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An overview of ichthyofaunal diversity in Nun River: A preliminary survey

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ABSTRACT

This study aims to investigate and document the ichthyofaunal diversity of the Nun River, a previously unexplored tributary of the River Tons in the District of Dehradun, to assess its ichthyofaunal diversity and identify potential conservation needs**.** Fish samples were collected from several sampling locations with the help of local fishermen, who are regularly engage in fishing activities at these locations, using a variety of fishing nets (mesh size: 20–40 mm) and traditional equipment. However, some fish were also procured from the local fishermen at different sampling sites. Over the course of the study period (August 2022−April 2023), the fish fauna of the Nun River was investigated. Overall, a total of 12 species belonging to 4 orders, 6 families, and 12 genera were recorded. Several anthropogenic stressors such as pollution from agricultural sources, human settlements, and sewage cause severe threats to the fish fauna and aquatic diversity of rivers. Nun River has not been explored earlier for its fish fauna. This is the first attempt made to explore the fish faunal diversity of Nun River. Since this small study area is rich in aquatic faunal diversity, hence its conservation must be given priority.

1. INTRODUCTION

Freshwater ecosystems in India face a myriad of pressing challenges that threaten their health and ichthyofaunal diversity. Rapid urbanization and industrialization contribute to pollution, sedimentation, and habitat degradation in rivers, lakes, and wetlands [1]. This pollution, including untreated sewage, industrial effluents, and agricultural runoff, poses significant threats to water quality and ecosystem integrity. Overexploitation of freshwater resources for irrigation, drinking water, and industrial purposes further strains these ecosystems, leading to altered hydrological regimes and diminished water availability. Human activities, such as pollution and habitat modification, significantly impact fish habitat preferences and distribution by altering water quality, temperature, and physical structures essential for their survival [2]. Pollutants such as heavy metals, pesticides, and industrial waste increase toxicity levels, leading to physiological stress, reduced reproductive success, and behavioral changes in fish [3]. Habitat modification, including dam construction, deforestation, and urbanization, disrupts natural water flow, reduces spawning grounds, and fragments aquatic ecosystems, forcing fish to relocate to less suitable environments. Consequently, these anthropogenic pressures result in altered distribution patterns, biodiversity loss, and reduced ecosystem resilience.

Freshwater biodiversity is far more diverse than terrestrial and marine habitats [4]. Freshwater habitats are home to a diverse range of animals and plants. Fish account for a significant portion of standing biomass in aquatic environments [5]. Over half of all vertebrate species contribute to water environments, human health, and economy worldwide [6]. Fish assemblages are commonly employed as ecological indicators to evaluate the health and degradation of water bodies of different sizes [7]. Fish populations are very dynamic spatially and temporally, from all the aquatic organisms fishes are the most important element and the major sources of dietary protein for the people [8]. Fishes can be found in nearly all aquatic environments, from high mountains and streams. Moreover, fish diversity studies contribute to conservation efforts by identifying species at risk, assessing the impacts of human activities on aquatic ecosystems, and guiding management strategies for sustainable fisheries and ecosystem restoration.

India possesses around 4% of the world's renewable freshwater reserves, which support over 18% of the world's population and a diverse array of aquatic and semi-aquatic biota. India holds globally sixth rank in freshwater ichthyofaunal diversity. The Indian fish

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population describes 11.72% of species, 23.96% of genera, 57% of families, and 80% of global fishes [9]. Uttarakhand state is a mountainous region in the northern side of India. Uttarakhand has abundant inland water resources, with most rivers originating from the Himalayas. In addition, this region also boasts numerous natural lakes. These resources contain indigenous fish species that are commercially useful to humans.

In the Doon Valley, characterized by a rich network of perennial rivers, hill streams, ponds, and reservoirs, an extensive diversity of fish species thrives. Research has predominantly focused on the Eastern Doon Valley, within the Ganga drainage basin, as indicated by recent literature reviews. The study conducted by Bhatt *et al.* [10] focused on assessing the fish fauna, species diversity, and relative abundance in the Yamuna River of the western Doon region in Uttarakhand. The findings likely provide valuable insights into the ecological health and ichthyofaunal diversity of this specific aquatic ecosystem. Assessing fish fauna and species diversity helps in understanding the composition and distribution of fish species in the river, which is crucial for ecosystem management and conservation. Recently, Bahuguna *et al.* [11], Uniyal [12], Uniyal and Kumar [13], Uniyal and Mehta [14], Gupta and Rana [15], Singh *et al.* [16], and Chaudhary *et al.* [17] have conducted a study on the fish and fisheries of the region. To add more information to the existing fish faunal diversity of Doon Valley, an attempt was made to explore the diversity of Nun River which has not been attempted earlier.

The significance of this study on the ichthyofaunal diversity of the Nun River extends beyond a local context, contributing valuable insights to both national and global perspectives on freshwater ichthyofaunal diversity. Freshwater ecosystems, which support a disproportionately high diversity of species compared to terrestrial and marine environments, are critical for global ichthyofaunal diversity, human health, and the economy. As India ranks sixth globally in freshwater biodiversity [18], understanding the species composition and ecological health of its rivers, such as the Nun River, is vital for conservation and sustainable management efforts. Documenting the fish diversity in the Nun River fills a crucial knowledge gap and enhances our understanding of the region's aquatic ecosystems, aligning with global efforts to preserve freshwater habitats and their unique biota.

2. MATERIALS AND METHODS

Monthly fish samples were collected during the study period (August 2022-April 2023), with the help of local fishermen, who regularly engage in fishing activities using a variety of nets (mesh size: 20–40 mm) and traditional equipment. The fishing methods used in India and abroad have been described by a number of workers including Bhilave [19]; Devi and Chaudhary [20].

Sampling in River Nun (Tributary of River Tons) was conducted at 03 sampling sites i.e., S1- Upstream Nun (Hariawalakhurd), S2- Midstream Nun (Jamunwala) and, S3 Downstream Nun (Bajawala) (Table 1). Fish were tested in the wild and in a laboratory, respectively, in both fresh and preserved conditions. In line with the standard literature and revisionary works that are currently available, fish samples were preserved in 4% formalin and brought to the laboratory for standard identification, meristic, and morphometric analyses [21–23].

Table 1. Details of sampling sites of River Nun.

S. No.	Sampling sites	Altitude (m asl)	Latitude	Longitude
1	Upstream Nun (Hariawala Khurd)	682	30° 22.77' N	78° 0.894' E
2	Midstream Nun (Jamunwala)	617	30° 21.84' N	78° 0.156' E
3	Downstream Nun (Bajawala)	554	30° 21.084' N	77° 59.385' E

2.1. Descriptive Statistics

Shannon–Wiener Species Diversity Index [24]: The monthly counts obtained through regular sampling were used to compute the Shannon–Wiener species diversity index (H). Seasonal values of H were computed for each genera to obtain total diversity.

$$H= \sum pi \; loge \sum pi$$

where, pi = ni/N,

ni = number of individuals of one species,

N = total number of organisms.

Dominance index: Also known as Simpson Diversity Index is a measure of diversity that takes into account the number of species present as well as the relative abundance of each species. As species richness and evenness increase diversity increases.

$$D = N(N-1)/(\sum n(n-1))$$

where

D = Diversity Index,
N = Total number of organisms of all species found,
n = Total number of individuals found of the species you are interested.

Margalef species richness index: Monthly variation in species richness was computed on the basis of data available on the number of species (genera) and individuals [25,26].

$$d' = (S-1)/logeN$$

where
d' = Margalef's index,
S = number of species,
N = total number of individuals in community.
Evenness index: The Monthly value of the evenness index was calculated in the following manner.

$$e = \frac{\bar{H}}{logeS}$$

where

H was the Shannon diversity index and S the number of species.

In all the indices, natural log (loge) was used.

2.2. Statistical Analysis

For the statistical analysis, Principal Component Analysis (PCA) was employed to reduce the dimensionality of the dataset and identify the key environmental gradients influencing fish species distribution.

3. RESULTS AND DISCUSSION

Overall, a total of 12 species (Plate 1–12) belonging to 4 orders, 6 families, and 12 genera were recorded. Nun River has not been explored

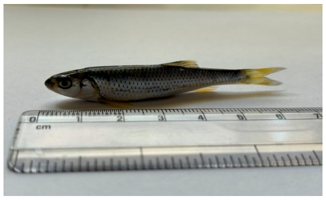

Plate 1. *Barillus bendelisis.*

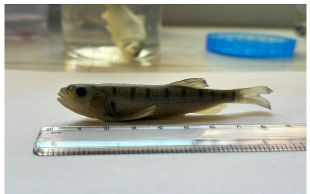

Plate 2. *Barillius vagra.*

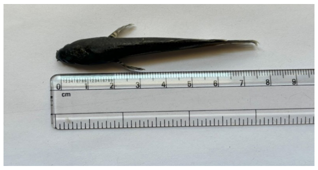

Plate 3. *Channa gachua*

Plate 4. *Garra gotyla*

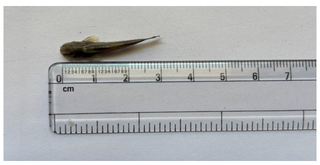

Plate 5. *Glyptothorax pectinopterus*

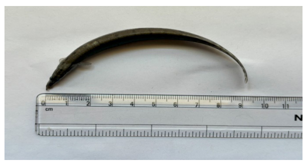

Plate 6. *Mastacembelus armatus*

Plate 7. *Acanthocobitis botia*

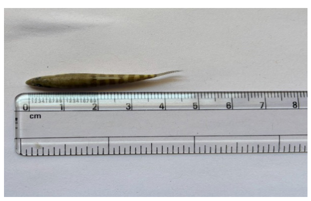

Plate 8. *Acanthocobitis benovi*

Plate 9. *Acanthocobitis rupicula*

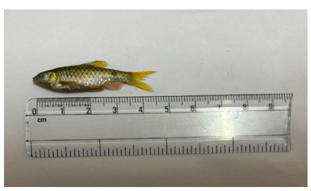

Plate 10. *Pethia conchonius*

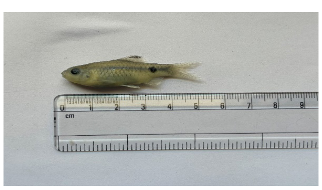

Plate 11. *Puntius sophore*

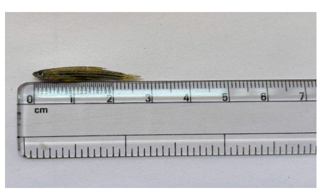

Plate 12. *Danio rerio*

earlier for its fish fauna. Table 2 represents the collected, examined, and identified fish species along with their local names, family, and IUCN categorization. 07 species were recorded from the upstream site of Nun River, and 06 species and 09 species were reported from midstream and downstream sites of Nun River, respectively (Table 3). At upstream, the dominant fish species found was *Barilius vagra,* followed by *Puntius sophore,* while at midstream, the dominant species was *Barilius bendelisis,* followed by *B. vagra.* At the downstream section, the dominant fish species reported were *B. vagra* and *P. sophore,* followed by *Garra gotyla* (Fig. 1). Overall, during the study period *B. vagra* contributed 45.07%, followed by *Barilius bendelisis* (21.83%), *P. sophore* (14.08%), *Acanthocobitis botia* (5.63%), *Garra gotyla* (4.93%), *Channa gachua* (2.11%), *Acanthocobitis rupicola* (1.41%), *Mastacembelus armatus* (1.41%), *Danio rerio* (1.41%), *Acanthocobitis bevani* (0.70%), *Pethia conchonius* (0.70%), and *Glyptothorax pectinopterus* (0.70%) (Fig. 2).

Fish habitat preferences were studied and are mentioned in Table 2. Fishes like *Naemacheilus botia, A. bevani, P. sophore,* and *P. conchonius* have restricted food habitats in sandy bottoms hiding under stones found mostly in runs, rapids, pools, and gravel grounds. Fish species like *Garra* and *Glyptothorax* have suction discs on their ventral side and, thus, are found in fast water currents. Family Cyprinidae was found to be the most dominant with 6 species. An assessment of family representation (Uniyal and Kumar, 2006 [13]; Uniyal and Mehta, 2007 [14]) indicates that the Cyprinidae family dominates the Doon Valley and the Eastern and Western drainages in particular. This is in line with previous observations from the Himalayas and the Doon Valley [14,27–30]. According to IUCN characterization, all 12 species fell under the Least Concern category. Fish diversity has been given a specific category (Endangered, Vulnerable, Least Concern, or Near Threatened) based on internationally recognized standards established under CAMP (1998) and IUCN (2024-1), according to Sreekantha *et al.* [31] and Sarkar *et al.* [32]. When the fish fauna of the Doon Valley was discussed in the past, a similar approach was taken [14–16].

The diversity indices calculated for three different sites along the Nun River reveal varying levels of species diversity and evenness. The Shannon–Wiener Index (H') values were 1.6565, 1.8244, and 2.8739 for Sites 1, 2, and 3, respectively, indicating that Site 3 has the highest species diversity. The evenness index (e) values were 0.5901, 0.7058, and 0.9066 for Sites 1, 2, and 3, suggesting that species distribution is most even at Site 3. The Margalef's Index (d') values were 1.3772, 1.3953, and 2.4008 for Sites 1, 2, and 3, which further supports the observation that Site 3 has the greatest species richness. The Simpson's Index (D) values were 0.024, 0.054, and 0.205 for Sites 1, 2, and 3, respectively, with higher values indicating higher dominance of certain species at Site 3 (Table 4). The diversity indices reveal that Site 3 has the highest species diversity and evenness, indicating a more balanced and stable ecosystem compared to Sites 1 and 2. This suggests Site 3 has favorable environmental conditions that support a wider variety of species. The higher dominance index at Site 3 also points to certain species being particularly successful there. These findings highlight the importance of Site 3 for conservation efforts and the need to investigate and mitigate factors limiting diversity at Sites 1 and 2. The variation in species diversity and evenness among the three sites along the Nun River can be attributed to several interrelated factors, including habitat structure, water quality, and anthropogenic influences. Site 3, exhibiting the highest diversity and evenness, likely benefits from a more complex habitat structure that provides varied niches for fish species, enhancing their ecological interactions and resource availability. In contrast, Sites 1 and 2 may experience greater environmental stressors, such as pollution from urban runoff or sedimentation from nearby land use, leading to degraded water quality that adversely affects fish health and reproduction. Several studies on fish diversity in Himalayan rivers have measured diversity indices such as Shannon–Wiener and Simpson's Index to assess biodiversity. For example, research on the Ghaghara River [33] identified over 70 fish species, with Cyprinidae being the most dominant family. It highlighted high diversity and evenness at specific sites, similar to patterns observed in other freshwater ecosystems of the region. Similarly, a study on the snow-fed Pinder River, a tributary of the Alaknanda in the central Himalaya, documented 27 fish species

Table 2. Systematic position of fish fauna recorded from river Nun and preferential habitat of fishes during the present study.

Phylum	Class	Order	Family	Genus	Species	Local name	Preferential habitat	IUCN status
Chordata	Actinopterygii	Cypriniformes	Cyprinidae	*Barilius*	*bendelisis*	Chaal	Rapids, Runs, Pools	Least concerned
				Barilius	*vagra*	Fulra	Rapids, Runs, Pools	Least concerned
				Pethia conchonius	*conchonius*	puti	Rapids, Runs, Pools	Least concerned
				Puntius	*sohore*	Puti	Rapids, Runs, Pools	Least concerned
				Danio	*rerio*	Patukari	Runs, Pools	Least concerned
				Garra	*gotyla*	Patharchatta	Runs, Pools	Least concerned
			Balitoridae	*Acanthocobitis*	*botia*	Bakati	Runs, Pools	Least concerned
			Nemacheilidae	*Acanthocobitis*	*bevani*	Gadiyal	Rapids, Runs, Pools, Gravel beds	Least concerned
				Acanthocobitis	*rupicola*	Gadera	Rapids, Runs, Pools, Gravel beds	Least concerned
		Anabantiformes	Channidae	*Channa*	*gachua*	Sowar	Rapids, Runs, Pools	Least concerned
		Siluriformes	Sisoridae	*Glyptothorax*	*pectinopterus*	Patherchatti	Runs, Sallow Pools, Gravel beds	Least concerned
		Synbranchiformes	Mastacembelidae	*Mastacembelus*	*armatus*	Baam	Rapids, Runs, Pools	Least concerned

Table 3. Site-wise occurrence of fish species in River Nun during the present study.

Name of fish	USN	MSN	DSN
Barilius bendelisis	+	+	+
Barilius vagra	+	+	+
Acanthocobitis botia	+	+	+
Acanthocobitis bevani	−	−	+
Acanthocobitis rupicola	−	−	+
Pethia conchonius	+	−	−
Puntius sophore	+	+	+
Danio rerio	−	+	−
Garra gotyla	+	−	+
Channa gachua	+	−	−
Glyptothorax pectinopterus	−	−	+
Mastacembelus armatus	−	+	+

+ = Present, − = Absent, USN= Upperstream Nun (S1), MSN= Midstream Nun (S2), DSN= Downstream Nun (S3).

across three orders and four families. The Cypriniformes order was dominant, followed by Siluriformes and Salmoniformes. Diversity indices such as the Shannon–Wiener index (3.09–4.10) and Simpson index (0.81–0.92) indicated strong species richness. Habitat variability significantly influenced fish distribution, with the highest richness found in deep pools [34].

The PCA analysis (Fig. 3) provides insights into the distribution of various fish species across different sites, highlighting how these species relate to each other and their environments. *Barilius bendelisis* and *B. vagra* species have high positive scores on PC1, with *B. vagra* showing an exceptionally high score (43.847). This indicates that these species are dominant or highly associated with sites that are characterized by the factors captured by PC1. *Barilius bendelisis* also shows a significant positive score on PC2 (16.473), suggesting its preference or abundance in sites with characteristics represented by both PC1 and PC2. *Puntius sophore* and *G. gotyla* species have notable positive scores on PC3 (3.0347 and 3.1776, respectively), indicating their significant association with sites defined by the variables contributing to PC3. Their negative scores on PC1 and PC2 suggest that they are less associated with the environmental factors captured by these principal components. *Channa gachua*, *Pethia conchonius* and *D. rerio* species show negative scores on all three principal components, indicating a distinct set of environmental preferences compared to other species. This may suggest that they thrive in sites with different ecological characteristics not strongly represented by PC1, PC2, or PC3. *Acanthocobitis species* (*Acanthocobitis botia, A. bevani,* and *Acanthocobitis rupicola*) species cluster closely with negative scores on PC1 and slightly varying scores on PC2 and PC3. This clustering suggests similar ecological niches or site preferences among these species, likely favoring sites with specific environmental conditions captured by their shared PCA scores. *Glyptothorax pectinopterus* and *Mastacembelus armatus* species have similar PCA scores to the *Acanthocobitis* species, indicating a potential overlap in habitat preferences or site associations. The PCA biplot reveals that *Barilius vagra* and *Barilius bendelisis* are strongly associated with certain site characteristics, while *Puntius sophore* and *G. gotyla* show significant associations with different environmental factors. The clustering of *Acanthocobitis* species and their similar PCA scores suggest shared ecological niches. Negative scores across principal components for *Channa gachua, Pethia conchonius,* and *D. rerio* indicate distinct environmental preferences compared to other species. Similarly, Quist *et al.* [35] reported that environmental factors influence fish assemblages, similar to the clustering of species in your PCA analysis. The observed habitat preferences of different fish species in the Nun River can be effectively connected to the PCA results, as outlined in Table 3. The analysis reveals distinct patterns in species occurrence across the upstream (USN), midstream (MSN), and downstream (DSN) sites, aligning with the environmental gradients captured by the principal components.

Barilius bendelisis, B. vagra, and *A. botia* were present at all three sites, indicating their adaptability to a range of environmental conditions. Their occurrence across different PCA scores suggests these species thrive in varied habitats, reflecting their generalist nature and ability to exploit diverse ecological niches.

In contrast, species like *A. bevani* and *A. rupicola* were only recorded at the DSN, which correlates with higher nutrient levels and lower

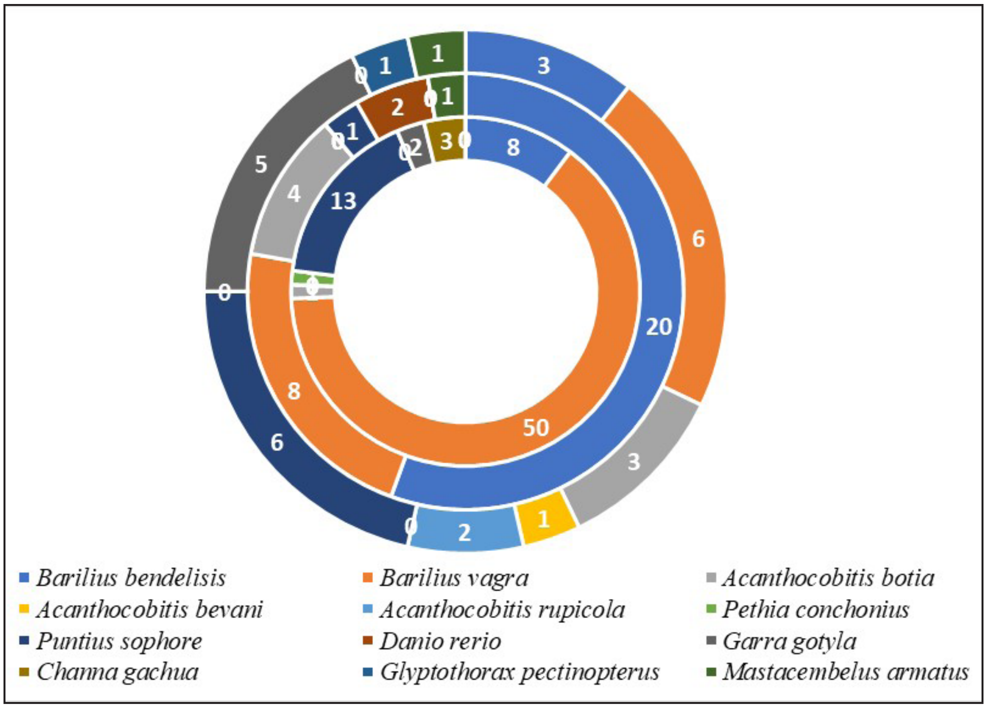

Figure 1. Number of samples recorded from different sampling sites (Inner circle represents S1, middle circle represents S2, and outer circle represents S3 site) during the present study.

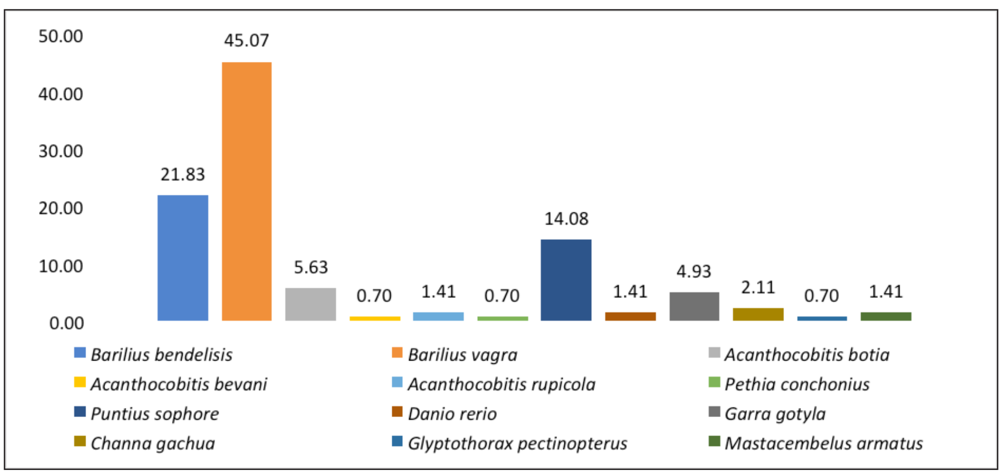

Figure 2. Histogram showing percentage (%) composition of fish diversity in River Nun during present study.

water quality associated with PC2. This may indicate their preference for more degraded environments, suggesting they are more tolerant to anthropogenic stressors.

Pethia conchonius and *C. gachua* were found only in the USN, suggesting they prefer cleaner, well-oxygenated waters typical of less disturbed areas, as highlighted by the positive correlation with higher PC1 values. This preference reflects their reliance on high-quality habitats for optimal growth and reproduction.

Danio rerio was recorded at the MSN only, indicating its preference for transitional habitats that may offer a balance between environmental

Table 4. Diversity index (H'), Richness (d'), Evenness (e), and Dominance (D), of fishes of Nun River at Sites 1, 2, and 3 during the study period from August 2023 to April 2024.

Indices	Sites 1	Sites 2	Sites 3
H'	1.6,565	1.8,244	2.8,739
e	0.5,901	0.7,058	0.9,066
d'	1.3,772	1.3,953	2.4,008
D	0.024	0.054	0.205

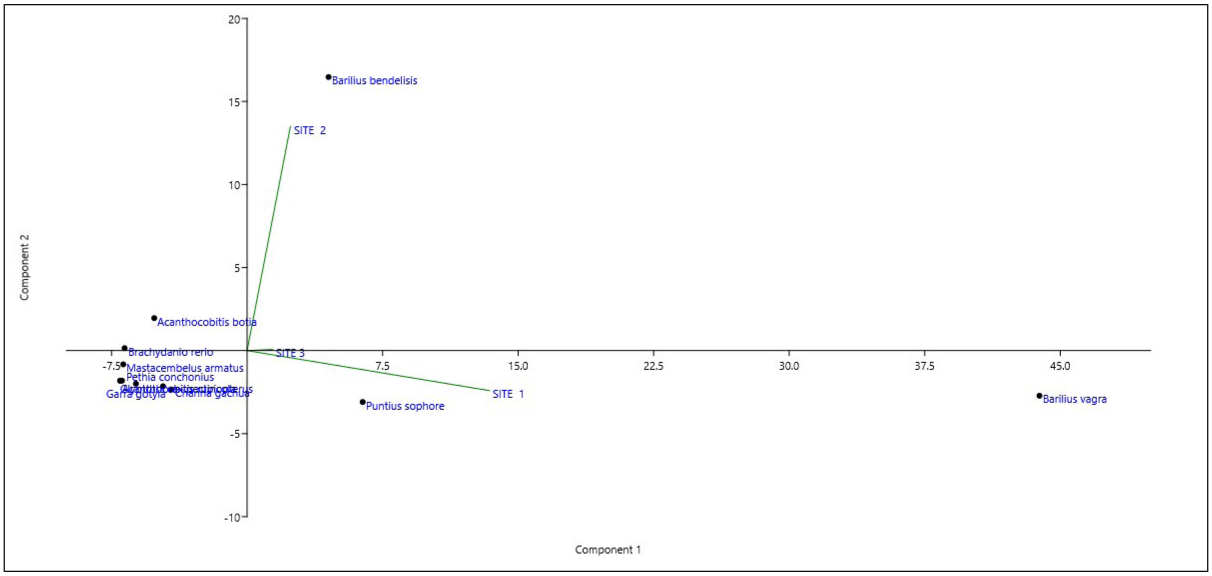

Figure 3. The PCA biplot shows the distribution of fish species along the first two principal components (PC1 and PC2), indicating their relationships with different site characteristics.

stress and ecological resources. Similarly, *Mastacembelus armatus* appeared at MSN and DSN, suggesting a wider tolerance range but still favoring areas with some structural complexity and associated biotic interactions represented by higher PC3 scores.

The presence of species like *G. pectinopterus*, which was restricted to the downstream site, aligns with the habitat's structural characteristics and nutrient dynamics.

The significant variation in species diversity and evenness across the three sites emphasizes the need for site-specific conservation efforts. Site 3, with its higher diversity indices, appears to be an ichthyofaunal diversity hotspot that could serve as a critical area for conservation. The higher dominance index (Simpson's D of 0.205) at Site 3 also indicates the success of certain species, which could be key to maintaining ecological balance and stability in the region. Understanding why Site 3 supports such diversity could help replicate these conditions in Sites 1 and 2, thereby enhancing overall river health. The use of fish assemblages as ecological indicators, as demonstrated in this study, underscores their value in assessing the health and degradation of aquatic ecosystems. The detailed analysis of diversity indices offers insights into the ecological integrity of different river sections. High diversity and evenness are often associated with healthy ecosystems, while low diversity and dominance by a few species can indicate ecological stress or degradation. Therefore, the findings from this study can be used to develop and refine bioassessment protocols for freshwater systems. The findings contribute to the global understanding of freshwater ichthyofaunal diversity, particularly in the context of the Doon Valley and the broader Himalayan region. By adding new data on the fish fauna of the Nun River, this study enriches the scientific knowledge base and supports broader efforts to document and conserve freshwater ichthyofaunal diversity. This is crucial for maintaining ecosystem services that support human well-being and for achieving global ichthyofaunal diversity targets.

The major threats to fish diversity in the Nun River include habitat degradation, pollution, overfishing, invasive species, and altered flow regimes. Habitat degradation occurs due to deforestation, sand mining, and riverbank erosion, which reduce spawning grounds and shelter for species like *A. bevani* [36]. Pollution from agricultural runoff, sewage, and industrial waste affects water quality, threatening sensitive species such as *G. pectinopterus*. Overfishing, including the use of unsustainable practices, depletes populations of species like *C. gachua* [37]. Invasive species may outcompete native fish, disrupting the ecological balance, while dam construction and water extraction alter the natural flow, affecting semi-migratory fish like *Mastacembelus armatus*.

To mitigate these threats, restoring riparian zones and regulating sand mining are essential to protect habitats. Implementing pollution control measures, such as treating industrial effluents and promoting organic farming, will improve water quality [38]. Sustainable fishing practices, such as regulated fishing seasons and gear restrictions, should be enforced to prevent overexploitation [39]. Additionally, periodic monitoring of invasive species and natural flow regimes must be maintained by limiting damming activities and ensuring environmental flow. These integrated approaches will help sustain fish diversity and promote ecological health in the river system [40].

This first study of the Nun River's fish fauna sets a significant precedent by providing foundational data that informs conservation efforts and guides future research. Despite its short-term nature, the study contributes valuable insights into the aquatic ichthyofaunal diversity of the region, emphasizing the need for continued monitoring and conservation measures to safeguard these valuable freshwater ecosystems. The study establishes a foundational dataset of fish species composition, distribution, and abundance in the Nun River. This baseline is crucial for future comparisons and assessments of changes over time due to environmental or anthropogenic factors. Reporting the findings increases scientific knowledge about lesser-known ecosystems like the Nun River. It also raises public awareness about the importance of conserving freshwater ichthyofaunal diversity and the role of rivers in sustaining local ecosystems and communities.

4. CONCLUSION

To protect the fish fauna of the Nun River, conservation strategies should focus on preserving habitat diversity, controlling pollution, and ensuring ecological connectivity across upstream, midstream, and downstream sections. Habitat restoration efforts, such as maintaining riparian vegetation and preventing erosion, are essential for structurally dependent species like *A. bevani* and *G. pectinopterus*. Pollution control through regulations on industrial discharge and sustainable farming practices is necessary to maintain water quality, particularly in downstream areas. Ensuring natural flow regimes and connectivity will benefit semi-migratory species like *Mastacembelus armatus*, while awareness programs and community involvement can promote eco-friendly practices and sustainable fishing. Monitoring water quality and biodiversity will provide early warnings of ecological disturbances, and conservation breeding programs for vulnerable species, such as *A. rupicola*, can aid in restoring depleted populations. These strategies together will foster the ecological resilience and long-term sustainability of the river's fish diversity.

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6. AUTHOR CONTRIBUTIONS

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agree to be accountable for all aspects of the work. All the authors are eligible to be an author as per the International Committee of Medical Journal Editors (ICMJE) requirements/guidelines.

7. CONFLICTS OF INTEREST

The authors report no financial or any other conflicts of interest in this work.

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9. RESEARCH CONTENT

The research content of the manuscript is original and has not been published elsewhere.

10. DATA AVAILABILITY

All the data is available with the authors and shall be provided upon request.

11. ETHICAL APPROVALS

The fish were collected with the help of local fishermen using non-invasive and legally permitted methods. The study did not involve endangered or protected species. All the activities complied with the Indian Biological Diversity Regulations.

12. USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declares that they have not used artificial intelligence (AI)-tools for writing and editing of the manuscript, and no images were manipulated using AI.

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