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continued on the back inside cover

Cover: *Saproamanita praeclara*: Sporocarp in habitat © Kantharaja. R.

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COMMUNICATION

Freshwater fish diversity in hill streams of Saberi River in Eastern Ghats of Odisha, India

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Abstract: Freshwater fish diversity of the hill streams of Saberi River (a major tributary of the Godavari River system) in Koraput district in Eastern Ghats of southern Odisha was studied from September 2017 to August 2019. Sites for the present study were located between Gupteswar Proposed Reserve Forest (PRF) of Odisha on the eastern side, and Kanger Valley National Park of Chhattisgarh on the western side. A total of 36 species of freshwater fish belonging to 24 genera, 13 families and six orders were recorded from the study sites, of which two species are exotic. Family Cyprinidae dominated with 14 species. Species richness and diversity is greater during the pre-monsoon months followed by post-monsoon and monsoon months respectively. The physico-chemical parameters of water in the study sites during all seasons are within prescribed limits for fish culture. Among the four major types of fish habitats identified in the study sites (riffles, runs, pools and logs), pools were the most preferred, and logs the least preferred habitat for the fishes. Habitat analysis indicated that deep pools and runs are the primary habitats contributing to the maximum species diversity, and therefore, protection of these particular habitats is recommended for conservation and management of ichthyodiversity.

Keywords: Godavari, habitat analysis, ichthyofauna, Koraput district, ichthyodiversity, mountain streams, physico-chemical parameters, species diversity.

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Author contributions: SKP developed the hypotheses. SS and SKP designed the methodology. SS collected the data. SKP performed the statistical analysis. SKP and SS prepared the manuscript. Both the authors contributed critically to the draft and gave final approval for publication.

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INTRODUCTION

Freshwater ecosystems and their resources are indispensable parts of human life, and the health of freshwater ecosystems is often reflected in the structure and characteristics of the fish communities they support (Facey & Grossman 1990). Freshwater habitats in rivers, streams, springs, and headwaters are heterogeneous because of alterations in their altitude, flow rate, dissolved oxygen, physical substrate, and the riparian zones for provision of food, shade and cover (Armantrout 1990). As a result, these habitats harbour diverse fauna, with fish serving as prime indicator of ecosystem status (Karr et al. 1986). A high degree of endemism is exhibited by riverine fauna, with most endemic species living in headwater streams or short stretches of river (Groombridge 1992; Kottelat & Whitten 1997). However, these aquatic bodies are among the least studied, and possibly many species from such ecosystems still await discovery (Kottelat & Whitten 1997).

Hill streams or head waters play a very important role in shaping major rivers, both in terms of physico-chemical conditions and water resources. Streams being fluvial ecosystems play an important role in aquatic faunal diversity, especially for ichthyofauna. Streams are designated as the narrow to broad fixed route through which water flows forming a channel cutting through the ground and rocks. These are classified into the freshwater lotic (running) ecosystem with a sophisticated water flow and diverse habitats with a complex ecological asset (Anonymous 2020). They are located in all latitudes and in all climatic conditions (Singh et al. 2013).

Generally, fish habitat requirements in freshwater streams are related to a number of factors, including the population dynamics of the fish themselves, geomorphology and climate, and the flow regime. In addition, the quality and quantity of riparian and in-stream habitat is vital to fish, particularly with regard to temperature, dissolved oxygen, sediment, and pollutants. Habitat diversity influences the structure and composition of stream fish communities (Golterman 1975; Magnuson et al. 1995). More diverse habitat conditions support a greater range of species and age classes compared to simple habitats. Therefore, the habitat use by stream fish can provide an understanding of this important component of species niches, and the changes in the availability of certain structures of instream habitats. So, it is essential to link fish ecology with the variability of the physical habitat at multiple scales and to detect how the size, persistence, and arrangement of the habitats may influence the distribution of the fish (Gosselin et al. 2010). Additionally, to restore habitats effectively, it is necessary to identify the relevant habitat features and which of them are potentially limiting (Bond & Lake 2003).

India contributes to about 7.7% of global fish diversity, of which, 1,668 species are marine, and 1,027 are freshwater (Gopi et al. 2017; Froese & Pauly 2019). Studies on fish assemblage structure and their requirements in Indian streams are limited, some studies being conducted in Himalayan region (Negi & Negi 2010; Singh & Agarwal 2013; Acharjee & Barat 2014), Western Ghats (Arunachalam 2000; Johnson & Arunachalam 2010; Abraham et al. 2011) and few in Eastern Ghats (Venkateswarlu & Bakde 1986; Ramanujam 2015).

The state of Odisha contributes about 13.92% to the freshwater fish fauna of India (Dutta et al. 1993) and around 186 species of fish (Mogalekar & Canciyal 2018) have been recorded from the state. Koraput district in northern Eastern Ghats of southern Odisha is endowed with hill streams, rivers and reservoirs. Gupteswar Proposed Reserve Forest (PRF) in Koraput bordering the interstate Saberi River is a biodiversity rich region with some significant faunal discoveries in the recent past (Debata et al. 2015, 2018; Mohapatra et al. 2016; Debata & Palita 2017; Purohit et al. 2017). In the present work, an attempt has been made to study the diversity of hill stream fishes in Saberi River at Gupteswar of Koraput district of Odisha.

MATERIALS AND METHODS

Study area

Study on fish diversity was carried out in hill streams of Saberi River at Gupteswar Proposed Reserve Forest (PRF) (18.8194–18.9038 N, 82.1608–82.1791 E) of Koraput district in Northern Eastern Ghats of southern Odisha (Figure 1) from September 2017 to August 2019. Saberi is one of the main tributaries of the Godavari River system and originates from the western slope of the Eastern Ghats of Odisha from Sinkaram Hill ranges at 1,370 m (Anonymous 2016). The river Saberi (also known as Kolab River) forms a 200 km long boundary with Chhattisgarh State, with Gupteswar PRF of Odisha on the eastern side and Kanger Valley National Park of Chhattisgarh on the western side.

Gupteswar forest range falls in the eastern plateau biotic province under the Deccan peninsular biogeographic zone. The topography consists of high land plateau with hills and undulating landscape. The study area experiences a tropical climate with three distinct seasons, pre-monsoon (February–May), monsoon (June–

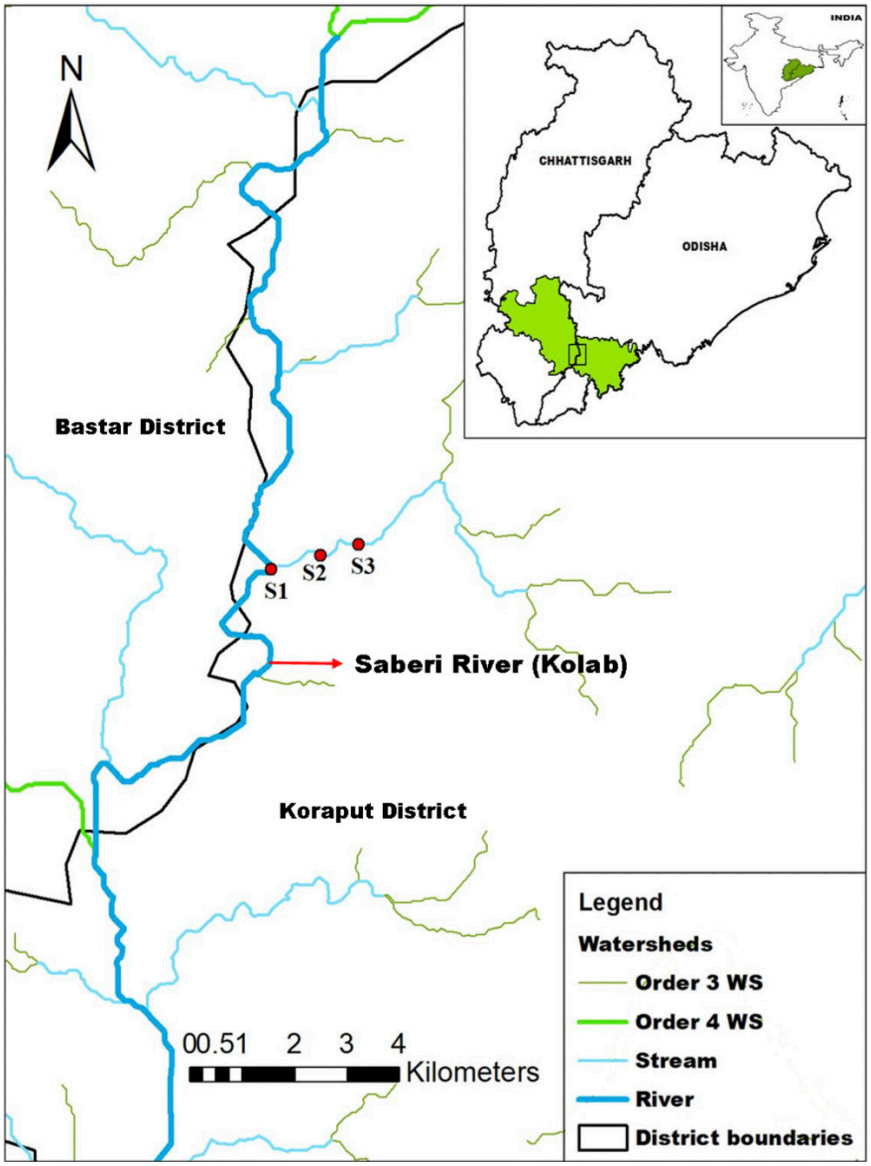

Figure 1. Map showing study sites in the Saberi River at Gupteswar, Koraput, Odisha.

September). and post-monsoon (October–January). The average annual precipitation in the region is around 1,524 mm. The vegetation of the study area at mid elevation is primarily deciduous forest. A good riparian vegetation cover including herbs, shrubs and trees is usually found in this area throughout the year.

Four major types of fish habitat were identified along the entire stretch of stream: riffles, runs, pools and logs (Image 1). These habitats were studied at three sites i.e. S_1 (18.814N – 82.166E), S_2 (18.816N – 82.174E) and S_3 (18.819N – 82.180E) located in the upper and lower stretches of hill stream of the Saberi river over a stretch of two km and with a distance of one km (approx.) from each other. The total stretch between two sites was divided into segments of 100 m length in all the streams which differed substantially in their location, elevation and geomorphology. Sampling for habitat study was done in each of these stretches. The stream bed consists of bed rock, boulders, gravels, sand and mud deposition due to organic detritus. The average stream depth varies from 0.35–0.75 m, and average stream width varies from 8–12 m with sloping stream bank. The water discharge in the river varies depending on the discharge of water from Kolab reservoir, maximum in monsoon, slowly declining through post-monsoon to pre-monsoon.

Sampling Methods

Most of the sampling was undertaken during the

morning hours (0700–1100 h) and occasional night sampling was also carried out. Fishes were collected by various fishing gears such as drag net, scoop net, gill net of varying mesh sizes, and hook and line were used for collection of fishes. Each gear was used at least five times during the entire sampling period. While catching fishes, habitats with greater width were surveyed using the drag net to scrap the benthic substratum for hidden fishes which were lured to the net when underparts of the rocks are disturbed. The scoop nets were used in habitats with narrow width for scooping out the fish. During night sampling, torches were used to attract the fishes into the scoop nets. Geographical coordinates were measured with the help of Garmin GPS (Garmin GPSMAP 64S, Kansas City, KS, USA). Fish were also collected from fishers and local villagers for creating a checklist. Photographs of fresh specimens were taken with a digital camera (Nikon P900).

Fish specimens were brought to the laboratory wrapped in cotton, soaked in 10% formalin solution and packed in polythene bag. Before identification, samples were washed in running tap water for half an hour, after which they were preserved in 70% ethanol for further study and identification. The valid nomenclature of species was adopted as per the Eschmeyer's Catalog of Fishes of the California Academy of Sciences (Fricke et al. 2021). Fishes were identified after referring to Jayaram (2010) and Nelson (2016). The current conservation status of fishes followed the IUCN Red List of Threatened Species. Lagler (1956) classified the fish species on the basis of their economic importance. On the basis of economic importance, fishes have been classified as 'commercial' (species which are prolific breeders, can be cultured and have market value), 'fine food' (having good taste and protein value), 'coarse food' (have less food value and preferred as a food by poor people), and 'aquarium fish' (can be maintained in aquarium for aesthetic and recreational value).

For physico-chemical analysis, water samples were collected between 0800–1100 h and were transported to the laboratory immediately for further analysis. Water temperature, pH, electric conductivity (EC) and total dissoved solids (TDS) was measured with multiple parameter PCS tester (TM35), while dissolved oxygen (DO) was analysed in the laboratory according to the methods suggested by APHA (2005).

Data Analysis

The following diversity indices were calculated to understand fish diversity:

Species Richness Index (Margalef's richness index as modified by Brower & Zar 1977).

$R = S\text{-}1/\ln N$

Where, S = total number of species; N = total number of individuals.

Shannon-Wiener Diversity index (Krebs 1999).

$$H' = -\sum_{i=1}^{s} pi \ln pi$$

Where, H' = Index of species diversity; S = Number of species; *pi* = Proportion of total sample belonging to i^{th} species (*ni*/N); *ni* = number of individuals of i^{th} species in the sample; N = Total number of individuals in the sample = Σni.

Evenness Index (Pielou 1966).

$J' = H' / \ln S$

Where, J' = Evenness index (range 0–1); H' = Shannon-Wiener diversity index.

Relative abundance: The commonness or rarity of a species in the hill stream in the present study was determined using relative abundance (RA) which was calculated as follows:

RA= Number of samples of particular species × 100/ Total number of samples

Statistical analyses were carried out using PAST software version 3.15 (Hammer et al. 2001) for calculating the diversity indices, and ANOVA was calculated using CropStat Vers. 7.2. (IRRI 2007).

RESULTS

Physico-chemical Parameters

Mean seasonal variations of physico-chemical parameters for a period of two years for the study sites are summarized in Table 1. Water temperature was observed in the range of 21–26.8 °C throughout the study period. Highest water temperature was recorded during pre-monsoon season (26.41±0.22 °C), followed by post-monsoon (22.19±0.15 °C), and the least was observed in monsoon season (21.63±0.28 °C). The recorded pH of water in three seasons were acidic and in the range 6.54–6.71, with maximum in monsoon (6.71±0.08) followed by post-monsoon (6.63±0.03) and pre-monsoon (6.54±0.03). Stream water was less turbid throughout the year and in the range of 171.11–221.08 ppm and below WHO standard, i.e., 1,000 mg/l. The highest TDS recorded during pre-monsoon (221.08±1.98 ppm) followed by post-monsoon (192.63±1.56 ppm), and least during monsoon (171.11±1.51 ppm). Electrical conductivity of an aqueous solution is a measure of the ability to carry out an electric current (Ram & Singh 2007). In the present study, EC varied within a range of 452.99 µS/cm to 510.85 µS/cm

Table 1. Physico-chemical parameters in hill streams of Saberi River at Gupteswar, Koraput in three different seasons (September 2017 to August 2019).

Season	Temperature (in °C)	pH	TDS (in ppm)	Conductivity (in µs/cm)	Dissolved oxygen (in mg/L)
Pre-monsoon	26.41 ± 0.22	6.54 ± 0.03	221.08 ± 1.98	510.85 ± 1.12	4.63 ± 0.25
Monsoon	21.63 ± 0.28	6.71 ± 0.08	171.11 ± 1.51	452.99 ± 1.59	5.21 ± 0.18
Post-monsoon	22.19 ± 0.15	6.63 ± 0.03	192.63 ± 1.56	495.98 ± 1.34	6.65 ± 0.24
SE (N = 04)	0.07	0.009	0.36	0.83	0.06
5% LSD	0.23	0.03	1.25	2.89	0.20

SE—Standard Error | LSD—Least Significant Difference.

Image 1. Microhabitats recorded at the study sites of Saberi River at Gupteswar, Koraput, Odisha: a—Riffle | b—Run | c—Pool | d—Log. © Supriya Surachita.

and this may be due to greater ionic concentration of the inlet flow (Jha & Barat 2003). Electrical conductivity varied among seasons, with maximum in pre-monsoon (510.85±1.12 µS/cm), followed by post-monsoon (495.98±1.34 µS/cm) and least by monsoon (452.99±1.59 µS/cm). Dissolved oxygen (DO) is the most essential parameter which can be used as an index of water quality, primary production and pollution. DO values also varied among seasons with highest during post-monsoon (6.65±0.24 mg/l), followed by monsoon (5.21±0.18 mg/l) and minimum values were recorded during pre-monsoon (4.63±0.25 mg/l). All five parameters (water temperature, water pH, turbidity, electrical conductivity and dissolved oxygen) showed variations among seasons that were statistically significant ($p<0.05$) (Table 1). The seasonal study showed that species richness and diversity is high in pre monsoon followed by post monsoon and monsoon respectively. The physico-chemical parameters during all seasons are within the tolerance limits of class 'D' water prescribed (I.S.I. 1982) for fish culture and wildlife propagation. However, growing anthropogenic activities can significantly affect the freshwater fish fauna unless

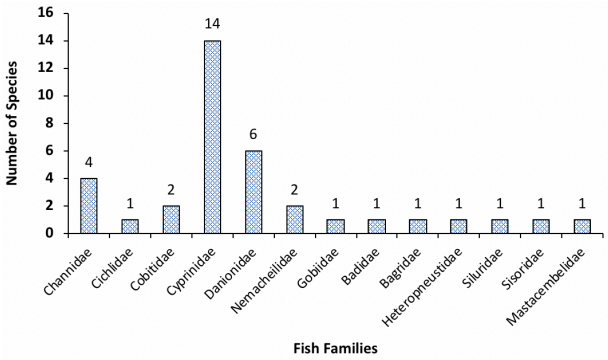

Figure 2. Family-wise fish species richness at study sites in Saberi River at Gupteswar, Koraput, Odisha.

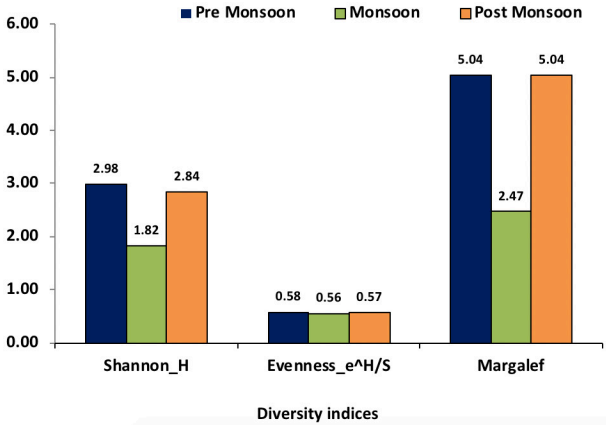

Figure 3. Seasonal fish species diversity at different study sites in Saberi River at Gupteswar, Koraput, Odisha.

conservation measures are adopted urgently.

Species Richness

During the study period a total of 36 species of fish belonging to 24 genera and 13 families and six orders were recorded. Family Cyprinidae dominated with 14 species, followed by Danionidae (six species), Channidae (four species), Cobitidae and Nemacheilidae (two species each) and Cichlidae, Gobidae, Badidae, Bagridae, Heteropneustidae, Siluridae, Sisoridae and Mastacembalidae (one species each) (Figure 2). Maximum species richness was observed in the order Cypriniformes (with 24 species under 16 genera and four families).

Among the species recorded, two species (*Cyprinus carpio* and *Oreochromis mossambicus*) are exotic, one species (*Wallago attu*) was assessed as Vulnerable (VU) and one species (*Bagarius bagarius*) as Near Threatened (NT) in the IUCN Red List. The presence of two exotic species (*C. carpio* and *O. mossambicus*), may pose potential threats to the native species and may cause loss of ecosystem function, habitat disruption, reduction of genetic diversity of native species in future.

Twenty-eight species were assessed as Least Concern (LC) (Table 2).

The site-wise relative abundance (RA) of all the species in different seasons is shown in Table 3. Maximum relative abundance (RA) value (68.18%) was recorded in case of *Devario aequipinnatus* in monsoon from Site S_3. All the major carps were recorded from Site S_1. Among the five major carps, *Labeo rohita* had the highest RA values in all the three seasons (50.0% in monsoon, 38.6% in post-monsoon and 31.25% in pre-monsoon), followed by *Labeo catla*. Next to carps, *Pethia conchonius* showed higher RA in monsoon and post monsoon seasons, and were recorded from sites S_2 and S_3. The RA of *W. attu* at site S_1 during monsoon was 12.50%. The two exotic species *Cyprinus carpio* and *Oreochromis mossambicus* had greater RA i.e. 13.13% and 5.00% respectively at site S_1 during pre-monsoon. The RA of *Bagarius bagarius was* 3.13% which was restricted to site S_1 during pre-monsoon. *Systomus sarana* was found only at site S_2 during all seasons. The RA of *S. sarana* was highest during monsoon (3.70%) followed by post-monsoon (1.16%) and pre-monsoon (0.87%) respectively. *Danio dangila* was only accessible at site S_3 during pre-monsoon and post monsoon with an RA of 2.59% and 2.33%, respectively.

Diversity indices

Higher species diversity in terms of fish species was observed in pre-monsoon with the Shannon–Wiener index value of H′ = 2.98, followed by post-monsoon with H′ = 2.84, and monsoon with H′ = 1.82 respectively. Maximum species richness was observed during pre-monsoon, followed by post-monsoon and monsoon respectively, and ANOVA analysis also indicates that species richness showed significant difference during pre-monsoon in comparison to post-monsoon and monsoon ($p < 0.05$) (Table 4). Similarly, evenness was also highest during pre-monsoon, followed by post-monsoon and monsoon, respectively (Figure 3). Mean abundance of fishes also showed a similar trend, maximum value in pre-monsoon followed by post-monsoon and monsoon it was statistically significant ($p < 0.05$).

Among the three sites studied, species richness was significantly higher ($p < 0.05$) at site S_2 in comparison to sites S_1 and S_3. Though species richness was higher at site S_1 compared to S_3, it was not statistically significant. Mean abundance also showed a similar pattern to species richness among sites (Table 4).

Habitat preference of fish

Four major types of fish habitat were identified at the

Table 2. Checklist of fishes recorded from hill streams of Saberi River at Gupteswar, Koraput, Odisha with their IUCN status and economic importance.

Name of the species	Common name	IUCN Red List status	Economic importance				
			Commercial	Fine food	Coarse food	Aquarium fish	Others
Order- Anabantiformes							
Family- Channidae							
Channa marulius (Hamilton, 1822)	Great Snakehead	LC	+			+	PF, LV
Channa gachua (Hamilton, 1822)	Dwarf Snakehead	LC	+			+	
Channa punctata (Bloch, 1793)	Spotted Snakehead	LC	+	+		+	Bt
Channa striata (Bloch, 1793)	Striped Snakehead	LC	+	+		+	PF, LV
Family- Badidae							
Badis sp.	-	-				+	
Order- Cichiliformes							
Family- Cichlidae							
Oreochromis mossambicus (Peters, 1852)	Mozambique Tilapia	Non-native / Invasive	+	+		+	GF
Order- Cypriniformes							
Family- Cobitidae							
Lepidocephalichthys guntea (Hamilton, 1822)	Guntea Loach	LC				+	
Lepidocephalichthys thermalis (Valenciennes, 1846)	Common Spiny Loach	LC				+	
Family- Cyprinidae							
Cirrhinus mrigala (Hamilton, 1822)	Mrigal Carp	LC	+	+			
Cirrhinus reba (Hamilton, 1822)	Reba Carp	LC		+			
Cyprinus carpio (Linnaeus, 1758)	Common Carp	Non-native / Invasive	+				GF
Garra mullya (Sykes, 1839)	Sucker Fish	LC				+	
Labeo catla (Hamilton, 1822)	Catla	LC	+	+			
Labeo calbasu (Hamilton, 1822)	Orangefin Labeo	LC		+			
Labeo rohita (Hamilton, 1822)	Rohu	LC	+	+			
Parapsilorhynchus sp.	-	-			+		
Pethia conchonius (Hamilton, 1822)	Rosy Barb	LC			+	+	
Pethia ticto (Hamilton, 1822)	Ticto Barb	LC			+	+	
Puntius chola (Hamilton, 1822)	Chola Barb	LC	+		+	+	
Puntius sophore (Hamilton, 1822)	Swamp Barb	LC			+	+	
Systomus sarana (Hamilton, 1822)	Olive Barb	LC	+			+	GF
Tor sp.	-	-	+				GF
Family- Danionidae							
Barilius vagra (Hamilton, 1822)	Vagra Baril	LC			+		
Danio dangila (Hamilton, 1822)	Moustached Danio	LC				+	
Danio rerio (Hamilton, 1822)	Zebra Fish	LC				+	
Devario aequipinnatus (McClelland, 1839)	Giant Danio	LC				+	
Opsarius bendelisis (Hamilton, 1807)	Hamilton's Barila	LC	+				
Rasbora daniconius (Hamilton, 1822)	Slender Rasbora	LC	+		+	+	
Family- Nemacheilidae							
Schistura denisoni (Day, 1867)	Sand Loach	LC				+	
Schistura sp.	-	-				+	

Name of the species	Common name	IUCN Red List status	Economic importance				
			Commercial	Fine food	Coarse food	Aquarium fish	Others
Order- Gobiiformes							
Family- Gobiidae							
Glossogobius giuris (Hamilton, 1822)	Tank Goby	LC	+	+		+	
Order- Siluriformes							
Family- Bagridae							
Mystus tengara (Hamilton, 1822)	Stripped Dwarf Catfish	LC			+		
Family- Heteropneustidae							
Heteropneustes fossilis (Bloch, 1794)	Stinging Catfish	LC		+			PF
Family- Siluridae							
Wallago attu (Bloch & Schneider, 1801)	Helicopter Catfish	VU	+	+			GF,PF
Family- Sisoridae							
Bagarius bagarius (Hamilton, 1822)	Dwarf Goonch	NT	+				GF
Order- Synbranchiformes							
Family- Mastacembelidae							
Mastacembelus armatus (Lacepède, 1800)	Zig-zag Eel	LC	+			+	

+—present | VU—Vulnerable | NT—Near Threatened | LC—Least Concern | GF—Game Fish | PF—Predatory Food Fish | LV—Larvivorous Fish | Bt—Bait.

study sites, i.e., riffles, runs, pools and logs, among which pools were the most preferred habitat, and logs the least preferred habitat for fish. All snakeheads were recorded from the three habitats (riffle, pool, and log) except runs, because they tend to avoid fast flowing waters. Among the snakeheads, *C. marulius* was only found in pool habitat, whereas *C. gachua* was found both in riffles and logs, but absent in pool. *C. punctata* and *C. striata* were observed in riffles, pools and logs. The invasive alien species, *O. mossambicus*, was found both in riffle and pool, but mostly in weedy pools. Two species of cobitid loaches (*L. guntea* and *L. thermalis*) preferred pools with substrate composed of soft mud. Among five major carps, three (*L. calbasu, L. catla* and *L. rohita*) were found in only riffles whereas other two (*C. mrigala* and the non-native *C. carpio*) were only found in pools. One minor carp (*C. reba*) was only recorded in logs. Among the six barbs recorded from the study site, *P. ticto* was only found in runs whereas *P. conchonius* and *S. sarana* were found both in runs and logs, whereas *P. chola*, *P. sophore*, and *Tor* sp. were found in both runs and pools. This suggests that all barbs were found in runs. *Garra mullya* was recorded in riffle and runs, whereas *Parapsilorhynchus* sp. was only found in pools. Among the six minnows recorded from the study sites, *D. dangila* was only found in logs whereas *B. vagra*, *D. aequipinnatus* and *R. daniconius* were found in both riffles and runs. Zebra fish, *D. rerio* was observed in runs as well as pools while Hamilton's Barilla, *O. bendelensis* was recorded in riffles, runs and pools. *Schistura* sp. was observed both in riffles and pools. Goby (*G. giuris*) and freshwater eel (*M. armatus*) were found in runs and riffles respectively. *Badis* sp. was found in both pools and logs. Stinging Catfish, *H. fossilis* and Helicopter Catfish, *W. attu* were recorded both in runs and pools. Striped Dwarf Catfish, *M. tengara* and Dwarf Goonch, *B. bagarius* preferred pool as their habitat.

Economic Importance

Among the fish species recorded from hill streams of Saberi at Gupteswar, 12 species (30% of species recorded) – *Bagarius bagarius, Channa marulius, C. punctata, Mastacembelus armatus, Opsarius bendelisis, Oreochromis mossambicus, Puntius chola, Rasbora daniconius, Systomus sarana, Tor* sp. and *Wallago attu* are commercial fishes. Among the recorded species, 18 species (50% of the species recoded) are ornamental fishes such as *Badis* sp., snakeheads (*C. marulius, C. gachua, C. punctata*, and *C. striata*), minnows (*D. dangila, D. rerio, D. aequipinnatus*, and *R. daniconius*), *Garra mullya, Glossogobius giuris,* loaches *(L. guntea, L. thermalis*), *Mastacembelus armatus , Oreochromis mossambicus,* barbs (*P. conchonius, P. ticto, P. chola, P. sophore*, and *S. sarana*), and sand loaches (*S. denisoni* and *Schistura* sp.*).* These species are preferred for aquariums due to their

Table 3. Relative abundance of fish species at three sites of Saberi River at Gupteswar, Koraput, Odisha during different seasons, and microhabitat preference of fish species.

Scientific names	Relative abundance (%)									Microhabitat			
	Pre-monsoon			Monsoon			Post-monsoon						
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	Riffle	Run	Pool	Log
Order- Anabantiformes													
Family- Channidae													
Channa marulius	-	0.87	-	-	-	-	-	-	-	-	-	+	-
Channa gachua	-	0.58	-	-	-	-	-	1.16	-	+	-	-	+
Channa punctata	-	8.12	-	-	-	-	-	9.25	-	+	-	+	+
Channa striata	-	5.22	-	-	-	-	-	2.89	-	+	-	+	+
Family- Badidae													
Badis sp.	-	11.01	21.24	-	-	-	-	4.05	5.81	-	-	+	+
Order- Cichiliformes **Family- Cichlidae**													
Oreochromis mossambicus	5	3.19	-	-	-	-	-	2.31	-	+	-	+	-
Order- Cypriniformes **Family- Cobitidae**													
Lepidocephalichthys guntea	-	5.22	-	-	-	-	-	3.47	-	-	-	+	-
Lepidocephalichthys thermalis	-	0.58	-	-	-	-	3.51	1.16	1.16	-	-	+	-
Family- Cyprinidae													
Cirrhinus mrigala	5	-	-	-	-	-	1.75	-	-	-	-	+	-
Cirrhinus reba	13.13	1.16	-	-	-	-	7.02	0.58	-	-	-		+
Cyprinus carpio	13.13	-	-	-	-	-	7.02	-	-	-	-	+	-
Garra mullya	0.63	0.29	-	-	-	-	1.75	1.16	-	+	+	-	-
Labeo catla	18.75	-	-	12.5	-	-	29.8	-	-	+	-	-	-
Labeo calbasu	4.38	-	-	12.5	-	-	10.5	-	-	+	-	-	-
Labeo rohita	31.25	-	-	50	-	-	38.6	-	-	+	-	-	-
Parapsilorhynchus sp.	-	-	-	-	-	-	-	1.16	-	-	-	+	-
Pethia conchonius	-	19.71	4.66	-	44.44	9.09	-	24.28	1.16	-	+		+
Pethia ticto	-	0.58	-	-	-	-	-	2.31	2.33	-	+		-
Puntius chola	-	5.8	-	-	-	-	-	4.05	-	-	+	+	-
Puntius sophore	-	1.16	-	-	-	-	-	2.89	-	-	+	+	-
Systomus sarana	-	0.87	-	-	3.7	-	-	1.16	-	-	+		+
Tor sp.	1.88	-	-	12.5	-	-	-	-	-	-	+	+	-
Family- Danionidae													
Barilius vagra	-	3.48	-	-	7.41	-	-	2.31	-	+	+	-	-
Danio dangila	-	-	2.59	-	-	-	-	-		-	-	-	+
Danio rerio	-	-	20.21	-	-	22.73	-	-		-	+	+	-
Devario aequipinnatus	-	-	35.75	-	22.22	68.18	-	-		+	+		-
Opsarius bendelisis	-	1.45	-	-	-	-	-	-	-	+	+	+	-
Rasbora daniconius	-	4.35	6.74	-	-	-	-	1.73	2.33	+	+	-	-
Family- Nemacheilidae													
Schistura denisoni	-	17.97	8.81	-	22.22	-	-	26.01	-	+	-	+	-
Schitura sp.	-	-	-	-	-	-	-	1.16	-	+	-	+	-
Order- Gobiiformes **Family- Gobiidae**													
Glossogobius giuris	-	4.64	-	-	-	-	-	4.62	-	-	-	-	-

Scientific names	Relative abundance (%)									Microhabitat			
	Pre-monsoon			Monsoon			Post-monsoon						
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	Riffle	Run	Pool	Log
Order- Siluriformes Family- Bagridae													
Mystus tengara	1.88	-	-	-	-	-	-	-	-	-	-	+	-
Family- Heteropneustidae													
Heteropneustes fossilis	-	2.32	-	-	-	-	-	0.58		-	-	+	-
Family- Siluridae													
Wallago attu	1.88	-	-	12.5	-	-	-	-	-	-	+	+	-
Family- Sisoridae													
Bagarius bagarius	3.13	-	-	-	-	-	-	-		-	-	+	-
Order- Synbranchiformes Family- Mastacembelidae													
Mastacembelus armatus	-	1.45	-	-	-	-	-	1.73		+	-	-	-

very attractive colour and beautiful banding patterns. The species of *Channa*, *Mastacembelus*, *Heteropneustes* have air breathing organs so it fetches good market value as live fish, as well. In the same way, eight species, namely, *Channa marulius, Oreochromis mossambicus, Cyprinus carpio, Labeo catla, L. rohita, Systomus sarana, Tor* sp., and *Bagarius bagarius* are categorized as game fishes (Froese & Pauly 2019).

Devario aequipinnatus is abundant while *Channa marulius* and *Mystus tengara* were less abundant in the study area during the study period. Though commercially important species are available in the study region, they are not sufficiently abundant to make fishery commercial and economical. Conservation measures such as afforestation in catchment and awareness of illegal fishing and killing of brood fishes and juveniles are required steps in the region. The present study of fish fauna in Gupteswar showed that most of the fish species recorded were widely distributed in the streams and rivers of Eastern Ghats.

Gupteswar being a place of pilgrimage, there is a large tourist footfall. It has been observed in the study sites that people use waterbodies for various purposes like bathing, garbage disposal and religious activities. Activities like construction of roads, building amenities for tourists have also increased in the study sites over the years.

Table 4. Freshwater fish species richness and abundance in hill streams of Saberi River at Gupteswar, Koraput, Odisha across seasons and among study sites.

Season	No. of samples	Species richness (Mean±SD)	Species abundance (Mean±SD)
Pre-monsoon	12	10 ± 4.95	58.17 ± 24.3
Monsoon	12	1.58 ± 0.9	4.75 ± 3.86
Post-monsoon	12	6.17± 3.93	26.33 ± 15.1
SE (N = 12)	-	0.81	3.31
5%LSD	-	2.33	9.58
Site			
S1	12	5.0± 3.72	18.75± 18.17
S2	12	9.17 ± 6.52	45.42± 35.56
S3	12	3.58± 2.19	25.08 ± 19.77
SE (N = 12)	-	0.81	3.31
5% LSD	-	2.33	9.58

SE—Standard Error | LSD—Least Significant Difference.

DISCUSSION

The record of 36 fish species within 24 genera and 13 families and six orders in the present study from hill streams of Saberi at Gupteswar is the first report from Koraput District of Eastern Ghats. Among the four habitats in hill streams documented as part of the present study, pool is the most preferred, followed by riffle, and log the least preferred habitat. Pool is a segment of the stream with reduced current velocity and suspended organic detritus, with depths exceeding other surrounding habitats, usable by fish for resting and covers (Armantrout 1998); thereby is the most preferred habitat than others. Habitat diversity influences the structure and composition of stream fish communities (Golterman 1975; Magnuson et al. 1998). Most fish in small, stable streams are most probably habitat specialists that have evolved various morphological and behavioural adaptations to exploit

specific habitat types (Magnuson et al. 1998). Many tropical stream fish specialize in habitat use and exhibit morphological segregation, with a close relationship between morphological and ecological characteristics. As a result, these ecomorphological specializations may serve to facilitate resource partitioning (Deacon & Mize 1997).

The Satpura hypothesis proposed by Hora (1949) suggests that the central Indian Satpura range of hills acted as a bridge for the gradual migrations of Malayan fauna into the peninsula and the Western Ghats of India. Menon (1951) carried out extensive surveys along Odisha hills (the part lying above Godavari River) and Eastern Ghats to understand if the Malayan elements were present in the fish or not. He collected 93 fish and critically analysed and concluded that the fish fauna of Odisha hills and Eastern Ghats have a very close affinity with that of Satpura-Vindhya mountains and the northern division of the Western Ghats and that there is a conspicuous absence of forms common to the fish fauna of Malayan region and peninsular India (Hora 1944). Dutta et al. (1993) collected 28 species of fish from the undivided Koraput district. Of this, only three species have been recorded from present Koraput district, and the remaining 25 species are from the current-day Nawrangpur District. In view of this, the present record of 36 species from hill streams of Saberi at Gupteswar is the first report from this region. The diversity recorded in the present study will be useful as baseline data for any future assessment though no detail study has been carried out in hill streams of Koraput. Most importantly, our study indicates considerable share in supporting fish biodiversity in the region despite alterations like anthropogenic activities including illegal fishing and habitat degradations.

The threat of exotic species on the indigenous fish species in the present study site was relatively low, but it is cause of concern for future. Sarkar et al. (2010) found that the higher relative abundance and distribution of exotic species indicate threat to the other local species due to their establishment in the River. This may cause difficulty to manage other species of conservation importance in the River, and may become more challenging due to the interaction of climatic changes (Rahel et al. 2008).

CONCLUSION

The different microhabitats in hill streams are home to diverse biotic communities which are threatened by major anthropogenic pressures. Though Gupteswar is a pilgrimage site, high anthropogenic pressure in the form of developmental activities result in quick deterioration of water quality, thereby posing threats to aquatic biodiversity, especially fish fauna. In addition, climate change has also become one of the greatest threats to aquatic systems in the study site. Natural modifications like temperature rise and irregular rainfall also have substantial effects on the stream morphology and hydrology. Assessing biodiversity vulnerability to future clime change is essential for developing conservation strategies in this region. Illegal fishing by locals should be strictly banned. The record of 36 species of freshwater fish in the present study highlights the importance of hill streams as critical fish habitats. Further, our habitat study shows that deep pools and runs are the primary habitats contributing to the maximum diversity of fish species, and therefore protection of these particular habitats is recommended for conservation and management of the region's fish biodiversity.

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