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continued on the back inside cover

Cover: Tamil Lacewing *Cethosia nietneri* with colour pencils and watercolours for the background; detailing with fine liners by Elakshi Mahika Molur.

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COMMUNICATION

Checklist on the ichthyofaunal resources and conservation status of Dikhu River, Nagaland, India

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Abstract: Dikhu River constitutes one of the major perennial rivers of Nagaland and due to its pristine beauty aids as a tourism spot. From the present study, ichthyofaunal diversity accounted for a total of 28 fish species belonging to 6 orders, 13 families, and 3 subfamilies. From the investigation, order Cypriniformes (67.9%) was found to be the most dominant, followed by Siluriformes (14.3%) and Anabantiformes (7.1%) while order Beloniformes, Synbranchiformes and Anguilliformes was found to be the least common with 10.7% in total. The IUCN red list of threatened species shows 71.4% are Least Concern, 7.1% Near Threatened, 3.6% Vulnerable, 3.6% Endangered, 10.7% Not Accessed and 3.6% Data Deficient. IUCN population status data shows that 57.1% are unknown, 10.7% stable, 10.7% not accessed, and 21.4% with decreasing population trends. Diversity indices (Shannon, Simpson, and Evenness) indices ranged 2.497–2.912, 0.892–0.936, and 0.820–0.908, respectively. Relative abundance determinations ranged from a high of 15.55% for *Devario aequipinnatus* to the lowest values for *Tariqilabeo latius* and *Botia rostrata* at 0.08%. Anthropogenic pressure on the Dikhu River has resulted in habitat modification and fragmentation, posing a hazard to fish diversity. Fish abundance was found to be highest in the post-monsoon season and lowest in winter. These findings are significant for academic purposes and support conservation strategies for local fish resources.

Keywords: Assessment, biodiversity, diversity index, fish species, fisheries management, ichthyofauna, Nagaland fisheries, population status, riverine habitat, threatened species.

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Competing interests: The authors declare no competing interests.

Author details: Metevinu Kechu is a research scholar and is actively engaged in ichthyofaunal exploration and documentation in Nagaland. Pranay Punj Pankaj is engaged in teaching fisheries as well as research and development activities on the subject in the region.

Author contributions: MK surveyed the Dikhu River of Nagaland and confirmation of the identity of the species. PPP supervised the work and interpreted the taxonomic information gathered by the Mk.

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INTRODUCTION

India has been identified as one of the mega biodiversity countries in the world (Mittermeier & Mitemeir 1997) and the northeastern part of India with its unique topography has been considered a biodiversity hotspot in the world (Groombridge & Jenkins 1998). The region's rich biodiversity is attributed to its tectonic placement (Kottelat 1989) and is considered a freshwater fish biodiversity hotspot in the world (Kottelat et al. 1996).

The state of Nagaland, located in the northeastern part of India, is known for its rich biodiversity, including a diverse range of fish species. Nagaland is bounded by beautiful hilly terrain and riverine system and shares boundaries with Assam (northern and western part), Arunachal Pradesh (northeastern part), Myanmar (eastern part), and Manipur (southern) (Kosygin & Vishwanath 1998). The three principal drainages of Nagaland consist of Brahmaputra and Barack of Indian origin and Chindwin drainage of Indo-Burma origin. The Dikhu River, flowing through Nagaland, serves as a prime location to study the ichthyofaunal diversity in the region. This river is characterized by its running waters and hilly terrain, making it an ideal habitat for various fish species. Furthermore, little information exists on the biology of these fish species, emphasizing the need for a comprehensive study of their diversity. The study of fish diversity in the Dikhu River would provide valuable insights into the ecological dynamics and conservation efforts in the region.

Biodiversity hotspots under freshwater ecosystems, are increasingly under threat, making their conservation a critical concern. Major factors such as habitat destruction, invasive species, overexploitation, and the impacts of climate change are driving the rapid decline of species populations. Studies have highlighted that approximately 24% of freshwater species are facing a high risk of extinction due to threats including pollution, dam construction, water extraction, agricultural practices, and the introduction of invasive species (Sayer et al. 2025). In the northeastern region of India, studies have provided valuable insights into the conservation status of freshwater fish species, illustrating both the rich diversity and the significant threats they face (Vishwanath 2017). A report presented at COP 28 in the United Arab Emirates further revealed that 25% of freshwater fish species worldwide are at risk of extinction, with climate change directly impacting at least 17% of these species (IUCN 2023). These findings underscore the urgent need for targeted conservation efforts to safeguard freshwater biodiversity.

The Shannon Index, Simpson Index, and Jacquard's Evenness Index are commonly used to measure biodiversity and community structure in ecological studies. Biodiversity is often astonishingly altered or overused to define the population of a community. It is a measure of the number of species that make up a biological community and is considered one of the most important aspects of community organization or structure (Jewel et al. 2018). Information about ichthyofaunal diversity is scarce in this region and only a few notable works have been done by Hora (1936), Menon (1954), Acharjee et al. (2012), and a few studies have been done on the biodiversity status in Dikhu River individually by Ezung et al. (2022) and Konyak & Limatemjen (2022). The use of these diversity indices would allow researchers to assess the species richness, evenness, and dominance of fish populations in the Dikhu River. By quantifying the diversity indices, researchers can determine the overall health and stability of the fish community in the river. Understanding the fish diversity in the Dikhu River is crucial for several reasons. Firstly, it aids in the conservation and management of fish populations. This information helps in formulating policies for sustainable fisheries management. Though it is considered a significant river in the state, there has been scarce information regarding its status and its habitat ecology and hence this present study is an attempt to identify the current fish species diversity in this river.

MATERIALS AND METHOD

Study area

Dikhu River is one of the tributaries of the Brahmaputra River and six stations were selected for sampling (Table 1). The study was conducted for a period of 12 months from March 2019 to February 2020. The locations of the study sites were taken using GPS (Garmin etrex-10) (Image 1). It originates from the Naruto Hill, Zunheboto, and later confluences towards the Brahmaputra River from Naginimora, Assam. It then channels through most of the Zunheboto and Mokokchung districts of Nagaland, covering a total distance of 170 km. The two major tributaries of the Dikhu River are Yangyu in Tuensang district and Nanung (Langpangkong range) in Mokokchung district (Ao et al. 2008).

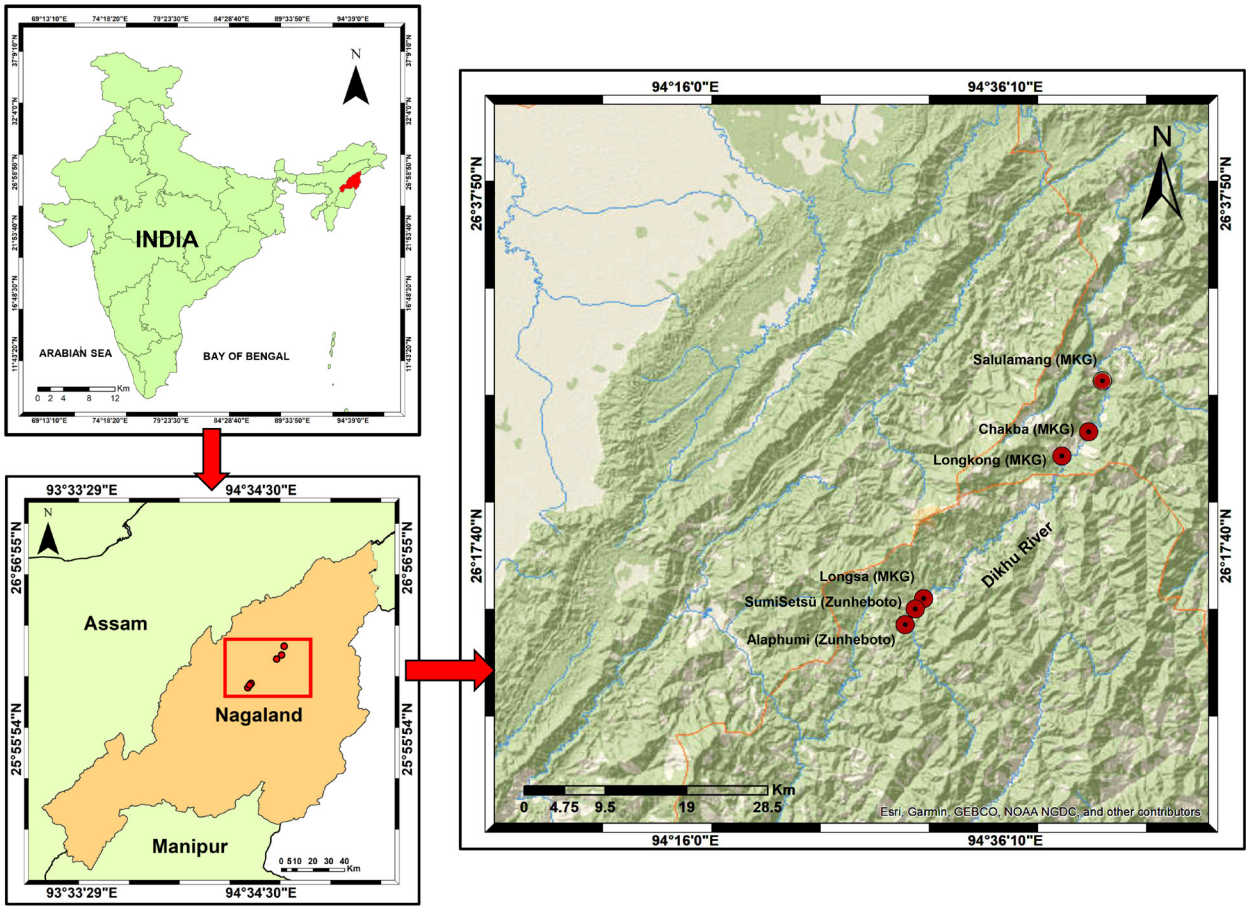

Image 1. Geospatial mapping of study site distribution along the Dikhu River, Nagaland.

Fish sampling

Fish samples were collected from various sampling sites along the course of the river with gears such as cast nets, gill nets, scoop nets, hooks and lines, and locally available indigenous traps. Sampling collection was done on a monthly basis. Collected fish samples were photographed with a Canon EOS 3000D camera and measured using a vernier caliper and graduated ruler (graduations in mm) while excess fishes were released back into the river then a few samples were preserved in 10% formalin solution for further identification. Samples were identified with the help of key identification characters given by Talwar & Jhingran (1991), Menon (1999), Vishwanath et al. (2007), and Jayaram (2010), and the latest nomenclature was based in accordance with the Catalog of Fishes (Fricke et al. 2025). Fish classification was conducted following the guidelines outlined by Nelson et al. (2016).

Table 1. Sampling sites of Dikhu River, Nagaland.

Stations	Geographical coordinates	Altitude
Longsa (MKG)	26.244° N 94.517° E	2230 ft or 679.7 m
Longkong (MKG)	26.380° N 94.662° E	1390 ft or 423 m
Chakba (MKG)	26.403° N 94.690° E	1292 ft or 393.8 m
Alaphumi (Zunheboto)	26.219° N 94.497° E	2383 ft or 726.3 m
Salulamang (MKG)	26.452° N 94.704° E	1164 ft or 354.7 m
SumiSetsü (Zunheboto)	26.234° N 94.508° E	2271 ft or 692.2 m

Species diversity

Shannon diversity index, (Shannon & Weaver 1949)

$H' = - \Sigma pi \ln (pi)$,

Where H' is the Shannon Diversity Index and pi is the number of individuals in the i^{th} species as a proportion of the total population. ln (pi) is the natural log of pi

The formula used for calculating Simpson's index (Simpson 1949) is:

$D = 1- (\Sigma n*(n-1)/N*(N-1))$

Where n is the number of individuals of a specific species. N is the total number of individuals of all species.

Pielou's Evenness Index (J) is calculated using the Shannon Diversity Index (H) and ln(S) is the natural logarithm of the total number of species (S) in the community. The formula for Pielou's Evenness Index (Pielou 1966) is:

J' = H'/H'max = H' / ln(S)

The relative abundance (percentage composition) of fish species across the six sampling stations was calculated using the following formula.

Relative Abundance (%) = (Number of individuals of a species × 100) / Total number of species

Statistical analysis: For data conversion and analysis, Microsoft Excel was used.

RESULTS

Fish assemblage

Fish species composition of Dikhu River showed the presence of 28 fish species belonging to six orders 13 families and three subfamilies (Images 2 & 3). Table 2 provides a detailed checklist of fish species, organized according to their IUCN conservation status (IUCN 2024) and documented population trends. Among the order of fish species, Cypriniformes were observed as the most dominant group with 67.9% followed by Siluriformes (14.3%) and Anabantiformes (7.1%) while the least common order group belonged to Beloniformes, Synbranchiformes, and Anguilliformes with combined (10.7%) in total (Figure 1). Cyprinidae dominated among the families represented by 14 species and among the genus group *Garra*, *Opsarius,* and *Danio* were the most common with three species each. Based on the IUCN red list of threatened species category 71.4% was represented under Least Concern (LC), 7.1% under Near Threatened (NT), 3.6% under Vulnerable (VU), 3.6% under Endangered (EN), 10.7% under Not Assessed (NA) and 3.6% under Data Deficient (DD) status (Figure 2). The population trend of fish species as per IUCN also showed 57.1% as unknown, 10.7% as stable, 10.7% as not accessed, and 21.4% as decreasing population trends (Figure 3). Assessing the species according to its economic value were categorized as 46.4% under food and ornamental, 35.7% under ornamental, 10.7% under food, and 7.1% under food and sport category (Figure 4).

Relative abundance

The relative abundance of small indigenous fish *Devario aequipinnatus* (15.55%), *Opsarius bendelisis* (11.39%), *Garra naganensis* (9.52%), and *Amblyceps apangi* (7.73%) were found to be high in the river under study indicating its abundance and dominance. Species under different conservation categories like *Neolissochilus hexagonolepis* (NT) showed relatively high RA with values of 4.31%, which indicates the stability of their population despite natural and anthropogenic threats in the sampling sites. While others under the threatened category like *Tor putitora* (EN), *Anguilla bengalensis* (NT), and *Botia rostrata* (VU) indicated decreasing trends with RA values of 0.62%, 0.16%, and 0.08 %. Other species with fairly high RA were *Schistura savona* (6.61%), *Psilorhynchus homaloptera* (5.91%), *Pterocryptis indica* (5.71%) and *Pethia conchonius* (5.25%). The lowest RA was recorded in *Tariqilabeo latius* and *Botia rostrata* with values of 0.08% each. It has been observed that the highest number of catches was recorded during the post-monsoon followed by the pre-monsoon season compared to the other seasons (Figure 5).

Diversity index

Diversity was highest (H' = 2.912, 1-D = 0.936) in post-monsoon season and lowest in monsoon season (H' = 2.497, 1-D = 0.892), and the values of evenness index (J') were recorded highest (J' = 0.908) in pre-monsoon season and lowest in monsoon season (J' = 0.82). The mean value and standard deviation of species found in each season, Shannon diversity (H'), Simpson's index (1-D), and Pielou's evenness (J') indices were recorded as, 23.75 ± 2.217, 2.716± 0.194, 0.915± 0.022 and 0.864± 0.044 (Table 3). The study concluded that the Dikhu River supports rich fish diversity, while there is a notable shift in the fish community structure.

DISCUSSION

The spatial distribution of fish species in the Dikhu River is influenced by a complex interplay of ecological factors, including abiotic conditions, biotic interactions, and evolutionary adaptations within the habitat (Pelicice et al. 2015; Bose et al. 2019; Satpathy et al. 2021; Alam et al. 2024). Among these factors, the dominance of Cypriniformes in the fish assemblages of the river is particularly notable. This pattern mirrors findings from other studies across northeastern Indian rivers, indicating a widespread dominance of this order (Taro et al. 2022; Ahmed et al. 2023; Chetry et al. 2023; Singh et al. 2024). The success of Cypriniformes in these ecosystems can be attributed to their evolutionary adaptations, including

Table 2. Comprehensive overview of fish catch composition of Dikhu River, Nagaland: conservation status, population trends, and economic significance.

	Systematic position	Local name (Ao)	Common name	IUCN status	Population trends	Economic value	Specimen number
Order: Anguilliformes Family: Anguillidae							
1	*Anguilla bengalensis* (Gray, 1831)	Angulang	Indian Mottled Eel	NT	Unknown	Fd	NUFM 1390
Order: Cypriniformes Family: Cyprinidae Subfamily: Barbinae							
2	*Neolissochilus hexagonolepis* (McClelland, 1839)	Seben	Katli or Chocolate mahseer	NT	Decreasing	Fd, Sp	NUFM 1279
3	*Tor putitora* (Hamilton, 1822)	Tzünger	Golden mahseer	EN	Decreasing	Fd, Sp	NUFM 1285
4	*Pethia conchonius* (Hamilton, 1822)	Tzünger	Rosy barb	LC	Unknown	Fd, Or	NUFM 1289
Subfamily: Danioninae							
5	*Opsarius bendelisis* (Hamilton, 1807)	Tawa	Indian hill trout	LC	Stable	Fd, Or	NUFM 1310
6	*Opsarius tileo* (Hamilton, 1822)	Tawa	Tileo baril	LC	Unknown	Fd, Or	NUFM 1316
7	*Opsarius barna* (Hamilton, 1822)	Tawa	Barna Baril	LC	Stable	Fd, Or	NUFM 1317
8	*Danio dangila* (Hamilton, 1822)	Zer	Dangila Danio	LC	Decreasing	Fd, Or	NUFM 1325
9	*Danio rerio* (Hamilton, 1822)	Zer	Zebra fish	LC	Decreasing	Fd, Or	NUFM 1329
10	*Danio assamila* (Kullander, 2015)	Zer	Not accessed	Not accessed	Not accessed	Fd, Or	NUFM 1332
11	*Devario aequipinnatus* (McClelland, 1839)	Zer	Giant danio	LC	Unknown	Fd, Or	NUFM 1319
Subfamily: Labeoninae							
12	*Tariqilabeo latius* (Hamilton, 1822)	Anget	GangeticLatia	LC	Unknown	Fd	NUFM 1295
13	*Garra lissorhynchus* (McClelland, 1842)	Anget	Khasi garra	LC	Unknown	Fd, Or	NUFM 1296
14	*Garra birostris* (Nebeshwar & Vishwanath, 2013)	Anget	Not accessed	Not accessed	Not accessed	Fd, Or	NUFM 1302
15	*Garra naganensis* (Hora, 1921)	Anget	Naga garra	LC	Unknown	Fd, Or	NUFM 1304
Family: Psilorhynchidae							
16	*Psilorhynchus homaloptera* (Hora & Mukherji, 1935)	Mernngo	Homaloptera minnow	LC	Unknown	Or	NUFM 1347
17	*Psilorhynchus arunachalensis* (Nebeshwar, Bagra & Das, 2007)	Mernngo	Not accessed	DD	Unknown	Or	NUFM 1353
Family: Botiidae							
18	*Botia rostrata* (Günther, 1868)	Nga-medaktsü	Gangetic loach	VU	Decreasing	Or	NUFM 1356
Family: Nemacheilidae							
19	*Paracanthocobitis botia* (Hamilton, 1822)	Sangsert	Mottled loach	LC	Decreasing	Or	NUFM 1335
20	*Schistura savona* (Hamilton, 1822)	Retong	*Half-banded Loach*	LC	Unknown	Or	NUFM 1341
Order: Siluriformes Family: Siluridae							
21	*Pterocryptis indica* (Datta, Barman & Jayaram, 1987)	Lorng	Siluras Catfish	DD	Unknown	Fd	NUFM 1360
Family: Bagridae							
22	*Olyra longicaudata* (McClelland, 1842)	Nenak	Torrent Catfish	LC	Unknown	Or	NUFM 1357
Family: Amblycipitidae							
23	*Amblyceps apangi* (Nath & Dey, 1989)	Nenak	Indian Torrent Catfish	LC	Unknown	Or	NUFM 1368
Family: Sisoridae							
24	*Glyptothorax indicus* (Talwar, 1991)	Jangmu	Catfish	LC	Unknown	Or	NUFM 1366
Order: Anabantiformes Family: Channidae							
25	*Channa melanostigma* (Geetakumari & Vishwanath, 2011)	Alopungo	snakehead	Not accessed	Not accessed	Fd, Or	NUFM 1374

	Systematic position	Local name (Ao)	Common name	IUCN status	Population trends	Economic value	Specimen number
Family: Badidae							
26	*Badis badis* (Hamilton, 1822)	Akngo	Badis	LC	Unknown	Or	NUFM 1379
Order: Beloniformes Family: Belonidae							
27	*Xenentodon cancila* (Hamilton, 1822)	Jokli	Freshwater Garfish	LC	Unknown	Or	NUFM 1385
Order: Synbranchiformes Family: Mastacembelidae							
28	*Mastacembelus armatus* (Lacepède, 1800)	Merü	Spiny Eel	LC	Stable	Fd, Or	NUFM 1388

DD—Data Deficient | EN—Endangered | LC—Least Concern | NT—Near Threatened | VU—Vulnerable | Fd—Food | Sp—Sport | Or—Ornamental.

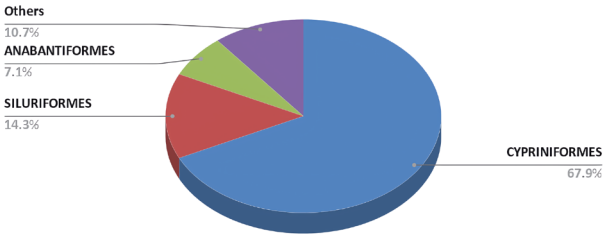

Figure 1. Distribution of fish species by order group.

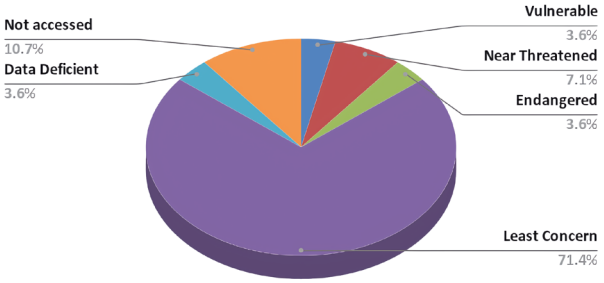

Figure 2. Distribution via IUCN conservation status.

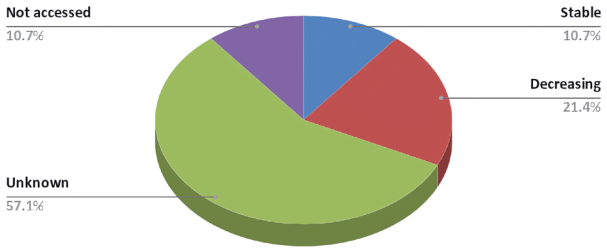

Figure 3. Distribution by population trend.

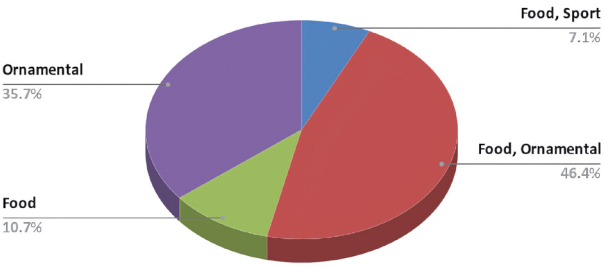

Figure 4. Distribution by economic value.

the ability to thrive in a range of water conditions, their varied feeding strategies, and reproductive behaviors, which have enabled them to outcompete other species in these freshwater habitats. Furthermore, their efficient use of resources has positioned Cypriniformes as central components of the ecological dynamics in these rivers (Mondal & Bhat 2020). Similar patterns of Cypriniformes dominance have been reported in studies conducted in Nagaland, with most species classified by the IUCN as either 'Least Concern' or 'Data Deficient' (Tsurunla et al. 2024), emphasizing the need for more focused studies on the region's ichthyofauna. The present study also identified a significant proportion (21.4%) of species experiencing a declining population trend, which is likely attributable to a combination of natural environmental pressures and anthropogenic influences (Nel et al. 2009; Kechu et al. 2021).

Relative abundance (RA) is an important metric in ichthyological studies as it reflects the proportional representation of species within a community. This measure is crucial for understanding species dominance, interspecies competition, and the overall health and stability of aquatic ecosystems (Hubbell 2005). In this study, *Devario aequipinnatus* and *Opsarius bendelisis* were found to have the highest RA, with values similar to those reported by Valentina et al. (2015) in Karbi Anglong district, Assam. Additionally, the post-monsoon season was marked by the highest number of catches, consistent with findings by Ali et al. (2004), who observed that receding water levels during this period tend to concentrate fish in shallower areas, thereby increasing catch rates.

The Shannon Diversity Index is a key tool for assessing the health of aquatic ecosystems. Values below 1

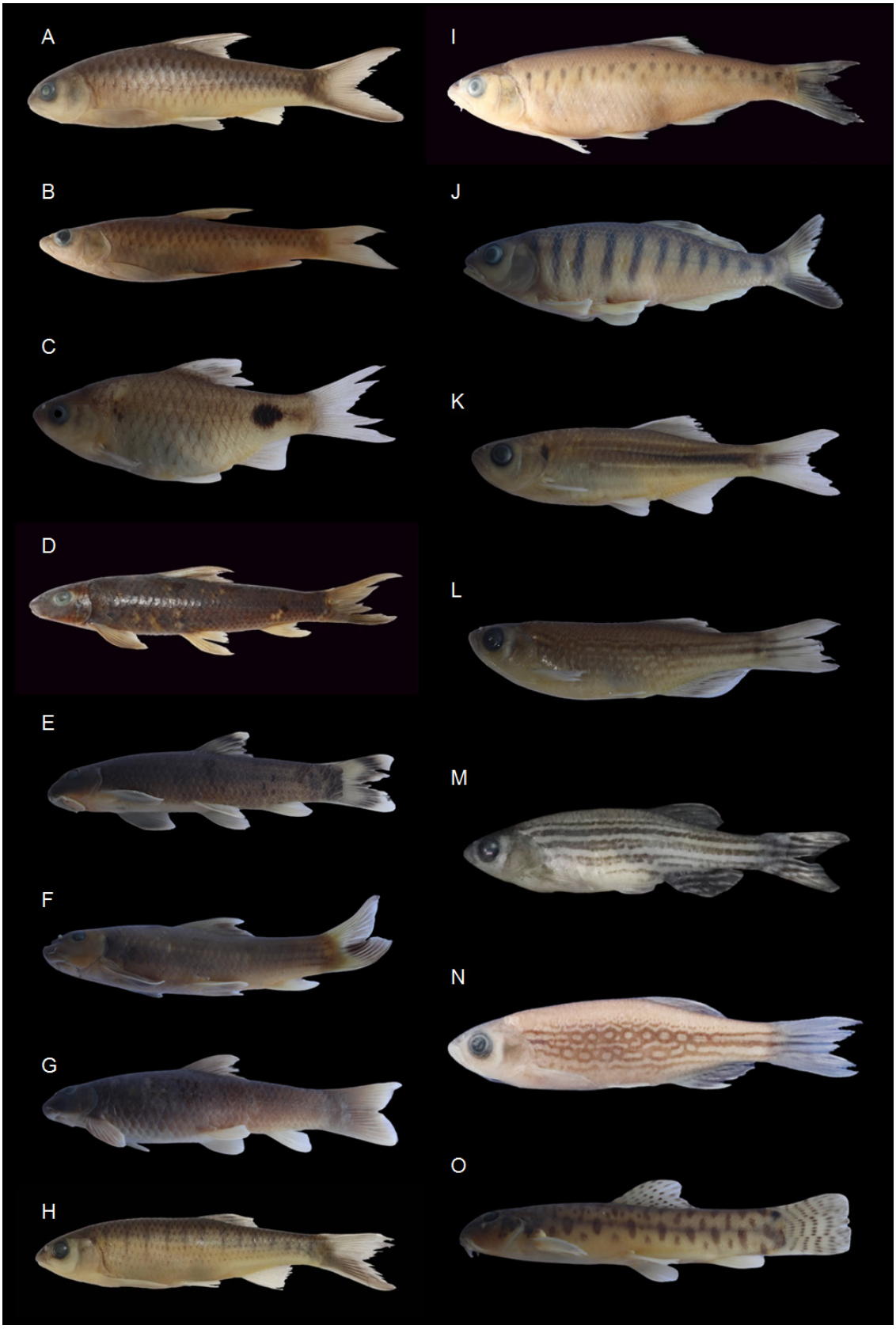

Image 2. Fish species recorded in Dikhu River, Nagaland: A—*Neolissochilus hexagonolepis* | B—*Tor putitora* | C—*Pethia conchonius* | D—*Tariqilabeo latius* | E—*Garra lissorhynchus* | F—*Garra birostris* | G—*Garra naganensis* | H—*Opsarius bendelisis* | I—*Opsarius tileo* | J—*Opsarius barna* | K—*Devario aequipinnatus* | L—*Danio dangila* | M—*Danio rerio* | N—*Danio assamila* | O—*Paracanthocobitis botia*. © Metevinu Kechu.

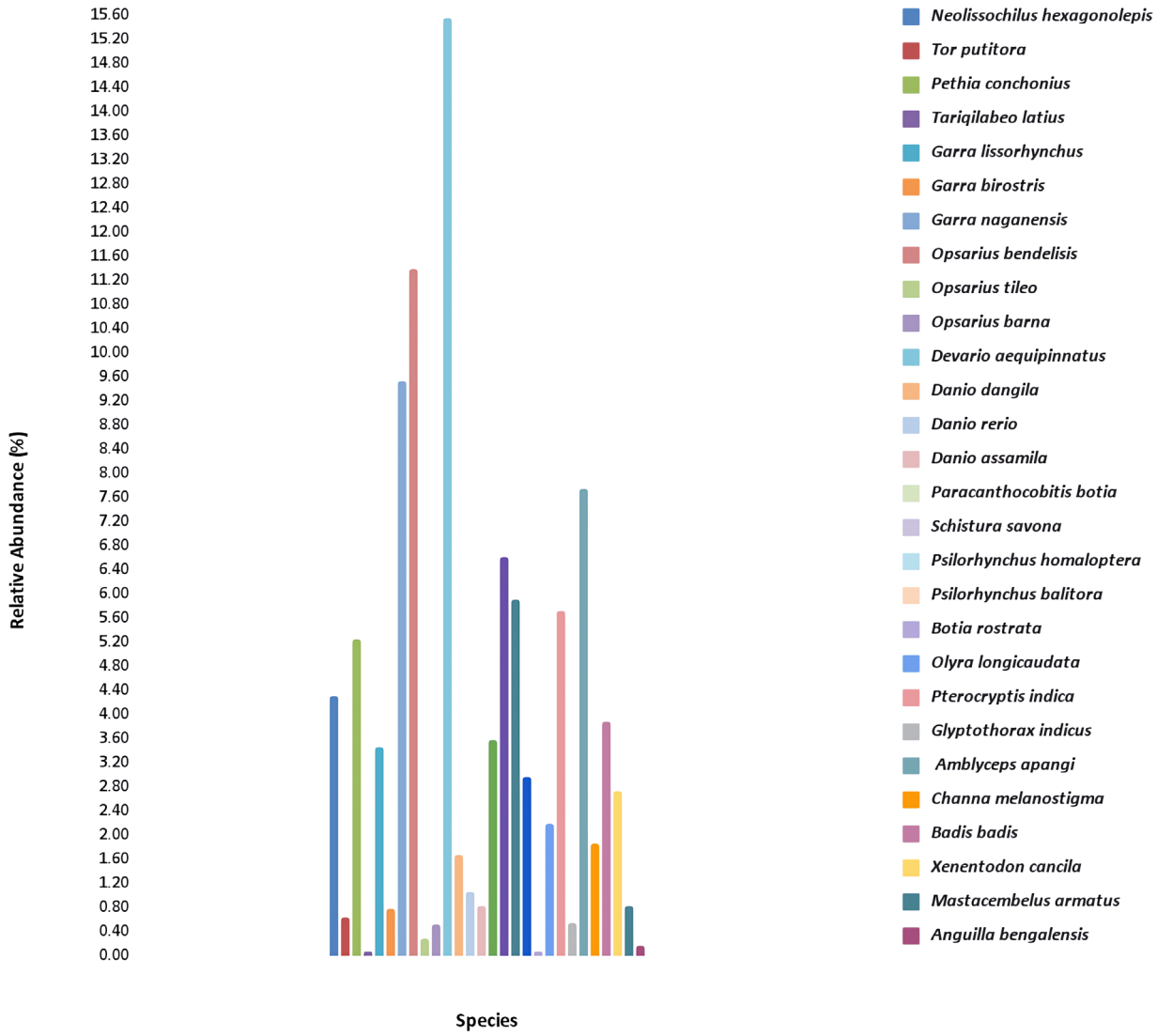

Figure 5. Relative abundance of fish species.

generally indicate high pollution and stress, values between 1 and 2 suggest moderate stability and values above 3 reflect a healthy, stable environment conducive to species survival (Stub et al. 1970). The findings from this study align with those of Dey & Sarma (2018), who reported the highest fish diversity during the post-monsoon season in the Manas River. Similarly, Satpathy et al. (2021) recorded a Shannon diversity value of 2.76 for the Subansiri River, suggesting moderate ecosystem health. Simpson's dominance index, which emphasizes the abundance of species over richness, also contributes to understanding the evenness of fish communities (Islam & Yasmin 2018). In this study, the highest evenness (J') was recorded during the pre-monsoon season, while the lowest value occurred during the monsoon. The average evenness across all seasons was 0.864 ± 0.044, indicating a fairly balanced distribution of species. The post-monsoon season consistently displayed the highest species richness and diversity, likely due to the influx of water from various sources, which brings additional species into the river system and enhances community diversity. Additionally, there is a rise in species richness due to the migration of fish from larger rivers for breeding and spawning. These seasonal dynamics underscore the critical role of water-level fluctuations in shaping fish community composition, with the post-monsoon period supporting the highest levels of biodiversity across the study area.

During field surveys, interviews with local villagers revealed a noticeable decline in fish diversity, primarily attributed to the use of destructive fishing practices. The increasing availability and affordability of such tools have

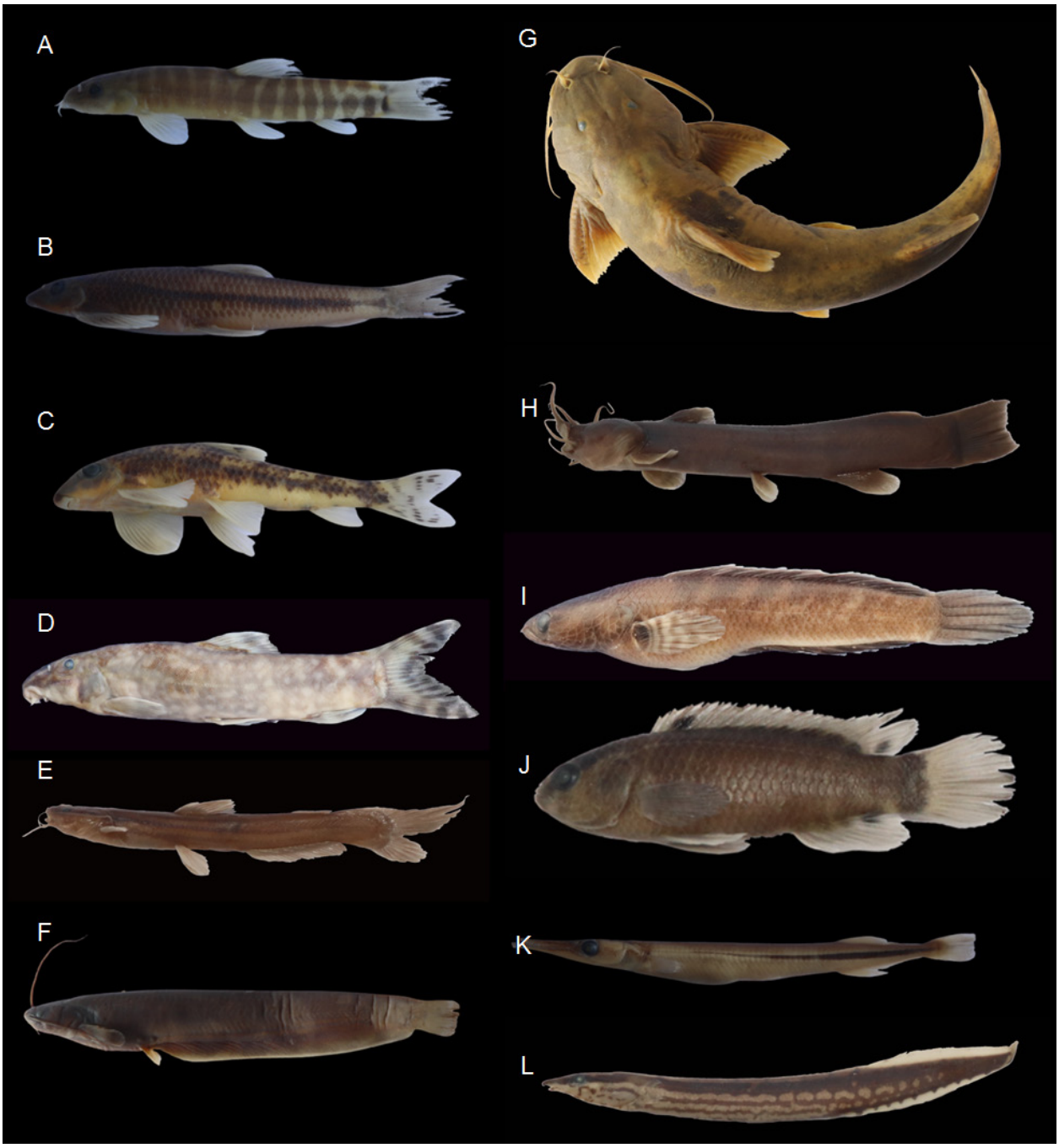

Image 3. Fish species recorded in Dikhu River, Nagaland: A—*Schistura savona* | B—*Psilorhynchus homaloptera* | C—*Psilorhynchus balitora* | D—*Botia rostrate* | E—*Olyra longicaudata* | F—*Pterocryptis indica* | G—*Glyptothorax indicus* | H—*Amblyceps apangi* | I—*Channa melanostigma* | J—*Badis badis* | K—*Xenentodon cancila* | L—*Mastacembelus armatus*. © Metevinu Kechu.

exacerbated the problem, leading not only to a reduction in fish populations but also negatively affecting the reproductive success of species, thereby causing long-term ecological harm. These observations are consistent with research suggesting that anthropogenic activities, such as overfishing and the use of harmful fishing techniques, are major contributors to fish population declines in river systems across Nagaland (Kechu et al. 2021).

The lack of comprehensive taxonomic surveys, genetic studies, and an understanding of the impacts of environmental changes poses significant challenges to the conservation of freshwater species in northeastern India. These gaps hinder accurate species identification

Table 3. Diversity indices distribution in four seasons in Dikhu River.

Season	Total individuals	Total species found in each season	Shannon diversity index H'	Simpson's dominance index (D)	Evenness (J)
Pre-monsoon	798	25	2.842	0.930	0.908
Monsoon	407	21	2.497	0.892	0.820
Post-monsoon	891	26	2.912	0.936	0.894
Winter	477	23	2.613	0.901	0.833
Total	2573				
Total no. of fishes	28				
Mean ± SD		23.75 ± 2.217	2.716± 0.194	0.915± 0.022	0.864± 0.044

and impede effective conservation planning, particularly for rare or endemic species. Integrating traditional ecological knowledge from local communities can provide valuable insights into fish migration patterns, breeding cycles, and habitat usage, complementing modern scientific research and enhancing conservation efforts (Albuquerque et al. 2021). There is an urgent need for more holistic and integrated conservation strategies, including habitat restoration, the promotion of sustainable fishing practices, and community-based conservation programs. Regular ecological monitoring and biodiversity assessments are crucial for safeguarding the aquatic ecosystems of the Dikhu River and for meeting both local and global biodiversity conservation goals.

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