

Amazon Forgotten Fishes

How the remarkable diversity of freshwater fishes is critical to people, rivers and forest



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FOREWORD

The Amazon is often imagined as an endless forest, yet this vision overlooks one of its defining features: up to 30% of the basin is composed of rivers, lakes, floodplains, wetlands, and seasonally flooded forests. Together, these interconnected freshwater systems form the world's largest and most complex river basin, sustaining the greatest diversity of freshwater fishes on Earth and underpinning the ecological, cultural, and economic foundations of the region. A healthy Amazon depends on the intimate and dynamic interaction between water and forest, mediated in large part by fish.

The Amazon Forgotten Fishes report seeks to elevate freshwater fish biodiversity within regional, national and global conservation and policy agendas. Fishes are at the heart of Amazonian freshwater systems: they connect rivers and forests through seasonal flood pulses, recycle nutrients, disperse seeds, sustain food webs, and support millions of people, particularly Indigenous Peoples and riverine communities. Yet despite their central role, freshwater ecosystems have long remained invisible in conservation, development, and climate strategies.

This report represents a unique collaborative effort, bringing together more than 50 experts from over 30 organizations. Combining science, Indigenous knowledge, and applied conservation experience, it provides an evidence base for action and emphasized the urgent need for coordinated and unified, basin wide solutions.

Protecting Amazon's freshwater biodiversity requires governance that matches ecological reality. The basin must be managed as one interconnected system, with stronger transboundary cooperation, harmonized policies and shared responsibility among all countries. Safeguarding river connectivity, through the protection of free flowing rivers and the restoration of disrupted connections, must be a guiding principle for energy, transport and

infrastructure planning aligned with low carbon and environmentally sustainable development. Freshwater ecosystems must also be fully integrated into the implementation of global biodiversity, climate and water commitments, as well as into international finance mechanisms and national development strategies.

Investment in monitoring, science and data systems is equally critical. Robust, long term data—supported by community led monitoring and Indigenous and traditional knowledge—are essential for adaptive management, informed decision making and accountability.

The window for preventing irreversible losses in the Amazon Basin is narrowing. Delayed or fragmented action will increase ecological, social and economic costs, both regionally and globally. Timely, coordinated actions at all levels are therefore imperative.

The future of the Amazon's freshwater life depends on our collective capacity to move beyond fragmented management and act at the scale of the basin. By aligning policy, science, finance and Indigenous stewardship within a shared governance framework, we can still secure a resilient, connected and productive Amazon freshwater system for generations to come.



Paula Caballero

Regional Managing Director
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EXECUTIVE SUMMARY

Across the vast sweep of the Amazon Basin, thousands of rivers, streams and floodplain lakes flow in an immense, interconnected waterscape—home to an unparalleled diversity of freshwater fishes. More than 2,700 species have so far been recorded, with dozens more added each year as scientific exploration continues.

This report dives beneath the surface to reveal their life histories, including their range and variety, the roles they play in the ecosystem, their adaptations and their niches. It also explores their place in human society, since millions of people across the Amazon rely on fish for food and livelihoods, and they have a unique place in the sociocultural heritage, histories and identities of Indigenous Peoples and local communities throughout the basin.

Two-thirds of the freshwater fishes in the Amazon are found nowhere else on Earth. This exceptional endemism is reflected in a dazzling range of species. Some are giants: the legendary pirarucu, for example, can reach a length of up to 3 m and tip the scales at 200 kg. Others are giants of movement: the ‘goliath catfishes’ are renowned for their long migrations, with the dourada known to travel more than 11,000 km in a migratory odyssey from the foothills of the Andes to the Atlantic Ocean and back.

The Amazon is also home to tiny neon tetras, jewel-like dwarf cichlids, razor-toothed piranhas, electric eels that hunt in packs, blind fish that inhabit saturated soil below the forest floor, and transparent candiru that drink blood from the gills of unwitting hosts. All of these species live in the connected hydrological system of white- black- and clearwater rivers, of seasonally flooded forests and richly varied habitats.

The fishes of the Amazon Basin are vital for its ecosystems. When the tambaqui and many other species migrate into flooded forests to feed on fallen fruits, they spread seeds across enormous areas, helping to regenerate tree cover. Other species act as mobile nutrient pumps, regulating primary production and supporting predators higher up the food web. In addition to holding the world’s greatest diversity of freshwater fish, the Amazon Basin hosts the highest global richness of freshwater megafauna, including large catfishes, river dolphins and giant otters, that depend on fish as their primary prey.

These same ecological processes that sustain biodiversity also underpin human well-being across the basin. Amazonian fishes are also dietary staples, with consumption topping 600 g per person per day in some remote riverine communities—the equivalent of two large fillets daily. For low-income households in particular,



fish are among the most affordable and reliable animal-source foods, providing essential nutrients that support healthy blood and the immune system, brain and heart development, and overall growth.

Taken together, this extraordinary diversity and ecological complexity underscore why Amazonian fishes matter not only to nature, but to people as well through the many ways fisheries sustain livelihoods, economies and cultural identities throughout the Amazon Basin.

Scarce data capture only part of the Amazon's extensive inland fisheries, as these are sustained largely by artisanal, small-scale and subsistence fishers whose catches rarely appear in statistics. Nonetheless, even the most conservative estimates show that at least 200 species are commercially harvested. Fishers use a wide variety of gears, designed to target specific species

under local environmental conditions. At least 15 types of gear are documented across the basin, most of which—from handlines to harpoons—are traditional and environmentally sustainable.

That said, not all Amazonian fisheries are targeted for the table. Hundreds of vividly colored and uniquely shaped ornamental species are captured alive for international export, ending up in aquariums all over the world. The most commonly traded species are familiar to amateur enthusiasts everywhere such as tetras, oto catfish, and arawanas—while other species require special permits for their sale, including some freshwater stingrays. Although the rise of captive breeding programs has transformed global markets in recent decades, the sector still exports tens of millions of individual fishes each year and supports thousands of livelihoods, so its continued sustainable management is critical. Notably,



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women are pivotal in the Amazon's ornamental fisheries, involved at every stage of the supply chain and playing very active roles in community associations.

Sport fishing, too, can provide valuable income for local communities, with well-managed catch-and-release tourist packages potentially raising more money in a week than could be raised in a year of commercial fishing in the same waters. Increasing numbers of sport fishers are visiting the Amazon, keen to pit their skills against peacock bass, large catfishes and other iconic trophy species. Many of the well-preserved, species-rich rivers that offer the best sporting experiences are in remote regions, and often in protected areas or Indigenous territories. A priority for the years ahead is to ensure that the sector's expansion remains sustainable, and that local communities are closely involved in its management and share fairly in its benefits.

But here's the issue: everything the fishes of the Amazon provide for the region itself and the wider world beyond—freshwater benefits, food and livelihoods, cultural heritage, wonder and delight—depends on them continuing to thrive. And for decades, in the Amazon, nature has been under attack. The International Union for Conservation of Nature (IUCN) lists 144 Amazonian fishes on its Red List of Threatened Species, and 334 other species are listed as Data Deficient. The true number

is likely much higher. Geographic and institutional gaps in national records, coupled with the absence of coordinated, cross-border collaboration, leaves further critical blind spots, making sustainable management much harder.

So why are so many species at risk? The answer is not a surprising one. Freshwater biodiversity in the Amazon is increasingly threatened by several major drivers, and all of them are the direct result of human activities. Most obviously, freshwater habitats are being degraded and destroyed at an unprecedented rate. Dams, drainage and diversions are all on the rise in the region, fundamentally transforming freshwater ecosystems by fragmenting their connections and changing the flow patterns that are crucial to fishes' life histories, physiologies and behaviors. Deforestation driven by agriculture, ranching, hydropower and infrastructure disrupts reciprocal relationships between trees and fruit-eating species, and quite literally muddies the waters the fishes swim in, limiting light penetration and clogging their gills. Pollution from other sources, including mining and oil extraction, can severely impair fish feeding, growth, reproduction and survival, while releasing contaminants such as mercury (a potent neurotoxin) that move through the food chain and pose risks to human health.

Overfishing has been increasing since the 1970s, due

to a lack of effective management, monitoring and enforcement systems. Regional studies are showing a reduction in the average size of fish landings, particularly of larger, more economically valuable species. As the makeup of fish communities changes, opportunities emerge for non-native species to establish themselves, which further disrupts freshwater ecosystems.

Intensifying the impact of all these threats is climate change, with consistent warming and significant changes in river flows projected through to 2050. In broad terms, as the planet heats, water in Amazonia will become scarcer, particularly during the dry season, which will hit floodplain species and the communities that rely on them particularly hard. Mountain streams are expected to be most affected, where warming waters will drive local extinctions of many endemic species.

Is the situation a hopeless one? Admittedly, in the face of so many daunting challenges, it would be easy to think that there's not much we can do to save the forgotten fishes of the Amazon Basin. But we already know what needs to happen to help these fish thrive—nations in the region need to put into practice the principles of the global Emergency Recovery Plan for Freshwater Ecosystems, based on six urgent and coordinated actions:

-  **Let rivers flow more naturally**
-  **Protect free-flowing rivers**
-  **End unsustainable management of resources**
-  **Protect and restore critical habitats and species**
-  **Prevent and control invasions by non-native species**
-  **Improve water quality in freshwater ecosystems**

There are unique opportunities to adapt and enhance these actions to the situation in the Amazon where water, sediments, nutrients and fishes respect no political borders. Safeguarding the fishes and freshwater ecosystems they inhabit requires a paradigm shift away from isolated national strategies and towards a unified, transboundary collaboration and governance framework. This must be anchored in collective action at a basin-wide scale led by governments working hand-in-hand with academia, the private sector, civil society and, importantly, with the Indigenous Peoples and local communities whose daily lives are intimately linked to

its natural cycles. Indeed, their central role is critical: the formal recognition of their stewardship and their significant traditional knowledge amplifies the potential for positive change.

Ultimately, this report demonstrates that the fate of the forgotten fishes of the Amazon relies on our ability to see the basin as they do: as one indivisible, flowing entity. By combining ancestral stewardship and knowledge with modern science, global engagement, robust transboundary governance and collective action to manage cumulative impacts, we can ensure that the Amazon remains a connected and thriving freshwater system far into the future.

An aerial photograph of a river basin filled with large, round, green lily pads. A person wearing an orange and black patterned shirt is sitting in a wooden boat, using a long wooden paddle to navigate through the lily pads. The water is dark brown. The text "A RIVER BASIN LIKE NO OTHER" is overlaid in white, bold, sans-serif font on the left side of the image.

A RIVER BASIN LIKE NO OTHER

© Andre Dib



Across the vast sweep of the Amazon, thousands of rivers, streams and floodplain lakes flow together in an immense, interconnected freshwater world. Here, white-, black- and clearwater rivers—each with their own chemistry, biodiversity and ancient origins—merge to form the most complex and dynamic freshwater mosaic on Earth. This singular hydrological engine shapes the conditions that give rise to the planet’s greatest freshwater fish diversity.

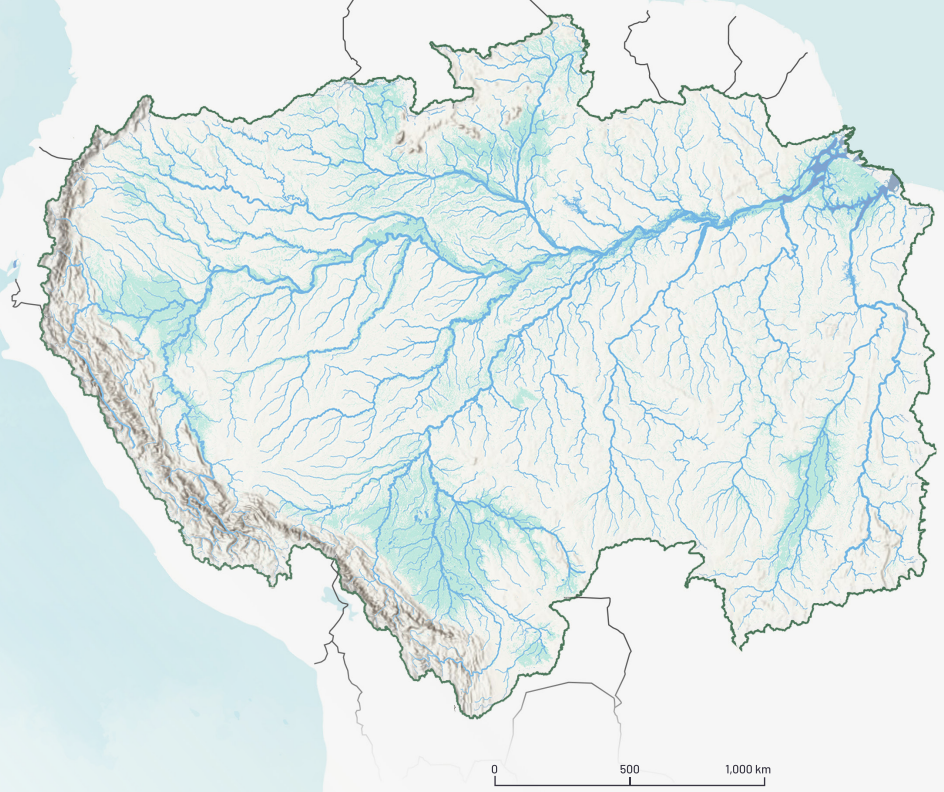
The Amazon, a river without equal

Between the eastern Andes and the Atlantic lies the vast Amazon Basin, the world’s largest river system. It covers an area of more than 7 million km²,¹ and pours more freshwater into the ocean than any other river in the world. Most of the Amazon Basin lies below 200 m in altitude, at which level there are no physical barriers along the main channel¹.

The rivers of the Amazon Basin form a complex corridor, changing their structure, ecological function and services as they proceed along their route. In the Andes, the rivers are constrained by the geology of the mountains, and transport a mixture of coarse (gravel, sand) and fine (clay, silt) particles. Their flow regimes are storm-driven and depend not only on precipitation patterns but also on upstream connectivity. As these rivers traverse the Andes, rocky gorges act as sediment filters, trapping coarse material and depositing it upstream, while finer sediments and sand are transported downstream on the current². On entering the lowlands the rivers begin to spread out, their single channels spilling into braided² multi-channel systems. This journey through a changing landscape creates a rich mosaic of habitats and ecological spaces³.

1 We also include here the Tocantins river basin, located south of the mouth of the Amazon River, which is ecologically and geographically connected to it by the Marajó complex.

2 A **braided river** is distinguished by having individual channels that can be straight, braided or meandering; with arms separated by stable islands; with or without vegetation; with calm waters that tend to develop in the lower parts of watercourses. They often develop in floodplains and over sedimentary basins²⁴⁴.



Hydrological cycle

● Dry season ● Flood season



Illustration of surface water extent during dry and flood seasons in the Amazon Basin⁴. Photographs illustrate the contrast of the same place, between both seasons in the Amazon Basin. Tefé, Amazonas, Brazil.

Amazonian rivers change with the seasons, with floods between December and May and low water levels between June and November. The annual flooding fertilizes land across floodplains, connects habitats, disperses seeds and promotes fish reproduction. This cycle is central to the life of communities in the Amazon, determining how they approach fishing, agriculture and transportation, but it also poses risks at both extremes, from floods and drought alike ⁵.

There are three main types of water in the Amazon Basin: white, black and clear. These create contrasting ecological conditions which shape fish diversity, productivity and migration patterns ^{6,7}. 'White waters', which originate primarily in the Andes Mountains, are rich in suspended sediments and nutrients, creating highly productive aquatic environments. They form the mainstems of the Amazon River, and seasonally spill across its extensive floodplains. 'Black waters', by contrast, mostly drain lowland regions of the basin and are nutrient-poor, acidic, and rich in dissolved organic matter,



Main River Types according to their waters features

— Black Water River — Clear Water River — White Water River



The map shows the distribution of major Amazonian river types—white, black, and clear waters—illustrated by the confluences of the A: Amazon (white) – Negro (black) and B: Amazon – Tapajós (clear) Rivers.

particularly tannins. Specialized communities of fishes have evolved to live in black waters, with physiological adaptations that reflect their chemical characteristics. Clear waters, which mainly originate from the Guiana and Brazilian Shields, are intermediate in pH, but are very clear, containing no sediments and very low levels of nutrients.

The contrasting productivity and water chemistry of these systems creates a mosaic of conditions that plays a major role in shaping the spatial and temporal patterns of fish migration and distribution across the Amazon Basin. Many species time their movements to coincide with the seasonal flooding of white-water rivers and their floodplains, taking advantage of the high productivity to grow and reproduce.

This report uses the term “freshwater” to encompass all inland aquatic ecosystems of the Amazon, including Andean systems, floodplains, and coastal areas influenced by saline inputs—whether permanent or seasonal—that give rise to estuarine or brackish environments. Although the term “freshwater” is widely used, it has historically framed aquatic ecosystems primarily as resources for human use. It is recognized that these systems are much more: they sustain essential ecological, social, and cultural benefits and hold intrinsic value as the habitat of extraordinary biodiversity.



WORLD-LEADING FISH BIODIVERSITY

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No other freshwater ecosystem on the planet rivals the Amazon. More than 2,700 fish species—about 15% of all known freshwater fishes worldwide, many found nowhere else—fill every conceivable niche, from mountain torrents to flooded forests. The basin yields new discoveries to science every month, reminding us that the world's largest reservoir of freshwater fish diversity remains mostly unexplored.

Unparalleled freshwater biodiversity

From the streams and glaciers of the Andes, through the vast seasonally flooded forests and savannas of the lowlands and on to the Atlantic, the interconnected freshwater ecosystems of the Amazon Basin are home to an unparalleled diversity of life¹.

Thanks to this extensive, varied and historically stable environment, the Amazon has the highest concentration of freshwater biodiversity on the planet⁸. This is especially true for fish: more than 2,550 species of freshwater fish have been documented in the Amazon Basin, representing about 15% of all known freshwater fishes worldwide. If the Tocantins-Araguaia basin (sometimes counted separately due to its distinct geological history) is included, the total rises to more than 2,700 species.⁹

Scientific exploration is still ongoing: in the 19th century, only about 500 Amazonian fishes were known; that number rose to about 1,500 by 1980 and then exceeded 2,500 in the 2020s¹⁰. Dozens of new species are still being described each year, while in 2017 a completely new family—the Tarumaniidae—was discovered¹¹. In other words, the inventory of Amazonian fish diversity is far from complete.

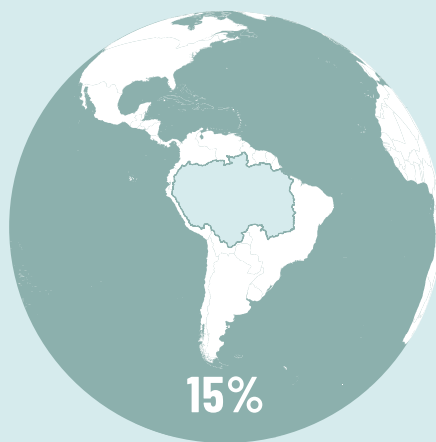
Not only are the Amazon's fish species extremely

diverse, but their composition is unique. About two-thirds (65%) of them—some 1,700 fishes—are endemic to the Amazon¹², with many of these being restricted to a single river system or even a single sub-basin. In fact, more than 830 fish species that live nowhere else have been identified in one single Amazonian sub-basin, which is a truly remarkable degree of localized endemism¹³.

From a taxonomic point of view, two orders—tetras and their allies (characiforms) and catfish (siluriforms)—dominate, together accounting for around 75% of all Amazonian fish species⁸. However, within these groups there is enormous variety, with a wide range of forms, diets and behaviors. There are tiny fishes which barely measure 2 cm, and there are giants that can reach lengths of up to 3 m; there are some fishes that have specialized to feed on microscopic algae, and others that break open hard fruits or hunt large prey.

The community of fishes in the Amazon has the greatest functional diversity of any freshwater community on the planet¹⁴. In other words, Amazonian fishes occupy more niches and have more varied adaptations than those found anywhere else in the world.

AMAZON AND NUMBERS



of the world's
freshwater fish species



of Amazonian fish
species are endemic

Mass migrations

It's reported that more than 100 species make migrations within the Amazon's freshwater ecosystems, with catfishes and characiforms responsible for most of the journeys¹⁵.

A group of economically and ecologically important fishes—mainly herbivorous and detritivorous species such as tambaqui (*Colossoma macropomum*), red-bellied pacu (*Piaractus brachypomus*), jaraquis (*Semaprochilodus spp.*), curimatās (*Prochilodus spp.*) and matrinxās (*Brycon spp.*)—are thought to use clear- and black-water tributaries as adult feeding and refuge grounds, and then to migrate towards nutrient-rich white waters to spawn in highly productive floodplains^{16–18}.

Other species—such as the goliath catfishes (*Brachyplatystoma spp.*) which perform some of the longest freshwater migrations in the world—are occasionally found in the same clear- and black-water rivers, but prefer the large white-water systems extending from the Andean foothills all the way to the estuary¹⁹.

Giant migrations: the goliath catfishes

The Amazon's so-called 'goliath catfishes'—including species such as *Brachyplatystoma vaillantii* (piramutaba), *Brachyplatystoma rousseauxii* (dourada/gilded catfish) and *Brachyplatystoma filamentosum* (piraiba)—are among the largest freshwater fishes in the world, growing as long as 2.5 m and weighing up to 200 kg²⁰. The huge size of these top predators is matched by the extraordinary migrations some of them undertake over the course of their life cycle. The dourada, for example, is born in the distant western headwaters of the Amazon, spawned at the base of the Andes in Colombia, Ecuador, Peru and Bolivia. Its tiny larvae are carried along on the current for thousands of kilometers until they reach the Amazon estuary in the Atlantic Ocean, where the young fish grows in the nutrient-rich waters. At around two years of age, the dourada begins an incredible odyssey back upriver, swimming immense distances against the current of the Amazon then ascending its tributaries to return to its spawning grounds in the foothills of the Andes²¹ in a journey that can last for 3 years. At the end of this round trip, a single dourada can have traveled more than 11,000 km¹⁹, making this the longest freshwater fish migration ever recorded—it's a truly epic journey, that involves an almost unbelievable degree of endurance and navigation. The piramutaba has a similar life cycle, undertaking roundtrip migrations of more than 6,000 km—although it has not been scientifically confirmed to spawn in the Andes¹⁹.

For centuries, Indigenous fishers recognized these cycles, and seasonal fisheries emerged at strategic points (e.g., narrow channels or rapids) to intercept the migrating catfish^{22,23}. However, most of this specialized fishery no longer exists. Areas such as the stretch from Cachoeira to Teotônio on the Madeira River were once vital fishing grounds where fish congregated—but the construction of two dams on the river has since submerged the landscape and severed the river's connection between the Andes and the Atlantic. These barriers now block the ancient migrations of the dourada, causing stocks to plummet and effectively ending this historic trade in the Madeira River.



Long-distance migratory goliath catfishes: a) *Brachyplatystoma rousseauxii* (dourada); b) *Brachyplatystoma vaillantii* (piramutaba)

© Michael Goulding



Long-distance migratory dourada catch at the Cachoeira do Teotônio of the Madeira River before it was dammed

Ingenious adaptations and endemic wonders

The evolutionary mosaic of Amazonian fishes is filled with remarkable adaptations and fascinating examples of rapid diversification. Isolation in specific habitats, from torrential mountain rapids to tranquil forest pools, has produced many highly specialized creatures that are often found only in those niches. Below, we highlight some groups that exemplify the evolutionary ingenuity and exceptional endemism of the Amazon.

Refined for the rapids: armored catfish

A spectacular case of endemic Amazonian diversification is that of its armored catfish (family Loricariidae). With bony plates covering their bodies and powerful sucker mouths, these fish attach themselves to rocks and wood and scrape algae and detritus for food. Of around 1,100 known species in the family, an impressive 17% of them were described only in the last decade, reflecting how many have remained 'hidden' until recently ²⁴. Although armored catfish inhabit all kinds of freshwater ecosystems in the Amazon, from quiet floodplain lakes to deep river channels, they reach their greatest diversity in rocky rapids and waterfalls. In these demanding habitats, they use their mouth suction cups to anchor themselves to rocks and graze; some use sturdy spoon-shaped teeth to scrape wood or plant matter, while others have sharp, fang-like teeth for extracting snails, insect larvae or crustaceans from crevices. These armored adaptation specialists come in a dizzying variety of sizes, shapes and color patterns, making them favorites of the global ornamental fish trade.

© Ricardo Oliveira

Armored catfish from the Negro River

River gems: dwarf cichlids

The dwarf cichlids of the genus *Apistogramma* are another endemic miracle. These small fish—usually 5–8 cm in length—are rightly famous for their beautiful bright colors and complex behaviors. Around 90 dwarf cichlid species have been described so far for the Amazon, and they are highly endemic, with each large river system usually harboring unique species found nowhere else ²⁵.

Elaborate parental care is a notable feature of many dwarf cichlid species, with females protecting their eggs and fry in caves. Along with their vivid appearance, it's another reason why they are very popular with aquarium enthusiasts.



Dwarf cichlids of the genus *Apistogramma* are key components of Amazonian freshwater biodiversity

© iStock

Seemingly the same—but different: corydoras

There are more than 100 species of highly endemic armored catfish from the subfamily Corydoradinae in the Amazon ²⁶, and many are visually striking, with patterns of spots, stripes or eye bars that resemble masks. Surprisingly, some of these species have developed almost identical color patterns and often feed together, forming mixed groups which all share the same predators warning signal ²⁷. Such mimicry is unusual in freshwater ecosystems, making Amazonian corydoras an intriguing example of evolutionary innovation. The phenomenon also reinforces small-scale endemism, where each tributary may harbor distinct corydoras communities, some with unique relationships between species not observed elsewhere.



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These two corydoras species share the same color pattern but belong to different genera. a) *Hoplisoma araguaiaensis*, b) *Brochis* sp

Masters of disguise: Amazon leaf fish

Mimicking another species of fish is impressive, but *Monocirrhus polyacanthus*, the Amazon leaf fish, achieves something even more extraordinary: in keeping with its name, its flattened body and mottled brown coloration perfectly mimic the veins and texture of a dead leaf. To complete the illusion, this fish drifts head-down, swaying gently with the current as if it were decaying plant matter. But the disguise is a sophisticated predatory tactic. The leaf fish possesses a specialized jaw that it can shoot forward to form a funnel, generating a powerful suction which can engulf prey in milliseconds. In the wild, unsuspecting small fish—such as *Nannostomus unifasciatus* (pencilfish)—swim among fallen leaves only to suddenly vanish into the void; a stark reminder that in these flooded forests, perfect camouflage can be the ultimate weapon of the predator.

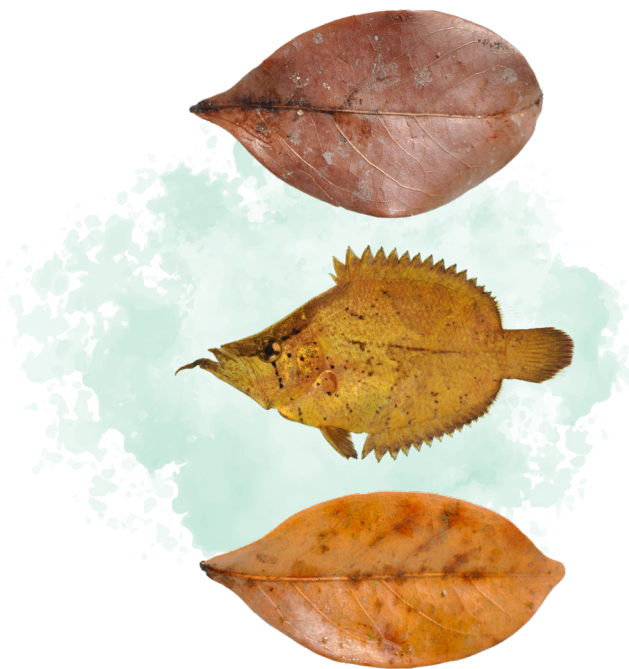
Icons of the Amazon: from mythical giants to tiny treasures

From air-breathing giants to bright sparkling neon tetras, Amazonian waters teem with life at all scales—and are home to some of the world's most iconic freshwater species.

Colossal inhabitant of the floodplains: pirarucu

Arapaima gigas—also known as pirarucu, arapaima or paiche—is an Amazonian legend that can reach a length of up to 3 meters and weigh 200 kg²⁸. Unusually for a fish, the pirarucu must surface periodically to breathe air or it will drown. Needing to breathe at the surface made this giant of the Amazon floodplains particularly vulnerable to overfishing: during the 19th and 20th centuries, fishers waited to harpoon it as it came up for air, their relentless efforts bringing the species to the brink of extinction in many areas. Fortunately, conservation measures were put in place in time to save the endangered giants. Strict fishing moratoriums, the creation of protected reserves, and innovative community management arrangements allowed pirarucu populations to recover in some areas²⁹. Instead of being harpooned by hunters, pirarucu are now counted by local fishers when they come up to swallow air, turning what was once their Achilles heel into a cornerstone of their conservation. The resurgence of this iconic fish is not only an ecological success but also a cultural one, as pirarucu meat—mild in flavor and almost boneless—is a highly prized traditional food. Today, the pirarucu shows that even the largest and most vulnerable species can be saved through intelligent management.

Not all Amazonian giants are predators. *Colossoma macropomum*, also known as tambaqui, is a large characin (related to



Amazonian leaf fish *Monocirrhus polyacanthus* mimicking fallen leaves

© Mark Sabaj



Pirarucu captured using a traditional harpoon in the Brazilian Amazon

piranhas) that can weigh 30 to 40 kg and reach about one meter in length. What makes this gentle giant iconic is its diet: it is perhaps the largest consumer of fruits and seeds among all the fish in the world. During the flood season, tambaqui spread out to forage through the flooded forest and use their powerful jaws and molar teeth to crush the hard seeds and fruits that fall from the treetops. Sustained by the trees, the tambaqui in turn play an essential role in dispersing their seeds around the flooded plains.

Jewels of the Amazon: cardinals, neons and discus

At the opposite end of the size spectrum, small Amazonian ornamental fish have achieved worldwide fame for their beauty. The tea-colored streams of the Negro River are home to schools of *Paracheirodon axelrodi*, the cardinal tetra, a tiny fish barely 3 cm long with a neon blue stripe on a bright red body. Along with its close cousin *P. innesi*, the neon tetra, these iridescent jewels are among the most popular aquarium fish in the world. Every year, tens of

millions of cardinals and neons are caught in Amazonian rivers (mainly in Brazil and Colombia) and exported to supply the international aquarium trade. Another iconic ornamental fish, *Symphysodon* spp. (discus), are larger (15–20 cm) and laterally compressed into a disc shape, hence their common name. Known by some as the kings of the aquarium, discus can fetch high prices on the global market.



Acará discus (*Symphysodon* spp.)

© Ricardo Oliveira



Cardinal tetra (*Paracheirodon axelrodi*) from the Negro River

© Hans Evers

Frightening and fascinating creatures

Among the wide variety of Amazonian fish, some have earned a fearsome reputation. From electric predators capable of stunning large animals to parasitic catfish that have inspired disturbing legends, these species display extraordinary adaptations—and add to the mystery of the Amazon.

Shocking predators: electric eels

Electrophorus spp.—electric eels—are notorious for the powerful electric shocks they deliver. One of the species, *Electrophorus voltai*, can discharge up to 860 volts, the highest bioelectric power recorded in any animal³⁰. Electric eels use their high voltage in attack and defense alike, both to subdue prey and to protect themselves from threats. Researchers recently discovered that electric eels sometimes hunt in groups to catch schools of small fish, generating shocks in unison to stun all their prey at once³¹. This behavior suggests

an unexpected level of social coordination in these animals, which were believed to be solitary. Although their electric shocks are rarely fatal to humans, they can nevertheless cause serious injuries, and there are cases of people who have drowned after being stunned by eels. It is not surprising that electric eels are feared and respected by local populations across the Amazon.



Electric eel (*Electrophorus voltai*), capable of generating powerful electric discharges

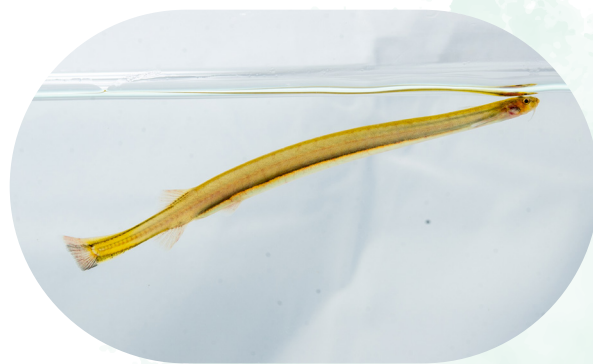
© Douglas Bastos



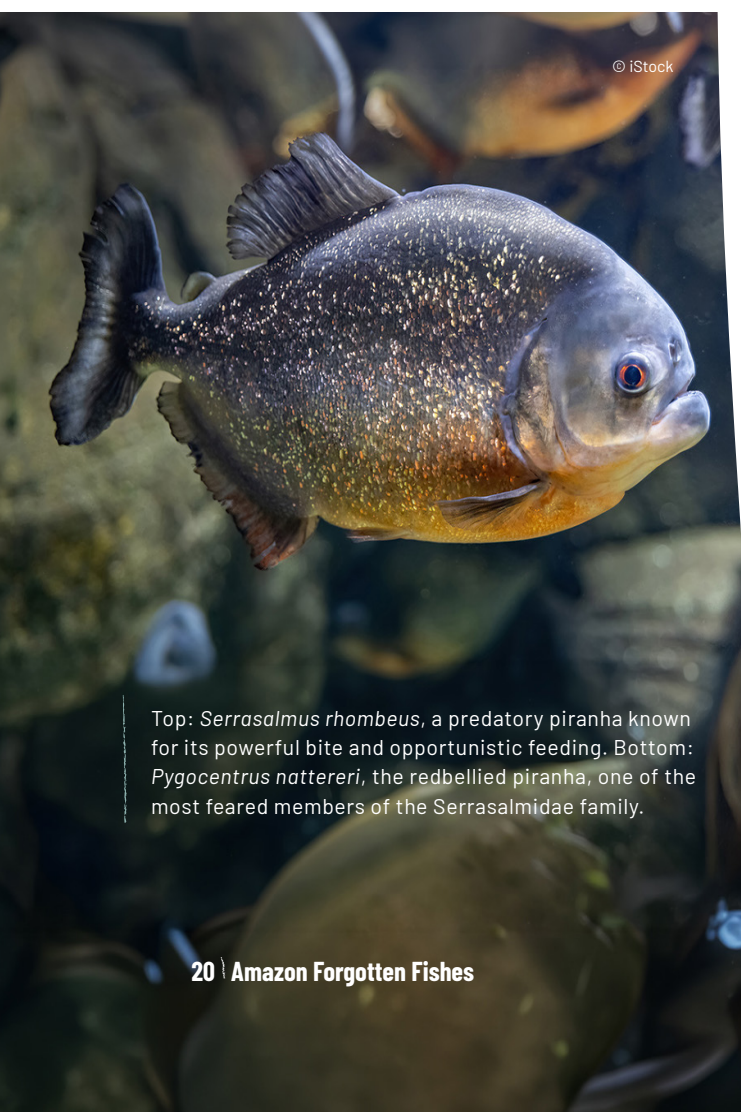
Tiny vampires: candiru

In stark contrast to the large and striking electric eel, the candiru is a tiny, almost transparent catfish that has nevertheless inspired outsized amounts of fear. ‘Candiru’ generally refers to several species of the genus *Vandellia* (family Trichomycteridae), which are parasitic fish known to feed on blood. They are usually only a few centimeters long and have a slender, eel-like body. In their normal ecological role, candiru invades the gill chamber of larger fish when they are feeding: they follow the water flow to the host’s gills, anchor themselves with small spines at the sides of the head, and feed on the gill filaments to drink blood, a vampiric lifestyle that goes unnoticed by humans. But it’s for stories of their attacks on humans that candiru became part of Amazonian folklore. According to these accounts, a candiru can mistake a human orifice for a fish’s gill opening, and make its way into the body

of an unsuspecting swimmer (for example, swimming into the urethra or the vagina—as is widely believed to occur in the Amazon). Once inside, the fish erects its head spines causing excruciating pain and bleeding (and a possible later infection). However, such cases seem to be extremely rare, and many reports are anecdotal or unverified. In reality, humans are not natural hosts for candiru, and any such incidents are likely accidental. Still, the fear of candiru remains very real in local cultures and is often enough to deter people from entering certain waters naked.



Candiru (*Vandellia* spp.), a small parasitic catfish that feeds on blood.



Top: *Serrasalmus rhombeus*, a predatory piranha known for its powerful bite and opportunistic feeding. Bottom: *Pygocentrus nattereri*, the redbellied piranha, one of the most feared members of the Serrasalminae family.

Celebrity carnivores: piranhas and family

Piranhas and their relatives (family Serrasalminae) loom large in humanity's collective imagination. They tend to be depicted in popular culture as voracious carnivorous predators, thanks in part to a series of films released since the 1970s which parody the famous *Jaws*. Although folklore often portrays piranhas as deadly to humans, there have been no confirmed cases of fatal attacks. Investigations of fatalities in which victims were found with piranha bite marks suggest that drowning likely occurred first, before the piranhas moved in. In practice, piranhas are more dangerous out of the water than in it, with most human bites occurring during handling by fishers removing them from nets or hooks. Perhaps surprisingly, in addition to well-known piranhas such as *Pygocentrus nattereri* (the red-bellied piranha), the family also includes species with entirely different feeding behaviors. In fact, piranhas are essentially carnivorous pacus, which feed on fruits and plant material, but also on insects and occasionally on scales and fins. Additionally, the large tambaqui belongs to the family and, along with other large serrasalmins, contributes to ecosystem services such as seed dispersal. For this reason, some members of the family—particularly pacu species from rapid habitats in the genus *Tomates*—have gained attention on social media as 'vegetarian piranhas,' as they feed almost exclusively on plants growing on rocks in fast-flowing waters.

A sting in the tail: *Potamotrygonidae*

The Amazon is home to a family of stingrays that are fully adapted to complete their life cycles in freshwater environments: *Potamotrygonidae*. The colorful disc patterns of these diverse cartilaginous fishes makes them highly valued in the ornamental trade, but they're also widely feared for the barbed stings they have on their tails. Species are bottom-dwellers, often partially or completely hiding in the substrate of the region's rivers and

lakes. These fishes do not attack people: their powerful sting is simply a defense mechanism for when unwary waders in the water happen to nudge against or step on them. Nevertheless, the wounds they inflict are extremely painful, and secondary bacterial infection often follows. Despite having a key role in aquatic habitats, many freshwater stingray species are threatened by habitat degradation and loss, unregulated capture for consumption or the ornamental fish trade, and harmful fishing practices³².

Hidden diversity: rare and enigmatic fishes

In this region studied by naturalists for centuries, new species—and even new families—of fish continue to be discovered, sometimes in unexpected places. A striking example is *Tarumania walkerae*, a fish so unique that researchers created an entirely new family (*Tarumaniidae*) to classify it as recently as 2017. *Tarumania* is a medium-sized (15 cm) predatory fish that spends most of its life

hidden among the tangle of fallen plant matter at the bottom of shallow isolated ponds in the forest. It has an elongated, eel-like body that allows it to slip between submerged leaves. During the dry season—when forest ponds can dry up completely—it is thought that *Tarumania* survives by burrowing into the wet debris or mud and entering a state of lethargy (known as ‘estivation’) until the rains return. This unique fish eluded discovery until very recently in an area near Manaus, one of the largest cities in the Amazon.



Potamotrygon sp. from Middle Negro River



© Douglas Bastos



© Patricia Charvet

Stingray tail highlighting the serrated stingers



Tarumania walkerae, a hidden Amazonian specialist revealed to science only in 2017.

©Douglas Bastos

Another intriguing example are tiny underground catfish, which have rarely been seen and remain enigmatic. One of them is the blind, worm-like *Phreatobius cisternarum*, only a few centimeters long, which was discovered living in hand-dug wells around Belém do Pará. It inhabits waterlogged underground layers, and its range may be much wider than we suppose based on the limited number of recorded occurrences. *Tarumania* and *Phreatobius cisternarum* push the boundaries of what we consider fish habitat, as they live in darkness beneath the forest floor.

Our knowledge of Amazonian fish is still far from complete. With each expedition and each application of modern tools (such as environmental DNA and hydroacoustics), researchers continue to find species new to science or unmask cryptic species that disguise themselves as other known species. But this hidden diversity comes with an important warning: many of these rare fish may be vulnerable to environmental changes or human

impact even before we fully know them. It also comes with a sense of wonder, reminding us that the Amazon, often called 'the last frontier of biodiversity', still holds mysteries to be discovered in its waters.

Protecting this aquatic realm is not only about safeguarding what we know, but also what we do not yet know. By preserving the integrity of Amazonian ecosystems and respecting the knowledge of those who have cared for them for centuries, we can ensure that the story of Amazonian fish, a story that is still being written, continues for generations to come.

"Forgotten" fish: an Indigenous perspective

The importance of the Amazon is not only biological, but also cultural. The region is home to incredible human diversity: according to the Coordinator of Indigenous Organizations of the Amazon River Basin³³, there are at least 511 Indigenous Peoples throughout the basin, with 88 groups living in voluntary isolation or initial contact. This cultural diversity is closely linked to linguistic diversity. In Brazil alone, an estimated 495 Indigenous Amazonian languages existed at the beginning of the 16th century—although 265 of these have since become extinct. Today 27 Amazonian languages



© Andre Dib

are considered fully alive, spoken fluently by communities with more than 5,000 speakers³⁴.

These Indigenous nations possess rich knowledge systems that are intertwined with the natural world. Here, freshwater ecosystems are fundamental to life: many communities refer to themselves as “water peoples”, with villages established along rivers and lakes for sustenance and transportation. Fish has always played a major role in the diet of these societies. However, the consumption of fish and other forest animals is governed by complex cultural and spiritual norms. Not all species are considered edible, and even edible fish are not for everyone, nor are they permitted at all times. Traditional knowledge includes food taboos that depend on factors such as a person’s health, stage of life (e.g., pregnancy or childhood), and spiritual considerations. Elders and shamans enforce these norms, as they understand that food can affect not only physical health, but also mental well-being, spiritual balance and even intellectual development.

Indigenous narratives throughout the Amazon often highlight the role of small, underfished species that Western science has overlooked. These species with little or no commercial value that scientists and governments tend to ignore are nevertheless remembered and protected by Indigenous communities through oral tradition and management.

Handing knowledge down through the generations is crucial for conservation: elders and fishers pass on the names, stories and ecological knowledge about each fish to their sons and daughters. This knowledge is holistic, acquired through lifetimes of observation, practice and spiritual connection with the environment. According to the Indigenous view, if an elder who possesses knowledge dies without passing on their teachings, a great deal of information may disappear; the knowledge “dies” with that person. This reveals a vulnerability and makes it imperative to protect Indigenous cultures and their oral traditions to preserve the full breadth of knowledge about biodiversity.

When it comes to conserving the “forgotten fishes” of the Amazon, on the one hand there are scientists who are concerned that many fish species have not been sufficiently studied and could become extinct before they are even described. On the other hand, however, there has always been the Indigenous perspective, which maintains that the only way to truly preserve all fish is to protect Indigenous Peoples and their territories. In other words, biocultural conservation is key: safeguarding the cultural practices, traditional ecological knowledge and territorial rights of Indigenous Peoples is synonymous with protecting the fish and freshwater ecosystems on which we all depend.

No creature is “forgotten” in Indigenous cosmology

According to Fany Kuiru, within the worldview and narrative of the Uitoto people and others, no being of nature should be forgotten; on the contrary, the wholeness of nature and culture means that every being of the forest is recognized, named and cared for. In the “yadiko” ceremonies (traditional Uitoto dance), the creation of nature is narrated according to its importance and size; in this praise of life, the naming begins with the smallest being through to the largest, and the territory is recreated, reborn and healed. This narrative is part of territorial ordering from ancestral times, and there, fish—whether edible or not—occupy a privileged place in the well-being and survival of the clans and the territory.

Fany Kuiru, Uitoto de la Chorrera, Amazonas, Colombia





**"No being of nature
should be forgotten"**

Fany Kuiru



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In the Amazon, fish, forests and people are intimately interconnected. Fish feed millions, sustain cultural identity and support local economies, while simultaneously shaping ecosystems by transporting nutrients, dispersing seeds and regenerating flooded forests. This deep ecological and cultural interdependence makes Amazonian fishes indispensable—not only for biodiversity and ecosystems, but also for the survival, wellbeing and cultural continuity of the basin's communities.

The ecological importance of fish

Healthy fish communities play an essential role in the Amazon's freshwater ecosystems, especially its seasonally flooded floodplains (várzeas). Acting as mobile nutrient pumps, fishes regulate primary production and support the stability of the food web. In floodplain forests, diverse fruit-eating species act as seed dispersers, linking aquatic and terrestrial processes and helping the forest to regenerate^{35,36}. In addition as floodwaters rise, insects and other invertebrates climb trees to escape drowning—but rain and wind knock them into the water all the same, where they become protein-rich meals for fish³⁷. In this way, fishes transfer energy and nutrients between terrestrial and aquatic ecosystems, playing an integral role in the productivity of the Amazon.

Healthy fish stocks are equally critical for predators higher up the food chain. As well as holding the world's greatest diversity of freshwater fish, the Amazon Basin also plays host to the highest global richness of freshwater megafauna—defined as vertebrates with a body mass ≥ 30 kg. The Amazon is home to 35 species of these giant fishes, mammals and reptiles³⁸, which help control other species and keep nutrients moving through the ecosystem. Notably, Amazon river dolphins—*Inia geoffrensis* (boto) and *Sotalia fluviatilis* (tucuxi)—rely primarily on fish as prey; while otters provide complementary top-down control. *Lontra longicaudis* (lontra/neotropical otter) mostly eats fish, although its diet varies with habitat and prey availability, while *Pteronura brasiliensis* (ariranha/giant otter) is an almost exclusively fish-eating cooperative hunter.^{39–42}



Amazon river dolphin (*Inia geoffrensis*), an iconic yet threatened species of South America's freshwater ecosystems.

© naturepl.com / Franco Banfi / WWF



The giant otter (*Pteronura brasiliensis*) in the Cristalino River (Tapajós Basin), a top predator and indicator of healthy Amazonian freshwater ecosystems.

©Marcos Amend

Reductions in biomass, size structure or diversity in fish populations can trigger cascading changes in the wider environment, dampening nutrient recycling, weakening cross-ecosystem linkages (e.g., seed dispersal) and limiting prey for apex predators such as river dolphins, giant otters and fish-eating birds. Conversely, conserving fish stocks and floodplain habitats boosts ecosystem functions like productivity, regeneration and pest control, as well as supporting predators, helping to sustain the wonderfully wide web of life found in Amazonian freshwater landscapes ^{35,36,40}.

Forest-fish interdependence: Ecological architects of the Amazon

When the tambaqui and many other fishes migrate into seasonally flooded forests to feed on fallen fruits, they spread seeds across



vast areas, helping to regenerate the forest⁴³. Given the enormous variability in size, shape and nutritional composition of the fruits these watery forests contain, floodplains with more extensive flooded forests and diverse tree species support a greater number of fruit-eating fish species, demonstrating the interdependence of forests and fish in Amazonia⁴⁴.



A kingfisher (top) and snakebird (bottom) with their catches, highlighting the links between riparian birds and the rich fish communities of Amazonian freshwater ecosystems.

© Marcos Amend

These fruit-eating fish are also significant targets for fisheries. Medium-sized species such as palometas, sabalos, sabaletas and sardinhas (genus *Myleus*, *Myloplus*, *Brycon* and *Triportheus*) are abundant in floodplain forests and are an integral part of the diets of local people. Commercial fisheries have historically tended to be directed towards larger species like tambaqui and red-bellied pacu, and this has contributed to their local extinction in many places across the Amazon⁴⁵. Deforestation makes the problem worse by reducing fruit availability and disrupting spawning cycles. Protecting flagship species like tambaqui needs therefore a dual conservation strategy, which also includes preserving the forests they help sustain.



Tambaqui (*Colossoma macropomum*), a famous Amazonian fruiteater that helps connect flooded forests and rivers through seed dispersal

Did you know?

A scientific analysis suggested that the biomass of tambaqui supported by floodplain fruits could have a greater economic value than could be obtained by cutting the same forest for timber. In other words, having a healthy population of fruit-eating fish can be worth more year after year as a renewable food and income source than the one-time harvest of the wood from their habitat⁴⁶.

Feeding millions: Fishes as pillars of food security and local economies

Amazonian fishes are not only ecological keystones—they are also dietary staples. In some remote riverine communities, fish consumption exceeds 600 grams per person per day^{47,48}. Even in inland urban centers like Iquitos, Peru, people eat an average of 130 grams per day⁴⁹. Consumption patterns vary by geography and seasonal hydrological cycles: lowland areas and dry-season periods generally see the highest intakes^{50,51}.

Fish provide essential nutrients such as iron, zinc, omega-3 fatty acids and vitamins, making them a critical source of animal protein⁵². The sheer diversity of fish species consumed in the Amazon—more than 200 are commonly reported⁵³, further increases their nutritional contribution. Different species offer different nutrient profiles, so biodiversity in diets translates into better health⁵². For low-income households especially, fish are among the most affordable and reliable animal-source foods. Moreover, this vital protein source bears a minimal environmental burden. Inland capture fisheries are recognized for their extremely low greenhouse gas emissions compared to other animal proteins, as they typically utilize low-energy, small-scale gear and serve local markets⁵⁴.

Economically, fisheries support millions of livelihoods. From fishers and processors to traders and market vendors, the fish economy is deeply embedded in Amazonian society. The fish trade also connects rural and urban communities, moving along supply chains that reinforce social networks as much as markets. Women play central roles within this economy, not only as fishers, but often as fish sellers, processors and household managers, ensuring that fisheries benefits flow into families and communities⁵⁵.



Fisherwoman and leader of a local fishing association in Santarém, Pará

Fish as family: Honoring ancestry and cultural memory in Amazonian waters

Fish also provide cultural ecosystem services. For Indigenous Peoples, Afrodescendant peoples and local communities, fishes are more than food and culinary tradition, they are ecologically vital and deeply embedded in their cultural, spiritual and economic lives⁵⁶. Tikuna people, for example, recount how their ancestral hero Yo'i "fished" them from the sacred waters of the Eware creek, symbolizing a kinship bond between people and fish^{57,58}. The Makushi of Guyana, meanwhile, regard the

pirarucu as the "mother and father of the fishes" and the "owner" of floodplain lakes, reflecting both its ecological and spiritual importance⁵⁹.

Rituals, seasonal fishing practices and intergenerational knowledge strengthen communities and link cultural identity with ecological stewardship^{56,60}. Increasingly, these traditions are shaping new conservation-oriented economies. In Guyana, Makushi, Patamona, Wapishana and Wai Wai communities manage pirarucu ecotourism through catch-and-release fly-fishing and fish-watching tours⁶¹. Community-run lodges combine traditional knowledge with sustainable tourism, generating income, strengthening cultural pride, and supporting habitat protection⁶¹. In Colombia, Tikuna youth lead the Painū Ecotourism Project, offering immersive experiences rooted in fishing traditions and storytelling⁶².

Evidence from all over the world conclusively shows that conservation initiatives are more likely to succeed when locals are empowered to look after their own resources⁶³; this is very much the case when it comes to the long-term sustainability of the Amazon's freshwater ecosystems and the resilience of the communities who protect them.



Drawing representing Yo'i fishing the Tikuna people from the waters of the Eware River, in the upper Amazon region. Artist: João do Carmo Ticuna, Museu Magüta, Benjamin Constant, Brazil

Voices from the River: The Mother of the Fish Migration

My grandfather Xanhua, named after a bird, told me about the Mother of the Migration. He said the little fish came upstream Iquitos, following their mother: a great boa. She gathers the small fish along her journey. My grandfather saw her in his ayahuasca visions. The boa, Ronin, spoke to him and said she would stay in the Sempaya pool of the Ucayali River for 20 days.

After 20 days, the boa visited my grandfather again in a vision and said she was heading to the Tambo and Urubamba Rivers, and then she said goodbye. When she left, the school disappeared from Sempaya. In all the places where the boa stayed, there was a lot of fish. They say the boa cages the fish and carries them either upstream or downstream. During the migration season, the boa would come from afar and tell my grandfather where she would be and how long she would stay.

That's how my grandfather knew it was migration time. The migration doesn't come for no reason—it has a mother. She brings all the small fish together and takes them away when she leaves the pools. Sadly, the Sempaya River changed course, and maybe now there is no mother, or she has gone elsewhere.

Belisario Carrera, Shahuaya Community, Ucayali River, Peru

Voices from the River: The pride of being a commercial fisherwoman

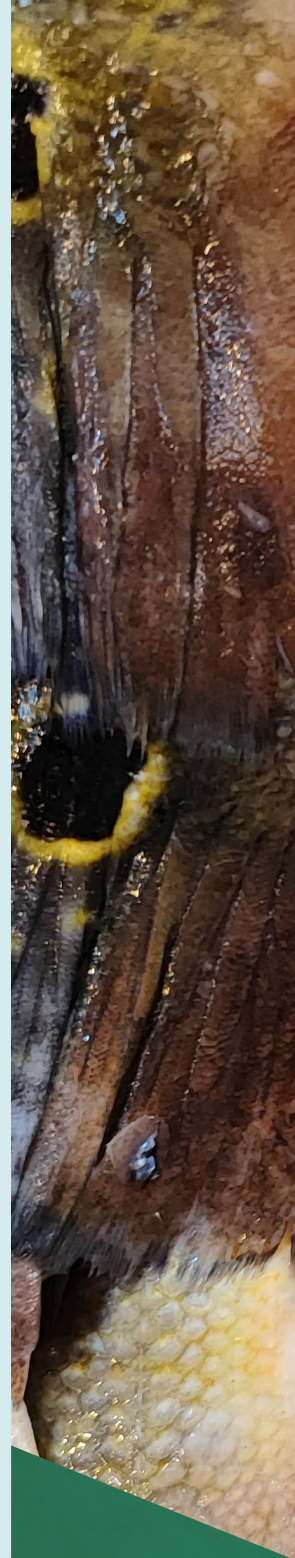
I am Rubí Cahuachi, from the Yagua people in Loreto, Peru. I'm 48 years old, and I started fishing 20 years ago when Héctor, my partner, taught me. He taught me everything I know about fishing—how to use nets and “puiteras,” how to recognize the spawning season, how to choose a good spot. But what I remember most is that he taught me the best time to fish and the best places to set the trap.

Fishing is better at night than during the day—from 6 p.m. to midnight, the fish go wild and come out to roam. They head to places where the “huayo” fruits fall. They love eating seeds and fruits, and those are the best places to fish. The spawning season is in September, when waters are low and fish pour out of all the creeks and lagoons—it's a great time for commercial fishers.

In my family, fishing is a team effort. We help each other: my partner sets the trap, I paddle; then I tighten the net, and he paddles. Other women don't fish, especially when they're menstruating, because they're afraid of the “buefo” [river dolphin]. Even men are afraid of it. But I'm not afraid, because I always fish with my husband. He smokes his tobacco so the buefo won't follow him and everything goes well without danger.

I'm proud to be a commercial fisherwoman alongside my partner because I contribute to my family's economy. I also go to Iquitos to sell my catch, and I'm the only one who manages my little bit of money. That's how I move forward as a woman.

Rubí Cahuachi, Yagua people, Loreto, Peru



IRREPLACEABLE AND INVISIBLE FRESHWATER FISHERIES

Official records capture only part of the Amazon's vast inland fisheries, a system sustained largely by artisanal, small-scale and subsistence fishers whose catches rarely appear in statistics. Even the most conservative estimates show that at least 200 species are commercially harvested. In reality, Amazonian catches are far larger and far more diverse, involving hundreds of species and supporting millions of people.

There are a variety of forms of fishing across the Amazon, each with distinct purposes, techniques and levels of organization. Subsistence fishing—conducted at a small scale using artisanal gears—is the most widespread, with fishers keeping the bulk of the catches for their own households (although small surpluses are sometimes exchanged or sold locally).

Artisanal fishing for commercial purposes supplies local and regional markets, and

often targets species in high demand that are also harder to catch, such as large catfishes. Artisanal fishers use methods that are mostly manual and limited in scale, including gillnets and seine nets, and often still rely on traditional ecological knowledge.

Sport fishing is a growing activity, particularly in areas connected to tourism. It generally follows a catch-and-release model and is conducted mainly by relatively wealthy visitors.

Ornamental fishing—targeting small and visually striking species for the aquarium trade—takes place across the basin, but updated and systematic information on its extent is lacking in most countries.

The Amazon's commercial fishery is notable for the size of its fish, the volume of its production, and the diversity of species caught. It also plays a prominent role in the regional economy, supporting a fishing fleet that ranges from small

Fisher casting net on river in the Amazon basin, Acre, Brazil



© Haroldo Palo Jr.

canoes to boats that can carry up to 80 tons of fish, and the hundreds of facilities that receive its production, including fish processing plants and port facilities along the main rivers⁶⁴. The annual value generated by migratory species in local, regional and international markets is more than US\$470 million⁶⁵.

Despite the importance of Amazonian fisheries, however, there is still considerable uncertainty over the size of the catches and the full range of species it includes. Estimates of annual catches during the 1980s and 1990s vary widely depending on the methodology used, ranging from 173,000 to 575,000 tons^{50,64,66}. Recent Brazilian catch statistics reflect this issue: they reported an average annual production of 575,000 tons in 2023 and 2024 for the Amazon states⁶⁷, numbers that are comparable to previous figures for the entire basin. What is more, thousands of arapaima harvested annually from community led management are

not included in official statistics⁶⁸, revealing persistent gaps in fisheries monitoring.

Estimates of the numbers of fish species caught in Amazonian fisheries are proportional to the basin's vast size and have increased as scientific knowledge has expanded. If we consider only the fishes that are traded in the major Amazonian ports, a conservative estimate would be that at least 200 species are exploited for food⁵³. However, a significant yet largely undocumented portion of the catch is eaten by local populations and does not make it into these calculations—this includes small species commonly consumed by Indigenous communities.

Tambaquis (*Colossoma macropomum*), highly appreciated Amazonian fish and fishing gear





Fishing landing in Manaus,
Amazonas, Brazil

Regional patterns in Amazon Basin fisheries

Commercial fisheries production in the Amazon Basin is heavily concentrated on just a few species and fishing zones, and there are distinct regional differences in how catches are made up. The most complete—if outdated—landing dataset, covering 66 major Amazonian fishing ports ⁶⁴, shows that a mere 30 fish species account for about 90% of total landings. Within this dataset, only six species—curimatã (*Prochilodus nigricans*), piramutaba (*Brachyplatystoma vaillantii*), jaraqui (*Semaprochilodus* spp.), tambaqui (*Colossoma macropomum*), mapará (*Hypophthalmus* spp.) and dourada (*Brachyplatystoma rousseauxii*)—contribute over half of all fish caught across the Amazon Basin. Since then, species composition in commercial landings has changed, particularly for large bodied migratory species

such as dourada and tambaqui. However, the absence of updated, basin wide analyses makes it difficult to robustly identify which species are currently dominant, or to assess how concentration patterns have evolved over time.

The most productive fishing areas are along the Amazon mainstem and its productive whitewater tributaries and extensive floodplains. The Central Amazon (around Manaus), the Amazon Estuary (near Belém) and Ucayali basin (Western Amazon) are the top-producing regions—see map ⁶⁴. Other important fishing zones include the Tocantins and Purus Rivers. In contrast, clearwater and blackwater systems (e.g., upper Negro, Tapajós) support lower levels of commercial food fish production; for example, the Negro River is far more important for ornamental fisheries than for food fisheries.

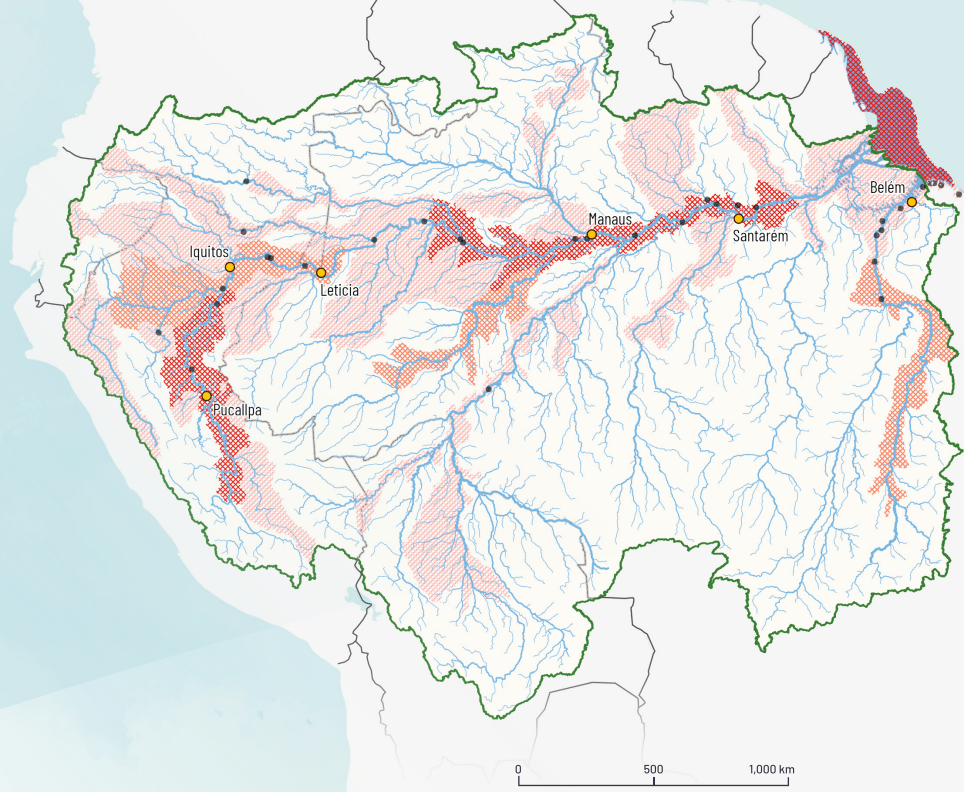
Major Fishing areas

by % total annual production

-  0-3%
-  3-10%
-  >10%

Main Cities

-  Main landing ports and distribution centers
-  Other landing ports



Major fishing areas by total production, principal landing ports, and distribution centers across the Amazon Basin.

Rivers with broad floodplains and flood forests foster large populations of species such as curimatās, jaraquis and tambaqui. As a result, fisheries in these regions tend to catch a higher proportion of scaled fish, and the overall species diversity in landings is higher. In upstream or slope regions with rapid flows and less flooded areas (e.g., Andean piedmont rivers like the headwaters of the Napo, Putumayo, Caquetá and Marañón), migratory catfish have a competitive advantage. These rivers deliver nutrient-rich sediments downstream, but have limited adjacent floodplain habitat. Instead, the river's productivity is often in the main channel, where large catfish migrate to feed and spawn. Fisheries here naturally focus on those catfish runs, often intercepting them during migration—in fact, over 60% of fish landings in upper Amazon areas are comprised of large catfishes⁶⁹.



Curimatās (*Prochilodus nigricans*), abundant detritivorous fish that form the backbone of many Amazonian fisheries.



© Andre Dib

Harpoon fishing targeting pirarucu

Fishers and fishing types in the Amazon region

Except for an industrial fishery for piramutaba in Brazil's Amazon Estuary, nearly all fishing in the basin is artisanal, practiced by riverine populations and Indigenous communities who depend directly on fish for food security, subsistence and income. Fishing is generally a family-based activity, passed down through generations, and deeply embedded in the cultural identity of these communities and their territories.

Amazonian fishers use a wide variety of fishing gear, designed to target specific species under local environmental conditions. At least 15 types of gear are documented across the basin, most of which are traditional and environmentally sustainable⁷⁰. The most commonly used fishing

gears include gillnets, which are adjusted in mesh size to selectively target specific species—these are particularly effective in slow-moving rivers and floodplain lakes—and seine nets made of multifilament nylon, which are deployed to encircle schools of fish in deeper waters and along sandy beaches. Other widely used tools include handlines, longlines, cast nets, harpoons and arrows, as well as traps made from local materials. Indigenous communities often use bows and arrows, spears, or plant-based poisons (e.g., barbasco/ timbó) to stun fish. Cast nets are thrown in shallow areas, while scoop nets and sieves are used for ornamental fish and shrimp. These artisanal techniques are closely tied to seasonal rhythms, allowing fishers to choose the best locations, timing, and gear to maximize their catch.



Principal types of vessels in the Amazon: a) canoes, b) wooden boats, c) industrial trawl boats operating in the Amazon Estuary to target goliath catfishes.

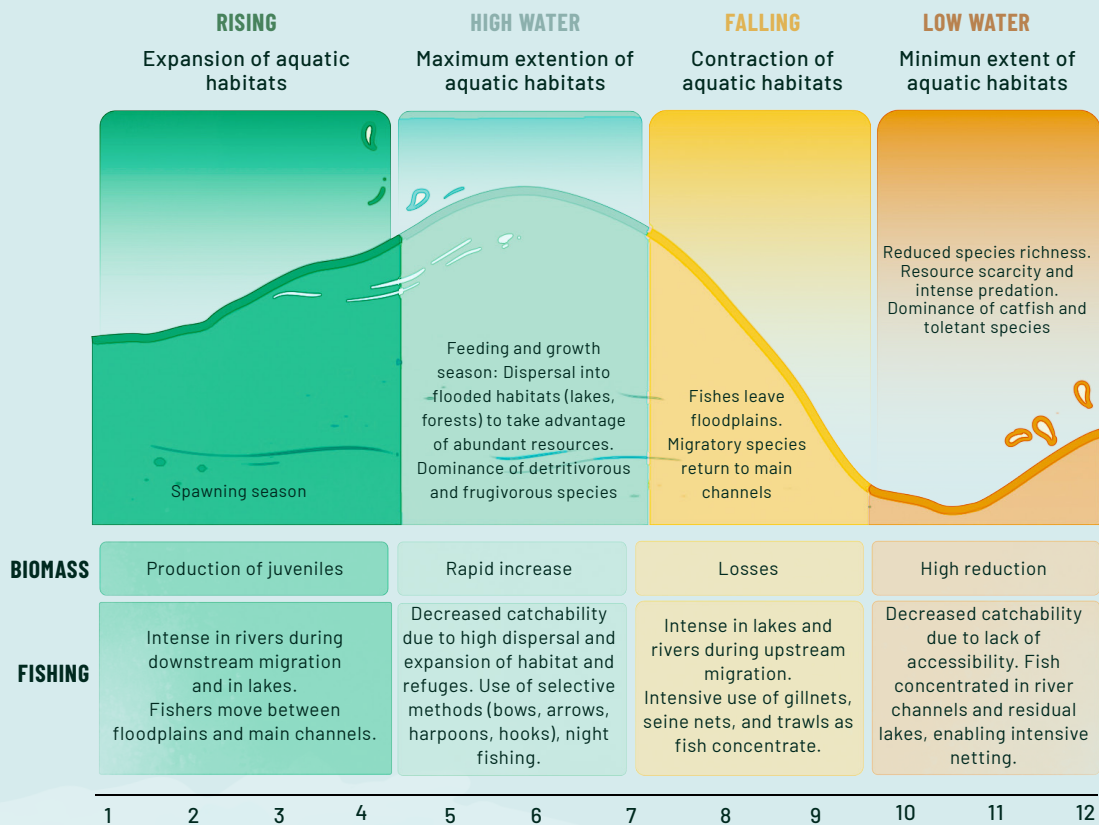
The vessels the fishers use vary widely too, from wooden canoes propelled by paddles or low-powered engines to boats equipped with ice compartments or refrigerated holds that can store several tons of fish. These simple, efficient boats are adapted to river conditions and are essential for getting to fishing grounds and transporting fish, people and gear. Near urban centers like Manaus, Santarém and Iquitos, medium-sized boats with outboard or inboard motors make multi-day trips to deliver fish to markets. In the Amazon Estuary, an industrial fleet operates iron-hulled boats equipped with GPS, sonar and bottom trawls, targeting large migratory catfish and shrimp.

Hydrological cycles and fishing effort

There are significant variations in the numbers and types of fish found across Amazon floodplains as hydrological cycles change with the seasons. During high-water periods, fish disperse into flooded habitats, making the most of the abundant resources in the flooded forest around lakes and rivers. This phase—when floodplain

connectivity is greatest—favors species that eat fruit and detritus. As water levels decline, habitats contract and the fishes in them become less diverse, with a higher proportion of migratory species adapted to main-channel environments. In low-water conditions, biomass and species richness drop significantly, with the remaining fish populations dominated by large catfish and other species which can tolerate restricted habitats⁷¹.

The annual high and low water cycles of Amazonian rivers directly influence the locations, timings and techniques used by local fishers, who move between floodplains and the main channels of rivers and lakes depending on water levels. During high water fish disperse, making them harder to catch. Fishers switch to selective methods like bows and arrows, harpoons and hooks, often fishing at night with flashlights. During low water fish come together in river channels and residual lakes, which enables fishers to make more intensive use of gillnets, seine nets and trawls⁵³.



Relationship between the hydrological cycle (water level), seasonal floodplain dynamics, and their impacts on fish biomass and fisheries. This figure is based on the central Amazon region— the months of the year may vary depending on the river basin. Adapted from⁷².

Where do Amazonian catches end up?

Inland fisheries catches in Brazil, Peru and Colombia³ are distributed through key urban hubs that connect dispersed fishing communities with consumer markets, although most of the catch stays within the region—in the Brazilian Amazon it's estimated that 60 to 70% of fish are consumed locally⁷³. Manaus and Santarém are Brazil's main landing ports, respectively receiving 22,000 to 25,000 and ~5,000 tons annually^{74,75}. Manaus handles mostly scaled fish like jaraqui and tambaqui from the middle Amazon and tributaries like the Purus and Madeira; while Santarém's catch comes from floodplain lakes and tributaries (the Tapajós and Trombetas Rivers etc.) and comprises a mix of species: abundant small catfish like mapará, along with jaraqui, curimatã, tucunaré and some large catfish (surubim, piraíba). Belém functions as Brazil's export center, processing around 47,000 tons each year, with Amazonian species like piramutaba and dourada making up 75% of the catch⁷⁶. Belém's large processors and the iconic Ver-o-Peso market handle the business. Much of this fish is destined for markets far beyond the Amazon, shipped to cities across Brazil and exported to Europe, Asia and the United States.

³ For other countries in the basin, information is either unavailable or spread across multiple institutions, making it difficult to trace supply chains.



Piramutabas sold at the Ver-o-Peso Market, a major distribution hub for catches from the Amazon Estuary and the Lower Amazon.

© WCS / Arthur Menescal

In Peru, the regions of Loreto and Ucayali contribute about 90% of Amazonian fish production, landing around 12,000 and 5,000 tons each year^{77,78}. The primary distribution centers are Iquitos (Loreto) and Pucallpa (Ucayali)⁷⁹. Iquitos receives nearly half of its fish via vessels carrying passengers and cargo from remote communities⁷⁸, with the main species including curimatã, pacu and mapará. The flow of fisheries products in the Peruvian Amazon is largely regional: Iquitos supplies the surrounding region and sends fish to smaller Loreto towns (e.g., Yurimaguas, Santa Rosa) by river. Pucallpa likewise supplies the Ucayali region and ships some catch overland to Huánuco and Lima via the central highway. Internationally, Iquitos's fish merchants report exports of about 35 Amazon species to Leticia, Colombia and at least 6 species (including pirarucu) to Tokyo, Japan⁷⁹.

In Colombia's Amazon region, fisheries distribution is heavily centered on Leticia, a tri-border town on the Amazon River. Leticia is effectively the sole major fish landing and trading hub for the Colombian Amazon, and it also receives catches from nearby Peruvian

and Brazilian waters. Annual landings are in the order of 6,000 tons⁶⁹. The vast majority of the catch is shipped out of the Amazon region to major cities like Bogotá, Medellín, Cali, Villavicencio and Bucaramanga⁶⁹. Leticia's airport is crucial—iced fish boxes are flown out daily, ensuring that fresh Amazon fish can reach markets over 1,000 km away.

Of course, official statistics often underestimate true catches because so much fish is sold outside of formal channels⁶⁷. Nonetheless, the available data and studies from a range of independent initiatives still give a clear outline of where fish caught in the Amazon region end up: predominantly they land on the plates of Amazonian residents, and secondarily they reach a wide range of more distant consumers via a handful of key port cities that connect the rainforest to the rest of the world.

Monitoring: A challenging prospect

It's challenging to systematically monitor fisheries in the Amazon, given the region's vast area, widespread logistical barriers and

limited institutional capacity⁸⁰. Freshwater fisheries are often located in remote areas, frequently without defined landing sites, and involve a large and diverse population of small-scale fishers. Catch volumes and the species involved vary with the seasons, and since much of the production is destined for domestic consumption rather than formal markets, monitoring and assessment are particularly complicated.

In Brazil, governmental programs have produced historical datasets, although these often have gaps in continuity and have lacked sufficient financial resources. There have however been recent efforts to rebuild the national fisheries database through partnerships with regional researchers and institutions, to support management decisions. Related projects have introduced standardized monitoring approaches in various Amazon sites and have explored effective approaches to take in data-limited fisheries^{81,82}. Citizen science initiatives are also underway, expanding data coverage and community engagement alike⁸³.

In Peru, fisheries monitoring is carried out by both national and regional institutions. The national marine research agency (IMARPE) conducts systematic surveys at landing sites and markets, collecting biological and effort data to inform adaptive management measures. In parallel, regional production directorates (DIREPROs) are responsible for fisheries monitoring at the subnational level, although these programs vary in scope and capacity, and often lack resources and coordination. Community-based monitoring and citizen science initiatives have emerged in remote tributaries, contributing valuable data and fostering local stewardship.

In Colombia, fisheries monitoring in the Amazon

is anchored by a centralized national statistical program that conducts daily census-style data collection at key landing sites. However, while this monitoring program provides standardized data, it covers only a limited portion of the basin. To complement official efforts, community-driven monitoring initiatives have been developed in more far-flung areas, using digital and offline tools to record catch data.

In other countries of the basin, monitoring efforts remain weak, and comprehensive datasets are largely absent.

Although citizen science is not yet integrated into governmental programs and decision-making in all Amazonian countries, it provides important information—especially on subsistence fisheries that are often invisible in official statistics. Multiple examples across Brazil, Peru and Colombia are showing that these initiatives help reveal fishing practices and ecological trends that would otherwise remain undocumented, offering valuable insights for future conservation and management strategies⁸⁴.

Strengthening fisheries monitoring through coordinated efforts among governments, research institutions, civil society and local communities offers a strategic opportunity to promote shared management and conservation. Reliable data are not only the foundation of effective regulation but are also an essential thread that links scientific knowledge, policy action, and the lived realities of millions of people. Furthermore, sustained monitoring is vital for diagnosing and mitigating the compounding effects of habitat fragmentation, pollution, and overfishing—critical threats that will be examined in depth in the following sections.



Why community-led fisheries management matters in the Amazon

Over the last five decades, local communities across the Amazon have taken the lead in managing their fisheries, demonstrating that conservation and community well-being can go hand in hand. At least 155 fisheries management initiatives covering nearly 13 million hectares have been identified in Brazil, Peru, Bolivia and Colombia. These efforts—many of which focus on the pirarucu—involve over 1,200 communities and more than 21,000 fishers⁸⁴.

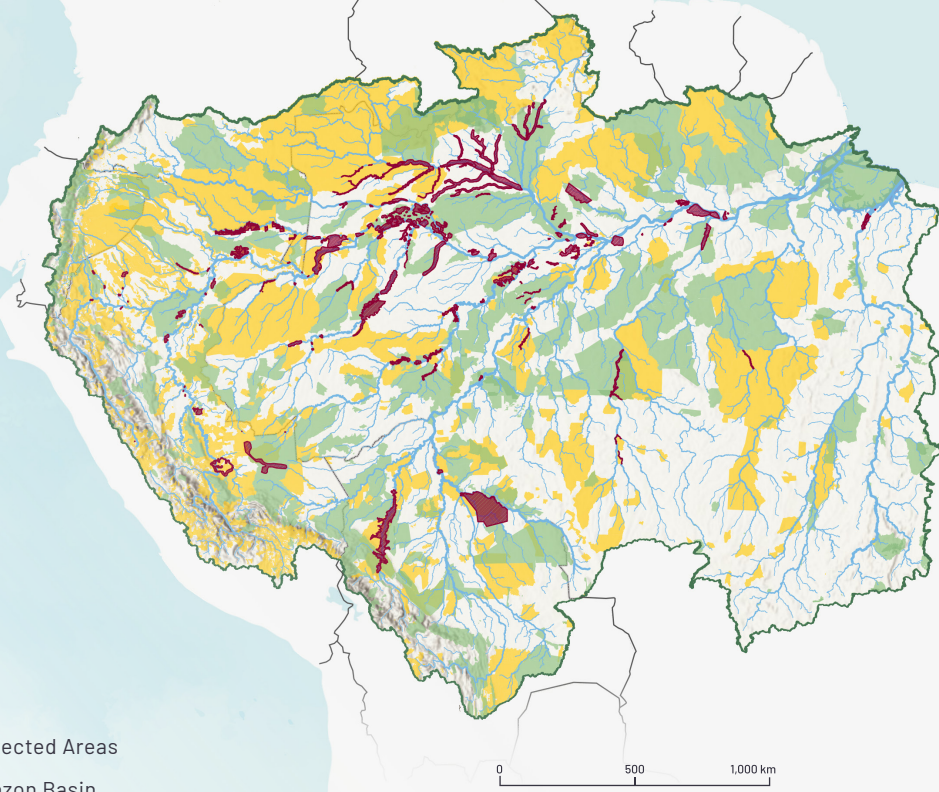
Notably, about a third (34%) of these management areas overlap with protected areas such as sustainable development reserves and national parks, while a quarter (26%) are located within Indigenous territories⁸⁴. Many initiatives operate informally yet play a vital role in protecting fish populations and strengthening local governance.

Sustainable, well managed fisheries are increasingly recognized as a powerful nature-based solution for the Amazon. They support biodiversity, improve water quality, and provide essential protein for local diets. They have also been linked to increases in fish abundance, species richness, and benefits for other aquatic animals such as freshwater turtles.^{71,85-88}

Beyond their ecological advantages, community-led fisheries also deliver social benefits: they support local economies, promote gender inclusion in fisheries activities and decision-making processes, and reinforce cultural traditions^{29,55}. Recognizing and supporting community-led fisheries management initiatives can strengthen their role in conserving freshwater ecosystems and protecting biodiversity, while sustaining the cultural heritage and food security of Amazonian communities.



- Fisheries Management Areas
- Protected Areas
- Indigenous Territories
- Amazon Basin



Community-led fisheries management initiatives identified across the Amazon. Modified from⁸⁴.

Case study: Co-management and sustainable development in the Brazilian Amazon floodplain

Fisheries co-management in the Brazilian Amazon began in the 1970s, when community fishing agreements emerged as a response to growing pressure from commercial fleets and the overexploitation of the region's lakes. Over time, these local efforts evolved into more structured approaches supported by public policies^{89,90}.

In the state of Amazonas, Brazil, co-management became part of a broader sustainable development strategy, with communities organizing around networks of lakes and reserves. A notable example is the development of pirarucu management systems that combine biological knowledge of the species with traditional practices. These systems have been regulated at the state level, which has enabled them to expand rapidly:

today, annual count of pirarucu exceeds one million individuals⁶⁸.

By contrast, these systems have developed more slowly in the state of Pará. Although there were early efforts to formalize co-management and regulate pirarucu fishing, progress stalled for many years. Only recently have new fishing agreements begun to be approved. As a result, in the Lower Amazon of Pará, pirarucu densities averaged only 0.55 adults per km², while the few communities that managed their local pirarucu fisheries reported densities of over 18 individuals per km²⁹¹.

This contrast illustrates the potential of community-managed lake networks to support migratory fish species, restore floodplain ecosystems, and enhance the well-being of local populations. Recognizing and strengthening these initiatives can help scale their benefits across the region.

Case study: Strengthening local fisheries governance in Sarayacu, Loreto, Peru

In Sarayacu in the Ucayali province of Loreto—a remote region of the Peruvian Amazon—several riverine and Indigenous communities have begun organizing themselves to protect and manage their lakes and the fish they contain. With a growing awareness of the importance of conservation, these communities have taken steps to monitor fish populations, share knowledge, and establish local committees to guide sustainable fishing practices.

While such efforts reflect strong local commitment and a deep understanding of freshwater ecosystems, it's still challenging for communities to put initiatives of this kind on a formal level. Geographic isolation, limited access to technical support, and complex administrative procedures often delay official recognition of their management plans. Additionally, differences in cultural perspectives and traditional practices can create misunderstandings that hinder collaboration.

Despite these obstacles, communities continue to develop informal arrangements to resolve conflicts and regulate fishing activities. However, without formal governmental recognition, these grassroots efforts risk being overlooked or under-supported.

The situation highlights the need for simplified legal pathways, culturally sensitive technical assistance, and inclusive dialogue. Recognizing and integrating traditional knowledge into fisheries management programs is essential. By investing in community capacity-building and creating fair mechanisms for conflict resolution, these initiatives can gain governmental legitimacy and contribute meaningfully to biodiversity conservation and local well-being.



Fisher with her catch of arapaima in a community-managed area

LIVING JEWELS OF THE AMAZON

© iStock



The Amazon's ornamental fish trade reflects the basin's remarkable aquatic diversity. Hundreds widely varied species enter global markets to grace aquariums in far-flung corners of the world, allowing those with a curious spirit to behold, up close, the enchanting beauty of these precious creatures. Weak monitoring and illegal trafficking pose risks for endemic fishes, while regulations vary and enforcement remains challenging. Yet, for thousands of Amazonian families, ornamental fisheries remain a vital source of income—a reminder that biodiversity, trade and conservation are deeply intertwined and must be balanced to ensure long-term sustainability.

The Amazon Basin is home to an exceptional diversity of freshwater fish species, and many of them are highly sought after in the global aquarium trade for their vivid colors, unique forms and characteristics, and ecological rarity. Brazil, Colombia and Peru are the region's leading exporters, and each country has distinct trade dynamics, regulatory frameworks and conservation challenges.

Brazil was the first country in South America to formally enter the Amazonian ornamental fish market in 1955, when the cardinal tetra was commercialized⁹². Since then, the trade has evolved into a demand-driven industry, where harvesting occurs only to meet specific international orders^{93,94}: exporters coordinate with intermediaries and fishers to collect targeted species.

Brazil reportedly collects around 400 species for export, though just 10 species make up 90% of exports⁹⁵, with the cardinal tetra still the flagship⁹⁶. The main areas where fishing for the trade takes place include the Negro River (especially around Barcelos), and the upper Amazon mainstream, Madeira, Japurá, Xingu and Tocantins Rivers. In 2024, Brazil exported 2 million individual fishes under the tariff heading "freshwater ornamental

fish and Arapaima,” valued at US\$3.7 million, with Germany receiving 30% of the shipments⁹⁷. Although this category formally includes captive bred specimens, in practice the majority of the exported volume is composed of wild caught fish.

Colombia legally permits the collection of 313 Amazonian species for ornamental purposes. In 2023, 4.8 million specimens from 77 species were harvested, with the dwarf catfish *Otocinclus macrospilus* alone making up half of the traded individuals⁹⁸. The Amazon contributes about 15% of the ornamental fishes exported in Colombia, primarily from species such as oto catfish, corydoras, tetras and arawana. It is important to note that a significant share of Brazilian Amazonian ornamental fish enters Colombia unofficially, crossing the Leticia–Tabatinga border before being re exported by Colombian or Peruvian companies. This practice is largely driven by the comparatively more restrictive regulatory framework for direct exports from Brazil, even for species that are legally permitted.



Silver arowana (*Osteoglossum bicirrhosum*), an iconic Amazonian fish valued in fisheries and the ornamental trade.

© Leandro Sousa

Peru’s Amazon hosts an estimated 500 native ornamental species, with Loreto as the main extraction and export hub. High-value species include *Potamotrygon tigrina* (tiger ray/ arraia-tigre), *Osteoglossum bicirrhosum* (silver arawana/aruanã) and *Brachyplatystoma tigrinum* (zebra shovelnose), although the latter is often exported illegally. In 2024, Peru exported 4.5 million live ornamental fish to 25 countries, with the United States accounting for nearly a quarter (23%) of the total⁹⁷. In Peru, direct export by fishers is also common⁹⁹. As in Brazil and Colombia, the country’s trade category includes both wild-caught and captive-bred specimens.



The tiger shovelnose catfish (*Brachyplatystoma tigrinum*), a high-value species in Peruvian ornamental fisheries.

Historically, the trade peaked between the 1960s and 1990s. In 1978 and 1979 Peru exported nearly 20 million fishes annually¹⁰⁰ supporting around 5,000 livelihoods. Colombia exported 23 million fishes in 1999 but exports had declined by 60% in Colombia and 40% in Peru in 2024 and 2017 respectively^{101,102}. This decline reflects market shifts, including the rise of captive breeding in countries including Singapore, Indonesia, Thailand, Sri Lanka, Japan and the Czech Republic, which now produce over 90% of



Ornamental *Pterophyllum scalare* (angelfish) from the upper Negro River

global freshwater ornamentals.¹⁰²⁻¹⁰⁶ Species composition has also changed. The main ornamental species from both countries—silver arawana, corydoras and cardinal tetras—have shown declines in their exports of up to 80% since the 1980s. Currently, *Otocinclus vestitus* (dwarf otocinclus) is Peru's most exported species, with more than 2.5 million individuals sold each year¹⁰².

Several factors influence trade trends, including fluctuating international demand, captive breeding of native species abroad, and overfishing. The latter raises concerns about the “tragedy of the commons,” where unsustainable harvesting leads to population collapse. Although habitat destruction is the primary threat to most species, commercial capture can also pose significant risks, especially for endemic or restricted-range species like *Apistogramma cinilabra* (dwarf cichlid)¹⁰⁷.

Some Amazonian ornamental species are listed

under CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora), which means that permits are required for export and trade volumes must be monitored. Key species include freshwater stingrays (Potamotrygonidae) on Appendix II and III; critically endangered zebra pleco (*Hypancistrus zebra*) on Appendix II, subject to a zero export quota for wild specimens for commercial purposes; and pirarucu on Appendix II, primarily for meat but occasionally for the ornamental trade¹⁰⁸. Inclusion in CITES helps to control trade and reduce trafficking in these species.

Nevertheless, the trade in ornamental fish is challenging to monitor and enforce. Much of the collection takes place in isolated rivers and floodplains, making it hard to control, while varied and inadequate border control mechanisms and regulations in the region mean it remains challenging to prevent illegal trade, particularly to countries in Asia and Europe.

Paracheirodon innesi (neon tetra) is a widely distributed Amazonian species and one of the most popular aquarium fish.

© WCS-José Zumaeta



Otocinclus cocama, a small catfish from Peru's Ucayali and Tigre rivers, is named after the Cocama people.

© WCS-José Zumaeta



Airport seizures in Brazil from 2012 to 2019 revealed that more than 30 species of ornamental fish were being trafficked; the cardinal tetra accounted for 41% of the seizures, with the silver arowana and the Critically Endangered zebra pleco also frequently featuring¹⁰⁹.

To ensure a sustainable trade in ornamental fishes from the Amazon, improvements are needed in data collection, regulation and traceability. Reliable figures on harvests, updated species protections, and transparent supply chains are essential. Technologies like microchips, mobile apps and DNA tracking could enhance monitoring, while requirements on importers for legal and sustainable sourcing could incentivize better practices. Ultimately, the ornamental fish trade offers a viable livelihood for Amazonian communities while giving people around the world a unique window onto the region's matchless biodiversity—but only if managed with care and foresight.

Women to the fore in Amazonian ornamental fisheries

Ornamental fishing is notably inclusive and empowering for women, when compared with other fishing activities in the Amazon region^{110,111}. Women play a pivotal role, with their involvement in the sector spanning all the way from catching to commercialization—while in other fisheries, actively participating in the extractive phase is often considered the domain of men. Women are also very active in ornamental fishing associations and guilds, such as those in the Nanay River basin, in Peru, where they frequently assume leadership and planning responsibilities, their independence and expertise in the field contrasting with other localities where their roles are more confined to domestic duties or fish processing tasks.

The dwarf pencilfish (*Nannostomus marginatus*) is a popular ornamental species from the Amazon Basin

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RIVERS OF ENDURANCE: THE RISE OF SPORT FISHING

© Enrique Moya

It's no surprise that sport fishers from around the world are drawn to the waters of the Amazon, keen to pit their skills against some of the most remarkable freshwater fishes on the planet—and when sport fishing is governed and managed well, with the genuine involvement of local people, it can provide communities with valuable revenue streams while having far less environmental impact than conventional capture fisheries.

The Amazon is home to some of the world's most iconic sportfishing species, with the peacock bass (*Cichla temensis*), or tucunaré-açu, standing out as a top target. Known for its explosive surface strikes and aggressive behavior, this fish can grow over one meter long

and live up to 14 years. Anglers from around the globe travel to the Negro River basin and other Amazonian tributaries to experience the thrill of battling this powerful predator.

The Amazon also hosts fierce predators like the payara (*Hydrolycus armatus*), or vampire fish, recognized by its long, dagger-like fangs and silver, streamlined body. Found in fast-flowing rivers, it delivers acrobatic fights and powerful runs, making it a favorite among thrill-seeking anglers. Additionally, massive catfish species like the piraíba (*Brachyplatystoma filamentosum*) and pirarara (*Phractocephalus hemiliopterus*) offer grueling, hours-long battles. Their size, strength, and striking appearances make them prized catches in the Amazon's "heavy-duty" freshwater sportfishing scene.

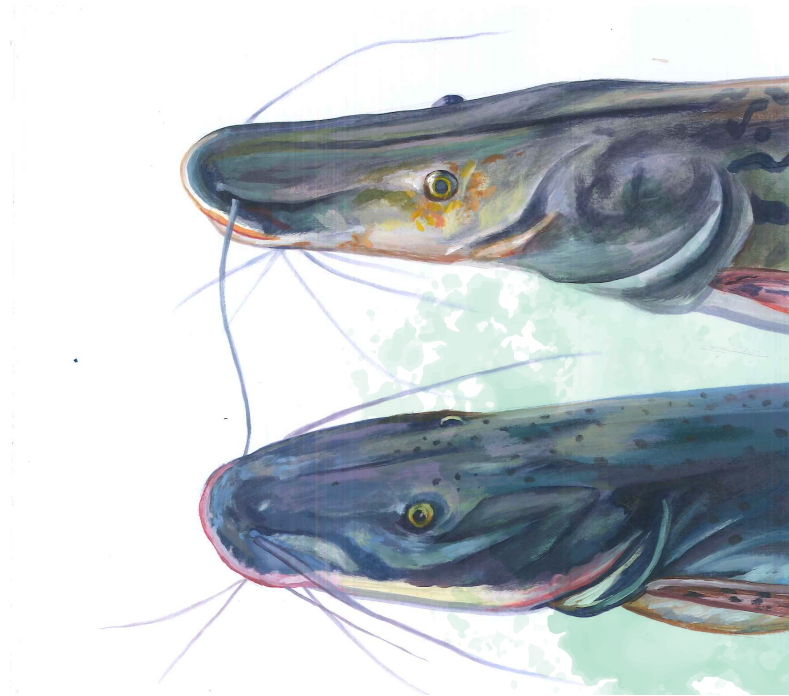
Payara (*Hydrolycus armatus*), the "vampire fish" of the Amazon, famed for its fangs and powerful fights in fast-flowing rivers.



© Rodrigo Salles

As those who realize their dream will confirm, unlike with capture fisheries, sport fisheries depend for their value on the quality of the experience they can offer rather than on the volume of fish they can extract.

Indeed, based on operator reported figures, a single week-long sport fishing package can be extremely lucrative, raising more than the annual income from commercial fishing in the same area. Sport fishers contribute to the tourist and service industry, bringing income streams that include lodging and service fees, territorial access permits, guiding and boat services, transportation, craft sales, and food and drink. In some cases, up to half of the money spent by sport fishers remains within host communities. Well-organized schemes provide predictable seasonal income that supports local households and community projects, financing river patrols, education, healthcare and small-scale infrastructure.



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Sport fishing: when and where it happens

The prime sport fishing season in the Amazon coincides with the dry period, running from September to December. During these months, river levels drop, concentrating fish populations and making them more accessible to anglers.

The state of Amazonas is one of Brazil's leading sport fishing destinations, since it's home to some of the species most sought-after by sport (and commercial) fishers. The Rio Negro basin is the main area for the activity, with hubs in the municipalities of Barcelos and Santa Isabel do Rio Negro, and operations across rivers such as the Urubaxi, Aracá, Cuiuni and Unini¹¹².

In Peru, the Loreto region—especially the

Pacaya Samiria National Reserve and rivers like the Amazon and Ucayali—is a top destination for catching pirarucu, as well as massive catfish like piraíba and surubim (*Pseudoplatystoma* spp.). In Colombia, the Amazon Trapezium near Leticia provides access to rich fishing grounds along the Amazon River and its major tributaries, including the Putumayo and Caquetá Rivers. These waters are home to iconic sportfishing species such as peacock bass, payara, and various large catfish. In Ecuador, the Oriente region—featuring pristine stretches of rivers like the Napo, Pastaza, and Aguarico—offers adventurous fishing experiences, often developed in collaboration with Indigenous communities and guided by conservation-focused tourism initiatives.



© Rodrigo Salles

Peacock bass (*Cichla temensis*), one of the Amazon's most iconic sportfishing species, renowned for its explosive strikes and powerful fights.

The impacts of sport fishing

Sport fishing does have potential negative impacts. These can include pressure on fish stocks because of high demand and inadequate management; while deforestation and environmental degradation from unregulated infrastructure cause broader ecosystem issues. Human relations are also a potential flashpoint: there are sometimes conflicts between local communities and commercial fishers over traditional practices and access to fishing areas, while unfair trade practices from unscrupulous operators undermine social equity^{113,114}.

The safety of catch-and-release practices also remains an important concern. Research indicates post-release survival of more than 95%, especially when single hooks and proper handling are used, but these studies generally occur under controlled conditions¹¹⁵. In reality, mortality rates may be as high as 18%, so there is still considerable uncertainty about the real impacts of sport fishing on fish survival¹¹⁶.

Sport fishing in protected areas and Indigenous territories

The search for well-preserved, species-rich rivers attracts sport fishers to remote parts of the Amazon Basin, many of which are located within protected areas or Indigenous territories. As the sector expands its range into these regions, it's vital that it does so sustainably, and that local communities receive fair social and economic benefits from their involvement.

In the past, sport fishing tended to rely on informal agreements with community leaders, but this often resulted in a lack of management and monitoring, unequal benefit distribution,

and socio-environmental conflicts¹¹⁷. Today, however, legitimate sport fishing initiatives are firmly based on shared management approaches. In Indigenous territories, this involves community-developed plans, and protocols recognized by national agencies. In protected areas, agreements follow management plans and institutional regulations. In both cases, formal contracts set out access rules, operational procedures, benefit-sharing mechanisms and decision-making processes. Transparent governance with representation from communities and operators is essential for accountability and long-term sustainability.

Fundamentally, sport fishing in protected areas and Indigenous territories becomes viable when it combines strong governance, controlled access, and a clear commitment to conservation, ensuring rivers will still be productive for future generations.

Sustainable sport fishing targeting pirarucu in the Cuyabeno Wildlife Production Reserve, Ecuador, guided by Indigenous Kichwa knowledge and stewardship.

Voices from the River: Sustainable sport fishing—an Indigenous perspective

The Kichwa Zancudo Cocha Community is an organization located in the northern Ecuadorian Amazon. Being situated within a protected area—the Cuyabeno Wildlife Production Reserve—productive activities are limited. Therefore, since 2012, 15 families have designed and established a sustainable tourism program through catch and release sport fishing, primarily targeting species such as the pirarucu and large catfish.

Our flagship experience is the catch of the pirarucu. Tourists typically stay for about eight days. During the first few days, they engage in fishing for smaller species (such as the peacock bass), while the final days focus on the larger fish. Catching these can take several days, and once a fish bites the hook, the struggle can last over two hours, particularly with large catfishes. It is then extremely important to handle the animal as little as possible and for no more than two minutes to avoid injury. The ultimate trophy is a photograph, as the fish is immediately returned to the water.

We use appropriate materials and equipment, such as circle hooks, which cause minimal harm to the animal and are easy to remove. This is a sustainable activity for the species, as the resource we preserve is greater than what we could obtain by selling its meat. Moreover, we respect and conserve its life.

Enrique Moya, Kichwa Zancudo Cocha Community, Ecuador



AMAZON FISHES AT RISK



© Ricardo Oliveira



Illustration of *Brachyplatystoma juruense*, classified as Vulnerable (VU) on the national Red Lists of Ecuador and Colombia

Of the approximately 2,700 freshwater fish species native to the Amazon Basin, 82 species are listed as Critically Endangered (CR), Endangered (EN) or Vulnerable (VU) in national assessments from Brazil¹¹⁸, Colombia¹¹⁹, Bolivia¹²⁰ and Ecuador^{121,122}, and 144 species feature on the IUCN Red List of Threatened Species¹²³. However, the true number is likely much higher, since most of them have yet to be evaluated with IUCN criteria.

CATEGORY	NATIONAL RED LISTS	IUCN
Critically Endangered, Possibly Extinct	2	0
Critically Endangered	12	27
Endangered	31	46
Vulnerable	37	71
TOTAL	82	144

Among those listed as Critically Endangered are iconic and highly range-restricted species such as the zebra pleco, which is endemic to the Xingu River in Brazil. This species is now severely threatened by habitat loss due to hydroelectric development, particularly the Belo Monte Dam.



© Leandro Sousa

Xingu River stingray (*Potamotrygon leopoldi*), a freshwater ray restricted to the Xingu Basin and widely traded in the international ornamental market.

Rheophilic (fast-water-adapted) fishes are disproportionately represented among VU and EN categories as they are especially vulnerable to habitat fragmentation and changing flows caused by dam construction and waterway development. The Xingu River and its tributaries are home to many endemic species, including *Scobinancistrus aureatus* (goldy pleco/pleco dourado) (VU—IUCN) and *Leporinus guttatus* (EN—Brazil and VU—IUCN). Similarly, the Tocantins River hosts endemic species such as the freshwater stingray *Potamotrygon adamastor* (EN—IUCN), the long-finned catfish *Baryancistrus longipinnis* (EN—Brazil, EN—IUCN), and *Aguarunichthys tocantinsensis* (*Tocantins pimelodus*) (EN—IUCN). These species are now largely confined to the remnants of habitats upstream of dams.

Of particular concern are nine cave-dwelling species from subterranean streams of the upper Tocantins: among these, *Ituglanis bambui* is already listed as CR by Brazil and the IUCN. These

Zebra pleco (*Hypancistrus zebra*), a critically endangered species in the Amazon



© Leandro Sousa

species have restricted ranges and are highly sensitive to disturbance. Although discovered in a relatively well-studied region, they likely represent only a small fraction of Amazonian subterranean biodiversity, much of which remains unexplored—but may already be threatened.

Two annual killifish have been categorized as Possibly Extinct under Brazil's Biodiversity Extinction Risk Evaluation System. *Moema piriana* has not been recorded since 1988 and is known only from a single temporary pool in Pará, despite repeated survey efforts in the region. *Hypsolebias marginatus* was documented from just one small seasonal pool in the Tocantins River basin, Goiás, but this site has since been destroyed by agricultural expansion and conversion to soybean cultivation^{124,125}.

The scale of the threat is further obscured by the 334 Amazonian species currently listed as Data Deficient by the IUCN¹²³. This means that over 12% of the region's freshwater fishes are so poorly understood that their conservation

status cannot be assessed, while there's a portion that haven't been even considered for evaluation. Global studies suggest that up to 50% of Data Deficient species may in fact be threatened¹²⁶, which means that the number of at-risk species in the Amazon could be significantly higher than current estimates suggest.

The lack of comprehensive data is compounded by major geographic and institutional gaps. For example, Peru is one of the most biodiverse countries in the Amazon Basin but lacks an official national Red List for freshwater fishes; while in Colombia, financial constraints have left a lack of institutional capacity to evaluate all the species present. These gaps mean there are a significant number of unevaluated species, which leaves a critical blind-spot for regional conservation planning. Moreover, the absence of coordinated data-sharing across national borders hinders the development of effective, basin-wide assessments and conservation strategies.

AMAZON FISHES AT RISK

**CRITICALLY
ENDANGERED (CR)**
NATIONAL:14
IUCN:27



ENDANGERED (EN)
NATIONAL:31
IUCN:46



VULNERABLE (VU)
NATIONAL:37
IUCN:71



ENDEMISM:

Critically Endangered species are highly endemic and thus extremely susceptible to environmental disturbances.

MIGRATORY CRISIS:

Long-distance migratory catfish (*Brachyplatystoma spp.*) are threatened across multiple national borders.

?

THE MISSING PIECE: PERU

Lacks an official national Red List for continental fishes, creating a significant data blind spot for the basin.

A photograph of a fish market stall. In the foreground, several large, silvery fish with long, thin tails are laid out on a wooden crate. A person's hand is visible on the right, touching one of the fish. In the background, there are blurred figures of people, including a person in a blue shirt and another in a yellow shirt, suggesting a busy market environment. The text "COMPOUNDING DRIVERS, INTENSIFYING THREATS TO AMAZON FISHES" is overlaid in white, bold, sans-serif font on the left side of the image.

COMPOUNDING DRIVERS, INTENSIFYING THREATS TO AMAZON FISHES

© WCS / Arthur Menescal



Several major drivers of biodiversity loss threaten the fishes of the Amazon Basin, and all of them stem directly from human activities. What's more, these drivers compound one another—when a species is weakened by one threat, it becomes more vulnerable to the impacts of others. As climate change increasingly intensifies the pressures on freshwater ecosystems, the challenges facing the Amazon today are unprecedented and deeply concerning.

Habitat degradation and loss

Amazonian fish habitats are under growing pressure from many directions. Human activities such as dams, wetland drainage, river channelization, and water diversions can fundamentally transform the underwater world, destroying areas fish rely on to feed, reproduce, and migrate. Compounding these impacts, pollution and climate change gradually degrade freshwater ecosystems, making it harder for fish to survive and thrive.

As a society, we tend to notice harm to terrestrial ecosystems because the damage is visually obvious. Rivers, by contrast, can continue to flow even when they've been severely degraded, which gives a false impression of intactness. It's difficult for society to fully conceptualize a river's vulnerability, and that makes effective management and decision-making harder to achieve¹²⁷.

Deforestation

In Amazonia, rivers, forests and floodplains are tightly connected. Many fish species depend on terrestrial inputs, such as fruit, leaf litter and insects, for their survival^{128,129,130}. Likewise, trees and large branches which end up in the water can become valuable habitats, offering refuge from predators and supporting spawning, nursery areas, and feeding sites for numerous species^{129,131}. Vegetation along the banks also helps to regulate light, water temperature, and nutrient export^{132,133}—all of which influence fishes' physical condition, the presence of particular species, and the ways in which they interact with each other¹³⁴.

Deforestation driven by agriculture, urban expansion, mining and infrastructure development has significantly altered Amazonian wetlands and riverine systems. Recent basin-wide mapping indicates that approximately 7.4 million hectares of wetlands had already been cleared by 2020, primarily in floodplain environments, with an additional 800,000 hectares lost between 2021 and 2024, largely due to agricultural expansion, urban growth, and gold mining^{135,136}. These changes ripple far beyond the forest itself. When vegetation is removed, soils are washed into rivers, increasing sediment loads and muddying waters. Riverbanks and floodplains lose the complex habitats on which many fish depend¹³³, while dams and land clearing disrupt the natural flow and flood cycles that give life to Amazonian rivers¹³⁷. At the same time, altered freshwater ecosystems become more vulnerable to invasive species, which can spread quickly and outcompete native fish¹³⁸.

On the floodplains, deforestation disrupts the reciprocal relationship between trees and fruit-eating fishes. Clearing riparian forests reduces the amount of food available for fish, which in turn weakens seed-dispersal by those fish—and the diminishing cycle continues¹³⁹. Fish species with limited dietary flexibility or strong dependence on terrestrial invertebrates are among the first to decline¹⁴⁰, but the effects ultimately cascade down to the human communities that depend on fish as a source of protein and livelihoods¹⁴¹.

Altered flows

The way in which a river flows is a key influence on the structure of the physical habitats it offers, which in turn influence the fish populations living in it¹⁴². In the Amazon, streamflow is strongly dependent on precipitation patterns¹⁴³, with seasonal rains driving changes in water level and flooding. These natural flow patterns are critical to fish populations as fishes have evolved specific physiological adaptations, life-history strategies, and behaviors in response to them^{142,144,145}. But factors such as climate change, deforestation, and the construction of dams and roads are affecting flows in the Amazon¹³⁷. In addition, growing demands on water resources, particularly from agriculture and energy production, are increasing pressure on rivers¹⁴⁷. Together, these pressures alter river hydrology and trigger a complex cascade of environmental and ecological changes which directly affect fish, including changes in habitat conditions and availability¹⁴⁸, as well as changes in water temperature and oxygen concentration¹⁴⁹.

Loss of aquatic connectivity

The Amazon Basin is the world's largest and most complex freshwater wetland system, and its functioning depends on aquatic connectivity. This includes longitudinal connectivity between upstream and downstream habitats, vertical connectivity between groundwater and surface water, and lateral connectivity between the river's main channel and its riparian areas. Together, these interconnected pathways sustain the ecological processes, life cycles, and habitat dynamics that make the Amazon one of the most biologically rich regions on the planet¹⁵⁰.

Some Amazonian rivers still flow freely from their headwaters to the sea, but others

have been blocked by dams and other barriers. The resulting fragmentation has severe consequences for fish populations. A loss of connectivity prevents fishes from reaching their spawning and feeding grounds, while changes in river flows alter the availability and productivity of their habitats. To ensure resilient populations, fish genes also need to flow freely: when connectivity is reduced, genetic isolation increases.

River connectivity status and locations of existing and potential dam projects in the Amazon Basin. Data source: ¹⁵¹.

River connectivity status

- Free-flowing
- Good connectivity
- Impacted

Hydropower and other dams

- ◆ Existing
- ◇ Planned

0 500 1,000 km

Dams

Many new dams have been constructed in the Amazon over the past two decades, and hundreds more are at various stages of planning^{152,153}. These dams are heavily concentrated in two main areas: in Andean-origin rivers of the Western Amazon and in Brazil's upper Xingu and Tocantins basins.

Dams on Andean rivers frequently function as water diversion systems, creating a dewatered reach of river between the dam and the downstream water return site, where water released from hydropower turbines reenters the river. This dewatered reach can extend from a few hundred meters to tens of kilometers. Damming and dewatering reduce or eliminate fish habitat and disrupts the natural upstream-

downstream movement of water and fishes alike. Downstream of water return sites, flows are driven by power generation cycles rather than natural processes, creating unstable and stressful conditions for fish that threaten their reproduction due to hormone disorders¹⁵⁴.

Lowland Amazonian dams also alter fish habitats but in a different way. They are typically much larger, often blocking entire river channels, diverting water, and creating in-channel reservoirs that turn flowing waters into more lake-like environments. Some 8% of Amazonian fishes (223 species) migrate as part of their life cycle¹⁵, with many traveling long distances to breed or feed. Blocking rivers has direct consequences: dams on the Madeira River near Porto Velho, for example, have led to declines in up to 70 migratory fish species^{155,156}.

Overexploitation of species: overfishing

In the Amazon, fishing pressure remained relatively low, shaped by sparse human populations, limited technological development, and major logistical barriers to fisheries distribution until the 1960s and 1970s. In the decades that followed, however, the prevalence of overfishing has increased, exacerbated by the absence of effective regulation and monitoring¹⁵⁷. This does not just threaten fish stocks, but entire ecosystems, livelihoods and food security^{56,158}.

A fish population is considered overfished when the harvest levels exceed the species' natural capacity to replenish itself, resulting in sustained decline of abundance. Importantly, overfishing interacts with other threats such as habitat degradation and loss of connectivity. As

environmental conditions deteriorate, fishing pressure that was once sustainable can exceed the ecosystem's diminished capacity to support the population.

Stock reduction of larger fish species is a predictable effect of fishing¹⁵⁹. This phenomenon, where long-lived, larger species are gradually replaced by short-lived, smaller species, is known as "fishing down the food web"¹⁶⁰. Regional studies show a reduction in the average size of landings over time, indicating that overfishing is affecting larger, more economically valuable species like pirarucu, tambaqui and the goliath catfishes¹⁶¹.

Beyond food fisheries, the Amazon's ornamental fish trade reveals a quieter but deeply concerning form of overexploitation. This fishery is highly selective, often focused on visually striking species, many of them rare and

Construction of the Teles Pires hydroelectric dam, Tapajós river basin



found nowhere else on Earth. High mortality after capture and intense pressure on small populations make these fishes especially vulnerable¹⁶².

The impacts are already visible. Iconic species such as the zebra pleco (*Hypancistrus zebra*) and the “black diamond” stingray (*Potamotrygon leopoldi*) have declined sharply due to rising demand, increased fishing effort, and habitat fragmentation by dam in the Xingu River^{32,163}.

Risks escalate further for species caught for both aquariums and food. In arowanas (*Osteoglossum spp.*), the widespread capture of juveniles—often involving the removal of males carrying eggs and larvae in their mouths—can quickly drain local populations and disrupt reproduction^{164,165}.

Invasive non-native species

Non-native species invasions are among the leading drivers of global biodiversity loss¹⁶⁶, particularly when combined with habitat

degradation and transformation¹⁶⁷. Species-rich communities tend to provide fewer available niches for potential invaders, making them more resilient to biological invasions and other human impacts^{6,13}. However, as habitats are altered, native species may lose the niches and resources they need to survive, resulting in population declines or even local extinctions^{168,169}. At the same time, these conditions create ecological opportunities for non-native species to move in and establish themselves.

Although there is limited information available for the Amazon region concerning non-native fish, the highest number have been found in Colombia, followed by Brazil and Bolivia. Most of the non-native species are used in aquaculture (12 species) and in the aquarium trade (12 species). The most frequently detected non-native fish were pirarucu (see box), *Poecilia reticulata* (guppy/gúpi) and *Oreochromis niloticus* (Nile tilapia)¹⁷⁰.

Arapaima gigas: Bolivian Amazon invader

Many people would be surprised to learn that the iconic pirarucu is invasive in parts of Amazonia. Although the species is native to the northern Amazon Basin, it's non-native to Bolivia's upper basin¹⁷¹, where it has become a significant biological invader. Originally introduced into the Peruvian Amazon for aquaculture, pirarucu escaped into the Madre de Dios river system and subsequently crossed into Bolivian territory around the 1970s¹⁷². Since then, the pirarucu has rapidly colonized the floodplains of the Beni, Orton and Madre de Dios river basins, expanding its range by more than 30 kilometers each year¹⁷². The pirarucu's large size, rapid growth rate and ability to breathe air allow it to thrive in the oxygen-poor waters of oxbow lakes, giving it a competitive advantage over many native species¹⁷¹.

The ecological and socioeconomic consequences of this invasion are profound and complex. Available evidence indicates that pirarucu may be reshaping local fish communities through competition and predation, with potential cascading impacts on native species and local fisheries¹⁷³. Paradoxically, the invasion has driven an economic boom: pirarucu has replaced depleted native stocks such as the pacu and large catfishes to become the dominant species in commercial catches, accounting for up to 80% of landings at major ports like Riberalta. While this provides livelihoods for local fishers, conservationists warn that in the long term, the dominance of the non-native pirarucu could severely reduce the ecosystem's resilience¹⁷².

Pollution

Polluted water can severely impair the feeding, growth, reproduction and survival of fish. Elevated nutrient loads, contaminants or suspended particles can alter fish behavior, stressing their physiology and reducing reproductive success^{174,175}. In the Amazon, sedimentation and turbidity—often driven by deforestation, runoff and land-use change—can limit light penetration, clog fish gills and hinder foraging, especially among species that rely on visual cues to feed^{176,177,178}. Pollution associated with petroleum activities such as oil spills, poses additional threats by directly exposing fish to toxic substances and reducing oxygen availability in affected waters^{179,180}. Pollution also introduces synthetic contaminants (e.g., microplastics, agricultural synthetic chemicals) that can accumulate in fish tissues, disrupting their hormones and interfering with their respiration, development and reproduction, or sometimes even killing them^{181,182,183}. Recent evidence from the Amazon shows there is widespread ingestion of plastic particles by fishes at many different levels of the food chain^{184,185}.

Mercury contamination

In South America, non-industrial gold mining is responsible for 83% of anthropogenic mercury emissions^{186,187}. Mercury is used to extract gold from ore and alluvial sediments, releasing large quantities of the metal into the environment. Part of this mercury is deposited directly into freshwater ecosystems, while the remainder is transported through the atmosphere over longer distances and ultimately captured in terrestrial environments. There, it can be later remobilized into freshwater systems through processes such as deforestation and biomass burning¹⁸⁸.

Elevated mercury exposure has severe ecological consequences. In fish, mercury can damage tissues, alter reproductive organs, reduce body size, and make breeding less successful^{189,190,191}. Because mercury bioaccumulates and biomagnifies, fish higher up the food chain tend to carry the highest concentrations¹⁹².

The human health impacts of mercury are equally alarming. Fish consumption is the primary pathway for mercury exposure in the Amazon, and fish are a dietary staple⁵². Mercury is a potent neurotoxin: it can cause cognitive and neurological damage, especially in children and infants, and is listed by the World Health Organization as one of the top 10 chemicals of public health concern^{193,194}.

Climate change

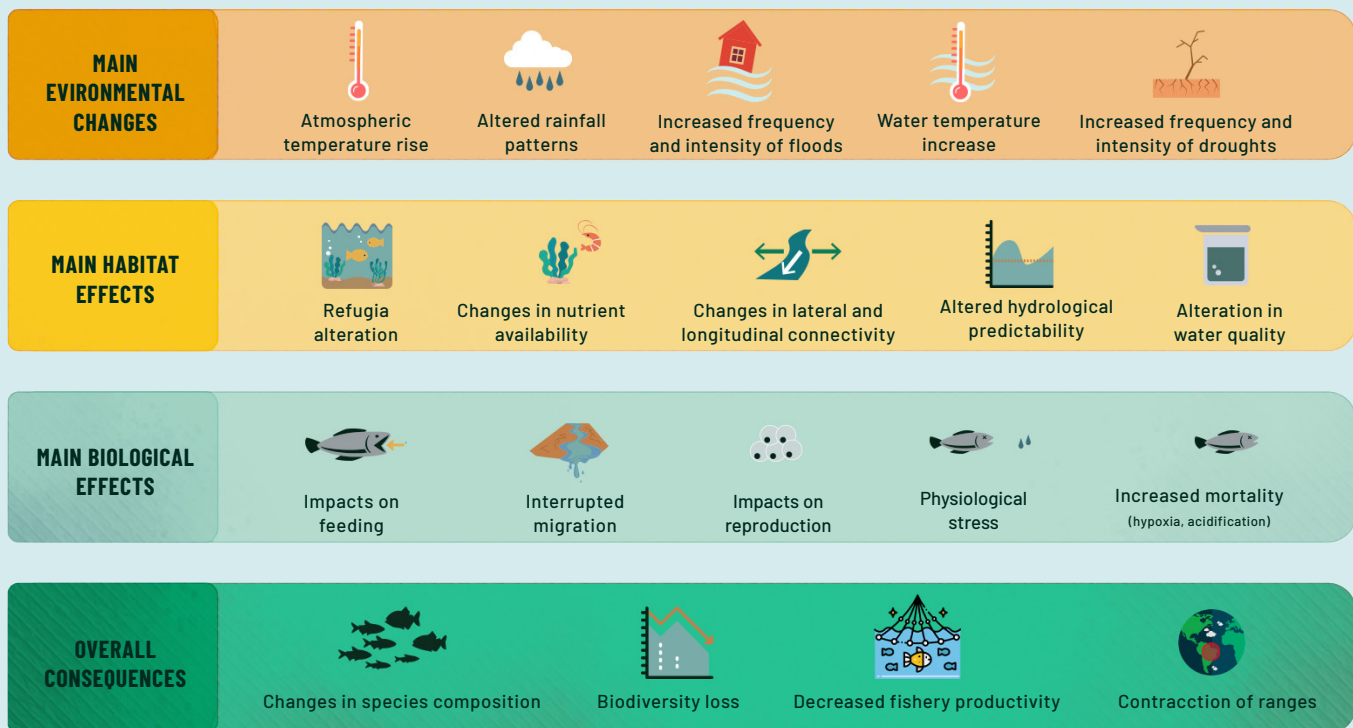
Climate change is intensifying pressures on Amazonian freshwater biodiversity by altering hydrological regimes, river connectivity, and habitat structure. Climate projections for the Amazon Basin consistently indicate rising temperatures and substantial shifts in river flow by mid-century. Most critically, annual river discharge is projected to decline by more than 40% in key regions, including the headwaters of the Madeira River, further amplifying existing human induced modifications to natural flow regimes¹⁹⁵. These reductions are expected to be most pronounced during the dry season, increasing water scarcity and reducing the extent and connectivity of aquatic habitats essential for fish populations^{196,197,198}.

Floodplain fish species are particularly vulnerable. Prolonged dry periods disrupt their reproductive cycles, reduce migration and juvenile recruitment, and diminish food availability. Shallow, overheated waters lead to low levels of oxygen and increased predation, further reducing survival rates^{196,197}. Large bodied migratory species that grow slowly, mature late, and rely on long distance and lateral connectivity between river channels and floodplains for spawning and early life stages are especially vulnerable, as these characteristics constrain their ability to recover from repeated drought induced recruitment failures¹⁹⁹.

In the Andean and Piedmont regions, climate change is driving biodiversity loss and altering the ways in which rivers flow. The cold, oxygen-rich streams in these upland areas are home to many endemic species that can only survive within a narrow range of temperatures. As temperatures rise, suitable habitats shrink, and species face local extinction²⁰⁰. In addition,

changes in water levels and flow speeds disrupt the migrations of species such as dourada and piramutaba which rely on predictable rising-water signals to initiate and sustain upstream spawning movements²⁰⁰.

Other pressures further compound climate impacts. Deforestation reduces water retention and alters rainfall patterns, intensifying droughts and increasing sedimentation. River damming fragments habitats and blocks migratory routes, already impacted by changed flows. Climate change also amplifies the impacts of pesticide use and mercury contamination by increasing contaminant concentrations during low-water periods, enhancing bioavailability under higher temperatures, and exacerbating physiological stress in fish, which together promote greater uptake and toxicity. Overfishing becomes more damaging under climate extremes, as droughts concentrate fish in smaller areas, making them more vulnerable to both capture and predation.²⁰¹⁻²⁰⁴





Severe drought in an Amazon River (2023)

A festival without its fish: Ongota's jandia Warmi and the changing Amazon

For generations, the Kichwa community of Ongota, located on the banks of the Misahualli River in the Napo River basin, has held a festival in honor of a highly prized fish. According to ancestral knowledge, each March, the jandias fish, or *matrinxãs* (*Brycon amazonicus*), would swim upstream, signaling the time to celebrate the festival of the queen *jandia Warmi*, or “jandia woman,” in gratitude for the sustenance the

species provided the community. In recent decades, however, regional development has encroached on the community. Now surrounded by cities, Ongota's rivers are under pressure from urban pollution and other anthropogenic stressors, and the jandia is no longer locally found. Even so, the community continues to celebrate the festival of the *jandia Warmi*, purchasing jandia from more distant locations since 2017. Their efforts speak to the enduring cultural connections between people, biodiversity and heritage.



FISHES, FRESHWATER AND THE FUTURE: CHALLENGES AND OPPORTUNITIES

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While the challenges that face the incredible fishes of the Amazon today are undeniably daunting, there's also real hope for the future. The key to their survival, and to maintaining the vital services they provide to millions of people, is to restore and protect the freshwater ecosystems on which they depend. The good news is that there's no mystery about how to do this: an Emergency Recovery Plan with six urgent and coordinated actions can lead us to bend the curve in the global loss of freshwater biodiversity.

The Emergency Recovery Plan, developed by 25 authors from 14 organizations, highlights the global freshwater biodiversity crisis and outlines six priority actions to guide policy responses aimed at reversing biodiversity loss²⁰⁵. The Amazon region presents unique opportunities to adapt and strengthen these actions, most notably through the central role of Indigenous Peoples and local communities. In several Amazonian countries, the formal recognition of these peoples—and of the value of their traditional knowledge and community-based management—greatly expands the potential for positive change. Additional opportunities arise from the work of the Amazon Cooperation Treaty Organization (ACTO), as well as from regional initiatives in fisheries co-management, protected and conserved areas, citizen science, and collaborative research networks. Together, these regional and local strategies, combined with the engagement of governments, civil society, and local and international organizations, can amplify the impact of the Emergency Recovery Plan and position the Amazon as a global model for the conservation and sustainable use of freshwater resources.



Action 1: Let rivers flow more naturally

The more naturally rivers flow, the better the outcomes for biodiversity. Nevertheless, maintaining flowing water is particularly challenging in Amazonian rivers. Dams and other physical barriers, such as weirs and intakes, retain and deflect sediment and nutrient loads, altering biogeochemical cycles and fish migrations²⁰⁶. Environmental flow implementation in the Amazon Basin must aim to maintain fishes' habitats and support their life histories, with a regime of consistent flow pulses and floods which also features low-flow cycles. The physical barrier that a dam creates in a river is a particularly significant management challenge. Fish ladders and elevators have been implemented in some hydropower facilities, in combination with spillways (passages for surplus water from a dam)^{207,208}. In the neotropical region, however, where fish ladders have been implemented, some reservoirs have become ecological traps for adults and larvae^{209,210}.

Implementing effective environmental flows requires a deeper understanding of the Amazon's complex natural flow regimes²¹¹. Environmental flows can also be safeguarded with a strategic, basin-scale approach to evaluate cumulative impacts and an assessment of the most suitable scenarios for developing hydropower and other water infrastructure that minimizes environmental harm while still meeting energy needs¹⁵³.



Jaraqui
(*Semaprochilodus*
spp), a key
component of
Amazonian freshwater
biodiversity and fisheries

© Michael Goulding

Action 2: Safeguard and restore freshwater connectivity

Safeguarding and restoring connected freshwater ecosystems in the Amazon Basin is not just good for fish: it's crucial for maintaining the ecological integrity of the entire biome, regional ecosystem services, and the balance of the global climate^{206,212}. The intricate links between people and freshwater systems are an essential foundation for these efforts²¹³.

Despite threats from infrastructure development, progress has been made through operational strategies and integrated water management approaches that prioritize connectivity¹⁵³. Key actions include rehabilitating floodplains and wetlands to restore natural hydrological cycles and enhance biogeochemical processes²⁰⁶. These efforts are not only ecologically beneficial but also support local communities by preserving access to fisheries, clean water, and transportation. Inclusive, transdisciplinary collaboration—especially with Indigenous Peoples and local communities—is critical to sustaining the social and cultural dimensions of connectivity²¹⁴.

Looking forward, implementing environmental

flow regimes and maintaining ecological integrity are proven, cost-effective tools for enhancing freshwater conservation. These measures help preserve the Amazon's fluvial dynamics, enabling species dispersal, supporting biodiversity, and reinforcing the basin's role in climate regulation. Protecting connectivity is both an urgent and achievable goal, offering wide-reaching benefits for ecosystems and people alike, and should be central to conservation and development planning in the Amazon Basin.

Action 3: End unsustainable management of resources

Declining Amazonian fish stocks are not solely the result of overfishing: the region's freshwater ecosystems themselves are highly vulnerable to disturbances across land and water²¹⁵. Harmful practices—from the use of poisons, explosives, and fine-mesh nets to the obstruction of river habitats—further compound the problem and intensify conflicts, particularly between rural and urban users²¹⁶.



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Addressing these intertwined ecological and social issues demands a diversity of governance models, from site-based regulations to inclusive, basin-scale frameworks²¹⁷. Sustainable management of declining fish stocks depends on the design and implementation of comprehensive policies, as well as international fisheries and conservation agreements that promote sustainability and adopt an ecosystem-wide perspective to tackle environmental threats^{218,219}.

Local fishers and Indigenous communities are integral to these solutions, and decision-makers must actively draw on their invaluable knowledge to develop effective, culturally appropriate and sustainable fisheries management strategies for the Amazon. Community empowerment is crucial for fostering stewardship and legitimacy in resource management, giving local organizations—such as surveillance committees, management committees and community groups—a sense of ownership and responsibility over their territories and natural resources. In some cases, Amazonian fishers have self-organized to restrict access to waters for unsustainable commercial operations. Such local efforts have delivered meaningful fisheries management outcomes, contributing to ecological recovery of high-value fish species²²⁰. Beyond ecological benefits, these collaborative approaches can also promote gender inclusion in fisheries activities and decision-making and strengthen cultural traditions^{29,55}.



Urban expansion in the Amazon drives demand for materials, degrading critical habitats for fish.

Action 4: Protect and restore critical habitats and species

Amazonian aquatic ecosystems support the world's most diverse communities of freshwater fish²²¹, serve as critical connectors across landscapes, and lock away nearly a quarter (23%) of all irrecoverable carbon on Earth^{222,223} all while occupying up to 30% of the Amazon Basin's surface^{4,224}. But these ecosystems are especially vulnerable¹⁵⁸.

Area-based conservation approaches, like Protected Areas and Other Effective area-based Conservation Measures (OECMs), are a focus under the KM-GBF. However, conservation initiatives overwhelmingly focus on terrestrial biodiversity²²⁵. Conventional management approaches—such as forest-focused conservation policies, protected areas, and national water legislation—are not well suited to address the interconnected nature of freshwater systems, which remain poorly represented and often only incidentally protected within terrestrial conservation frameworks^{158,226}. One exception is the

Freshwater Challenge. It aims restore 300,000 kilometers of degraded rivers and 350 million hectares of degraded wetlands by 2030, while securing the protection of freshwater ecosystems important for biodiversity and ecosystem services. 54 countries, including many of the Amazon Basin countries, have signed up to it, providing hope for long-term freshwater conservation in the region.

Integrating the unique needs of freshwater ecosystems into area-based strategies can improve conservation effectiveness, build climate resilience and sustain fisheries^{156,225}. A range of approaches can be used to prioritize which freshwater habitats to conserve. These include protecting fish hotspots based on key ecological criteria (irreplaceability, representativeness, and vulnerability to deforestation and habitat fragmentation by dams)²²⁷; prioritizing areas of high species richness and endemism¹; and adopting functional approaches that emphasize connectivity, for example to promote connectivity for migratory fishes or to link

existing protected areas²²⁸. Each approach highlights different results and identifies different sets of areas as critical for protection.

In parallel, expanding from local-scale actions to coordinated, transformative, catchment-scale management shows promise²²⁹. Locally developed co-management approaches—such as community-led initiatives such as fishing agreements—have demonstrated significantly higher species richness, density and biomass than in adjacent protected area zones. This framework of co-management can reconcile ecological and socioeconomic benefits, and provide evidence that encourages the conservation of freshwater ecosystems elsewhere too²³⁰. This is particularly important since preserving and restoring connectivity requires transnational efforts to protect sufficient habitats for species, especially migratory ones.

At the local scale, Indigenous knowledge highlights the importance of restoring *pepeaderos*: plants found around wetlands and in flooded forests that provide refuge, breeding and spawning habitats for fish. These plants attract numerous fish species, yet many have been cut down, underscoring the need for their restoration²³¹. A better understanding of the tight ecological link between freshwater ecosystems and riparian zones is essential for effective conservation in the Amazon. Recognizing this interdependence would guide land-use and fisheries management toward protecting riparian forests and restoring floodplains with native fruiting species, helping to rebuild fish food resources, support seed dispersal, and strengthen ecosystem resilience.

Action 5: Prevent and control invasions by non-native species

Effective prevention and control of non-native species requires a multidimensional strategy that addresses both risk mitigation and restoration of affected ecosystems. A critical first line of defense is the regulation and control of the species trade, including enhanced controls at key entry points such as ports and airports, with stricter penalties for violations. On the ground in the Amazon, actively engaging local communities in monitoring invasive species is also essential²³².

Control efforts should be targeted and context-specific to be effective. Direct eradication of invasive species, management of their spread through physical or chemical barriers, and restoration of affected habitats are all critical. However, interventions must be applied cautiously to avoid unintended negative effects on other species or on the wider ecosystem²³³.

Artificial intelligence (AI) is beginning to provide useful tools for managing invasive species, addressing complex challenges with greater efficiency and precision. It is already showing promise in early detection, the delimitation of affected areas, and the design of control and eradication strategies²³⁴. Future applications of AI are expected to involve more integrated and flexible models. The increasing accessibility of AI tools will foster interdisciplinary collaboration and help to integrate diverse data sources.





Action 6: Improve water quality in freshwater ecosystems

Improving water quality in freshwater ecosystems involves integrating modern science and technology with the traditional knowledge of Indigenous Peoples and local communities, who have long safeguarded these water worlds. Traditional agroforestry practices, such as the Chakras systems practiced by Kichwa communities in Ecuador's Amazon, help to maintain soil health and reduce erosion, thereby keeping rivers clean and healthy. Similarly, initiatives like Brazil's "Y Ikatu Xingu" campaign demonstrate that restoring riparian vegetation for carbon, freshwater and biodiversity can rehabilitate degraded headwaters, and implementing community-driven governance can strengthen local communities^{235,236}.

Protected areas and Indigenous territories also offer measurable benefits for freshwater quality and human health. Rivers flowing through these regions exhibit lower turbidity and electrical conductivity than those outside their boundaries, largely due to dense forest cover that filters sediments and regulates nutrient flows²³⁷. Beyond ecological benefits, evidence from 35 developing countries demonstrates that conserving upstream forests is closely linked to improved public health outcomes downstream²³⁸. Expanding and effectively managing these protected landscapes is therefore crucial to sustaining natural hydrological cycles, enhancing water quality, and supporting community well-being.

At the same time, urban wastewater pollution must be addressed. Many Amazonian towns and urban centers lack adequate sewage treatment, resulting in the discharge of pathogens and organic waste directly into rivers. Constructed wetlands, natural systems that use aquatic plants and microbes to filter water, offer an

affordable, low-maintenance solution well suited to the region's climate and geography²³⁹. Upgrading existing sanitation infrastructure and deploying decentralized treatment facilities could further reduce nutrient loads and disease risk in local water bodies.

While preventing contamination is always better than cleaning it up, new technologies are increasingly capable of treating water polluted by heavy metals and oil residues from mining and industrial activities. Nanotechnologies are already being used to remove contaminants from water²⁴⁰, while electrochemical water treatment and membrane filtration systems can further assist²⁴¹. In parallel, microbial and biofilm-based systems that degrade petroleum hydrocarbons offer low-energy, environmentally-friendly alternatives that complement engineering methods²⁴². These technologies should be deployed in already polluted areas, while the expansion of high-impact activities into pristine freshwater areas should be banned.

Finally, global commitments with measurable improvements to freshwater water quality, such as the Minamata Convention, are increasingly critical amid rising metal prices and persistent gaps in current water quality efforts²⁴³. Ultimately, improving water quality in the Amazon needs a layered strategy that combines coordinated basin-wide action with Indigenous stewardship, protected areas, sustainable production practices, technological innovation, modern sanitation and global engagement.

THE WAY FORWARD: TOWARD UNIFIED BASIN MANAGEMENT



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Key messages

- ~ **Think basin-wide:** The Amazon's health depends on transboundary cooperation and harmonized policies across all countries.
- ~ **Empower communities:** Indigenous Peoples and local communities are central to conservation; their rights, knowledge and governance systems must be respected.
- ~ **Conserve or, where needed, restore connectivity:** Embedding river connectivity into energy and infrastructure planning supports a green transition to environmentally sustainable, lowcarbon, and resource efficient development.
- ~ **Manage cumulative impacts:** Basin-scale management must account for the combined effects of multiple anthropogenic drivers—including dams, mines, roads, and land-use change. These interconnected pressures cannot be solved by addressing each driver in isolation; they require a holistic strategy to mitigate their synergistic impact on the ecosystem.
- ~ **Invest in monitoring and science:** Reliable data, community-led monitoring, science, and Indigenous and traditional knowledge are essential for co-management, adaptive management and policy action.
- ~ **Align global commitments:** Integrate freshwater ecosystems into the implementation of international waters, biodiversity and climate commitments, international finance priorities, and national development agendas.
- ~ **Act now:** The window to prevent irreversible losses is closing; coordinated action at local, national and international levels is urgent.

The Amazon Basin harbors the greatest diversity of freshwater life on Earth, in a single immense vascular system where water, sediments, nutrients and fish respect no political borders. Safeguarding its fishes and the freshwater ecosystems they inhabit requires a paradigm shift away from isolated national strategies and towards a unified, transboundary collaboration and governance framework. This must be anchored in collective action at a basin-wide level that is led by governments working hand-in-hand with Indigenous Peoples and local communities, academia, the private sector and civil society. This work is advanced at the transboundary, country and local levels, as described below.

Transnational and transboundary levels:

Effective conservation demands both coordinated and joint state action. This means close collaboration between national authorities, as well as the harmonization of legal frameworks, fisheries regulations, enforcement and monitoring protocols, and the creation of international fisheries agreements across Amazonian nations. The ACTO and some of the binational institutions operating in the region play a pivotal role in facilitating transboundary agreements to manage free-flowing rivers across borders, coordinate control of invasive species at ports of entry, design sustainable fishing guidelines, and establish joint protections for long-distance migratory routes—including as the region's collective contribution to the 30x30 target under the Convention on Biological Diversity. Strategic conservation planning must prioritize transnational ecological freshwater corridors, from source to sea, ensuring that critical habitats for fish are managed as part of the larger cohesive unit that is the Amazon river system, rather than as fragmented territories. The Amazonian Mechanism for Indigenous Peoples (MAPI), supported by ACTO, is a key platform for strengthening dialogue between the governments of the eight Member Countries and representative organizations of Amazonian

Indigenous Peoples. Its purpose is to ensure that Indigenous voices and knowledge are integrated into efforts to conserve free-flowing rivers and maintain healthy fisheries in the region.

Engaging stakeholders

Development banks and financial institutions play a critical role in ensuring that investments in the Amazon prioritize healthy and connected freshwater ecosystems. This requires development planning on a scale sufficient to account for cumulative or transboundary impacts, and to preserve the overall connectivity of the river-floodplains system, as well as strong environmental and social safeguards for infrastructure projects.

The **private sector** can drive environmentally responsible businesses that support local livelihoods and nature-positive outcomes. Activities such as fisheries (including ornamental fish) and tourism must ensure they protect biodiversity and avoid harmful practices.

For **donors**, the Amazon is a global conservation priority. Freshwater conservation must be explicitly included in this agenda, and more resources from climate funds redirected to ensure fish species and the ecosystems they depend on are not overlooked.

Academia contributes essential data and analysis to inform decision-making. Initiatives such as the **Science Panel for the Amazon** provide science-based recommendations for maintaining freshwater connectivity.

Civil society, NGOs, and grassroots movements play a key role in promoting and implementing actions for freshwater conservation, exposing the need to address key threats and advocating for policies that protect rivers and wetlands. They are essential in mobilizing funding and—particularly through networks such as the **Amazon Waters Alliance**—driving collective action.

A historic achievement for Amazonian catfish conservation

In February 2024, at the 14th Conference of the Parties (COP) of the Convention on Migratory Species (CMS), Brazil's proposal to include the *dourada* (*Brachyplatystoma rousseauxii*) and *piramutaba* (*Brachyplatystoma vaillantii*) in Appendix II was unanimously approved. This landmark decision strengthens the protection of two iconic Amazonian species and their critical habitats, paving the way for regional cooperation.

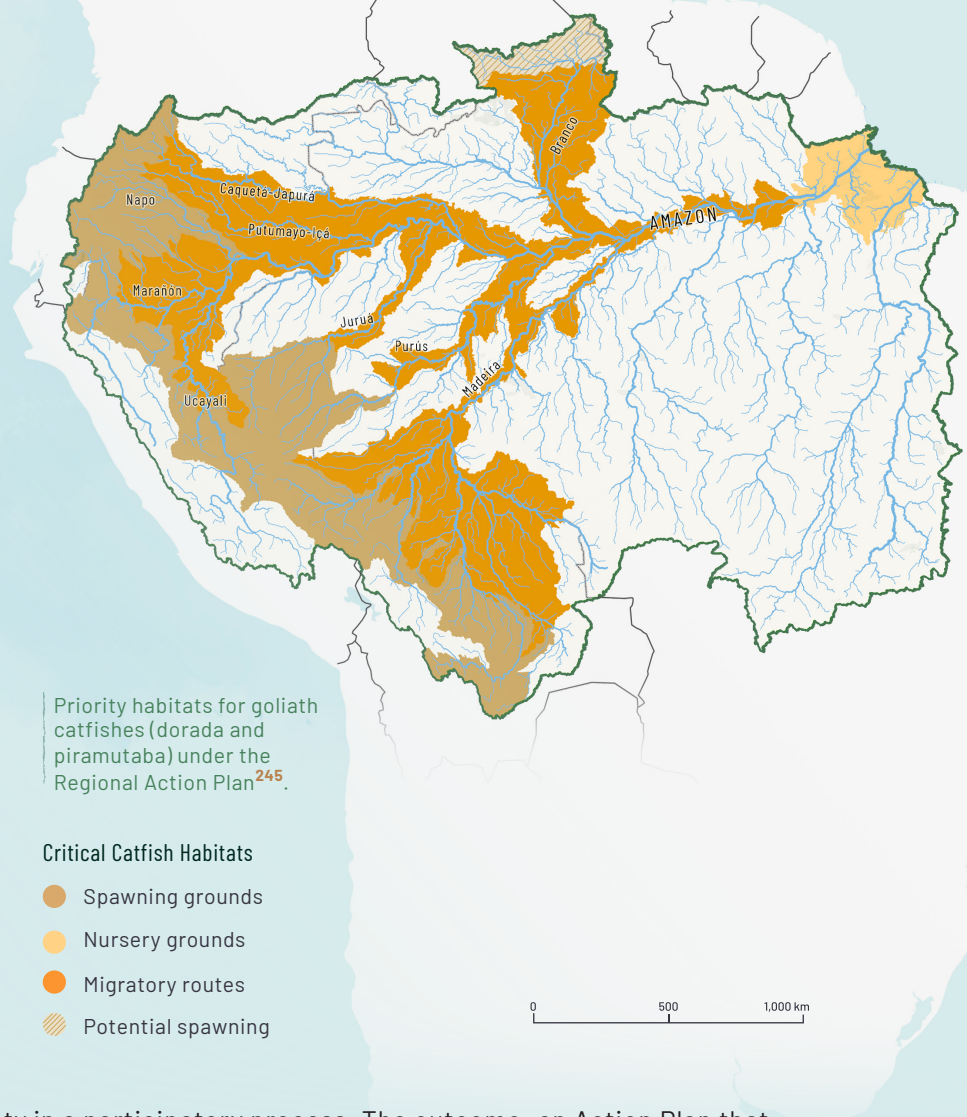
Following this inclusion, Amazonian countries committed to developing a Regional Action Plan under CMS guidelines. To drive implementation, the Amazon Waters Alliance convened a steering group, engaging governments, fishers, academia, international partners and civil society in a participatory process. The outcome: an Action Plan that, while initially focused on two species, is designed to benefit all Amazonian migratory catfish. This plan goes beyond fulfilling the Convention's mandate to foster regional agreements—it establishes a concrete mechanism for the sustainable management of migratory catfish across their entire range. It reinforces national initiatives, promotes technical and political dialogue among countries, and lays the foundation for the coordinated action that is essential to safeguard these iconic species.

The plan addresses critical threats—intensive fishing, dams, mining, deforestation, pollution and climate change—and is structured around five strategic objectives:

1. Protect key habitats for reproduction, migration and growth.
2. Generate and share knowledge to enable collaborative management.
3. Maintain river connectivity, integrating scientific and traditional knowledge.
4. Strengthen the catfish value chain, making it traceable, sustainable and fair by 2036.
5. Advance policies and regulations that ensure conservation and sustainable use.

Implementing this plan represents a historic opportunity to preserve the connectivity of Amazonian rivers, enhance ecosystem resilience, and deliver economic and food security benefits for millions of people across the region.

At COP15 CMS in 2026, the Regional Action Plan for these two species was formally endorsed, marking a major step forward in transboundary cooperation for Amazonian freshwater conservation. This achievement reflects a growing political commitment to freshwater biodiversity and reinforces the global relevance of the Amazon's migratory fish.

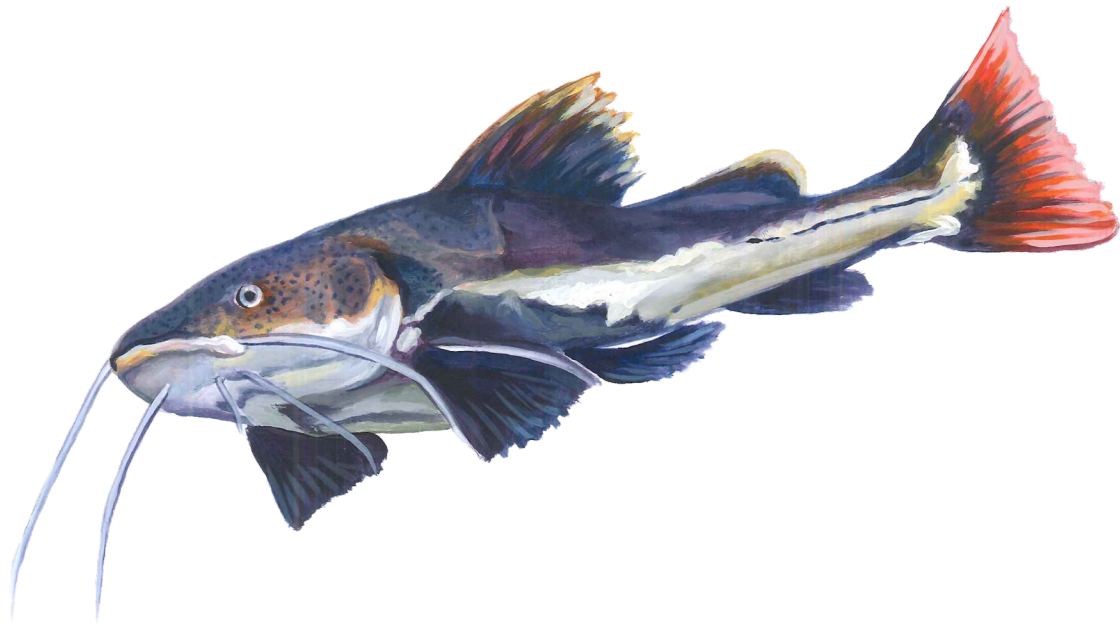


Country level: To promote thriving fish populations in the Amazon, governments must integrate freshwater biodiversity into their national and sub-national development agendas, National Biodiversity Strategies and Climate Adaptation Plans. Infrastructure decisions—such as those regarding dams and waterways—must undergo rigorous transboundary impact assessments to ensure that development in one nation does not degrade the freshwater resources of another. National policies must respect international law and be aligned with multilateral environmental commitments that support freshwater conservation, and funding mechanisms should be directed toward collaborative action that protects freshwater resources and research that bridges data gaps between countries.

Local level: Global, regional and national policies must ultimately empower local action. Co-management and community-led management have proven to be among the most effective tools for conservation, yet they often operate in isolation. Strengthening local

governance involves enforcing water rights for uses like fishing and tourism, legally recognizing fishing agreements, respecting territorial rights, and supporting freshwater conservation and community-led monitoring programs that utilize both scientific and Indigenous or traditional knowledge. For sustainable management success, these local initiatives must be connected through cross-border community networks, allowing stakeholders to manage shared stocks and habitats that straddle national frontiers.

Ultimately, the fate of the “forgotten fishes” of the Amazon relies on our ability to see the basin as they do: as one indivisible, flowing entity. By combining the ancestral stewardship and knowledge of its Indigenous Peoples and local communities with robust transboundary governance and collective action, we can ensure that the Amazon remains a connected and thriving freshwater system far into the future.



LIST OF BIBLIOGRAPHY

- 1 Jenkins, C. et al. Global importance of Amazonian freshwaters. *Front. Ecol. Environ.* 23, (2025).
- 2 Abad, J. et al. River Geomorphology and Fish Diversity Around the Manseriche Gorge, the Last Andean Crossing Is in Peril. *Water Resour. Res.* 60, (2024).
- 3 Abad, J. D. et al. Morphodynamics of anabranching structures in the Peruvian Amazon River. *Earth Surf. Process. Landf.* 50, (2024).
- 4 Souza, C. M. Jr. et al. Enhanced Amazon wetland map with multi-source remote sensing data. *Remote Sens.* 17, 3644 (2025). <https://doi.org/10.3390/rs1721364>
- 5 Torres-Bejarano, A. M., Sullivan, S. M. P., González-Daza, W., Cáceres, C. & Colorado Z, G. J. Riparian vegetation structure and seasonality influence functional diversity more than taxonomic diversity of stream fish assemblages in the Colombian Amazon. *Aquatic Ecology* 202156:156, 153–172 (2021).
- 6 Bogotá-Gregory, J. D. et al. Fishes from the Colombian Amazonia region: species composition from the river systems within the rainforest biome. *Biota Neotrop.* 22, (2022).
- 7 Sioli, H. The Amazon and its main affluents: Hydrography, morphology of the river courses, and river types. 127–165 (1984) doi:10.1007/978-94-009-6542-3.5.
- 8 Oberdorff, T. et al. Unexpected Fish Diversity Gradients in the Amazon Basin. www.amazon-fish.com (2019).
- 9 Jézéquel, C., Oberdorff, T., Tedesco, P. A. & Schmitt, L. Geomorphological diversity of rivers in the Amazon Basin. *Geomorphology* 400, (2022).
- 10 Fricke, R., Eschmeyer, W. N. & van der Laan, R. Eschmeyer's Catalog of Fishes: Genera, Species, References. (2025)
- 11 Pinna, M. DE, Zuanon, J., Rapp Py-daniel, L. & Petry, P. A New Family of Neotropical Freshwater Fishes from Deep Fossorial Amazonian Habitat, with a Reappraisal of Morphological Characteriform Phylogeny (Teleostei: Ostariophysi). *Zoological Journal of the Linnean Society* vol. 182 <https://academic.oup.com/zoolinnean/article-abstract/182/1/76/4080717> (2018).
- 12 Jézéquel, C. et al. Freshwater fish diversity hotspots for conservation priorities in the Amazon Basin. *Conservation Biology* 34, 956–965 (2020).
- 13 Dagosta, F. C. P. & Pinna, M. De. The Fishes of the Amazon: Distribution and Biogeographical Patterns, with a Comprehensive List of Species. *Bulletin of the American Museum of Natural History* vol. 431 1–163 Preprint at <https://doi.org/10.1206/0003-0090.431.1.1> (2019).
- 14 Su, G., Tedesco, P. A., Toussaint, A., Villéger, S. & Brosse, S. Contemporary environment and historical legacy explain functional diversity of freshwater fishes in the world rivers. *Global Ecology and Biogeography* 31, 700–713 (2022).
- 15 Herrera-R, G. A. et al. A synthesis of the diversity of freshwater fish migrations in the Amazon basin. *Fish and Fisheries* 25, 114–133 (2024).
- 16 Araujo-Lima, Carlos. & Goulding, Michael. So Fruitful a Fish : Ecology, Conservation, and Aquaculture of the Amazon's Tambaqui. (Columbia University Press, 1997).
- 17 Silva, E. A. & Stewart, D. J. Reproduction, feeding and migration patterns of *Prochilodus nigricans* (Characiformes: Prochilodontidae) in northeastern Ecuador. *Neotropical Ichthyology* 15, 1–13 (2017).
- 18 de Brito Ribeiro, M. C. L. & Junior, M. P. Fisheries ecology and management of the Jaraqui (*Semaprochilodus Taeniurus*, S. Insignis) in central Amazonia. *Regulated Rivers: Research & Management* 5, 195–215 (1990).
- 19 Barthem, R. B. et al. Goliath catfish spawning in the far western Amazon confirmed by the distribution of mature adults, drifting larvae and migrating juveniles. *Sci. Rep.* 7, (2017).
- 20 Barthem, R. & Goulding, M. Os Bagres Balizadores: Ecologia, Migração e Conservação de Peixes Amazônicos. (Sociedade Civil Mamiará, Tefé, 1997).
- 21 Hauser, M. et al. Unmasking continental natal homing in goliath catfish from the upper Amazon. *Freshw. Biol.* 65, 325–336 (2020).
- 22 Rodríguez, F. C. A. Arponeros de La Trampa Del Sol (Sustentabilidad de La Pesca Comercial En El Medio Río Caquetá). (1999).
- 23 Trujillo, L. A., Rodríguez, C. A. & Makurtofe, C. H. Piraiba: Ecología Ilustrada Del Gran Bagre Del Amazonas. (Tropenbos Colombia, 2018).
- 24 Carvalho, R. L. et al. Pervasive gaps in Amazonian ecological research. *Current Biology* 33, 3495–3504.e4 (2023).
- 25 Estivals, G. et al. The Amazonian dwarf cichlid *Apistogramma agassizii* (Steindachner, 1875) is a geographic mosaic of potentially tens of species: Conservation implications. *Aquat. Conserv.* 30, 1521–1539 (2020)
- 26 Dias, A. C. et al. Phylogenomic analyses in the complex Neotropical subfamily Corydoradinae (Siluriformes: Callichthyidae) with a new classification based on morphological and molecular data. *Zool. J. Linn. Soc.* 203, (2025).
- 27 Alexandrou, M. A. et al. Competition and phylogeny determine community structure in Müllerian co-mimics. *Nature* 469, 84–88 (2011).
- 28 Junk, W. J., Soares, M. G. M. & Bayley, P. B. Freshwater fishes of the Amazon River basin: Their biodiversity, fisheries, and habitats. *Aquatic Ecosystem Health and Management* vol. 10 153–173 Preprint at <https://doi.org/10.1080/14634980701351023> (2007).
- 29 Freitas, C. T. et al. Co-management of culturally important species: A tool to promote biodiversity conservation and human well-being. *People and Nature* 2, 61–81 (2020).
- 30 de Santana, C. D. et al. Unexpected species diversity in electric eels with a description of the strongest living bioelectricity generator. *Nat. Commun.* 10, 4000 (2019).
- 31 Bastos, D. A., Zuanon, J., Rapp Py-Daniel, L. & de Santana, C. D. Social predation in electric eels. *Ecol. Evol.* 11, 1088–1092 (2021).
- 32 Lúcia, M., De Araújo, G., Charvet-Almeida, P., Pinto Almeida, M. & Pereira, H. Freshwater Stingrays (Potamotrygonidae): status, conservation and management challenges. *CITES AC20 Inf.* 8, (2004).
- 33 COICA. Coordinadora de las Organizaciones Indígenas de la Cuenca Amazónica ¿Quiénes somos? Available at: <https://coicamazonia.org/quienes-somos/>. (2016).
- 34 Lima, A. dos S., Mello, A. A. S. & Sousa, R. M. de. Amazonia: the last surviving Amazonian indigenous languages. Preprint at <https://doi.org/10.33774/coe-2020-hmm80> (2020).
- 35 Costa, G., Weiss, B. & Piedade, M. T. F. Larger Fish Disperse Larger Seeds in Oligotrophic Wetlands of the Central Amazon. *Wetlands* 44, 18 (2024).
- 36 de Moraes, R. J., Small, G. E., Caramori, S. S. & Teresa, F. B. The Role of Fish in Nutrient Recycling Across a Conservation Gradient in Neotropical Streams. *Freshw. Biol.* 70, (2025).
- 37 Correa, S. B. & Winemiller, K. Terrestrial-aquatic trophic linkages support fish production in a tropical oligotrophic river. *Oecologia* 186, 1069–1078 (2018).
- 38 He, F. et al. Freshwater megafauna diversity: Patterns, status and threats. *Divers. Distrib.* 24, 1395–1404 (2018).
- 39 Damasceno, S. J., Delponte, J. C. & Shiralwa, M. C. S. Dietary Adaptability of the Giant Otter, *Pteronura brasiliensis* (Mammalia: Mustelidae), in two Floodplain Systems in the Pantanal Wetland, Mato Grosso State, Brazil. *IUCN Otter Spec. Group Bull* 38, (2021).
- 40 Echeverría, A. et al. Trophic ecology of Amazonian River dolphins from three rivers in Brazil and Bolivia. *Mammalian Biology* 2022 102:5 102, 1687–1696 (2022).
- 41 Juárez-Sánchez, D., Blake, J. G. & Hellgren, E. C. Variation in Neotropical river otter (*Lontra longicaudis*) diet: Effects of an invasive prey species. *PLoS One* 14, e0217727 (2019).
- 42 Pardini, R. Feeding ecology of the neotropical river otter *Lontra longicaudis* in an Atlantic Forest stream, south-eastern Brazil. *J. Zool.* 245, S0952836998008024 (1998).
- 43 Correa, S. B., Costa-Pereira, R., Fleming, T., Goulding, M. & Anderson, J. T. Neotropical fish-fruit interactions: Eco-evolutionary dynamics and conservation. *Biological Reviews* 90, 1263–1278 (2015).
- 44 Correa, S. B. et al. Floodplain forests drive fruit-eating fish diversity at the Amazon Basin-scale. *Proc. Natl. Acad. Sci. U. S. A.* 122, (2025).
- 45 Prestes, L. et al. Proactively averting the collapse of Amazon fisheries based on three migratory flagship species. *PLoS One* 17, (2022).
- 46 Araujo-Lima, C. A. R. M., Goulding, M., Forsberg, B., Victoria, R. & Martinelli, L. The

- economic value of the Amazonian flooded forest from a fisheries perspective. *SIL Proceedings*, 1922-2010 26, 2177-2179 (1998).
- 47 Begossi, A. et al. Fish consumption on the Amazon: a review of biodiversity, hydropower and food security issues. *Brazilian Journal of Biology* 79, 345-357 (2019).
- 48 Miranda, L. N. L. Do rio para o prato: o que influencia o consumo de peixe na Amazônia? (Universidade Federal de Minas Gerais, Belo Horizonte, 2024).
- 49 Ministerio de la Producción. Patrones de Consumo de Productores Hidrobiológicos En El Perú: Una Aproximación Con La Encuesta Nacional de Hogares. (2015).
- 50 Isaac, V. J. & Almeida, M. C. El Consumo Del Pescado En La Amazonia Brasileña. (2011).
- 51 Isaac, V. J. et al. Food consumption as an indicator of the conservation of natural resources in riverine communities of the Brazilian Amazon. *An. Acad. Bras. Cienc.* 87, 2229-2242 (2015).
- 52 Heilpern, S. et al. Accessible, low-mercury, and nutritious fishes provide win-wins for conservation and public health. *One Earth* 8, 101174 (2025).
- 53 Barthem, R. B. & Fabrê, N. N. Biologia e diversidade dos recursos pesqueiros da Amazônia. In *A pesca e os recursos pesqueiros na Amazônia brasileira* (ed. Ruffino, M. L.) 11-55 (MMA/IBAMA, Brasília, 2004).
- 54 Coates, D. et al. The Role and Potential of Inland Fisheries in Low-Emission Food Production and Climate Change Mitigation. (FAO, Rome, 2025). doi:10.4060/cd4601en.
- 55 Alencar, E. F. & Souza, I. S. Women in the management of fisheries resources in the middle Solimões region, Amazon: biodiversity conservation, access to income and fisheries resilience. *Revista do PPGCS - UFRB - Novos Olhares Sociais* 4, (2021).
- 56 Athayde, S. et al. Interdependencies between Indigenous peoples, local communities, and freshwater systems in a changing Amazon. *Conservation Biology* 39, (2025).
- 57 Magüta Museum, n. d. Permanent exhibit about the Magüta (Tikuna) people. .
- 58 Pinilla, N. H., Vásquez, A. & Martínez, C. Historias Tikunas de Las Selvas Del Amacayacu. Plantas, Seres y Saberes. (Organización Yulik Airu, 1997).
- 59 Fernandes, D. 'More Eyes Watching' Community-based Management of the Arapaima (*Arapaima gigas*) in Central Guyana. Preprint at <https://hdl.handle.net/10535/711> (2006).
- 60 Toledo, V. M. & Barrera-Bassols, N. La Memoria Biocultural. La Importancia Ecológica de Las Sabidurías Tradicionales. (Icaria Editorial, Barcelona, Spain, 2008).
- 61 Orth, D. Fish, Fishing, and Conservation. *Fish, Fishing, and Conservation* (Virginia Tech Publishing, 2023). doi:10.21061/fishandconservation.
- 62 Associação Intercomunitária Painu. Painu: Turismo comunitario indígena. (2025).
- 63 Hayes, T. & Murtinho, F. Diagnosing Participation and Inclusion in Collective Decision-Making in the Commons: Lessons from Ecuador. *Int. J. Commons* 17, 37 (2023).
- 64 Barthem, R. B. & Goulding, M. Um Ecossistema Inesperado: A Amazônia Revelada Pela Pesca. (Grafica Biblos, Lima, Perú, 2007).
- 65 Duponchelle, F. et al. Conservation of migratory fishes in the Amazon basin. *Aquat. Conserv.* 1-19 (2021) doi:10.1002/aqc.3550.
- 66 Bayley, P. B. Aquatic productivity in the central amazon várzea in the context of the fishery yield. in *I Simpósio do Trópico Úmido* 325-334 (1984).
- 67 MPA. Boletim Estatístico Da Pesca e Aquicultura. (2025).
- 68 Buck, C. Í. et al. 26 Anos Do Manejo de Pirarucu No Estado Do Amazonas: Aprendizados e Desafios de Um Modelo de Gestão Compartilhada. (2025).
- 69 Duarte, L. et al. Estadísticas de Desembarco y Esfuerzo de Las Pesquerías Artesanales de Colombia - Enero a Octubre de 2022. (2022).
- 70 Batista, V. D. S., Isaac, V. J. & Viana, J. P. Exploração e manejo dos recursos pesqueiros da Amazônia. in *A pesca e os recursos pesqueiros na Amazônia* (ed. Ruffino, M.) 63-151 (Ibama, Brasília, 2004).
- 71 Silva, P. B., Arantes, C. C., Freitas, C. E. C., Petrer, M. & Ribeiro, F. R. V. Seasonal hydrology and fish assemblage structure in the floodplain of the lower Amazon River. *Ecol. Freshw. Fish* 30, 162-173 (2021).
- 72 Lowe-McConnell, R. Estudos Ecológicos de Comunidades de Peixes Tropicais. (EDUSP, São Paulo, 1999).
- 73 Ruffino, M. L. Status and Trends of the Fishery Resources of the Amazon Basin in Brazil. Inland fisheries evolution and management. case studies from four continents. *FAO Technical Paper* (2014).
- 74 Batista, V. da S. & Petrer, Júnior, M. Characterization of the commercial fish production landed at Manaus, Amazonas State, Brazil. *Acta Amazon.* 33, 53-66 (2003).
- 75 IBAMA. Estatística Da Pesca 2005 Brasil: Grandes Regiões e Unidades Da Federação. (2006).
- 76 Oliveira, D. M., Frédou, T. & Lucena, F. A pesca no Estuário Amazônico: uma análise uni e multivariada. *Boletim do Museu Paraense Emílio Goeldi Ciências Naturais* 2, 11-21 (2007).
- 77 DIREPRO-LORETO. Anuario Estadístico de La Producción Pesquera En Loreto, Gobierno Regional. www.produce.gob.pe (2019).
- 78 Garcia, A., Tello, S., Vargas, G. & Duponchelle, F. Patterns of commercial fish landings in the Loreto region (Peruvian Amazon) between 1984 and 2006. *Fish Physiol. Biochem.* 35, 53-67 (2009).
- 79 PRODUCE. Anuario Estadístico Pesquero y Acuicola. www.produce.gob.pe (2020).
- 80 Doria, C. R. da C., Ruffino, M. L., Hijazi, N. C. & Cruz, R. L. da. A pesca comercial na bacia do rio Madeira no estado de Rondônia, Amazônia brasileira. *Acta Amazon.* 42, 29-40 (2012).
- 81 Doria, C. R. da C., Lima, M. A. L. & Angelini, R. Ecosystem indicators of a small-scale fisheries with limited data in Madeira river (Brazil). *Boletim do Instituto de Pesca* 44, (2018).
- 82 Carruthers, T. R. et al. Evaluating methods for setting catch limits in data-limited fisheries. *Fish. Res.* 153, 48-68 (2014).
- 83 Doria, C. C. R. The potential of citizen science to assess migratory patterns of Amazon fish. *Neotropical Hydrobiology and Aquatic Conservation* 3, (2022).
- 84 Silva, F. et al. Amazon Fisheries: Mapping Management and Monitoring Initiatives. (2025).
- 85 Almeida, O. T., Lorenzen, K. & McGrath, D. G. Fishing agreements in the lower Amazon: For gain and restraint. *Fish. Manag. Ecol.* 16, 61-67 (2009).
- 86 Campos-Silva, J. V. & Peres, C. A. Community-based management induces rapid recovery of a high-value tropical freshwater fishery. *Sci. Rep.* 6, (2016).
- 87 Medeiros-Leal, W. M., Castello, L., Freitas, C. E. C. & Siqueira-Souza, F. K. Single-Species Co-management Improves Fish Assemblage Structure and Composition in a Tropical River. *Front. Ecol. Evol.* 9, (2021).
- 88 Miorando, P. S., Rebêlo, G. H., Pignati, M. T. & Brito Pezzuti, J. C. Effects of community-based management on amazon river turtles: A case study of podocnemis sextuberculata in the Lower Amazon Floodplain, Pará, Brazil. *Chelonian Conservation and Biology* 12, 143-150 (2013).
- 89 IBAMA. Instrução Normativa 35, de 18 de Junho de 2004. <http://www.ibama.gov.br/category/40?download=2588%3A34-2004-p-.pdf> (accessed 3 April 2015) (Brazil, 2004).
- 90 IBAMA. Projeto Iara. Administração dos Recursos Pesqueiros do Médio Amazonas: Estados do Pará e Amazonas. Série Estudos de Pesca. Preprint at (1995).
- 91 Castello, L., Arantes, C. C., McGrath, D. G., Stewart, D. J. & Sousa, F. S. De. Understanding fishing-induced extinctions in the Amazon. *Aquat. Conserv.* 25, 587-598 (2015).
- 92 Santos, F. W. M. Comércio internacional de peixes ornamentais no Brasil: uma análise sob a perspectiva das políticas brasileiras de ordenamento pesqueiro. (Universidade Federal de Santa Catarina, Florianópolis, SC, 2013).
- 93 Ajiaco Martinez, R. Elena., Ramirez Gil, Hernando., Sánchez-Duarte, Paula., Lasso, C. A. & Trujillo, Fernando. Diagnóstico de La Pesca Ornamental En Colombia. (Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, 2012).
- 94 Prang, G. Industry analysis of the freshwater ornamental fishery with particular reference to the supply of Brazilian freshwater ornamentals to the UK market. *Scientific Magazine UAKARI* 3, 7-52 (2008).
- 95 Batista, D., Tavares-Dias, M., Fujimoto, R. & Martins, M. Amazonian Ornamental Fish: Diversity, Reproduction, and Commercial Applications. (AQUOS/UFSC, Florianópolis, 2025).
- 96 Tribuzy-Neto, I. A., Beltrão, H., Benzaken, Z. & Yamamoto, K. C. Analysis of the ornamental fish exports from the Amazon State, Brazil. *Boletim do Instituto de Pesca* 46, (2021).
- 97 Legiscomex. Estadísticas de Comercio Exterior. (2025).
- 98 AUNAP. Resolución 1924 de 2015. Autoridad Nacional de Acuicultura y pesca. Available from: <https://aunap.gov.co/download/resolucion-numero-1924-3-no-viembre-2015/> (2015).
- 99 Ministerio del Ambiente de Perú. Línea de Base de Los Peces Ornamentales Con Fines de Bioseguridad En El Perú. Available from: <https://Bioseguridad.Minam.Gob.Pe/Wp-Content/Uploads/2021/12/Ldb-pecesornam-2021.Pdf>. www.gob.pe/minam (2021).
- 100 Tello, J. S. & Canepa, J. R. Estado actual de la explotación de los principales peces ornamentales de la Amazonia Peruana. *Folia Amazónica* 3, 107-128 (1991).
- 101 AUNAP. Respuesta a Derecho de Petición (Radicado S2025 NC 00257)[AUNAP-OAJ- 387-2025]. (2025).
- 102 García-Dávila, C. et al. Peces Ornamentales de La Amazonia Peruana. Instituto de Investigaciones de la Amazonia Peruana (Instituto de Investigaciones de la Amazonia Peruana, 2021).

- 103 Dey, V. The Global Trade in Ornamental Fish. <https://pt.scribd.com/document/384726219/GLOBAL-TRADE-IN-ORNAMENTAL-FISH-pdf> (2016).
- 104 Evers, H. G., Pinnegar, J. K. & Taylor, M. I. Where are they all from? Sources and sustainability in the ornamental freshwater fish trade. *J. Fish Biol.* 94, 909–916 (2019).
- 105 Domínguez, L. M. & Botella, Á. S. An overview of marine ornamental fish breeding as a potential support to the aquarium trade and to the conservation of natural fish populations. *International Journal of Sustainable Development and Planning* 9, 608–632 (2014).
- 106 Raghavan, R. et al. Uncovering an obscure trade: Threatened freshwater fishes and the aquarium pet markets. *Biol. Conserv.* 164, 158–169 (2013).
- 107 Römer, U. et al. *Apistogramma cinilabra* sp. n.: Description of a potentially endangered endemic cichlid species (Teleostei: Perciformes: Cichlidae) from the Departamento Loreto, Peru. *Vertebr. Zool.* 61, 113–135 (2011).
- 108 CITES. Convention on International Trade in Endangered Species of Wild Fauna and Flora. Appendices I, II and III. Available in <https://cites.org/eng/app/appendices.php> (2025).
- 109 Beltrão, H., Magalhães, E. R. S., Benzaken, Z. S. & Sousa, R. G. C. Trafficking of ornamental fish in the Brazilian Amazon. *Boletim do Instituto de Pesca* 47, (2021).
- 110 Suárez Pizarro, M. G. Rol de la mujer en la pesca ornamental en la cuenca alta media y baja del río Nanay Loreto Perú. Preprint at <https://hdl.handle.net/20.500.12737/10013> (2023).
- 111 WCS. Género y Pesquerías En La Amazonia: Una Aproximación al Rol y Participación de Las Mujeres y Población LGTBIQ En La Pesca y Sus Conflictos En La Región Loreto. (2021).
- 112 Estupiñán, G. et al. A pesca artesanal e o turismo de pesca no médio rio Negro. in 139–159 (2022).
- 113 Barroco, L., Lubich, C. & Vasconcelos, M. Pesca esportiva na Amazônia: um enfoque para a sustentabilidade dos estoques pesqueiros. in *Pesca Amadora no Brasil: Um panorama sobre estudos, políticas públicas e desafios de gestão* (eds. Garrone Neto, D., Gomes, A., Freitas, T. & Motta, F.) 279–296 (Natureza em Foco, Brasília, 2025).
- 114 Lubich, C., Campos, C., Freitas, C. & Siqueira-Souza, F. Effects of Fishing on the Population of Speckled Pavon Cichla temensis in the Middle Negro River (Amazonas State, Brazil): A Decrease in the Size of the Trophy Fish? *Trans. Am. Fish. Soc.* 150, 667–678 (2021).
- 115 Thomé-Souza, M. J. F., Maceina, M. J., Forsberg, B. R., Marshall, B. G. & Carvalho, Á. L. Peacock bass mortality associated with catch-and-release sport fishing in the Negro River, Amazonas State, Brazil. *Acta Amazon.* 44, 527–532 (2014).
- 116 Barroco, L. S. A., Freitas, C. E. C. & Lima, Á. C. Estimation of peacock bass (*Cichla* spp.) mortality rate during catch-release fishing employing different post-capture procedures. *Brazilian Journal of Biology* 78, 195–201 (2017).
- 117 Crepaldi, D. & Zeinad, A. A pesca esportiva em áreas protegidas da Amazônia brasileira. . in *Pesca amadora no Brasil: um panorama sobre estudos, políticas públicas e desafios de gestão* (eds. Garrone Neto, D., Gomes, A., Freitas, T. & Motta, F.) 205–225 (Natureza em Foco, Brasília, 2025).
- 118 PORTARIA GM/MMA Nº 1.667, DE 27 DE ABRIL DE 2026. (2026)
- 119 MMADS. Resolución 0126 de 06 de Febrero de 2024. Ministerio de Ambiente y Desarrollo Sostenible. Preprint at (2024).
- 120 MMAA. Libro Rojo de La Fauna Silvestre de Vertebrados de Bolivia. Ministerio de Medio Ambiente y Agua. 571 (La Paz, Bolivia, 2009).
- 121 MA. Acuerdo Ministerial 069 de 23 de Julio de 2019. Ministerio Del Ambiente . (2019).
- 122 Aguirre, W. et al. Lista Roja Nacional de peces de agua dulce de Ecuador. <https://doi.org/10.60545/HIHUMM> (2019) doi:10.60545/HIHUMM.
- 123 IUCN. The IUCN Red List of Threatened Species. Version 2025-2. <https://www.iucnredlist.org> (2026).
- 124 Fukakusa, C. K. et al. Ficha de *Hypsolebias marginatus*. Datasets - Sistema SALVE - ICMBio Preprint at <https://doi.org/10.37002/salve.ficha.25829.2> (2026).
- 125 Fukakusa, C. K. et al. Ficha de *Moema piriana*. Datasets - Sistema SALVE - ICMBio Preprint at <https://doi.org/10.37002/salve.ficha.25799.2> (2026).
- 126 Borgelt, J., Dorber, M., Høiberg, M. A. & Verones, F. More than half of data deficient species predicted to be threatened by extinction. *Communications Biology* 2022 5:15, 679–(2022).
- 127 López-Casas, S. et al. El repoblamiento como estrategia de manejo pesquero y su rol en la dilación del manejo de los ecosistemas acuáticos. *Rev. Biol. Trop.* 72, e57639 (2024).
- 128 Thompson, M. S. A. et al. Large woody debris “rewilding” rapidly restores biodiversity in riverine food webs. *Journal of Applied Ecology* 55, 895–904 (2018).
- 129 Bega, J. M. M., Saltarelli, W. A., Furlley, T. H., dos Reis Oliveira, P. C. & Cunha, D. G. F. Potential use of wood addition for restoring ecosystem metabolism and nutrient uptake in a subtropical river. *Ecohydrology & Hydrobiology* 25, 100665 (2025).
- 130 Correa, S. B. & Winemiller, K. Terrestrial-aquatic trophic linkages support fish production in a tropical oligotrophic river. *Oecologia* 2018 186:4 186, 1069–1078 (2018).
- 131 Crook, D. A. & Robertson, A. I. Relationships between riverine fish and woody debris: implications for lowland rivers. *Mar. Freshw. Res.* 50, 941–953 (1999).
- 132 Ilha, P., Schiesari, L., Yanagawa, F. I., Jankowski, K. J. & Navas, C. A. Deforestation and stream warming affect body size of Amazonian fishes. *PLoS One* 13, e0196560 (2018).
- 133 Lo, M. et al. The Influence of Forests on Freshwater Fish in the Tropics: A Systematic Review. *Bioscience* 70, 404 (2020).
- 134 Blevins, Z. W., Effert, E. L., Wahl, D. H. & Suski, C. D. Land use drives the physiological properties of a stream fish. *Ecol. Indic.* 24, 224–235 (2013).
- 135 Renó, V. F., Novo, E. M. L. M., Suemitsu, C., Rennó, C. D. & Silva, T. S. F. Assessment of deforestation in the Lower Amazon floodplain using historical Landsat MSS/TM imagery. *Remote Sens. Environ.* 115, 3446–3456 (2011).
- 136 Souza, C. M. et al. Enhanced Amazon Wetland Map with Multi-Source Remote Sensing Data. *Remote Sens. (Basel)*. 17, 3644 (2025).
- 137 Beveridge, C. F. et al. The Andes–Amazon–Atlantic pathway: A foundational hydroclimate system for social–ecological system sustainability. *Proc. Natl. Acad. Sci. U. S. A.* 121, (2024).
- 138 Pusey, B. J. & Arthington, A. H. Importance of the riparian zone to the conservation and management of freshwater fish: A review. *Mar. Freshw. Res.* 54, 1–16 (2003).
- 139 Correa, S. B. & Winemiller, K. O. Niche partitioning among frugivorous fishes in response to fluctuating resources in the Amazonian floodplain forest. *Ecology* 95, 210–224 (2014).
- 140 Bojsen, B. H. Diet and condition of three fish species (Characidae) of the Andean foothills in relation to deforestation. *Environmental Biology of Fishes* 2005 73:1 73, 61–73 (2005).
- 141 Fabre, N. & Alonso, J. Recursos Icticos no Alto Amazonas: Sua Importância para as populações ribeirinhas. *Boletim do Museu Paraense Emílio Goeldi* 1, 19–55 (1998).
- 142 Bunn, S. E. & Arthington, A. H. Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. *Environ. Manage.* 30, 492–507 (2002).
- 143 Anderson, E. P. et al. A baseline for assessing the ecological integrity of Western Amazon rivers. *Communications Earth & Environment* 2025 6:16, 623–(2025).
- 144 Welcomme, R. L. River fisheries (No 262). FAO Fisheries Technical Paper 330 (1985).
- 145 Junk, W. J., Bayley, P. B. & Sparks, R. E. The flood pulse concept in river-floodplain systems. Canadian special publication of fisheries and aquatic sciences 106, 110–127 (1989).
- 146 López-Casas, S. Magdalena potamodromous migrations: effects of regulated and natural hydrological regimes. (Universidad de Antioquia, 2015).
- 147 Lowe-McConnell, R. H. & Halls, A. S. Dependence of tropical river fisheries on flow. in *Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries Volume 2* (eds. Welcomme, R. L. & Petr, T.) 267–285 (Food and Agriculture Organization of the United Nations & Mekong River Commission. FAO Regional Office for Asia and the Pacific, Bangkok, 2004).
- 148 De Vocht, A. & Baras, E. Effect of hydropeaking on migrations and home range of adult barbel (*Barbus barbus*) in the River Meuse. in *Aquatic Telemetry: Advances and Applications. Proceedings of the Fifth Conference on Fish Telemetry held in Europe* (eds. Spedicato, M. T., Lembo, G. & Marmulla, G.) 35–44 (FAO/COISPA, Ustica, 2003).
- 149 Junk, W. J. & Wantzen, K. M. The Flood Pulse Concept: New Aspects, Approaches and Applications - An Update. in *Second International Symposium on the Management of Large Rivers for Fisheries Volume 1* (ed. Food and Agriculture Organization of the United Nations & Mekong River Commission. FAO Regional Office for Asia and the Pacific, B.) vol. 116–140 (RAP Publication 2004/16, 2004).
- 150 Alianza Aguas Amazónicas. Humedales: La cuenca Amazónica, un gran humedal. <https://aguasamazonicas.org/humedales> (2020).
- 151 Caldas, B. et al. Identifying the current and future status of freshwater connectivity corridors in the Amazon Basin. *Conserv. Sci. Pract.* 5, (2023).
- 152 Anderson, E. P. et al. Energy development reveals blind spots for ecosystem conservation in the Amazon Basin. *Front. Ecol. Environ.* 17, 521–529 (2019).
- 153 Flecker, A. S. et al. Reducing adverse impacts of Amazon hydropower expansion. *Science* (1979). 375, 753–760 (2022).

- 154 De Fex-Wolf, D., López-Casas, S. & Jiménez-Segura, L. F. Hydropower effects on *Prochilodus magdalenae* (Prochilodontidae) reproduction: evidence from endocrine response. *Rev. MVZ Córdoba* 24, 7180–7187 (2019).
- 155 Hauser, M. et al. Quantitative impacts of hydroelectric dams on the trans-Amazonian migrations of goliath catfish. *Conserv. Lett.* 17, (2024).
- 156 de Souza, A. L. M. et al. Impacts of Hydroelectric Dams on Amazonian Fisheries: Assessing Functional Attributes in the Madeira River. *River Res. Appl.* 41, 1493–1502 (2025).
- 157 Castello, L. et al. The vulnerability of Amazon freshwater ecosystems. *Conserv. Lett.* 6, 217–229 (2013).
- 158 Castello, L. & Macedo, M. N. Large-scale degradation of Amazonian freshwater ecosystems. *Glob. Chang. Biol.* 22, 990–1007 (2016).
- 159 Bayley, P. B. & Petrere, M. P. Amazon fisheries: Assessment methods, current status and management options. in *Proceedings of the International Large River Symposium* (Honey Harbour, 1989).
- 160 Pauly, D., Christensen, V., Dalsgaard, J., Froese, R. & Torres, F. Fishing Down Marine Food Webs. *Science* (1979). 279, 860–863 (1998).
- 161 Heilpern, S. A. et al. Biodiversity underpins fisheries resilience to exploitation in the Amazon river basin. *Proceedings of the Royal Society B: Biological Sciences* 289, (2022).
- 162 Araújo, J. G. de, Santos, M. A. S. dos, Rebello, F. K. & Isaac, V. J. Cadeia comercial de peixes ornamentais do Rio Xingu, Pará, Brasil. *Boletim do Instituto de Pesca* 43, 297–307 (2017).
- 163 Sousa, L. M. de, Lucanar, O., Arroyo-Mora, J. P. & Kalacska, M. Conservation and trade of the endangered *Hypancistrus zebra* (Siluriformes, Loricariidae), one of the most trafficked Brazilian fish. *Glob. Ecol. Conserv.* 27, e01570 (2021).
- 164 Moreau, M. A. & Coomes, O. T. Aquarium fish exploitation in western Amazonia: Conservation issues in Peru. *Environ. Conserv.* 34, 12–22 (2007).
- 165 Salvador, G. *Osteoglossum bicirrhosum*. IUCN Red List of Threatened Species Preprint at https://doi.org/10.2305/IUCN.UK.2023-1.RLTS.T49830060A85282193_en (2023).
- 166 IUCN/SSC. Guidelines for the Prevention of biodiversity loss caused by alien invasive species. Gland, Switzerland: IUCN Species Survival Commission., International Union for the Conservation of Nature, Gland, Switzerland. 25 (2000).
- 167 Contreras-Balderas, S. et al. Freshwater fishes and water status in México: A country-wide appraisal. *Aquat. Ecosyst. Health Manag.* 11, 246–256 (2008).
- 168 Chichorro, F., Juslén, A. & Cardoso, P. A review of the relation between species traits and extinction risk. *Biol. Conserv.* 237, 220–229 (2019).
- 169 Jan, A., Arismendi, I. & Giannico, G. Double Trouble for Native Species Under Climate Change: Habitat Loss and Increased Environmental Overlap With Non-Native Species. *Glob. Chang. Biol.* 31, (2025).
- 170 Doria, C. R. da C. et al. The Silent Threat of Non-native Fish in the Amazon: ANNF Database and Review. *Front. Ecol. Evol.* 9, (2021).
- 171 Miranda-Chumacero, G. et al. Distribution of arapaima (*Arapaima gigas*) (Pisces: Arapaimatidae) in Bolivia: implications in the control and management of a non-native population. 1, 129–138 (2012).
- 172 Damme, P. A. Van et al. The expansion of *Arapaima cf. gigas* (Osteoglossiformes: Arapaimidae) in the Bolivian Amazon as informed by citizen and formal science. *Management of Biological Invasions* 6, 375–383 (2015).
- 173 Rejas, D., Oberdorff, T., Declerck, S. A. J. & Winder, M. The introduced *Arapaima gigas* in the Bolivian Amazon: Trophic position and isotopic niche overlap with native species. *Ecol. Freshw. Fish* 32, 926–937 (2023).
- 174 Malik, D. S., Sharma, A. K., Sharma, A. K., Thakur, R. & Sharma, M. A review on impact of water pollution on freshwater fish species and their aquatic environment. in *Advances in Environmental Pollution Management: Wastewater Impacts and Treatment Technologies* 10–28 (Agro Environ Media – Agriculture and Environmental Science Academy, Haridwar, India, 2020). doi:10.26832/aesa-2020-aepm-02.
- 175 de Sousa, R. S. et al. Connections among Land Use, Water Quality, Biodiversity of Aquatic Invertebrates, and Fish Behavior in Amazon Rivers. *Toxics* 10, 182 (2022).
- 176 Lovgren, S. Brazil Amazon fires threaten river habitat of thousands of fish species. National Geographic https://www.nationalgeographic.com/environment/article/amazon-fires-brazil-threaten-fish?utm_source=chatgpt.com (19AD).
- 177 Cohen, A. S., Bills, R., Cocquyt, C. Z. & Caljon, A. G. The Impact of Sediment Pollution on Biodiversity in Lake Tanganyika. *Conservation Biology* 7, 667–677 (1993).
- 178 Ribeiro-Brasil, D. R. G. et al. Contamination of stream fish by plastic waste in the Brazilian Amazon. *Environmental Pollution* 266, 115241 (2020).
- 179 Sadauskas-Henrique, H. et al. Oil spill in an amazon blackwater environment: Biochemical and physiological responses of local fish species. *Environ. Res.* 250, 118347 (2024).
- 180 Azevedo-Santos, V. M. et al. Amazon aquatic biodiversity imperiled by oil spills. *Biodiversity and Conservation* vol. 25 2831–2834 Preprint at <https://doi.org/10.1007/s10531-016-1192-9> (2016).
- 181 Barreto, L. S., Souza, A. T. da C., Martins, C. C., Araujo, S. B. L. & Oliveira Ribeiro, C. A. de. Urban effluents affect the early development stages of Brazilian fish species with implications for their population dynamics. *Ecotoxicol. Environ. Saf.* 188, 109907 (2020).
- 182 Nagamatsu, P. C. et al. Post hatching stages of tropical catfish *Rhamdia quelen* (Quoy and Gaimard, 1824) are affected by combined toxic metals exposure with risk to population. *Chemosphere* 277, 130199 (2021).
- 183 Sierra-Marquez, L., Espinosa-Araujo, J., Atencio-Garcia, V. & Olivero-Verbel, J. Effects of cadmium exposure on sperm and larvae of the neotropical fish *Prochilodus magdalenae*. *Comparative Biochemistry and Physiology Part – C: Toxicology and Pharmacology* 225, 108577 (2019).
- 184 Andrade, M. C. et al. First account of plastic pollution impacting freshwater fishes in the Amazon: Ingestion of plastic debris by piranhas and other serrasalmids with diverse feeding habits. *Environmental Pollution* 244, 766–773 (2019).
- 185 ZINK, L., VAL, A. L. & WOOD, C. M. Perspectives on the impact of microplastics (MPs) on fish of the Amazon that exhibit air-breathing and aquatic surface respiration. *An. Acad. Bras. Cienc.* 97, (2025).
- 186 Programme, U. N. E. Global Mercury Assessment 2018. UN Environment Programme, Chemicals and Health Branch vol. 3 (2019).
- 187 Oiu, X. et al. Declines in anthropogenic mercury emissions in the Global North and China offset by the Global South. *Nat. Commun.* 16, 1179 (2025).
- 188 Gerson, J. R. et al. Amazon forests capture high levels of atmospheric mercury pollution from artisanal gold mining. *Nature Communications* 2022 13:113, 559– (2022).
- 189 Evers, D. C. et al. Global mercury concentrations in biota: their use as a basis for a global biomonitoring framework. *Ecotoxicology* 33, 325–396 (2024).
- 190 Evers, D. The Effects of Methylmercury on Wildlife: A Comprehensive Review and Approach for Interpretation. in *Encyclopedia of the Anthropocene* 181–194 (Elsevier, 2018). doi:10.1016/B978-0-12-809665-9.09985-7.
- 191 Depew, D. C. et al. Toxicity of dietary methylmercury to fish: Derivation of ecologically meaningful threshold concentrations. *Environ. Toxicol. Chem.* 31, 1536–1547 (2012).
- 192 Escobar-Camacho, D. et al. Mercury in aquatic ecosystems of two indigenous communities in the Piedmont Ecuadorian Amazon: evidence from fish, water, and sediments. *Ecotoxicology* 33, 440–456 (2024).
- 193 Basu, N. et al. A State-of-the-Science Review of Mercury Biomarkers in Human Populations Worldwide between 2000 and 2018. *Environ. Health Perspect.* 126, (2018).
- 194 WHO. Exposure to Mercury: a Major Public Concern. <https://apps.who.int/iris/handle/10665/340715> (2021).
- 195 Carvajal, M. et al. Desafíos Del Cambio Climático En La Amazonia: Recomendaciones Desde Una Adaptación Equitativa Basada En El Agua. (2025).
- 196 Röpke, C., Pires, T. H. S., Zuchi, N., Zuanon, J. & Amadio, S. Effects of climate-driven hydrological changes in the reproduction of Amazonian floodplain fishes. *Journal of Applied Ecology* 59, 1134–1145 (2022).
- 197 Freitas, C. E. C., Siqueira-Souza, F. K., Humston, R. & Hurd, L. E. An initial assessment of drought sensitivity in Amazonian fish communities. *Hydrobiologia* 705, 159–171 (2013).
- 198 Dubos, N. et al. Protection gaps in Amazon floodplains will increase with climate change: Insight from the world's largest scaled freshwater fish. *Aquat. Conserv.* 32, 1830–1841 (2022).
- 199 Isaac, V. J., Castello, L., Santos, P. R. B. & Ruffino, M. L. Seasonal and interannual dynamics of river-floodplain multispecies fisheries in relation to flood pulses in the Lower Amazon. *Fish. Res.* 183, 352–359 (2016).
- 200 Feng, D. et al. Future climate impacts on the hydrology of headwater streams in the Amazon River Basin: Implications for migratory goliath catfishes. *Hydrol. Process.* 34, 5402–5416 (2020).
- 201 Dalagnol, R., Borma, L. de S., Mateus, P. & Rodriguez, D. A. Assessment of climate change impacts on water resources of the Purus Basin in the southwestern Amazon. *Acta Amazon.* 47, 213–226 (2017).
- 202 de Souza, S. S. et al. Effects of climate change and mixtures of pesticides on the Amazonian fish *Colossoma macropomum*. *Science of The Total Environment* 922, 171379 (2024).
- 203 Fritz, B., Peregovich, B., da Silva Tenório, L., da Silva Alves, A. C. & Schmidt, M. Mercury and CO2 emissions from artisanal gold mining in Brazilian Amazon rainforest. *Nat. Sustain.* 7, 15–22 (2024).
- 204 Furtado, M. da S. C. et al. How does climate change affect small scale fisheries? A

- case study of the Lower Amazon in Brazil. *Fish. Manag. Ecol.* 31, (2024).
- 205 Tickner, D. et al. Bending the Curve of Global Freshwater Biodiversity Loss: An Emergency Recovery Plan. *Bioscience* 70, 330–342 (2020).
- 206 Fassoni-Andrade, A. C. et al. Amazon Hydrology From Space: Scientific Advances and Future Challenges. *Reviews of Geophysics* 59, (2021).
- 207 Paudel, S., Koprowski, J. L., Thakuri, U., Sigdel, R. & Gautam, R. C. Ecological responses to flow variation inform river dolphin conservation. *Sci. Rep.* 10, 22348 (2020).
- 208 Chaudhari, S. et al. In-stream turbines for rethinking hydropower development in the Amazon basin. *Nat. Sustain.* 4, 680–687 (2021).
- 209 Ohms, H. A. et al. Poor downstream passage at a dam creates an ecological trap for migratory fish. *Canadian Journal of Fisheries and Aquatic Sciences* 79, 2204–2215 (2022).
- 210 Pelicice, F. M. & Agostinho, A. A. Fish-passage facilities as ecological traps in large neotropical rivers. *Conservation Biology* 22, 180–188 (2008).
- 211 Siddiqui, S. F. et al. Classifying flow regimes of the Amazon basin. *Aquat. Conserv.* 31, 1005–1028 (2021).
- 212 Sorribas, M. V. et al. Projections of climate change effects on discharge and inundation in the Amazon basin. *Clim. Change* 136, 555–570 (2016).
- 213 Padilha, J. et al. Worsening Drought and the Bleak Future for Biodiversity and Ecosystem Services in the Amazon Basin. *Aquat. Conserv.* 35, (2025).
- 214 Arthington, A. H. . Environmental Flows: Saving Rivers in the Third Millennium. (University of California Press, 2012).
- 215 Alho, C. J. R., Reis, R. E. & Aquino, P. P. U. Amazonian freshwater habitats experiencing environmental and socioeconomic threats affecting subsistence fisheries. *Ambio* 44, 412–425 (2015).
- 216 Wildlife Conservation Society. Caracterización de los principales conflictos pesqueros en Loreto. <https://peru.wcs.org/LinkClick.aspx?fileticket=004dqN94pK-g%3d&portalid=94&language=es-ES> (2020).
- 217 Wildlife Conservation Society [WCS]. Pesquerías En Loreto, Amenazas Emergentes y Presiones Prevalentes. <https://peru.wcs.org/LinkClick.aspx?fileticket=ShX-D7Bx9Ybl%3D&portalid=94&language=es-ES> (2020).
- 218 Amazon Cooperation Treaty Organization. Study will provide a regional overview of the mercury contamination situation in the Amazon Basin. - Amazon Basin Project. <https://aguasamazonicas.otca.org/study-will-provide-a-regional-over-view-of-the-mercury-contamination-situation-in-the-amazon-basin/?lang=en> (2024).
- 219 Anderson, E. P. et al. Fragmentation of Andes-to-Amazon connectivity by hydro-power dams. *Sci. Adv.* 4, ea01642 (2018).
- 220 Arantes, C. C. et al. Institutional effects on ecological outcomes of community-based management of fisheries in the Amazon. *Ambio* 51, 678–690 (2022).
- 221 Cassemiro, F. A. S. et al. Landscape dynamics and diversification of the megadiverse South American freshwater fish fauna. *Proceedings of the National Academy of Sciences* 120, (2023).
- 222 Noon, M. L. et al. Mapping the irrecoverable carbon in Earth's ecosystems. *Nat. Sustain.* 5, 37–46 (2021).
- 223 Goldstein, A. et al. Protecting irrecoverable carbon in Earth's ecosystems. *Nat. Clim. Chang.* 10, 287–295 (2020).
- 224 Junk, W. J. et al. A classification of major naturally-occurring Amazonian lowland wetlands. *Wetlands* 31, 623–640 (2011).
- 225 Leal, C. G. et al. Integrated terrestrial-freshwater planning doubles conservation of tropical aquatic species. *Science* (1979). 370, 117–121 (2020).
- 226 Abell, R., Lehner, B., Thieme, M. & Linke, S. Looking Beyond the Fenceline: Assessing Protection Gaps for the World's Rivers. *Conserv. Lett.* 10, 384–394 (2017).
- 227 Jézéquel, C. et al. Freshwater fish diversity hotspots for conservation priorities in the Amazon Basin. *Conservation Biology* 34, 956–965 (2020).
- 228 Miqueleiz, I., Ariño, A. H. & Miranda, R. Spatial priorities for freshwater fish conservation in relation to protected areas. *Aquat. Conserv.* 33, 1028–1038 (2023).
- 229 Haase, P. et al. Successes and failures of conservation actions to halt global river biodiversity loss. *Nature Reviews Biodiversity* 1, 104–118 (2025).
- 230 Silva, M. et al. Comanagement and reconciling of ecological and economic benefits in an Amazonian freshwater fishery. *Conservation Biology* 39, (2025).
- 231 Tiká, U. N. de C. P. N. y V. A. Relevancia de los pepeaderos en la várzea de la quebrada y lagos de Yahuaracaca (Leticia, Amazonas). Afiche Preprint at https://www.linkedin.com/posts/aguasamazonicas_relevancia-de-los-pepeaderos-en-la-v%C3%A1rzea-activity-7185728597880451072-Kv1H/?originalSubdomain=es (2023).
- 232 Oswalt, S. et al. Inventory and Monitoring of Invasive Species. in *Invasive Species in Forests and Rangelands of the United States: A Comprehensive Science Synthesis for the United States Forest Sector* (eds. Poland, T. M. et al.) 231–242 (Springer Nature, 2021). doi:10.1007/978-3-030-45367-1.
- 233 Lurgi, M., Ritchie, E. G. & Fordham, D. A. Eradicating abundant invasive prey could cause unexpected and varied biodiversity outcomes: The importance of multispecies interactions. *Journal of Applied Ecology* 55, 2396–2407 (2018).
- 234 Fenollosa, E. & Salguero-Gomez, R. IA y Big Data para la biología de invasiones: descubrir, modelar y predecir las dinámicas poblacionales de las especies invasoras. *Ecosistemas* 2933 (2025) doi:10.7818/ECOS.2933.
- 235 Sanches, R. A., Fudemma, C. R. T. & Alves, H. Q. Indigenous territories and governance of forest restoration in the Xingu River (Brazil). *Land use policy* 104, 104755 (2021).
- 236 Viejó-Bautista, M.-J., Higuchi, A. & Coq-Huelva, D. Food, monetary, energy, and socio-environmental features of a post-cacao agroforestry system in the Ecuadorian Amazonia: the case of Rukullakta. *Agroforestry Systems* 99, 171 (2025).
- 237 Zanin, P. R. et al. Do protected areas enhance surface water quality across the Brazilian Amazon? *J. Nat. Conserv.* 81, 126684 (2024).
- 238 Herrera, D. et al. Upstream watershed condition predicts rural children's health across 35 developing countries. *Nat. Commun.* 8, 811 (2017).
- 239 Shepard, G. H. Water, water everywhere: health and sanitation in Indigenous communities of the Amazon. in *The Lowland South American World* (eds. High, C. & Costa, L.) (Routledge, London, 2024). doi:10.4324/9781003005124.
- 240 Kharisov, B. I., Dias, H. V. R. & Kharissova, O. V. Nanotechnology-based remediation of petroleum impurities from water. *J. Pet. Sci. Eng.* 122, 705–718 (2014).
- 241 Liu, J. et al. Current applications of electrocoagulation in water treatment: a review. *Desalination Water Treat.* 74, 53–70 (2017).
- 242 Xu, J. et al. Effects of an electrocoagulation-air flotation-microfiltration pretreatment process on the start-up of a moving bed biofilm reactor: performance and microbial community structure. *Environ. Sci. (Camb.)* 10, 743–756 (2024).
- 243 Dupraz-Dobias, P. Mercury rising: gold rush exposes Minamata Convention gaps - Geneva Solutions. Geneva Solutions - Climate & Environment <https://genevasolutions.news/climate-environment/mercury-rising-gold-rush-highlights-minamata-convention-gaps> (2025).
- 244 Nanson, G. C. Anabranching and Anastomosing Rivers. in *Treatise on Geomorphology* 544–564 (Elsevier, 2022). doi:10.1016/B978-0-12-409548-9.12518-7
- 245 Aliança Águas Amazônicas. Zonas dos grandes bagres migratórios na bacia amazônica [Camada geográfica SHP não publicada]. Documento compartilhado no âmbito da colaboração técnica (2026)

THE AMAZON: PLANET EARTH'S FISH BIODIVERSITY GIANT

- ~ More than **2,700 fish species** live in the Amazon Basin.
- ~ The Amazon River is the world's most biodiverse river for fishes, hosting **15% of all freshwater species** found on Earth.
- ~ About **65% of Amazonian fish species** are found nowhere else.
- ~ Some Amazon fish migrations exceed **11,000 km**—the longest inland migration in the world.
- ~ Fish are the primary protein source for millions of people; in some remote communities, daily consumption exceeds **600 grams per person**.
- ~ More than **500 Amazonian fish species** are exploited for the aquarium trade.
- ~ Fruit-eating fish act as arboreal architects, dispersing seeds that regenerate the rainforest.
- ~ Traditional knowledge and community-led management are among the most effective tools for conservation in the Amazon Basin.

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