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Fish Species Distribution and Diversity Indices of Hemavathi Reservoir, Hassan, Karnataka

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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 total number of fish species recorded was 42, spanning 25 genera, 13 families, and 5 orders. Cypriniformes were the predominant, accounting for 40.4% of the total, subsequent to Siluriformes (18.8%) and Perciformes (15.4%). The Cyprinidae family was the most common, representing 42.9% of the species. The most prevalent species was *Oreochromis niloticus*, particularly prevalent at Station 1, where it accounted for 68.31% of the total harvest. The diverse and abundant species population, especially at Station 2 in September, was indicated by Margalef's Richness Index

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values, which ranged from 2.00 to 3.20 toward the conclusion of the study period. At Station 3 in August 2022 the highest diversity had been observed, with the Shannon-Wiener Diversity Index (H') ranging from 2.75 to 3.12. The dominance of specific species across stations was indicated by the Simpson index (λ), which fluctuated between 0.92 and 0.97. In July 2022, the Evenness Index (J') values were at their lowest, ranging from 0.87 to 0.96, which was attributed to environmental stresses. Overall, the research suggests that the distribution of fish species is highly variable, with seasonal fluctuations impacting the species richness as well as evenness. This variability reflects the hydrological and geographical factors that have influenced the aquatic ecosystem.

Keywords: Fish species diversity; Oreochromis niloticus; richness index; evenness index.

1. INTRODUCTION

Biodiversity is evident at every level of biological organization, extending from individual cells to entire ecosystems. The terrestrial, marine, and freshwater environments, incorporate the immense variety of living organisms, that inhabit them. The ecological balance, which is essential for the sustainable development and survival of all living things, including people, is maintained by rich biodiversity [1]. Biodiversity, or biological resources, supplies food, loading, medicine, clothes, as well as spiritual nourishment to humanity [2].

Freshwater habitats, constituting merely 0.01% of the Earth's surface water, are vital for 10% of all species, encompassing 55% of fish. Aquatic biodiversity includes the diversity of life within freshwater habitats, such as lakes, rivers, and wetlands, as well as marine settings, including oceans, estuaries, along with coral reefs. This diversity encompasses all organisms, from phytoplankton and aquatic plants to fish, birds, and mammals, as well as their habitats and interactions [3,4]. Many factors, like as industrial pollution, rising acidification, and agricultural runoff containing pesticide or fertilizer residues, pose a threat to freshwater habitats. Furthermore, numerous river habitats are destroyed by the construction of dams. However, in recent times, it has been shown to be fast declining as a result of environmental deterioration brought on by urbanization, damming, water abstraction for irrigation as well as power generation, and pollution. Freshwater fish diversity is under extreme stress as a result of this environmental stress [5,6]. The preservation of biodiversity is a potent method for maintaining clean water as well as ecological health.

Fish species fulfill a significant role as measures of ecological health since their numbers and state of well-being reflect the overall status of water systems [7]. In recent decades, the state's fish biodiversity has been rapidly diminishing because of several anthropogenic activities, including unsustainable fishing practices, destruction of the habitat, fragmentation, the non-native species introduction, and changes in the environment such as decreased volume of water, elevated sedimentation, pollution, as well as extraction of water [8].

Reservoirs are man-made structures created by building a dam across a river, diverting its flow to store water in a controlled manner. As a transitional area between lotic and lentic ecosystems, reservoirs are highly significant water bodies from an ecological, economic, and recreational standpoint [9]. Reservoirs have characteristics of both terrestrial and aquatic ecosystems; serve as ecotones, and transition between several environments.

India has vast reservoir resources, covering 3.42million ha (19,386 numbers). To ensure the sustainable exploitation of resources, scientific management systems must be developed [10,11]. Fish species diversity typically declines as a result of the impoundment, even if the reservoir's fish variety essentially reflects the parent river system's fauna. On the other hand, Indian reservoirs protect a comparatively wide range of fish species [12]. In India, big reservoirs typically support 60 different species of fish, at least 40 of which are important for commercial fisheries [13]. Fish variety in a reservoir at a given time, according to Sugunan [12], is the outcome of some natural and man-made alterations to the original fauna of the parent river. Numerous research studies have documented the detrimental impacts of impoundments on fish populations, specifically on fish migration in India [14,12,15].

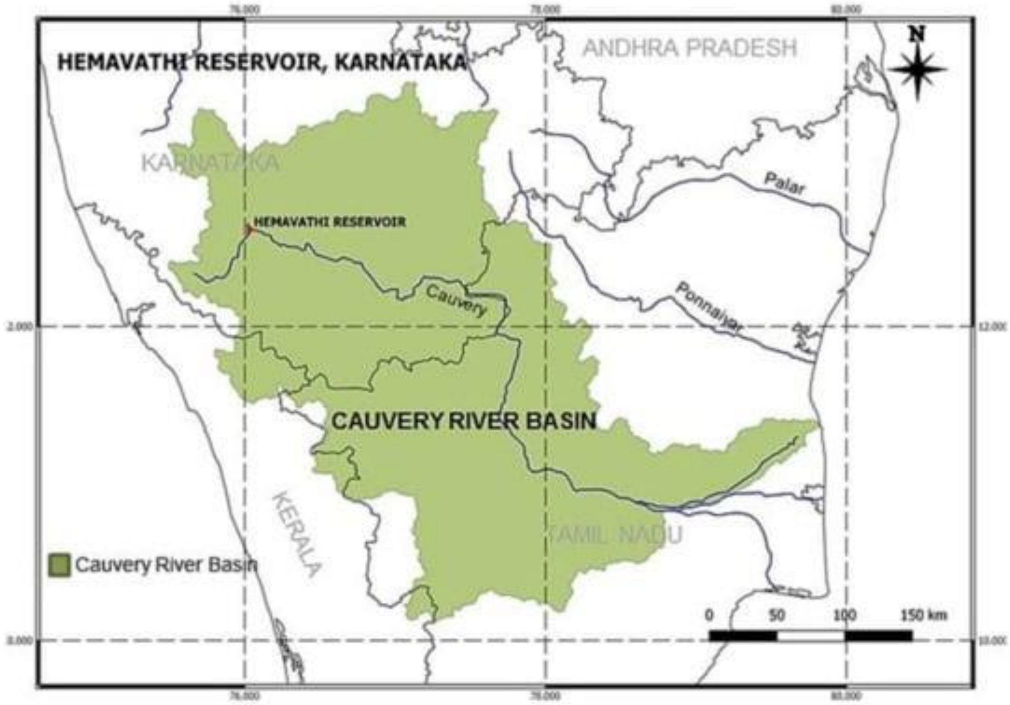

Fig. 1. Location of hemavathi reservoir in the upper cauvery basin: blue line denotes the river network

The Hemavati River, which begins in the Western Ghats at Ballala Rayana Durga in Chikkamagalur District, plays a vital role as a water source for the southern districts of Karnataka, including Mandya, Mysore, Hassan, and Tumkur. The river traverses Chikkamagalur, Hassan, Mandya, and Mysore districts, spanning around 245 kilometersbefore merging with the Kaveri River near Krishnarajasagara. The river has a catchment area of approximately 5,410 square kilometers and begins at a height of around 1,219 meters [16].

The investigation emphasizes the Hemavathi reservoir's potential concerning fish community and biodiversity for conservation, stock enhancement, and management challenges, and recommends the development of innovative strategies to sustain fish biodiversity in rivers as well as reservoirs. Therefore, this research was performed to examine the diversity profile of the Hemavathi reservoir in Karnataka.

2. MATERIALS AND METHODS

The Hemavathi Reservoir is located in the Hassan district of Karnataka, India. The Hemavathi Dam on Hemavathi River, a tributary of the Kaveri River in Karnataka, has generated this substantial water body. Hemavathi dam is situated at Latitude 12º 45’0” North and Longitude 76º03’0” East. It is 44.5 meters in height and 4692 meters long. The reservoir water spread submerges an area of 8502ha (21008 acres).

2.1 Site Selection

Hemavati Reservoir is divided into five sites for the study. Site 1 (S1), the Inlet Zone, is located near the main inflow where upstream water enters the reservoir. Site 2 (S2), the Central Zone, the central area of the reservoir; Site 3 (S3), the Outlet Zone, near the primary outflow where water exits towards downstream areas; Site 4 (S4), the Littoral Zone, along the shoreline; and Site 5 (S5), the Deep Water Zone. For a period of 17 months, from May 2022 to October 2023, this research had been performed. Water, fish samples, and plankton were collected monthly from each site for study purposes.

2.2 Fish Sampling

Fishes were sampled monthly in each sampling site using specially designed multi mesh sized gill nets having a total length of 180 m, consisting of 20, 30, 50, 60, 70, and 90 mm mesh sizes with a length of about 30 m each. The fishing net was operated in the dusk hours of the day at each sampling station and hauled the net in the next morning. The fish samples were collected, segregated, as well as preserved in “10% formalin." The specimens had been transported to the laboratory for identification.

2.3 Taxonomic Study

Fish identification was based on both fresh and preserved fish. Fish specimens collected had been recognized to species level utilizing standard references, Fish Base, http://fishbase.org by Pauly along with Froese, [17]. These provided the comprehensive taxonomic information required for accurate identification and classification [17], ITIS (Integrated Taxonomic Information System) Standard Report (http://www.itis.gov).

2.4 Data Analysis

Diversity indices of the ichthyofauna were computed with the “Shannon-Weiner” and “Pielou's evenness indices." In view of the high variability of individual sizes among fish species, these indices were expressed in terms of biomass rather than the number of individuals. All values were subjected to square root transformation before analysis to standardize the data. “The PRIMER-E analytical package developed by Plymouth Marine Laboratory, U.K." [18,19] was used in this study for computing the diversity indices. Bio-Diversity Pro statistical analysis software was used. These tools enabled detailed statistical analysis to compare species diversity and evenness among different sample stations and times of sampling, allowing for a perfect understanding of the ichthyofaunal biodiversity of Hemavathi Reservoir [20].

2.5 Univariate Analysis

Measurement of Biodiversity (Indices): The following indices were calculated so that inferences can be drawn from data collected regarding distribution and abundance.

(a) Richness index: It is taken to be the total of unique species designating the community or sample richness. This metric simply measures biodiversity by counting the unique species number identified within a sample or specified region.

i. Margalef's index: The Margalef's index was employed to compute species diversity for each of the samples, considering both the species richness along with the overall plenty of individuals. The overall number of different species (indicated as S) as well as the overall number of individuals (indicated as N) for each sample were recorded.

$$“R = \frac{S-1}{\ln{(n)}}”$$

Where,

“R= Margalef's species richness Index”,
“S= Total number of species in the sample”
“n= Total number of individuals in the sample”.

(b) Diversity indices

i. Simpson index

The biodiversity measurement was developed using the Simpson index, which determines the possibility that two randomly chosen individuals from a sample belong to different species.

$$“\lambda = \frac{\sum_{i=1}^{R} n_i(n_i-1)}{N\,(N-1)}”$$

Here,

“λ= Simpson index”
“n_i= Number of individuals in the ‘i^{th}’ species”
“N = total no. of individuals”
“S = total number of species”

ii. Shannon-Weiner index.

The Shannon-Wiener index integrates the species’ diversity and their distribution, yielding a more precise assessment of biodiversity within a community.

Where,

“H'= Shannon-Wiener index”
"p_i= proportion of the individual of the species in the total sample”
R = “total number of species”

(c) Evenness Index

i Pielou evenness indices (J’)

It measures the evenness of distribution in a community.

$$E_1(J') = \frac{H'}{In\ (S)}$$

Here,

H'=Shannon-Wiener index
S=Total number of species

2.6 Data Matrix

Biomass values of the ichthyofaunal species were used in representing the data matrix, whereas each row represented a different location or time point, and columns were correspondingly individual species.

2.7 Data Transformation

The data had been subjected to square root transformation prior to the examination of diversity indices, similarity, and cluster analysis. The adjustment was implemented on the biomass data of ichthyofaunal species to stabilize variance as well as minimize the impact of highly skewed data. By converting the original biomass values into their square root equivalents, the analysis ensured a more balanced data distribution and improved the accuracy of the multivariate techniques [21,22].

3. RESULTS AND DISCUSSION

During the investigation, 42 fish species from 25 genera, 13 families, as well as 5 orders had been documented. The bulk of capture belonged to the order Cypriniformes, comprising 40.4% of the entire fish species identified, followed by Perciformes (15.4%), Siluriformes (18.8%), and Synbranchiformes (3.8%) (Fig. 2). Cyprinidaehadbeenthe most prevalent family, accounting for 42.9% of the entirespeciesnumber, subsequently Bagridae (6.8%), Cichlidae (6.8%), and Siluridae (4.6%), with the other families contributing less than 2% each (Fig. 3). *Oreochromis niloticus* was the most common species found at all five sample sites, accounting for 22% of the total catch. Station one contained the largest percentage of *Oreochromis niloticus*, totalling 68.31% of the total capture from that station. Other prominent species were *Catlacatla* (5.5%), *Cyprinus carpio* (4.9%), and *Labeofimbriatus*(4.2%), along with *Puntius sahyadriensis*, *Chanda nama*, *Osteobrama cotiocunma*, *Hypselobarbus kolus, Puntius sophore*, and *Chanda nama* from different stations (Figs. 4 to 8). Fish species distribution varies substantially owing to hydrological and geographical conditions.

Margalef's Richness Index values varied from 2.00 to 3.20 across the study period at all stations. The highest value of 3.25 was recorded in September at Station 2, followed by Station 5 (3.22), Station 1 (3.20), Station 4 (3.18), and Station 3 (3.10) in September, October, August, and October, respectively. This implies a diversified species population at the conclusion of the research period. Margalef's species richness varied significantly by season (Tables 1-5). The consistent rise in species richness at these sites shows that better circumstances or seasonal variables aided in the spread of a wider variety of species.

The Shannon-Wiener Diversity Index (H') exhibited variation among months. The Shannon-Wiener index (H') (at log 10) varied among 2.75 and 3.12 in all stations (Tables 1–5). The highest value of 3.12 was observed in August 2022, suggesting the existence of a very diversified and well-distributed species population at station 3, followed by station 1 and station 3, which had values of 3.11 in August 2022 and August 2023. The Simpson index (λ) varied between 0.92 and 0.97. The average value reported across all stations was 0.93. (Tables 1–5).

The Evenness Index (J') varied from 0.87 to 0.96 throughout the different sample sites, with the highest evenness recorded at Stations 1 and 3 in August 2023 (Tables 1-5). The lowest number of 0.87, recorded in July 2022, shows that species were more common during this time, perhaps due to natural factors such as higher temperatures or the effects of the rainy season.

The total fish diversity identified in the study was 42 species, in which the order Cypriniformes was shown to be the most numerous, followed by Osteoglossiformes, Synbranchiformes, Perciformes, Siluriformes, and Beloniformes. *Oreochromis niloticus* was the most frequent species, providing the biggest percentage of the total capture along that *Cyprinuscarpio, Catlacatla, Puntius sahyadriensis, Labeofimbriatus, Chanda nama, Osteobramacotiocunma, Puntius sophore, Hypselobarbuskolus,* and *Chanda nama* was recorded. Similarly, Sreenivasan and Mahesh, [23] reported 58 species reported from the Cauvery Wildlife Sanctuary in the Western Ghats of Karnataka. Nayaka [24] documented 11 fish species in the freshwater of Kallambella Tank in

Tumkur District. According to Jain [25], Cypriniformes (23) have the most species, followed by Siluriformes (15), Perciformes (8), and Clupeiformes (4). Siddiqui et al. [26] also discovered that Cypriniformes has the most species, with 13, followed by Siluriformes with 6, Mastacembeliformes with 2, Clupeiformes with one, and Beloniformes with one species.

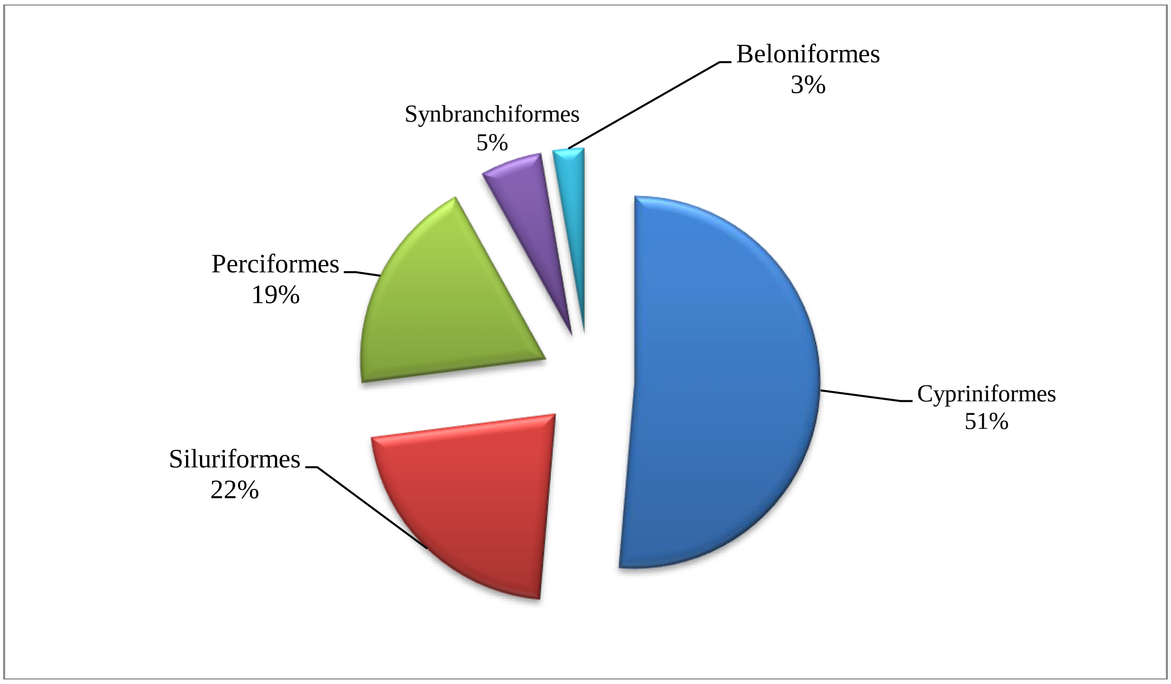

Fig. 2. Diagrammatic representation of the % number contribution of each order

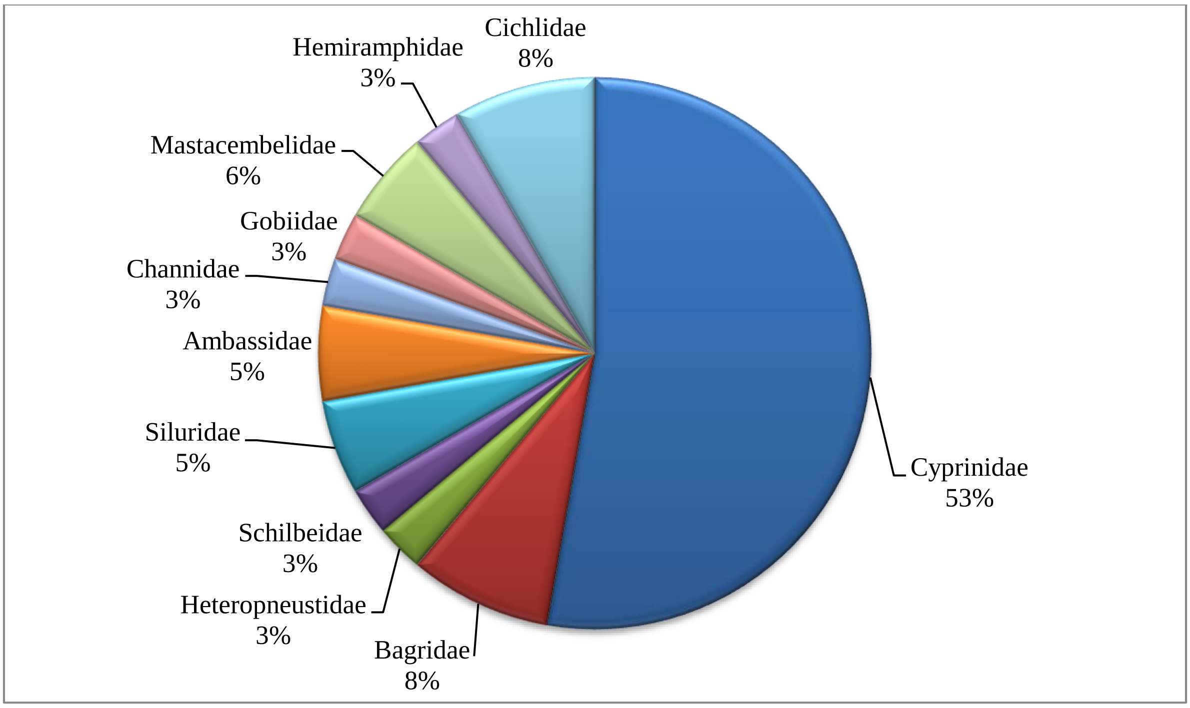

Fig. 3. Diagrammatic representation of the % number contribution of each family

In the present study, to characterize species abundance within the community diversity indices have been employed. Diverse indicators are employed in marine ecology to delineate these relationships. The Shannon-Wiener Index (H') showed temporal fluctuations across different months, with values (log10) ranging from 2.75 to 3.12. Throughout the research period, the Margalef's Richness Index varied from 2.00 to 3.20 across all stations. Similar to research done at Chulkinala Reservoir, Margalef's Richness Index (d) varied from 6.90 to 7.24, while the H' fluctuated from 1.398 and 1.492. Pielou's Evenness Index (J') varied from 0.898-0.918, while Simpson's Index of Dominance (1-Lambda') varied from 0.947-0.960 across several seasons [27]. The Shannon-Wiener Diversity Index in Anjanapura Reservoir varied from 2.4-3.0 [28]. The Simpson's Index of Diversity (1-D) ranged from 0 to 1, whereas the Simpson's Dominance Index values varied from 0.08 to 0.2.

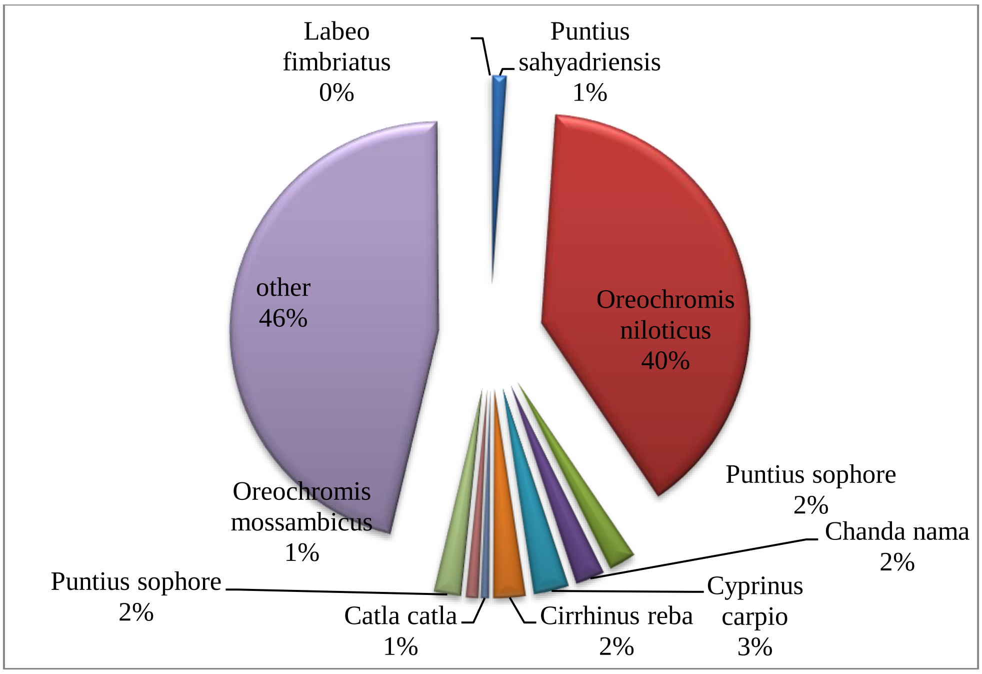

Fig. 4. Diagrammatic representation of the % number contribution at Station 1

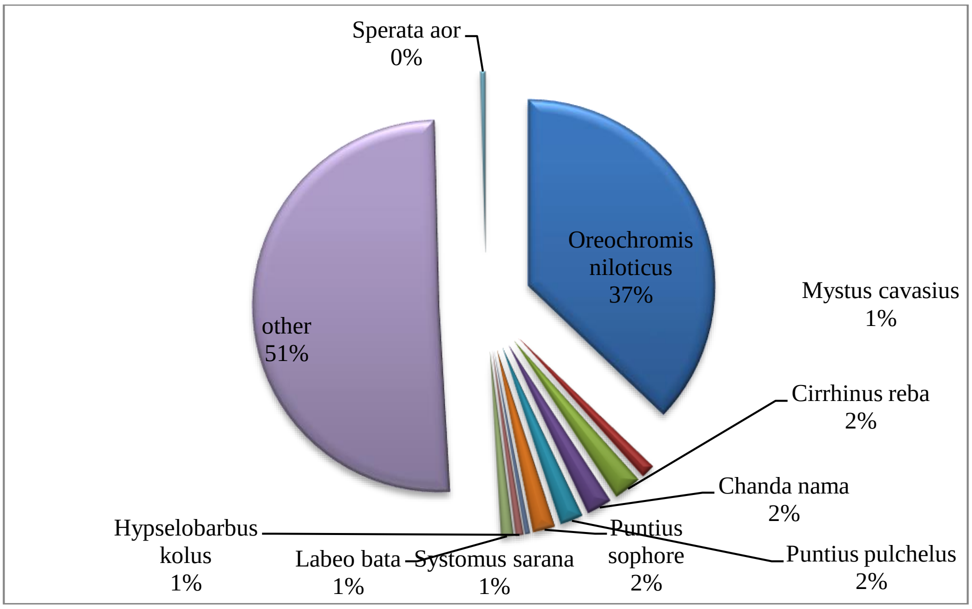

Fig. 5. Diagrammatic representation of the % number contribution at Station 2

A study indicated the Shannon-Wiener Diversity Index at 0.838, Simpson's Index at 0.745, and Pielou's Evenness Index between 0.044 and 0.838 for Jaisamand Lake in India [29]. Research along the Sutlej River in Ludhiana, Punjab, found that the indices peaked in November and throughout the post-monsoon season, with the Margalef Richness Index at 12.14, the H' at 3.871, as well as the Simpson Index at 0.979 [30]. In Zobe Reservoir, Katsina State, Nigeria, the H' varied from 1.81-2.34 on a monthly basis. Simpson's Dominance Index (C) fluctuated among 0.10 and 0.78; the Species Evenness Index (E) varied from 0.596 to 1.00; Margalef's Index of Species Richness (d) ranged from 1.40 to 1.53; as well as the reciprocal of Simpson's Index (D') varied from 1.29 to 9.96 [31].

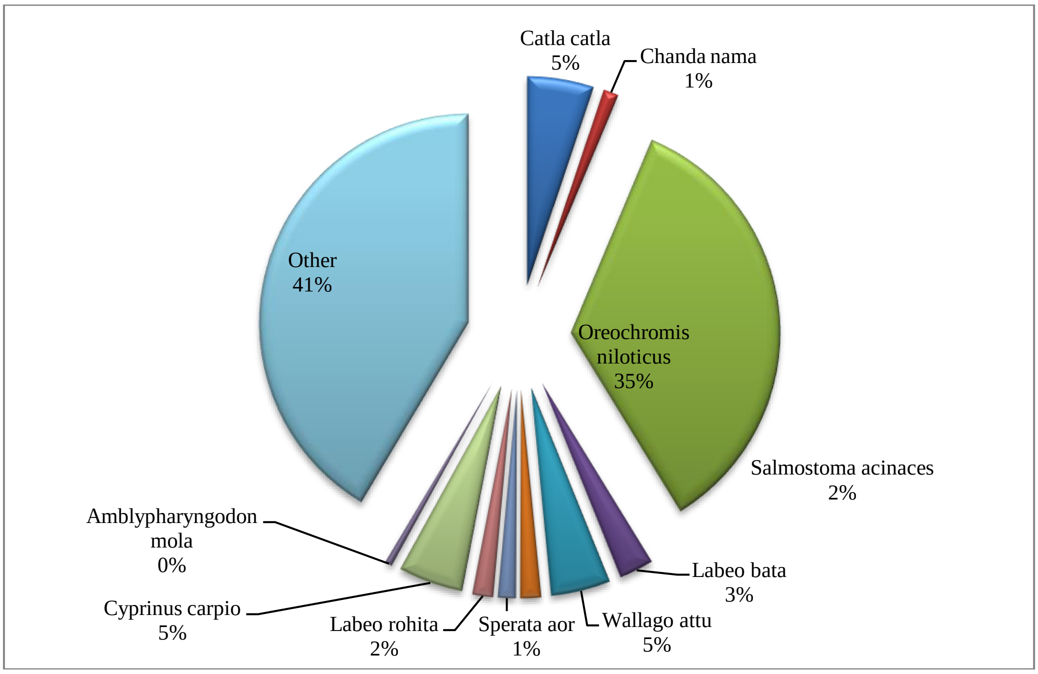

Fig. 6. Diagrammatic representation of the % number contribution at Station 3

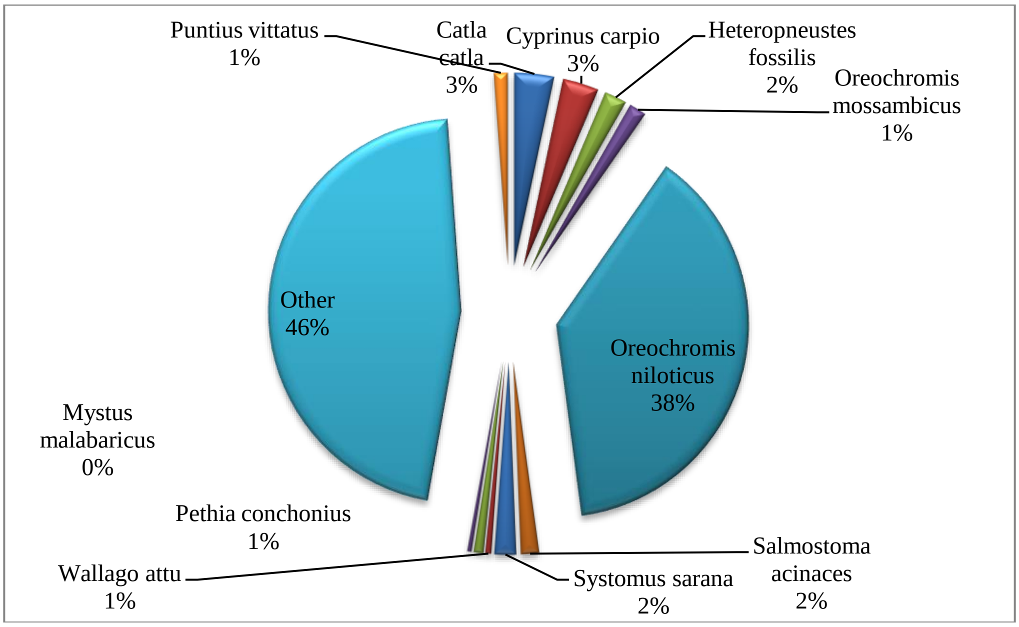

Fig. 7. Diagrammatic representation of the % number contribution at Station 4

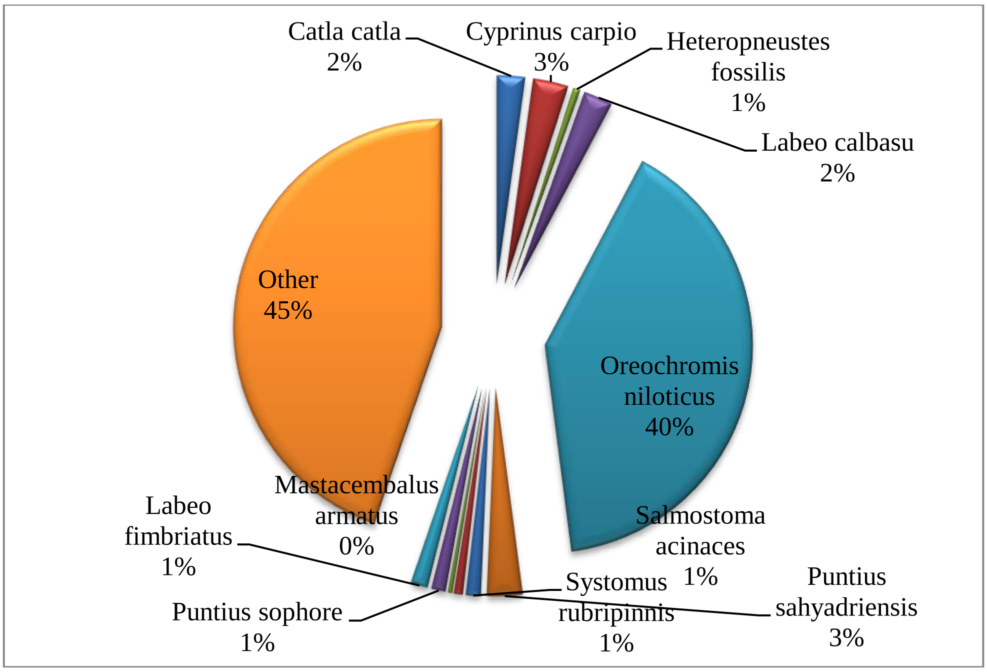

Fig. 8. Diagrammatic representation of the % number contribution at Station 5

Table 1. Monthly variations of different indices for species abundance at station 1 during May, 2022 to October 2023

Month-Year	Number of Individuals (N)	Number of Species (S)	Margalef's Diversity Index (d)	Shannon Diversity Index (H')	Evenness (J')	Lambda (1 Lambda')
May 2022	21	15	2.30	2.81	0.94	0.95
June 2022	23	17	2.40	2.76	0.91	0.94
July 2022	27	19	2.60	2.87	0.89	0.93
August 2022	20	13	2.00	3.11	0.92	0.95
Sept. 2022	26	18	2.50	3.02	0.93	0.94
October 2022	25	16	2.35	2.95	0.91	0.93
May 2023	28	20	2.65	2.83	0.93	0.94
June 2023	28	20	2.65	2.88	0.92	0.93
July 2023	22	14	2.15	2.90	0.94	0.95
August 2023	30	22	2.80	3.10	0.96	0.97
Sept. 2023	32	24	2.90	3.05	0.94	0.96
October 2023	39	29	3.20	3.00	0.92	0.94

Table 2. Monthly variations of different indices for species abundance at station 2 during May, 2022 to October 2023

Month-Year	Number of Individuals (N)	Number of Species (S)	Margalef's Diversity Index (d)	Shannon Diversity Index (H')	Evenness (J')	Lambda (1-Lambda')
May 2022	22	14	2.25	2.80	0.93	0.94
June 2022	24	16	2.35	2.77	0.92	0.93
July 2022	25	17	2.45	2.84	0.90	0.92
August 2022	19	12	1.95	3.09	0.91	0.94
Sept. 2022	24	17	2.38	3.00	0.92	0.93
October 2022	23	15	2.30	2.93	0.90	0.92
May 2023	27	19	2.58	2.81	0.92	0.93
June 2023	26	18	2.52	2.86	0.91	0.92
July 2023	21	13	2.12	2.89	0.93	0.94
August 2023	29	20	2.72	3.08	0.95	0.96
Sept. 2023	31	21	2.82	3.04	0.93	0.95
October 2023	37	25	3.10	2.99	0.91	0.93

Table 3. Monthly variations of different indices for species abundance at station 3 during May, 2022 to October 2023

Month-Year	Number of Individuals (N)	Number of Species (S)	Margalef's Diversity Index (d)	Shannon Diversity Index (H')	Evenness (J')	Lambda (1-Lambda')
May 2022	20	13	2.10	2.83	0.94	0.95
June 2022	21	14	2.15	2.79	0.91	0.94
July 2022	23	15	2.25	2.90	0.89	0.93
August 2022	18	11	1.85	3.12	0.92	0.95
Sept. 2022	22	14	2.20	3.03	0.93	0.94
October 2022	21	13	2.12	2.96	0.91	0.93
May 2023	25	16	2.40	2.85	0.93	0.94
June 2023	24	15	2.35	2.89	0.92	0.93
July 2023	19	12	1.95	2.91	0.94	0.95
August 2023	28	18	2.65	3.11	0.96	0.97
Sept. 2023	29	19	2.70	3.06	0.94	0.96
October 2023	34	22	2.90	3.01	0.92	0.94

Table 4. Monthly variations of different indices for species abundance at station 4 during May, 2022 2023 to October

Month-Year	Number of Individuals (N)	Number of Species (S)	Margalef's Diversity Index (d)	Shannon Diversity Index (H')	Evenness (J')	Lambda (1-Lambda')
May 2022	20	14	2.12	2.80	0.93	0.95
June 2022	18	15	2.15	2.75	0.90	0.92
July 2022	24	11	2.28	2.88	0.94	0.96
August 2022	21	12	1.85	3.05	0.91	0.93
Sept. 2022	23	15	2.22	2.90	0.89	0.91
October 2022	25	16	2.11	2.83	0.87	0.89
May 2023	15	16	2.44	2.79	0.91	0.93
June 2023	20	17	2.30	2.84	0.92	0.94
July 2023	26	15	1.94	2.91	0.95	0.97
August 2023	22	14	2.65	3.00	0.93	0.95
Sept. 2023	19	18	2.60	2.95	0.90	0.92
October 2023	17	23	2.85	2.89	0.88	0.90

Table 5. Monthly variations of different indices for species abundance at station 5 during May, 2022 to October 2023

Month-Year	Number of Individuals (N)	Number of Species (S)	Margalef's Diversity Index (d)	Shannon Diversity Index (H')	Evenness (J')	Lambda (1-Lambda')
May 2022	25	16	2.23	2.82	0.91	0.93
June 2022	27	17	2.11	2.77	0.89	0.91
July 2022	22	12	2.30	2.86	0.90	0.92
August 2022	19	13	1.80	3.02	0.94	0.96
Sept. 2022	21	16	2.25	2.91	0.92	0.94
October 2022	24	17	2.20	2.85	0.93	0.95
May 2023	18	12	2.44	2.80	0.92	0.94
June 2023	23	15	2.3	2.84	0.91	0.93
July 2023	20	17	1.95	2.89	0.88	0.90
August 2023	26	18	2.60	3.04	0.93	0.95
Sept. 2023	17	20	2.65	2.98	0.89	0.91
October 2023	15	22	2.75	2.93	0.90	0.92

4. CONCLUSION

The research indicated a varied fish population over five sample points, with Cypriniformes and the species *Oreochromis niloticus* being the most prevalent. The Seasonal fluctuations, environmental conditions, and hydrological impacts greatly altered species richness and distribution. The indices (Margalef's, Shannon-Wiener, Simpson, and Evenness) suggested a strong, diversified ecosystem; however, particular species demonstrated dominance over various months owing to environmental stresses such as temperature and monsoon influences.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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