

Multivariate analysis of ichthyofaunal diversity in the Kasaraiya Dhar Wetland, Bihar, India

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Abstract

Kasaraiya Dhar is a perennial wetland located in Khagaria District of Bihar, at 25.492937°N and 86.619178°E. Spanning over 100 ha, it was formed as a result of meandering of the Budhi Gandak River. In the present investigation, the ichthyofaunal diversity and water quality parameters of Kasaraiya Wetland were assessed during 2021-23. Water quality parameters such as water temperature, pH, dissolved oxygen (DO), alkalinity, hardness, nitrite, ammonium ion, phosphate, electric conductivity (EC), total dissolved solid (TDS), gross primary productivity (GPP) and net primary productivity (NPP) were assessed. A total of 58 finfish, 2 prawn and three mollusc species belonging to 26 families and 14 orders were identified. The family Cyprinidae contributes maximum species diversity (20 species) followed by the family Mastacembelidae and the Bagridae. The Pielou's Evenness Index, Shannon-Weiner diversity index and Simpson index of Kasaraiya Dhar wetland indicated high fish diversity with evenly distributed fish in all three seasons viz., pre-monsoon, monsoon and post-monsoon. The findings of the present study provide baseline information on the wetland, which will be highly valuable for ecosystem-based wetland fisheries management.

Introduction

Floodplain wetlands are the most productive ecosystems in the world. These ecosystems are typically situated in the catchment area of rivers, provide a unique repository of biodiversity as well as play a significant role in livelihoods and nutritional security to a large populace of the developing countries (Datta, 2011; Mao *et al.*, 2018; Rai and Kumar, 2018; Sarkar *et al.*, 2020; Bharti *et al.*, 2022; Ghosh *et al.*, 2023). In India, wetlands are partially utilised for fisheries enhancement with high-value fish species. Besides, they play a vital role in water purification, flood control, pollutant reduction and climate regulation due to their unique ecological functions (Roy *et al.*, 2018; Gupta *et al.*, 2021; Bharti *et al.*, 2022; Raman *et al.*, 2023). Floodplain wetland ecosystems serve as critical breeding and nursery grounds for fish that migrate from riverine systems during the

monsoon. This seasonal ingress provides refuge and supports early development, acting as a lifeline for sustaining aquatic biodiversity and enhancing productivity of riverine fisheries (Bharti *et al.*, 2022; Raman *et al.*, 2023).

Despite their vital role in socio-economic security and cultural significance in rural India, these wetlands are increasingly threatened by both natural as well as anthropogenic pressures, leading to a reduction in water spread area and a decline in fish diversity (Sarkar and Borah, 2018; Ghosh *et al.*, 2023; Nahiduzzaman *et al.*, 2023). The two major sources of pollution, viz., point sources (industrial discharge) and non-point sources (agricultural runoff) are key contributors to hydro-ecological changes in wetland water quality (Gupta *et al.*, 2021). The variation in the fish species in an aquatic ecosystem depends upon the food supply chain and changes



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in the hydrological parameters of the ecosystem (Roy et al., 2018; Chandran et al., 2019; Nahiduzzaman et al., 2023).

Unwise human interventions in wetland ecosystems, have placed many species from these wetlands at risk of extinction (Galib et al., 2009; Datta, 2011; Nahiduzzaman et al., 2023). Evaluation of the present biodiversity is highly essential for understanding the wellbeing of ecosystem and ensuring effective management strategies for sustainable management of wetlands (Sarkar et al., 2020; Das et al., 2024). In Bihar, almost 90% of the wetlands locally known as Chaur, Maun and Dhar, exist in its northern part under the vast catchment area of the Ganga and its tributaries (Sarkar et al., 2020; Bharti et al., 2022; Raman et al., 2023). The total estimated area of wetlands in Bihar is 9.5 lakh ha under private and government control (Sarkar et al., 2021; Bharti et al., 2022). In most wetlands, fish production relies primarily on capture fisheries practices yielding only 40-50 kg ha⁻¹ year⁻¹, which is significantly lower than the actual production potential (Sarkar and Borah, 2018). Fish production can be enhanced to 1000-2000 kg ha⁻¹ year⁻¹ by adopting modern scientific and technological practices (Alam et al., 2017; Chand and Prasad, 2021; Bharti et al., 2022). The present investigation aims to assess seasonal variations in water quality parameters and ichthyofaunal diversity in Kasariya Dhar, with the aim to support ecosystem-based fisheries management.

Materials and methods

Study area

Kasariya Dhar, located east of Khagaria town in Bihar, is a perennial oxbow lake in Khagaria District, characterised by its distinct sickle shape. Kasariya Dhar extends approximately 6 km, from NH 31 on the western side to Farreh on the north-eastern side covering an area of more than 100 ha. It maintains an average depth of about 20 feet even during summer season. Approximately 50-60% of the wetland is covered by floating macrophytes viz. *Eichhornia crassipes*, commonly called water hyacinth. A total of 11 villages are situated at the bank of this wetland, where an average of

300-400 families in each village depend on this wetland for fisheries, irrigation, bathing and cleaning clothes as well as for grazing purposes. This wetland is managed by a fisheries co-operative society, with fishing rights exclusively held by its member fishermen for capture-based fisheries (Fig. 1). Major gears used for fishing practice are Kachal Jal and Chhatti Jal (a type of seine net) operated from the traditional wooden boat (dingy).

Sampling operations for the water quality and fish diversity were carried out in the wetland from July 2021 to December 2023. Monthly water quality and fish data were collected and analysed. For temporal analysis, the monthly data were categorised into three seasons, pre-monsoon (Feb-May), monsoon (Jun-Sept) and post-monsoon (Oct-Jan).

Water quality parameters

Water quality parameters such as water temperature, air temperature, pH, conductivity and total dissolved solids (TDS) were measured using multi-parameter water analyser sensors at the sampling sites (Hana, China). Total hardness was measured in laboratory using standard EDTA solution in the presence of ammonium chloride and ammonium hydroxide as a buffer and eriochrome black-T as an indicator. Alkalinity of the water sample was estimated titrimetrically using standard sulphuric acid in the presence of phenolphthalein and methyl orange as indicators. Estimations of ammonium-N, nitrite-N and phosphate-P in water samples were carried out spectrophotometrically (APHA, 2005). Primary productivity was determined following standard method of light and dark bottles as per Winkler method (Wetzel and Linkens, 2000). Observed gross primary productivity (GPP) and net primary productivity (NPP) in mg l⁻¹ h⁻¹ were converted into mg C l⁻¹ h⁻¹ (Benton and Werner, 1972).

Assessment of ichthyofaunal diversity

Fish samples were collected from artisanal fishermen who captured fish using various traditional gears such as gillnet, cast net, seine net of different mesh sizes, as well as hook and line in the Kasariya

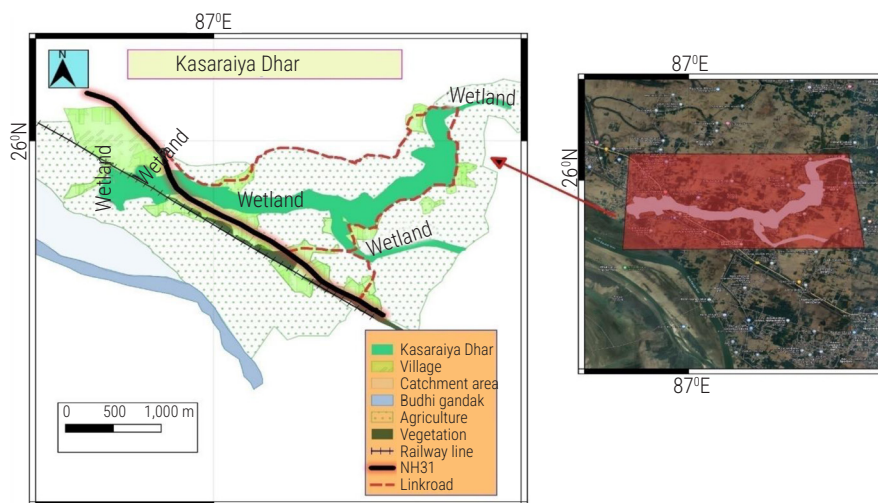


Fig. 1. Map showing the location of Kasariya Dhar wetland

wetland. The collected fish were identified and examined for their morphological features, colour bands or spots present on the body and meristic counts following standard literature (Jhingaran and Talwar, 1991; Jayram, 1999). Data collected on fish species was subjected to diversity analysis comprising the concepts of variety and variability such as richness and evenness (Burton *et al.*, 1992). The diversity was assessed based on the number of species (species richness) using Shannon-Weiner Index (H') and Simpson's index (1-D).

Shannon-Weiner index of diversity (Shannon and Weaver, 1949),

$$H' = -\sum p_i \ln p_i$$

where, p_i is the proportion of the i^{th} species in the sample.

Simpson's index (1-D) of diversity (Simpson, 1949), which reflects both the number of species and the abundance of each species, is frequently used to measure the biodiversity of the habitat employing the following formula:

$$1 - D = 1 - (\sum p_i^2)$$

where p_i is the proportional abundance for each species.

Pielou evenness index (J') was calculated based on numerical abundance (Pielou, 1966). Pielou's evenness is expressed as the ratio between a community's H' value and the value H' would take if the community was perfectly even (H'_{max}) and is calculated as:

$$J' = \frac{H'}{H'_{\text{max}}}$$

Statistical analyses

Hierarchical agglomerative clustering with group average linking and non-metric multidimensional scaling (nMDS) were performed to investigate similarities among the three seasons. The community succession during three seasons was summarised using the submodule in the cluster of Bray-Curtis similarities from species abundance (Bray and Curtis, 1957). The multivariate Cluster and nMDS analyses were performed using R software (R-4.3.1) in the presence of Community Ecology Package Vegan (version 2.6-4) (Oksanen *et al.*, 2019; R Core Team, 2021). The nMDS analysis based on the similarity of species composition was evaluated using the Bray-Curtis index to assess the differences in the species composition in three seasons. The analysis of similarities (ANOSIM) was performed in R software to test the significant differences in species composition among the three seasons (Delgado *et al.*, 2012). Water quality parameters in three seasons were compared using one-way analysis of variance (ANOVA) at 5% level of significance. The mean difference was analysed by Duncan's multiple range test (DMRT) using 'Agricolae' package in R.

Results and discussion

Water quality analysis

Significant seasonal variations were observed in the water quality of Karasira Dhar. Both air and water temperatures were notably lower during the monsoon and post-monsoon seasons as compared to the pre-monsoon period. These fluctuations in water temperature

closely correspond to changes in air temperature. In Karasira Dhar water, alkalinity ranged from 196.47 to 265 ppm and hardness varied between 161.93 and 244.9 ppm, during the study period. Alkalinity, hardness and nitrite levels were found to be at their lowest during the monsoon season. Similar to this finding, Singh *et al.* (2020) reported the total hardness and alkalinity in Kanwar Lake as 219-299 and 194-304 mg l⁻¹, respectively. Phosphorus concentration was significantly higher during the monsoon season (0.58 ppm). The high phosphate level recorded in the present study are consistent with the findings of Vass *et al.* (2015), which reported elevated phosphate levels of 0.1-1.08 ppm in nearby wetlands during the monsoon season due to high nutrient influx from the catchment area. Major contributors to increased phosphate levels in this wetland include fertiliser runoff from the agriculture field, effluents containing detergents from washing clothes and animal wastes. Solim and Wanganeo (2008) reported an excessive phosphorus level in the Dal Lake of Kashmir due to the impact of an urbanised watershed. The high phosphate level in the present wetland has influenced the seasonal gross primary productivity and net primary productivity dynamics as reported by Roy *et al.* (2018). As phosphate is a key driver of aquatic plant growth in the freshwater ecosystem (Conley *et al.*, 2009), seasonal variations in phosphate concentrations are closely linked to wetland productivity.

Water pH in Kasaraiya Dhar ranged from 7.16 to 7.29, reflecting its alkaline nature. This alkaline pH is influenced by biological processes such as photosynthetic activity and respiration rates in the wetland. During periods of high photosynthetic activity, increased CO₂ uptake raises the pH, whereas respiration can lower the water pH (Gupta *et al.*, 2021). The alkaline pH observed in the Kasaraiya Dhar wetland in this study aligns with the findings from the Media wetland (Adhishwar and Choudhary, 2020; Ghosh *et al.*, 2023). Dissolved oxygen (DO) in Kasaraiya Dhar wetland ranged from 5.89 to 7.38 ppm (Table 1), consistent with values reported from other wetlands in Bihar such as Kusheshwar Astahn (Gupta *et al.*, 2021; Singh *et al.*, 2022); Kanwar (Adhishwar and Choudhary, 2020) and Gogabeel Lake wetlands as well as from wetlands of Punjab (Singh *et al.*, 2022). Electrical conductivity (EC) was lowest during monsoon (417.45 µS cm⁻¹) season. EC of water reflect dissolved ions from weathering processes, decaying plant matter and the contribution of organic and inorganic waste via sewage runoff (Dey and Dey, 2015; Gupta *et al.*, 2021). The pronounced EC during monsoon observed in the present study, is likely due to dilution by rainfall (Gupta *et al.*, 2021).

Ichthyofaunal diversity

In this study, a total of 58 finfish, 2 prawn and three mollusc species representing 26 families and 14 orders were identified from the Kasaraiya Dhar (Table 2). Among these fish species, the maximum number of species (20 species) belonged to Cyprinidae family, followed by Mastacembelidae and Bagridae (4 species each), Channidae, Anabantidae and Ambassidae (3 species each) and Botiidae, Siluridae, Botopteridae, Gobiidae and Clupeidae (2 species each). The families like Heteropneustidae, Claridae, Siliidae, Sisoridae, Schilbeidae, Nandidae, Synbranchidae, Mugilidae, Belonidae and Tetraodontidae contained one finfish species each. In case of molluscs, one species was recorded from each family of Ampullariidae, Viviparidae and Planorbidae, however, two species of prawns were found from the Palaemonidae family. The

Table. 1. Water quality parameters recoded in the Kasaraiya Dhar wetland across three seasons (Values presented as Mean±SE with range given in parenthesis)

Parameters	Seasons		
	Pre-monsoon	Monsoon	Post-monsoon
Air temperature (°C)	28.82±0.76 ^a (26.5-31)	26.88±0.67 ^b (25-29)	25.38±0.26 ^b (25-27)
Water temperature (°C)	31.44±1.44 ^a (27.4-38)	33.16±0.62 ^a (31.3-37.6)	19.89±0.94 ^b (14.8-25.3)
pH	7.25±0.15 ^a (6.61-8)	7.29±0.16 ^a (6.34-8.5)	7.16±0.12 ^a (6.4-7.8)
DO (ppm)	5.89±0.52 ^a (3.76-8.05)	6.97±0.44 ^a (4-8.2)	7.38±0.84 ^a (2-12.85)
Alkalinity (ppm)	262.9±18.66 ^a (220-412)	196.47±14.96 ^b (88-264)	265±939 ^a (192-320)
Hardness (ppm)	244.9±30.59 ^a (144-412)	161.93±10.68 ^b (80-232)	244.0±14.8 ^a (179-360)
Nitrite (ppm)	0.08±0.01 ^a (0.03-0.14)	0.05±0.01 ^b (0.02-0.08)	0.08±0.01 ^a (0.05-0.11)
Ammonium ion (ppm)	0.81±0.16 ^a (0.09-1.41)	0.27±0.04 ^b (0.09-0.55)	0.84±0.19 ^a (0.11-1.88)
Phosphate (ppm)	0.18±0.03 ^b (0.14-0.23)	0.58±0.00 ^a (0.57-0.60)	0.24±0.05 ^b (0.16-0.59)
EC (µS cm ⁻¹)	448.39±20.00 ^{ab} (352.7-532.6)	417.45±22.07 ^b (346.4-507.3)	493.01±14.3 ^a (392.6-531.4)
TDS (ppm)	462.4±8.78 ^a (435-524.2)	453.62±34.74 ^a (343.3-543.2)	491.60±13.8 ^a (434.3-587.5)
GPP (mgC l ⁻¹ h ⁻¹)	90.0±17.3 ^b (60-120)	225.0±20.1 ^a (180-270)	110.0±26.5 ^b (60-150)
NPP (mgC l ⁻¹ h ⁻¹)	50.0±10 ^b (30-60)	165.0±20.1 ^a (120-210)	70.0±20 ^b (30-90)

Superscripts indicate significant differences in the parameters at 5% level of significance

Table 2. Checklist of finfish and shellfish species available in the Kasaraiya Dhar

S. No.	Groups	Scientific name	Local name	Family	Order
1		<i>Labeo rohita</i>	Rohu	Cyprinidae	Cypriniformes
2		<i>L. bata</i>	Bata	Cyprinidae	Cypriniformes
3		<i>L. calbasu</i>	Keronchi	Cyprinidae	Cypriniformes
4		<i>L. gonius</i>	Khursa	Cyprinidae	Cypriniformes
5		<i>L. boga</i>	Boga	Cyprinidae	Cypriniformes
6		<i>L. angra</i>	Kharsa	Cyprinidae	Cypriniformes
7		<i>Cirrhinus mrigala</i>	Naini	Cyprinidae	Cypriniformes
8		<i>Catla catla</i>	Catla	Cyprinidae	Cypriniformes
9		<i>Ctenopharyngodon idella</i>	Grasscarp	Cyprinidae	Cypriniformes
10		<i>Cirrhinus reba</i>	Reba	Cyprinidae	Cypriniformes
11		<i>Puntius ticto</i>	Pothia	Cyprinidae	Cypriniformes
12		<i>P. sophore</i>	Pothia	Cyprinidae	Cypriniformes
13		<i>P. muzzafarpurnsis</i>	Pothia	Cyprinidae	Cypriniformes
14		<i>P. sarana</i>	Darahi	Cyprinidae	Cypriniformes
15		<i>Salmostoma phulo</i>	Chalhawa	Cyprinidae	Cypriniformes
16		<i>Aspidoparia morar</i>	Chilwa	Cyprinidae	Cypriniformes
17		<i>Amblypharyngodon mola</i>	Dhawai	Cyprinidae	Cypriniformes
18		<i>Salmostoma clupiodes</i>	Chela	Cyprinidae	Cypriniformes
19		<i>Osteobrama cotia</i>	Cotia	Cyprinidae	Cypriniformes
20		<i>Salmostoma boopis</i>	Chela	Cyprinidae	Cypriniformes
21		<i>Botia rostra</i>	Baghi	Botiidae	Cypriniformes
22		<i>Nemacheilus botia</i>	Baghi	Botiidae	Cypriniformes
23		<i>Mystus tengara</i>	Tengra	Bagridae	Siluriformes
24		<i>M. cavasius</i>	Tengra	Bagridae	Siluriformes
25	Finfish	<i>M. vitatus</i>	Tengra	Bagridae	Siluriformes
26		<i>M. bleekeri</i>	Palwa	Bagridae	Siluriformes
27		<i>Ompok bimaculatus</i>	Papta	Siluridae	Siluriformes
28		<i>Wallago attu</i>	Buwari	Siluridae	Siluriformes
29		<i>Heteropneustes fossilis</i>	Singhi	Heteropneustidae	Siluriformes
30		<i>Clarias batrachus</i>	Mangur	Clariidae	Siluriformes
31		<i>Ailia coila</i>	Patasi	Ailiidae	Siluriformes
32		<i>Gagata cenia</i>	Baghawa	Sisoridae	Siluriformes
33		<i>Eutropiichthys vacha</i>	Bachawa	Schilbeidae	Siluriformes
34		<i>Channa marulius</i>	Bohra	Channidae	Anabantiformes

Contd.....

35		<i>C. striata</i>	Soura	Channidae	Anabantiformes
36		<i>C. punctus</i>	Garai	Channidae	Anabantiformes
37		<i>Colisa fasciata</i>	Kholisa	Anabantidae	Anabantiformes
38		<i>C. lalia</i>	Khosti	Anabantidae	Anabantiformes
39		<i>Anabas testudineus</i>	Kobai	Anabantidae	Anabantiformes
40		<i>Chanda nama</i>	Chanari	Ambassidae	Perciformes
41		<i>Parambassis ranga</i>	Chanari	Ambassidae	Perciformes
42		<i>Ambassis gymnocephalus</i>	Chanari	Ambassidae	Perciformes
43		<i>Nandus nandus</i>	Dhallo	Nandidae	Perciformes
44		<i>Macrognathus caudocellatus</i>	Gainchi	Mastacembelidae	Synbranchiformes
45		<i>M. aral</i>	Gainchi	Mastacembelidae	Synbranchiformes
46		<i>M. pancalus</i>	Gainchi	Mastacembelidae	Synbranchiformes
47		<i>Mastacembelus armatus</i>	Bami	Mastacembelidae	Synbranchiformes
48		<i>M. deyi</i>	Bami	Mastacembelidae	Synbranchiformes
49		<i>Monopterusuchia</i>	Anahi	Synbranchidae	Synbranchiformes
50		<i>Notopterus notopterus</i>	Bhuna	Notopteridae	Osteoglossiformes
51		<i>Chitala chitala</i>	Moya	Notopteridae	Osteoglossiformes
52		<i>Rhinomugil corsula</i>	Aruari	Mugilidae	Mugiliformes
53		<i>Glossogobius biocellatus</i>	Bulla	Gobiidae	Gobiiformes
54		<i>Pseudapocryptes elongatus</i>	Cheua	Gobiidae	Gobiiformes
55		<i>Xenentodon cancila</i>	Kauwa	Belonidae	Beloniformes
56		<i>Gudusia chapra</i>	Suhia	Clupeidae	Clupeiformes
57		<i>Setipinna phasa</i>	Phasia	Clupeidae	Clupeiformes
58		<i>Tetraodon cutcutia</i>	Galphulani	Tetraodontidae	Tetraodontiformes
59		<i>Pila globosa</i>	Ghonga	Ampullariidae	Architaenioglossa
60	Mollusc	<i>Bellamya bengalensis</i>	Ghongi	Viviparidae	Architaenioglossa
61		<i>Segmentina trochoidea</i>	Ghongi	Planorbidae	Basommatophora
62		<i>Macrobrachium lamarrei</i>	Ichna	Palaemonidae	Decapoda
63	Prawn	<i>Macrobrachium gangeticum</i>	Ichna	Palaemonidae	Decapoda

scientific names along with the local name of the species recorded from Kasaraiya Dhar are depicted in Table 1. Similarly, Das *et al.* (2015) observed a total number of 35 species with the dominant groups being Perciformes, Cypriniformes and Siluriformes, from the Kusheshwar Asthan wetland in north Bihar. Ichthyofaunal diversity of Gogabeel Lake was studied by Chandra (2014) and found 39 species belonging to 12 families with dominance of Cyprinidae. In this study area, the Cypriniformes order had the maximum number of species compared to the other orders because of the ideal water quality conditions and depth profile of the wetland, where fish from Cypriniformes thrives for existence. Juveniles of most of the fish species were dominant in the catch during post-monsoon period, which indicates that the Kasaraiya Dhar served as breeding ground for the indigenous fish species (Sahoo *et al.*, 2021).

Biodiversity indices of fishes

In the current study, Shannon-weiner diversity indices were recorded at 3.072, 3.313 and 3.498 for monsoon, post-monsoon and pre-monsoon, respectively. The lowest H' during the monsoon and highest during pre-monsoon reflect corresponding changes in the fish abundance (Tikadar *et al.*, 2021). According to our findings, species richness peaked in the pre-monsoon season and lowest during monsoon. According to Biligrani (1988), H' value within range of 3.0-4.5, indicates water conditions that are highly conducive for maintaining fish diversity. These results indicate that fish diversity in Kasaraiya Dhar has remained stable, even though it is a closed type wetland demonstrating the suitability of the wetland for sustaining indigenous fish species. However,

diversity indices of the ecosystem can be influenced by several factors like geographic extent, survey duration, seasonal spawning migrations, fishing methods and seasonal fishing regulations (Ullah *et al.*, 2023). Simpson's diversity index ranges from 0 to 1 with higher values denoting greater diversity. In this study, the pre-monsoon (0.958) recorded the highest Simpson's index, followed by post-monsoon (0.950) and monsoon (0.935), with values that are remarkably similar. This indicates that, despite seasonal shifts in species richness, the distribution of individuals among species remains highly even (Chandran *et al.*, 2019). Pielou's evenness index which quantifies the uniformity of species abundance within a community was highest in the pre-monsoon (0.894) and lowest in the post-monsoon season (0.875) (Fig. 2).

These findings are in accordance with Mili and Saikia (2022) in the wetlands of Assam, where Pielou's evenness index values ranged between 0.79 and 0.92 for fish caught in gillnets. Our results also aligns with the previous finding that species richness was high during the dry season when fish were confined to smaller habitat volumes (Grubh and Winemiller, 2018). However, in contrast to the present findings, Kiranya *et al.* (2018) reported the lowest evenness values in the monsoon and the highest in the post-monsoon, in the Poonthura Estuary of Kerala. The consistently high Pielou's evenness and Shannon-weiner indices of Kasaraiya Dhar wetland indicate a well-balanced, diverse fish community across all three seasons, indicating the wetland's healthy condition for fish production (Chintey *et al.*, 2022).

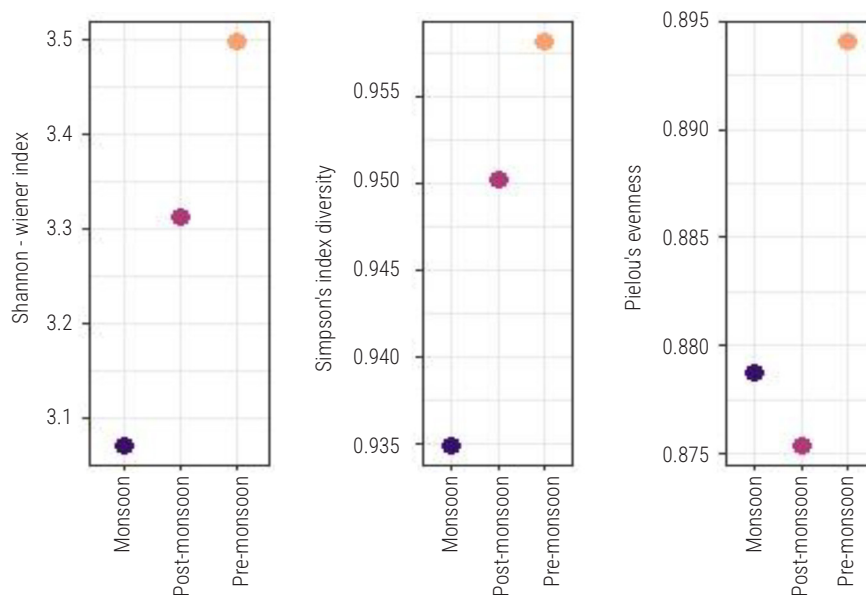


Fig. 2. Biodiversity indices across three seasons in Kasaraiya Dhar

Bray-Curtis cluster analysis, revealed two distinct groups in the species composition of Kasaraiya Dhar (Fig. 3). pre-monsoon samples representing one cluster while monsoon and post-monsoon samples clustered together, indicating a clear separation of pre-monsoon assemblage. Non-metric multidimensional scaling (nMDS) confirmed these seasonal differences, with pre-monsoon samples well-separated from the monsoon and post-monsoon at a stress value of 0.1573 (Fig. 4), below the 0.2 threshold for reliable interpretation (Yang *et al.*, 2015). Complementary ANOSIM analysis yielded a highly significant R of 0.8621, corroborating the pronounced seasonal variation in species composition. Similar findings were reported by Nahiduzzaman *et al.* (2023) and Grubh and Winemiller (2018).

Kasaraiya Dhar is a perennial sickle-shaped oxbow lake in Khagaria District, covering an area of more than 100 ha with an average depth of 20 feet even in the summer. The water quality parameters

analysed, such as water temperature, pH, DO, alkalinity, hardness, nitrite, ammonium ion, phosphate, EC, TDS, GPP and NPP were found to be within the ranges favourable for fish growth. Consequently, the wetland exhibits high biodiversity, as evidenced by high Pielou's evenness and Shannon-wiener indices, reflecting a well-distributed fish population across pre-monsoon, monsoon, and post-monsoon seasons. However, 50-60% coverage by water hyacinths impedes fishing operations. Biological and mechanical measures are therefore recommended to enhance sustainable fisheries. Reasonably sufficient water depth and perennial

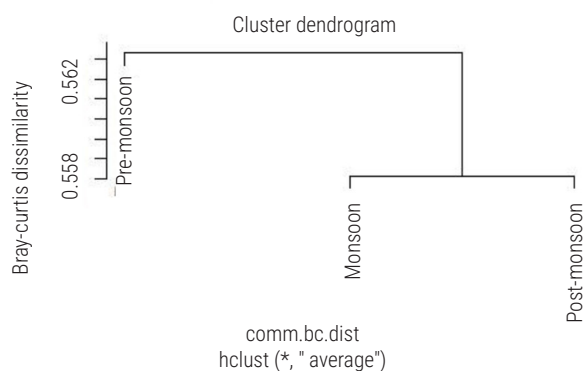


Fig. 3. Dendrogram showing Bray-Curtis similarity clustering for species composition among three seasons

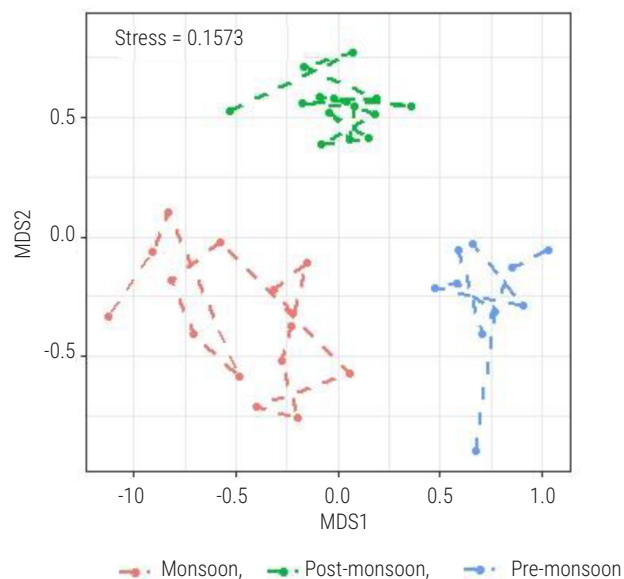


Fig. 4. Non-metric Multidimensional Scaling (nMDS) plot showing the grouping of species in three seasons based on finfish and shellfish abundance in Kasaraiya Dhar

retention of water with conducive quality of water in this wetland offer tremendous scope for increasing fish production through enclosure culture, integrated fish farming, culture-based fisheries and community based fish farming in participatory mode.

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