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Taxonomic Check List of Ichthyofaunal Diversity at Hiramandalam Reservoir, Srikakulam Dt. Andhra Pradesh, India

Gunta Laxminarayana [a++], K. Rama Rao [b*] and M. Ratnakala [c]

[a] Department of Zoology, AU TDR- HUB, Andhra University, Visakhapatnam, Andhra Pradesh, India.
[b] Department of Zoology / Fisheries, Dr. V. S. Krishna Govt. Degree and PG College (A), Visakhapatnam, India.
[c] Department of Zoology, Andhra University, Visakhapatnam, Andhra Pradesh, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The ichthyofaunal investigation revealed that the occurrence of 59 fish species belonging to 11 orders, 23 families, and 39 genera observed Feb 2022 to Jan 2023 at Hiramandalam Reservoir. These fish were transferred to the lab, fixed in glass jars, and then preserved in a 9-10% formalin solution. The fish were identified based on morphometric traits, meristic counts, and descriptive attributes. The fish were identified to the species level using keys for Indian subcontinent fishes. Five of the 59 species are alien. Order cypriniformes was dominant with 24 species which contributed to 40.67% of the total species followed by Siluriformes 12 (20.33%), Anabantiformes 6 (10.16%), Cichliformes with 4 (6.77%), Synbranchiformes 3 (5.08), Anguilliformes. Beloiniformes, Gobiiformes, and Perciformes each with 02 (3.38%), Osteoglossiforme and Cyprinodontiformes each with 1 (1.69%). Recorded families out of 23, Siluriformes 06 (26.08%), Cypriniformes 05

[++] Research Scholar;
**Corresponding author: Email: drkarriramarao@gmail.com;*

(21.23%), Anabantiformes 3 (13.04%), Beloiniformes 2 (8.69%), Osteoglossiformes, Cyprinodontiformes, Anguilliformes, Gobiiformies, Synbranchiformes, Cichliformes, and Perciformes each 01 (4.34%). The taxonomic trophic levels in the current study were classified as omnivores have a highest percentage of 29 (49.15%), followed by the carnivorous 18 (30.50%), and the herbivorous 11 (19.64%). The population Status is highest with common which contributed to 45.76%, 25.42% were rare, abundant which contributed to 19.64% and moderate which contributed to 10.16% in the total taxa. The composition of trophic levels, IUCN status and Shannon - Wiener Diversity Index and a detailed taxonomic account of these species is documented in this paper

Keywords: Ichthyofauna; trophic level; herbivorous; omnivorous; carnivorous; IUCN; shannon - wiener diversity index.

1. INTRODUCTION

The nation also has more than 10% of the world's fish species and is one of 17 mega-biodiversity hotspots.1074 freshwater fish have been documented from the Indian subcontinent (NFDB). Indian reservoirs are located in tropical regions with rapid nutrient turnover, promoting biogenic productivity. Reservoir productivity was poor (average: 49.9, medium: 12.3, and large: 11.4 kg ha¡1yr¡1) compared to projected yields of 100, 75, and 50 kg ha¡1yr¡1 [1]. Taxonomy is commonly defined as the study and method for defining, identifying, and categorizing living things. It makes simple to identify the types of species in order to gain an understanding of the current situation and develop essential steps for preserving biodiversity. Such research is critical for a thorough knowledge of biodiversity and its preservation. Fish biodiversity supports a variety of ecological functions, including as water filtering, preventing erosion, and the storage of carbon. Protecting populations of fish and habitats helps to preserve these amenities, which benefit both humans and the natural world. The wide range of fish populations provides to the adaptability and long-term viability of aquatic environments. A large variety of fish species found in various aquatic settings across the world, from freshwater rivers and lakes to enormous oceans, demonstrate the tremendous diversity of this group of animals. Multiple causes endanger global biodiversity, including anthropogenic intervention, climate change, and invasive alien species [2]. Predators are often larger than their prey, hence the trophic level should grow with body size. Trophic ecology will increase our knowledge and forecasts of food web structure and dynamics. Fish's different ecological strategies, trophic level, and food web patterns and processes should not be extrapolated based just on body size [3]. The dead storage at Hiramandalam Reservoir is being used to provide potable water to 800 settlements in Uddanam. Artisanal fishing refers to a wide range of small-scale, low-tech, and low-cost fishing practices. Endemic species are key components of a country's natural history and have worldwide relevance. As a result, places with considerable populations and/or biologically significant indigenous, are good candidates for species conservation and the protection of environments of unique ecological or scientific importance [4]. Aquaculture, sport fishing, malaria prevention, decorative purposes, research, national fair demonstrations, and accidental introductions are the primary causes for their introduction [5]. The present study intends to provide up-to-date information on the fish species that live in this reservoir. The investigation aims to update the taxonomic variety of fish species in Hiramandalam Reservoir, including locals, endemics, exotics, and transferred species. It also provides information on distribution and protection status.

2. MATERIALS AND METHODS

2.1 Study Area

The Hiramandalam Reservoir is around 45 kilometers from Srikakulam District, which is located 18.6783° N, 83.9463° E in Andhra Pradesh's extreme northeast area. The Vamsadhara River begins in Orissa's Eastern Ghats and runs through Srikakulam District, before joining the Gulf of Bengal at Kalingapatnam. The Hiramandalam reservoir, with a storage capacity of 19 TMC was finished. There is now just 2.5 TMC of dead storage and 5 TMC of natural runoff from catchment areas. Hiramandalam Reservoir might be utilized as the bottom reservoir of a 10,000 MW pumped storage hydroelectric facility in the future to address the region's ongoing renewable and green electricity demands (Fig. 1&2).

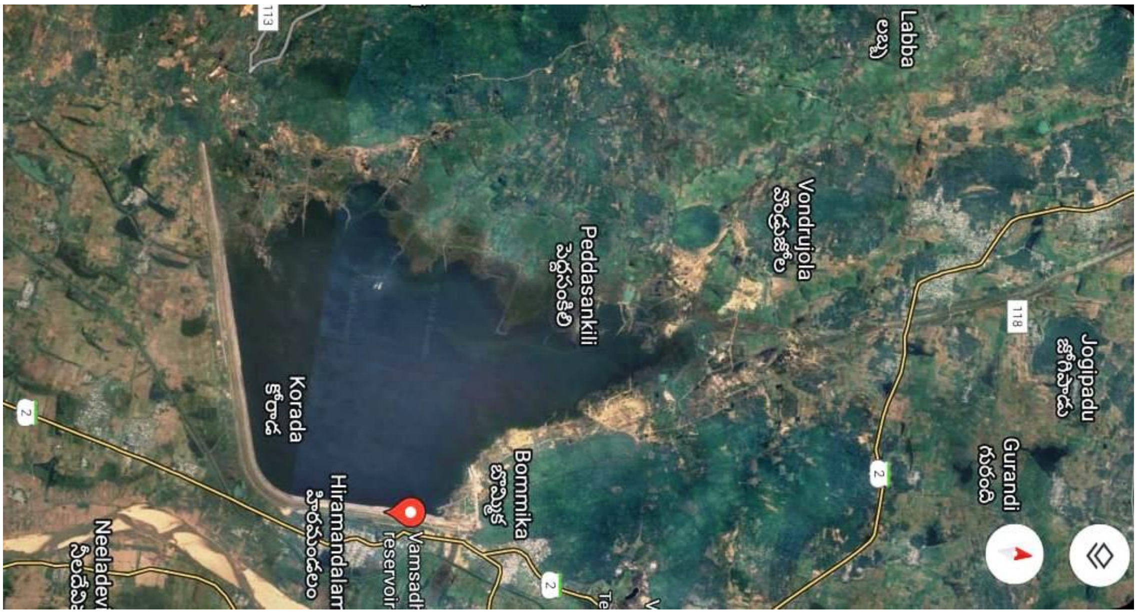


Fig. 1. Hiramandalam Reservoir (Google courtesy)

Fig. 2. Hiramandalam Reservoir outlet and Uddanam freshwater supply pipe line

2.2 Sample Collection

"The fish were collected from several stations with the assistance of local fishermen using various types of gear (Drag nets, Push nets, Cast nets, Stationary gill nets) and Bamboo traps [6]. Freshly collected fish were carefully cleansed and photographed. These fish were taken to the lab and fixed in glass jars before being preserved in a 9-10% formalin solution" [7]. "The fish were identified using morphometric features, meristic counts, and descriptive characteristics. Morphometric characters include measurable characteristics such as total body length, standard body length, length and depth of the head, diameter of the eye, length of the snout, maximum and minimum girth, length of dorsal fin, depth of dorsal fin, depth of anal fin, length of pectoral fin, length of ventral fin, distance between pectoral and ventral fins, length of caudal fin. Meristic features include dorsal fin rays, pectoral fin rays, ventral fin rays, anal fin rays, caudal fin rays, lateral line scales, lateral line transverse scales, and other such characteristics. Descriptive traits include body profile and form, skin texture and coloring, location and shape of the mouth, lips, and snout, barbels and jaws, scales and lateral line system, origin, shape, size, and nature of median, paired, and caudal fins, and unique markings. The fishes were recognized to the species level using keys for Indian subcontinent fishes. The species were identified primarily based on morphometric and meristematic characteristics" [8,7,9,10,11]. The IUCN conservation status of the fish species has been listed [12].

Biodiversity: The statistical calculation on biodiversity of fish taxa was studied using the formula of Shannon Weaver diversity index [13] which is calculated as follows.

2.3 Statistical Analysis

The mathematical expression of Shannon - Wiener Diversity Index as

Shannon - Wiener diversity index

Shannon-Wiener index denoted by H = - SUM [(p_i) × ln(p_i)]

SUM = summation
p_i = proportion of total sample represented by species *i* Divide no. of individuals of species *i* by total number of samples
S = number of species, = species richness
H_{max} = ln(S) Maximum diversity possible
E = Evenness = H/H_{max}

3. RESULTS AND DISCUSSION

The results of the present investigation revealed that the occurrence of 59 fish species belonging to 11 orders, 23 families, and 39 genera observed Feb 2022 to Jan 2023. Out of 59 species five are exotic species (* indicates). In the current study, a list of taxa were compiled, including their order, family, genus, species, population status, trophic level and IUCN status. In the current investigation the listed taxa and percentage composition of families, genera and species under different orders are shown in Table 1. Rama Rao [14] reported 49 fish species from 12 orders, 19 families, and 33 genera in Gotta Barrage at Hiramandalam. Sridhar [15] reported 26 species in Gottabarrage reservoir, belonged to the orders Cypriniformes, newline Siluriformes, Perciformes, Synbranchiformes, Osteoglossiformes and Anguilliformes. Priyanka et al. [16] studied of ichthyofaunal diversity shows occurrence of rich ichthyofaunal diversity, witha total of 40 fish species belonging to 29 genera, 15 families, and 9 orders in Siddheshwar reservoir. The similar results were found at various reservoirs in this region. Rama Rao [17] recorded 57 fish species belong to seven orders, 18 families and 34 genera were reported including four are exotic species at Kalingadal reservoir. The taxa of Ichthyofaunal diversity were more in the present study.

Table 1. Check list taxa of Ichthyofauna at Hiramandalam Reservoir

No.	Order / Family	Scientific Name	Trophic level	Population Status	IUCN Status
I	**Osteoglossiformes/**				
1	Notopteridae	*Notopterus notopterus*	3.5	C	LC
II	**Cypriniformes/**				
2	Cyprinidae	*Labeo catla*	2.8	A	LC
3		*Labeo calbasu*	2.0	C	LC
4		*Labeo dyocheilus*	-	R	LC
5		*Labeo rohita*	2.2	A	LC
6		*Cirrhinus mrigala*	2.4	A	LC
7		*Cirrhinus reba*	2.5	C	LC
8*		*Cyprinus carpio*	3.1	M	VU
9		*Garra gotyla*	2.0	R	LC
10		*Gymnostomus ariza*	2.7	C	LC
11*		*Hypopthalmicthys molitrix*	2.0	R	NT
12		*Osteobrama cotio*	2.9	C	LC
13		*Puntius chola*	2.5	A	LC
14		*Puntius ticto*	2.2	A	LC
15		*Systomus sarana*	2.9	C	LC
16		*Puntius sophore*	2.6	A	LC
17	Danionidae	*Rasbora daniconius*	3.1	C	LC
18		*Salmostoma bacaila*	3.2	C	LC
19		*Salmostoma phulo*	3.2	C	LC
20		*Amblypharyngodon microlepis*	3.3	A	LC
21		*Amblypharyngodon mola*	3.3	A	LC
22		*Danio devario*	3.0	C	LC
23	Cobitidae	*Lepidocephalichthys guntea*	2.7	R	LC

No.	Order / Family	Scientific Name	Trophic level	Population Status	IUCN Status
24	Nemacheilidae	*Nemacheilus corica*	2.8	R	LC
25*	Xenocyprididae	*Ctenopharyngodon idella*	2.0	C	LC
III	**Cyprinodontiformes/**				
26	Aplocheiidae	*Aplocheilus panchax*	3.8	C	LC
IV	**Siluriformes/**				
27	Bagridae	*Mystus bleekeri*	3.3	C	LC
28		*Mystus cavasius*	3.4	C	LC
29		*Mystus gulio*	4.0	R	LC
30		*Mystus tengara*	3.2	A	LC
31		*Mystus vittatus*	3.1	A	LC
32	Siluridae	*Ompok bimaculatus*	3.9	C	NT
33		*Ompok pabda*	3.8	C	NT
34		*Wallago attu*	3.7	C	NT
35	Schibeidae	*Eutropiichthys vacha*	3.9	C	LC
36	Claridae	*Clarias batrachus*	3.4	C	LC
37	Heteropneustidae	*Heteropneustes fossilis*	3.6	C	LC
38	Pangasiidae	*Pangasius pangasius*	3.4	R	LC
V	**Anguilliformes/**				
39	Anguillidae	*Anguilla bengalensis*	3.8	R	LC
40		*Anguilla bicolor bicolor*	3.6	R	NE
VI	**Beloiniformes/**				
41	Belonidae	*Xenentodon cancila*	3.9	R	LC
42	Exocoetidae	*Hyporhamphus limbatus*	3.1	R	LC
VII	**Anabantiformes**				
43	Anabantidae	*Anabas testudineus*	3.0	M	DD
44	Channidae	*Channa orientalis*	3.8	C	NE
45		*Channa marulius*	4.5	R	LC
46		*Channa panctata*	3.8	A	LC
47		*Channa striatus*	3.6	C	LC
48	Osphronemidae	*Trichogaster fasciata*	2.8	M	LC
VII	**Gobiiformies/**				
49	Gobiidae	*Glossogobius giuris*	3.7	C	LC
50		*Gobiopsis macrostoma*	3.8	R	LC
VIII	**Synbranchiformes /**				
51	Mastacembelidae	*Macrognathus aral*	3.1	R	LC
52		*Mastacembelus armatus*	2.8	C	LC
53		*Macrognathus pancalus*	3.5	C	LC
IX	**Cichliformes/**				
54*	Cichlidae	*Oreochromis mossambicus*	2.2	M	NT
55*		*Oreochromis niloticus*	2.4	R	NT
56		*Etroplus suratensis*	2.9	M	LC
57		*Pseudetroplus maculatus*	2.7	M	LC
X	**Perciformes /**				
58	Ambassidae	*Chanda nama*	3.9	C	LC
59		*Parambassis ranga*	3.6	C	LC

A= Abundant (76-100%); C = Common (51-75%); M = Moderate (26-50%); R = Rare (1-25%) of the total catch.
EN- Endangered; VU- Vulnerable: LC- Least concern; DD- Data deficient; NE- Not evaluated, NT: Near threaten.
**Exotic fishes No.s: 8, 11, 25, 54 and 55*

Order cypriniformes was dominant with 24 species which contributed to 40.67% of the total species followed by Siluriformes 12 (20.33%), Anabantiformes 6 (10.16%), Cichliformes with 4 (6.77%), Synbranchiformes 3 (5.08), Anguilliformes. Beloiniformes, Gobiiformes, and Perciformes each with 02 (3.38%), Osteoglossiforme and Cyprinodontiformes each with 1 (1.69%). Recorded genera out of 39, Cypiniformies dominant with 15 (38.46%), followed by Siluriformes contributed 7 (17.94%), Anabantiformes and Cichliformes each with 3 (7.69%), Beloiniformes, Gobiiformies and Perciformes each with 2 (5.12%). Recorded families out of 23, Siluriformes 06 (26.08%), Cypriniformes 05 (21.23%), Anabantiformes 3 (13.04%), Beloiniformes 2 (8.69%), Osteoglossiformes, Cyprinodontiformes, Anguilliformes, Gobiiformies, Synbranchiformes, Cichliformes, and Perciformes each 01 (4.34%) Table 2, Fig 3. Priyanka et al. [16] reported to Cypriniformes dominated with 18 species, followed by the orders Siluriformes with 8, Channiformes with 4, Preciformes with 3, Clupeiformes and Mastcembeliformes with 2, and the rest of the orders Angulliformes, Beloniformes, and Mugiliformes with a single species. The homogeneous percentage of Order Cypriniformes was contributed to 42.86% of the total species observed in Narayana puram anicut at Nagavali River [18], Rama Rao [19].

The taxonomic trophic levels in the current study are classified as herbivorous (2.0-2.5), omnivore (2.5-3.5), and carnivorous (3.5-4.5) based on their trophic level. The omnivores have a highest percentage of 29 (49.15%), followed by the carnivorous 18 (30.50%), and the herbivorous 11 (19.64%) (Tab. 3, Fig. 4). A similar study was observed by Rama Rao [14] reported the highest number of omnivores (51.02%, followed by carnivores (26.53% and herbivores (18.36%) in Gotta Barrage at Hiramandalam. The trophic level community structure of recorded fish species demonstrated the dominance of top-level carnivores (39%), followed by mid-level carnivores (28%), predators (17%), omnivores (14%), and herbivores or planktivores (2%), according to Haojie Su [20]. The majority of the finfish species identified during this investigation were found to meet human protein requirements.

Table 2. Taxonomic percentage composition under various orders

S.No	Orders	% of families in an order	% of genera in an order	% of species in an order
1	Osteoglossiformes	4.34	2.56	1.69
2	Cypriniformes	21.23	38.46	40.67
3	Cyprinodontiformes	4.34	2.56	1.69
4	Siluriformes	26.08	17.94	20.33
5	Anguilliformes	4.34	2.56	3.38
6	Beloiniformes	8.69	5.12	3.38
7	Anabantiformes	13.04	7.69	10.16
8	Gobiiformies	4.34	5.12	3.38
9	Synbranchiformes	4.34	5.12	5.08
10	Cichliformes	4.34	7.69	6.77
11	Perciformes	4.34	5.12	3.38

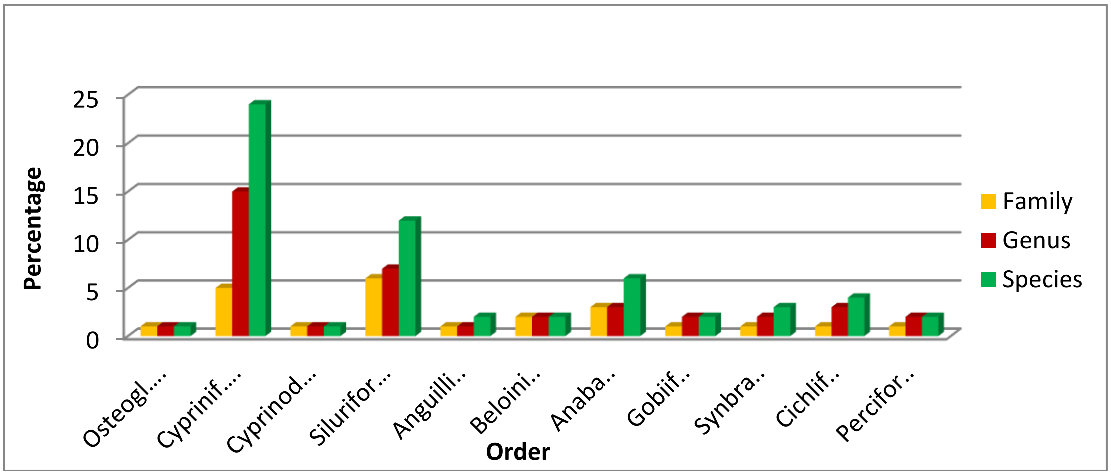


Fig. 3. Taxonomic composition

In the present investigation the number and percentage composition of Population Status is 27 species were common which contributed to 45.76%, followed by 15 species were rare which contributed to 25.42%, 11 species were abundant which contributed to 19.64% and 06 species are moderate which contributed to 10.16% in the total taxa (Table 4, Fig. 5). The similar results were reported by Rama Rao [14] 25 species were common which contributed to 51.02%, 12 species were abundant which contributed to 24.48%, 7 species are moderate which contributed to 14.28% and 5 species were moderate which contributed to 10.20% in the total catch. According to IUCN status 49 species contributed to 83.05% are least concern (LC), six species contributed to 10.16% are near threaten (NT), 2 species were not evaluated (NE) with 3.38%, one species contributed to 01.69% are vulnerable (VU) and data deficient (DD) Table 4, Fig 6. The similar study was reported by Priyanka et al. [16] represents the IUCN red list categories, 52.5% of the species are least concern, 20% are not evaluated, 10% are near threatened, 5 % are data deficient, 5% are lower risk near threatened and vulnerable, and2.5% are lower risk least concern [21].

In the current investigation, Shannon-Wiener diversity indices of fish taxa in Hiramandalam reservoir the richness was highest (54) in October 2022 and lowest (43) in Jan 2023 (Table 5, Fig 7). The diversity index (H) ranged from 1.85 (Feb) to 2.62 (Oct) in 2022–23. The maximum diversity possible ln(S) highest was recorded (3.93) in September 2022, and the lowest (3.76) in January 2023. The fish taxa diversity evenness (E) lowest was recorded in Feb 2022 (0.48), and the highest was 0.64 in Sep 2022 (Fig 8). These results indicated that the Hiramandalam reservoir has a good diversity index in terms of fish taxa. Rama Rao and Ramachandra Rao [18] reported the diversity indices, indicated by the abundance of fish species, were highest in September and lowest in April and May. The diversity (H) varied from 0.91 to 1.57 at Narayana Puram, Anicut. Srinivas Kumar and Rajendar [22] reported the Shannon-Wiener Index (H), which ranged from 1.24 to 1.84. The maximum diversity was recorded in the

Table 3. Taxonomic trophic level of fish species at Hiramandalam Reservoir

Trophic level	Herbivorous (2.0–2.5)	Omnivorous (2.6–3.5)	Carnivorous (3.6–4.50	Data Deficient
Number of species	11	29	18	1
% Composition	19.64	49.15	30.50	1.69

Table 4. Taxonomic composition of population status and IUCN (2024)

Population Status	Abundant (76-100%)	Common (51-75%)	Moderate (26-50%)	Rare (1-25%)	-
Number of species	11	27	06	15	-
% Composition	19.64	45.76	10.16	25.42	-
IUCN (2024)	VU	NT	LC	DD	NE
No. of species	1	06	49	1	2
% contribution	1.69	10.16	83.05	1.69	3.38

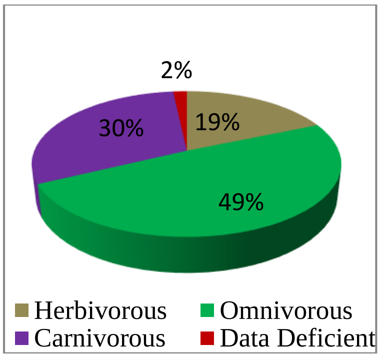


Fig. 4. Trophic level

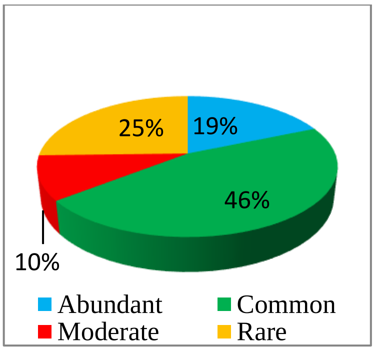


Fig. 5. Population status

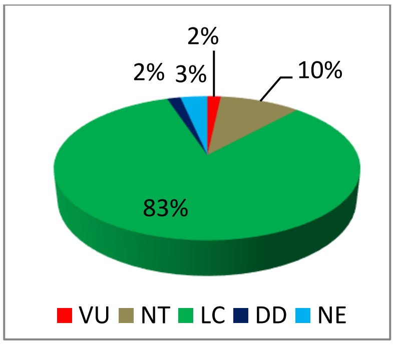


Fig. 6. IUCN (2024)

months of July and August 2019, with the lowest recorded in January and February 2020. Evenness was reported to be highest in January 2020 and lowest in May 2019. These results indicate a good diversity index in the Kinnerasani reservoir. Rama Rao [19] examined a comparable diversity measure, which represents the highest possible diversity (ln(S) ranged from 2.37 to 4.03). Fish species diversity evenness (E) ranges from 0.58 to 0.88 at Lower Manair Dam, Karimnagar District. The similar investigation Shannon Weiner index by Naik et al. [23] on ichthyofaunal diversity assessment was at its peak in monsoon, coinciding with the favourable monsoon conditions such as sufficient water and ample food resources in the upper Mullamari reservoir, Karnataka [24,25,26].

Table 5. Shannon - Wiener diversity index of Ichthyofaunal taxonomy from 2022 to 2023

Diversity index	Feb 2022	Mar 2022	Apr 2022	May 2022	Jun-2022	Jul 2022	Aug 2022	Sep 2022	Oct 2022	Nov 2022	Dec 2022	Jan-2023
Species richness	45	45	47	47	45	48	48	51	54	52	48	43
H	1.85	2.02	2.23	2.42	2.39	2.46	2.39	2.55	2.62	2.48	2.37	2.12
ln(S)	3.80	3.80	3.85	3.85	3.80	3.87	3.87	3.93	3.98	3.95	3.87	3.76
Evenness (E)	0.48	0..53	0.57	0.62	0.62	0.62	0.61	0.64	0.65	0.62	0.61	0.56

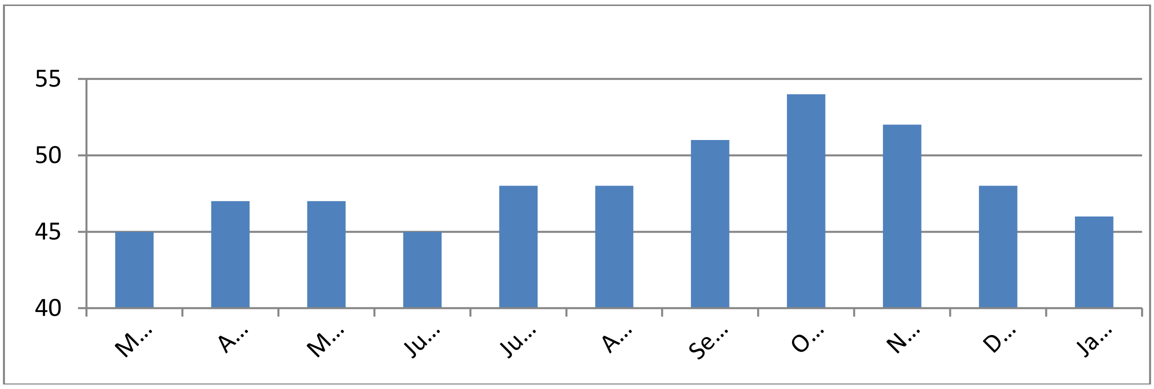


Fig. 7. Taxa richness

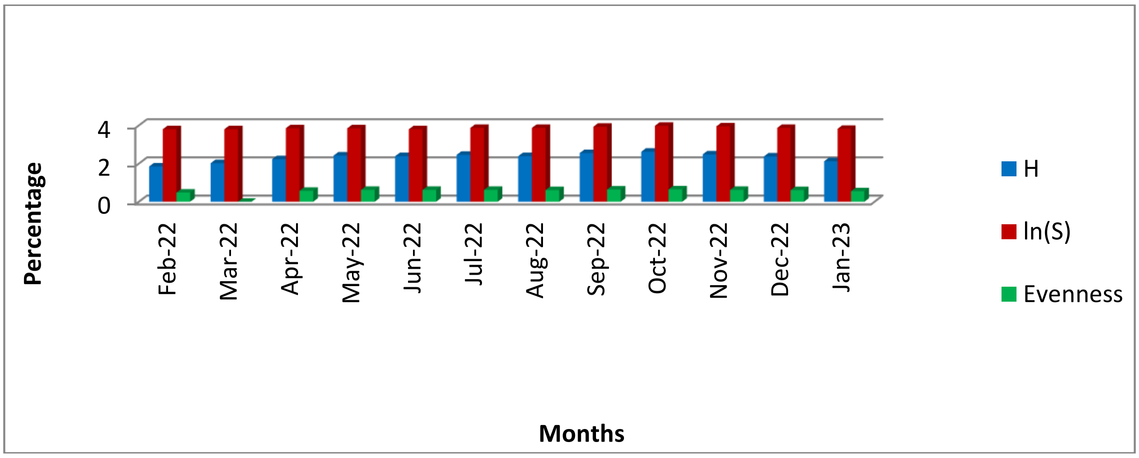
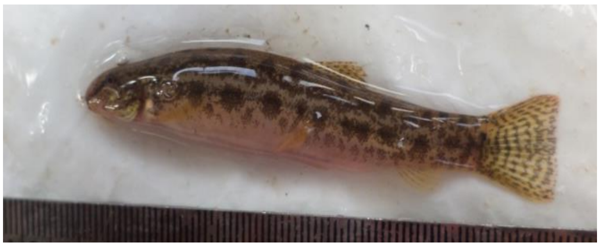


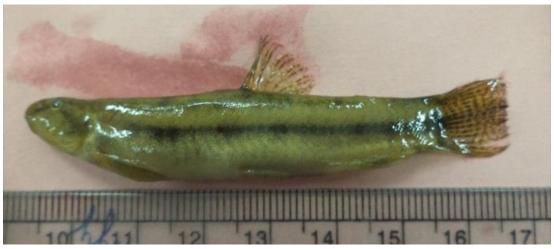
Fig. 8. Taxa diversity, In S and Evenes

Labeo dyocheilus

Hypopthalmicthys molitrix

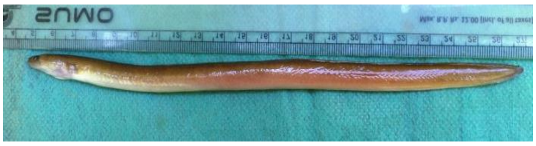


Lepidocephalichthys guntea



Nemacheilus corica

Anguilla bengalensis



Anguilla bicolor bicolor

Xenentodon cancila

Hyporhamphus limbatus

Mystus gulio

Pangasius pangasius

Channa marulius

Macrognathus aral

Gobiopsis macrostoma

Oreochromis niloticus

List 1. List of rare fish species in Hiramandalam Reservoir

4. CONCLUSION

The current study focuses on the ichthyofaunal diversity of Hiramandalam Reservoir, which is home to a broad range of freshwater fish, indicating a healthy ecology. Identify the struggle against ghost fishing and prioritize prevention and removal. The preventative method involves the loss or disposal of fishing gear. The study suggested that fisheries development authorities make guidance and provide knowledge to cooperative societies for reservoir fisheries development, fish fauna conservation, sustainable use of aquatic resources, and improving the socioeconomic status of local fishermen.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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