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Biodiversity and Taxonomy of Catfish Species in the Amazon Basin

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Abstract

With the world's richest freshwater biodiversity and increasing human issues, The Amazon Basin is certainly a biodiversity flashpoint. A lack of data on the geographical distribution of freshwater fish species in this basin obstructs an inclusive knowledge of this hyper-diverse ecosystem as a whole. The Amazon Fish Initiative, an international partnership, prioritises closing this gap. Based on the research data, we give the most comprehensive distribution records for fish species in the Amazon drainage. The database includes 2,406 confirmed freshwater native fish species, 232,936 georeferenced records, and findings from a comprehensive species distribution survey involving 590 sources (including published articles, grey literature, online biodiversity databases, and scientific assortments from museums and academies around the world), as well as field trips conducted during the development. This database is a very useful data source for more research on the biodiversity, biogeography, and conservation of freshwater fish. Studies conclude that the trichomycterus species is one of the members of the catfish family. The lineage associated with this species is diverse and is responsible for its phylogenetic relationship with the other species members of the family. The evolution phases shown by trichomycterids species are influenced by certain climatic factors. It is provided at georeferenced locales (21,500 localities) and sub-drainage grains.

Keywords: Biodiversity (BD), Taxonomy (TT), Catfish Species (CS), Amazon Basin (AB)

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Introduction

The appearance of different kinds of lives in a specific area is called biodiversity. A large variety of animals in which animals, plants, fungi and even microorganisms like bacteria and viruses are involved. All these living organisms unite to make the environment of the natural world. Within an ecosystem, all the species and organisms work together just like a web that is interconnected. This web is important in providing maintenance and support in our life. Biodiversity plays an important role in supporting all the factors required for survival in life like food, clean water, medicine and shelter. But human beings use and consume too much resources, which becomes the reason for putting pressure on planet Earth(Littmann et al., 2021). These things become the reason for creating disturbance in the management of the ecosystem and the loss of biodiversity. According to a report, there is a decrease of almost 69% in the population globally. This decline has occurred in the population of mammals, birds, fish, reptiles, and amphibians since 1970. According to the 2019 global assessment report, This report is made by the intergovernmental platform, which is all about biodiversity and ecosystem services(Cooke et al., 2012). This report showed the danger of extinction of more than 1 million animals and plants. This number seems the highest in the whole of humanity's history. Three-quarters of the environment, which is land-based, and the remaining 66%, which is ocean-based environment, undergo changes, and all of these changes are significant. The land's surface is about one-third portion, and the freshwater resources, with a percentage of 75%, are fixed now for the production of crops and livestock. Catfishes are placed into the phylum of Chordata, and the subphylum is Vertebrata, the class is Actinopterygii, the order is Siluriformes and the suborder is

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Mematognathi(van der Sleen & Albert, 2017). A connection is also found with the Ostariophysi super order in which the following involve cypriniformes, Gonorynchiformes and Gymnotiformes. Catfish are found in the superorder Ostariophysi. The following are included in it: cypriniformes named as carps and minnows Characiforms called chacins and tetras. Gonorynchiformes, like milkfish and beaked salmons, and Gymnotiformes, like knife fish of South America. A well-known characteristic of superorder is the presence of weberian apparatus. Traditional classification distributes the fish into three classes: Agnatha, Chondrichthyes, and Osteichthyes(Dagosta & De Pinna, 2019). All those extinct forms are placed into those groups or sometimes placed into their classes. More than half of species of vertebrates come into the category of fish. Craniate is the term, which is the name of the group, and is based on all sections of the tree of life that are found on the earth. Its origin was the earliest fishes (Frederick & Alexander, 2023). An order named siluriformesis a freshwater body and is of scale, less bony type fishes in which long barbels are found, which are tactile. Catfish belongs to the family of Ictaluridae (Formiga et al., 2021). The science in which the naming, description, and classification of organisms are involved, as well as plants, animals, and microorganisms of the world, are found in it. The variations that related to behavior, genetics, and biochemical changes fall under the classification category. The following phenomena are part of taxonomy, such as characterization, identification, and classification. The concept of biological species describes the species as members of all those populations that have can interbreed naturally or potentially. However, there are no conditions for having similarity in appearance. No doubt, appearance is very helpful for identifying species(Lehmann et al., 2018). However, it does not play any role in describing the species. Fish taxonomy is of great significance as it wipes out all the problems, even concerning thinking or approaching, that are required for the maintenance and well-being of fish biology. It leads towards producing catalogues, revisions, handbooks, keys and monographs. A taxonomy group, called a tax on, belongs to any rank. Here are some examples of taxonomic ranks: species, genus, family Order, class, phylum and domain. The body shape of catfish is such that they have a cylindrical body along with a flat Ventral side that makes it easy for them to do benthic feeding(Reis et al., 2016). The name Catfishes is due to the shape of their bodies, which are based on whisper-like barbels. These barbels are located on the nose and each side of the mouth and can also be seen on the chin. Leading spines are also the characters found on their fins, which are found on their dorsal and pectoral sides. The part of South America from which water is drained towards the Amazon River and its associated parts is called the Amazon Basin. The area covered by the Amazon drainage basin is about 7000000km². One of the reasons for the popularity of the Amazon is the presence of rainforests surrounding its shores(Reis & Lehmann A, 2022). The Amazon rainforest is the representation of the remaining rainforests of the earth. It is considered the largest reservoir in the world. It serves as the role of home for more than one million species. The location of the Amazon Basin is such that it covers a large portion of the Central eastern areas of South America. Their location is towards the east side of the Andes Mountain, extending from the Guyana Plateau north to the Brazilian Plateau south (Ochoa et al., 2015). Fish species' existence and geographic distribution in the Amazon Basin are essentially unknown. Several new species are uncovered each year, and huge sections of the basin remain unknown. This was one of the primary motivations behind the transnational cooperative undertaking Amazon fish, which aimed to close the gaps by launching scientific collecting expeditions in under-sampled areas and gathering the most up-to-date and complete information on the distribution of freshwater fish species across the Amazon drainage basin. This database was produced by gathering information from multiple sources, including field expedition reports, published research, grey literature, online biodiversity databases, scientific collections from universities and museums worldwide, and study-organized field excursions. With 2,406 genuine native freshwater fish species documented from 590 sources throughout nearly two centuries (1834-2019), this compilation encompasses around 235,064 occurrence data (232,936 georeferenced and 2,128 non-georeferenced) and 21,500 sampled locales (also known as sampling

sites). Recently, two parallel compilation operations were launched to characterise the distribution of freshwater fish species in the Amazon Basin. Van der Sleen and Albert's field guide includes a detailed evaluation of the present state of knowledge in fish ecology and genus-specific distribution maps (van der Sleen & Albert, 2017). The Dagosta & De Pinna compilation includes species listings for 30 Amazonian sub-drainages; yet, it is incomplete (Dagosta & De Pinna, 2019). We complement these earlier approaches by displaying species-level distributions in a database structure incorporating data from sampling locations and sub-drainage grains (144 units). By accumulating data on the geographic distribution of freshwater fishes and filling both taxonomic and sampling gaps, the Amazon Fish database should become a large and long-term source of data for ecological and conservation studies. The database is being used to assess basin-scale fish diversity trends, identify diversity hotspots for the Amazon Basin's conservation purposes, and predict the likely implications of fragmentation and climate change on biodiversity. In addition to strengthening our fundamental knowledge of the patterns and mechanisms that underpin the evolution of Neotropical freshwater fish diversity, the information provided can help to establish regional conservation efforts and large-scale transnational ecosystem management initiatives. Species occurrences are recorded at two geographical scales: sample sites (with specified geographic coordinates) and sub-drainage (144 units) grains. The database consists of two sub-datasets and a single shapefile. The first dataset provides a list of species by sub-drainage, as well as the taxonomic Fish Base reference name (Family et al. species valid name, and Author), species status (native or alien), and occurrence status (valid, to be verified, or marine; see technical validation for more information). The second dataset comprises the original species name (e.g., "synonym" or "typing error") as defined in the source, the geographic coordinates for georeferenced items, and the source of each item. Last but not least, the shapefile contains a list of all sub-drainages and the geographic information related with them. Future updates will add nomenclatural changes, the distribution of freshly identified species, and more occurrence data from collections, publications, and field trips to overcome sampling gaps. The database is not comprehensive (Rivot, 2023). A total of nearly seven million square kilometres makes up the Amazon basin. The world's biggest river basin is this one. It contributes to water discharge from every single continent, or roughly one-sixth of all freshwaters, into the world's seas. Specific properties of this ecosystem create countless types of creatures on the world. These characteristics include the ecosystem's antiquity, location close to the equator, and diverse aquatic behaviour (Junk et al., 2007).

Research Objective

The main objective of this research is to understand the Biodiversity and Taxonomy of Catfish species in the Amazon Basin. This understanding will be very helpful for researchers who work on the presence and functioning of Catfishes.

Literature Review

Researchers reveal that spatial changes are observed in the Amazon River after the seasonal changes. This change in the Amazon Ocean's spatial distribution promotes fish species' migration. migration of species and their richness in an area during the seasonal shift is determined using SDMs(Alvarez et al., 2024). Studies reveal that the colour pattern of *Scobinancistrus* species makes its identification process easier in the Xingu River of Brazil. The *Scobinancistrus* species belongs to the catfish group and is identified because of its unique colo(Chaves et al., 2023).the characterization of catfish species is based on their patterns of skin colour. In the RPSB, the two closely related species of catfish are found due to the similarity in the colour patterns of these two species(Costa, Mattos, et al., 2024).Studies claim that a new species of catfish is observed in the Amazon basin that has a unique structure. the structural information regarding this species of catfish makes it distant

from other species of catfish family(Datovo et al., 2023).A large number of stingrays are found in the Amazon River. despite the large, diverse population of stingrays, little information is known about their existence in the Amazon River. the studies on freshwater species of the Utama River predict the presence of four stingrays in this river(Gomes et al., 2024).studies reveal that translucent fish species belonging to the catfish group are identified in the Madeira River drainage. these translucent spices are found to belong to the Triden genus of catfish(Henschel et al., 2023).Historical studies related to freshwater species predict that water floods influence the migration of freshwater species. The migration patterns of fish species provide information about their ancestral history. Most freshwater species migrate to Amazon freshwater to maintain diversity(Herrera-R et al., 2024).Studies claim that the process of evolution is studied under evolutionary biology. This subject provides information about the evolution of species in the aquatic environment over time. The environment in which an organism lives is responsible for its survival. Any fluctuations in environmental factors can lead to the decline of spices. Certain biotic factors disturb the genetic behaviour of species. The mutation in the species gene results in mutation and loss of the species' natural habitat. The catfish species has been greatly affected due to abiotic factors (Janzen, 2023).studies reveal that in neo-tropical regions, the presence of catfish belonging to *Pimelodus* is found, but studies cannot resolve the taxonomic relationship of this species with catfish. the molecular level studies on catfish reveal that it is a cryptic species with diversified behaviour that makes it resemble the *Pimelodus* genus(Limeira Filho et al., 2024). Moreover, for research-based study purposes, the *Pimelodus* species are kept in special fish centres.

The analysis of *Pimelodus* catfish reveals that it is a species of commercial importance.the monitoring of *Pimelodus* catfish is carried out using an efficient monitoring system. *Pimelodus* catfish is present in the southern part of the Amazon River, and thus, a monitoring management process is carried out in the southern region of the Brazilian Amazon River (Lourenço et al., 2024).the presence of sailfin catfish in the Indian freshwater ecosystem is studied to assess the ecological importance of catfish. The assessment procedure for catfish utilizes the mesocosm-based methodology(Mallick et al., 2023).Scholars show that species related to the genus Rineloricaria are present southeast of the Amazon River. catfish species related to this genus show diversified taxonomic features. The use of the species delimitation method provides information about the presence of five catfish species in the river basin of the Amazon. This method of species identification provides details about the taxonomic boundaries associated with species(Mejia & Buckup, 2024).Studies claim that species richness in an area is associated with species interaction with the environment. bushy nose catfish is found in abundance in the Pachitera River. This catfish shows a relationship with the genus *Ancistrus.* Despite being a rich species in the Pachitera River, the bushynose catfish is not fully studied .little information is known about the taxonomic background of bushynose catfish due to a lack of research studies made on this species of catfish(Neuhaus et al., 2024).studies suggest that special features are found in tropical fish species that require effective strategies for their proper management. Ecological risk assessment strategies are adopted to assess the risk associated with overfishing. These strategies are used before the PSA approach is implemented. Also, many aquatic fish species risk becoming vulnerable due to overfishing activities. The PSA approach is used to save fish populations from losing their diversity before devising an aquatic ecosystem management plan(Pereira et al., 2023).Studies suggest that in the Peruvian region of the Amazon River, various traces of venerable species have been found. These traces reveal that these fish species are becoming vulnerable due to water release in this Amazon River region (Frantz et al., 2023). Experimental studies were performed to study the vulnerable species of the Peruvian region experimentally. the result of the study predicts that the species found in this region of the Amazon River are not vulnerable but are regarded as species of the least concern(RUIZ-TAFUR et al., 2023).scholar studies predict that the presence of the *rineloricaria* species in the Colombian ocean is indicated because of the dark patches observed on the body of this catfish species(Urbano-Bonilla et al., 2023). Studies

on M.mickeyii species reveal that it is closely related to the myxobolidea family because of its small ribosomal sequencing. the presence of M.mickeyii species in various other closely related hosts predicts that it can cause tissue infection in the host(Velasco et al., 2024).scholars elaborate that little information is available about the presence of fauna species found in the Munim River.to make studies on Munim river species, the effect of anthropogenic factors is assessed on the species' habitat. The assessment results predict that a great variety of freshwater species are found in the Munim River. However, these species are at higher risk of declination due to anthropogenic factors(Vieira et al., 2023) (Volpi et al., 2023).Scholar studies provide evidence that CVG is an endangered species found in an area where most fish species are at risk of extinction. a poorly studied clade catfish is found in the endangered region close to the neo-tropical areas(Costa, Feltrin, et al., 2024)(Figure 1).

Figure 1: Biodiversity

Taxonomic and Status Validation

Every species name identified in the source was cross-checked against lists of valid and synonym species names from Fish Base and Eschmeyer's Catalogue of Fishes to ensure the correctness of the identifications supplied by the information source. During this taxonomic validation, 294 species names not included in either scientific catalogue were discovered, along with 1,332 synonyms and 781 typos. The expanded table, "Complete Database," which lists the species' original scientific names, allows users to extract subspecies, synonyms, or names for unidentified species. Following the confirmation of the taxonomic names, we determined that every taxonomically valid species contained in our database was present in the Amazon Basin. Each species was assigned a status according to this detailed review, a vital element in the database's creation. The species' status is appraised using data from the data source, expert views from Amazon Fish partners, and general distribution statistics from Eschmeyer's Catalogue of Fishes or Fish Base. When a species' presence deviated from its genuine known range, it was classified "to be verified". A recently available database on the global distribution of freshwater fish species was also analysed to validate each species' overall range, assess its alien status, and identify species indigenous to the Amazon basin. As a consequence, in addition to information on the validity of each species, the database includes information on species occurrences and names that require additional research (for example, "to be verified" and "unknown name at present"). This allows database users to apply their expertise and experience to verify the accuracy of the source, species name, and range (ideally by contributing to the Amazon Fish) (Figure 2).

Figure 2: Catfish taxonomic

Species Distribution Validation

The physical coordinates of the locations were compared to the sub-basin location name as specified in the source. When there was a discrepancy, the coordinates were eliminated from the database, leaving just the data at the sub-basin level; this error was referred to as "geographic." A simple geographic analysis was used to confirm the correctness of species distribution (for "native" and "valid" species) within the Amazon Basin. A list of sub-drainages a particular species might inhabit was developed by creating a convex outer envelope for each species based on its occurrence locations. The list of sub-drainages with at least one record for each species was compared to this list. This study found that around 200 species had irregular distributions (outlying occurrences). Every one of these instances was thoroughly studied and either confirmed or rejected. The catfish family Pimelodidae, one of the most varied in the order Siluriformes, is limited to the Neotropical area and consists of 30 genera and 116 species. Several species are valuable resources for South American commercial and subsistence fishing. Pimelodids have a classic catfish shape due to their body colouration, which ranges from uniform grey to complicated patterns of stripes and dots. The fish of the genus Pimelodus LaCépède, 1803, the most specialist of the family Pimelodidae, live in northern Argentina, between the River Plate and Panama. Despite the fact that 36 Pimelodus species have been discovered (Soares Costa et al., 2022), the systematics of this genus is regarded as one of the most challenging of any pimelodid taxon. It is still difficult to reliably identify species in the genus since no apomorphic characteristic has been widely recognised. A collection of phylogenetically uninformative features insufficient for defining a monophyletic taxon has long served as the basis for diagnosing the genus Pimelodus. Therefore, a more thorough examination of the systematics of the genus Pimelodus has been impeded by the vast number of species that are now included in the genus, as well as the variation in the morphology and colouration patterns of the various forms. This suggests that the genus' evolutionary relationships and species-level categorisation are poorly understood. Numerous evolutionary investigations have highlighted the intricacy of this taxon, which currently has unresolved problems about the status of species and monophyly. Furthermore, species with a more extensive range, such as Pimelodus blochii Valenciennes, 1840, Pimelodus pictus Steindachner, 1876, and Pimelodus ornatus Kner, 1858, appear to form species complexes. Many of the recognised Pimelodus species remain poorly understood due to their complex morphology, and they may represent multi-species lineages that have yet to be fully described. In this situation, assessing inter-basin differentiation patterns and defining species will require molecular data, especially when

morphology-based identification proves insufficient. This will uncover diversity that has been undervalued or not yet acknowledged by science. The research found that the gradual addition of molecular investigations, which have progressively shown the existence of discrete components that may constitute candidate species, has enhanced modern systematics. The majority of creatures may be identified primarily by their physical characteristics, but as technology has advanced, more and more criteria are being used to determine species. In recent years, there has been a resurgence in taxonomic research on the species idea, taxon-delimitation methods, and their applications. In 2003, a standardised approach for molecular species identification was proposed: DNA barcoding, based on a particular section of a mitochondrial gene's DNA sequence. More recent research has used analytical approaches that include diverse methodologies for determining Molecular Operational Taxonomic Units, or MOTUs, and various other methods for molecular species delimitation. A recent study on Pimelodus employed genetic markers to identify two separate evolutionary lineages from the trans-Andean area as new species. Most Pimelodus taxa in Maranhão's hydrographic basins have only been classified using traditional taxonomic criteria, with little research in Northeastern Brazil. Furthermore, the genus's taxonomy is ambiguous; for example, the name P. blochii has been used arbitrarily for a number of long-whiskered catfish species from diverse Amazonian locations, most likely representing multiple species. Given that several specimens from the Maranhão basins have also been classified as P. blochii, a similar condition probably exists there as well. To guarantee a more accurate species diagnosis and a deeper comprehension of the variety of this genus, supplementary investigations utilising genetic methods must be included.

Taxonomy

According to molecular evidence, all catfish belong to a monophyletic group despite the order's high degree of morphological variety. Catfish are members of the Ostariophysi superorder, distinguished by the Weberian apparatus. It is not as often acknowledged that Gymnotiformes is a sub-order of Siluriformes. The sister group of the Gymnotiformes is now thought to be the Siluriformes. However, this has been disputed by more recent molecular findings. About 3,093 species of catfish were known to exist as of 2007, and there were roughly 36 families left. The order of catfishes is the second or third most diversified, with one species of every twenty vertebrates being a catfish. It is believed that catfish originated in Gondwana since the oldest groupings of catfish are found in South America. The Andinichthyidae, Vorhisia vulpes, and maybe Arius were among the earliest known definite members to reside in the Americas from the Campanian to Maastrichtian periods of the Late Cretaceous. There is a possible fossil record from the early Coniacian-Santonian phases in Niger, West Africa. However, it has been deemed untrustworthy. Afrocascudo, the assumed first armoured catfish known from the fossil record, existed in Morocco, North Africa, during the Cenomanian period of the Late Cretaceous. According to Afrocascudo's description, the occurrence of a derived loricariid at such a young age suggests that catfish, or at least loricariids, had significant variety before the Late Cretaceous period. Because surviving loricariids are only known from South America, many of these species must have existed on the supercontinent of West Gondwana before it was divided into South America and Africa. Britz and colleagues believe Afrocascudo is a juvenile obaichthyid lepisosteiform that might be a junior synonym of Obaichthys. The original study's authors continued to argue that it could not be a juvenile since the bones were fully ossified, citing the lack of prominent holostean features. The pectoral fins of catfish also include a system for producing sound. Large abductor and adductor muscles are used to move the spine, and an increased initial pectoral fin ray is found in several catfish species. A series of brief pulses are produced when the ridges on the spine of catfishes are pressed against the pelvic girdle groove. Normally, the spine glides inside the groove on the fish's pelvic girdle during normal movement. A sequence of sharp taps results from the action, comparable to a finger running along a comb's teeth. The ways that men and women produce sound are frequently different. Males of some

catfish have longer pectoral fins than females of the same length, and variations in the characteristics of the noises they make have also been noted.

According to research by Maria Clara Amorim, comparisons between catfish families of the same order revealed vocalisation patterns distinct to each family and species. All males of the three species of Corydoras catfish actively generated stridulation noises prior to egg fertilisation during courting behaviour, and the duration and number of pulses in each species' songs varied. Catfish may also produce sound in response to warning calls and fights. Research by Kaatz found no significant difference between agonistic behaviour and sounds for disturbance (such as alarm), suggesting that agonistic sound production variation might be sampled using distress sounds. However, when a few different species of tropical catfish were compared, some of the fish in distress made stridulatory noises that were more intense than drumming sounds. Morphological limitations, such as varying pectoral spine and drumming muscle sizes, determine the proportion of stridulation versus drumming noises. Some fish might be unable to style a particular comprehensive because of these limitations. Aggressive sound production happens when defending a covered place or when other fish pose a threat to a variety of catfish species. More precisely, stridulations are utilised as a defence signal and drumming noises as a threat in long-whiskered catfish. Catfish make more swimbladder noises during intraspecific disputes and more stridulatory sounds during disturbances, according to Kaatz's analysis of 83 species from 14 families (Figure 3).

Figure 3: Catfish Species

Conclusions

The current study's findings indicate the requirement of a complete taxonomic investigation of the genus Pimelodus. Although more extensive and in-depth inquiry is necessary to develop a more exact categorisation, research might discover a wider diversity of Pimelodus species than is already acknowledged. A population genetics approach may possibly be used to analyse the genetic diversity of the research groups. DNA barcode studies helped characterise the species of this fish group and identified its original presence in the Munim River basin in Maranhão, Brazil. Based on the results of molecular species delimitation techniques, multiple possible new species may exist in the current study. These findings may affect future taxonomic study better to appreciate freshwater fish diversity in the Neotropical region. The Amazon River's primary branches, the Marañón and Apurimac rivers in Peru, originate in the Andes Mountains to the west of the basin. The tallest peak in the Amazon watersheds is Yerupajá, the second-largest mountain at 6,635 meters (21,768 ft). The Amazon River Basin, which spreads throughout central and eastern South America, is located east of the Andes Mountain range

and extends from the Guyana Plateau in the north to the Brazilian Plateau in the south. It is one between the world's two biggest rivers, measuring over 6,400 kilometres (4,000 miles) before spilling into the Atlantic Ocean. A committee of professionals has decided that the Amazon is longer than the Nile, even though the river's real length is still controversial. The Amazon system transmits the most water of any river system, accounting for about 20% of all the water that rivers bring to sea. Some Amazonian rainforests have been lost owing to the spread of animal goods ranches and soybean farms. Before the Andes, the Amazon basin travelled west to the Pacific Ocean; now, it flows east to the Atlantic Ocean.

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