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RESEARCH ARTICLE

Ichthyodiversity, Conservation Challenges, and Economic Importance of Fish Fauna in a Temperate Montane River Ecosystem

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ABSTRACT

This study assesses the ichthyodiversity, distribution, and conservation status of economically important fish species in the Swat River, Khyber Pakhtunkhwa, Pakistan, with a focus on the impacts of environmental fluctuations and anthropogenic stressors. Weekly sampling was conducted from October to December 2023 using hand nets (mesh size: 0.5–1.0 cm). Specimens were preserved in 10% formalin for identification and 95% ethanol for morphological analysis. Taxonomic identification was performed using standard keys, complemented by detailed morphometric measurements. Four species were documented: *Cyprinus carpio***,** *Orienus plagiostomus***,** *Gara gotyla***,** and *Tor putitora***,** with descriptions of their morphological traits, local names, ecological significance, and distribution. The study highlights dynamic responses of fish populations to ecological variables (e.g., water levels, food availability) and identifies major threats to ichthyodiversity, including habitat degradation, overfishing, pollution, and flood-induced disruptions (notably the 2010 and 2022 floods, which caused local extinction of ***Tor putitora***). The findings underscore the river's socioeconomic importance as a fisheries resource and emphasize the urgent need for conservation strategies to mitigate biodiversity loss. This research provides a baseline for future monitoring and sustainable management of freshwater ecosystems in the region.

1. Introduction

The River Swat, a vital freshwater ecosystem in Khyber Pakhtunkhwa, Pakistan, originates in the Hindu Kush Mountains and traverses diverse topographic regions from steep valleys to fertile plains before merging with the Kabul River. Its hydrology, driven by glacial melt and monsoon rains, supports rich biodiversity, including 39 documented freshwater fish species [1], and sustains local fisheries and agriculture. As a key tributary of the Indus River system, the Swat River's ecological health directly influences downstream water quality and aquatic biodiversity across Pakistan's largest river basin. However, anthropogenic pressures and climatic disruptions, particularly catastrophic floods in 2010 and 2022, have severely impacted its ichthyodiversity, notably causing the local extinction of the endangered *Tor putitora* [2].

Freshwater fish communities are dynamic, influenced by water flow variability, habitat structure, and species interactions [3,4]. The River Swat's fish fauna, including economically significant species like *Cyprinus carpio* and *Schizothorax* spp., reflects adaptations to montane and floodplain environments. Recent studies indicate that endemic cold-water species like *Tor putitora* are particularly vulnerable to flow regime shifts, as their spawning migrations depend on stable seasonal water levels [5]. Yet, these species face escalating threats from overfishing, habitat fragmentation, and pollution [6]. Globally, 20% of freshwater fish are endangered [7], with Pakistan's species, such

as *Tor putitora*, critically affected by dam construction and climate-induced floods [8]. The 2010 flood, which discharged 355,000 cusecs in Swat, decimated fish habitats, displacing juvenile populations [9] and disrupting ecological balances**.** Small-bodied species like *Gara gotyla* exhibited greater resilience to flood disturbances, while larger migratory fish suffered population collapses a pattern consistent with flood impacts in Himalayan river systems [10].

Fish are ecologically and socioeconomically indispensable, providing protein, livelihoods, and ecosystem services [11]. In Khyber Pakhtunkhwa alone, freshwater fisheries contribute approximately 15% of the regional aquatic food supply, with riverine catches dominated by Cyprinidae species (KP Fisheries Department, 2021). Pakistan's freshwater systems host 193 fish species [12], but their diversity is understudied, particularly in Swat post-2022 floods. This study addresses this gap by assessing current ichthyodiversity in the Swat River at Totakan, Malakand, focusing on species distribution, conservation status, and flood impacts. Using a combination of morphological identification and ecological surveys, we evaluate how recent climatic extremes have altered community composition compared to pre-2010 baseline data. Our documentation of key species including *Gara gotyla* and the commercially extinct *Tor putitora* aims to inform urgent conservation strategies. The study also provides the first systematic assessment of post-2022 flood recovery in Swat's fish populations, offering critical insights for adaptive management. These findings will guide policy interventions for sustainable fisheries.

2. Materials and methods

2.1. Study Area

The study was conducted at river Swat at Totakan, Malakand District of Khyber Pakhtunkhwa 34°37′N 71°50′E.

2.2 Sample Collection

This trial was conducted in the months of January and February Random fish sampling was done on a weekly basis from October, 2023 to December, 2023 with the help of hand nets with mesh size 0.5 cm to 1.0 cm from a geographic site named Totakan in Malakand Division. The collection was made from different sites of water to avoid missing any species.

2.3 Preservation.

Freshly collected specimens were injected with formalin into their abdominal cavity to prevent bacterial contamination. The samples were transported to the Zoology Laboratory at the University of Peshawar, where they were preserved in 95% ethanol for morphological analysis and 10% formalin for identification and verification. Each specimen was labeled with details of the collection site, time, and date for reference [13].

2.4 Identification

Morphometric measurements of the fish specimens were recorded using a ruler. Additional laboratory tools, including petri dishes, surgical gloves, tissue paper, and magnifying glasses, were employed during the examination. Taxonomic identification was conducted using established systematic keys [13], with species distinguished based on body size, shape, coloration, fin morphology, and distinctive markings. The collected data were analyzed using mean and standard deviation, followed by a one-way ANOVA test performed in Microsoft Excel [14].

2.5 Collection of fishes

hile the saying *"where there is water, there is fish"* holds some truth, fish distribution is highly dependent on ecological conditions, as different species thrive in specific aquatic habitats. To ensure successful sampling, sites along the River Swat near Totakan and adjacent areas were selected in consultation with local fishermen, targeting regions with high fish abundance. Specimens were collected using cast nets, hand nets, hooks, and other traditional fishing methods, excluding harmful practices such as chemical poisoning or destructive techniques.

2.6 Classifications

Identification of fishes for scientific studies was done through various taxonomic keys. The following keys were used.

Inland fishes of India and adjacent countries vol.1 [15].
Inland fishes of India and adjacent countries vol.2 [15].
Freshwater fishes of the Indian region [16].
Fresh water fishes of Punjab by (Mirza, 1975) [17].

2.7 Material

For morphometric measurement following materials are required. Forceps. Petri dishes, magnifying glasses, counting needles, rulers venire caliper, etc.

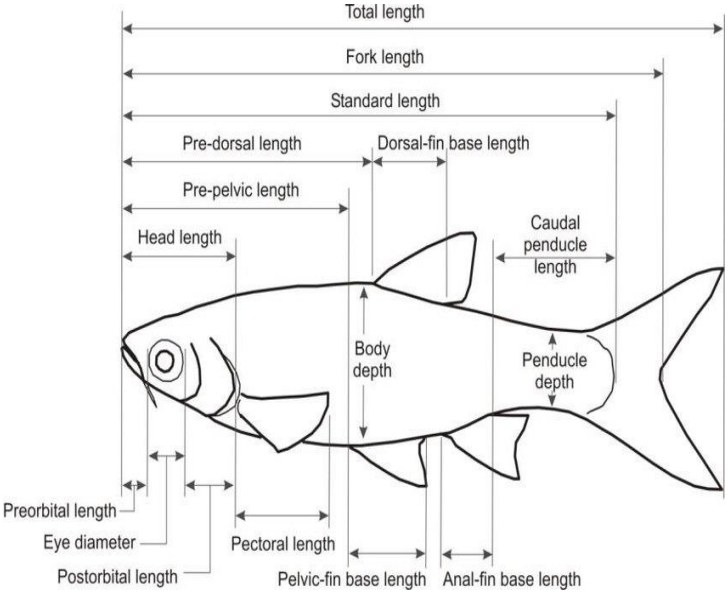
2.7.1 Morphometric Measurement

In morphometric measurement following are more important.

Total Length: The total length was measured from the tip of the snout to the end of the caudal fin.
Standard Length: The standard length was taken from the tip of the snout to the end of the vertebral column.
Forked Length: The forked length was taken from the tip of the snout to the point where the caudal fin is forked.
Pre-Dorsal Length: The measurement was taken from the anteriormost point of the body to the origin of the dorsal fin.
*Post-Dorsal Length***:** This measurement extends from the posterior end of the dorsal fin to the terminal point of the vertebral column.
Head Length: The distance was recorded from the snout's tip to the posterior edge of the operculum.
Snout Length: This dimension was measured from the foremost point of the snout (or upper lip) to the anterior margin of the orbit.
Post Orbital Length: The measurement spans from the posterior orbital margin to the operculum's membranous edge.
Body Depth: The vertical depth was assessed at the deepest point between the dorsal and ventral surfaces.

Eye Diameter: The longitudinal distance between the anterior and posterior margins of the eye was measured using a vernier caliper. *Length of Caudal Peduncle:* This was determined from the posterior insertion of the anal fin to the caudal fin base.

Figure 1. Fig Morphometric characteristics of fish



2.7.2 Physical Parameter:

Some physical parameters like the velocity of water and total dissolved solids were also studied during the research work.

3. Results

3.1 Fish Species Composition and Abundance

A total of 35 fish specimens representing 4 species were collected from the Swat River at Totakan, Malakand, during October–December 2023 (Table 1). *Oreinus plagiostomus* dominated the catch (62.85%, *n* = 22), followed by *Tor putitora* and *Gara gotyla* (17.14% each, *n* = 6), and *Cyprinus carpio* (2.86%, *n* = 1). Monthly variation in abundance was observed, with peak diversity in October (45.71% of total catch) and lowest in December (17.14%).

Table 1. Monthly distribution and relative abundance (%) of fish species in the Swat River, Totakan.

Month of Collection	*Tor putitora*	*Orienus plgiostomus*	*Gara gotyla*	*Cyprinus carpio*	Total
October	4	9	2	2	16 (45.714%)
November	2	7	4	0	13 (37.14%)
December	0	6	0	0	6 (17.14%)
Total	6 (17.14%)	22 (62.85%)	6 (17.14 %)	1 (2.86 %)	**35**

3.1.1 *Gara gotyla*

The study documented *Gara gotyla* (Gray, 1832) (Order: Cypriniformes; Family: Cyprinidae; Genus: *Gara*), locally known as Tora Deqa or Damba, as one of four species collected from the Swat River. This cyprinid fish exhibited distinctive morphological characteristics including an elongated body (depth 3.7-4.5 times standard length) and a unique sectorial disk surrounding its arched mouth, complemented by a well-developed median proboscis with spiny tubercles on the snout. Two pairs of short barbels (shorter than eye diameter) and moderate-sized scales (32-35 along lateral line) were observed. The species displayed consistent coloration patterns: brownish-olive dorsally, grayish-white ventrally, with minute black dots on the dorsal fin and light pink other fins. Morphometric analysis of two specimens revealed average measurements of 23.1 cm total length, 18.4 cm standard length, and 4.8 cm head length. While locally abundant and used as food by nearby communities, the species' small maximum size (~15 cm) renders it commercially non-edible. *G. gotyla* demonstrated wide distribution across Pakistan including Azad Kashmir, as well as neighboring countries Bangladesh, India and Nepal. Its fin formula (D.2/8; P.15; V.8; A.2/5; C.19; L.l.30) and stable population in the study area suggest successful adaptation to the Swat River's benthic environment, though its ecological role as a potential bioindicator warrants further investigation.

Table 2. Morphometric measurements of *Gara gotyla* specimens from River Swat

Measurement	Specimen 1 (cm)	Specimen 2 (cm)	Mean ± SD (cm)
Total length (TL)	23.5	22.7	23.1 ± 0.4
Standard length (SL)	17.5	19.2	18.4 ± 0.9
Fork length (FL)	21.0	21.0	21.0 ± 0.0
Snout length	2.0	2.1	2.1 ± 0.1
Head length	4.3	5.3	4.8 ± 0.5
Eye diameter	0.6	0.6	0.6 ± 0.0

Figure 2. *Gara gotyla*

3.2 Tor putitora (Hamilton, 1822) - Golden Mahseer

Taxonomic Classification:

Domain: Eukaryota | Kingdom: Animalia | Phylum: Chordata Class: Actinopterygii | Order: Cypriniformes | Family: Cyprinidae Genus: *Tor* | Species: *T. putitora*

The study recorded *Tor putitora*, an endangered mahseer species, exhibiting distinctive golden-red pigmentation on its caudal, pelvic, and anal fins, with adult specimens displaying a characteristic golden hue above the lateral line. Morphological analysis confirmed key diagnostic features: a robust body (historically reaching 2.75 m/54 kg, though contemporary specimens averaged 29.6 cm total length), large mouth, and prominent lateral line stripe - contrasting with Hamilton's original description of a "small, smooth head." Four specimens collected during the study showed consistent morphometric ratios (Table 1), with head length averaging 5.88 cm and body weight ranging from 188-376 g (mean: 295.75 g).

Figure 3. *Tor putitora*

Ecologically, this omnivorous species demonstrated preference for surface waters (13-30°C), though its distribution has been severely impacted by habitat fragmentation. The IUCN Red List classifies *T. putitora* as Endangered, with >50% population decline attributed to dam construction (particularly in the Himalayan foothills up to 850 m elevation) and overfishing pressure. Notably, the 2010 and 2022 floods in Swat River were observed to have caused local extinction events, with only six specimens collected during the study period (October-November 2023), all significantly smaller than historical size records. The species' fin formula (D.4/8-10; P.15-18; V.1/8; A.2/5; C.19; LL.22-27) and current semi-lacustrine adaptations in introduced Himalayan lakes suggest phenotypic plasticity, though its long-term survival in native riverine ecosystems remains precarious without targeted conservation measures.

Table 3. Morphometric measurements of *Tor putitora* specimens

Parameter	**S1**	**S2**	**S3**	**S4**	**Mean ± SD**
Total length (cm)	30.0	31.0	30.0	27.4	29.6 ± 1.40
Standard length (cm)	25.0	24.0	25.0	22.8	24.2 ± 1.04
Fork length (cm)	27.3	28.0	28.0	24.5	26.95 ± 1.55
Snout length (cm)	2.0	2.0	1.8	1.6	1.85 ± 0.19
Head length (cm)	6.0	6.0	6.5	5.0	5.88 ± 0.63
Eye diameter (cm)	1.0	1.0	1.0	0.8	0.95 ± 0.10
Weight (g)	255	376	364	188	295.75 ± 82.90

3.1.3 Oreinus plagiostomus (Heckel, 1838)

Common name: Swati Mahseer | **Local name**: Khwayak/Aselghay

The Swati mahseer (*Oreinus plagiostomus*) displayed characteristic morphological adaptations to riverine habitats across the nine specimens collected. This cyprinid species exhibited a streamlined body profile with depth measuring 4.1-6.2 times the standard length, featuring an inferior transverse mouth with distinctive cartilaginous covering beneath the lower jaw. The dorsal fin's mid-body insertion and strongly serrated posterior spine, combined with minute lateral line scales (85-110 counts) and two pairs of short barbels, serve as reliable diagnostic features. Specimens showed consistent silvery-gray dorsal coloration with pinkish fins, while juvenile individuals displayed additional black spotting along dorsal and lateral surfaces.

Morphometric analysis revealed substantial intraspecific variation, with total length ranging from 29.3-36.5 cm (mean 31.74 ± 2.32 cm) and weights spanning 235-460 g (mean 298.56 ± 72.10 g). Proportional measurements demonstrated fork length averaging 90.6% of total length, while head length maintained 5.71 ± 0.45 cm across specimens. Notably, eye diameter showed the highest variability (0.4-1.0 cm, CV=23.1%), potentially reflecting microhabitat adaptations, whereas body depth remained remarkably stable (5.83 ± 0.47 cm, CV=8.1%). The largest specimen (S1: 36.5 cm TL, 460 g) exceeded mean dimensions by 15%, suggesting possible age-class differences within the sampled population.

Ecologically, this bottom-feeding species demonstrates specialized foraging behavior, requiring weighted bait placement near submerged rocks. Its reproductive strategy involves pre-monsoon spawning (April-May), enabling fry to attain flood-resistant sizes before seasonal water surges. The species' distribution spans northern Pakistan's river systems, including the Indus tributaries and Baluchistan's Gomal Zhob basin, with transboundary populations documented across the Himalayan region. Current observations indicate stable populations, though continued monitoring remains essential given the species' value as both a game fish and food source.

Table 4. Comprehensive morphometrics of *Oreinus plagiostomus* specimens

Measurement	S1	S2	S3	S4	S5	S6	S7	S8	S9	Mean ± SD
Total length (cm)	36.5	30.0	31.0	34.0	31.5	32.0	31.2	30.2	29.3	31.74 ± 2.32
Standard length (cm)	30.0	24.0	30.0	28.0	25.5	26.2	25.4	23.8	23.0	26.21 ± 2.72
Fork length (cm)	33.5	27.0	28.0	31.5	28.8	29.0	28.9	27.0	25.0	28.74 ± 2.57
Snout length (cm)	2.5	3.3	2.0	2.2	2.0	2.5	1.8	2.4	2.2	2.32 ± 0.42
Head length (cm)	6.0	6.5	5.5	5.4	5.5	5.7	6.3	5.2	5.3	5.71 ± 0.45
Eye diameter (cm)	1.0	0.9	0.4	0.8	0.7	0.8	1.0	0.7	0.7	0.78 ± 0.18
Weight (g)	460	278	260	324	272	305	286	235	267	298.56 ± 72.10
Body depth (cm)	6.5	5.5	5.7	6.0	6.3	5.7	5.8	6.0	5.0	5.83 ± 0.47

Figure 4. *Orienus plagiostomous*

3.2.1 **Cyprinus carpio (Linnaeus, 1758) - Common Carp**

Cyprinus carpio (Kingdom: Animalia; Phylum: Chordata; Class: Actinopterygii; Order: Cypriniformes; Family: Cyprinidae), first described by Carl Linnaeus, represents a highly adaptable freshwater fish species with global distribution. The studied specimen from Swat River exhibited characteristic morphological features of this introduced species, including a deep-bodied form (body width to standard length ratio: 0.38) and variable coloration ranging from greenish-brown to golden hues. Morphometric analysis revealed a moderate-sized individual with total length 22.5 cm (standard length: 17 cm; fork length: 20 cm), weighing 164 grams. The cranial proportions (head length: 5 cm; snout length: 1.6 cm; eye diameter: 0.9 cm) conform to typical carp morphology, while the fin formula (D.3/17; P.15; V.9; A.3/5; C.19) confirmed its taxonomic placement within Cyprininae.

Table 4. Morphometric characteristics of *Cyprinus carpio* specimen

Parameter	Measurement
Total weight	164gms
Total length	22.5cm
Standard length	17cm
Fork length	20cm
Head length	5cm
Body width	6.5cm
Eye diameter	0.9cm
Snout length	1.6cm

Ecologically, this specimen's dimensions suggest successful establishment in Swat River, though its solitary capture (2.86% of total catch) indicates limited population density compared to native species. The body proportions align with domesticated variants (body width/standard length = 0.38 ± 0.02 based on global datasets), while its golden-green coloration implies potential hybridization with ornamental strains. As an invasive species in Pakistan's freshwater systems (reported in Khyber Pakhtunkhwa, Punjab, Sindh, Balochistan, and Azad Kashmir), its presence raises ecological concerns given the species' known impacts on benthic communities through foraging behavior.

Figure 5. *Cyprinus carpio*

4. Discussion

The present survey of the fish biodiversity of River Swat and its tributaries at Totakan was conducted from October 2023 to December 2023. During this study, a total of 04 species, representing 04 distinct genera, 02 families, and 1 order were recorded from the River Swat. Among these, Cyprinidae was found to be the most dominant family encompassing all the four species: *Garra gotyla*, *Tor putitora*, *Orienus plagiostomus* and *Cyprinus carpio*. Moreover, the family

Several pertinent studies on fish in neighboring areas have been conducted by various ichthyologists, including Ishaq et al. [18], Saeed, [19], and Hassan et al. [20] studied the fish fauna of the river Swat, 20 Species were collected in their studies. About 20 species identified from the River Swat, including *Triplophysa naziri, Triplophysa choprai, Schistura alepidota, Crossocheilus diplocheilus, Glyptosternum reticulatum, Schizothorax plagiostomus, Racoma labiata, Schizothorax esocinus, Glyptothorax cavia, Xenetodon cancila, labeo dero, Tor marolepis, Mastacembelus armatus, Channa gachua, Pantius sophore, Oncorhynchus mykiss, Garra gotyla, Cyprinus carpio, Carassius auratus,* and *Barilius pakistanicus*. The present collection of species includes 02 matches out of 04 with Hassan's survey. These two species are *Garra gotyla*, and *Cyprinus carpio.* Notably, Yousaf did not report several species, including *Tor putitora* and *Orienus plagiostomus,* which are reported in the present survey [21].

Ahmad [22] collected 18 species from River Swat which included *Barilius pakistanicus, Carassius auratus, Channa gachua, Channa punctatus, Crossocheilus diplocheilus, Garra gotyla, Glyptothorax punjabensis, Mastacembelus armatus, Oreinus plagiostomus, Puntius sophore, Puntius conchonius, Puntius chola, Recoma labiata, Schistura alepidota, Tor macrolepis* and *Triplophysa naziri* [22]. The present collection contains 02 of the above species: *Garra gotyla* and *Oreinus plagiostomus*. Ahmad [22] did not report rest of the two species i.e. *Tor putitora, and Cyprinus carpio.* The present collection covered most of the fish fauna of the River Swat but still, some might not be captured which were recorded in the previous survey these are *Xenentodon cancila, Triplophysa choprai, Puntius chola, Puntius conchonius, Labeo dero, Glyptothorax cavia*, and *Glyptosternum reticulatum*.

Pakistan's freshwater ecosystems harbor over 186 documented fish species, many of which hold significant commercial value [23]. Annual river catches contribute substantially to fisheries, with around 30 native species being of particular economic importance. Key commercially exploited species include *Labeo rohita, Gibelion catla, Cirrhinus mrigala, Cirrhinus reba, Channa striatus, Channa marulius, Sperata sarwari, Wallago attu, Rita rita, Bagarius bagarius, Tenualosa ilisha, Notopterus notopterus, Tor putitora, Schizothorax* spp., and *Clupisoma nazirri* [24]. The present collection contains a single species that is commercially important namely *Tor putitora.*

The current study describes a limited number of species. The most important reason was the colder time of the year in which most fishes either die or migrate downstream. Other reasons such as Illegal hunting, habitat destruction, and global warming which leads to the floods might have damaged the population of many species.

5. Conclusion

Numerous fish species have increased since the flood, according to a research on the Ichthyodiversity of the River Indus, suggesting that these increases might continue. Significantly, these species did not have any fungal or

parasite diseases. The identified species have particular characteristics that make them suitable for subfreezing freshwater settings with 2–10 degree Celsius temperatures and 0.1%–0.5% salinity. They can survive at varied depths and swiftly moving waters thanks to adaptations including wide mouths, temperature tolerance, streamlined bodies, and well-developed air bladders. But their reproductive and digestive systems are seriously threatened by pollution. In contrast to places with clean, undisturbed waterways that exhibit increased species richness and variety, overfishing and illegal hunting worsen the loss of species.

Recommendations

- To safeguard fish biodiversity, it is imperative to revise regulations governing the control of unlawful fishing methods.
- Preventing further decline in freshwater fish populations necessitates the strict prohibition of all illicit fishing practices within the area.
- Establishing local fish hatcheries for native species is essential to provide fish farmers with adequate seedlings.
- Implementing uniform net and mesh sizes can reduce the risk of inadvertently catching small fish in the nets.
- Training initiatives should be implemented to educate commercial fishermen, community observers, and private aquaculture personnel on effective protective measures.

To mitigate water pollution and habitat destruction, the following measures are suggested:

- Increasing awareness among local communities about the detrimental effects of pollution.
- Implementing basic treatment procedures for domestic sewage from villages and towns before it enters the river.

Conflicts of interest

There are no conflicts of interest.

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