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Original Article

Taxonomic, morphometric and limnological assessment of the commercially important ichthyofauna of Sakhakot Stream, Malakand, Pakistan

Avaliação taxonômica, morfométrica e limnológica da ictiofauna comercialmente importante do Riacho Sakhakot, Malakand, Paquistão

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Abstract

The present study was conducted for the taxonomic, morphometric and limnological assessment of the commercially important ichthyofauna of Sakhakot Stream, Malakand, Pakistan. The study area was divided into three sites along the water course namely Dargai Stream, Sakhakot Stream and Shergarh Stream. Fish samples were collected randomly during January to August 2017 with the help of fish gears. A taxonomic key was designed for the collected fish specimens. Ten fish species were identified belonging to 3 orders and 4 families. Family Cyprinidae was the dominant family with seven representative species while families Siluridae, Nemacheilidae and Mastacembelidae were represented by one species each. Lower mean total length and standard length was recorded in *Puntius conchonius* (Hamilton, 1822) as 9.2 ± 0.6 cm and 7.3 ± 0.6 cm respectively, while highest mean total length and standard length was recorded in *Mastacembelus armatus* (Lacepede, 1800) as 28.1 ± 1.7 cm and 15.9 ± 2.4 cm respectively. Mean pH of the water ranged from 6.1 at Shergarh Stream in August to 8.7 at Sakhakot Stream in January. Average temperature range was recorded from 10.9 °C in January at Dargai Stream to 18.7 °C in August at Shergarh Stream. No statistically significant difference was found for temperature ($p = 0.96$) and pH ($p = 0.14$) in the three water streams. The present study will provide a baseline for the rearing and enhancement of wild stock of the commercially important ichthyofauna in the field of aquaculture and fisheries.

Keywords: Cyprinidae, Puntius conchonius, Mastacembelus armatus, morphometrics, taxonomic key, Malakand.

Resumo

O presente estudo foi realizado para a avaliação taxonômica, morfométrica e limnológica da ictiofauna comercialmente importante do Riacho Sakhakot, Malakand, Paquistão. A área de estudo foi dividida em três locais ao longo do curso de água, nomeadamente Riacho Dargai, Riacho Sakhakot e Riacho Shergarh. As amostras de peixes foram coletadas aleatoriamente durante janeiro e agosto de 2017, com a ajuda de artes de peixes. Uma chave taxonômica foi projetada para os espécimes de peixes coletados. Foram identificadas dez espécies de peixes pertencentes a 3 ordens e 4 famílias. A família Cyprinidae foi a família dominante, com sete espécies representativas, enquanto as famílias Siluridae, Nemacheilidae e Mastacembelidae foram representadas por uma espécie cada. O comprimento total médio mais baixo e o comprimento padrão foram registrados em *Puntius conchonius* (Hamilton, 1822) como 9.2 ± 0.6 cm e 7.3 ± 0.6 cm, respectivamente, enquanto o comprimento total médio e o comprimento padrão mais altos foram registrados em *Mastacembelus armatus* (Lacepede, 1800) como 28.1 ± 1.7 cm e 15.9 ± 2.4 cm, respectivamente. O pH médio da água variou de 6.1 no Riacho Shergarh em agosto a 8.7 no Riacho Sakhakot em janeiro. A faixa de temperatura média foi registrada de 10.9 °C em janeiro no Riacho Dargai a 18.7 °C em agosto no Riacho Shergarh. Não foi encontrada diferença estatisticamente significativa para temperatura (p = 0,96) e pH (p = 0,14) nos três cursos de água. O presente estudo fornecerá uma linha de base para a criação e aprimoramento do estoque selvagem da ictiofauna comercialmente importante no campo da aquicultura e pesca.

Palavras-chave: Cyprinidae, *Puntius conchonius*, *Mastacembelus armatus*, morfometria, chave taxonômica, Malakand.

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1. Introduction

Fishes are one of the most diverse group of vertebrates comprising 41% of freshwater species, 58% marine water species and 1% migratory species living between marine and freshwater bodies (Helfrich et al., 2019). Fish represent half of the world vertebrate fauna with more than 21,723 species (Shinde et al., 2009). Various products of fish like fish glue, fish meal and fish oil are consumed globally (Shaikh et al., 2011). Fish also play a vital role in aquatic ecosystem occupying the second trophic level in a food chain (Dubey et al., 2012).

The study of ichthyofauna generates an idea to provide a fruitful product to aquaculture (Naveed et al., 2014). The diversity, presence and abundance of fish fauna is different worldwide due to difference in geological and geographical characteristics of the environment (Shaikh et al., 2011; Joshi et al., 2017). The diversity, characteristics, abundance and population of fish depend upon breeding ground, food availability, geological and geographic features, physiochemical parameters, water, size, depth, water current and topographic characteristics (Bhattacharjya et al., 2017). Ichthyofauna in various parts of Khyber Pakhtunkhwa, Pakistan include 180 fish species in River Indus (Mirza, 2007), 11 species in Tanda Dam, Kohat (Haseeb et al., 2015), 5 species in Kandar Dam, Kohat (Haseeb et al., 2016) and 7 species in Chamla, District Buner (Din et al., 2016).

Taxonomic keys are helpful in the identification of unknown specimens. Limnological assessment helps in finding out association of fish and aquatic fauna with the ambient environment and can be used in sustainable aquaculture. Morphometric analyses are useful in finding out minimum and maximum sizes obtained by different species in a habitat associated with the external environmental conditions. The present study was aimed to devise a taxonomic key associated with morphometric and limnological assessment of the commercially important ichthyofauna of Sakhakot Stream, Malakand, Pakistan.

2. Materials and Methods

2.1. Study area

The study area was divided into three sites along the water course from the main tributary of Sakhakot including Dargai Stream (34.5143° N, 71.8946° E), Sakhakot Stream (34.4579° N, 71.9075° E) and Shergarh Stream (34.3895° N, 71.8986° E), Malakand, Pakistan (see Figure 1).

2.2. Data collection

Fish collection was carried out twice a month from January to August 2017. Various fishing instruments like gill nets, lift nets, hooks and cast nets were used to collect fish samples. The large specimens were preserved in 10% formalin while the smaller ones were preserved in 5% formalin. Specimens were collected month wise from

Figure 1. Study area, District Malakand, Pakistan, where sample collection was carried out. A. Sakhakot Stream, B. Dargai Stream, C. Shergarh Stream.

January to August. Each specimen was labelled according to locality, time and date of collection.

2.3. Taxonomic, morphometric, meristic and limnological analysis

A dichotomous taxonomic key was designed for the collected fish specimens based on two contrasting characters in the collected specimens. Taxonomic keys are used for the identification of specimens. The samples were measured with the help of a scale and all morphometric measurements were taken in centimeters (as shown in Table 1). The meristic counts were done with the help of magnifying lens and microscope. Each specimen was weighed with the help of a digital scale. The pH and temperature of water were taken with the help of digital pH meter and thermometer respectively (as shown in Table 2).

2.4. Identification

Specimens were compared with available literature and keys (Mirza and Sandhu, 2007; Talwar, 1991; Jayaram, 1999). Morphometric measurements and meristic counts are helpful in the proper identification of fish species. The data was calculated as mean, standard deviation and was subjected to one-way ANOVA for temperature and pH in the three water streams using Microsoft Excel (ver. 2016).

3. Results

The present study was carried out in the water course of Sakhakot Stream running through Shergarh and Dargai, Malakand Division, Pakistan. The study area was thus divided into three collection sites known as Dargai Stream, Sakhakot Stream and Shergarh Stream. Ten identified fish species belonged to three orders and four families. The identified species were *Puntius conchonius* (Hamilton, 1822), *Crossocheilus diplocheilus* (Heckel, 1838), *Carassius auratus* (Linnaeus, 1758), *Schizothorax plagiostomus* (Heckel, 1838), *Devario devario* (Hamilton, 1822), *Garra gotyla* (Gray, 1830), *Tor putitora* (Hamilton, 1822) (Cyprinidae), *Wallago attu* (Bloch & Shneider, 1801) (Siluridae), *Schistura curtistigma* (Mirza & Nalbant, 1981) (Nemacheilidae) and *Mastacembelus armatus* (Lacepede,

Table 1. Mean values of the morphometric parameters of fish species.

Fish Species	No.	T.L (cm)	F.L (cm)	S.L (cm)	B.D (cm)	B.W (g)
		Mean ± SD	Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD
P. conchonius	*10*	9.2 ±0.6	8.2 ±0.5	7. 2 ±0.6	2.8 ±0.2	13.6 ±2.5
S. curtistigma	05	10.8 ±0.5	10.4 ±0.6	9.4 ±0.6	1.8 ±0.3	20.3 ±1.3
C. auratus	05	19.0 ±1.1	18.2 ±1.0	17.6 ±0.9	5.3 ±0.3	71.9 ±6.7
M. armatus	05	28.1 ±1.7	Conf	15.9 ±2.4	2.1 ±0.1	58.7 ±2.8
W. attu	08	13.7 ±3.3	13.0 ±3.0	11.9 ±3.0	2.9 ±0.9	29.4 ±11.8
S. plagiostomus	05	14.8 ±1.1	13.5 ±1.2	12.4 ±1.1	2.7 ±0.1	25.7 ±1.2
D. devario	08	10.2 ±1.7	9.45 ±1.6	8.23 ±1.5	2.7 ±0.1	13.5 ±5.2
C. diplochilus	10	12.0 ±1.9	11.2 ±1.8	9.81 ±1.7	2.0 ±0.1	1.44 ±0.3
T. putitora	05	21.9 ±5.5	18.9 ±5.0	20.7 ±5.5	4.1 ±1.4	3.27 ±0.4
G. gotyla	05	13.3 ±1.6	10.3 ±1.2	12.1 ±1.6	2.2 ±0.1	1.62 ±0.3

Legend: T.L., Total length; F.L., Fork length; S.L., Standard length; B.D., Body depth; B.W., Body weight; SD, Standard deviation; Conf., Confluent fins.

Table 2. Mean temperature (°C) and pH of the water streams from January to August 2017

Month	Dargai Stream		Sakhakot Stream		Shergarh Stream	
	Temp. (°C)	pH	Temp. (°C)	pH	Temp. (°C)	pH
January	10.9	8.4	11.1	8.7	11.3	8.2
February	12.1	8.1	12.3	8.5	12.4	7.8
March	13.0	7.8	13.2	8.1	13.3	7.6
April	14.1	7.6	14.3	7.9	14.4	7.3
May	16.1	7.3	16.4	7.7	16.6	7.1
June	17.2	7.0	17.4	7.4	17.7	6.6
July	18.1	6.7	18.3	7.2	18.6	6.4
August	18.3	6.5	18.5	7.1	18.7	6.1

After one-way ANOVA, P-value for temperature was 0.96 and for pH was 0.14 showing no significant difference of temperature and pH in the three streams.

1800) (Mastacembelidae). The family Cyprinidae was represented by 7 species whereas Siluridae, Nemacheilidae and Mastacembelidae comprised of one species each. The detailed morphometric parameters of the collected fish species were calculated (as shown in Table 1). *P. conchonius* and *C. diplocheilus* were the dominant species recorded in the present study (see Figure 2). The physiochemical parameters were taken separately in the three sites including Dargai, Sakhakot and Shergarh. The average temperature and pH of Dargai site was 14.97 °C and 7.4, Sakhakot was 15.18°C and 7.2 and Shergarh was 15.37 °C and 7.1 respectively (as shown in Table 2). The average width and depth of the three water bodies was measured which shows the level of water suitable for the fish species (as shown in Table 3). A dichotomous key was designed for the identified fish species which will be helpful for future taxonomic work for the commercially important ichthyofauna.

Dichotomous key to the fish species collected at Sakhakot Stream, Malakand, Pakistan

Key to the Fish Orders

1a (i): Scales mostly present teeth on the jaws always absent, no dorsal adipose fins, pectoral fin without a spine ..... **Order Cypriniformes**

1b (ii): Scales are always absent, teeth on the jaws usually present, dorsal adipose fin present or absent pectoral fin with a spine..... **2**

2a (1b): Pelvic fin is presen..... **Order Siluriformes**

2b (1b): Pelvic fin is absent **Order Synbranchiformes**

Key to the Fish Families

1a: Barbels 2, 4 or absent; scales are prominent ..... **Cyprinidae**

1b: Barbels 4, 6 or non; scales are indistinct or absent ... **2**

2a Barbels 6..... **Nemacheilidae**

2b Scales absent..... **3**

3a Barbels 4..... **Siluridae**

3b Barbels absent ..... **Mastacembelidae**

Key to the Fish Genera

1a Lateral line scales are present **2**

1b Lateral line scales are absent..... **3**

2a Lateral line scales range from 20-35 ..... **4**

2b Lateral line scales more than 35..... **5**

3a Body with conspicuous bars, caudal and anal fins are not confluent..... **Schistura**

3b Body with-out conspicuous bars, caudal and anal fins are confluent 6

4a Body Shape is cylindrical or elongated ..... **Tor**

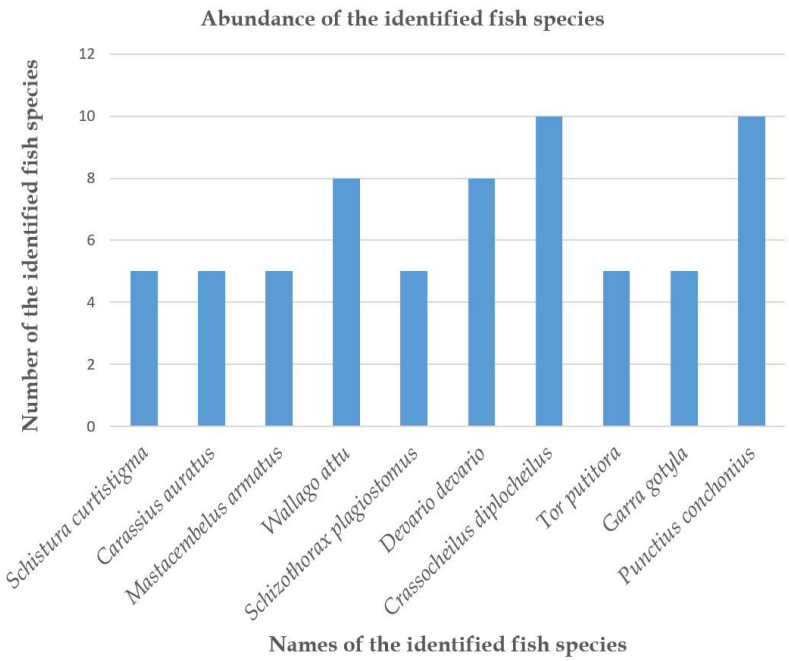

Figure 2. Abundance of the identified fish species at Sakhakot Stream, Malakand, Pakistan.

Table 3. Average width, depth and fish diversity of the three streams.

S.No.	Study site	No. of species	Average depth (m)	Average width (m)
1	Dargai Stream	3	1.99	14.85
2	Sakhakot Stream	5	2.34	12.98
3	Shergarh Stream	2	2.06	43.70

4b Body shape is not cylindrical.....**7**
5a Lower lip is modified into a suctorial disc.....**8**
5b Lower lip is not modified into a suctorial disc.....**9**
6a Upper jaw longer than the lower jaw .....**Mastacembelus**
6b Lower jaw is longer than the upper jaw.....**Wallago**
7a Black spot present on the lateral line scales .....**Puntius**
7b Black spot absent on the lateral line scales.....**Carassius**
8a Suctorial disc is found on the chin snout with proboscis.....**Garra**
9a Pelvic fin is present below in front of dorsal fin.....**Devario**
9b Pelvic fin is not present below in front of dorsal fin **10**
10a Doral fins have 3-4 spins.....**Tor**
10b Dorsal fin have last undivided osseous, strong serrated ray .....**Schizothorax**

Key to Species

1a Silvery with black spots on the dorsal and lateral side.....**2**
1b Dorsally dark brown or greyish, ventrally white or yellow.....**6**
2a Longitudinal band along the lateral line absent.....**4**
2b Longitudinal band along the lateral line is present **5**
4a Silvery with greyish back, fins pinkish, found in mountain stream or rivers .....***S. plagiostomus***
4b Occasionally dorsal fin tipped black, operculum shot with gold, found in fast flowing water..... ***P. conchonius***
5a Silvery with one bluish band along the lateral line, two more bluish band above and below the middle one, found in river and pond in plain and mountain regions.....***D. devario***
5b 2 spots found along the lateral line one dark oval shape on shoulder and the other one is diffused near the caudal fin base, found in large river and estuaries with muddyor silty substrate .....***W. attu***
6a Vertical bars present on the body **7**
6b Vertical bars not present on the body **8**
7a 11 vertical bars on the body reaching the lateral line but not beneath, 4 rows of Minute spot on caudal fin found in shallow clear swift stream ..... ***S. curtistigma***
8a Brownish or Brownish olive on dorsal surface **9**
8b Greyish brown on dorsal surface **10**
9a Grayish white below with a very fin lateral streak ending in a small spot at the caudal base dorsal fins with minute dots other fins pinkish found in mountain streams .....***G. gotyla***
9b Dark brown spots or bars on dorsal surface or side under surface yellowish white, Fins usually spotted found in streams and river with sandy, pebby or rocky substrate .....***M. armatus***
10a Grayish brown on back and yellowish white or yellow red below, caudal gray in the lower half, other fins **11**
10b Grayish brown in the wild state become golden, red, orange etc under domestication used in aquaculture as aquarium pet. .....***C. auratus***
11a Yellowish white below, caudal gray in the lower half, other fins light pink, found in mountain streams and lakes.....***C. diplocheilus***
11b Yellow red bellows caudal anal and pelvic fins show tint of reddish golden Colour while the body above lateral line is golden in colure in adults, fund in the stream ..... ***T. putitora***

4. Discussion

Cyprinidae family was the most prevalent fish family in the study area. Saeed et al. (2013) has reported 11 fish species from Barandu, District Buner, Pakistan which belonged to four families and three orders. The fish species were *Schistura punjabensis*, *Puntius sophore*, *Glyptothorax punjabensis*, *Channa gachua, Gara gotyla*, *Schizothorax plagiostomus*, *Crossocheilus latius*, *Tor putitora*, *Triplopysa naziri*, *Baralius pakistanicus* and *Mastacembelus armatus*. Only two species were detected in the present study that were also reported by Saeed et al. (2013) and the remaining species were not detected in both studied areas. The difference may be due to coldness and hardness of water because the fish species are very sensitive to temperature fluctuations and limnological parameters. Ishaq et al. (2014) has reported 18 species from Madyan to Chakdara in River Swat, Pakistan belonging to 5 orders and 6 families. The species were *Cyprinius carpio*, *Crossocheilus diplochilus*, *Carassius auratus*, *Barilius pakistanicus*, *Garra gotyla*, *Schizothorax esocinus*, *Orienus plagiostomus*, *Racoma labiata*, *Puntius sophore*, *Oncorhynchus mykiss*, *Mastacembelus armatus*, *Tor macrolepis*, *Glyhptothorax pujabensis*, *Schistura alepidota*, *Channa gachua*, *Triplophysa naziri*, *Glyptothorax stocki* and *Channa puntatus*. Family Cyprinidae was the most abundant family having 10 species. The similarity with the present study may be due to similar limnological and ecological parameters in both habitats. Lachner and Jenkins (1971) reported that the members of the family Cyprinidae are more sensitive to climatic conditions like drought and to ecosystem fluctuations.

The mean water temperature of the study area during January to March was lower due to flow of Dargai Stream in to Sakhakot Stream which causes a decrease in the warm water fishes in this period. About fifty species of fish fauna have been reported from River Swat during survey from 2004 to 2010 which comprised of about sixteen edible species including *Tor macrolepis*, *Carassius auratus*, *Eutropiichthys vacha*, *Channa gachua*, *Cyprinus carpio*, *Channa puntatus*, *Schizothorax plagiostomus*, *Crossocheilus diplochilus*, *Labeo diplostomus*, *Clusprisoma garua*, *Mastercembelus armatus*, *Clupisoma naziri*, *Salmo trutta fario*, *Mystus bleekeri*, *Racoma labiata* and *Oncorhynchus mykiss* (Hasan et al., 2013). The five fish species were recorded in both studies. The present study was carried out in stream which may be less diversified than the river. The *Puntius conchonius* of family Cyprinidae is a deep body fish and also known as 'bloz' species. The hardiest barbs, unchallenging and attractive; during breeding season it

shows remarkable colored bodies. They are distributed in the lakes and streams of Kashmir valley. The maximum total length recorded was 14.0 cm in males (Talwar, 1991). During the present study, the total length of the fish was recorded as 9.8 cm, the black spot on the base of the caudal peduncle was observed, it was brighter and collected from the Sakhakot Stream. The size difference may be due to the difference in limnological conditions in both studied areas. *S. plagiostomus* in an area is the symbol of diverse fish fauna. The species is found at high altitudes and mostly inhabit cold waters (Langler et al., 1977). During present study, *Schizothorax plagiostomus* was also found in Dargai Stream which was also on high altitude as compared to the other collection sites.

Fish of various sizes were captured in which the smallest was *P. conchonius* while the largest fish was *M. armatus*. *W. attu* and *M. armatus* have confluent fins while rest of fish were paired. *M. armatus* have saw like spine on the back side which may be used as an organ of defense against the predators. The biological functions and other physical and chemical parameter of aquatic life is affected by temperature, the range of temperature required for proper growth of fish in tropical water may be from 20 and 32°C (Mbalassa et al., 2014). The variation of temperature in our study may be due to different landform.

Decline in the fish populations according to Jalal et al. (2012) is mainly due to pollution (siltation, industrial wastes, agricultural run offs and domestic sewage etc.), changes in habitats due to developmental works and introduction of new species in a given area. In the present study, the population of *S. plagiostomus* was very low at Dargai Stream which may be due to introduction of carnivorous fish species from adjacent water bodies. Vass (2005) has reported that the prevalence of Mahasheer (*T. putitora*) depends on water temperature and not on the altitude. During the present study, Mahasher was captured from Sakhakot Stream which is located at low altitude. This conforms to the report of Vass (2005). The carnivorous fish species, *W. attu* (Siluridae: Siluriformes) is an important freshwater fish inhabiting lakes and streams and is commonly found in Indonesia, India, Nepal and Pakistan (Giri et al., 2002). The carnivorous species was captured at Shergarh Stream where the flow of water was slow as compared to rest of the sites. Sakhakot Stream was dominant in sand and mud while that of Shergarh and Dargai Streams were dominant by rocks and gravel. The richness of freshwater fish is lower in an area with sand or mud substrates than rocks or gravel substrates (Marquet and Mary, 1999; Haynes et al., 1989).

Migration and distribution of fish is affected by water temperature, dissolved oxygen, ammonia, pH and salinity. Kia and Mehrabi (2013) reported that the water with dissolved oxygen range between 6.68 and 8.92, temperature range of 14.3 to 22.7 °C and pH range from 7.85 to 8.16 is best for fish farms and aquaculture. The mean temperature recorded from Dargai Stream ranged from 10.9 to 18.3 °C, Sakhakot Stream ranged from 11.1 to 18.5 °C and Shergarh stream ranged from 11.3 to 18.0 °C. The difference in temperature was due to differences in altitudes of the study areas. Saeed et al. (2013) recorded pH range from 6 to 8.5 in River Barandu, Buner, Pakistan. During the present study, the pH of Dargai Stream ranged from 6.5 to 8.5 while that of Sakhakot Stream ranged from 7.1 to 8.7. The pH of Shergarh Stream was from 6.1 to 8.2. The pH range in both studies is comparable. The range of pH was high in Sakhakot Stream that may be due to anthropogenic activities in the area. De Silva et al. (2007) reported that the pH, turbidity, conductivity and dissolved oxygen are different in various sites due to variation in land pattern. This is the main causes for fish distribution and diversity. Deviation from pH range of 6.5 to 9.0 affect the organisms and may cause death of fish species (USE\PA, 1976, 1986). In the present study, the pH values recorded in all of the three sites were in the optimum range which is a key factor for the high ichthyo-diversity in the study area. Yousafzai et al. (2013) has reported that the lower portion of River Swat shared its fish fauna with River Kabul which shows more diversity compared to upper parts of River Swat. During the present study, the Sakhakot Stream showed more diversity because it shared fish fauna with Meherdi Stream. The diversity may be increased due to changes in temperature in the water bodies. The water temperature of Meherdi Stream was higher than that of Sakhakot Stream.

It has been concluded that Sakhakot Stream harbor commercially important ichthyofauna. The taxonomic key designed for the collected fish specimens, morphometric analysis and limnological evaluation will help in the rearing and enhancement of the wild stock of fish. Conservation measures should be ensured for preserving the water bodies and maintaining optimum limnological conditions. This will help in the enhancement of fisheries and aquaculture thereby ensuring the food security of the local populace.

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