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Freshwater Ecology

Exploring ecohydrology through the lens of local fishers in the Bolivian Amazon

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Abstract

The natural flow regimes of Andean-Amazon tributaries play a vital role in sustaining their rich biodiversity and productive local fisheries, but ongoing and proposed alteration of river flow regimes by large dams threatens to negatively impact river ecosystems. Despite its importance, our understanding of how hydrologic variability influences ecological functions in the Andean Amazon is limited, particularly in regions with scarce data. In these regions, growing research highlights the value of fishers' local ecological knowledge in addressing these gaps. This study focused on increasing our knowledge of ecohydrological relationships in the Beni River of Bolivia through the analysis of fishers' knowledge through 28 individual semi-structured interviews. Results indicate how key species rely on hydrologic variability, connectivity, and flooding dynamics to carry out their life stages of reproductive migration and access different habitats in the floodplains. Fishers mentioned using hydrologic indicators at multiple scales to guide their fishing activity. For instance, flooding extent and duration help anticipate fish abundance in the next years; connectivity between the main channel and oxbow lakes indicates fish migration; and within-site observations of water level on the bank, water depth, flow direction, flow velocity, and backwater effects are used to select a fishing location. In addition, the fishers described characteristics of habitat such as substrate, vegetation, and turbidity, as well as fish feeding habits and sequential migration patterns that represent valuable observations about fish ecology. The comparison with scientific information not only confirmed existing insights but also extended our understanding of ecohydrological relationships and helped explain possible causes of relevant long-term trends. In conclusion, our findings highlight the vital role of the flooding dynamics in the fishing practice and draw attention to the potential negative impacts of hydrologic alteration on the livelihoods of fishers.

KEYWORDS
fish ecology, hydropower impact, local knowledge, natural hydrologic variability, qualitative analysis, small-scale fisheries

INTRODUCTION

Small-scale fisheries are a cornerstone of food security, livelihoods, and cultural identity for Amazon riverine communities. They often supply the main source of animal protein and sustain local economies through subsistence catches and commerce (Hallwass et al., 2020; Mikkola, 2024). However, Amazonian aquatic habitats face degradation and fragmentation caused by multiple pressures (Duponchelle et al., 2021; Goulding et al., 2019; Tognelli et al., 2019; Van Damme et al., 2023). Deforestation and climate change alter the basin's water balance and intensify extreme events (Anderson & Maldonado-Ocampo, 2011; Marengo et al., 2024; Oberdorff et al., 2015). In addition, the construction of large dams stands out as one of the most significant challenges to riverine ecosystems (Anderson et al., 2018; Latrubesse et al., 2017; Winemiller et al., 2016). Storage dams reduce seasonal flow variability, shorten flood durations, and decrease the frequency of large flood events (Chaudhari & Pokhrel, 2022; Timpe & Kaplan, 2017). These alterations translate into severe impacts on fish ecology, including blocked migration routes, reduced habitat availability in floodplains, and disrupted hydrologic cues that synchronize with fish life stages (Bunn & Arthington, 2002; Wu et al., 2019). The evaluation of these impacts requires understanding the fundamental role that hydrologic variability plays in fish ecology and floodplain dynamics.

In river floodplain systems, the degree of connectivity among water bodies determines their use as a shelter or migration corridor (Lewin & Ashworth, 2014). In systems where the principal source of water is overbank flow, the influence on the fish ecology in the floodplains is described by the flood pulse concept (Junk et al., 1989, 2020). During extended and predictable flood pulses, fish migrate to floodplains for spawning, feeding, and shelter. As water levels recede, the fish return to the main channel or tributaries (Herrera-R et al., 2024; Melack et al., 2009; Welcomme, 1985). The duration of the flood pulse and retention time in the floodplain reflect tolerances and adaptations to hypoxic conditions in fish and riparian vegetation. In addition to lateral connectivity to the floodplains, longitudinal connectivity is necessary for long-distance migratory fish to reproduce upstream (Duponchelle et al., 2021; Vasconcelos et al., 2021).

Besides fish ecology, hydrologic variability also affects the fishing practice. Factors such as the seasonal permanency of water, the accessibility to water bodies, and hydraulic settings are relevant for navigation and inform the selection of the fishing site and gear (Welcomme, 1985). In artisanal fisheries in the Amazon basin, the analysis of catch records showed a close relationship with flood pulse dynamics (Castello et al., 2015; Lima et al., 2017; Sousa et al., 2017). Extreme floods presented a yearly lagged positive correlation with the annual catch, indicating higher reproduction rates in the floodplains, which also matched the growth time and longevity of the fish species (Isaac et al., 2016; Santos et al., 2020). The seasonal variability showed that during low-water periods, the concentration of fish in water bodies facilitated higher catches; while during flood periods, fish dispersed into inaccessible flooded forests (Lauzanne et al., 1990; Santos et al., 2018).

Riverine natural resources are often managed by indigenous peoples and local communities that contribute to governance through conservation, knowledge co-production, resistance to unsustainable practices, advocacy for environmental justice, and alternative perspectives on people–nature relationships (Brondízio et al., 2021). Traditional knowledge shows a deep ecological understanding reflected in the systematic use of diverse environments. In the Peruvian Amazon, local and indigenous knowledge systems reflect complex techniques adapted to flooding dynamics, integrating conservation and production through sequences of agriculture, fishing, gathering, and hunting (Hiraoka, 1985; Pinedo-Vasquez et al., 2002). Likewise, local knowledge of soils provides valuable insights for sustainable crop production in floodplains (WinklerPrins & Barrios, 2007).

Similarly, local fishers' knowledge presents potential advantages to inform effective management, including broader spatial and temporal scales, a perspective closer to nature, and their participation in the local socioeconomic context (Collins, 2007; Stephenson et al., 2016; Taylor & de Loë, 2012). Previous research studies have integrated local and scientific knowledge, validating and extending insights about fish ecology. Their results highlighted new information incorporated into conceptual models of fish life traits and improved understanding of their linkages with flow variability. The analysis of local knowledge helped to increase the level of confidence in existing theories, assess the validity of spatial extrapolation, and reveal new hypotheses or identify those that need further testing (Finn & Jackson, 2011; Gaspare et al., 2015; Jackson et al., 2014; Nunes et al., 2019; Silvano & Valbo-Jørgensen, 2008).

This paper examines how hydrologic variability influences fish ecology and the practice of fishing through the analysis of the fishers' knowledge along a poorly studied reach of the Beni River in the Bolivian Amazon. This reach of the river is threatened by plans to construct a major upstream dam that would significantly alter the river's flow regime. We aim to expand our understanding of the system by studying fishers' knowledge about ecohydrologic relationships and interpret the potential impacts of hydrologic alteration. The result is intended to provide a qualitative perspective to inform further research on the potential ecological impacts of hydrologic alteration of the Beni River and support more effective planning and management practices.

MATERIALS AND METHODS

Study area

The Beni River originates in the Eastern Andean foothills and flows through a dynamic river floodplain system where fishing is prominent (Carvajal-Vallejos et al., 2011; Miranda-Chumacero et al., 2011). The region presents a distinct climatic pattern, with the rainy season from November to March and a dry austral winter. At the town of Rurrenabaque (see Figure 1a,b), average monthly discharge varies from 760 m^3/s in August to 4700 m^3/s in February, with an annual mean of 2000 m^3/s. Suspended sediment load is significant at 200×10^9 kg/year (±27%) (Vauchel et al., 2017), resulting in high rates of channel migration and formation of oxbow lakes. Oxbow lakes serve as fish habitats, and access to them is mainly influenced by overflow from the main channel (da Silva et al., 2013; Gautier et al., 2007). However, a planned upstream hydropower project that consists of a storage dam located in the Chepete Strait and a run-of-river dam in El Bala Strait will alter the natural hydrologic variability in the main channel downstream of Rurrenabaque, where floodplain ecosystems become more expansive and where both indigenous and nonindigenous communities live (see Figure 1b,c). This study is focused on that section.

In one of the most recent inventories of fish biodiversity in the Amazon, the Beni basin stands out with 435 species verified (Jézéquel et al., 2020). However, despite the high biodiversity in the area, research about fish ecology and aquatic habitat remains limited. The most relevant studies have focused on species distribution (Mariac et al., 2022), identification of reproduction areas (Miranda-Chumacero et al., 2015, 2020), trophic dynamics in streams (Pouilly et al., 2006), and fishing activity (Argote et al., 2014; Coca-Méndez et al., 2012; Macnaughton et al., 2015; Miranda-Chumacero et al., 2011).

The study reach of the Beni River (Figure 1b,c) extends ~200 km downstream of Rurrenabaque, where fishing is practiced for commercial and subsistence purposes by indigenous and nonindigenous communities. Fishers include residents of Rurrenabaque, the indigenous communities (Tacana ethnicity) of Tierra Comunitaria de Origen (TCO) Tacana I (La Paz, represented by Consejo Indígena del Pueblo Tacana [CIPTA]) and TCO Tacana III (Beni, represented by Organización de Comunidades Indígenas Tacana de Ballivián [OCITB]), Esse Ejja families (Esse Ejja ethnicity), and nonindigenous riverine communities (unknown ethnicity). Commercial fleets operating further downstream usually land their catches in Riberalta, ~500 km downstream of Rurrenabaque.

Rurrenabaque, a town of ~21,000 inhabitants, is the region's main commercial fishing port and economic center. Livelihoods depend on commerce, agriculture, livestock, fishing, forestry, and tourism (Instituto Nacional de Estadística, 2025). The ethnicities in Rurrenabaque include white, mestizo, and migrants from indigenous highlands (Lopez-Pila, 2014). Landed fish are sold locally or transported to major cities (80%–90% of catches). Annual landings were estimated at 142×10^3 kg in 2008 and ~209×10^3 kg in 2015. Key species include *Zungaro zungaro* (Humboldt, 1821), *Pseudoplatystoma tigrinum* (Valenciennes, 1840), and *Piaractus brachypomus* (Cuvier, 1818), locally known as bagre, surubí, and tambaquí (Espinoza-Antezana & Van Damme, 2020; Van Damme et al., 2011).

The TCO Tacana I communities have a strong organizational capacity and collaborate with various nongovernmental organizations. Their livelihood depends on fishing, hunting, agriculture, and the use of forest resources (timber and non-timber) (Bauer et al., 2018). A self-monitoring study about the fishing practice of six communities in 2008 estimated ~20×10^3 kg/year of fish catch, 65% sold commercially, with the same key species as Rurrenabaque (Consejo Indígena del Pueblo Takana and Wildlife Conservation Society, 2010). The importance of fishing was emphasized after the 2014 extreme flood, which destroyed agricultural fields and game resources but left fish abundant enough to mitigate food insecurity (Townsend, 2017).

Esse Ejja families are primarily nomadic. While they have small settlements, they have no official territory. Their livelihoods rely heavily on fishing for subsistence

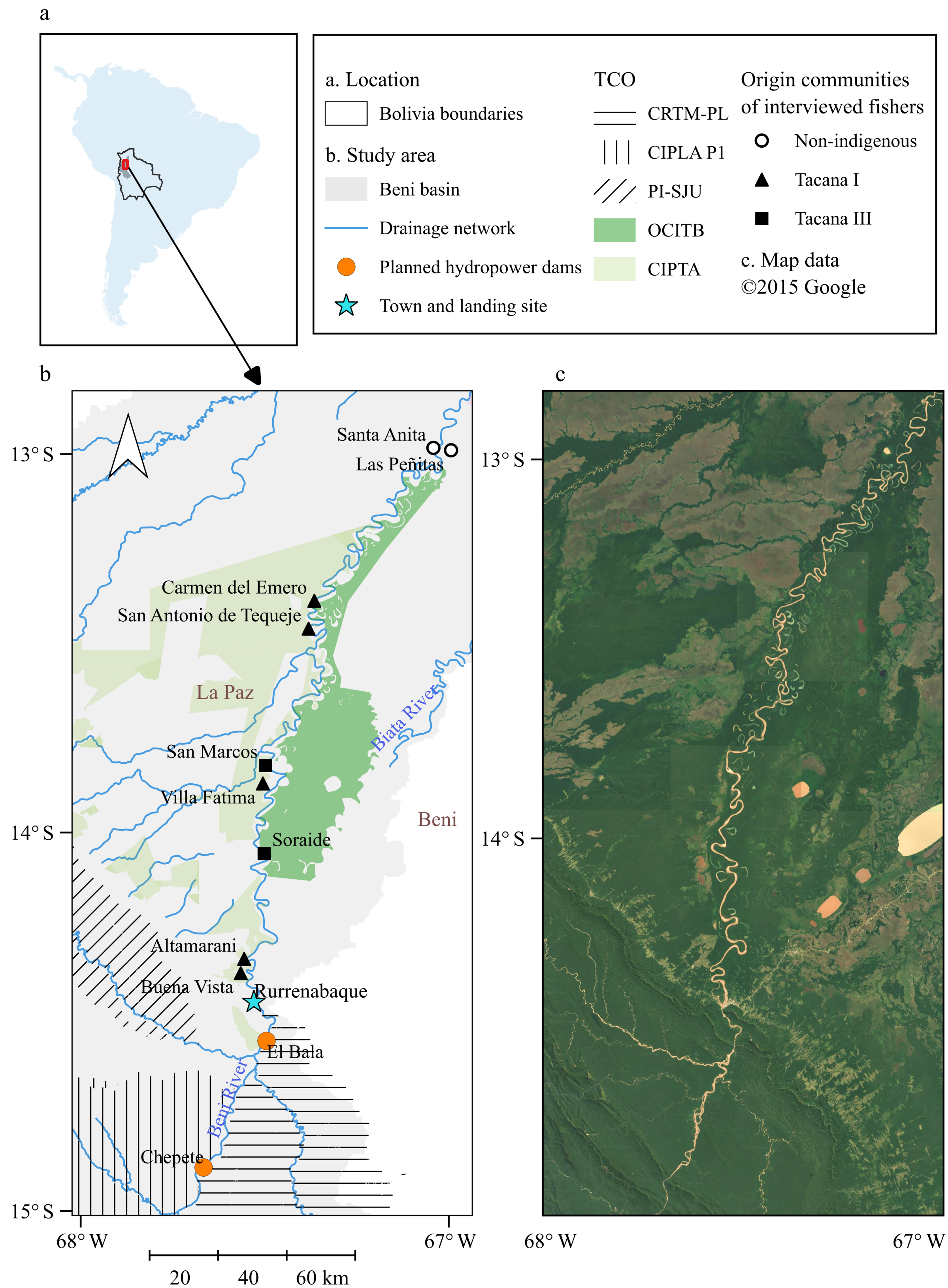

FIGURE 1 (a) Location of study area within Latin American boundaries. (b) Beni River reach indicating the reach downstream Rurrenabaque with origin communities of interviewed fishers and the area upstream showing the location of planned hydropower dams. Origin community territories are Tierra Comunitaria de Origen (TCO) represented by Consejo Indígena del Pueblo Tacana (Tacana I) (CIPTA); Organización de Comunidades Indígenas Tacana de Ballivián (Tacana III) (OCITB); Consejo Regional Tsimane Mosetenes Pilón Lajas (CRTM-PL); Central Indígena del Pueblo de Leco de Apolo Polígono 1 P1 (CIPLA); Pueblo Indígena de San José de Uchupiamonas (PI-SJU) (shapefile obtained from https://geo.gob.bo/catalogue/#/dataset/2105). (c) Satellite image of the study reach from map data (©2015 Google).

and small-scale commerce (Bénéfice et al., 2010; Tschirhart, 2011).

Information on indigenous TCO Tacana III communities is scarce, with little documentation on organization or fishing practices. Similarly, there are no studies about the nonindigenous communities further downstream.

Fishing techniques in the region include different types of nets (malla, tarrafa) in all water bodies, hook-and-line methods (espinel, lineada) for large species in lentic water bodies, and spears for migratory fish. Subsistence fishing is mainly carried out in canoes (small motorboats with a capacity of 200–500 kg), while commercial fishers use cascos (larger boats with storage capacity of 1000–2000 kg) (Alviz Costa, 2006; Van Damme et al., 2011).

Migratory patterns of key species correspond to the medium-distance, large-bodied group (Duponchelle et al., 2021). *Z. zungaro* migrates upstream during rising waters to feed; *Pseudoplatystoma* spp. undertake upstream reproductive migrations; and the characiform *Pi. brachypomus* uses multiple water bodies for feeding and spawning (Herrera-R et al., 2024).

While not recorded in catches, *Arapaima gigas* has been spotted in the study reach. This species has been recorded in Bolivia since the 1980s after it was accidentally introduced from Perú into the Madre de Dios basin. It has since expanded upstream into the Beni River floodplain (Miranda-Chumacero et al., 2012; Van Damme et al., 2015). Their migration pattern group is short-distance resident species (Duponchelle et al., 2021).

The number of active commercial fishers in the region fluctuates with resource availability and alternative income opportunities such as timber extraction. During the study period, the number of fishers for the three largest associations was collected: 23–30 belong to the Fishers Agropecuary Association of Mamuri, 25 are members of Agropecuary Association of Fishers Paiche, and 25 are from the Agropecuary Association of Panete. These associations operate both within and beyond the study reach, with some landing catches as far downstream as Riberalta.

In the river system, fishers have unrestricted access to the main channel. However, access to lakes and streams is determined by the territorial jurisdiction of the nearest community upstream on the same river margin. In addition, a closed fishing season is imposed tentatively from November to March for particular species and sizes according to departmental government regulations (Reglamento para la pesca y comercialización de especies piscícolas en el Departamento del Beni issued by Servicio Departamental Agropecuario SEDAG Beni, 2016).

Analysis of local knowledge through qualitative data

The semi-structured interview was designed using a topic guide to inquire about the details of fishing practices and their connection to hydrologic variability. The interview sections included general data about the fishers, access to resources (planning and fishing techniques), fishing site characteristics, seasonal variability, fish ecology, preferred species, and production (see Appendix S1). The questions were formulated to explore the spatiotemporal variability of these aspects and to investigate potential links with hydrology. The questions focused on the fishers' experiences and permitted new information to emerge, as recommended by O'Keeffe et al. (2016). For this purpose, three levels of inquiry were followed, including descriptive, relational, and cause-and-effect analysis, as described in DePoy and Gitlin (2016).

The aim of participant selection was to interview as many fishers as possible along the study reach, given the time and resources available. Fieldwork was conducted between April and June 2022. The reach from Rurrenabaque to Carmen del Emero was visited on 4 and 5 April 2022. Ten fishers were interviewed: four in communities (Carmen del Emero, San Antonio de Tequeje, Villa Fátima, and Soraide) and six along the main channel. At the time of the visit, a few fishers were at the communities, while others were fishing, hunting, or working in agricultural plots. In particular, San Antonio de Tequeje was nearly abandoned following the severe 2014 flood, which had destroyed homes and fields. Along the main channel, interviews were conducted at commercial fishers' temporary camps, though some camps were empty when crews were fishing farther away in oxbow lakes. Subsistence fishers were also encountered on their boats along the river.

To increase the likelihood of finding participants, further interviews were conducted at the Rurrenabaque landing site (18 interviews in the intervals of 7–12 April, 16–17 May, and 2–16 June). Typically, for each boat, one crew member was designated to respond while others continued their activities. In some cases, fishers declined because they were busy.

In total, 36 fishers were contacted during the study period, 28 of whom agreed to participate. The sample included both commercial and subsistence fishers, representing Tacana I, Tacana III, nonindigenous communities, and Rurrenabaque. Unfortunately, no Esse Ejja fishers were interviewed. Subsistence fishers were more difficult to locate, as their livelihoods involve multiple activities beyond fishing.

Community visits were conducted with Authorization Request to the leader, and all interviews followed ethical guidelines of informed consent, with approval from the Delft University of Technology Human Research Ethics Committee (Letter of Approval number 1994). Responses were anonymized and transcribed.

The data analysis involved a detailed description of the case and its context; it was organized into categories that represented distinct patterns, functions, and processes. The identification of these categories was the result of a coding process in Microsoft Excel, in which responses were linked to specific categories of fish species (general, specific species), temporal (hydrologic periods), and spatial scale (water bodies) (Rädiker & Kuckartz, 2019; Saldaña, 2013). The emergent categories were linked, reflecting their interdependencies. Next, the coded responses were interpreted based on the frequency, specificity, degree of elaboration, and new insights (Chi, 1997; Sijbesma & Postma, 2008). A synthesis table showing the interview questions, assigned code, categories, number of mentions, and association with separate categories (fish species, hydrologic period, water body, and others) is presented in Appendix S2: Table S1.

For example, a response to question P1 (Production long-term change) is "In these years there has been low fish catch, it depends on the flooding", and it was coded as follows: General fish (fish species), Flooding (hydrologic period), Unspecified (water body), Decline (observation), and Flooding (associated factor/cause).

Fish production is not officially recorded by any institution. However, estimating the recent amounts is helpful to assess the relevance of the fishing practice. For this purpose, we asked for data from the National Agricultural Health and Food Safety Service (Servicio Nacional de Sanidad Agropecuaria e Inocuidad Alimentaria [SENASAG]), which monitors the quantity of fish transported from Rurrenabaque to the cities. Also, we have inquired with collectors about estimated counts of standard freezing units (300–350 kg/unit) for the recent year.

TABLE 1 Characteristics of all interviewed fishers by origin territory or town, age group, and fishing purpose.

No.	TCO/town	Age group	Purpose
1	T1	G3	S
2	T1	G3	C
3	T1	G1	S
4	T1	G3	S
5	R	G3	C
6	T1	G1	C
7	T3	G1	C
8	T3	G2	S
9	T1	G1	S
10	T1	G1	S
11	R	G1	C
12	T3	G1	C
13	T1	G2	C
14	R	G2	C
15	R	G1	C
16	T1	G2	C
17	R	G2	C
18	N-I	G1	C
19	T1	G2	C
20	T1	G1	C
21	N-I	G1	C
22	T1	G1	C
23	R	G1	C
24	R	G2	C
25	R	G1	C
26	N-I	G1	C
27	T3	G1	C
28	R	G1	S

Abbreviations: C, commercial; G1, 21–35 years; G2, 36–50 years; G3, 51–65 years; N-I, nonindigenous; No., participant number; R, Rurrenabaque; S, subsistence; T1, Tacana I; T3, Tacana III; TCO, origin community territories (indigenous).

RESULTS

General aspects of the fishing practice and terminology

Information about the origin territory, age group, and fishing purpose of the 28 fishers is presented in Table 1. The participants mainly originate from indigenous communities (57%) and the town of Rurrenabaque (32%). Most of the interviewees practice fishing full-time for commercial purposes (75%) and the rest for subsistence. The age of the fishers ranged from 23 to 63 years, with a mean age of 36 ± 12 (SD) years. Most fishers interviewed were male (86%), but a few women also led fishing trips mainly for subsistence purposes.

As a result of the coding process, common terms and categories of space, time, and fish species were identified. Fishers recognize five types of water bodies: the river (main channel), the lakes (oxbow lakes), the clearer western streams, the darker eastern streams, and the rapids (upstream). The temporal periods are mainly associated with river hydrology and flood dynamics: the dry period during which water levels and flooded area are reduced to the minimum (July–October), the period of rising waters that starts with the heavy rains

(November–December), the flooding period that initiates when the main channel overflows to and connects the oxbow lakes (January–March) and finally, the period of receding waters during which the oxbow lakes drain back to the main channel and become disconnected (April–June).

Fishers also distinguish fish species by body cover and size, as presented in Table 2. These categories are associated with fishing sites and fish preferences. Body cover was specified by 11 fishers, and the main factors associated were water body and turbidity (4), feeding habits (4), and preference (4). Size type was mentioned by 12 fishers who linked it with fish life traits (5) and water body (4).

Experienced fishers have noticed important changes in recent years, particularly the proliferation of the paiche, a significant decline in the abundance of native species, and shifts in upstream migration patterns, as indicated in the quotes in Table 3. They attribute the reduction of native species to various causes. The most frequently mentioned (64%) is the increasing use of gill nets for commercial purposes, followed by the possible consequences of dry years (18%) and predation by paiche (18%). The disruption of migration patterns of pintao and sábalo was also linked to the dams located further downstream in the Madeira River (Brazilian territory). In response to these changes, fishers who practice for subsistence have to increase their efforts and visit more remote water bodies.

The target fish species mainly depend on the purpose of production, the temporal variation of demand, and the abundance in the river system. As indicated in the relative frequency of responses in Figure 2, when fishing for commercial purposes, fishers target large species such as paiche and skin-covered species such as bagre and surubí. In contrast, native species are preferred for local

TABLE 2 Characteristics of key fish species including local names, body cover types and size categories indicated by fishers for key fish species, with corresponding scientific names and migration patterns from the literature.

Local name	Body cover	Size	Scientific name	Migration pattern[a]
Bagre, chanana	Skin	Large	*Zungaro zungaro* (Humboldt, 1821)[b]	G2
Dorado	Skin	Medium	*Brachyplatystoma rousseauxii* (Castelnau, 1855)[c]	G1
Pacú	Scale	Medium	*Colossoma macropomum* (Cuvier, 1816)[b]	G2
Paiche	Scale	Large	*Arapaima gigas* (Schinz, 1822)[b]	G4
Pintao, chuncuina	Skin	Large	*Pseudoplatystoma* spp.[c]	G2
Piraíba	Skin	Large	*Brachyplatystoma filamentosum* (Lichtenstein, 1818)[b]	G1
Piraña	Scale	Small	*Serrasalmus* spp.[c]	G4
Ruta	Scale	Medium	Anostomidae spp.[c]	
Surubí	Skin	Large	*Pseudoplatystoma* spp.[b]	G2
Tambaquí	Scale	Medium	*Piaractus brachypomus* (Cuvier, 1818)[b]	G2
Tucunaré	Scale	Medium	*Cichla pleiozona* (Kullander & Ferreira, 2006)[b]	G4
Tujuno	Skin	Small	*Leiarius marmoratus* (Gill, 1870)[b]	G2
Yatorana	Scale	Small	*Brycon cephalus* (Günther, 1869)[b]	G3
Jatara	Scale	Medium	*Mylossoma duriventre* (Cuvier, 1818)[b]	G2
Sábalo	Scale	Small	*Prochilodus nigricans* (Spix & Agassiz, 1829)[b]	G3
Buchere	Scale	Medium	*Hoplosternum littorale* (Hancock, 1828)[b]	G4
Carancho	Skin	Small	*Pterygoplichthys multiradiatus* (Hancock, 1828)[c]	G4
Llorona	Scale	Small	Curimatidae spp.[c]	...
Panete	Scale	Small	*Triportheus angulatus* (Spix & Agassiz, 1829)[b]	G3
Sardina	Scale	Small	*Iguanodectes spilurus* (Günther, 1864)[b]	...
Griso	Skin	Small	*Pimelodus blochii* (Valenciennes, 1840)[b]	G2
Bentón	Scale	Small	*Hoplias malabaricus* (Bloch, 1794)[b]	G4
Tachacá	Skin	Small	*Pterodoras granulosus* (Valenciennes, 1821)[c]	G2

[a]Van Damme et al. (2011): Group G1 migrate >3000 km, G2 are large and migrate 100–1500 km, G3 are small and migrate 100–1500 km, G4 migrate <100 km.
[b]Sarmiento et al. (2014).
[c]CIPTA and WCS (2010), Froese and Pauly (2024).

TABLE 3 Illustrative quotes from fishers about long-term changes in fish ecology and the fishing practice.

Frequency of responses (%)	Long-term change	Illustrative quotes
20 (71)	Reduction of fish catch in general (particularly pintao and pacú)	"In general, there is a decrease in fish catches. This year it was low. I do not why that is, maybe the increase of fishers." "Before, there were small pintaos, now we only find tachacá when we install the gill nets. The fish catch is low because there are too many gill nets." "In these years there has been low fish catch, it depends on the flooding." "Now, there are no (native) fish. The paiche is preying on them."
11 (40)	Increase of paiche	"One year ago the paiche has appeared and proliferated in the lakes."
6 (21)	Change in migration patterns of sábalo, surubí	"Before 2009, the fish would migrate upstream; we do not see them anymore." "In the past, the dry period was the best to go fishing because the sábalos used to migrate upstream"... "Now we have to target the fish that migrate from the lakes back to the main channel during receding waters period" "In the past, the sábalos would migrate upstream, now they can't because of the dams downstream. Now they are very small, before they were big." "We were affected by the dams downstream in Brazil, it has affected dorado and surubí, they do not migrate upstream anymore."

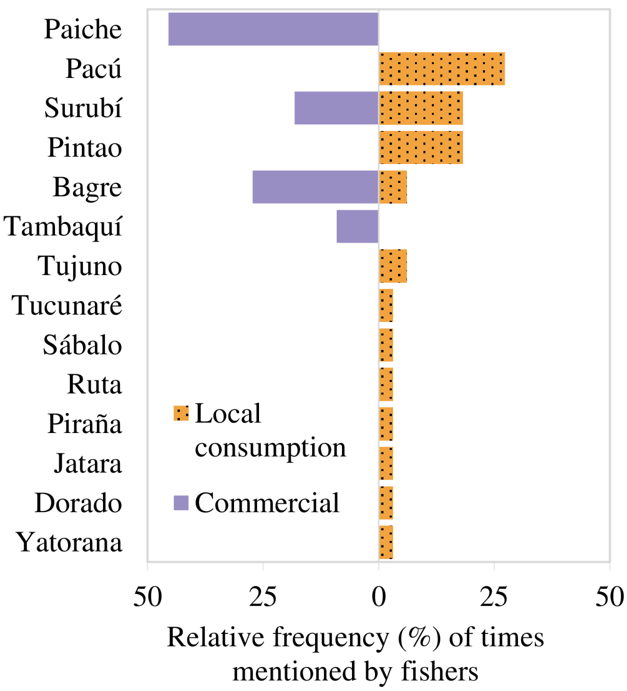

FIGURE 2 Relative frequency (in percentage) of times that fishers mentioned the target fish species for local consumption (32 mentions) or commercial purposes (21 mentions).

consumption in the town and communities. The most popular species are pacú (scale-covered body) because of the good flavor and quality of the meat, as well as pintao and surubí (skin-covered body), followed by diverse native species of medium or small-sized groups. The recent reduction of some of the larger species has led to an increase in the preference for smaller species.

Fish production is mainly associated with the abundance of fish in the river system during the different hydrologic periods, the temporal fluctuations in demand, and the fishing restrictions. According to data collected from Senasag, the amount of fish transported from Rurrebabaque to larger Bolivian cities was 294×10^3 kg from May 2021 to April 2022, with a maximum in April (43×10^3 kg) due to high demand linked to religious traditions and the minimum in January during the flooding and restriction period (19×10^3 kg). The collectors estimate that approximately 80% of the fish production is transported to the cities, while the remaining stays in the local markets. Therefore, an approximate production for this period is 370×10^3 kg. On the other hand, the estimations made by collectors and the count of freezer units indicate a production of 284×10^3 kg ($\pm 47 \times 10^3$ kg) for the last year.

The fish catch composition is mainly comprised of paiche, followed by pintao, pacú, bagre, surubí, and tambaquí. Paiche is the most important species during the rising and flooding periods, whereas the other species become more available during the receding and dry periods. Fish collectors suggested that paiche constitutes at least half of the monthly production, underscoring the dominance of this species in general.

Hydrologic variability and the fishing practice

The selection of water bodies for fishing is primarily based on the seasonal flooding dynamics and fishing restrictions, as indicated in Table 4. Figure 3a presents the hydrograph at Rurrenabaque station, indicating maximum, mean, and minimum daily discharge obtained from the Amazon basin water resources Observation

TABLE 4 Characteristics of fishing practices during different hydrologic periods, highlighting restrictions, demand level, preferred water bodies, and general production level.

Fishing practice characteristics	Flooding	Receding	Dry	Rising
Months	Jan, Feb, Mar	Apr, May, Jun	Jul, Aug, Sep, Oct	Nov, Dec
Partial restrictions on native species	Jan, Feb			Nov, Dec
High demand		Apr		
Main fishing water body	Lakes	Main channel, streams	Main channel, streams, lakes	Main channel
General production	Low	High-medium	High	Medium

Service HyBAm database (https://hybam.obs-mip.fr/, accessed in 2022) for the period 1989–2016, and Figure 3b shows the migration patterns of native species and paiche during each hydrologic period. In the case of native species, fish disperse and migrate to the lakes and shallow flooded depressions or "bajíos." During this period, only deep open water bodies (1.5–4 m) are accessible, while flooded depressions are covered by forest and access is difficult. Navigation risks also increase during flood waves, further limiting fishers' activities. As waters recede, fish return to the main channel where diverse species initiate their reproductive migration upstream. This movement indicates to the fishers that the main channel is a good fishing site. Afterwards, as the water levels further reduce, the fish concentrate in all water bodies and the migration activity intensifies in the main channel and streams. Thus, fishers expect high catches in all water bodies. After breeding upstream, the fish migrate downstream during the period of rising waters and continue their growth phase in the lakes or the main channel. In this period, there is no clear fishing preference for a water body and there are navigation risks in the main channel.

In the case of paiche, the migration patterns are only laterally to lakes where paiche carries out most of its life stages. Thus, the fishers who target this species visit the lakes during most of the year; if there is no connectivity, some will portage boats by land, and during the flooding period, there are low catches because of the fish dispersal in the flooded depressions. The quotes presented in Box 1 reflect the perception of these changes.

In addition to seasonal flooding, fishers also consider interannual dynamics and short-duration events to predict the migratory behavior of native species. Occasional connectivity due to intense rainfall can occur throughout the year; falling water levels and return flow to the main channel indicate potential catch there. The interannual flooding variability is taken into account to predict the production of future years, as described in interview quotes in Box 1. In dry years, there is minimal connectivity between most lakes and the main channel; thus, most of the fish that were growing in the lakes remain there. In contrast, in years with extensive and prolonged flooding, such as in 2014, fish were able to take advantage of the abundant resources in the flooded depressions and later migrate upstream in better conditions to reproduce. Thus, fishers anticipated abundant catches in the main channel for that year and even future years. These observations allow fishers to either invest in resources for fishing or to select temporally alternative economic activities.

After the fishers have selected a water body or a section along the main channel, they search for physical signals that suggest the presence of particular fish species or categories as specified in the quotes in Box 1. They associate areas with high water levels and slow currents with the presence of medium-sized fish. In the main channel or streams, they search for backwater, swirls, and areas with accumulated woody debris. The confluence of a stream and the main channel is a typical place to find fish, especially during migration periods.

The choice of fishing gear depends on the target species, flow velocity, and water depth. Gillnets are preferred in slow-flowing lake waters, while hook-and-bait methods are better suited for shallow areas and traps for deeper areas in the main channel. Paiche is mainly caught using hook-and-bait sets or traps in the lakes, whereas native species such as pacú, surubí, and pintao are typically captured in deeper sections of the main channel using both nets and hook-and-bait techniques. Bait selection varies according to the target species and their seasonal feeding habits. For carnivorous fish such as paiche, fishers commonly use species like llorona, sábalo, bentón, buchere, carancho, and panete as bait. Pacú, on the other hand, is caught with fruits, while various worms are generally effective for a wide range of species.

Hydrologic variability and fish ecology

The main habitat characteristics that fishers associate with fish species are preferred water bodies, water depth, substrate, turbidity levels, and vegetation. In general,

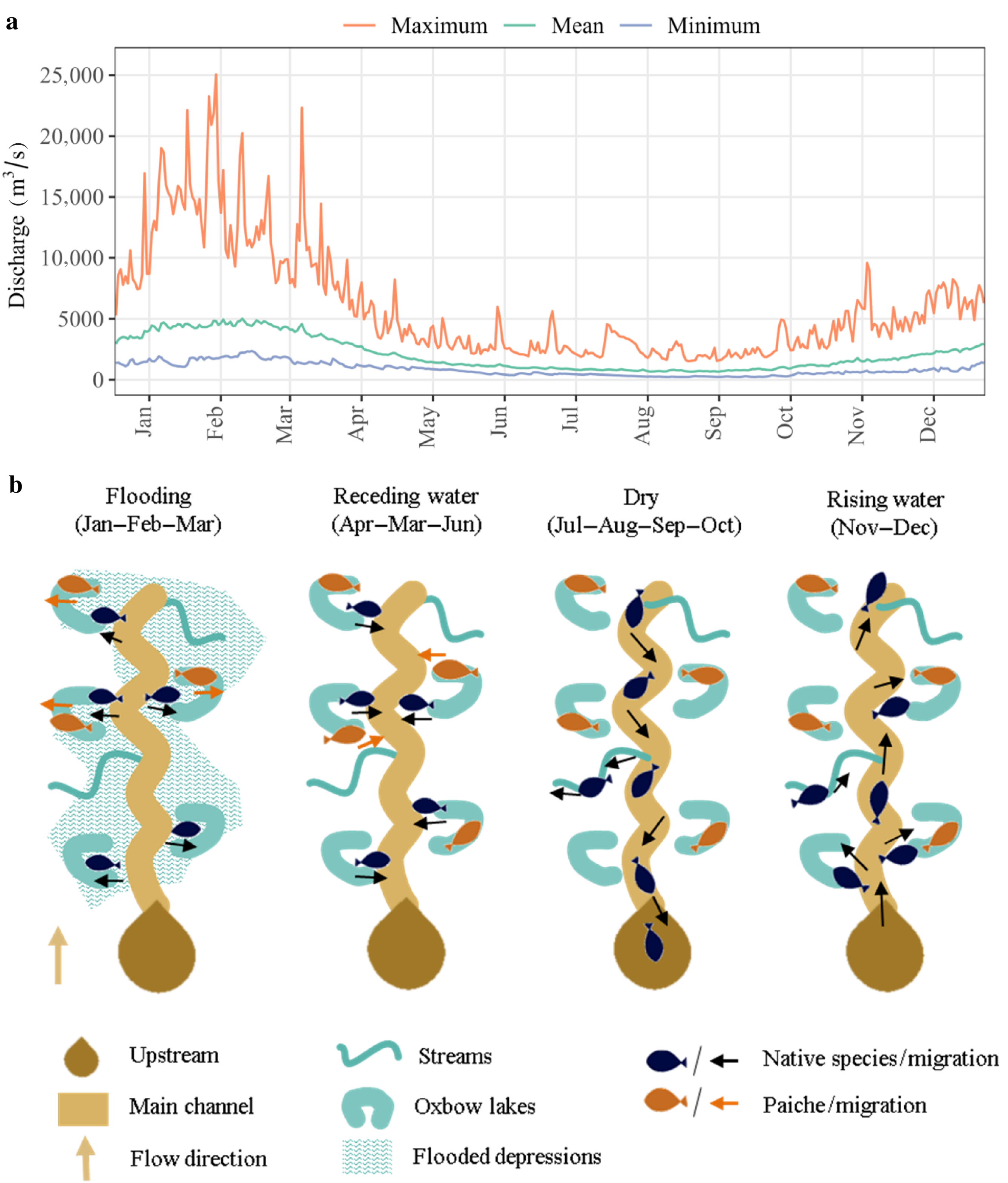

FIGURE 3 (a) Hydrograph at Rurrenabaque station indicating maximum, mean, and minimum daily discharge obtained from the Amazon basin water resources Observation Service HyBAm database (https://hybam.obs-mip.fr/) for the period 1989–2016. (b) Fishers' description of migration patterns of native fish species and paiche in each hydrologic period. Illustration credit: Lina G. Terrazas-Villarroel.

fishers note that most fish species can be found in most types of water bodies as they constantly move between them, while certain species show a preference for specific types, as indicated in quotes in Box 2 and in Table 5. Water depth is associated with fish size and characteristics such as feeding habits and morphology. Fishers

BOX 1 Illustrative quotes from fishers about hydrologic factors that affect the fishing practice

Illustrative quotes about seasonal flooding dynamics and water body selection for fishing

"During the flooding period there is low fish catch because the fish are in the bajíos."

"During the flooding period we enter the lakes because it is possible to access from the main channel."

"When the water level reduces, there are plenty of fish going from the lakes and bajíos to the main channel, the fish catches are high."

Illustrative quotes about interannual flooding dynamics and prediction of fish catch

"The fish catches will be low; there was no flooding this year...."

"There has to be a larger inundation so that fish can come out of the lakes to the main channel...."

"There was no flooding; the fish in the lakes have not come out...."

"The flood in 2014 wiped out Villa Fatima, several animals died; but there was abundant fish because the lakes were flooded, and the fish migrated back to the main channel afterwards."

Illustrative quotes about interpretation of physical aspects in a water body

"We fish near rapid currents; behind the debris... these are strategic locations in the beach where we install the hook and bait."

"We put the fixed hook and bait in backwater zones, confluences, in the turns of the main channel and streams."

"The gill nets are mainly installed in the lakes, in a backwater location with low current."

estimate depth using a leafless shrub called chichío (*Tessaria intergrifolia*) of approximately 4 m maximum. Vertical movement is notable for preying on smaller species during the night, sheltering in deep waters during temperature drops or full moons, as well as for air-breathing, especially observed in paiche.

In the proximity of vegetation, fishers commonly find fish species that feed on fruits or use the aquatic vegetation as shelter and nursery sites for juveniles that feed on algae and the roots of aquatic plants. Fishers identify various fruit tree species along the margins of water bodies, including bibosi, ambaibo, chonta, cedrillo, panejaja, coquino, and chirimoya with corresponding scientific names *Ficus pertusa*, *Cecropia concolor*, *Spondias mombin*, *Pouteria nemorosa*, *Xylopia ligustrifolia*, and *Annona cherimola* (Killeen & García, 1993). Aquatic vegetation environments are locally called yomomo, tarope, and cañuela. They may include communities formed by herbaceous and floating plant species such as *Oxycarium cubensis* and *Paspalum repens* (Navarro, 2011).

Water quality is reflected in water turbidity and linked to fish categories. Scaled fish are commonly found in the clear waters of lakes and western streams. Surubí and pintao are known to seek clear waters during the rising water period. Bagre, however, is the only species that is more associated with turbid waters in the main channel and upstream. Three respondents pointed out that turbidity reflects the contamination levels that affect the quality of the fish meat, which explains their higher preference for fish mainly found in clear water bodies. In addition, 10 fishers have observed events of mass mortality, especially of sábalo, following heavy rains in water bodies that contain more organic material. The possible causes they suggest include the drainage of ashes from agricultural activities upstream and the decomposition of vegetation.

Fish migration for reproduction is locally referred to as "arribada." Large schools of fish are audibly and visibly recognized as they migrate upstream along the main channel. Most fish lay their eggs in unknown locations further upstream, and the smallest species reach more distant locations than the larger species. The fishers note that migration occurs in ascending order of size from April to August, as indicated in Table 5, with larger species preying upon smaller ones. The stomach content informs the feeding preference of the larger fish and bait selection. The timing and size of schools in the main channel are used as predictors of the potential production for the year.

Fishers also observe other stages of reproduction and growth. For instance, they observe the eggs drifting through the main channel like oil drops as water levels rise, also in the lakes where hatching occurs, and juveniles' growth during the flooding period, taking advantage of abundant food resources. In regard to the adult

BOX 2 Illustrative quotes from fishers about fish habitat and fish ecology

Illustrative quotes about habitat

"In the lakes we find paiche, sábalo, pacú, carancho, surubí. The bagre is found in rapid waters."

"Paiche is abundant in the lakes, there is also pintao, pacú, tujuno, sábalo, piraña. In the river we find chanana, pintao, tujuno, piraíba, tachacá."

"Pacú and pintao are found in deep waters, the paiche is found at all water depths."

"The paiche is found in deep and shallow waters. It comes out to breath."

"Under bibosi tree we find pacú, yatorana and jatara (…). Paiche is found in aquatic vegetation."

"Paiche lives within yomomo, where there they prey on small fish."

Illustrative quotes about fish migration

"The sábalo, yatorana, pacú migrate upstream through the main channel."

"The paiche does not migrate upstream, it is from stagnant waters."

"Pacús migrate upstream in schools in November. The surubís migrate upstream preying on the sardinas and sábalos."

"First the sardina and small sábalo migrate upstream. When there is flooding, they migrate earlier in April to June. The large fish migrate upstream preying on the schools of smaller fish."

Illustrative quotes about fish reproduction and growth

"There is a delay in the reproductive migration of pacús, tambaquís and pintaos. We see them and they do not have eggs yet."

"Paiche reproduces in the lakes, pacú and pintao in the main channel."

"Paiche reproduces faster than the other fish species. In March you can see them with the juveniles in the lakes where they grow under the care of the parents, which guard the group from the front and behind."

Illustrative quotes about feeding habits from bait selection and vegetation in habitat

"Pacú eats bibosi, coquino, chirimoya during the flooding season."

"The most carnivorous fish are paiche and piraña."

"For the large skin-covered fish the best bait is carancho, buchere, panete."

"For paiche and pintao, we use llorona."

"The selection of bait depends on which fish species are migrating upstream through the main channel. For instance, now it is sardina."

care of juveniles, paiche shows this behavior as two adult fish flank a school of juveniles on the front and behind, protecting it from potential predators. Also, the carnivorous feeding habits of paiche are partially informed by the bait selection.

Table 6 presents a spatiotemporal synthesis of the qualitative insights from fishers and their link to quantifiable and measurable hydrologic variables. These ecohydrologic relationships represent the ecological functions linked to hydrologic indicators that allow the evaluation of alteration scenarios, including natural extreme events and human alterations.

DISCUSSION

Exploring the knowledge of fishers has significantly contributed to our understanding of fish ecohydrology in the Beni River. The increasing importance of fishing in the Beni River is evident in the estimated rise (+40%) in fish production from 209×10^3 kg in 2015 (Espinoza-Antezana & Van Damme, 2020) to 294×10^3 kg estimated for 2022 (using data from Senasag). The identification of the most valuable fish species reflects trends previously observed in downstream communities, particularly the rise in paiche catches (Coca-Méndez et al., 2012;

TABLE 5 Summary of most frequent attributes associated with fish species for habitat and fish ecology.

	Water body			Habitat characteristics				Fish ecology	
Fish species	**MC**	**OL**	**S**	**Depth**	**Substrate**	**Turbidity**	**AV**	**Main food**	**Migration in MC**
Paiche		X		Shallow		Clear	Y	Meat	NA
Pacú		X	X	Deep		Clear	Y	Fruits	Fi, Mi
Surubí	X	X		Shallow		Clear			Mi
Pintao	X	X	X	Both		Clear		Meat	Mi, La
Bagre	X			Deep	Clay	Turbid		Meat	La
Tambaquí				Deep				Fruits	La
Tujuno				Shallow					Mi
Jatara		X	X					Fruits	La
Piraña		X	X					Meat	
Sábalo	X	X		Shallow	Mud			Mud	Fi, Mi, La
Tucunaré		X				Clear			
Yatorana								Fruits	Mi, La
Piraíba	X			Deep	Clay				La
Griso				Shallow	Sand				Fi, Mi
Tachacá		X				Clear		Fruits	
Sardina				Shallow					Fi
Panete					Sand			Fruits	Fi, Mi, La

Abbreviations: AV, aquatic vegetation; Fi, first; La, last; MC, main channel; Mi, middle; NA, not applicable; OL, oxbow lake; S, stream; X, fish is present; Y, Yomomo.

TABLE 6 Indicators of hydrologic variability that influence the fishing practice.

Temporal scale	Spatial scale and observations of hydrologic variability	Influence on fishing practice	Influence on fish ecology
Multiannual	River system: connectivity; duration of flooding; flooding extent	Expectation of catch levels for next year, invest in resources	Paiche: explore and occupy new lakes Native species: optimize reproductive migration strategies for survival
Seasonal	Water body: water level changes; flooding extent	Select water body; prepare resources for fishing; prepare additional resources for small boat transport	Paiche: shelter in available flooded depressions Native species: reproductive migration upstream
Weekly/daily	Connectivity areas: flow from lake to main channel; confluence of stream and main channel Water body: flow velocity in main channel Fishing location: water depth; flow velocity; flow direction	Schedule fishing trip; selection of specific fishing location; selection of suitable fishing technique; assess navigability risk	Paiche: local migration Native species: signal for lateral migration; vertical migration; response to hypoxia

Macnaughton et al., 2015). In addition, the decline in native species is concerning because of their high preference for local consumption. Although native species and paiche show very distinctive life traits, their abundance and access to habitats depend largely on flooding dynamics, as well as connectivity, as depicted in Figure 3b and Table 6. Thus, fishers' knowledge highlights the importance of maintaining hydrologic connectivity in meandering rivers.

The influence of hydrologic variability on the fishing practice is evidenced in the use of various indicators to predict fish catches seasonally and for future years. The selection of water bodies based on hydrologic periods and fish migration patterns coincides with documented strategies in the Mamoré and Madeira rivers (Isaac et al., 2016; Lauzanne et al., 1990). Quantitative studies indicate similar trends of expected catches of native species, with high fish catch during the dry period and low during the flooding period (Lauzanne et al., 1990; Zacarkim et al., 2015). In the Madeira River, water level changes and flooded areas were also used to predict fish catch and inform the number of fishing trips (Santos et al., 2018, 2020). The relationship between annual fish yields and flooding dynamics was analyzed through correlation studies, showing that high and low waters in a given year affect yields two or three years later with higher fish biomass and fishing effort (Castello et al., 2015; Isaac et al., 2016). This coincides with fishers' expectations of higher catch after humid years and lower catch after dry years. Similarly, the extent of flooding was highly correlated with fish production in the Lower Amazon (da Doria et al., 2018; Isaac et al., 1996). While dry years in the Beni River have been linked to lower catches, studies in the Negro River near Manaus report more severe drought effects, including fish mortality, species loss, and smaller catch sizes (Camacho Guerreiro et al., 2016). These findings highlight the potential ecological and livelihood disruptions as a consequence of hydrologic alterations.

Comparative insights from local and scientific knowledge about key fish species

The proliferation of paiche partially explains the estimated increase in recent fish production. The expansion of this species was facilitated by hydrologic connectivity to lakes with adequate temperature and rare anoxic events, as well as high reproduction rates and parental care, also observed by the fishers (Carvajal-Vallejos et al., 2011; Coca-Méndez et al., 2012). The migration patterns between the lakes and flooded depressions coincide with those studied in the Japura floodplains (Castello, 2008). Although primarily carnivorous, paiche has displayed omnivorous traits in the Madre de Dios floodplains (Villafán et al., 2020), indicating that feeding habits depend on the local and temporal availability of resources. In our study, the fishers mentioned diverse species used as bait for paiche (small species) and preying sites near aquatic vegetation. While paiche is an introduced species to the Beni River, it has become a dominant preferred species among commercial fishers who require sustainable management.

The fishers closely observe how native fish migration patterns are linked to hydrologic variability, emphasizing the upstream migration and eggs drifting downstream. In tropical systems, the seasonal reproduction patterns are considered an adaptation to the flood pulse timing, which allows both adults and juveniles to benefit from the food resources and shelter in the floodplains (Goulding, 1980; Junk, 1997; McConnell & Lowe-McConnell, 1987; Welcomme, 1985). Beyond supporting widely recognized ecological concepts, fishers' knowledge also contributes new evidence of habitats. For instance, in the Tapajos River, fishers' observations about migration patterns point to new potential spawning and feeding sites (Nunes et al., 2019). In our study, fishers' knowledge about the sequence (ascending size) and timing of fish species during the upstream migration along the Beni main channel was not found. In other studies, these patterns should be further evaluated to find links with hydrologic connectivity and fish abundance.

Sábalo (*Prochilodus nigricans*) is highlighted as one of the most important native species for fishers, with observed disruptions in their migration patterns and mass mortality attributed to changes in water quality. This species was known to migrate in large shoals upstream along the main channel on two occasions during the receding waters and dry period, similar to observations in the Central Amazon (Petrere, 1978). The initial migration of juveniles aims to switch food sources and evade hypoxia, while the second migration of adult fish synchronizes with hydrologic signals for reproduction purposes (Fernandes, 1997). Sábalo is particularly vulnerable to hydrologic changes because it has a short reproductive period and requires a minimum growth level prior to leaving the floodplains (Barros et al., 2021; de Magalhães Lopes et al., 2018). One of the responses to hydrologic changes is the mechanism of "skipped breeding," in which only part of the adult population migrates for reproduction, and the rest remains in the floodplains to increase their chances of survival (de Magalhães Lopes et al., 2018). These studies can partially explain the observations of the fishers and the association of lower flooding during dry years.

Relevant species such as pacú and *Pseudoplastisoma* spp. (surubí and pintao) are also in decline. One of the possible causes linked to predation by paiche was also reported in downstream fisheries (Macnaughton et al., 2015; Miranda-Chumacero et al., 2012; Van Damme et al., 2015). The descriptions of habitat preferences of pacú coincide with studies that indicate the use of aquatic vegetation as nursery zones in lakes, proximity to forest trees to feed on fruits, and shelter in deep areas in the main channel (Córdova et al., 2012; da Silva et al., 2000). In regard to *Pseudoplastisoma* spp., they are predators during the reproductive migration along the main channel. This aligns with regional studies that found faster growth rates during the receding waters, while in the dry period, predation is low due to high densities and competition (Armas et al., 2022; Loubens & Panfili, 2000). These observations highlight the need to investigate trophic dynamics and propose measures to protect declining fish species.

Fishers' and local knowledge about dam development

Hydropower development in the Amazon has deeply affected riverine ecosystems and local livelihoods. Local knowledge studies on the impact of the Belo Monte Dam (Xingu River) revealed major disruptions to fisheries and vegetation. Fishers reported declining catches, altered practices, and loss of income, demanding operational changes to protect spawning sites (Assunção et al., 2024; Juruna et al., 2025). Similar impacts were described by fishers within the impact area of the Tucuruí Dam (Tocantins River), including the abandonment of fishing sites, change of techniques, increased effort, as well as reduced income and food security (Lima et al., 2024; Santos & Pelicice, 2023). On the Madeira River, the Jirau and Santo Antônio dams caused declines in catch per unit effort, loss of migratory species, lower income, and fish consumption (Arantes et al., 2022, 2023; de Souza et al., 2025). These cases expose the continued marginalization of small-scale fishers in hydropower planning (da Doria et al., 2018) and the overlapping distributional, procedural, and recognitional injustices faced by downstream communities (Castro-Diaz et al., 2024).

In this study, the identified ecohydrologic relationships help us point out various potential impacts of the planned Chepete dam on the natural hydrologic regime. At the seasonal scale, flood-pulse attenuation could reduce lateral connectivity between the main channel and oxbow lakes, limiting adult native fish from migrating upstream to spawn and restricting juvenile access to feeding and nursery habitats during rising waters. Prolonged disconnection of oxbow lakes could lead to drying or water quality degradation, exacerbated by reduced sediment and nutrient inflows from the main channel. The dam would also block longitudinal migrations of species that spawn further upstream. Although nearby streams might offer alternative habitats, their suitability would vary by species. Reduced habitat availability for paiche could increase overfishing risks, while declining fish abundance might push commercial fishers toward timber extraction and threaten the food security of subsistence fishers, increasing pressure on hunting and crops. The evaluation of these impacts at the planning stage could help to reduce impacts and evaluate alternative scenarios.

Fishers' and local ecological knowledge have a key role in assessing and mitigating dam impacts (Baird et al., 2021). In the Tapajós River, fishers' observations about fish habitat preference, connectivity, and migratory species informed how a dam could affect the fishing practice and threaten their livelihoods (Runde et al., 2020). Studies in other regions show how local knowledge can extend ecohydrological understanding and inform environmental flow assessments (Finn & Jackson, 2011; Jackson, 2017). Thus, incorporating local knowledge into hydropower planning is not only a matter of stakeholder inclusion but a practical need for planning more just, adaptive, and ecologically sustainable water management strategies.

Fishers' and local knowledge about hydrologic variability and river floodplain processes

Fishers also described key river-floodplain processes and long-term hydrologic trends. They identified drivers of lateral connectivity between the main channel and oxbow lakes, including overbank flow, intense local rainfall, and stream inflow. Also, their perception of reduced flooding over time is coherent with a reported decline of about $100\ m^3\ s^{-1}\ year^{-1}$ in the Beni River (Laureanti et al., 2024). Similarly, in clear-water rivers, fishers have reported drier conditions in the Tocantins, more frequent floods in the Trombetas, and variable trends in the Tapajós. They also associated poor water quality with pollution, as well as with dams, mining, and deforestation (Nunes et al., 2019). Collectively, these insights show how local knowledge can contribute to detecting and understanding hydrologic and environmental change.

Integrating diverse knowledge sources and analytical tools is needed to further understand the Beni River's floodplain processes. In this dynamic meandering system where main channel migration continually forms and erodes oxbow lakes, remote sensing can help characterize individual oxbow lakes, their connectivity patterns with the main channel, and changes in water quality (Terrazas-Villarroel et al., 2026). These insights can inform hydrologic models simulating dam operations and different scenarios of hydrologic alterations. Combining local knowledge, remote sensing, and hydrologic modeling allows for a comprehensive assessment of multiple environmental pressures and supports adaptive habitat conservation.

Limitations

Our analysis of fishers' knowledge using a qualitative approach implemented with semi-structured interviews has provided in-depth insights and flexibility. Despite its value, we acknowledge limitations in data collection and analysis. The limited sample size restricted extensive frequency analysis, with responses mainly reflecting different fish species and lower frequencies. The content of the interviews is constrained by the fishers' experience, age, fishing purpose, target species, and specific fishing locations. In our study, 60% of participants were young adults (21–35 years), while only 14% were older adults (51–65 years), which indicates that long-term trends represented a smaller time interval for the younger fishers. In the preliminary analysis, a couple of instances of species terminology conflict were discarded. Some of these limitations can be addressed in further qualitative studies organized per fish species or type of fisher.

CONCLUSION

In conclusion, the analysis of local knowledge has revealed important changes in valuable species and emphasized their reliance on hydrologic variability, connectivity, and flooding dynamics for various life stages. The fishers use this information to predict fish catches and strategically plan their fishing activity. We have extended the information about reproductive migration by highlighting the fishers' detailed observations of the sequence and timing of shoals of different species, as well as variable fish feeding habits. The continuous observation of these life traits revealed temporal trends also linked to hydrologic variability that should be further studied. The potential hydrologic alteration caused by a hydropower dam would lead to reduced connectivity and a potential decline in fish abundance, which in turn would negatively affect the subsistence and livelihoods of fishers. In summary, this study highlights the need to incorporate local and fishers' knowledge into hydropower planning, environmental assessments, and river floodplain studies. This would help to recognize and safeguard the dependence links between local and indigenous communities with river dynamics.

AUTHOR CONTRIBUTIONS

Lina G. Terrazas-Villarroel: Conceptualization; methodology; writing—original draft; funding acquisition. **Jochen Wenninger:** Conceptualization; supervision; writing—review and editing; funding acquisition. **Marcelo Heredia-Gómez:** Supervision; writing—review and editing; funding acquisition. **Nick van de Giesen:** Supervision; writing—review and editing. **Michael E. McClain:** Conceptualization; supervision; writing—review and editing; funding acquisition.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data are not publicly available due to privacy protection of research participants. Qualified researchers may contact Lina G. Terrazas-Villarroel (linaterrazas@gmail.com) for access.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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