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Current status of the last river titans, the catfishes of the genus *Brachyplatystoma* in the Ecuadorian Amazon: *In memoriam*

Estado actual de los últimos titanes de río, los bagres del género *Brachyplatystoma* en la Amazonía de Ecuador: *In memoriam*

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Abstract

Current knowledge about giant catfishes of the genus *Brachyplatystoma* reported from the Ecuadorian Amazon is incipient despite their remarkable value in continental commercial fisheries. For this reason, this paper includes a review of the existing knowledge about the species reported for Ecuador based on bibliographic consultation and the study of specimens from Gustavo Orcés V. museum in Quito. Six species are reported from the Ecuadorian Amazon: *B. filamentosum*, *B. rousseauxii*, *B. vaillantii*, *B. platynemum*, *B. juruense*, and *B. tigrinum*. Data are presented on their distribution at the river basin level, body characteristics for adult fish, aspects of their migration, diet, and spawning, as well as crucial data on their reproductive biology to promote sustainable management. The main threats to their conservation are also identified. Based on this diagnosis, alternatives for their conservation was proposed, focused on the application of fishing regulations and the creation of conservation zones in the main Amazonian waterways of the country. With the information presented, it is expected that, will in the medium term, it will be possible to favor the conservation of the last giant Amazonian fish, given their importance for the riparian peoples and ecosystems.

Keywords: siluriformes; Pimelodidae; biodiversity; conservation; giant catfishes; continental fishery.

Resumen

El conocimiento actual sobre los bagres gigantes del género *Brachyplatystoma* reportados para la Amazonía ecuatoriana es incipiente, aun ante su notable valor en la pesca comercial continental. Por esta razón, este trabajo incluyó una revisión del conocimiento existente acerca de las especies reportadas para Ecuador realizada a partir de la consulta bibliográfica y el estudio de especímenes del Museo Gustavo Orcés V. de Quito. En la Amazonía ecuatoriana se reporta la existencia de seis especies: *B. filamentosum*, *B. rousseauxii*, *B. vaillantii*, *B. platynemum*, *B. juruense* y *B. tigrinum*. Se presentaron datos de su distribución a nivel de cuenca hidrográfica, características corporales para peces adultos, aspectos de su migración, dieta y, desove, así como datos cruciales de su biología reproductiva para promover el manejo sustentable. También fueron identificadas las principales amenazas para su conservación. A partir de este diagnóstico se propusieron alternativas para su conservación, enfocadas en la aplicación de regulaciones de pesca y la creación de zonas de conservación en los principales cauces amazónicos del país. Con la información presentada, se espera que sea posible en el mediano plazo favorecer a la conservación de los últimos peces gigantes amazónicos, dada su importancia para los pueblos y ecosistemas ribereños.

Palabras clave: siluriformes; Pimelodidae; bagres gigantes; biodiversidad; conservación; pesquería continental.

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Introduction

The current number for valid species of freshwater fish is 18,614 (50.80% of the world's total) (Fricke et al., 2023). In the Neotropics, freshwater species are the most diverse, reaching almost 5,500 species (30% of all freshwater species and 10% of vertebrae), among which Characiformes, Siluriformes and Gymnotiformes are the most prominent (Pelicice et al., 2017). All of these species are responsible for various provisioning, regulation, support and cultural processes on their ecosystems (Ferreira et al., 2023; Pelicice et al., 2023). However, overfishing of inmature specimes, water pollution, deforestation, river depletion for other uses and flow interruptions causes by dams, the introduction of exotic species are the main threats for these species (Barriga, 2012; Valdiviezo et al., 2012). In the Amazon Basin, some of the Siluriformes species are widely exploited for commerical, sport and subsistance fishing due to their great size (Torrico et al., 2020). Despite of how important fishing in the Amazon is for the economic income and employement it provides, the lack of data for this region keeps it invisible (Almeida et al., 2004).

The order Siluriformes includes 36 families, 478 genus and 3,093 species (Ferraris, 2007). These fish are commonly known as catfish for their prominent barbicels, and constitute the second most diverse order of Neotropic fish (Rivadeneira et al., 2010). The majority of genus of this order have maxillary and mental arbicelli, teeth arranged in patches and pads, a shoulder girdle developed and attached to the skull, and their dorsal and pectoral fins have a first ray modified into a sharp spine (Galvis et al., 1997). One of the most diverse families of Siluriformes is the Pimelodidae, with 29 genus, 93 live species, and 4 fossil species (Ferraris, 2007). This family presents the following characteristics: naked body (without scales); head flattened dorsiventrally, with two large gill openings; ventral or terminal mouth (never sucker-shaped), three pairs of barbicels (one on the upper jaw and two mental), adipose fin present and elongated and very long dorsal and caudal filaments in juveniles of large species (Palencia, 1995; Galvis et al., 1997; Van der Sleen y Albert, 2018).

The genus *Brachyplatystoma* stands out among Pimelodidae for including the most important species for fishing in the Amazon basin. The main anatomical characteristics of *Brachyplatystoma* species are the following: 1) wide head, covered by skin, with a broad, fur-covered head, with a strongly depressed muzzle; 2) small eyes, lateral dorsi, with a free orbital rim; 3) long maxillary barbicels, extending to or beyond the caudal peduncle; 4) rounded muzzle and wide mouth, with protruding upper jaw; 5) furced caudal fin; 6) Adipose fin base longer than the anal fin base (Burgess, 1989). The species of this genus, their high value as a fishing resource notwithstanding, are not well-known, in particular their characteristics that would help to their conservation (Lundberg and Akama, 2005).

In Ecuador, of the 43 species of Pimelodidae catfish, six of them belong to the *Brachyplatystoma* han have been found in the Napo-Pastaza and Morona Santiago ichthyohydrographic zones: *B. filamentosum*, *B. rousseauxii, B. vaillantii, B. platynemum*, *B. juruense* y *B. tigrinum* (Barriga, 2012).According to IUCN (2022), of all the *Brachyplatystoma*, species, only *B. rousseauxii* is considered to be a Least Concern (LC) species. According to the National Red List of Freshwater fish of Ecuador (Lista Roja Nacional de Peces de agua dulce del Ecuador), published in 2019, the *Brachyplatystoma* genus exported to Ecuador show the following catgories on a national scale (Aguirre et al., 2019), taking into account their vulnerability for including fish of greater size, with migratory behaviours of the Amazon (table 1).

Table 1. Giant catfish species of the *Brachyplatystoma* genus in Ecuador, their common names and their national categories of danger.

Scientific Name	Common name	Kichwa name	National Category of Threats
Brachyplatystoma filamentosum (Lichtentein, 1819)	Lechero	Saltun bagri	Vulnerable
B. rousseauxii (Castelnau, 1855)	Plateado	Arawaru bagri	Endangered
B. vaillantii (Valenciennes, 1840)	Playa mota	Angu chupa	Endangered
B. platynemum (Boulenger, 1898)	Baboso	Arawi	Endangered
B. juruense (Boulenger, 1898)	Bagre cebra	Muru santi	Vulnerable
B. tigrinum (Britski, 1981)	Pintadillo tigre	Wituk bagri	Vulnerable

The biology of migratory catfish in Latin America is not well-known, despite their biological, cultural and economical importance. The fishing of these species, as a subsistence and commercial activity, provides food and economic income (Harvey and Carolsfeld, 2003). In the

Amazon, the species from the genus *Brachyplatystoma* are the most valuable to commercial fishing (Díaz-Sarmiento and Álvarez-León, 2003). Despite their high value, the knowledge about these catfish is insufficient on a grand scale, because there is not enough information about their reproductive biology, abundance, eating habits, ecology, migration routes, migration travel distance, nesting spots, harvesting levels and other key aspects for planning their long term conservation (Bonetto y Castello 1985; Lundberg and Akama, 2005; Willink et al., 2005; Valdiviezo et al., 2012). Moreover, a decrease in fishing stock of *Brachyplatystoma* genus in the entire basin is noticeable, as a consequence of conflict between local fishermen (Harvey and Carolsfeld, 2003; Villamil-Rodríguez et al., 2018).

In this context, the objective of the research was to synthesize the information about the giant catfish of the *Brachyplatystoma* genus reported in Ecuador, through a literature review and scrutiny of specimens from the historical ichthyological collection of the Museo de Historia Natural Gustavo Orcés V. (MEPN) in Quito.

Materials and methods

Considering the scarce information about the *Brachyplatystoma* catfish genus at a national scale, the following review aims to synthesize the existing information for ecuadorian species from existing data from the Ecuadorian Amazon and neighbouring countries, in order to answer the following questions:

(i) ¿Which species from the *Brachyplatystoma* genus live in Ecuador and are distributed in the Ecuadorian Amazon along spatial and altitudinal levels?

(ii) ¿What are their migration patterns, reproductive parameters and eating habits?

(iii) ¿What are the characteristics of river catfish fishing in the Ecuador?

(iv) ¿What are the main threats for this group in Ecuador?

(v) ¿What are the conservation alternatives that are viable for these species?

Answering these questions implies searching and consulting information available on the Internet, concerning Ecuador and neighbouring countries, as well as a review of historic data from ichthyological collection of species from this genus available in Ecuador (Colección Ictiológica de la Escuela Politécnica Nacional, Museo de Historia Natural Gustavo Orcés V.). The study hopes to give to recommendations that may lead to further research that could fill the knowledge gaps and propose strategies for conservation considering the complex ecologies for transnational migrating species.

Results and discussion

Fossil evidence

The fossil record of the genus *Brachyplatystoma* is restricted to the Miocene of Colombia and Venezuela, and the extant species currently inhabit the Orinoco and Amazon basins; in addition to the previous records, the description of a new species of *Brachyplatystoma* (*B. elbakyani nov*. sp.) in the Paleoparaná basin is added (Argentina), which showed a connection to the Amazon Basin up to the start of Late Miocene (Agnolin and Bogan, 2020). There is no information of fossil findings from this fish in Ecuador.

Systematics

The *Brachyplatystoma* genus show the following distinctive characteristics: widehead, strongly depressed towards the muzzle; elongated and elliptical fontanelle; wide supra-occipital process and strongly attached to the nuchal plate; postoccipital process twice as large as the predorsal plate; small eyes in lateral dorsal position; premaxillary teeth without major development; maxillary chin of variable size; wide mouth and rounded muzzle; strong dorsal and pectoral spines, not covered with skin; caudal fin deeply forked, with lobes and sometimes filaments at the base of the anal fin; long and strong caudal filaments in juveniles (García and Calderón, 2006; Van der Sleen and Albert, 2018).

The caudal fin of juvenile and subadult fish of the genus *Brachyplatystoma* has the filaments of the upper and lower lobes markedly elongated, and each filament is composed of a simple, unbranched main radius. In adults of *B. vaillantii*, *B. filamentosum, B. rousseauxii*, and *B. capapetrum,* the caudal filaments are short and may be lost to damage, while the caudal filaments persist in adults of *B. platynemum, B. juruense*, and *B. tigrinum* (Lundberg and Akama, 2005).

The main morphological characteristics for adults of *Brachyplatystoma* species found in the Ecuadorian Amazon are presented below (tabla 2).

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Table 2. Morphological characteristics of *Brachyplatystoma* adult fish reported for the Ecuadorian Amazon

N.-	Species	Visible corporeal characteristics in adult fish					Source
		Maximum size (cm)	Maximum weight (kg)	Body	Head and barbicels	Fins	
1	*Brachyplatystoma filamentosum* (figure 1A)	200 a 300	110 a 200	Cylindrical body, silver grey on the back and white ventrally. Well-marked lateral line. Skin hard to tear	Upper jaw longer than the lower jaws. Cylindrical barbicels and long jaws. Short mentonian barbicels.	Dorsal fin with six spokes. Short adipose fin, being its base equal to that of the anal fin. Forked caudal fin, with long filamentous lobes (if not broken). Secretory glands at the base of the pectoral fin.	Salinas and Agudelo, 2000; Galvis et al., 2006; García-Dávila et al., 2018.
2	*B. rousseauxii* (figure 1B)	150	20	Shiny golden and glowing body. Little marked lateral line. Smooth and soft skin, easily tear.	Upper and lower jaw equal in length. Short and cylindrical barbicels, head length.	Long and forked caudal fin. Origins of anal fins and adipose at the same level.	Román 1985; Salinas and Agudelo, 2000; Galvis et al., 2006; García-Dávila et al., 2018. L. Guarderas com. per.
3	*B. vaillantii* (figure 1C)	80 a 100	10	Dark grey back;whitlish upper part of the head, belly and chin Flanks with longitudinal striations on the skin.	Upper jaw protrudes slightly from the lower jaw. Flattened maxillary barbicels, exceed the adipose fin. Mentonian barbicels do not reach beyond half the body. Small, dorsal eyes.	Dorsal and pectoral fin with sharp spines. High and low dipose fin, whose base is twice the base of the anal fin. Forked caudal fin, with prolonged lobes in long filaments. Origin of pelvic fins, below the dorsal fin termination	Salinas and Agudelo, 2000; Galvis et al., 2006; García-Dávila et al., 2018.
4	*B. platynemum* (figure 1D)	80 a 100	5	Grey body on the back and white ventrally. Skin with lots of live mucus.	Upper jaw longer than the lower jaw. Flat barbicels, wide, do not reach the pelvic fins. Small, dorsal eyes. Flattened head.	Forked caudal fin with long filaments (even longer than the fish, when not broken).	Salinas and Agudelo, 2000; García-Dávila et al., 2018.
5	*B. juruense* (figure 1E)	60	7	Body with eight to 10 dark oblique transverse bands, not very symmetrical, alternating on brown background at the sides, and in adipose fin. Head of dark color.	Upper jaw slightly longer than the lower jaw. Short and thin barbicels. Small, dorsal eyes. Rounded mouth.	Base of the adipose fin is equal to the base of the anal fin. Forked caudal fin with reticulated pigmentation and very long filaments. Origin of the pelvic fins below the dorsal fin.	Román 1985; Salinas and Agudelo, 2000; Galvis et al., 2006; García-Dávila et al., 2018.
6	*B. tigrinum* (figure 1F)	65	2	Body with 13 to 15 blackish transverse bands on white background.	Upper jaw slightly longer than the lower jaw. Big depressed head. Small, dorsal eyes.	First flexible spine. Fins with bands. Caudal fin frucate.	Salinas and Agudelo, 2000. L. Guarderas com. per.

Figure 1. *Brachyplatystoma* adult exemplars. A. *B. ilamentosum* (Photo: Lida Guarderas Flores); B. *B. rousseauxii*; C. *B. vaillantii* (preserved specimen MEPN-I 19572); D. *B. platynemum* (Photo: Lida Guarderas Flores); E. *B. juruense*; F. *B. tigrinum* (Photo: Lida Guarderas Flores)

Distribution of the genus *Brachyplatystoma* for the main watersheds of the Amazon of Ecuador (map/table)

In the Ecuadorian Amazon, the presence of six species of the genus is reported: *B. filamentosum, B. juruense, B. platynemum, B. rousseauxii, B. tigrinum* y *B. vaillantii.* The localities for each species that were identified based on previous research and the review of the Ichthyological collection at the Escuela Politécnica Nacional are shown in the following graphs (table 3; figures 2 and 3). There are no published references about these species from the Corrientes and Conambo river sub-basins..

Migratory patterns of *Brachyplatystoma* species reported for Ecuador

Research on fish migration is key to the sustainable management of fisheries, since the seasonal movements of fish condition their fishing and reproduction (Bonetto y Castello, 1985). A species is considered migratory when it spawns only after moving between geographical zones (Harvey y Carolsfeld, 2003).

Table 3: Distribution of *Brachyplatystoma* species in the Ecuadorian Amazon (numbers from the catalog of specimens at the MEPN Museum)

Amazonian drainage basin in Ecuador: Putumayo river
Type of river: Whitewater river
Altitude and Location of reference: Border region with Ecuador, with Puerto Leguizamo, Colombia as a reference (114 MASL); columbian-peruvian section.
Reported species with their local names *B. filamentosum* (lechero, saltón, pirahiba), *B. rousseauxii* (plateado, dorado), *B. vaillantii* (pirabutón, manitoa, blanco pobre), *B. platynemum* (baboso, vaselina, barbachata), *B. juruense* (siete babas, alianza, camisa rayada) and *B. tigrinum* (alianza, cebra, camiseta).
References: Castro, 1994; Salinas and Agudelo, 2000; Ortega et al., 2006.
Amazonian drainage basin in Ecuador: San Miguel river.
Type of river: Whitewater river.
Altitude and Location of reference: section between Peña Blanca and Palma Roja (260 a 220 masl).
Reported species with their local names: *B. filamentosum* (saltón), *B. rousseauxii* (arawaro), *B. vaillantii* (anguchupa) and *B. platynemum* (arawi).
References: Jácome-Negrete et al., 2022.
Amazonian drainage basin in Ecuador: Aguarico river
Type of river: Whitewater river.
Altitude and Location of reference: Section beginning at the mouth of the Eno and Shushufindi rivers, to the mouth of the Cuyabeno river (200 a 300 masl)
Reported species with their local names: *B. filamentosum* (barbo blanco, bo simi), *B. rousseauxii* (plateado, taisimi), *B. vaillantii* and *B. juruense.*
References: Vickers, 1989; Hermann et al., 2021; MEPN-I 19571; MEPN-I 19572; MEPN-I 19775.
Amazonian drainage basin in Ecuador: Napo river.
Type of river: Whitewater river.
Location and altitude of reference: Puerto Francisco de Orellana, Añango, Pompeya, Nuevo Rocafuerte (175 to 25o masl).
Reported species with their local names: *B. filamentosum* (lechero), *B. rousseauxii* (plateado), *B. vaillantii* (playa mota), *B. platynemum* (baboso), *B. juruense* (muru santi) and *B. tigrinum* (cebra).
References: Stewart et al., 1987; Hermann et al., 2021; Anaguano-Yancha et al., 2022; MEPN-I 19574.
Amazonian drainage basin in Ecuador: Yasuní river.
Type of river: Blackwater river.
Location and altitude of reference: Cuenca baja del río Yasuní y bocana con el río Napo en Nuevo Rocafuerte (175 masl).
Species reported and their local names: *B. filamentosum*, *B. rousseauxii*, *B. vaillantii*, *B. platynemum* and *B. juruense*.
References: Barriga, 1994; Hermann et al., 2021; MEPN-I 19565.
Amazonian drainage basin in Ecuador: Tiputini river.
Type of river: blackwater river.
Location and Altitude of reference:Tiputini river, Chambira and laggons adjacent to the Guiyero commune (224 msnm).
Reported species with their local names: *B. filamentosum* (omara) and *B. juruense* (bagre rayado).
References: Albuja, 2011.
Amazonian drainage basin in Ecuador: Curaray river.
Type of river: whitewater river.
Location and Altitude for reference**:** section from the San José de Curaray river to the Danta Cocha,lagoon, at the border with Peru (180 to 250 masl).
Reported species with their local names: *B. filamentosum* (saltun bagre), *B. rousseauxii* (arawaru), *B. platynemum* (arawi) and *B. juruense* (micolas bagre, muru santi).
References: Guarderas y Jácome, 2013; Jácome-Negrete y Guarderas, 2014; Jácome-Negrete et al., 2022; MEPN-I 19942.
Amazonian drainage basin in Ecuador: Pinduc river.
Type of river: blackwater river.
Location and altitude of reference: kichwa commune of Yana Yacu, located 30 km up river at the confluence of the Pinduc and Conambo rivers (200 masl).
Reported species with their local names: *B. filamentosum* (saltun bagri), *B. rousseauxii* (arawaru) y *B. juruense* (micolas bagri).
References: Jácome, 2005; Jácome y Guarderas, 2005.
Amazonian drainage basin in Ecuador: Pastaza river.
Type of river: whitewater river.
Location and Altitude of reference: between Andoas and Rimachi lagoon, border zone of Ecuador and Peru (170 to 250 masl).
Reported species with their local names: *B. vaillantii* (aikiam).
References: Willink et al., 2005.
Amazonian drainage basin in Ecuador: Morona river.
Type of river: whitewater river.
Location and altitude of reference: Puerto Morona (220 masl).
Reported species with their local names: *B. filamentosum* and *B. vaillantii*.
Referencias: Barriga, 2012.

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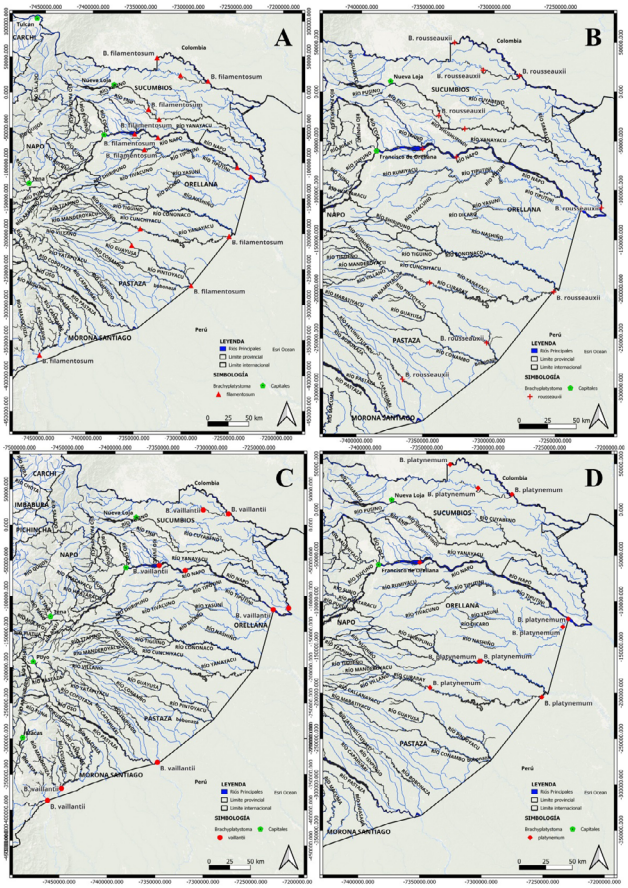

Figure 2. Distribution of species *Brachyplatystoma* in the Ecuadorian Amazon. A. *B. filamentosum*; B. *B. rousseauxii*; C. *B. vaillantii*; D. *B. platynemum*.

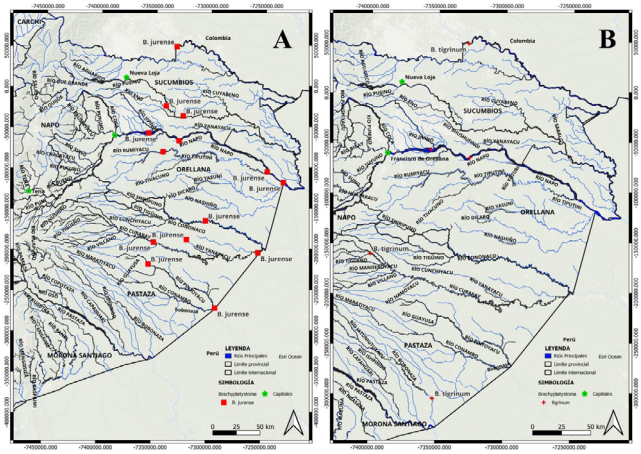

Figure 3. Distribution of species *Brachyplatystoma* in the Ecuadorian Amazon. A. *B. juruense*; B. *B. tigrinum*.

These species migrate upstream for reproductive purposes at the beginning of winter, spawning in the headwaters, then return to the estuaries feeding in abundance to replenish energy, while their reproductive products (eggs and larvae) drift downstream with the pulse of the flood concentrating in the banks of the river or in lateral lagoons (Bonetto and Castello, 1985). The study of the migration of siluriform catfishes was more complex, since they were species that moved along the bottom of the river, being more difficult to detect (Goulding, 1980).

The local knowledge of fishermen clarifies knowledge gaps related to the migration of Amazonian fish, being an effective source on how these fish move and the environmental impacts they endure. (Nunes et al., 2019).The catfish from the genus *Brachyplatystoma*, including *B. filamentosum*, *B. rousseauxii* and *B. vaillantii*, were categorized as altitudinal migratory species with reproductive intent in the Amazon Basin (Burgess, 1989). These *Brachyplatystoma* species' journey begins at the estuaries of the Amazon, ending at the river head to spawn at, because their gonodal maturity happens during their upriver journey. For example, *B. vaillantii* has been found in the higher regions of the Peruvian Amazon, more than 3.500 km from the Amazon mouth (Agudelo et al., 2000). *Brachyplatystoma filamentosum*, the biggest catfish of the genus, reaching upt to 25 kg in weight, is confined to the main canals of the great tributaries, with no access to the forest swamps and lagoons (Goulding, 1980).

In Ecuador, indigenous knowledge is the only current source of information about *Brachyplatystoma* migration. At the moment, it is known that these catfish migrate altitudinally for reproducing and transversally to mature. Kichwa fishermen at the Curaray river, in the province of Pastaza, catch young *B. rousseauxii* between the months of october and december, when they cross the border into Peru; likewise, at the end of the year, juvenile specimens of *B. juruense*, *B. vaillantii*, and *B. filamentosum,* go upriver (Jácome, 2005). These species make two migrations per year, accordinng to ancestral kichwa knowledge, one in march, (high water) and another between october and december (low water). In these migrations they go up to the river mouth, following their prey, other finfish such as curimatids and characids that also migrate. It is known that in the higher parts of the Curaray river, up to Huituc, they would have traveled about 400 km from the peruvian border. It is possible that these catfish come from Peru, and even Brazil (Jácome-Negrete and Guarderas, 2014).

Through a study on the presence of catfish individuals with mature gonads and an statistical analysis to estimate the

migratory distances of larvae and juveniles specimens, it was established that *B. rousseauxii*, *B. platynemum* and *B. juruense* spawn on sites near the Andes and western Amazon, and the *B. rousseauxii* species have the largest migration distance of freshwater fish (Barthem et al., 2017). *Brachyplatystoma rousseauxii* migrate from their nursery habitat in the Amazon estuaries up to the river head in western Amazon. Their breeding station happens during low water times (García Vásquez et al., 2009).

Through a spectometry of otholits it was possible to determine that *B. rousseauxii* carries out a transamazonian migration of more than 8.000 km, from their nursery habitat at the Amazon estuaries, to the Upper Amazon (such as the Beni river in Bolivia) where adult invididuals at their reproductive stage are captured (Hauser et al., 2019). Some studies on the molecular diversity of *B. rousseauxii* in the Amazon Basin suggest that the individuals at their reproductive stage go upriver to spawn on the same estuaries where they were born at (Batista y Alves-Gomes, 2006). Based on a study on the macrochemistry of the otholites, it was concluded that the *B. platynemum* did not use the Amazon estuary as a nursery habitat, only migrating some thousands of kilometers within the Basin, crossing borders between Brazil, Bolivia and Peru (Hauser et al., 2019).

In the case of *B. platynemum*, there is data that indicates that the individuals can move between two Amazonian river systems. For example, an individual that was marked in the Madeira river, State of Amazonas, Brazil, after a dam was closed was recaptured in the Solimoes River after travelling 1.272 km in 84 days (Hahn et al., 2019).

At this moment, the information about the migration patterns of *Brachyplatystoma* in Ecuador is still incipient, and is supported mainly by local ethnopsicatory knowledge. Other type of studies, using techniques such as otholits spectometry on these fish, have not yet been carried out. There is no information either on whether the migratory patterns of males and females are similar, or between juveniles and adults.

In the Napo river (Coca sector at 254 msnm and Nuevo Rocafuerte at 175 masl), the highest quantity of Siliuriforme larvae was found during the month of april, coinciding with the start of the raining season in the region (Hermann et al., 2021). These larvae were captured over sand substrates at night The catfish larvae spawning zone is possibly located between the cities of Coca and Pañacocha (208 msnm). In the border area (Nuevo Rocafuerte) *B. filamentosum* (5), *B. juruense*, *B. tigrinum* (9) y *B. rousseauxii* (1) larvae were recollected, at a total lenght of 4 to 6 mm , an estimated 1 to 4 days since hatching, and a total of 776 larvae. Based on the speed of the river's current, these larvae were probably deposited as eggs between 100 to 400 km upriver (in the vicinity of the city of Coca)(Hermann et al., 2021).

In the Bolivian Amazon (Beni river), in a study that identified fish larvae and egg using molecular techniques, it was determined that the spawning area of *B. rousseauxii* was located in a transition zone, where sand beaches started to give way to rock beaches, just south of the last Andean mountain chains (Miranda-Chumacero y Venticinque, 2022).

A study carried out in the Amazon Basin showed that the *B. rousseauxii* larvae migrated downstream from the Andean piedmonts to the lower Amazon, where they would grow for a long period before migrating upstream as adults; but not all fish would spend their breeding stage in the estuaries. However, passing through the central Amazon was a mandatory part of their life cycle, and the majority of adults came back to their native geographical area within the subbasin (Duponchelle et al., 2016).

Reproductive parameters of *Brachyplatystoma* species present in Ecuador

Table 4 shows the data regarding the size and ages of these fishes in the first stage of maturity, spawning periods, fertility and other important aspects of their reproducitve biology that are key for the sustainable management of fisheries. It is important to note that, due to the lack of data from the Ecuadorian Amazon, the present information comes from the neighbouring countries, in particular Colombia and Peru (table 4).

Based on the information presented in table 4, there is more research about the reproductive biology of the bigger species of *Brachyplatystoma*, as they are the most important for local fisheries: *B. filamentosum*, *B. rosseauxii*, *B. vaillanti* and *B. platynemum*. The fact that these species are more documented is probably due to a higher availability of captured specimens in commercial fishing.

The following questions intend to promote further research on these species in the Ecuadorian Amazon:

The localities and altitudes of the main river channels. At the moment, the longitudinal movement of adults is only partially known for the Curaray river and downstream larvae to the Napo river. For the rest of the river of the basin in the Ecuadorian territory, there is no published data. Moreover, the migration patterns according to sex and age, as well as the habitats that are used for migration by different species in Ecuador are not known. It is also important to note that for the specific case of *B. tigrinum*, specimens have been captured only at 200 masl, which suggest that this species in particular only inhabits the river heads.

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Table 4. Reproductive parameters of *Brachyplatystoma* species important for fisheries management.

Species	Tyoe of migration	Maximum size for the Amazon TL= total length Weight	L50* Size at first maturation stage(cm) and age SL= Standard Length	Conservation measures taken in the Amazon	Average size of Capture in Ecuador (Napo river) LT	Spawning period	Fertility	Location where it was reported	Referencia
Brachy-platystoma filamentosum	Cross-border Currently unknown, but juveniles have been found at the middle Amazon basin	280 ato300 cm 200 kg	Female: 148 cm SL/11 years Male: 126 cm/8 años	Minimum capture size: 100 - 110 cm SL (Colombia)	119 cm	High water	68.170 a 203.608 ovocytes/ female 1.000.000 eggs/ female 48 kgs	Colombian and Peruvian Amazon	Salinas and Agudelo, 2000; Araujo-Lima and Ruffino, 2003; Ajiaco-Martínez et al., 2012; García-Dávila et al., 2018; Anaguano-Yancha et al., 2022.
B. rousseauxii	Cross-border Exact migration pattern unknown, but 6 cm juveniles have been found in the middle basin of the Amazon, while large juveniles (96cm) have been found in the estuaries. Adults have been found in the western Amazon.	140 cm 10 kg	Female: 91 to 101 cm SL/10 years Male: 83-89 m/8 years	Minimum capture size: 85 cm SL (Colombia)	109 cm	Low water	42.600 a 35.0000 ovocytes/ 22-26 kg female 1.045.284 ovocyte/ 34 kg female	Colombian and Peruvian Amazo	Salinas and Agudelo, 2000; Araujo-Lima and Ruffino, 2003; García Vásquez et al., 2009; Agudelo et al., 2012; García-Dávila et al., 2018; Anaguano-Yancha et al., 2022.
B. vaillantii	Cross-border This species migrates 3,500 km upstream from the mouth of the Amazon to spawn in Andean tributaries (400 meters above sea level)	105 cm	42 cm/3 years 51 cm/6 years	Minimum captue size: 40 cm LE (Colombia)	40 cm	Early high water	200.000 a 315.000 ovocytes/ female	Peruvian Amazon	Araujo-Lima and Ruffino, 2003; Galvis et al., 2006; Ajiaco-Martínez et al., 2012; García-Dávila et al., 2018; Anaguano-Yancha et al., 2022.
B. platynemum	Cross-border	100 cm 5 kg	Female: 78 cm Male: 65 cm	Minimum capture size: 70 cm SL (Colombia)	51 cm	Low water	353400 ovocytes/ female	Peruvian Amazon	Ramírez-Gil et al., 2012; García-Dávila et al., 2018; Anaguano-Yancha et al., 2022.
B. juruense	Unknown	70 cm	No data	Minimum cap-ture size: 50 cm SL(Colombia)	59 cm	Low water	No data	Ecuadorian Amazon	Anaguano-Yancha et al., 2022.
B. tigrinum	Unknown	100 cm	No data	Minimum capture size: 50 cm SL: (Colombia)	54 cm	Low water	No data	Ecuadorian Amazon	Anaguano-Yancha et al., 2022. L. Guarderas com. per.

*L50= average gonadal maturity length, is the length at which 50% of the individuals in a fish population are suitable for reproduction.

Other aspects related to larvae that should be studied more thoroughly, are the spawning sites in the various tributaries. Currently, the only available information is for the Napo river, where spawning occurs between the cities of Coca and Pañacocha. Likewise, there is a lack of information on other key aspects such as: what is the behaviour of males and females during spawning?; how many spawning cycles do adults have per year?; what morphological characteristics do the larvae and eggs of the different reported species in Ecuador possess?; how do the larvae use water columns?; Do juveniles go throug direct development or do they experience significant morphological change as they grow?

Diet:

Brachyplatystoma catfish are river superpredators, having a preference for curimatids, prochilodontids, anostomids, erythrinids, gymnotids, frogs, eggs and river turtles (*Podocnemis* sp.), and even aquatic bird chicks, according to local knowledge (Goulding, 1980; Jácome and Guarderas, 2005; 2014).

In a study on the stomach content of 26 species from this genus in the Colombian Amazon, the following preference for prey was reported: *Hypopthalmus*, *Calophysus*, *Pimelodus*, *Pimelodella*, *Rhamdia*, *Prochilodus* and *Potamorhina* (Agudelo et al., 2000). These fish often prefer the species at surface water, predominantly Characiformes and Siluriformes (Agudelo et al., 2000). Moreover, when analyzing the diet in these fish, it was often common to find their stomach empty when they were captured (Goulding, 1980).

So far there are no studies that focus on the diet of the great catfish in the Ecuadorian Amazon, and that have used methods beyond inquiring local knowledge.

Characteristics of *Brachyplatystoma* cat fish fishing in Ecuador

Migratory fish are an integral component of amazonian society. because they contribute 93% of fishing landing in all of the Amazon Basin, with approximately 436 millions USD in profit (Duponchelle et al., 2021). *Brachyplatystoma rousseauxii* is one of the species with the highest value in amazonian fishing, being exploited in its juvenile stage in Brazil, and as adults in Bolivia, Colombia, Ecuador and Peru. Consequently , it is exploited in most of its distribution area (Duponchelle et al., 2015). *Brachyplatystoma vaillantii* is also a very important fishing resource in the Amazon Basin (Brito-Junior y Tavares-Dias, 2021). *Brachyplatystoma tigrinum* fry are very valuable in the international market as ornamental fish and the adults are consumed locally (Alcántara et al., 2009).

Fishing has been historically the main food resource for both indigenous and colonizer inhabitants in the lower Ecuadorian Amazon (Barriga, 1994). In the Central Amazon, south of the Yasuní National Park. local fishermen living on the banks of the Curaray and Pinduc rivers, use two methods for capturing *Brachyplatystoma catfish*. One method consists of using a big single hook (20cm) dangling from a rope suspended on branches over the deepest part of the main river channel. This method is used to catch *B. filamentosum*, *B. rousseauxii*, *B. vaillantii, B. platynemum*, and *B. juruense* (Jácome, 2005; Jácome-Negrete et al., 2022).

Another more intensive method used by commercial fishermen is the use of calenders (lines of up to 25 hooks 12 to 15 cm length) which are baited using curimatid fish, cichlids, gymnotids, bird viscera or charapa turtle eggs as bait. These calenders are left in the river overnight and checked first thing in the morning. This type of fishing is done more frequently during the summer months (October to January) (Jácome-Negrete y Guarderas, 2014). Local fishermen have five to 10 calanders and are able to catch catfish of up to 90 kg (200 lb). (Jácome, 2005). The use of hook lines is relatively recent in the area, as it started to be used in the year 2000 (Jácome and Guarderas, 2005). In other areas of the Colombian Amazon, besides the hooklines, the fishermen use floating or draggin stationary nets, and harpoons, the net being the most used method, especially in low water, while single harpoons were more effective in periods of high water (Agudelo et al., 2000).

Currently, commercial catfish fishing in the Ecuadorian Amazon is still classified as artisanal, since fishermen use small boats and simple fishing gear, without having fish storage infrastructure; Moreover, there is no further information on the catches made and their sustainability. (Anaguano-Yancha et al., 2022).

In a monitoring study of the catfish trade carried out in two ports of the Napo River (Coca/Orellana and Pompeya/Sucumbíos) during 69 days of fair held between 2009 and 2011, the sale of 679 fish of 18 species of catfish was recorded. (2787 kg). Of this number, 35 were *B. vaillantii* (17 kg), 23 B. platynemum (30 kg), 22 B. *tigrinum* (42 kg), seven *B. filamentosum* (7 kg), seven *B. juruense* (21 kg) and six *B. rousseauxii* (43 kg). These species were captured with catfish nets, buoys, hooks and diving (Anaguano-Yancha et al., 2022). In the Peruvian Amazon, *B. tigrinum* is captured with nets of different sizes (43 kg). These species were captured with catfish nets, buoys, hooks and diving. (Anaguano-Yancha et al., 2022). In the Peruvian Amazon, B. tigrinum is captured with nets of different sizes (Alcántara et al., 2009).

Current threads to *Brachyplatystoma* catfish in the Ecuadorian Amazon

The main threats to Amazonian migratory fish are overexploitation, pollution and the increasing development of hydroelectric dams (Duponchelle et al., 2021).

Overexploitation

Detailed studies indicate that the fishing stock of *B. filamentosum* has decreased significantly throughout the Amazon basin. According to Petrere et al. (2004) this species is more sedentary than others of the same genus, so fishing fleets located in the western Amazon can have a more direct impact on their populations, especially on larger and reproductive fish. Furthermore, its fishing is older in the Amazon Estuary than in the western Amazon. Industrial fishing for this species in the basin began in 1971, after seven years it reached its highest peak, and decreased by the end of 1990 in the estuary (Petrere et al., 2004). (Petrere et al., 2004).

For the last 25 years, there have already been warnings about the possible consequences for the aquatic species of the lower Napo River basin, including migratory catfish, due to the expansion of oil activities and construction projects associated to the north of the Yasuní National Park. (Barriga, 1994). Currently, throughout the Ecuadorian Amazon, there is a palpable reduction in the fishing stock of all *Brachyplatystoma* species caused by different circumstances: the excessive use of gillnets, fishing with dynamite or other unsustainable methods such as barbasco and increased traffic. river (Anaguano-Yancha et al., 2022; Narankas et al., 2022).

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Pollution of rivers

Throughout the Ecuadorian Amazon, there is a decline in all *Brachyplatystoma* species caused by oil spills, mining products, and pollution of waste from cities (Anaguano-Yancha et al., 2022; Narankas et al., 2022). It has been confirmed that the use of alluvial gold washing machines throughout the middle Amazon basin causes pollution for the fish (Petrere et al., 2004). So far, some examples of this have been reported, such as the bioaccumulation of heavy metals in certain species such as the slimy catfish *B. platynemum*, whose level of total mercury in its meat is higher than what is permissible according to the World Health Organization, caused by the mining in the Colombian Amazon, with the consequent deterioration of the populations of this species (Nuñez-Avellaneda et al., 2017).

In the upper basin of the Napo River (section of the Yutzupino River), an analysis of the impact of small-scale mining on water and soil, reported the presence of heavy metals in the soils, especially arsenic, with a value higher than the established permissible limit. In Ecuadorian legislation, as a product of locally developed mining, with the consequent impact on water quality and soil degradation (Medina-Bueno et al., 2023). In the province of Morona Santiago, in rivers where there is illegal mining, such as the Cuchipamba River, lead contamination has been recorded, the values of which were detected exceeding permissible limits. (Brito, 2022). In mining exploitation sites on the Ecuadorian coast, bivalve mollusks of the *Anadara* genus and Siluriformes fish of the *Chaetostoma* genus have been found, with concentrations of lead, arsenic, chromium, cadmium, zinc and mercury higher than the maximum permissible limits established in international standards. (Rebolledo et al., 2014; Tobar et al., 2017).

Currently, it is also reported for Ecuador that in places where gold mining activities are carried out, the value of mercury existing in the sediments of freshwater estuaries exceeds permissible limits. (González et al., 2018). The presence of mercury in freshwater fish species of the *Andinocara* genus has caused very serious chromosomal alterations, such as fractures, mitotic spindle dysfunction, and chromatin fragmentation (Nirchio et al., 2019).

The consumption of large predatory fish, contaminated by mercury, is the main cause of human exposure to methylmercury, as a toxic agent that affects the nervous system, since the concentrations of this toxin are higher in these species (Gia, 2015). The existence of significant bioaccumulation and biomagnification of mercury has been confirmed in mining areas of Ecuador, with mercury levels in the blood of women FROM these sites equivalent to those found for women living in mining areas of China, greater than those found in other European countries; However, research on possible negative health effects is still in its early stages. (Marín et al., 2016). In Amazonian indigenous territories, such as Sinangué, gold extraction, in addition to causing health problems, especially for children; water resources are significantly degraded and aquatic life is disturbed (Orellana et al., 2020).

Dam construction

The main negative impacts generated by dams on Amazonian fish populations are the following: blocking the natural migration of fish upstream for reproductive purposes, such as what happened with *B. rousseauxii* and *B. vaillanti* in the Madeira River (Brazil), species that, due to their size, cannot find and cross the fish passages of the dams. This causes genetic homogenization. Likewise, in dams there is less oxygen dissolved in the water so only species adapted to less oxygen will remain (Val et al., 2016).

In the Bolivian Amazon, the populations of the golden *B. rousseauxii*, a species that migrates long distances, are in the process of reduction due to the construction of the Jirau and Santo Antonio dams, in the middle section of the Madeira River (Brazil). The dams cause the fragmentation of the tributaries, they also limit the access of the fish to the headwaters, which are their reproductive areas, and the juvenile fish are trapped between the turbines (Carvajal-Vallejos et al., 2020). Significant differences were found in catches and CPUE for *B. rousseauxii* between before and after the closure of two dams located on the Madeira River. The age of the few individuals captured above the dams suggests that they are a mixture of adults that managed to pass the dams before their closure and residents born after the closure. (Van Damme et al., 2019).

Although in Ecuador, at the moment there are no projects for the construction of new dams that overlap with the documented migratory routes of the *Brachyplatystoma*, in the event of new project proposals, these new dams would interrupt the migratory routes of the large catfish, will cause serious problems in their populations (Jácome-Negrete et al., 2022).

Conservation alternatives for giant amazonian catfish

The conservation of migratory fish requires a broad portfolio of research, management and conservation actions, with an ecosystem management scheme at the scale of the entire Amazon basin, including alliances between countries and

revaluation of the importance of maintaining the connectivity of freshwater ecosystems (Duponchelle et al., 2021). In this context, at least two alternatives are priorities to guarantee the conservation of *Brachyplatystoma* populations in the Ecuadorian Amazon.

Urgent fishing regulations

It is essential and urgent to promote research and monitoring of the populations of all *Brachyplatystoma* species and current fishing levels in all Amazonian tributaries. In addition, it is necessary to create official and community fishing regulations that would stop altogether the use of dynamite in fishing or other harmful products such as mullein. (Jácome, 2005; Jácome-Negrete y Guarderas, 2014) and that smoked catfish meat merchants be sanctioned when they use protected species. In the Colombian Amazon, the establishment of closed periods has worked successfully, a practice supported the study of the reproductive seasons of the species. (Agudelo et al., 2000). Another fishing regulation that has favored the conservation of *B. rousseauxii* in the border sector between Brazil, Colombia and Peru has been the use of "golden" sling nets, adapted for the capture of specimens larger than the established capture size used voluntarily by local fishermen (Gil, 2008).

Creation of conzervation zones for migratory fish

At the local level, the riverside communities of the Ecuadorian Amazon propose starting a zoning process of the main channels, identifying conservation zones and areas for fishing. (Jácome-Negrete y Guarderas, 2014). These conservation zones should include identified spawning areas to safeguard larval development. (Agudelo et al., 2000; Jácome, 2005). From a technical point of view, it is highly advisable to protect varzeas as aquatic environments that serve as nursery sites for many migratory species (Val et al., 2016).

Giant fish (fish weighing 30 kg or more) are important to people and ecosystems around the world. Around the world, their populations are declining and more information is needed for their conservation. For example, in Cambodia, the Mekong River, one of the largest rivers in the world, is considered one of the last refuges for giant fish (Campbell et al., 2020). The Mekong giant catfish (Pangasianodon gigas Chevey 1930) is a species endemic to this basin, being one of the largest freshwater fish in the world at more than 3 m long and weighing even more than 300 kg (Mattson et al., 2002). In Thailand, these fish have been reproducing using artificial insemination since 1983 and subsequently released by the government in protected lakes and reservoirs in the country for sustainable use by the inhabitants. (Mitamura et al., 2006). The Mekong River and the Amazon are hotspots for a wide diversity of large catfish and still maintain populations of giant catfish such as P. gigas and *B. filamentosum,* respectively. (Hogan, 2011).

For these migratory giant catfish, conservation of their habitats is key. In this context, the identification, demarcation and protection of fry sites for species such as P. gigas in the Mekong River has favored its conservation, carried out in alliance with local fishermen. (Lorenzen y Sukumasavin, 2007). At this basin, Since 1998, hundreds of conservation areas for fish, called "fish sanctuaries", have been created in the interior of the Lao People's Democratic Republic with the direct participation of local inhabitants, which have gradually become key areas for the protection of various freshwater species throughout this basin, with the feasibility of replication in other tropical regions with similar ecological and cultural characteristics (Baird, 2006).

These zones are a form of spatial management that is established along a river, where fishing activities are partially or totally restricted with the purpose of safeguarding the remaining populations of fish, favoring the increase in their diversity, abundance and sizes. (Loury et al., 2019). Among the main criteria to delimit a possible fish conservation area, the following should be considered: that they are spawning, feeding or shelter sites for fish; that contain high richness, abundance of fish or rare or threatened species; that they can be confluence sites between two rivers, and that their length should be at least 10 times the width of the body of water (Loury, 2020).

Taking these reference criteria into account, the following preliminary proposal of conservation zones for giant catfish of the genus *Brachyplatystoma* in the interior of the Ecuadorian Amazon is suggested. (figure 4). The findings by Hermann et al. (2021) have been taking into account: the presence of Siluriformes larvae between 250 (Coca) to 200 masl (Pañacocha) and where beaches with sandy substrate begin.

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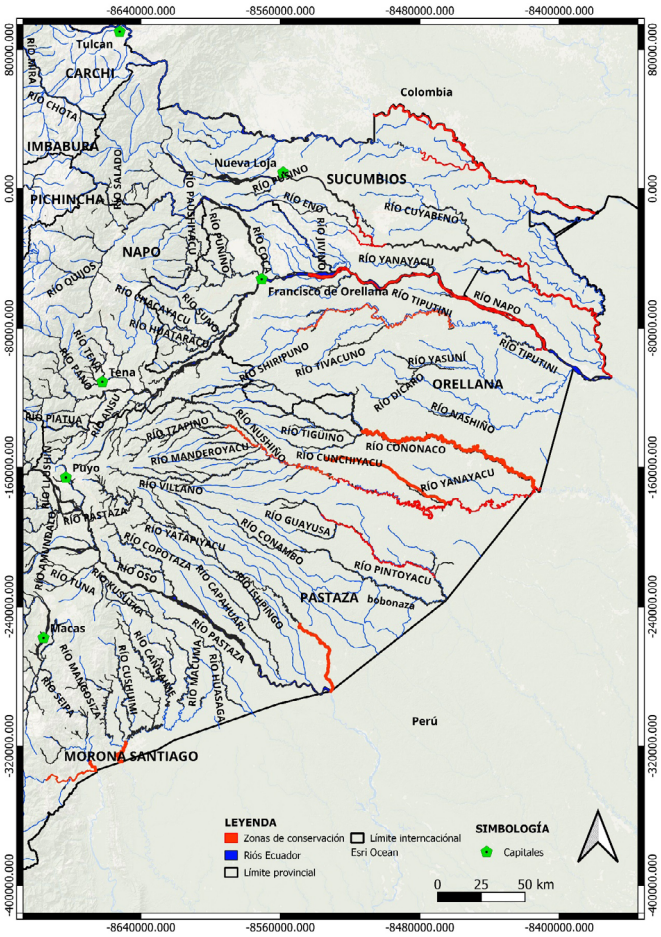

Figure 4: Map of preliminary proposal for conservation zones for giant catfishes of the genus *Brachyplatystoma* in the Ecuadorian Amazon.

Conclusion

To this date, six species of catfish of the genus *Brachyplatystoma* are recorded in the Ecuadorian Amazon: *B. filamentosum, B. rousseauxii, B. vaillantii, B. platynemum, B. juruense and B. tigrinum.* In this work, descriptions and photographs are presented to support the identification of adult specimens in the field, and their distribution at the watershed scale supported by the consultation of previous publications and museum specimens. There is no information for the Corrientes and Conambo river basins.

Based on Kichwa knowledge, migration is described for four of the six species. These species cross the border with Peru and go back to the headwaters of the main channels for reproductive purposes, then return downstream. There are no studies carried out from other contexts in the country that document the migratory patterns of these species. Specifically, for the Napo River there is a single study on probable spawning sites for Siluriformes larvae located between 250 masl (Coca) to 200 masl (Pañacocha), and which coincides with the presence of the sand bed for the channel major. Only data on average capture sizes (Napo River basin) are known for the species analyzed; However, data on size at first maturation, fecundity or spawning times are unknown, as basic parameters necessary for fisheries management. *Brachyplatystoma* are mainly piscivorous, fulfilling the role of top predators in aquatic ecosystems.

Currently, due to the type of boats and capture gear used, fishing for these giant catfish is still classified as artisanal and is more common in basins with more riverside human settlements. However, the diversity, abundance and sizes for these species have been reduced throughout the Ecuadorian Amazon. The main threats to these species are overexploitation and contamination of waterways. Given this, the development and application of fishing regulations, and the creation of fish conservation zones, overlapping with sites with the presence of larvae, within the main channels, are proposed as alternatives.

Given the limited existence of research on these species for Ecuador, it is urgent to promote new studies, especially in basins for which information is not yet available. It is also key to involve local fishermen in all these processes to promote fishing management measures that safeguard the populations of all species for the future.

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Conflict of interests

The authors declare that there is no conflict of interest in this publication or in any of its stages.

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Author's contribution statement according to the CRedit classification

Iván Vinicio Jácome-Negrete: Conceptualization, Investigation, Formal Analysis, Writing - original draft, Writing – review & editing. **Cristian Israel Founes-Pinto:** Formal Analysis, Methodology, Writing - review & editing.