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FISHES OF THE PARQUE NACIONAL CALILEGUA, JUJUY, ARGENTINA

Peces del Parque Nacional Calilegua, Jujuy, Argentina

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Abstract. We present the first formal checklist of the fish species composition inhabiting Parque Nacional Calilegua (PN Calilegua). In total, 28 species were recorded, distributed among three orders and 13 families, three of which are under threat according to the IUCN (*Piabina thomasi*, *Psalidodon chico*, *Loricaria holmbergi*). Although PN Calilegua is a protected area, we identified some environmental problems in the tributaries of the Sauzalito stream, possible related to hydrocarbon extraction, which have modified the physicochemical conditions of the water.

Keywords. Hydrocarbons, Hill numbers, fish, species richness, Yacimiento Caimancito

Resumen. Presentamos el primer listado formal sobre la composición de peces presentes en el Parque Nacional Calilegua (PN Calilegua). En total, se registraron 28 especies, distribuidas en tres órdenes y 13 familias, de las cuales tres especies presentan algún grado de amenaza según la IUCN (*Piabina thomasi*, *Psalidodon chico*, *Loricaria holmbergi*). Aunque el PN Calilegua es un área protegida, identificamos algunas problemáticas ambientales que se presentan en tributarios del arroyo Sauzalito, posiblemente relacionadas a la extracción de hidrocarburos, las cuales han modificado las condiciones fisicoquímicas del agua.

Palabras clave. Hidrocarburos, números de Hill, peces, riqueza de especies, Yacimiento Caimancito

INTRODUCTION

The global decline in biodiversity in continental aquatic ecosystems has become one of the priority issues on the environmental agendas of the United Nations General Assembly (ONU, 2015, and 2018). Physical alterations, deforestation, water withdrawal, overexploitation, and the introduction of exotic species are the main causes of the decline in freshwater species and the degradation of these ecosystems (Revenga *et al*. 2005). These factors are compounded by other impacts such as pollution and climate change, which together pose significant challenges for natural populations (Vitousek *et al*. 1997; Palumbi, 2001; Stockwell *et al*. 2003). When organisms are unable to adapt to such habitat modifications, it may result in a reduction or complete loss of species (Pimm *et al*. 1995; Hughes *et al*. 1997).

Among the different pollutants that exist, chemicals such as pesticides and heavy metals are among the most harmful to aquatic ecosystems, to which many species may exhibit multiple teratogenic effects or be unable to cope with these conditions (Madesh *et al*. 2024). Natural populations exposed to chemical pollutants are generally small (i.e., with a small number of individuals), and when contamination persists over time, it can cause drastic reductions in species richness, community integrity, and environmental productivity (Klerks and Weis, 1987; Lotze and Milewski, 2004; Revenga *et al*. 2005; Johnston and Roberts, 2009). Another of the main pollutants of aquatic ecosystems is crude oil (Rolshausen et al., 2015), where polycyclic aromatic hydrocarbons have a mutagenic, carcinogenic, and toxic effect on organisms (Samanta *et al*. 2002; Hylland, 2006).

Natural areas emerge as a necessity to protect biodiversity and ecosystem services (Dudley, 2008; Andam *et al*. 2013), taking on a fundamental role in the current biodiversity crisis. However, protected areas are not exempt from extractive activities that endanger the integrity of ecosystems. Rodríguez-Jorquera *et al*. (2016), in a compilation of pollution events in protected areas in Latin America, found 119 cases of chemical contamination that occurred within protected areas or that directly affected them. These cases originated mainly from activities such as mining and oil and gas extraction.

In northwestern Argentina, in the province of Jujuy, is the Parque Nacional Calilegua (PN Calilegua). This protected area created in 1979, wich currently encompasses approximately 76.300 hectares, covering an elevation range that goes from 500 to 3.600 m a.s.l. The national park is within the Yungas Ecoregion which includes the Pedemontana Forest, the Montane Forest and the Mist Grasslands (Lomáscolo *et al*. 2010). This protected area represents a biological corridor between the dry Chaco and the high Andes ecoregions (Brown *et al*. 2009; Lomáscolo *et al*. 2010).

Since 1969, the eastern limit of the Parque Nacional Calilegua (PN Calilegua) has been concessioned for oil extraction activities (AGN, 2017). Currently, twelve wells are active in this area, while others are not currently being exploited. This area, known as the Caimancito oil field, could be generating some type of environmental contamination in the streams that drain this area. Therefore, this study seeks to develop a formal list of fishes for Parque Nacional Calilegua to establish a baseline of the fish fauna that will allow, in the future, us to understand the response and possible changes in fish assemblages to contaminating factors.

MATERIALS AND METHODS

Sampling and collection área

The study was carried out within the area known as Yacimiento Caimancito, an oil field of approximately 5.766 ha, located in the province of Jujuy in the department of Ledesma, approximately 15 km from the municipality of Caimancito, within the perimeter of the Parque Nacional (PN) Calilegua on the eastern edge of the mountain range, where four streams, Las Lajitas, Zanjón Seco, Sauzalito and Yuto converge. Those are tributaries of the San Francisco River, which is part of the upper Bermejo River basin. This area is in the Yungas terrestrial ecoregion, a humid subtropical forest with monsoon rainfall concentrated during the summer period (between November and April).

Sampling was carried out at 9 stations, six located on first-order tributaries of the Sauzalito stream, and three on the main channel of the Yuto and Sauzalito (Figure 1). The sampling campaigns were carried out from October 2 to 6, 2023, and from November 18 to 22, 2024. Physicochemical water parameters were taken *in situ*. Fish were collected using electrofishing equipment and a trawl net, in a 100 m section at each study site, where all the available mesohabitats were explored (e.g., pools, rapids, etc.). Captured specimens were identified in the field, counted, and subsequently released into the water. For species of uncertain identification, a unharmed partial sample of five specimens was taken from each sampling station, which were then euthanized by immersion in tricaine methanesulfonate (MS222) and subsequently fixed in 10% formalin. The specimens were transferred to the Fundación Miguel Lillo ichthyology lab-

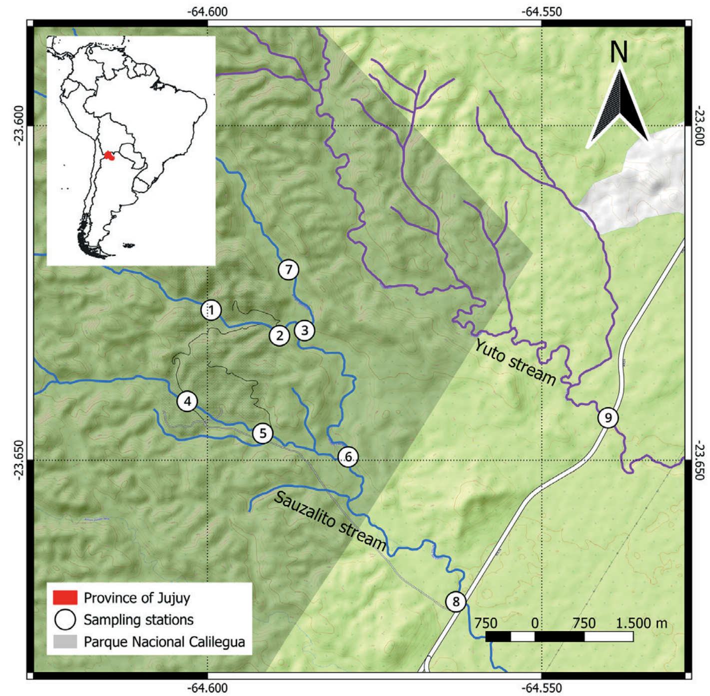

Figure 1 - Location map of the sampling stations on the Sauzalito and Yuto streams.

oratory, where they were washed with running water and preserved in 70% ethanol. Taxonomic identification was performed using published surveys of the Bermejo River basin (Mirande and Aguilera, 2009), as well as original species diagnoses and descriptions (Weyenbergh, 1877; Fowler *et al*. 1940; Rodriguez and Miquelarena 2005; Rosso *et al*. 2018). Finally, voucher specimens of all species were deposited in the Ichthyological Collection of the Fundación Miguel Lillo (CI-FML).

Data analysis

To construct the species list for PN Calilegua, information from both field collection events and the database of the Sistema de Información de Biodiversidad de la Administración de Parques Nacionales (SIB-APN) was included. Species accumulation curves and effective numbers were estimated using Hill number series (Jost, 2006; Jost and González-Oreja, 2012) to compare the diversity of fish present in the among streams for each sampling event. Dissimilarity in species composition between sampling stations for Sauzalito Stream was assessed through pairwise analysis based on turnover and nestedness components, calculated from the Jaccard index and using the presence-absence matrix. All these analyses were performed in the iNEXT (Hsieh *et al*. 2020) and betapart (Baselga, 2016) packages of the statistical software RStudio (RStudio Team 2025).

RESULTS

In total, 28 species were recorded in PN Calilegua (Table 1), of which 18 species (1.303 individuals) were distributed in the Sauzalito and Yuto streams (Figure 2). The most representative order in terms of captures was Characiformes (75.2%), with six fami-

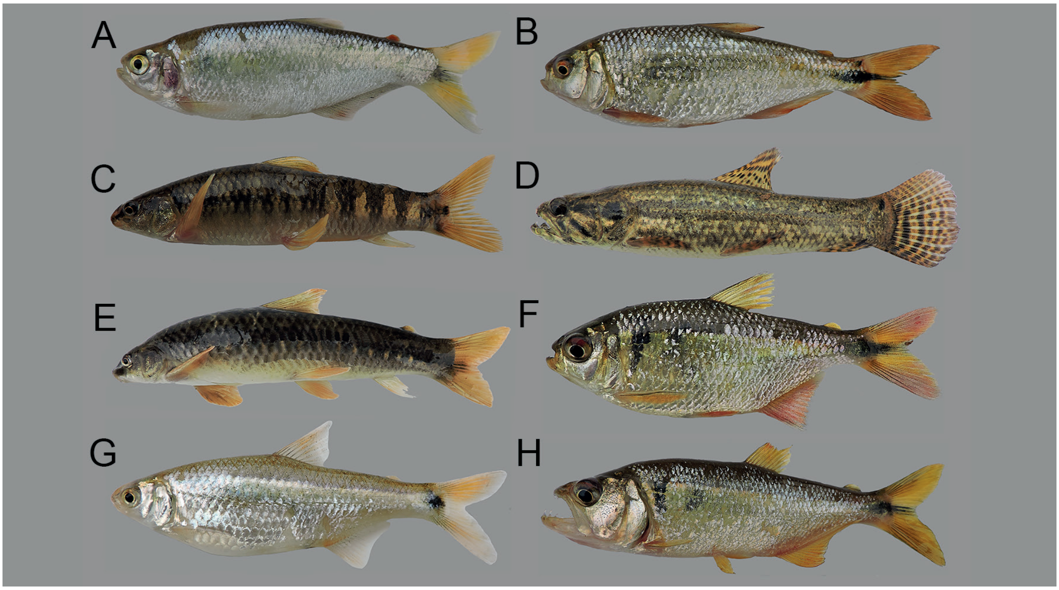

Figure 2 - Live photographs of the species captured for the Sauzalito and Yuto streams. A: *Acrobrycon tarijae*, B: *Astyanax lineatus*, C: *Characidium* cf. *zebra*, D: *Hoplias argentinensis*, E: *Parodon carrikeri*, F: *Psalidodon chico*, G: *Odontostilbe microcephala*, H: *Oligosarcus bolivianus*.

Table 1 - List of fish of Parque Nacional Calilegua. Abbreviation: * - species documented by the SIB-APN; + - Species of dubious identification.

Order	Family	Systematic update	Catalog number
Characiformes	Acestrorhamphidae	*Astyanax abramis*	CI-FML 8176
		Astyanax lacustris	CI-FML 8170
		Astyanax lineatus	CI-FML 8120
		*Ctenobrycon kennedyi**	
		*Moenkhausia bonita**	
		Oligosarcus bolivianus	CI-FML 8128
		Psalidodon chico	CI-FML 8121
		*Psalidodon eigenmanniorum**+	
		*Psalidodon rutilus**+	
	Anostomidae	*Megaleporinus obtusidens**	
	Characidae	*Odontostilbe microcephala*	CI-FML 8122
		*Serrapinnus microdon**	
	Crenuchidae	*Characidium cf. zebra*	CI-FML 8115
	Erythrinidae	*Hoplias argentinensis*	CI-FML 8177
	Parodontidae	*Parodon carrikeri*	CI-FML 8113
	Prochilodontidae	*Prochilodus lineatus**	
	Stevardiidae	*Acrobrycon tarijae*	CI-FML 8119
		Piabina thomasi	CI-FML 8135
Siluriformes	Trichomycteridae	*Trichomycterus barbouri*	Not conserved
		Trichomycterus corduvensis	CI-FML 8125
	Loricariidae	*Hypostomus commersoni**	
		Hypostomus cordovae	CI-FML 8124
		Loricaria holmbergi	CI-FML 8118
		*Pseudohemiodon laticeps**	
	Heptapteridae	*Heptapterus mustelinus*	CI-FML 8157
		Rhamdia quelen	Not conserved
	Pimelodidae	*Pimelodus albicans*	CI-FML 8178
Cichliformes	Cichlidae	*Crenicichla* sp.*	

lies, 9 genera, and 11 species. The families with the highest richness and abundance were Acestrorhamphidae (5 species, 419 individuals) and Stevardiidae (2 species, 295 individuals). Among the recorded species, *Piabina thomasi* (Fowler, 1940) (n = 231), *Characidium* cf. *zebra* Eigenmann, 1909 (n = 190), *Heptapterus mustelinus* (Valenciennes, 1835) (n = 158) and *Psalidodon chico* (Casciotta and Almirón, 2004) (n =142) were the most representative in terms of abundance. Additionally, one endemic species from the upper Bermejo River basin were captured, such as *Psalidodon chico*.

Sampling coverage completeness (SC) for both collection events was 100% for Sauzalito Stream and 99.3% for Yuto Stream, indicating good representativeness of the local fish community. The diversity analysis denoted that the observed richness (q=0) for

Table 2 - Observed and estimated richness of order diversity q= 0, 1 y 2 for the streams sampled by collection event. Abbreviation: n – abundance; s.e. – standard deviation; LCI – lower confidence interval; UCI – upper confidence interval.

Streams (years)	n	Diversity	Observed	Estimated	s.e.	LCI	UCI
Sauzalito (2023)	510	q=0	12.00	12.00	0.00	12.00	12.00
		q=1	9.24	9.35	0.28	8.80	9.89
		q=2	7.49	7.59	0.38	6.84	8.33
Sauzalito (2024)	678	q=0	15.00	15.00	0.91	15.00	16.77
		q=1	10.78	10.89	0.25	10.40	11.39
		q=2	9.22	9.33	0.33	8.68	9.98
Yuto (2023)	47	q=0	4.00	4.00	0.28	4.00	4.55
		q=1	2.43	2.51	0.35	1.83	3.19
		q=2	1.82	1.85	0.30	1.26	2.45
Yuto (2024)	68	q=0	10.00	10.49	1.89	10.00	14.22
		q=1	6.67	7.19	0.74	5.75	8.63
		q=2	5.00	5.32	0.75	3.85	6.80

the Sauzalito stream was 12 species for the collection event carried out in 2023, with an increase of three species for 2024 (15 spp.) (Figure 3a). In contrast, Yuto Stream exhibited a significant increase in species between events, with four species recorded in 2023 and 10 species in 2024 (Figure 3b). Regarding Shannon (q=1) and Simpson (q=2) diversity, this was higher in the 2024 event in both streams, but in greater proportion for the Sauzalito stream, with an estimated 10 common and 9 dominant species (Table 2). When discriminating by sampling stations for the Sauzalito stream, we found that station 7 exhibited the highest species richness for both collection events (Figure 4 a-b).

The variation in species composition between sites was mainly explained by the turnover (replacement) component for the 2023 (β_{JTU} = 0.421) and 2024 (β_{JTU} = 0.529) events which are summarized as species substitution between sites. For 2023, station 8 presented the greatest dissimilarity with respect to the other evaluated locations (Figure 5a), while stations 6 and 7 were the most similar, sharing the same number of species (12 spp.). For 2024, the dissimilarity exhibited values lower than 60%, with stations 1 and 4 being the most similar in composition, both points sharing 9 species, with the exception of a single species that was not shared between both locations (e.g., *Trichomycterus barbouri* (Eigenmann, 1911)). On the other hand, station 5 presented the greatest dissimilarity (Figure 5b).

Regarding the physicochemical parameters (Table 3), temperature, pH, and dissolved oxygen showed similar behavior between the different sampling stations and during the two collection events. However, total dissolved solids and conductivity were the variables that presented the greatest variation, exhibiting a decreasing behavior during the 2024 campaign, with the exception of stations 6, 7, and 9, which showed a significant

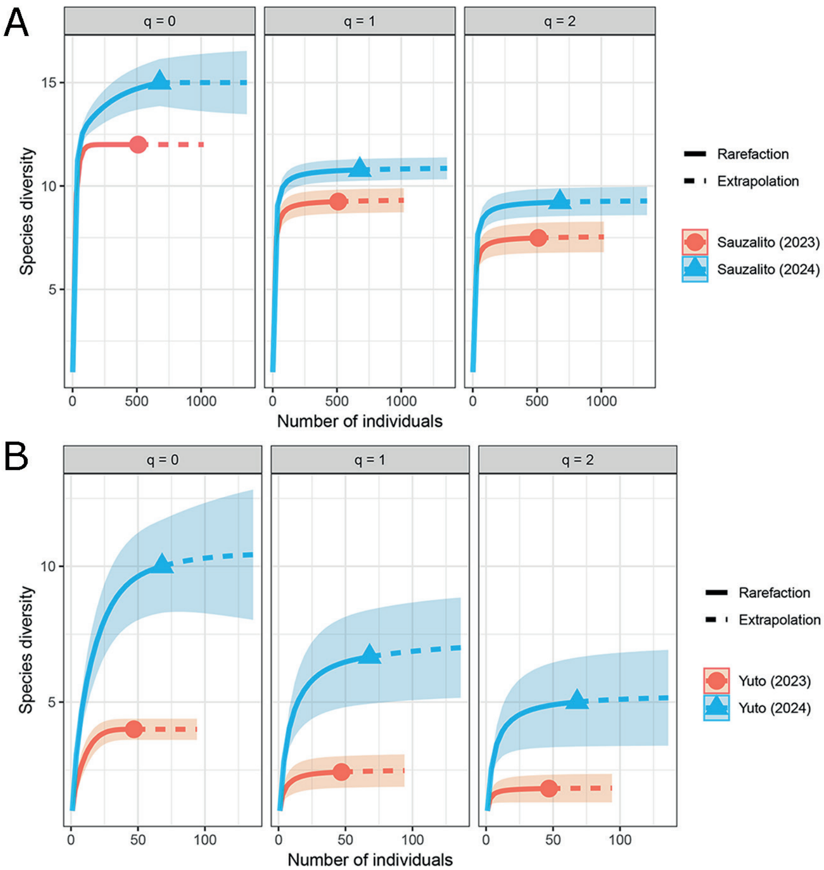

Figure 3 - Species accumulation curve estimated through the Hill number series (0=Riqueza; 1=Shannon; 2=Simpson), for the two collection events on the Sauzalito (A) and Yuto (B) streams.

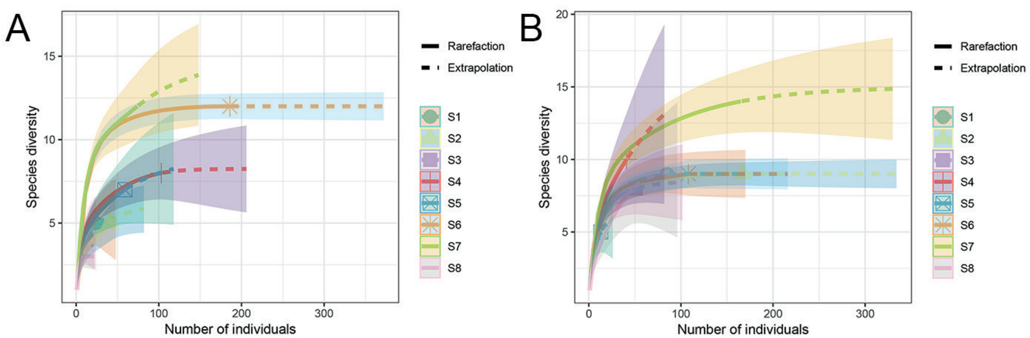

Figure 4 - Species accumulation curve (q=0) estimated for the eight sampling stations on the Sauzalito stream for the collection events of 2023 (A) and 2024 (B).

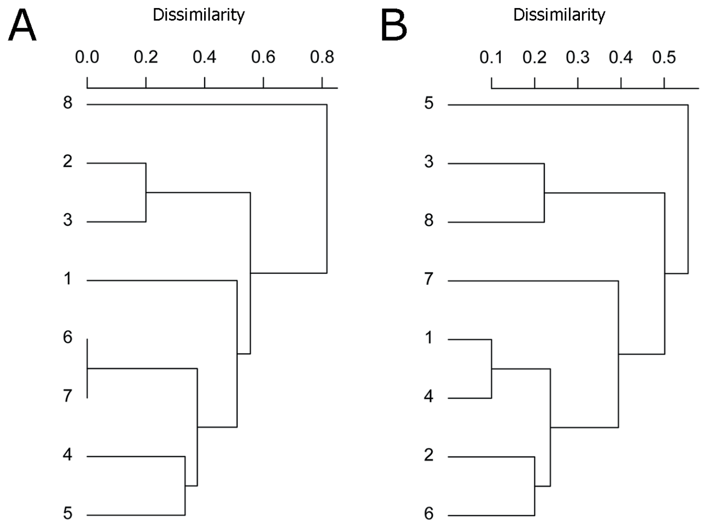

Figure 5 - Dendrogram of the Jaccard dissimilarity between the sampling stations on the Sauzalito stream for the collection events of 2023 (A) and 2024 (B).

increase. For its part, it is worth highlighting that station 9 on the Yuto stream was the place where the highest values of conductivity (x̄ = 3816) and TDS (x̄ = 1905 ppm) were recorded.

DISCUSSION

To elaborate a baseline list of fish species found in the streams of Parque Nacional Calilegua (PN Calilegua), is an essential component of developing strategies for the conservation and preservation of biodiversity in this protected area (PA). Although most PAs focus their attention on the conservation of species that inhabit terrestrial ecosystems, freshwater aquatic biota receives limited support in much of the world (Abell *et al*. 2007; Herbert *et al*. 2010). In Argentina, studies on fish surveys in PAs are scarce (Liotta *et al*. 2003; Haene *et al*. 2001; Llompart *et al*. 2012; Almirón *et al*. 2015; Casciotta *et al*. 2016; Bauni *et al*. 2019; Saravia *et al*. 2023), and this issue is also evident in Calilegua National Park, where only two technical reports are available (Gill, 1996; ERM, 2009), in addition to two more recent surveys conducted by Aguilera (2024, 2025), which form the basis of the present contribution. In this context, the present study constitutes the first formal contribution on the composition of fish species in the PN Calilegua, whose richness is estimated at 28 species, represented in three orders and 13 families.

It is important to highlight that the richness observed for the drainages of PN Calilegua represents 29.5% of the species listed for the Bermejo River basin (Mirande and Aguilera, 2009), and partially coincides with the ichthyofauna reported for the eastern Parano-Platense and central Endorheic ecoregions (López *et al*. 2002, and 2008). However, there is a need for more extensive monitoring, since some species were not recorded in the streams under study (e.g., *Ctenobrycon kennedyi*, *Moenkhausia bo-*

Table 3 - Physicochemical parameters of water measured for the Sauzalito and Yuto streams in two collection events. Abbreviations: Cond. – conductivity (μS/cm); TDS – total dissolved solids; DO – dissolved oxygen (ppm); Temp. – temperature (°C).

Sampling 2023					
Stations	**pH**	**Cond.**	**TDS**	**DO**	**Temp.**
1	8.52	625	313	9.16	27.5
2	8.28	701	348	5.62	24.7
3	7.98	805	401	6.11	22.2
4	8.22	491	246	8.47	28.7
5	8.18	641	320	7.46	26
6	8.46	300	146	9.15	21.5
7	8.53	408	204	7.02	30.2
8	8.78	570	286	8.1	21.4
9	8.37	3708	1850	8.26	21.8
Sampling 2024					
Stations	**pH**	**Cond.**	**TDS**	**DO**	**Temp.**
1	8.59	324	160	7.06	21.9
2	8.34	323	156	7.05	21.9
3	8.41	796	398	7.06	21.8
4	8.20	328	166	6.96	21.9
5	8.20	921	460	6.98	22.1
6	8.06	888	443	7.60	21.8
7	8.34	207	105	7.45	23.5
8	8.06	178	86	7.56	23.7
9	8.52	3923	1959	8.52	27.8

nita, *Prochilodus lineatus*, *Pseudohemiodon laticeps* and *Crenicichla* sp.) or are of doubtful identification (e.g., *Psalidodon eigenmaniorum* and *P. rutilus*), as they do not occur in the Bermejo River basin or whose identification may correspond to the species *Psalidodon chico*, *P. endy* and *Astyanax lineatus*. For the moment, we maintain these records as valid until further sampling efforts are carried out.

Regarding environmental variables, the values recorded in this study did not reveal anomalous conditions, with the exception of station 9 on the Yuto Stream, which exhibited very high conductivity and total dissolved solids concentrations, incompatible with the historical values exhibited by the natural environments of the Bermejo River basin (Pedrozo and Bonetto, 1987). According to a report by the Auditoria General de la Nación (AGN, 2017) a discharge of formation water was detected in the Yuto Stream, the result of a discharge from an abandoned oil well, whose waters are accompanied by a high concentration of salts and soluble hydrocarbons. In this sense, the high conductivity and TDS values observed can be attributed to this type of discharge, which is a clear indication of environmental alteration that persists today. On the other hand, we also observed a progressive increase in these parameters at stations 5 and 6 located on the Sauzalito stream, whose section is represented by active extraction wells that could be discharging waters with high salt concentrations. It is also important to highlight that for station 4, several specimens with skin lesions were detected (i.e., presence of conspicuous dark spots on the head and body), which may possibly correspond to exposure to polycyclic aromatic hydrocarbons, as demonstrated by Murawski *et al*. (2014) and Hale *et al*. (2016) for some fish from the Gulf of Mexico after the Deepwater Horizon platform explosion.

In this regard, there is a need for more monitoring activities in the streams of the PN Calilegua, especially for those drainages directly impacted by extractive or agricultural production activities. We also recommend further studies on fish exhibiting these skin abnormalities, in order to determine whether these morphological features are the result of hydrocarbon residues, with the goal of developing conservation strategies for these streams and the biota present.

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