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Research Article

Fish diversity assessment of a tributary of Pakke river: A preliminary study from the Eastern Himalayas

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Abstract: This study presents preliminary assessment of fish diversity in a small tributary of the Pakke River system, located within the Pakke Tiger Reserve of Arunachal Pradesh, Eastern Himalayas. Systematic single-season fish sampling was conducted in the year 2023 during pre-monsoon months of February at coordinates 26°59'14.85"N, 93°00'50.1"E near Golloso village, Seijosa. A total of 13 distinct fish species across three orders and seven families were documented, with Cypriniformes dominating the assemblage, including four families and total of 9 species. Among families, Danionidae emerged as the most dominant with a total of 5 distinct fish species. Diversity indices, including Shannon-Wiener ($H' = 2.09$), Simpson ($D = 0.84$), Margalef (2.71), and Pielou's evenness (0.81), indicated moderate to high species diversity of the Pakke river and a relatively balanced community structure. Notably, threatened fish species such as Semiplotus semiplotus (vulnerable), Aborichthys kempi and Ompak pabda (both near threatened) were recorded, underscoring the conservation significance of this pristine river system. The integration of traditional ecological knowledge with scientific sampling method enhanced species detection, particularly of cryptic taxa. This baseline biodiversity data provides critical insight for future conservation planning and highlights the river's role in maintaining freshwater biodiversity within the Eastern Himalayan biodiversity hotspot.

Keywords: Freshwater fish diversity, Eastern Himalayas, Pakke river, Cypriniformes dominance, Conservation.

1. Introduction

Freshwater ecosystems harbour disproportionately high levels of biodiversity relative to their limited spatial extent, supporting approximately 40% of all fish species despite occupying less than 1% of the Earth's surface (Dudgeon et al., 2006). Among these systems, tropical mountain rivers are particularly significant for their role in maintaining high levels of endemism and serving as an evolutionary center for

freshwater fish diversification (Hugueny et al., 2010). The Eastern Himalayas, recognized as one of the world's 25 biodiversity hotspots, exemplify this pattern with their exceptional ichthyofaunal diversity shaped by complex geological history and ongoing orogenic processes (Myers et al., 2000).

Northeast India, encompassing a significant portion of the Eastern Himalayan biodiversity hotspot, represents one of the most ichthyologically diverse regions globally, containing more than 62.81% of India's total freshwater fish species (Goswami et al., 2012). This remarkable diversity is attributed to the region's unique topographical features, varied climatic conditions, and complex drainage patterns that create a mosaic of aquatic habitats ranging from high-altitude cold-water streams to tropical lowland rivers (Vishwanath, 2017). The region's fish fauna comprises a complex assemblage of endemic hill stream specialists, Indo-Gangetic elements, and species with Myanmarese and South Chinese affinities. This may be attributed to the area's biogeographical significance as a transition zone between major zoogeographical realms (Rodgers et al., 2000).

Within Northeast India, Arunachal Pradesh stands out as a centre of freshwater fish endemism and diversity. Systematic ichthyological surveys have documented a progressive increase in known species richness, from an initial record of 170 species to the current tally of 272 total species from the state (Kosygin et al., 2024). Recent studies by Kosygin et al. (2024) indicate that the state is now home to 100 endemic freshwater fish species. As per the National Bureau of Fish Genetic Resources (NBFGR) 36 species found in Arunachal Pradesh were assessed as either Vulnerable (25 species) or Endangered (11 species), though conservation assessments remain incomplete for many endemic forms (Gurumayum & Nath, 2022).

The Brahmaputra drainage system, to which the Pakke River belongs, represents one of the most significant river networks in the Eastern Himalayas. This system supports 22 endemic species and exhibits distinct ichthyofaunal assemblages along its longitudinal gradient (Vishwanath, 2017). Tributaries of the Brahmaputra, particularly those draining the Eastern Himalayan slopes, have proven to be repositories of unique fish diversity, with recent studies continuing to reveal new reports and range extensions (Khiham et al., 2025). The varied topography of these tributaries, from steep mountain torrents to meandering foothill streams, creates diverse ecological niches that support specialized fish communities adapted to specific hydraulic and habitat conditions (Satpathy et al., 2021).

The Pakke River, a tributary of the Brahmaputra system flowing through the Pakke Tiger Reserve in East Kameng district, represents a relatively understudied component of this biodiverse landscape. The river originates from the Eastern Himalayan ranges at an elevation of 1355 m (27°10’55.59’’, 93°17’89’’) and flows through pristine forests, creating a gradient of aquatic habitats from high-altitude streams to broader valley reaches. The Pakke Tiger Reserve, established in 1977 and covering 862 km², provides critical habitat protection for the river system and its associated biodiversity (Johnsingh et al., 2004).

Despite the conservation significance of this protected area, comprehensive ichthyofaunal surveys of the Pakke River remain limited, with most regional studies focusing on larger river systems or more accessible areas.

Previous ichthyological research in adjacent river systems has revealed remarkable diversity patterns. Studies in the Kameng drainage documented 117 species with high levels of endemism (Dey et al., 2021), while surveys in the Siang system recorded 90 species, including several range extensions (Das et al., 2014). The upper Subansiri River, another major tributary, supports 26 fish species with distinct community structure related to environmental gradients (Satpathy et al., 2021). These studies collectively suggest that tributaries of the Pakke River, situated within the same biogeographical region and sharing similar ecological characteristics, likely harbour significant fish diversity that remains inadequately documented.

The conservation significance of documenting the ichthyofauna of the Pakke river's tributaries extends beyond academic interest. Freshwater fish communities in the Eastern Himalayas face increasing threats from habitat degradation, climate change, and anthropogenic disturbances (Dudgeon, 2011). Many endemic species have restricted distributions and specialized habitat requirements, making them particularly vulnerable to environmental changes (Kachari et al., 2014). The lack of comprehensive baseline data for many river systems, including the Pakke River, hampers effective conservation planning and management decisions, with only scanty studies focused on generating baseline information, such as in the Kherem river flowing in the eastern Arunachal (Tenali et al., 2025; Khiham et al., 2025).

Furthermore, traditional ecological knowledge of local communities regarding fish diversity and distribution patterns remains largely undocumented, representing a significant gap in our understanding of the region's ichthyofaunal heritage (Satpathy et al., 2021). Indigenous fishing practices and local nomenclature systems provide valuable insights into species ecology and historical abundance patterns that complement scientific surveys (Drew & Henne, 2006).

Against this backdrop, the present study aims to provide the first comprehensive assessment of fish diversity in the Pakke River system. The specific objectives include: (1) documenting the complete species composition and taxonomic diversity of fish communities in Pakke River; (2) assessing the conservation status and endemism levels of recorded species; (3) evaluating the ecological significance of Pakke River within the broader context of Eastern Himalayan ichthyofauna; and (4) providing baseline data and recommendations for conservation management of this pristine river system.

This study contributes to the growing body of knowledge on Eastern Himalayan freshwater fish diversity while addressing critical information gaps for an ecologically significant but understudied river

system. The results will inform conservation strategies for Pakke Tiger Reserve and contribute to a broader understanding of ichthyofaunal patterns in the Eastern Himalayas biodiversity hotspot.

2. Methodology

Study Area: The Pakke Kessang district, established in 2018, is one of the 28 administrative districts of Arunachal Pradesh, India, carved out from the southern units of East Kameng district. The district comprises five major administrative areas: Pakke-Kessang, Seijosa, Pijerang, Passa Valley, and Dissing Passo, with Lemmi serving as the administrative headquarters. The Pakke River flows through Seijosa, traversing the Pakke Tiger Reserve (also known as Pakhui Tiger Reserve), which covers an area of approximately 861.95 km². This reserve represents a vital aquatic and terrestrial habitat in Arunachal Pradesh. The study area is located at coordinates 26°59'14.85"N, 93°00'50.1"E near Golloso village, Seijosa. The river system exhibits diverse habitat types ranging from shallow riffles and runs to deeper pools, creating varied microhabitats that support different fish assemblages.

Fisheries constitute a significant contributor to the socio-economic well-being of local communities, with fish serving as a staple dietary component in the region. The pristine nature of the study area, protected within the tiger reserve boundaries, provides an ideal setting for assessing natural fish community structure without significant anthropogenic disturbance.

Fish Sampling: Fieldwork was conducted during February 2023 from Itanagar, with single-season sampling performed in collaboration with local community members. Sampling was carried out using fishing gears like cast net, gill net of varying mesh sizes (0.5 to 5cm). Additionally, the collection of samples also employed traditional bamboo traps and traditional stream-blocking and flow-diversion techniques, wherein stones and sand were used to construct temporary barriers to direct water flow. This approach enabled the effective dewatering of the stream segment, facilitating fish collection by hand. This method was particularly employed to sample smaller-sized fishes, particularly those hiding beneath large boulders, which cannot be effectively caught using gill nets or cast nets. This traditional technique, employed by local communities, allowed for thorough sampling of cryptic species often missed by standard methods. Gill nets were utilised for sampling in pool habitats for about four to five hours, and cast nets were employed to sample run, rapid and riffle habitats following the methodologies detailed in (Johnson and Arunachalum, 2009). The collected samples were examined and photographed for identification to the species level. After appropriate identification and recording of total length (TL), standard length (SL) and weight (W), the samples were released back into the streams. Precise geographic coordinates

(26°59'14.85N 93°00'50.1E) were recorded at each sampling site to ensure spatial accuracy and reproducibility.

Fish identification and preservation: All collected specimens were examined and photographed in situ for initial identification. Morphometric measurements, including total length (TL), standard length (SL), and weight (W), were recorded for each individual. Following identification and data recording, specimens were released back into the stream to minimize impact on the fish community. Specimens requiring further confirmation and additional laboratory analysis were preserved in a 10% buffered formalin solution to safeguard their integrity for subsequent laboratory identification and analysis. Fish species were confirmed based on standard literature (Talwar & Jhingran, 1991; Jayaram, 1999; Vishwanath, 2021), and nomenclature was updated in accordance with the catalogue of fishes (Fricke et al., 2025).

Analysis: Fish community structure was analysed using multiple diversity indices to provide a comprehensive assessment of species richness, evenness and dominance patterns, like Shannon diversity index (Shannon and Wiener, 1949), Simpson index (Simpson, 1949), Pielou's evenness index (Pielou, 1966) and Margalef's species richness (Margalef, 1958) to investigate species diversity patterns.

The Shannon diversity index was computed using the formula $H' = -\sum i\ pi\ Ln\ pi$, where H' is the diversity index, Ln is the natural logarithm, pi is the proportion of individuals belonging to species i ($pi = ni/N$), ni is the number of individuals of species i and N is the total number of individuals across all species.

The Simpson diversity index was computed using the formula $D = \sum i \left(\frac{ni}{N}\right)^2$, where ni is the number of individuals in species i, N is the total number of individuals of all species, and S is the total number of species. The species evenness index was calculated based on the formula: $J = H'/Ln\ S$, where H' is the Shannon diversity index, and S is the number of species. Species richness was calculated based on the formula: $D = S - 1/Ln\ N$, where D is Margalef's richness index; the sample size is expressed as N, where N represents all individuals overall, and S represents the total number of species. All indices were calculated in R version 4.4.1 (R Core Team, 2024) using the packages vegan to assess community diversity patterns and provide baseline data for future monitoring efforts.

Figure 1: Study area map illustrating the sampling site along the Pakke river, Seijosa, Pakke Kessang district, Arunachal Pradesh.

Figure 2: Field photograph depicting a riffle habitat within the Pakke river channel.

3. Results

A total of 84 individuals representing 13 distinct fish species were recorded from the Pakke River system. The assemblage encompassed three orders: Cypriniformes, Siluriformes, and Anabantiformes, distributed across eight families: Danionidae, Cyprinidae, Cobitidae, Nemacheilidae, Bagridae, Siluridae, Badidae, and Channidae (Table 1). Order Cypriniformes dominated the community with 10 species (76.9%), including representatives from families Danionidae (5 species), Cyprinidae (2 species), Cobitidae (1 species), and Nemacheilidae (1 species) (Figure 4). Order Siluriformes was represented by 2 species (15.4%) from family Siluridae. Order Anabantiformes contributed 1 species (7.7%) each from families Badidae and Channidae (Figure 3). Key species recorded included *Barilius barila*, *Danio dangila*, *Semiplotus semiplotus*, *Lepidocephalichthys guntea*, *Aborichthys kempi*, *Badis assamensis*, and *Channa punctata*. Overall, the most diversity was observed in the family Danionidae, followed by Cyprinidae and Siluridae. Family Cobitidae, Nemacheilidae, Badidae and Channidae were the least diverse families. IUCN Red List categorization revealed varying conservation concerns within the fish assemblage. Notably, *Semiplotus semiplotus* was classified as vulnerable (8% of total species) and *Aborichthys kempi,* along with *Ompok pabo,* as near threatened, constituting 15% of total species, while most other species were listed as least concern (LC) per IUCN categories, constituting 61% of the total sampled species. Other like species *Olyra longicaudata* were not evaluated (8%), and *Badis assamensis* was data deficient (8%) (Figure 5). Diversity metrics indicate moderate to high fish diversity in the study area with the following diversity index values: Species richness: 13; Shannon index: 2.09; Simpson index: 0.84; Margalef index: 2.71; Pielou evenness: 0.81. The Shannon-Wiener index value of 2.09 indicates moderate diversity, while the high evenness value (0.81) suggests relatively balanced species abundances across the community (Table 2). The Simpson index value confirms that no single species completely dominated the assemblage, though some species showed higher relative abundances. The most abundant species were: *Lepidocephalichthys guntea* (22 individuals, 26.2%), *Badis assamensis* (16 individuals, 19.0%), *Devario aequipinnatus* (13 individuals, 15.5%) and *Channa punctata* (11 individuals, 13.1%).

Table 1: Details of fish species recorded from a tributary Pakke river with their orders, families as well as the IUCN status.

Order	Family	Sl.No.	Species	IUCN
CYPRINIFORMES	Danionidae	1	*Barilius barila* (Hamilton, 1822)	LC
		2	*Danio dangila* (Hamilton, 1822)	LC
		3	*Devario devario* (Hamilton, 1822)	LC
		4	*Devario aequipinnatus*	LC

			(McClelland, 1839)	
		5	*Opsarius bendelisis* (Hamilton, 1807)	LC
	Cyprinidae	6	*Semiplotus semiplotus* (McClelland, 1839)	VU
		7	*Tarqilabeo latius* (Hamilton, 1822)	LC
	Cobitidae	8	*Lepidocephalichthys guntea* (Hamilton, 1822)	LC
	Nemacheilidae	9	*Aborichthys kempi* **(**Chaudhuri, 1913)	NT
SILURIFORMES	Bagridae	10	*Olyra longicaudata* (McClelland, 1842)	Nev
	Siluridae	11	*Ompok pabo* (Hamilton, 1822)	NT
ANABANTIFORMES	Badidae	12	*Badis assamensis* (Ahl, 1937)	DD
	Channidae	13	*Channa punctata* (Bloch, 1793)	LC

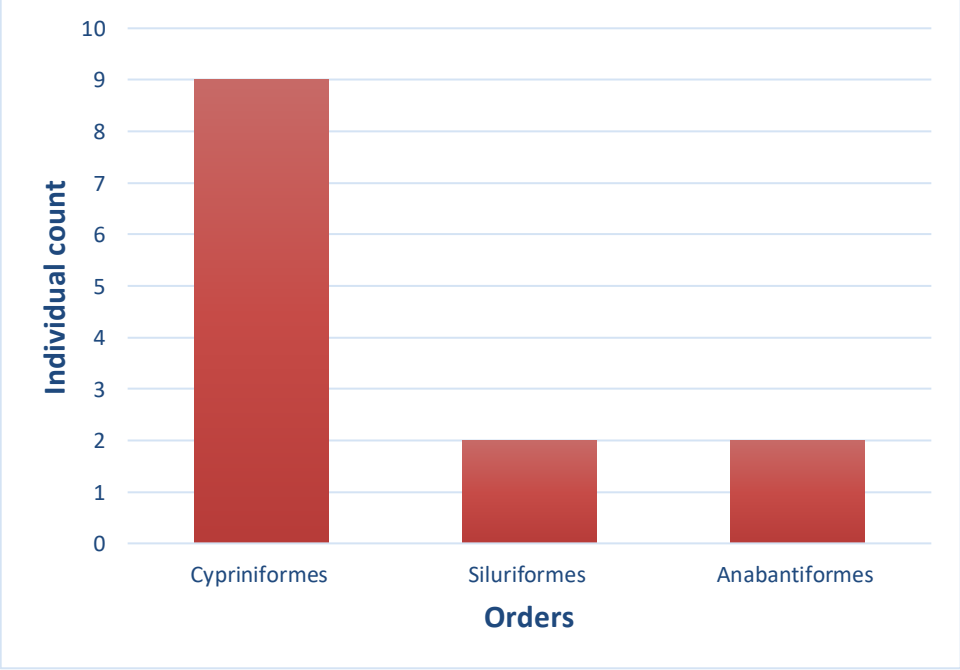


Figure 3 : Order-wise distribution of 13 fish species documented from a tributary of the Pakke river. Order Cypriniformes resulted as the most diverse order comprising.

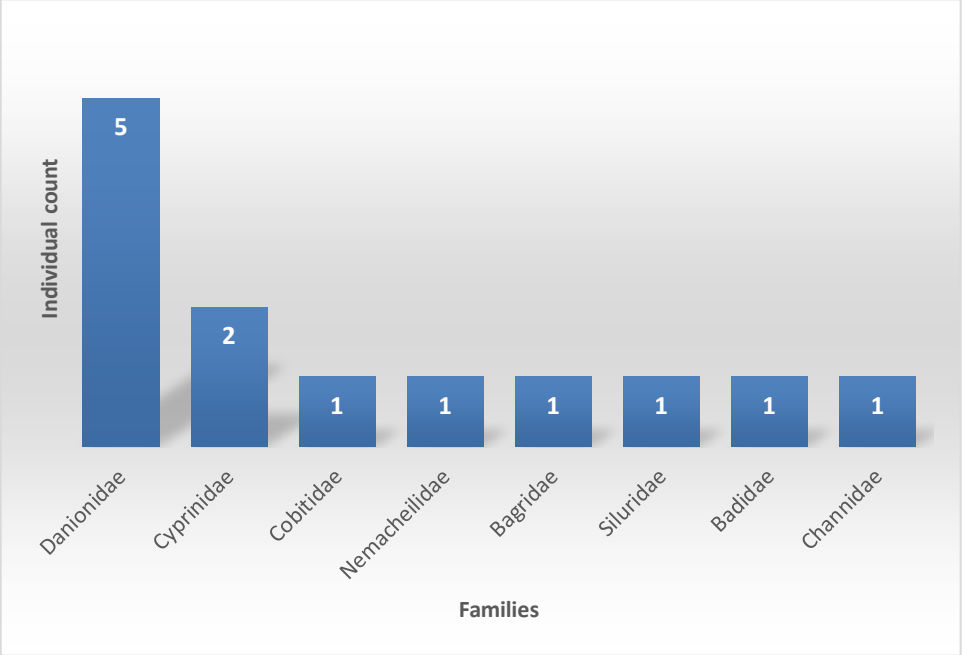


Figure 4: Family-wise distribution of 13 fish species documented from a tributary of the Pakke river. Family Danionidae emerged as the most dominant with total 5 different species.

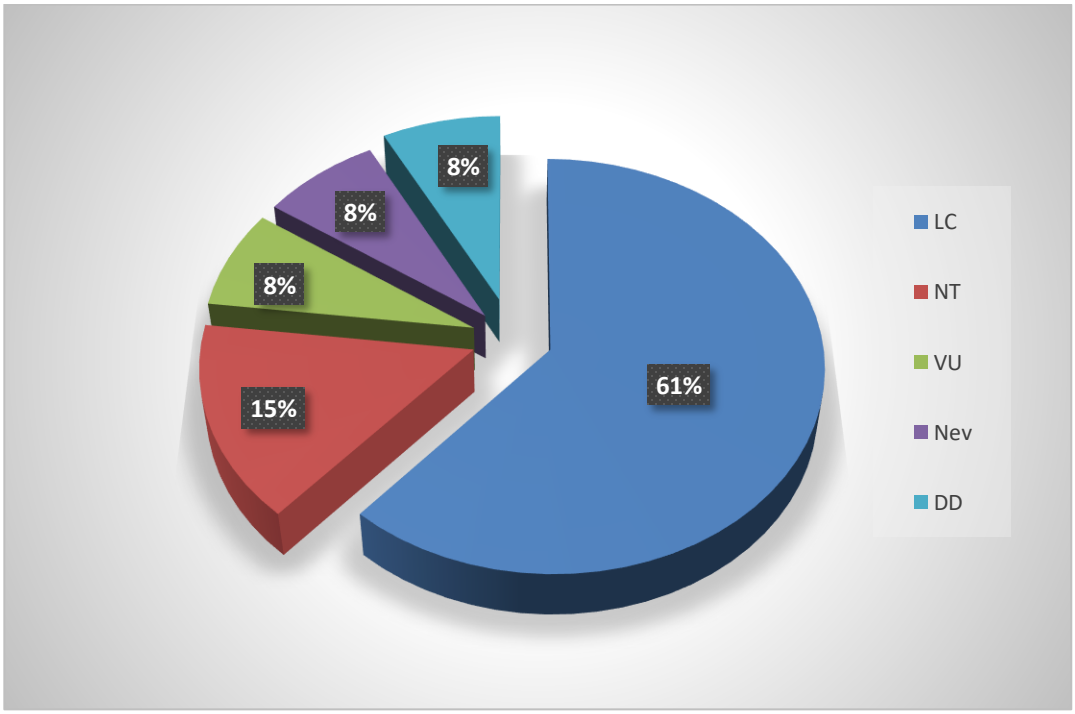


Figure 5: IUCN categories of 13 distinct fish species recorded from a tributary of Pakke river channel. LC - least concern, NT- near threatened, VU-vulnerable, Nev- not evaluated and DD- data deficient.

Table 2: Diversity indices values of fish assemblage from a tributary of Pakke river.

Individual	Species	Shannon	Simpson	Margalef	Pielou

count	richness	index	index	index	evenness
84	13	2.086154	0.8424036	2.708304	0.8133313

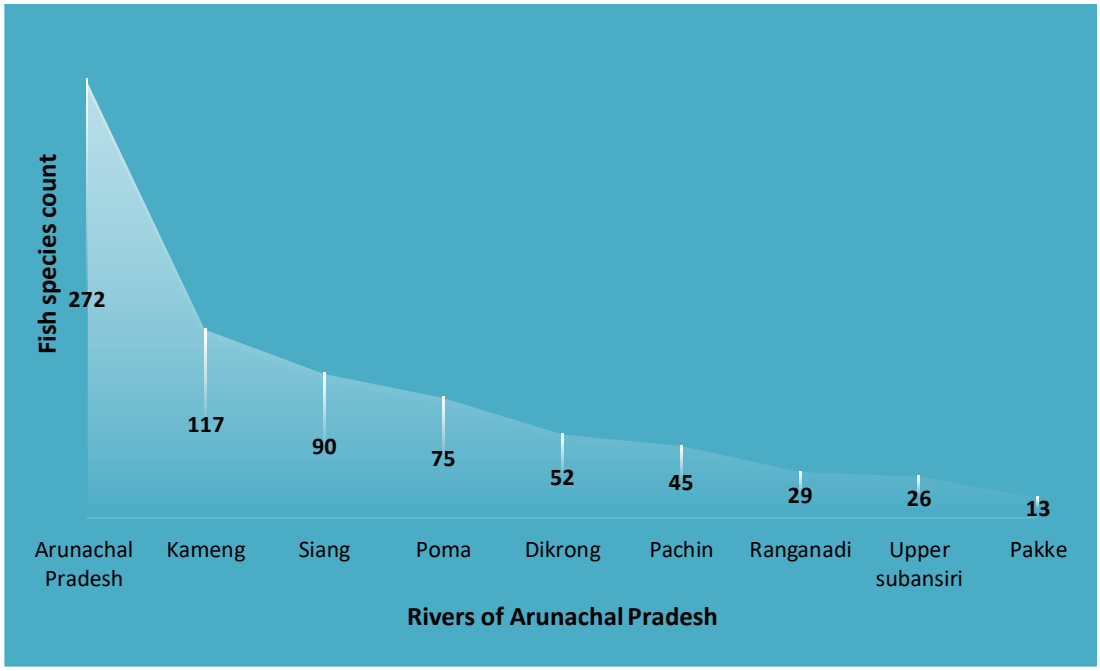
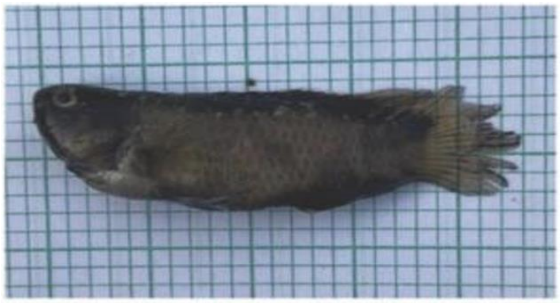
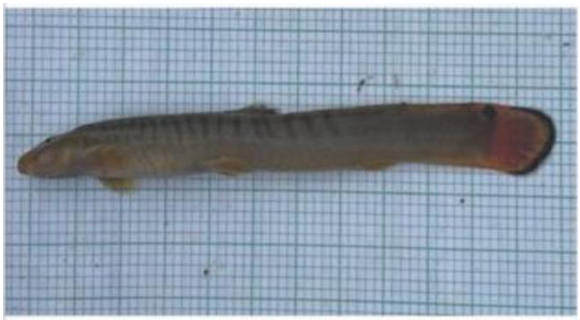


Figure 6: Comparative analysis of total fish species reported from a small tributary of the Pakke river with adjacent river systems of Arunachal Pradesh. This preliminary study highlights the need for continued ichthyofaunal surveys of the Pakke river.

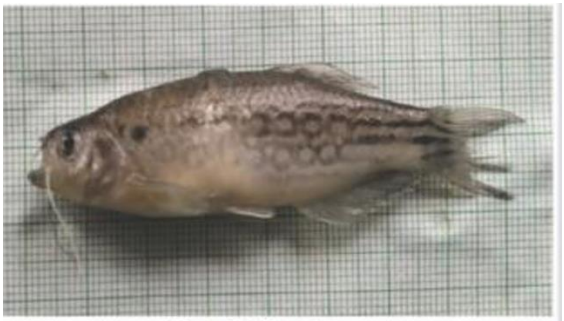
Lepidocephalichthys guntea



Badis assamensis

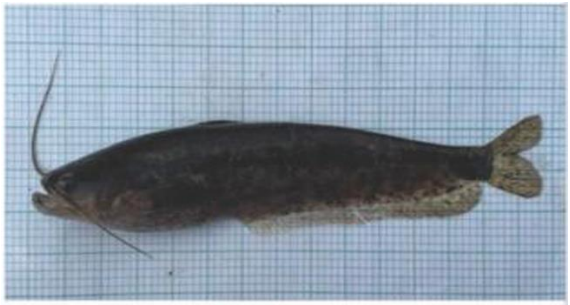


Aborichthys kempi



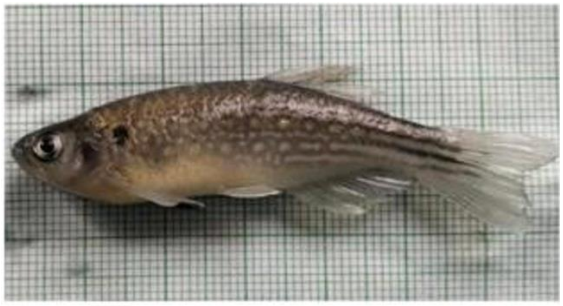
Devario devario

Olyra longicaudata

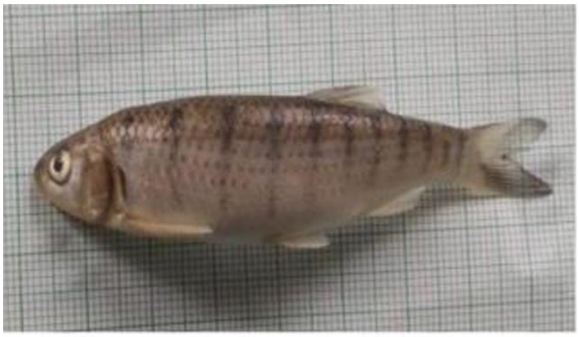


Ompok pabo

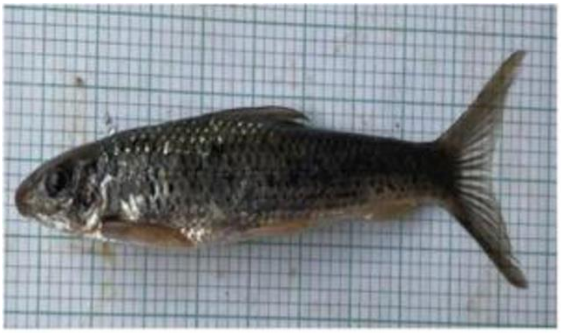
Devario aequipinnatus



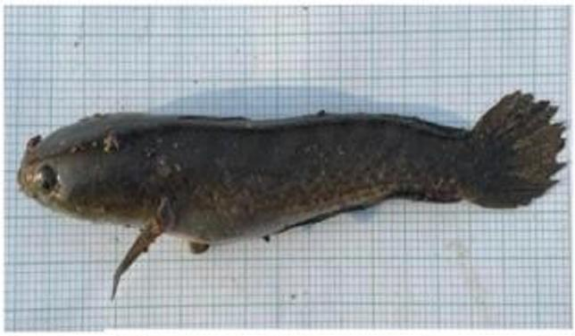
Danio dangila



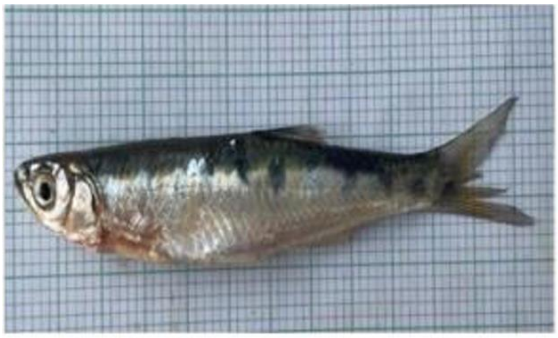
Opsarius bendelisis



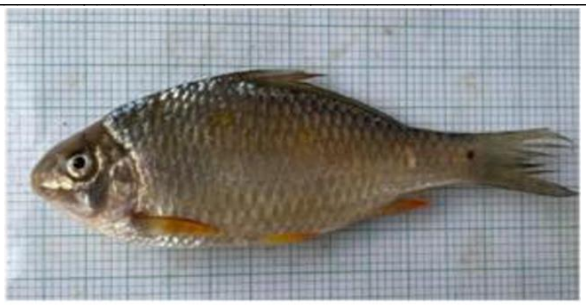
Tarqilabeo latius



Channa punctata



Barilius barila



Semiplotus semiplotus

Figure 7: Fish species documented from a small tributary of Pakke river. The photographs were taken after the fishes were sampled in the field before the preservation in formaldehyde solution.

4. Discussions

The present preliminary study revealed moderate to high fish diversity along the tributary of the Pakke River, as evidenced by diversity indices and species composition. The Shannon-Wiener diversity index ($H' = 2.09$) corresponds to moderate water quality, suggesting that this stretch of the river is clean to moderately polluted, consistent with established thresholds where H' values between 2 and 3 indicate moderate ecosystem health and resilience (Mishra et al., 2010; Mason, 1988). This aligns with other studies in Eastern Himalayan rivers, where habitat structure, flow regimes, and riparian vegetation contribute to maintaining suitable habitats of hillstream fish species (Khiham et al., 2025). Pakke river accounts for approximately 4.78% of the total 272 fish species listed from different river systems in Arunachal Pradesh (Kosygin et al., 2024). Other prominent river systems adjacent to the Pakke river have likewise documented a diverse assemblage of fish species through various studies. For instance, a total of 26 species were reported from the upper Subansiri river (Satpathy et al., 2021), 45 species from Pachin river (Nanda, 2016), 75 species from Poma river of Arunachal and Assam (Gurumayum, 2021), 90 species from Siang river (Das et al., 2014), 52 and 29 potential ornamental fish species reported from Dikrong and Ranganadi, respectively and as many as 117 species reported from Kameng river (Dey et al., 2021) (Figure 6). These observations underscore the significant capacity of Eastern Himalayan rivers to support diverse fish fauna and the need for more comprehensive ichthyofaunal surveys of the Pakke river to document its full fish diversity.

The Pakke River was observed to maintain relatively good water quality, consistent with its protected status within the tiger reserve. The observed evenness index of 0.81 indicates a relatively equitable distribution of individuals among species, approaching the theoretical maximum of 1.0. Such values suggest that no single species dominates the assemblage, which is characteristic of stable, undisturbed ecosystems and points toward a balanced ecosystem with limited environmental stress (Krebs, 1999; Faurie et al., 2001). This condition is favourable for long-term community stability, as evenness often correlates with ecosystem functionality and the maintenance of trophic interactions (Peet, 1974). The Margalef species richness index (2.71) observed in

this study further indicates substantial species diversity and a complex food web structure, supporting Margalef's hypothesis that higher diversity signals longer food chains and functional complexity in aquatic systems (Margalef, 1958). The dominance index (Simpson's index, D = 0.84), however, suggests that a few species, such as *Lepidocephalichthys guntea* and *Badis assamensis*, are numerically dominant. High Simpson index values often reflect uneven community composition, potentially driven by selective pressures, habitat fragmentation, or overfishing (Whittaker, 1972). The presence of some numerically dominant species (*L. guntea*, *B. assamensis*) may reflect their ecological adaptations to specific habitat conditions within the river system. Such patterns highlight the importance of ongoing biodiversity monitoring for detecting shifts in community structure and ecosystem health.

The dominance of Cypriniformes (76.9% of species) aligns with typical patterns observed in Himalayan freshwater systems, where cyprinids constitute the most diverse fish group (Rashid et al., 2025). The family Danionidae showed the highest species richness (5 species), reflecting the group's success in hill stream environments. This pattern is consistent with findings from other Eastern Himalayan tributaries, where Danionids often dominate fish assemblages due to their morphological and physiological adaptations to flowing water conditions (Barman et al., 2024). The presence of specialized hill stream taxa such as *Aborichthys kempi* (Nemacheilidae) and various Danionid species indicates the maintenance of habitat conditions suitable for rheophilic (current-loving) fish communities. These species typically require well-oxygenated and fast-flowing waters with rocky substrates, conditions that appear to be maintained within the study area. The documentation of two threatened species, for instance, *Semiplotus semiplotus* (Vulnerable) and *Aborichthys kempi* (Near Threatened), within the relatively small study area underscores the conservation importance of the Pakke River system. These species often have restricted distributions and specific habitat requirements, making them particularly vulnerable to environmental changes (Ering et al., 2021). The high proportion of Least Concern species (61.5%) suggests a relatively stable fish community, though this may also reflect incomplete conservation assessments for many regional endemic taxa. The presence of Data Deficient (*Badis assamensis*) and Not Evaluated (*Olyra longicaudata*) species highlights ongoing taxonomic and conservation assessment needs for Eastern Himalayan ichthyofauna. The prevalence of Least Concern species alongside vulnerable taxa illuminates both the conservation potential and the susceptibility of the system to anthropogenic impacts. Maintaining natural habitats, preventing overexploitation, and mitigating pollution are essential for safeguarding the diversity and sustainability of these assemblages (Dudgeon et al., 2006). The integration of traditional fishing methods with conventional sampling techniques proved effective for comprehensive species detection. The stream-blocking method, in particular, enabled capture of cryptic species that might otherwise be missed using standard sampling protocols. This approach demonstrates the value of incorporating traditional ecological knowledge into scientific surveys.

Overall, our findings demonstrate the Pakke River's ecological significance within the Brahmaputra drainage and Eastern Himalayan biodiversity hotspot. The documented community structure serves as a baseline for future conservation planning and offers valuable insight into local and regional ichthyofaunal patterns. Expanding systematic surveys and integrating traditional ecological knowledge will further refine our understanding of species interactions and inform adaptive management strategies. Given the Pakke River's role in supporting endemic and threatened species—and its representation of larger biogeographic patterns—its preservation is crucial for maintaining the integrity and function of Eastern Himalayan aquatic ecosystems. Ongoing assessment of species diversity, evenness, and dominance remains central to detecting ecological change and developing effective conservation responses.

Future research should focus on expanding temporal and spatial sampling to capture seasonal variations and habitat-specific assemblages. Detailed taxonomic and molecular documentation is the need of the hour, along with a better understanding of population structure and evaluating environmental drivers of this population. Future projects can also focus on the long-term trends in community structure against the swift domain of climate change. Additionally, this study underscores the need for strict riparian habitat protection, long-term monitoring of threatened species, continued ecological research, community-based conservation, and preservation of river connectivity to sustain fish diversity and ecological integrity.

5. Conclusion

This study provides the first comprehensive assessment of fish diversity in the Pakke River system, documenting 13 species across three orders and eight families. The fish community exhibits moderate to high diversity with balanced species abundances, indicating a relatively healthy ecosystem. The presence of threatened species highlights the conservation significance of this protected river system within the Eastern Himalayan biodiversity hotspot. The dominance of Cypriniformes, particularly Danionids adapted to hill stream environments, reflects the river's characteristic flowing water conditions. Diversity indices suggest good water quality and minimal anthropogenic disturbance, consistent with the protected status of the Pakke Tiger Reserve. The integration of traditional and scientific sampling methods proved effective for comprehensive species detection, demonstrating the value of community-based research approaches. The documentation of threatened taxa (*Semiplotus semiplotus* and *Aborichthys kempi*) underscores the need for continued habitat protection and monitoring efforts. This baseline study contributes essential data for conservation planning and management of the Pakke River system while highlighting the broader importance of Eastern Himalayan tributaries as repositories of freshwater fish diversity. Continued research and protection efforts are crucial for maintaining the ecological integrity of this significant aquatic ecosystem.

To further enhance future monitoring of fish biodiversity and ecosystem health, the convergence of molecular barcoding techniques is encouraged for more accurate species identification, along with habitat-based conservation assessments to inform focused management interventions. Such approaches will enhance species detection and taxonomic resolution, thereby supporting adaptive and evidence-based conservation planning in freshwater ecosystems.

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Availability of Data and Materials: The data and specimens that support the findings of this study are openly available *at Fish museum of Dera Natung Government College, Itanagar,Arunachal Pradesh.*

Ethical Declarations: No animals/humans were harmed during the study.

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