron diferencias significativas entre los periodos hidrológicos y las estaciones de muestreo, sin embargo, el periodo de aguas bajas y la St3 exhibieron la mayor riqueza de especies. El periodo hidrológico más disímil fue la temporada de aguas altas y las variables que influyeron significativamente en el ensamblaje de peces fueron la temperatura del agua (p = 0.02) y el oxígeno disuelto (p = 0.05).

Palabras clave — Ensamblaje, números de Hill, periodos hidrológicos, río Meta.

INTRODUCTION

The Orinoco River basin is recognized for its high number of fish species (722), and for its high rates of endemism that represents a 12 % of the species of the country (DoNascimiento et al., 2021). This basin is mainly affected by deforestation because of the expansion of the agricultural, oil and urban frontier (Lasso, Machado-Allison, Taphorn, 2016; DoNascimiento et al., 2017), which may be causing a loss of diversity. In the last decade, several efforts have been carried out to document the fish richness of the region (Mojica, 1999; Maldonado-Ocampo, 2000, 2001, 2004; Galvis et al., 2007; Lasso et al., 2004; Maldonado-Ocampo et al., 2006, Maldonado-Ocampo, Vari, Usma, 2008; Lasso et al., 2009; Urbano-Bonilla et al., 2009; Machado-Allison, Lasso, Usma, Sánchez-Duarte, Lasso-Alcalá, 2010; Ramírez-Gil, Ortega-Lara, Ajiaco-Martínez, Pineda-Arguello, 2011; Villa-Navarro, Urbano-Bonilla, Ortega-Lara, Taphorn, Usma-Oviedo, 2011; Maldonado-Ocampo, Urbano-Bonilla, Preciado, Bogotá-Gregory, 2013; Urbano-Bonilla et al., 2014; Usma et al., 2016; Urbano-Bonilla et al., 2018). However, most of the studies have focused on the tributaries of the foothills of the Meta River, leaving an information gap for the sub-basins and micro-basins of the high plains (Usma et al., 2016).

Currently, one of the challenges of ecology and conservation biology is to understand the factors that determine the richness, abundance, and distribution of species in megadiverse regions (Arrington and Winemiller, 2005), due to the crisis of biodiversity loss produced by anthropogenic impacts (Cardinale et al., 2012; Montoya-Ospina, López-Delgado, Hevia, Villa-Navarro, 2020). For the Colombian Orinoquia, most of the studies on fish communities have focused on the surveying (Urbano-Bonilla et al., 2009; Ramírez-Gil et al., 2011; Villa-Navarro et al., 2011; Maldonado-Ocampo et al., 2013; Urbano-Bonilla et al., 2014; Usma et al., 2016; Zamudio et al., 2017; Urbano-Bonilla et al., 2018), and a few studies have focused on fish assemblages, based on habitat structural complexity (Montoya-Ospina et al., 2020; Lasso et al., 2021) and temporality (Ospina-O, Bedoya-Giraldo, Villa-Navarro, 2021). Therefore, the objective of this study was to describe the fish assemblage of the Mitimiti stream and test the hypothesis that they vary at a spatial and temporal level.

MATERIAL AND METHODS

Study Area

The Mitimiti stream is a first-order tributary, which drains the middle part of the Meta River basin. It is located to the northwest of the municipality of Puerto Gaitán (4°31'37.8"N 71°48'36.3"W) in the department of Meta (Figure 1) and it has an approximate length of 20 km and an elevation that oscillates between 150 and 200 m. It is a channel characterized by being located in the well-drained flat sheets and alluvial plains of the Meta River, that is located at the tropical humid forest formation (Bh-) (Instituto Geográfico Agustín Codazzi [IGAC] (1977)). It has an average annual temperature of 26-28 °C and an average annual rainfall of 2,000-2,500 mm (Instituto de Hidrología, Meteorología y Estudios Ambientales [IDEAM] (2005)). The annual hydrological cycle of Mitimiti stream is unimodal, with minimum rainfall in January and maximum during the months of June-July (IDEAM, 2023).

Sampling and Data Collection

To obtain samples of fish community assemblages, samples were collected at a spatial level at four sampling stations (St) on the Mitimiti stream, during three contrasting rainfall seasons: descending (November-2021), low (March-2022) and high (June-2022) waters. To capture the fish, collection events were carried out during the day, using a 12 m x 1.5 m trawl net with a 5 mm mesh eye; a total of 10 trawls were made for each collection event, covering both the shores and the central zone of each body of water, with a sampling effort of approximately 2 hours by station. Some physicochemical variables were determined in situ, such as water temperature (ºC), pH, dissolved oxygen (mg/l), electrical conductivity (μS/cm) and total dissolved solids (g/l) using a Hanna HI98x94 multiparameter equipment.

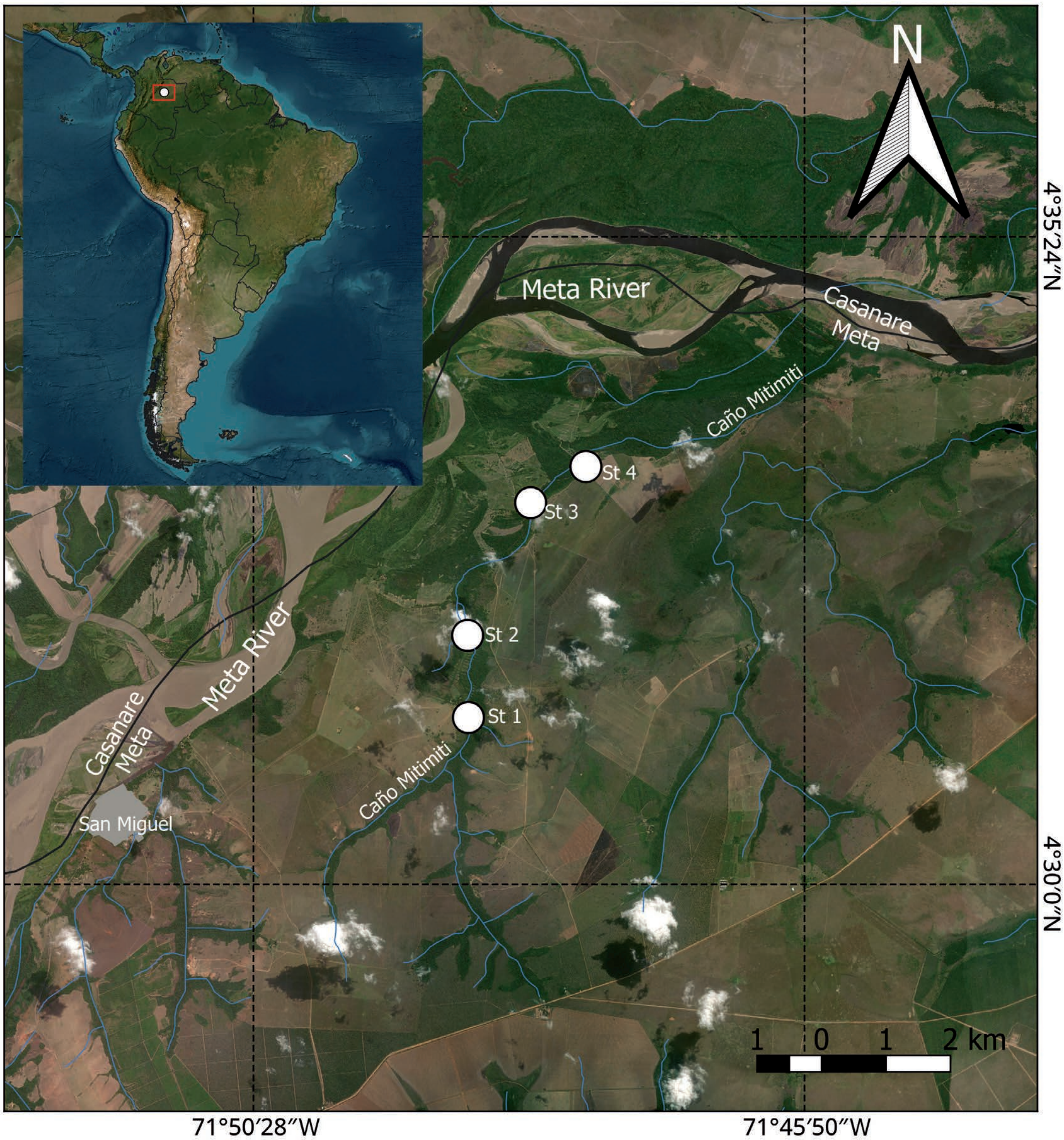

Figure 1. Geographical location and sampling stations on the Mitimiti stream.

The captured fish were anesthetized and sacrificed in a clove oil solution (Eugenol 0.5 ml/L) (Lucena et al., 2013). The specimens were separated by morphotypes and fixed in a 10% formaldehyde solution, and finally preserved in 70% alcohol. For the identification of the collected species, specialized taxonomic keys, original descriptions, and taxonomic revisions were used (Eigenmann & Henn, 1914; Isbrücker and Nijssen, 1988; Vari, 1984, 1989, 1991, 1992a, 1992b; Vari, Castro, Raredon, 1995; Silfvergrip, 1996; Lasso and Machado-Allison, 2000; Taphorn, 2003; Malabarba, 2004; Bührnheim and Malabarba, 2007; Buitrago-Suárez and Burr, 2007; Sidlauskas, Garavello, Jellen, 2007; Benine and Lopes, 2008; Menezes and Lucena, 2014; Crampton, de Santana, Waddell, Lovejoy, 2016; Lima, 2017; Marinho and Menezes, 2017; Armbruster, Van der Sleen, Lujan, 2018; Bockmann and Slobodian, 2018; Birindelli and Akama, 2018; Birindelli and de Souza, 2018; Covain and Van der Sleen, 2018; Kullander, López-Fernández, Van der Sleen, 2018; Mattox, Van der Sleen, Toledo-Piza, 2018; Reis and Van der Sleen, 2018; Sidlauskas and Birindelli, 2018; Van der Sleen and Lima, 2018; Van der Sleen, Netto-Ferreira, Malabarba, 2018; Cortés-Hernández, DoNascimiento, Ramírez-Gil, 2020; Lima, 2022). The validation of the taxonomic status of the species was corroborated in the Eschmeyer's Catalog of Fishes (Fricke, Eschmeyer, Van der Laan, 2023). The lots were deposited in the ichthyological collection of the Museo de Historia Natural Unillanos (MHNU-I).

Statistical Analysis

To determine the existence of significant statistical differences between the physicochemical variables at a temporal level, a non-parametric one-way Kruskal-Wallis test was performed using the package stats v. 4.3.0 of the R Core Team programming language (2023). For the diversity analysis, the sampling effort on the Mitimiti stream was estimated, through the completeness of the sampling coverage (SC) as suggested by Chao and Jost (2012) and Chao et al. (2014). In addition, to compare the diversity of fish present in each sampling station and hydrological period, an analysis of the effective number of species was carried out based on the first three numbers of the Hill series (Jost, 2006; Jost and González-Oreja, 2012); all analyses were carried out in the iNEXT package (Hsieh, Ma, Chao, 2020) of Rstudio statistical software (Rstudio Team 2023).

The total dissimilarity between the hydrological periods was obtained by means of the abundance data matrix, which was calculated using the Ruzicka dissimilarity index in the betapart package (Baselga, 2016). The variation in species composition was represented in hierarchical clustering dendrograms generated from the component dissimilarity matrices. To determine if fish assemblage variation is directly influenced by water physicochemical variables (e.g., water temperature, pH, electrical conductivity, total dissolved solids and dissolved oxygen), a canonical correspondence analysis (CCA) was performed on the vegan package (Oksanen et al., 2022). All these analyzes were carried out using the Rstudio statistical software (Rstudio Team 2023).

RESULTS

For the physicochemical variables, no statistically significant differences were detected between the hydrological periods (Kruskal-Wallis, water temperature $p = 0.2757$; pH $p = 0.0976$; electrical conductivity $p = 0.4664$; total dissolved solids $p = 0.4292$; dissolved oxygen $p = 0.4909$). The St3 presented the highest values of water temperature, especially in periods of low and falling water. The pH was very similar between the sampling stations, characterized by being acidic waters (4.71–6.54). The St1, St3 and St4 presented the highest values of electrical conductivity for the periods of descending and high waters. The St4 presented the lowest values of dissolved oxygen in the three hydrological periods sampled (Table 1).

Table 1. Physicochemical parameters measured in four sampling stations on the Mitimiti stream. Abbreviations: EC – Electrical conductivity (µS/cm); TDS – Total dissolved solids (g/L); DO – Dissolved oxygen (mg/L).

Sampling station	Hidrological periods	Temperature (°C)	pH	EC	TDS	DO
1	Falling water	27.04	4.76	7	0.003	3.08
	Low water	28.33	5.75	7	0.003	4.08
	High water	26.79	5.17	24	0.012	4.11
2	Falling water	26.67	5.51	6	0.003	4.21
	Low water	26.29	6.54	5	0.003	4.68
	High water	26.12	5.02	6	0.003	4.71
3	Falling water	30.42	5.76	77	0.038	2.78
	Low water	36.06	6.18	10	0.005	5.19
	High water	27.87	6.12	45	0.021	1.86
4	Falling water	27.38	4.71	10	0.005	1.98
	Low water	27.83	5.80	11	0.006	2.03
	High water	25.92	5.89	33	0.017	0.94

A total of 2,493 individuals distributed in six orders, 31 families, 91 genera and 115 species (Table 2; Figure 2-3) were collected. The most representative orders in catches were Characiformes, with 17 families, 52 genera and 68 species, followed by Siluriformes, with 9 families, 26 genera and 31 species. The families with the greatest richness and abundance were Characidae (29 species, 25.2%; n = 903, 36.2%), Cichlidae (12 species, 10.4%; n = 384, 15.4%), Curimatidae (9 species, 7.8%; n = 313, 12.5%) and Lebiasinidae (2 species, 1.7%; n = 141, 5.6%). The most abundant species among the total specimens collected were *Hemigrammus micropterus* Meek, 1907 (n = 249), *Cyphocharax spilurus* (Günther, 1864) (n = 123), *Hyphessobrycon metae* Eigenmann & Henn, 1914 (n = 120), *Copella eigenmanni* (Regan, 1912) (n = 112) and *Thoracocharax stellatus* (Kner, 1858) (n = 110). For the three hydrological periods sampled, the orders with the highest relative abundance were Characiformes and Blenniiformes, both contributing 89.6 % of the abundance.

The completeness of the sampling coverage (SC) for the Mitimiti stream was 99.2%. Extrapolation (q = 0) suggests that the estimated richness for Mitimiti stream is approximately 130 species (95% CI = 115.0–148.6), where the observed richness represents 88.4% of the estimated richness. The diversity of order q = 1 was estimated in 52 common species and for order q = 2 it was estimated in 32 dominant species. When discriminating by hydrological periods, it was found that the completeness of the sampling coverage (SC) varied between 98.0% in descending waters and 98.4% in low waters (Table 3). For the diversity of order q = 0, no significant differences were found between the hydrological periods, however, the low water period presented the highest species richness observed (q0 = 76) and the descending water period the lowest richness (q0 = 61). The diversity of order q = 1 varied between 24.7 to 36.4 equivalent species, being the hydrological period of high waters the of higher number of common species. The diversity of order q = 2 varied between 15.4 and 24.6 effective species, being the hydrological period of falling waters the least number of dominant species (Table 3; Figure 4). When discriminating by sampling stations under a range of comparable abundance, we did not find significant differences in diversity of order q = 0; however, St3 was significantly different compared to St1 and St2 for diversity of order q = 1 and 2 (Figure 5). St 3 presented

Table 2 (page 1 of 3). List of species captured and their abundance for the three contrasting hydrological periods on the Mitimiti strem. Abbreviation: MHNU-I – Ichthyological collection of Museo de Historia Natural Unillanos.

Order / Family / Species	Falling water	Low water	High water	MHNU-I
CHARACIFORMES				
Acestrorhynchidae				
Acestrorhynchus falcirostris (Cuvier, 1819)	0	5	11	4454
Acestrorhynchus microlepis (Jardine, 1841)	5	1	0	4055
Anostomidae				
Laemolyta taeniata (Kner, 1858)	0	0	2	4511
Leporellus cf. vittatus (Valenciennes, 1850)	0	0	1	4512
Leporinus friderici (Bloch,1794)	0	2	1	4175
Megaleporinus sp.	1	0	0	4100
Schizodon scotorhabdotus Sidlauskas, Garavello & Jellen, 2007	3	0	5	4076
Bryconidae				
Brycon falcatus Müller & Troschel, 1844	1	3	0	4455
Brycon whitei Myers & Weitzman, 1960	0	5	0	4142
Salminus hilarii Valenciennes, 1850	4	0	2	4054
Characidae				
Aphyocharax erythrurus Eigenmann, 1912	5	29	7	4518
Astyanax aff. *bimaculatus* (Linnaeus, 1758)	0	2	19	4488
Astyanax integer Myers, 1930	1	5	1	4143
Axelrodia riesei Géry, 1966	26	24	31	4057
Charax apurensis Lucena, 1987	0	0	2	4473
Charax notulatus Lucena, 1987	0	0	2	4489
Charax sp.	11	0	0	4086
Cheirodontops geayi Schultz, 1944	1	1	0	4105
Ctenobrycon spilurus (Valenciennes, 1850)	10	6	31	4163
Cyanogaster noctivaga Mattox, Britz, Toledo-Piza & Marinho, 2013	19	0	11	4122
Cynopotamus bipunctatus Pellegrin, 1909	0	0	8	4491
Gephyrocharax valencia Eigenmann, 1920	0	19	0	4187
Gymnocorymbus bondi (Fowler, 1911)	0	21	11	4145
Hemibrycon metae Myers, 1930	0	0	57	4492
Hemigrammus barrigonae Eigenmann & Henn 1914	15	6	0	4124
Hemigrammus cf. *analis* Durbin, 1909	2	0	0	4058
Hemigrammus micropterus Meek 1907	115	132	2	4059
Hemigrammus newboldi (Fernández-Yépez, 1949)	0	0	10	4521
Hyphessobrycon metae Eigenmann & Henn, 1914	104	5	11	4126
Hyphessobrycon otrynus Benine & Lopes, 2008	1	0	0	4061
Hyphessobrycon sweglesi (Géry, 1961)	0	0	2	4552
Markiana geayi (Pellegrin, 1909)	0	0	1	4493
Moenkhausia copei (Steindachner, 1882)	0	1	7	4148
Moenkhausia dichroura (Kner, 1858)	0	3	14	4164
Moenkhausia lepidura (Kner, 1858)	9	5	13	4106
Odontostilbe splendida Bührnheim & Malabarba, 2007	23	21	8	4108
Poptella compressa (Günther, 1864)	0	0	16	4528
Roeboides affinis (Günther, 1868)	2	0	9	4088
Tetragonopterus argenteus Cuvier, 1816	0	4	2	4214
Chilodontidae				
Caenotropus labyrinthicus (Kner 1858)	0	4	0	4190
Chilodus punctatus Müller & Troschel, 1844	0	14	10	4150
Crenuchidae				
Characidium zebra Eigenmann, 1909	2	2	0	4097
Melanocharacidium dispilomma Buckup,1993	0	2	0	4213

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Ctenoluciidae				
Boulengerella cuvieri (Spix & Agassiz, 1829)	3	0	0	4103
Curimatidae				
Curimatella dorsalis (Eigenmann & Eigenmann, 1889)	0	8	0	4176
Curimatella immaculata (Fernández-Yépez, 1948)	0	11	0	4177
Curimatopsis evelynae Géry, 1964	0	28	21	4139
Cyphocharax festivus Vari, 1992	0	2	3	4178
Cyphocharax spilurus (Günther, 1864)	50	42	31	4077
Potamorhina altamazonica (Cope, 1878)	62	2	0	4078
Psectrogaster ciliata (Müller & Troschel, 1844)	4	0	0	4079
Steindachnerina argentea (Gill, 1858)	0	1	2	4160
Steindachnerina pupula Vari, 1991	13	33	0	4080
Cynodontidae				
Cynodon gibbus (Spix & Agassiz, 1829)	4	0	0	4073
Erythrinidae				
Hoplerythrinus unitaeniatus (Spix & Agassiz, 1829)	2	3	0	4114
Hoplias malabaricus (Bloch, 1794)	11	6	2	4049
Gasteropelecidae				
Thoracocharax stellatus (Kner, 1858)	5	105	0	4083
Hemiodontidae				
Hemiodus semitaeniatus Kner, 1858	1	1	7	4051
Hemiodus unimaculatus (Bloch, 1794)	8	1	4	4052
Iguanodectidae				
Bryconops giacopinii (Fernández-Yépez, 1950)	0	13	16	4151
Lebiasinidae				
Copella eigenmanni (Regan, 1912)	43	66	3	4053
Pyrrhulina lugubris Eigenmann, 1922	8	21	0	4118
Prochilodontidae				
Prochilodus mariae Eigenmann, 1922	65	20	0	4081
Serrasalmidae				
Catoprion mento (Cuvier, 1819)	3	9	16	4050
Piaractus orinoquensis Escobar L., Ota, Machado-Allison, Andrade-López, Farias & Hrbek, 2019	0	0	1	4465
Pygocentrus cariba (Humboldt, 1821)	1	2	0	4074
Serrasalmus irritans Peters, 1877	0	5	3	4137
Triportheidae				
Triportheus venezuelensis Malabarba, 2004	2	18	71	4082
GYMNOTIFORMES				
Hypopomidae				
Brachyhypopomus brevirostris (Steindachner, 1868)	0	1	1	4216
Sternopygidae				
Eigenmannia cf. *limbata* (Schreiner & Miranda Ribeiro, 1903)	3	14	0	4090
SILURIFORMES				
Aspredinidae				
Bunocephalus aloikae Hoedeman, 1961	1	2	0	4111
Auchenipteridae				
Pseudepapterus hasemani (Steindachner, 1915)	0	1	0	4167
Tatia reticulata Mees, 1974	0	0	1	4559
Tatia romani Mees, 1988	0	0	1	4560
Trachelyopterus galeatus (Linnaeus, 1766)	1	2	5	4129
Callichthyidae				
Corydoras axelrodi Rössel, 1962	0	1	0	4192
Corydoras cf. *cortesi* Castro, 1987	0	2	0	4193

Table 2 (page 3 of 3). List of species captured and their abundance for the three contrasting hydrological periods on the Mitimiti strem. Abbreviation: MHNU-I – Ichthyological collection of Museo de Historia Natural Unillanos.

Order / Family / Species	Falling water	Low water	High water	MHNU-I
Hoplosternum littorale (Hancock, 1828)	1	8	0	4091
Doradidae				
Agamyxis albomaculatus (Peters, 1877)	0	0	5	4502
Amblydoras gonzalezi (Fernández-Yépez, 1968)	2	0	16	4093
Oxydoras niger (Valenciennes, 1821)	4	2	0	4094
Platydoras armatulus (Valenciennes, 1840)	1	2	0	4131
Heptapteridae				
Imparfinis sp.	0	0	1	4504
Pimelodella longibarbata Cortés-Hernández, DoNascimiento & Ramírez-Gil, 2020	0	1	0	4197
Pimelodella sp.	0	0	3	4536
Rhamdia laukidi Bleeker, 1858	0	3	0	4222
Rhamdia sp.	0	0	1	4505
Loricariidae				
Ancistrus triradiatus Eigenmann, 1918	0	3	2	4195
Farlowella vittata Myers, 1942	0	1	0	4218
Hypoptopoma machadoi Aquino & Schaefer, 2010	0	0	18	4531
Hypostomus plecostomus (Linnaeus, 1758)	3	0	2	4063
Loricariichthys sp. Bleeker, 1862	9	14	11	4092
Panaqolus maccus (Schaefer & Stewart, 1993)	1	0	0	4110
Rineloricaria eigenmanni (Pellegrin, 1908)	0	0	3	4534
Pimelodidae				
Hemisorubim platyrhynchos (Valenciennes, 1840)	1	3	0	4095
Pimelodus albofasciatus Mees, 1974	8	43	15	4112
Pseudoplatystoma metaense Buitrago-Suárez & Burr, 2007	2	1	0	4096
Pseudoplatystoma orinocoense Buitrago-Suárez & Burr, 2007	0	1	0	4439
Sorubim lima (Bloch & Schneider, 1801)	0	1	4	4171
Pseudopimelodidae				
Microglanis iheringi Gomes, 1946	0	0	2	4561
Trichomycteridae				
Ochmacanthus alternus Myers, 1927	7	10	0	4109
CARANGIFORMES				
Achiridae				
Achirus novoae Cervigón, 1982	0	4	1	4172
BLENNIIFORMES				
Cichlidae				
Aequidens metae Eigenmann, 1922	25	11	4	4064
Andinoacara sp.	1	3	1	4113
Apistogramma hongsloi Kullander, 1979	0	0	56	4563
Apistogramma macmasteri Kullander, 1979	13	35	2	4133
Cichla orinocensis Humboldt, 1821	0	1	0	4438
Crenicichla lugubris Heckel, 1840	1	0	0	4066
Crenicichla lenticulata Heckel, 1840	46	0	2	4068
Crenicichla saxatilis (Linnaeus, 1758)	1	0	0	4067
Geophagus abalios López-Fernández & Taphorn, 2004	0	4	0	4445
Mesonauta egregius Kullander & Silfvergrip, 1991	9	7	6	4069
Mikrogeophagus ramirezi (Myers & Harry, 1948)	7	17	43	4070
Satanoperca mapiritensis (Fernández-Yépez, 1950)	23	25	41	4071
SYNBRANCHIFORMES				
Synbranchidae				
Synbranchus marmoratus Bloch, 1795	0	0	2	4538

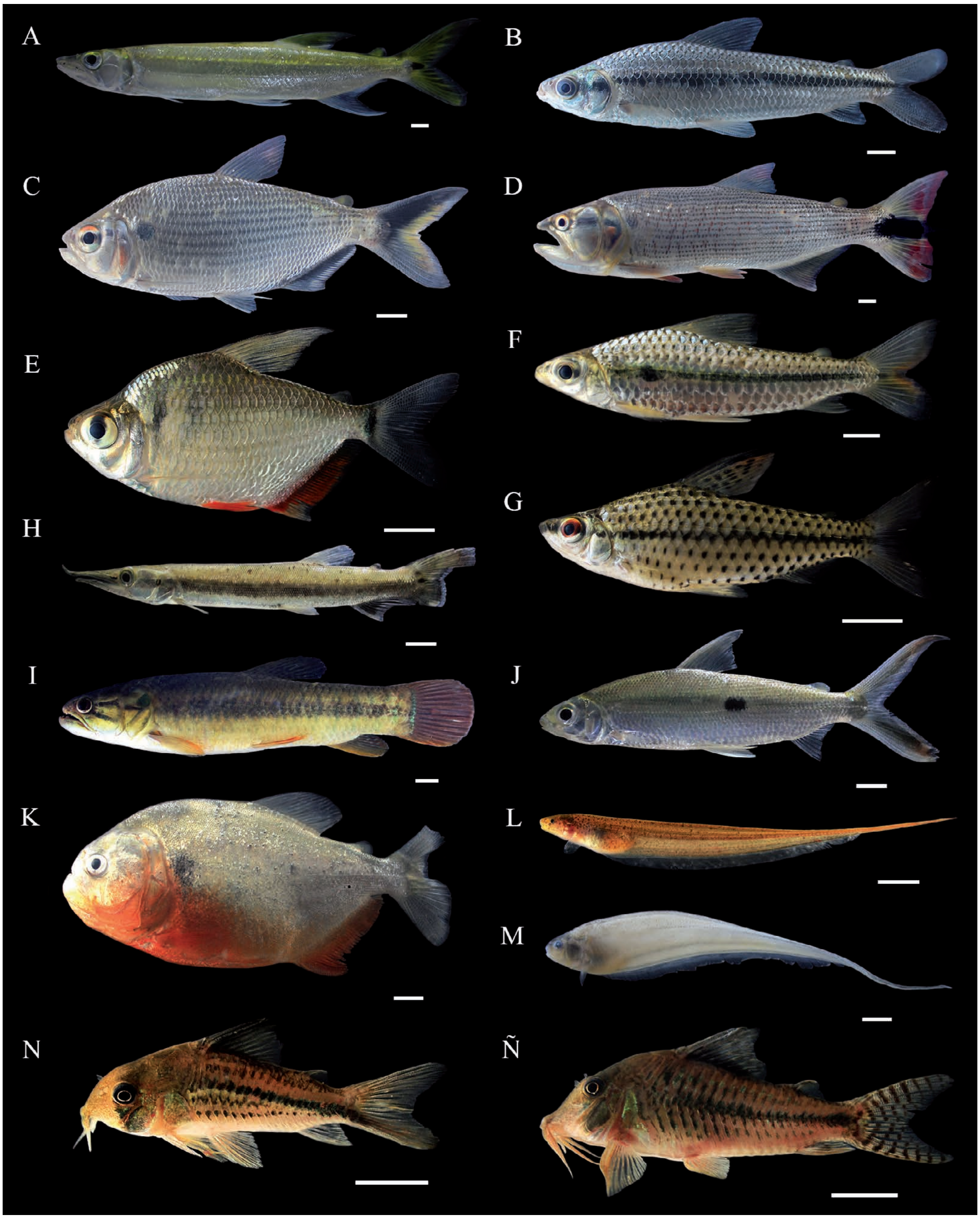

Figure 2. Live photographic record of the species collected in the Mitimiti stream. A. *Acestrorhynchus falcirostris*, B. *Schizodon scotorhabdotus*, C. *Brycon falcatus*, D. *Salminus hilarii*, E. *Tetragonopterus argenteus*, F. *Caenotropus labyrinthicus*, G. *Chilodus punctatus*, H. *Boulengerella cuvieri*, I. *Hoplerythrinus unitaeniatus*, J. *Hemiodus unimaculatus*, K. *Pygocentrus cariba*, L. *Brachyhypopomus brevirostris*, M. *Eigenmannia* cf. *limbata*, N. *Corydoras axelrodi*, Ñ. *Corydoras* cf. *cortesi*. 1 cm scale bar.

the highest richness of effective (q0 = 47.0), common (q1 = 21.2) and dominant (q2 = 12.9) species. The lowest richness of common and dominant species was presented by St 2 (q1 = 15.4 and q2=8.2) (Table 4).

The total dissimilarity of species for the hydrological periods (βRUZ) was 0.80, the balanced variation component of abundance was greater (βRUZ-BAL = 0.78)

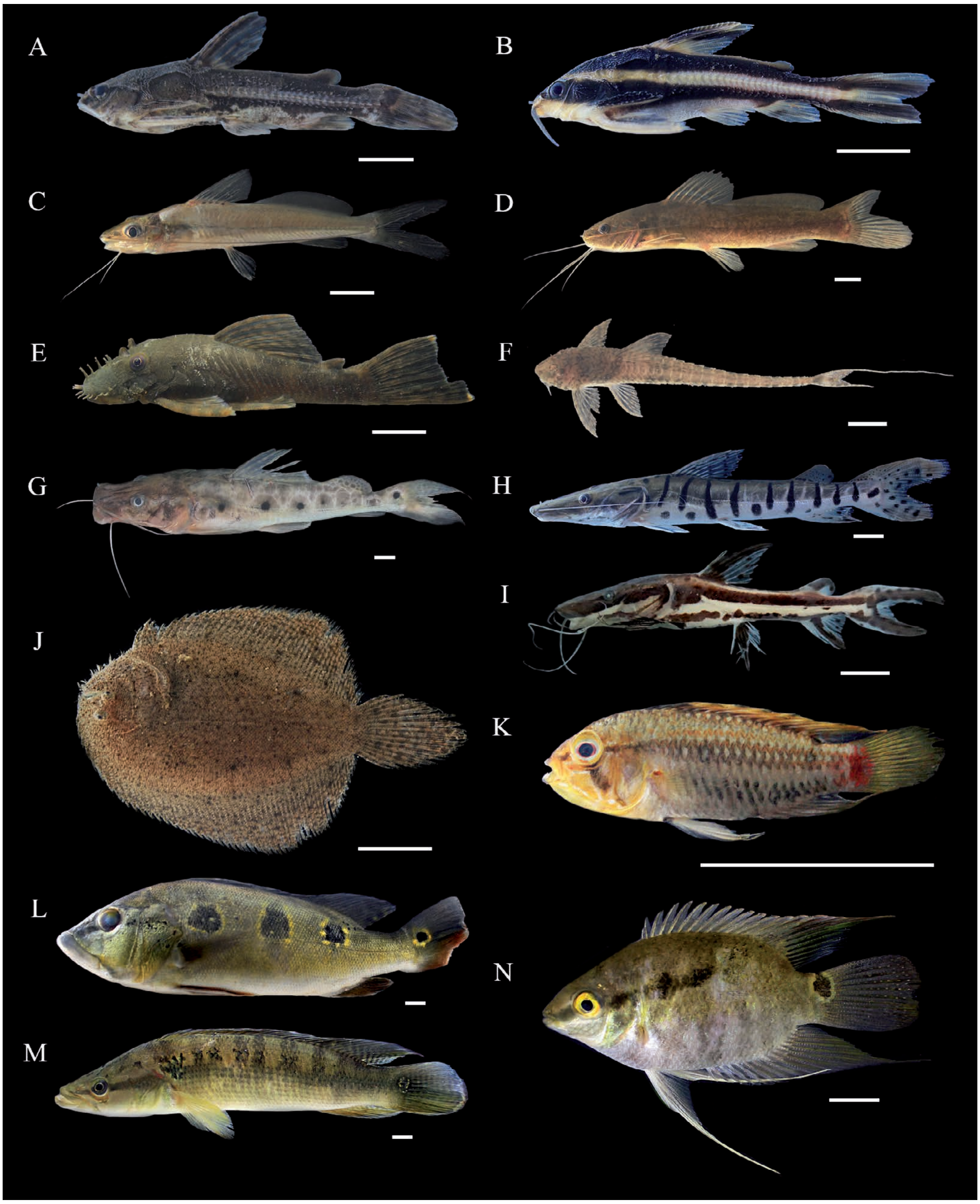

Figure 3. Live photographic record of the species collected in the Mitimiti stream. A. *Amblydoras gonzalezi*, B. *Platydoras armatulus*, C. *Pimelodella longibarbata*, D. *Rhamdia laukidi*, E. *Ancistrus triradiatus*, F. *Rineloricaria eigenmanni*, G. *Hemisorubim platyrhynchos*, H. *Pseudoplatystoma metaense*, I. *Sorubim lima* (juvenile), J. *Achirus novoae*, K. *Apistogramma hongsloi*, L. *Cichla orinocensis*, M. *Crenicichla saxatilis*, N. *Mesonauta egregious.* 1 cm scale bar.

than the abundance gradient (βRUZ-GRA = 0.02). The grouping based on the dissimilarity matrix derived from the component of balanced variation in abundance between hydrological periods, showed that the high-water period is the most dissimilar with respect to the other hydrological periods (βruz-bal > 0.8) (Figure 6). The CCA showed that our transformed and standardized data exhibit a unimodal response, where the length of the first two axes presents a deviation greater than

Table 3. Observed and estimated richness of the diversity of order q= 0, 1 and 2 for the hydrological periods. Abbreviations: n – abundance; S. obs – absolute wealth; SC – percentage of completeness of sampling coverage; Obs. – observed; Est. – estimated.

Hidrological periods	n	S. obs	SC	q = 1		q = 2		q = 3	
				Obs.	Est.	Obs.	Est.	Obs.	Est.
Falling water	815	61	98.0	61.0	79.2	24.7	26.1	15.4	15.7
Low water	942	76	98.4	76.0	85.3	33.1	34.8	19.2	19.6
High water	736	70	98.3	70.0	74.7	36.4	38.4	24.6	25.4

Table 4. Observed and estimated richness of the diversity of order q= 0, 1 and 2 for the sampling stations. Abbreviations: n – abundance; S. obs – absolute wealth; SC – percentage of completeness of sampling coverage; Obs. – observed; Est. – estimated.

Sampling station	n	S. obs	SC	q = 0		q = 1		q = 2	
				Obs.	Est.	Obs.	Est.	Obs.	Est.
1	960	42	98.9	42.0	58.6	17.1	17.6	9.9	10.0
2	441	44	96.8	44.0	60.2	15.4	16.5	8.2	8.4
3	580	47	98.6	47.0	51.5	21.2	22.2	12.9	13.1
4	329	40	96.9	40.0	45.5	18.4	19.8	11.8	12.2

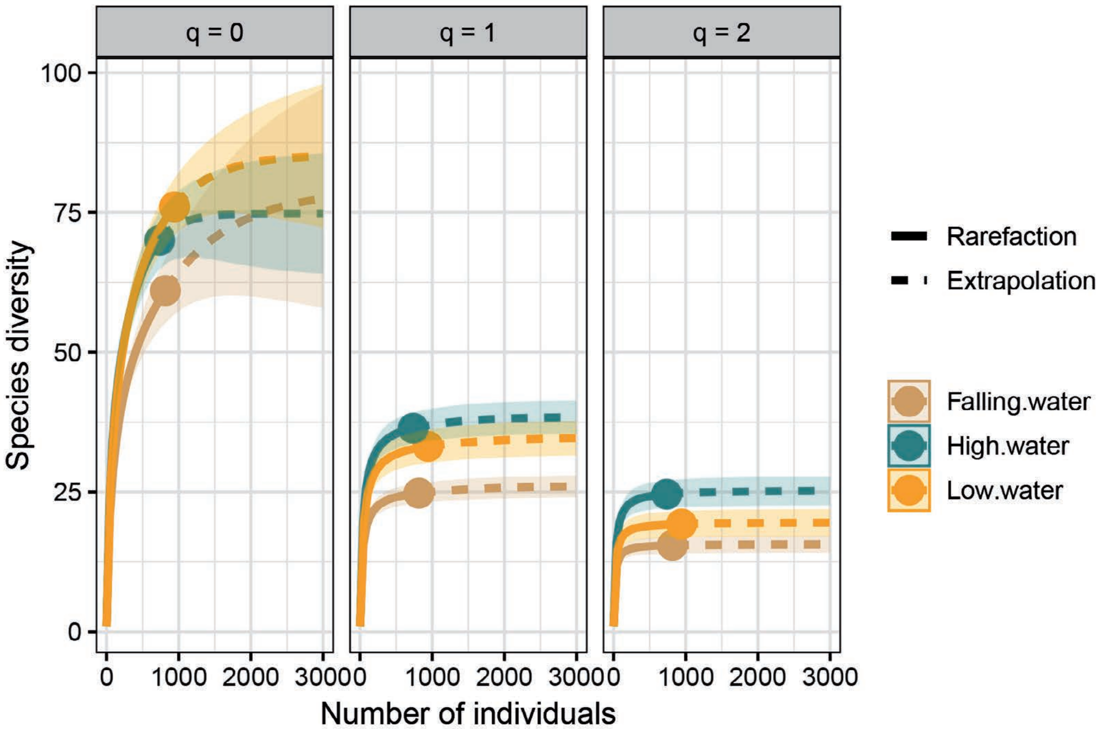

Figure 4. Species accumulation curve estimated through Hill numbers (0=Richness; 1=Shannon; 2=Simpson), for the hydrological periods of Mitimiti stream.

three units (DCA1 = 3.6969 and DCA2= 3.4802). The percentage of accumulated variance for the first two components was 28.6%. The variables that significantly influenced the assembly of fish in the Mitimiti stream were water temperature (p = 0.02) and dissolved oxygen (p = 0.05). The variable water temperature was associated with the St3 and St4 for the hydrological periods of descending and low waters, where they were grouped with the species *Pseudoplatystoma orinocoense*, *Pseudepapterus hasemani*, *Cichla orinocensis*, *Eigenmannia* cf. *limbata*, *Thoracocharax stellatus*, *Bunoceph-*

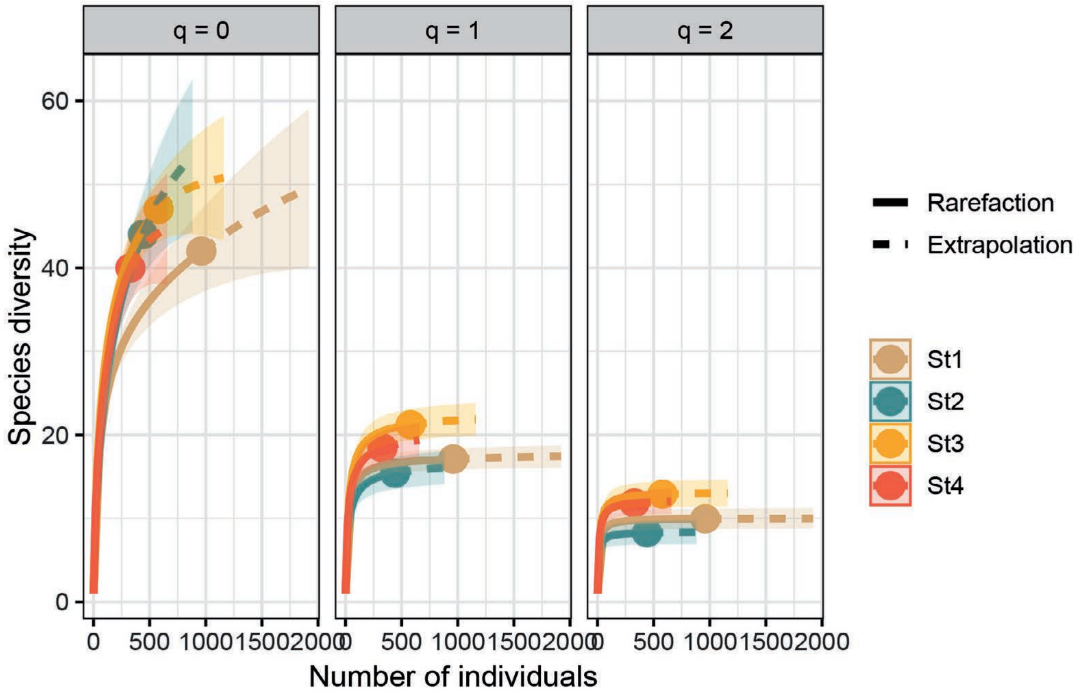

Figure 5. Species accumulation curve estimated through Hill numbers (0=Richness; 1=Shannon; 2=Simpson), for the sampling stations of Mitimiti stream.

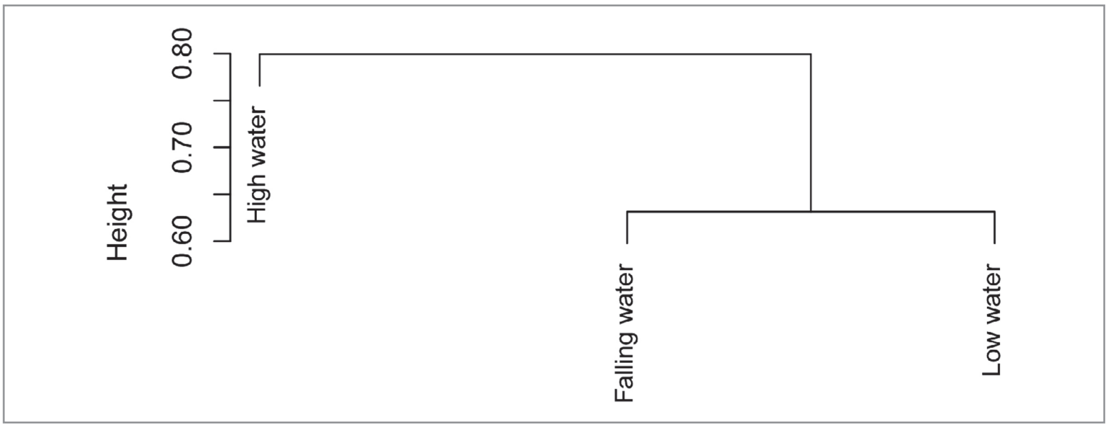

Figure 6. Hierarchical clustering dendrograms generated from component dissimilarity matrices βruz-bal for the hydrological periods of Mitimiti stream.

alus aloikae and *Hoplosternum littorale.* The dissolved oxygen variable was associated with St1 for the three hydrological periods and St2 only for the high water period, where they are grouped with the species *Apistogramma hongsloi*, *Bryconops giacopinii*, *Piaractus orinoquensis*, *Charax apurensis*, *Hyphessobrycon sweglesi*, *Tatia reticulata* and *T. romani* (Figure 7).

DISCUSSION

The species collected from the Mitimiti stream show a very similar taxonomic composition to that reported for other Neotropical drainages, where the orders Characi-

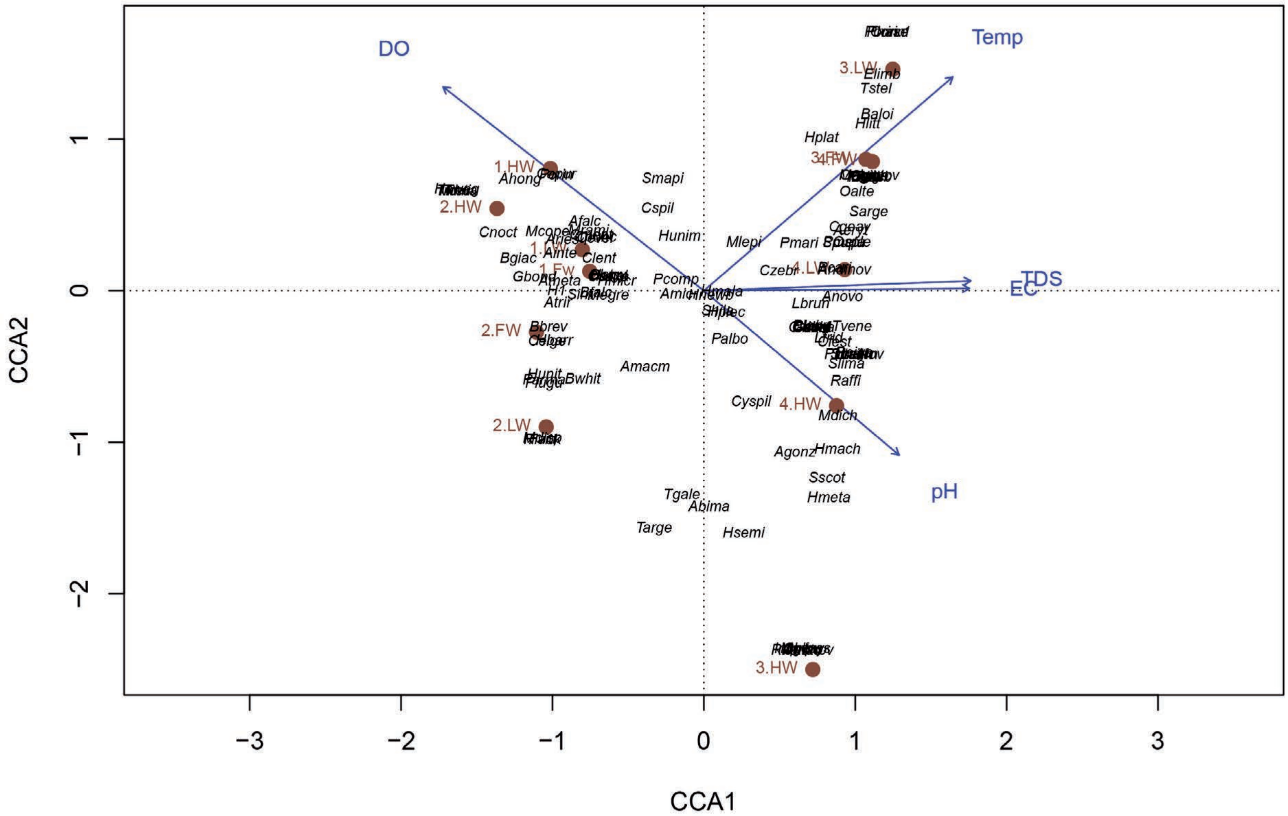

Figure 7. Canonical Correspondence Analysis (CCA), relating the structure of the fish community with environmental variables and sampling sites on the Mitimiti stream.

formes and Silurifomes contribute significantly to species diversity (Albert and Reis, 2011; Reis et al., 2016; Van der Sleen and Albert, 2018). In this study, 115 species were recorded, which represent approximately 30.3 % of the species reported for the Meta River (Usma et al., 2016), and 15.9 % for the Orinoco River basin (Do Nascimiento et al., 2021). However, it is important to highlight that the taxonomic richness of the Mitimiti stream is underestimated (88.4%), since some micro and macrohabitats along the stream remain unsampled (e.g. poorly drained depressions of *Maurita flexousa*, temporary puddles of rainwater origin in sheets, sandbars and bottoms of the main channel), similar to what was documented by Lasso et al. (2020) for some drainages of the low plains of the Colombian Orinoquia.

Despite the fact that the drainages of the Orinoco River basin exhibit a hydrometric seasonality that influences fish assemblages (Winemiller and Jepsen, 1998; Arrington, Winemiller, Layman, 2005), this study did not find differences in diversity of order q = 0 for the hydrological periods and sampling stations, which may be attributable to a certain sampling bias related to the fishing gear used (Montoya-Ospina, López-Delgado, Villa-Navarro, 2017), or to the continuous availability of water during the different climatic regimes, product of its direct connection with the Meta River. Additionally, the proximity of the sampling stations and the stability of the physicochemical conditions of the water, allow a constant change of species along the stream. This finding is consistent with what was observed by Sánchez, Castro, Galvis, (1996) and Ospina-O et al. (2021), who found no changes in fish richness at a temporal level, for some rivers and wetlands of the Casanare and Meta floodplains. Regarding the diversity of order q = 1 and 2, it was found that the high-water period presented the highest values of common and dominant species, this behavior could be attributed to the increase in abundance of some species found in larval and juvenile stages, as is the case of *Agamyxis albomaculatus*, *Amblydoras gonzalezi*, *Apistogramma hongsloi*, *Astyanax* aff. *bimaculatus*, *Catoprion mento*, *Ctenobrycon spilurus*, *Hemiodus semitaeniatus*, *Hypoptopoma machadoi*, *Laemolyta taeniata*, *Microglanis iheringi*, *Mikrogeophagus ramirezi*, *Piaractus orinoquensis*, *Poptella compressa*, *Roeboides affinis*, *Satanoperca mapiritensis*, *Schizodon scotorhabdotus*, *Sorubim lima*, *Synbranchus marmoratus*, *Trachelyopterus galeatus* y *Triportheus venezuelensis*. This pattern of diversity is similar to that observed by Lowe-McConnell (1964) for some rivers in the Rupununi savannas, where there is an increase in the abundance of juvenile fish during the high-water season.

The estimate of beta diversity at a temporal scale (0.80) in the Mitimiti stream, was mainly characterized by the predominance of the balanced variation component, which is summarized in a strong substitution of species (species turnover) throughout the climatic regime, where the period of high water is the most dissimilar with respect to the other periods. This which would indicate a behavioral response of the different species to the variation in rainfall, triggering migration and isolation processes (Suzuki, Vazzoler, Marques, Perez-Lizama, Inada, 2004; Duponchelle et al., 2007; Bailly, Agostinho, Suzuki, 2008). Regarding the environmental variables analyzed, they explained 28.6 % of the variation of the species in the evaluated habitats. Species such as: *Pseudoplatystoma orinocoense*, *Pseudepapterus hasemani*, *Cichla orinocensis*, *Eigenmannia* cf. *limbata*, *Thoracocharax stellatus*, *Bunocephalus aloikae* and *Hoplosternum littorale*, were associated with seasons with higher water temperature and low percentage of dissolved oxygen, where *H. littorale* is the clear example of species that develop physiological mechanisms of resistance (estivation and metabolic reduction) that guarantee their survival during periods of low rainfall (Machado-Allison and Zaret, 1984; Machado-Allison, 1986; Machado-Allison, De La Fuente, Mikolji, 2020).

On the other hand, our results highlight the importance of the Mitimiti stream as a valuable area for the development and reproduction of some species of fishery importance that are under some category of threat, such as *Pseudoplatystoma metaense*, *P. orinocoense* and *Sorubim lima* (DoNascimiento et al., 2021). The Mitimiti stream currently suffers major interventions, where uncontrolled burning and deforestation of the riparian forest are carried out to make way for commercial agriculture (e.g., ginger, corn, banana, cassava, soybean, oil palm crops) (Takemoto com. pers.), activities that can promote sedimentation and homogenization of the substrate, an increase in water temperature and the establishment of generalist species (Manzotti et al., 2020). Therefore, this group of slow-growing catfish, with only one reproductive event per year and without parental care, are directly or indirectly susceptible to environmental changes occurring in the Mitimiti stream (Ajiaco-Martínez, Ramírez-Gil, Bolaños-Briceño, 2015). In this sense, it is necessary to continue carrying out continuous monitoring of the ichthyofauna of the Mitimiti stream, which will allow the design and implementation of conservation strategies for drainage.

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AUTHORS' CONTRIBUTION

MACH contributed to the collection and identification of specimens, contextualization, data acquisition, data analysis and interpretation, and writing of the manuscript. EAB contributed to the collection of specimens and the critical review of the document. LFCL critical review of the document.

CONFLICTS OF INTEREST

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

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