

Chthyofaunal Diversity and Water Quality Assessment of River Kurram, Bannu, Khyber Pakhtunkhwa

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ABSTRACT

This study provides the first baseline assessment of fish diversity and water quality in the River Kurram, District Bannu, Khyber Pakhtunkhwa. A total of 496 specimens were collected from 14 sampling sites, including seven freshwater and seven sewage-polluted stations. The samples represented 11 species, 8 genera, and 4 families, with Cyprinidae dominating (72% of the catch). *Cyprinus carpio* and *Amblypharyngodon mola* were the most abundant species, while *Sperata aor* and *Carassius carassius* were rare. Freshwater sites supported 8 species, whereas sewage-polluted sites sustained only 3 species, reflecting the strong influence of water quality on biodiversity. Analysis of 14 water quality parameters revealed neutral pH in freshwater (7.0) but acidic conditions in sewage water (5.68), along with elevated heavy metals (Pb 1.25 mg/L; Cr 0.5 mg/L) and fluoride (3.5 mg/L), all exceeding permissible limits. High hardness (250–251 mg/L) and alkalinity variations further distinguished habitat conditions. These results demonstrate that pollution significantly reduces ichthyofaunal diversity, with only tolerant species persisting in degraded habitats. The findings highlight the urgent need for pollution control, water quality management, and conservation planning to safeguard aquatic biodiversity and fisheries resources of the River Kurram.

Keywords: Ichthyofauna, River Kurram, Bannu, Fish diversity, Cyprinidae, Water quality, Heavy metals, Pollution

Introduction

Fish (class *Osteichthyes*) are cold-blooded aquatic vertebrates with a backbone and specialized respiratory structures, primarily gills, that facilitate gas exchange in water. They exhibit remarkable physiological processes such as osmoregulation and locomotion through fins, allowing adaptation to diverse aquatic environments (Looby et al., 2022; Galib et al., 2013). Representing the most diverse vertebrate group, fishes

display extraordinary morphological and ecological adaptations that enable survival across a wide range of freshwater and marine ecosystems (Levêque et al., 2008).

The global diversity of fish, collectively referred to as ichthyofauna, has been estimated at approximately 33,000 species, though some sources report higher values. FishBase (2005) documented around 28,900 species, distributed across 62 orders, 515 families, and nearly 4,500 genera (Divovich et al., 2015). Freshwater ecosystems, despite occupying less than 1% of the earth's surface, harbor nearly 18,000 species—almost half of the world's fish diversity (Aguirre et al., 2021). These ecosystems provide critical ecological services, such as nutrient cycling, water purification, and food security, in addition to sustaining local livelihoods. Globally, freshwater fishes constitute approximately 13,000–15,000 species, including those inhabiting brackish environments.

Pakistan is endowed with diverse aquatic habitats shaped by its varied topography and hydrology. Approximately 193 freshwater fish species have been recorded, belonging to 13 orders, 30 families, and 86 genera (Bibi et al., 2018). This diversity underlines the ecological and economic importance of freshwater fish resources. Surveys in southern Punjab documented 43 species commonly used by indigenous communities, reflecting the socio-economic role of fish in local livelihoods (Iqbal et al., 2013). The Indus River system, along with its tributaries and smaller water networks, supports both widespread and endemic ichthyofaunal assemblages, contributing to Pakistan's ecological richness (Haseeb & Yousafzai, 2023)..

In Khyber Pakhtunkhwa (KP), ichthyofaunal surveys have identified 68 freshwater species distributed across 14 river systems (Haseeb & Yousafzai, 2023). The family Cyprinidae dominates the region, comprising nearly half of the recorded species. Studies along the Panjkora River reported 911 cyprinid specimens from five sites in Dir, illustrating the group's ecological dominance (Ullah, Yousafzai, & Muhammad, 2025). Similarly, surveys in the River Indus (KP region) documented 110 specimens belonging to seven species across three families, with cyprinids again being the most abundant. These findings emphasize the ecological significance of cyprinids in regulating freshwater ecosystems in Pakistan. Freshwater habitats are the most species-rich yet vulnerable ecosystems worldwide. Approximately 40% of all fish species depend exclusively on freshwater, which covers only 0.8% of the earth's surface (Reid et al., 2019). These systems provide essential ecosystem services such as water purification, flood regulation, and food security. In Pakistan, rivers and lakes are not only vital for biodiversity but also central to agriculture, fisheries, and rural livelihoods. However, freshwater biodiversity faces unprecedented pressures. Global assessments indicate that nearly one-fourth of freshwater fish are at risk of extinction, with 17% directly impacted by climate change (Reid et al., 2019). Migratory freshwater fish populations have declined by 81% between 1970 and 2020. Major threats include overfishing, agricultural runoff, deforestation, industrial effluents, urbanization, and habitat fragmentation, all of which degrade water quality and disrupt ecological balance (Tinazzi, 2024)..

The Kuram River, located in Bannu District of KP, Pakistan, represents a crucial freshwater ecosystem with ecological, social, and economic importance (Khan et al., 2024). Flowing through a semi-arid landscape, it supports agriculture, fisheries, and household water use. Its heterogeneous habitats—ranging from slow-moving to fast-

flowing stretches—create niches that sustain diverse aquatic species. Despite its importance, the ichthyofauna and water quality of the Kuram River remain poorly studied. Anthropogenic pressures, such as agricultural runoff laden with fertilizers and pesticides, untreated municipal discharges, and industrial effluents, are increasingly affecting the river's ecological health. These stressors alter water quality parameters, influencing fish abundance and diversity. In the absence of systematic monitoring, the ecological responses of fish communities remain poorly understood, limiting predictive capacity for conservation and sustainable management. The Kuram River ecosystem is experiencing intensifying environmental stressors that threaten its ecological stability and biodiversity. The lack of comprehensive baseline data on fish diversity and water quality represents a major scientific and management gap. Without this knowledge, conservation planning and resource management remain ineffective, particularly in the face of rapid population growth, climate change, and land-use changes in the Bannu region. Addressing this gap is critical for understanding ecosystem dynamics and safeguarding freshwater resources.

Fish diversity serves as a reliable bioindicator of aquatic ecosystem health. Species-specific tolerances to habitat changes, pollutants, and water quality parameters allow researchers to evaluate ecosystem integrity (Hossain et al., 2012). Monitoring fish communities helps identify pollution sources, assess habitat quality, and guide conservation strategies. Importantly, changes in fish assemblages provide early warnings of ecological degradation, facilitating timely interventions to protect biodiversity and ecosystem services.

Research Objectives

To assess the diversity of fish species in the Kuram River, Bannu, Khyber Pakhtunkhwa.

To analyze the key water quality parameters of the Kuram River and their relationship with fish diversity.

Methodology

Research Design and Study Area

A descriptive cross-sectional design was adopted for this research. This approach is well suited for biodiversity assessments because it allows broad recording of ecological conditions without experimental manipulation of the environment. It also facilitates exploratory correlation analyses to evaluate the relationship between water quality parameters and fish diversity, thereby identifying the environmental factors influencing fish community structure in the Kuram River.



Figure 1. Map of the Kuram River Flowing through Bannu, Khyber Pakhtunkhwa

The Kuram River is a major tributary of the Indus River system. Originating from the Safed Koh mountain range in Afghanistan, it flows through North Waziristan and Kurram District before joining the Indus River near Isa Khel in Punjab. The river travels approximately 320 kilometres and supports diverse freshwater habitats. For the purpose of this study, an 85-kilometre stretch was surveyed, representing upstream, midstream, and downstream zones. The upstream section, located at an elevation of about 1,200 metres above sea level, is steep and rocky with limited human disturbance. The midstream section is wider and slower-flowing, influenced moderately by agricultural activities such as maize and wheat cultivation. The downstream section experiences intensive farming, urbanisation, and possible industrial effluents, making it the most impacted part of the system. Within each zone, three sampling sites were established on the basis of accessibility, water depth of more than six metres, and the availability of comparable habitats. Sampling was coinciding with high water flow and peak fish diversity.

Fish Sampling

Fish sampling was conducted monthly during the study period using multiple techniques to capture a wide range of species across body sizes and habitats. Gill nets with mesh sizes ranging from 25 to 150 millimetres were the primary gear and were set overnight to account for both diurnal and nocturnal activity. Nets were checked every four hours to reduce mortality and preserve specimen quality. Electrofishing was employed in rocky habitats using a portable backpack electrofisher operating at 300–400 volts to collect small and juvenile fish. Seine nets measuring fifteen metres in length with five-millimetre mesh were used to sample schooling species in shallow areas, while cast nets were deployed in concentrated microhabitats.

Fish were kept in containers with aerated river water to minimise stress, photographed

for documentation, and identified using the taxonomic keys provided in *Freshwater Fishes of Pakistan* (Mirza and Sandhu, 2007), supplemented with updated references. Morphometric measurements were recorded for each specimen. Voucher specimens, totalling 124 individuals, were preserved and deposited in the ichthyological collection of Kohat University of Science and Technology for future reference.

Water Quality Assessment

Water quality was measured concurrently at each sampling site to examine its influence on fish diversity. Physicochemical parameters were recorded in situ using calibrated portable instruments. Temperature was measured with a digital thermometer, dissolved oxygen with an oxygen meter, pH with a pH meter, turbidity with a turbidimeter, and conductivity along with total dissolved solids using a conductivity meter.

Water samples were collected in acid-washed bottles for laboratory analyses of chemical parameters, including nitrates, phosphates, and heavy metals such as lead, cadmium, mercury, and zinc. Samples were preserved according to standard procedures, and quality control was maintained by including duplicate and blank samples to ensure accuracy and precision.

Data Analysis

The analysis of fish community structure was carried out using ecological diversity indices. Species diversity was quantified using the Shannon-Wiener index, dominance was evaluated through Simpson's index, and evenness was calculated using Pielou's index. These indices were applied to each site and month to allow spatial and temporal comparisons.

The relationship between water quality parameters and fish diversity indices was analysed using Pearson's correlation. Multiple regression models were employed to identify the environmental variables most strongly associated with fish diversity. To visualise community structure and explore environmental gradients, non-metric multidimensional scaling (NMDS) was conducted. Where assumptions of parametric tests were not met, non-parametric alternatives were applied.

Ethical Considerations and Quality Assurance

The research was conducted under the ethical guidelines of the Department of Zoology at Kohat University of Science and Technology. Fish handling protocols were designed to minimise stress and mortality. Most specimens were returned alive to the river after identification, and only individuals needed for taxonomic confirmation were euthanised humanely using clove oil.

Quality assurance was maintained through regular calibration of instruments, replication of field measurements, and validation of taxonomic identifications using photographs, morphometric comparisons, and expert consultation. Statistical analyses were checked for normality, outliers, and distributional assumptions, with adjustments made where necessary.

Limitations

The study was limited by its temporal scope, as sampling was carried out only between April and August 2025, which may have excluded species active during other seasons. Accessibility also restricted sampling in certain river reaches, potentially omitting key habitats. Moreover, water quality measurements were point-based and did not capture short-term fluctuations such as storm events or episodic discharges. Despite these limitations, the study applied a consistent and standardised methodology that provides valuable baseline information on fish diversity and water quality in the Kuram River.

Results and Discussion

Overall Species Composition

A total of 496 fish specimens were collected from the River Kurram during the survey period. These specimens represented 11 species distributed across four families: *Cyprinidae*, *Platycephalidae*, *Bagridae*, and *Anguillidae*. The dominance of *Cyprinidae* was particularly notable, accounting for the majority of recorded species, which aligns with patterns commonly observed in South Asian rivers where cyprinids dominate freshwater fish assemblages due to their ecological adaptability and feeding versatility.

Species Abundance and Dominance Patterns

The abundance of species varied substantially across the river system, highlighting both ecological adaptability and niche specialisation among taxa. The most abundant species was *Cyprinus mola* (Common Carp), represented by 92 individuals (18.55%). Its dominance reflects broad ecological tolerance, omnivorous feeding behaviour, and high reproductive potential. These characteristics enable it to persist under fluctuating water quality conditions and to exploit multiple trophic levels.

The second most abundant taxon, *Amblypharyngodon mola* (Mola Carplet), contributed 68 specimens (13.71%). This species thrives as a planktivore and displayed strong associations with nutrient-rich stretches of the river. Morphological adaptations such as specialised gill rakers enhance its efficiency in filtering plankton, while schooling behaviour increases feeding success and predator avoidance.

Phoxinus phoxinus (Minnow) was recorded with 60 specimens (12.10%). Although more commonly reported in cooler European streams, its occurrence in the Kurram River suggests adaptability to local hydrological conditions. Its shoaling behaviour and insectivorous diet make it a crucial component of the food web, while its sensitivity to pollution designates it as a potential bioindicator.

Labeo rohita (Rohu) accounted for 52 specimens (10.48%). Its presence indicates productive herbivorous niches supported by aquatic vegetation and algal communities. As a key aquaculture species in South Asia, its ecological role in nutrient cycling and energy transfer within the river ecosystem is substantial.

Oreonectes platycephalus (Flat-headed Loach) represented 48 individuals (9.68%), highlighting the ecological importance of benthic habitats within the river. Its occurrence points to stable substrates and adequate populations of benthic invertebrates.

Notably, *Tor putitora* (Golden Mahseer) was captured in 44 specimens (8.87%). This

flagship species is ecologically significant as an apex predator and serves as an indicator of riverine ecosystem health. Its presence in the Kurram River underscores the conservation value of this system, despite regional threats from habitat degradation and overfishing.

Other taxa included *Conger eel* (Anguillidae, 7.26%), *Cirrhinus mrigala* (Mrigal, 5.65%), *Puntius chola* (Swamp Barb, 5.65%), *Carassius carassius* (Crucian Carp, 4.84%), and *Sperata aor* (Khagga, 3.23%). These species, though less abundant, reflect ecological heterogeneity and habitat diversity across the surveyed reaches.

Ecological Interpretation

The overwhelming representation of *Cyprinidae* demonstrates the family's evolutionary success in freshwater ecosystems of South Asia. Their dominance reflects adaptive feeding strategies (omnivory, herbivory, and planktivory), tolerance to physicochemical variability, and efficient reproductive traits. The high abundance of *Cyprinus mola* and *Amblypharyngodon mola* indicates strong primary productivity and abundant plankton communities, while the occurrence of *Tor putitora* signals relatively intact ecosystem processes supporting higher trophic levels.

Overall, the observed community structure suggests that the River Kurram supports a productive and diverse fish assemblage, with species adapted to both benthic and pelagic habitats, herbivorous and predatory niches, and seasonal variability in resource availability.

Table 1: Fish Species Composition and Relative Abundance in the River Kurram

Serial No.	Scientific Name	Common Name	Family	Number of Specimens	Relative Abundance (%)
1	<i>Cyprinus mola</i>	Common Carp	Cyprinidae	92	18.55
2	<i>Amblypharyngodon mola</i>	Mola Carplet	Cyprinidae	68	13.71
3	<i>Phoxinus phoxinus</i>	Minnow	Cyprinidae	60	12.10
4	<i>Labeo rohita</i>	Rohu	Cyprinidae	52	10.48
5	<i>Oreonectes platycephalus</i>	Flat-headed Loach	Platycephalidae	48	9.68
6	<i>Tor putitora</i>	Golden Mahseer	Cyprinidae	44	8.87
7	<i>Conger eel</i>	Baam Fish	Anguillidae	36	7.26
8	<i>Cirrhinus mrigala</i>	Mrigal	Cyprinidae	28	5.65
9	<i>Puntius chola</i>	Swamp Barb	Cyprinidae	28	5.65
10	<i>Carassius carassius</i>	Crucian Carp	Cyprinidae	24	4.84
11	<i>Sperata aor</i>	Khagga	Bagridae	16	3.23

Total	496	100.00
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Taxonomy and Morphological Features

Common Carp (*Cyprinus carpio*)

The common carp belongs to the order *Cypriniformes* and the family *Cyprinidae*. It is characterised by the fin formula D 3/17; P 1/5; V 9; A 3/5; C 19. Morphologically, the back is greenish-brown, while the sides are golden to silvery and the belly is pale. Juveniles measure approximately 10–12 cm, whereas adults typically reach 30–60 cm in ponds and lakes, with some riverine specimens growing beyond one meter and exceeding 20 kg. This species thrives in ponds, lakes, rivers, and reservoirs, favouring muddy bottoms with aquatic vegetation. Its tolerance to low oxygen levels and wide temperature ranges explains its broad distribution.



Figure 2. Common Carp

Mola Carplet (*Amblypharyngodon mola*)

The mola carplet, a cyprinid, is placed under the genus *Amblypharyngodon*. Its fin formula is D 2/7; P 1/14; V 1/7; A 2/10; C 19. The body is silvery with a bluish-green back and a whitish, shiny belly, while fins are pale or faintly yellow. Individuals are small, typically 10–12 cm in length and weighing less than 50 grams. They occur in ponds, lakes, rivers, and floodplains, preferring shallow and calm waters.



Figure 3. Mola Carplet

Minnow (*Phoxinus phoxinus*)

The minnow is classified in the order *Cypriniformes* and family *Cyprinidae*. Its fin formula is D 3/9–10; P 1/16; V 2/9; A 2/5; C 19. This small fish exhibits a dark greenish-brown back, silvery flanks with a distinct lateral band, and a whitish belly. During breeding, males develop striking reddish hues. Typically 7–10 cm in length, individuals may reach a maximum of 14 cm. Minnows prefer clear, cool, well-oxygenated rivers and streams with sandy or gravel bottoms, and they are widely

distributed across Asia, including Pakistan.



Figure 4. Minnow

Rohu (*Labeo rohita*)

Rohu belongs to the genus *Labeo* within the family *Cyprinidae*. Its fin formula is D 3/9–10; P 1/16; V 2/9; A 2/5; C 19. The species shows a bluish or dark-grey back, silvery flanks with a golden sheen, and a whitish belly, sometimes with reddish fins. Juveniles are 12–15 cm long, while adults reach 50–75 cm. Rohu inhabits rivers, lakes, and ponds, preferring slow-moving freshwater bodies.



Figure 5. Rohu

Flat-headed Loach (*Oreonectes platycephalus*)

This species, belonging to the family *Nemacheilidae* and genus *Oreonectes*, has the fin formula D 3/7; P 17; V 8; A 5; C 19. It displays a brownish to grey coloration with darker patches, aiding camouflage, and a lighter underside. Individuals measure 6–10 cm in length. Flat-headed loaches are adapted to shallow, rocky, or sandy-bottomed streams where they occupy benthic habitats.



Figure 6. Flat-headed Loach

Golden Mahseer (*Tor putitora*)

The golden mahseer, a member of *Cyprinidae*, has the fin formula D 4/7; P 15; V 9; A 5; C 19. Its body exhibits a metallic golden sheen with dark green to bluish backs and reddish or orange-tinged fins. A large species, it may reach 2 meters in length and

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weigh 10–20 kg, with exceptional specimens exceeding 40 kg. It inhabits clear, fast-flowing rivers with rocky and gravelly substrates, as well as reservoirs and upland streams, making it an important ecological and conservation species.



Figure 7. Golden Mahseer

Baam Fish (*Anguilla bengalensis bengalensis*)

The baam fish is an anguillid eel belonging to the order *Anguilliformes*. Its fin formula is D 250–300; P 30–35; V absent; A 220–250; C confluent with dorsal and anal fins. It has a slimy, scaleless body with a dark brown dorsum and a yellowish-white underside. Reaching 1–1.5 meters in length and weighing 2–6 kg, it is found in rivers, ponds, canals, and swamps, preferring muddy bottoms. This species is migratory, moving to the sea for spawning.



Figure 8. Baam Fish

Mrigal (*Cirrhinus mrigala*)

Mrigal is a cyprinid fish under the genus *Cirrhinus*. Its fin formula is D 4/8; P 15; V 9; A 5; C 19. The species displays a bluish to dark-grey back, silvery sides, and a whitish belly, with darker fins. Adults grow up to one meter and usually weigh 5–10 kg, though some individuals exceed 15 kg. It inhabits rivers and freshwater ponds, often being cultivated in tanks for aquaculture.



Figure 9. Mrigal

Swamp Barb (*Puntius chola*)

The swamp barb, belonging to the genus *Puntius*, is a small cyprinid with the fin formula D 3/8; P 15; V 8; A 5; C 19. The species is silvery with a bluish or greenish sheen and a distinctive reddish spot behind the gill cover. Fins are frequently tinged reddish or orange. Measuring 5–10 cm, with a maximum of 12–15 cm, this slender-bodied fish thrives in rivers, ponds, lakes, and swamps, particularly in shallow, slow-moving waters.



Figure 10. Swamp Barb

Crucian Carp (*Carassius carassius*)

The crucian carp, a cyprinid, has the fin formula D 3/15–20; P 15; V 8; A 3/5–7; C 19. Its body is golden-bronze with a darker back and shiny golden to greenish sides, while fins are reddish-brown or grey. Individuals usually range from 15–30 cm but can grow to 50 cm and 3 kg. This species inhabits lakes, ponds, and slow-moving rivers, often in muddy, vegetated habitats, and is notable for its high tolerance of low-oxygen environments, even under ice cover.



Figure 11. Crucian Carp

Khagga (*Wallago attu*)

Khagga, a large predatory catfish from the family *Bagridae*, is classified under the order *Siluriformes*. Its fin formula is D 1/7; P 12–14; V 6; A 84–97; C 17. The body is greyish-green dorsally with silvery flanks and a whitish belly, while fins are generally dark. Khagga grows 1–1.5 meters long, with weights reaching 20–40 kg in larger specimens. It inhabits large rivers, lakes, and reservoirs with muddy bottoms and is a carnivorous predator, feeding primarily on smaller fishes.



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Figure 12. Khagga

Biodiversity Indices

To quantify the diversity of the fish assemblage in the River Kurram, various biodiversity indices were calculated using the species abundance data following Das and Sen (2018). The results showed a species richness of 10, a Shannon–Wiener diversity index (H) of 2.18, a Simpson diversity index (D) of 0.89, and an evenness index (J) of 0.95. The Shannon index value indicates a moderate to high diversity of fish, suggesting that the assemblage comprises a considerably diverse group without strong dominance by any single species. This finding is further supported by the Simpson index of 0.89, which confirms the presence of a large diversity and minimal species dominance within the community. Moreover, the evenness value of 0.95 reflects a balanced distribution of individuals among species, indicating that no species is disproportionately abundant. Such high evenness suggests that the ecosystem supports a relatively stable fish community where species are evenly represented in terms of abundance. Overall, these indices highlight that the River Kurram sustains a healthy aquatic system with considerable biodiversity richness.

Analysis of Water Quality Parameters

Water quality is assessed through a range of physical, chemical, and biological parameters that collectively determine the capacity of an aquatic system to support life. These parameters indicate not only the suitability of water for sustaining fish populations but also reflect the overall ecological health of aquatic environments. In this study, a standard water quality testing kit was employed to evaluate 14 parameters across both freshwater and brackish water samples collected from the River Kurram. Seven tests were conducted on freshwater samples, while the remaining seven were carried out on sewage-contaminated water to compare the influence of pollution on water quality and aquatic health.



Figure 13. Water quality kit.

Table 2: Comparative Analysis of Water Quality Parameters

Parameter	Optimal Range for Fish Culture	Freshwater	Sewage Water	Remarks
pH	6.5–8.5	7.0	5.68	Sewage water acidic; indicates pollution
Total Alkalinity (mg/L)	50–150	120	140	High buffering capacity in sewage
Carbonate (mg/L)	50–150	80	22	Carbonate depletion in sewage
Hardness (mg/L)	50–200	251.9	200	Freshwater above optimum, very hard
Chloric Acid (mg/L)	0	0	37.5	Industrial/domestic contamination
Copper (mg/L)	<0.5	0	0.5	Present in sewage, potential industrial source
Total Chlorine (mg/L)	0	0	0	Absent, desirable
Free Chlorine (mg/L)	0	0	0.1	Byproduct of disinfection in sewage
Bromine (mg/L)	0	1.0	0.25	Elevated in sewage, likely from cleaning agents
Bromate (mg/L)	0	1.0	0.25	Detected in both, should be minimal
Nitrate (mg/L)	≤25	0	3.5	Above natural baseline, may come from fertilizers
Nitrite (mg/L)	<0.1	0	0.25	Elevated in sewage, source: organic/fertilizer waste
Iron (mg/L)	<0.3	2.0	0.38	High in fresh water, microbial activity indicator
Chromium (mg/L)	0	0	0.5	Detected in sewage, potential industrial source
Lead (mg/L)	0	4.0	1.25	Elevated in both, toxic to fish
Fluoride (mg/L)	<1.5	4.0	3.5	Exceeds safe limits in both water types

Correlation Analysis

Correlation analysis was conducted to examine the relationships between water quality parameters and fish community structure. Ecological interpretation of the data

provides insight into species tolerance and ecosystem resilience under varying environmental conditions. The occurrence of diverse fish assemblages in areas with heterogeneous water quality suggests that some species are capable of tolerating stressors, thereby maintaining ecosystem stability.

The dominance of the Cyprinidae family in the River Kurram highlights its adaptive advantage. Species such as *Cyprinus mola* and *Labeo rohita* are recognized for their broad environmental tolerance, which explains their persistence even in habitats affected by pollution. Their abundance in degraded environments underscores their resilience and ecological plasticity compared to more sensitive taxa.

Comparative Analysis with Regional Studies

The fish diversity of the River Kurram is comparable to other rivers in Khyber Pakhtunkhwa and across South Asia. Consistent with regional studies, Cyprinidae dominate the assemblages, typically representing 60–80% of recorded communities. This pattern highlights the ecological importance of the family across riverine systems of the region and confirms its adaptive success under diverse environmental conditions.

The diversity assessment further indicates the need for targeted conservation strategies. Protection of upstream habitats is essential to safeguard sensitive species, while particular attention should be given to threatened taxa such as *Tor putitora*. Effective management also requires the active involvement of local communities in conservation initiatives, ensuring their participation in planning and implementation. Long-term ecological monitoring must be established to track biodiversity trends and detect changes in water quality over time.

Opportunities for ecological restoration were also identified. Riverbank vegetation should be strengthened to stabilize riparian zones and reduce erosion. Control of point-source pollutants is necessary to minimize direct anthropogenic impacts on the ecosystem. The reintroduction of native species can aid in replenishing depleted fish populations, while integrated river basin management offers a holistic approach that simultaneously considers hydrology, water chemistry, and biodiversity.

Linear Models and Forecasts

Multiple regression models were applied to identify predictors of fish diversity. The analysis revealed that pH, heavy metal concentrations, and dissolved oxygen were the most significant variables influencing species composition. These factors explained much of the observed variation in richness and abundance, reflecting the combined roles of natural dynamics and human-induced stressors in shaping fish communities. A structured risk assessment framework was developed to classify different sections of the river. Areas with extreme pH values below 6.5 or above 8.5, lead concentrations exceeding 2 mg/L, or fluoride levels above 3 mg/L were categorized as high-risk zones. Segments exceeding one or two of these thresholds were classified as moderate risk, while areas with most parameters within acceptable limits were identified as low-risk. This classification provides a practical basis for prioritizing conservation and guiding management interventions across the river system.

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<http://amresearchreview.com/index.php/Journal/about>**Table 3: Test 1-Comparative Analysis of Pollutant Levels**

S. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Polluted Water	78	100	80	425	0	0	0	0	0	0	0	0	0	0	0	4
Fresh Water	7.8	180	300	425	0	0	0	0	0	0	0	0	0	0	0	2.5

The comparative analysis (Test 1) indicates a clear difference between polluted and freshwater samples. Polluted water exhibited a broader range of pollutant concentrations (0–425), with the highest recorded value reaching 425. Freshwater, while significantly cleaner, still showed variation (0–300), suggesting background levels of natural or low-intensity pollution. Although contamination is present in both sample types, the magnitude is substantially higher in polluted water, demonstrating the negative impact of anthropogenic inputs.

Table 4: Test 2- Comparative Pollutant Concentrations in Polluted and Freshwater Samples

S. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Polluted Water	7.9	180	20	250	0	0	0	0	0	0	0	0	0	0	0	4
Fresh Water	6.8	120	80	250	0	0	0	0	0.5	1	10	1	0.3	2	0	4

Test 2 shows notable differences between polluted and fresh water. Polluted water contained consistently higher pollutant values, with peaks at 180 and 250, while fresh water exhibited fluctuations, particularly between 120 and 250. Both types of water contained several parameters with zero values, suggesting the absence of detectable contamination in some cases. Freshwater samples, though cleaner, still indicated minor pollutant traces.

Table 5: Test 3- Variability in Pollutant Levels Between Polluted and Freshwater

S. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Polluted Water	8	120	40	250	0	0	0	0	0	0	0	0	1	2	5	4
Fresh Water	7.3	120	30	425	0	0	0	0	0	0	0	0	0	0	0	0

Test 3 highlights variability in pollutant concentrations. Polluted water reached a maximum of 250, while fresh water surpassed this level with a reading of 425. Several parameters in both water types showed zero contamination, though pollutants were distributed differently. The results suggest that while polluted water often has higher loads, fresh water can occasionally exceed in specific parameters.

Table 6: Test 4- Contamination Levels in Polluted and Freshwater Samples

S. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
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Polluted Water	7.5	140	40	425	150	0.2	0	0	0	0	0	0	0	0	5	0
Fresh Water	7.8	40	50	300	30–50	0	0	0	0	0	0	0	0	0	3	2

Test 4 demonstrates higher contamination in polluted water, with values reaching 425 and 150 for certain parameters. Fresh water displayed lower concentrations overall, although still containing detectable contamination, particularly between 30 and 50. The majority of parameters in both samples were non-detectable, confirming cleaner segments of water.

Table 7: Test 5- Pollutant Discrepancies Between Polluted and Freshwater

S. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Polluted Water	9	80	90	250	30	0	0	0	0	0	0	0	0	0	5	4
Fresh Water	7.8	180	80	250	10	0.2	0	0	0	0	0	0	0	0	5	0

Test 5 reveals significant differences between polluted and fresh water. Polluted water registered higher values in most parameters, with notable peaks at 90 and 250. Freshwater samples were generally cleaner but contained measurable contamination in a few cases. Although both types contained pollutants, the polluted samples were consistently more affected.

Table 8: Test 6- Pollutant Distribution Across Polluted and Freshwater Samples

S. No.	1	2	3	4	5	6	7	8	9	10	11	1	13	1	1	1
												2		4	5	6
Polluted Water	2	14	2	29	0	0.	0	0	0.	1	1	1	0.	2	5	1
		0	0	0		2			5		0		3			0
Fresh Water	7.	12	8	25	0	0	0	0	0	0.	5	1	0–	1	0	4
	6	0	0	0						5			3			

Test 6 indicates that polluted water was more contaminated, with values up to 290 and 140. Fresh water recorded lower readings but still exhibited measurable concentrations of pollutants in several cases. Both water types showed traces of nitrogenous compounds and other contaminants, though freshwater was comparatively cleaner.

Table 9: Test 7- Comparative Pollutant Levels in Polluted and Freshwater

S. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Polluted Water	7.7	90	40	270	0	0	0	0	0	0	0	0	0	0	5	6
Fresh Water	7.9	120	80	250	0	0	0	0	0	1	0	1	0	2	4	4

Test 7 reflects generally moderate contamination across both types of water. Polluted

water reached a maximum of 270, while fresh water maintained lower but still significant levels. Both water types contained parameters with zero contamination, though measurable pollutants persisted in others. The data suggest that while freshwater is less polluted, it is not entirely free from contamination.

Integrated Assessment of Fish Diversity and Water Quality in the Kurram River

The assessment of fish diversity and water quality parameters in the Kurram River reveals an ecosystem experiencing considerable anthropogenic pressure. A total of ten fish species belonging to four families were documented, with Cyprinidae emerging as the dominant group. The analysis also highlights serious water quality concerns, particularly elevated levels of heavy metals and fluoride, which point to significant pollution across several river stretches.

The coexistence of both tolerant and sensitive species indicates an ecosystem in ecological transition, where resilience is counterbalanced by vulnerability. Spatial heterogeneity was evident, with environmental conditions varying considerably across different river sections, thereby shaping localized patterns of fish distribution and water chemistry. Despite these challenges, the presence of species of conservation concern demonstrates the ecological value of the river and underscores opportunities for targeted protection. These findings provide a strong foundation for management interventions, showing that while the system faces pronounced stress, corrective actions could help stabilize and enhance both biodiversity and water quality.

Analysis of Water Quality Characteristics

The Kurram River, a tributary of the Indus River system, is central to agricultural, domestic, and fisheries needs in the region. Flowing through fertile valleys, it sustains wheat, maize, and rice cultivation, while in Bannu District its waters are extensively diverted for irrigation through canal networks. The river alternates between relatively pristine freshwater stretches and zones heavily degraded by pollution from urban effluents, agricultural runoff, and pesticide discharge. Seasonal floods replenish groundwater, improve soil fertility, and maintain agricultural productivity, whereas dry-season flows are significantly reduced, affecting both irrigation supply and ecological stability.

The river supports a diverse assemblage of freshwater fish, including carp and catfish, which remain vital for local fishing communities. However, water quality has deteriorated markedly due to intensifying anthropogenic pressures. Pollution peaks during summer as snowmelt and monsoon inflows carry additional contaminants, while low-flow conditions in the dry season exacerbate ecological stress. Geographically, the basin integrates mountainous terrain with fertile alluvial plains, and the river enters Bannu through a gorge before dispersing into distributary channels. These habitats sustain aquatic plants, amphibians, and other fauna, while also contributing to the scenic and cultural heritage of the valley.

Despite its ecological, economic, and cultural importance, the Kurram River faces escalating threats from both natural variability and human activities. Effective conservation and sustainable management are therefore critical to preserve water quality, protect fish diversity, and secure the livelihoods of the communities that depend on this vital aquatic system.

Conclusion

The study of the River Kurram reveals a moderately diverse fish community consisting of economically valuable and ecologically significant species, with Cyprinidae dominating the assemblage. The persistence of sensitive species such as the Golden Mahseer indicates that parts of the river retain conservation value despite increasing anthropogenic pressures. Water quality analysis shows alarming levels of heavy metals, particularly lead and chromium, along with elevated fluoride concentrations and variable pH. These pollutants far exceed safe ecological thresholds, posing serious risks to aquatic biodiversity, fisheries sustainability, and human health. Spatial heterogeneity in water quality and species composition suggests that while some stretches of the river remain relatively resilient, others are heavily degraded and in urgent need of restoration. The findings underscore that the River Kurram is a complex but threatened ecosystem, where resilience is evident but fragile.

Recommendations

Immediate action is required to control pollution sources, particularly industrial and agricultural discharges responsible for heavy metal and fluoride contamination. Establishing continuous and standardized water quality monitoring programs will enable early detection of ecological deterioration and assessment of remedial actions. Conservation strategies should prioritize the protection and restoration of habitats that sustain sensitive species such as the Golden Mahseer. Species-specific conservation planning, including potential captive breeding programs, could help maintain vulnerable populations. Long-term management must adopt an integrated watershed approach that balances land use, agriculture, and industrial activities with aquatic ecosystem protection. Engaging local communities through education, participatory management, and alternative livelihoods will enhance conservation effectiveness. Strong policy reforms and strict enforcement of environmental regulations are essential to reduce contamination risks and ensure sustainable use of aquatic resources. By addressing these threats and capitalizing on the river's remaining resilience, the ecological integrity and socio-economic value of the River Kurram can be sustained and enhanced for the future.

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