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Temporal variations in fish diversity in the main channel of the Chaliyar River, Western Ghats, Kerala, India

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Abstract

The present study examined the temporal patterns in ichthyofaunal diversity of the Chaliyar River over a three-year period (2017–2020), including the extreme flood year of 2018. Fish samples were collected from eight sampling stations distributed across three river stretches during pre-monsoon, monsoon, and post-monsoon seasons using multiple fishing gears. A total of 2,347 specimens belonging to 53 species, 25 families, and 11 orders were recorded. Biodiversity assessment was performed using species richness, dominance index, and Shannon–Wiener diversity index, along with dominance curves and cluster analysis. The results indicated a noticeable decline in fish diversity during 2018 (0.94), coinciding with the flood event, suggesting ecological disturbance in the river system. Cypriniformes and Perciformes dominated the ichthyofaunal assemblage across the study period. Cluster analysis highlighted distinct seasonal patterns, with monsoon observations forming a separate cluster. Conservation assessment highlighted the ecological sensitivity of the Chaliyar River and emphasised the need for community-based conservation, continuous monitoring, and scientifically informed management strategies to sustain riverine fish diversity.



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Rivers maintain unique biotic resources and perform a wide range of fundamental ecological services such as providing biodiversity, shelter, food, nursery grounds, and feeding bases for fishes (Shao *et al.*, 2019a; Poff *et al.*, 2001). Around 65% of the world's riverine habitats were identified as biodiverse zones, but they are increasingly threatened by multiple environmental stressors such as pollution and invasive species (Vörösmarty *et al.*, 2010). The riverine resources of India have also been subjected to similar biodiversity threats (CEBPOL, 2018), with the Chaliyar River in Kerala, South India, being one notable example (Acharya *et al.*, 2019).

Over the years, researchers recognised the need for implementing stepwise and effective conservation strategies (Soo *et al.*, 2021) along with potential mitigation measures for the revival of riverine fisheries. Such actions required knowledge of fundamental

aspects of riverine ecology, particularly the spatio-temporal patterns of fish species distribution (Shao *et al.*, 2019a). Although numerous studies on fish fauna have been conducted in the Indian subcontinent, most have primarily focused on the relationship of fish fauna with morphological features of rivers, the description of new species, and the genetics or phylogenetic analyses of various species. Only a few studies, such as those by Nair (1986), Shaji and Easa (1995), Easa and Shaji (1997), Lal Mohan and Rema Devi (2000), and Gopi (2006), addressed the temporal dimension of species diversity in the Chaliyar River.

In this context, the present study focused on highlighting the temporal fluctuations in fish diversity in the Chaliyar River, Western Ghats, India. The study aimed to provide a better understanding of the temporal ichthyofaunal diversity of the river, which

could serve as a stepping stone for developing future conservation strategies.

The Chaliyar River bound (11.12°-11.56°N; 75.81°-76.55°E), has a catchment area of 1535 km². It originates in the Western Ghats at the Elambalari hills in Tamil Nadu and flows through Wyanad, Malappuram and Kozhikode districts of Kerala (South India) before emptying into the Arabian Sea (Fig. 1). The total length of the river is 165 km.

Fish samples were collected from 8 stations spread across 3 stretches of the river. Sampling stations are detailed in Table 1. The sampling period extended over three years (2017–2020) across three seasons: pre-monsoon (PRM; February–May), monsoon (MON; June–September), and post-monsoon (POM; October–January). The year 2018 experienced a major flood event in the study area. Fish samples were collected with the assistance of local fishermen, who obtained samples from comparatively undisturbed areas of the main river channel during fishing hours.

Various selective and non-selective gears such as gill nets, cast nets, drag nets, and hook-and-line were used for sampling to represent the entire range of fish habitats across different water depths (0.35–12 m). Gill nets were deployed overnight (17:00–07:00 hrs) for sample collection. One sample per station per season was collected using gill nets and drag nets, while three replicate samples were collected using cast nets at each station during each season. Hook-and-line sampling was performed for approximately one hour at each station using baited hooks. The collected specimens were then transported to the laboratory for taxonomic identification following Talwar and Jhingran (1991) and were subsequently classified into different orders and families. The fishery data thus obtained were further segregated on temporal scales (year-wise and season-wise) for diversity-based analyses and interpretation.

The pooled data of all the collected variables from each station in the study (abundance data of fish) were analysed using various packages in Primer 7.0 (Clarke and Gorley, 2015) and R (R Core Team, 2013).

The fish abundance data were normalised using log (x+1) transformation to reduce the influence of extreme values in the fish assemblage, including zero values, on temporal (yearly and seasonal) scales. The transformed data were subsequently used to calculate various diversity indices to assess the status of the fish assemblage in the study area. Three major biodiversity indices, namely species richness, dominance index, and Shannon–Weiner diversity index, were used to estimate the discrepancy of fish communities in this study. Species richness (S) is defined as the total number of fish species in the ecosystem studied.

Dominance index (D) helps to identify the dominant fish species in the selected area of study (Harper, 1999). The minimum index value is 1. It is calculated using the following equation:

$$D = \sum (n_i/n)^2 \text{ (Harper, 1999) ----- (1)}$$

where n_i is the number of individuals of taxon i , and n is the total number of individuals in the sample.

Shannon diversity index (SD) is a measure of species abundance as well as richness and is used to quantify the diversity of the species. In most ecological studies, the Shannon–Wiener diversity index typically ranges between 1.5 and 3.5 (Ulfah *et al.*, 2019); however, values above 4 are rarely observed in natural communities (Magurran, 2004). It is calculated as (Shannon and Weiner, 1949):

$$SD = - \sum P_i \log 2 p_i \text{ (Shannon \& Weiner, 1949) ----- (2)}$$

where P_i is the proportion of the number of individuals of the i^{th} species, within the sample; n_i is the number of individuals in the i^{th} species and N is the total number of individuals.

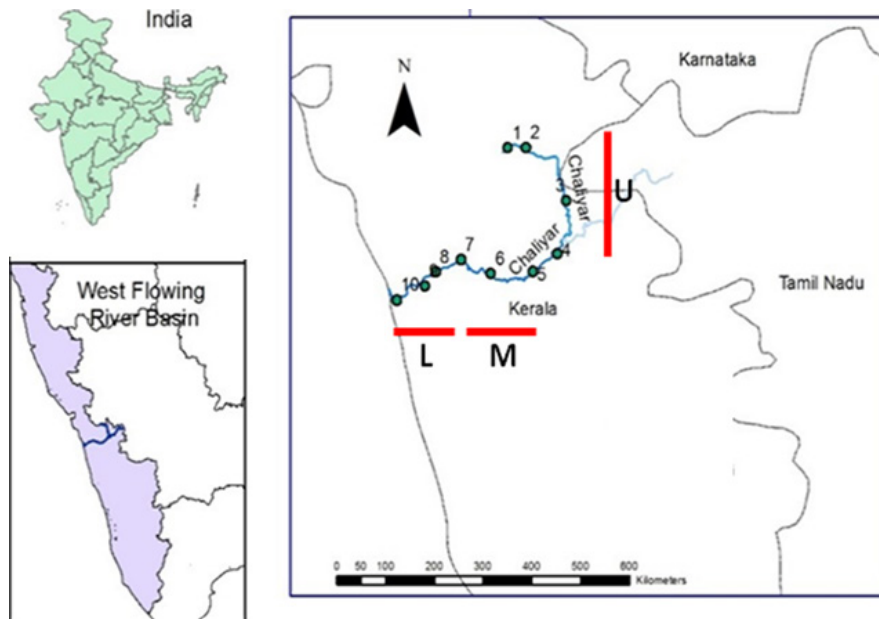


Fig. 1. Sampling stations in the Chaliyar River

Table 1. Station-wise habitat characteristics of Chaliyar River (Source: Ajoy *et al.*, 2019)

| Stretch | Stations | Co-ordinates | Distance from source (km) | Districts |
|---|-------------|------------------|---------------------------|------------|
| Upper stretch (Freshwater/Riverine stretch) | Cholamala | 12.82°N; 77.20°E | 0 | Wyanad |
| | Arrapetta | 12.60°N; 77.28°E | 6 | |
| Middle stretch (Freshwater stretch) | Nilambur | 12.07°N; 76.72°E | 44 | Malappuram |
| | Mampad | 11.27°N; 77.07°E | 52 | |
| | Edavanna | 11.27°N; 76.83°E | 60 | |
| Lower stretch (Brackishwater/Estuarine stretch) | Areekode | 11.62°N; 76.23°E | 74 | Kozhikode |
| | Azhinjillam | 11.95°N; 76.03°E | 101 | |
| | Feroke | 11.57°N; 76.68°E | 110 | |

The dominant species of the ecosystem were identified by plotting the dominance curve (Jennings *et al.*, 2001). The dominance curves were plotted to identify the most stable system across different seasons and stretches. The steepest and most elevated curve shows the lowest diversity and the most perturbed system state. Table 2 provides a detailed list of species. Hierarchical cluster analysis of Chaliyar fisheries data was carried out to identify the temporal patterns in species distribution.

The diversity analysis of the Chaliyar River indicated that it was a highly diverse aquatic environment. A total of 2,347 fish samples, representing 53 species belonging to 25 families and 11 orders, were recorded from the Chaliyar River during the study period (2017–2020). The analysis further indicated that the orders Cypriniformes and Perciformes dominated the river during the study period.

Table 3 shows a decline in fish diversity in the Chaliyar River in 2018 with a diversity index of 0.94. This decrease may be attributed to the major flood that occurred that year, which likely impacted the river’s fishery ecosystem. Fig. 2 shows the absence of orders such as Clupeiformes, Synbranchiformes, Cyprinodontiformes, Elopiformes, and Gobiformes, along with a minimal presence of Beloniformes (0.16%), Pleuronectiformes (0.04%), Siluriformes (0.04%), and Mugiliformes (0.41%). This pattern clearly indicates a decline in species diversity in 2018 compared to 2017 and 2019.

All orders except Anabantiformes showed a decline in diversity, which may be related to the ecological characteristics of each

order. The increase in Anabantiformes during the 2018 flood could be explained by the fact that the species in this group can tolerate extremely unfavourable water conditions and are often associated with turbid and stagnant waters, as reported by Pethiyagoda (1991). Such conditions are typically characterised by elevated levels of total dissolved solids (TDS), silicates, and other stressors (specific conductivity).

Cypriniformes (Fig. 2) contributed to 43.35% of ichthyodiversity in 2017 compared to 2018 (11.51%) and 2019 (29.72%). Perciformes contributed to 34.4 % in 2018 compared to 2017 (31.62%) and 2019 (60.34%). Fig. 3 indicates instability in the ecosystem during 2018, due to the dominance of a single species and ecological disturbances due to flood, as revealed by the dominance curve. The figure shows a stable aquatic ecosystem in the Chaliyar River in 2017 and 2019, with no single order predominating. The predominant species were *Rasbora daniconius* (14%) in 2019 and *Arius arius* (64.72%) in 2017.

The seasonal diversity pattern (Fig. 4) indicated higher diversity during POM 2017 (3.33), PRM 2017 (3.19), and MON 2019 (3.17). The high species diversity observed during POM 2017 and PRM 2017 is supported by Miranda (2001), who suggested that declining water levels during pre-monsoon and post-monsoon periods often resulted in the concentration of fish populations in small pools within rivers.

River shorelines tended to become highly unstable when water levels fluctuated (Agostinho *et al.*, 2007), which indirectly led to the

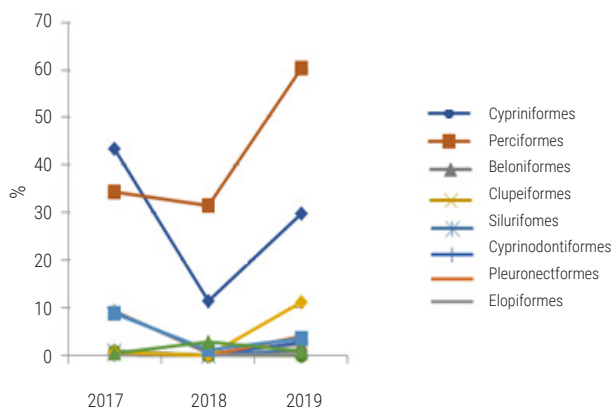


Fig. 2. Fish diversity of the Chaliyar River based on taxonomic orders

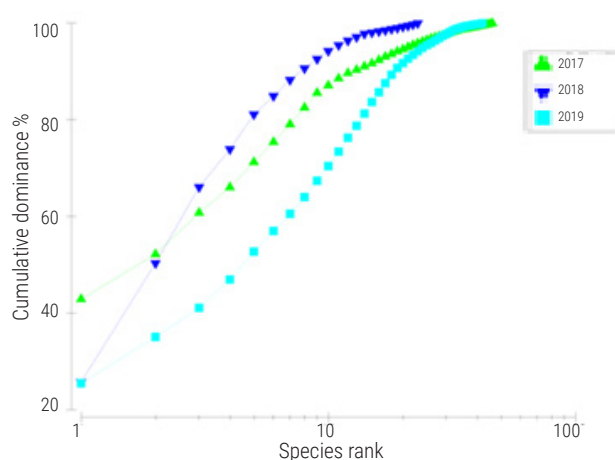


Fig. 3. Year-wise dominance curve of species abundance in Chaliyar river

Table 2. Chaliyar fish diversity

| Order | Family | Species | Conservation status |
|-------------------|-----------------|--------------------------------------|---------------------|
| | Ambassidae | <i>Ambassis ambassis</i> | L.C |
| | Carangidae | <i>Caranx ignobilis</i> | L.C |
| | Sciaenidae | <i>Daysciaena albida</i> | L.C |
| | Epinephelidae | <i>Epinephelus coioides</i> | L.C |
| | Epinephelidae | <i>Epinephelus diacanthus</i> | L.C |
| | Cichlidae | <i>Etilopius maculatus</i> | L.C |
| | Cichlidae | <i>Etilopius suratensis</i> | L.C |
| | Gerreidae | <i>Gerres filamentosus</i> | L.C |
| | Gobiidae | <i>Glossobius giurus</i> | L.C |
| | Sciaenidae | <i>Johnius</i> sp. | L.C |
| Perciformes | Leiognathidae | <i>Leiognathus bindus</i> | L.C |
| | Leiognathidae | <i>Leiognathus equulus</i> | L.C |
| | Lethrinidae | <i>Lethrinus</i> sp. | L.C |
| | Lutjanidae | <i>Lutjanus argentimaculatus</i> | L.C |
| | Lutjanidae | <i>Lutjanus fulviflamma</i> | L.C |
| | Monodactylidae | <i>Monodactylus argenteus</i> | L.C |
| | Scatophagidae | <i>Scatophagus argus</i> | L.C |
| | Carangidae | <i>Scomberoides tol</i> | L.C |
| | Siganidae | <i>Siganus javus</i> | L.C |
| | Sillaginidae | <i>Sillago sihama</i> | L.C |
| | Sphyraenidae | <i>Sphyraena jello</i> | L.C |
| | Terapontidae | <i>Terapon jarbua</i> | L.C |
| | Triacanthidae | <i>Triacanthus biaculeatus</i> | L.C |
| | Sparidae | <i>Acanthopagrus berda</i> | L.C |
| | Ariidae | <i>Arius arius</i> | L.C |
| | Bagridae | <i>Horabagrus brachysoma</i> | V.U |
| | Bagridae | <i>Mystus malabaricus</i> | L.C |
| Siluriformes | Siluridae | <i>Wallago attu</i> | L.C |
| | Cyprinidae | <i>Barilius bakeri</i> | L.C |
| | Cyprinidae | <i>Barilius gatensis</i> | L.C |
| | Balitoridae | <i>Bhavana australis</i> | E.N |
| | Cyprinidae | <i>Devario aquipinnatus</i> | L.C |
| | Cyprinidae | <i>Dawkinsia filamentosa</i> | L.C |
| | Cyprinidae | <i>Garra mullya</i> | L.C |
| | Cyprinidae | <i>Hypselobarbus curmuca</i> | E.N |
| Cypriniformes | Cobitidae | <i>Lepidocephalichthys thermalis</i> | L.C |
| | Cyprinidae | <i>Pethia punctata</i> | L.C |
| | Cyprinidae | <i>Puntius mahecola</i> | L.C |
| | Cyprinidae | <i>Rasbora daniconius</i> | L.C |
| | Cyprinidae | <i>Salmophasia boopis</i> | L.C |
| | Cyprinidae | <i>Haludaria fasciata</i> | L.C |
| | Channidae | <i>Channa marulius</i> | L.C |
| | Channidae | <i>Channa striata</i> | L.C |
| Anabantiformes | Pristolepidae | <i>Pristolepis fasciata</i> | L.C |
| | Nandidae | <i>Nandus nandus</i> | L.C |
| | Anabantidae | <i>Anabas testudineus</i> | L.C |
| Clupeiformes | Engraulidae | <i>Thryssa malabaricus</i> | L.C |
| | Clupeidae | <i>Anodontostoma chacunda</i> | L.C |
| | Psettodidae | <i>Psettodus erumei</i> | L.C |
| Pleuronectiformes | Soleidae | <i>Brachirus orientalis</i> | L.C |
| Scorpaeniformes | Platycephalidae | <i>Platycephalus indicus</i> | L.C |
| Elopiformes | Megalopidae | <i>Megalops cyprinoides</i> | L.C |
| Synbranchiformes | Mastacembelidae | <i>Mastacembelus armatus</i> | L.C |
| | Mugilidae | <i>Liza</i> sp. | L.C |
| Mugiliformes | Mugilidae | <i>Mugil cephalus</i> | L.C |
| | Mugilidae | <i>Valamugil cunnesius</i> | L.C |
| | Hemiramphidae | <i>Hyporhamphus limbatus</i> | L.C |
| Beloniformes | Belontiidae | <i>Strongylura strongylura</i> | L.C |
| | Belontiidae | <i>Xenentodon cancila</i> | L.C |

Table 3. Year-wise diversity indices

| Diversity indices | 2017 | 2018 | 2019 |
|-------------------|------|------|------|
| Dominance index | 0.32 | 0.50 | 0.34 |
| Shannon_H (SD) | 1.37 | 0.94 | 1.43 |
| Evenness index | 0.33 | 0.37 | 0.38 |

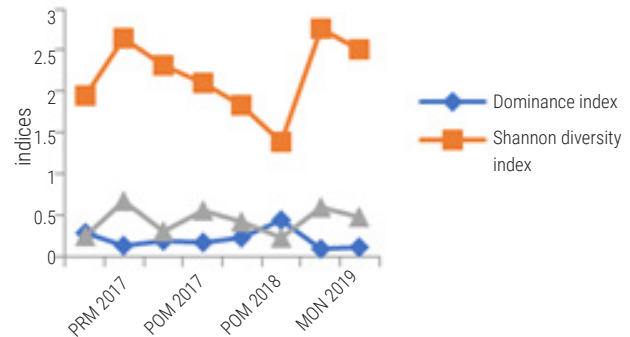


Fig. 4. Seasonal diversity indices of the Chaliyar River. PRM: Pre-monsoon, POM: Post monsoon, MON: Monsoon

aggregation of fish populations and consequently increased species richness in relation to seasonal water availability. This observation was consistent with the findings of the present study, which recorded the maximum number of species during POM 2017 (34 species), followed by MON 2017 (27 species) in the Chaliyar River. The observed pattern may also have been associated with increased food availability during these seasons. Miranda (2001) reported that rising water levels during monsoon and post-monsoon periods temporarily flood riparian vegetation, thereby enhancing the availability of food and shelter, supporting a greater number of fish species, as also observed in the present study.

The dominance index remained low across all seasons (Fig. 4), indicating a relatively balanced distribution of fish orders and a healthy diversity status of the aquatic ecosystem. Cluster analysis based on the Bray–Curtis similarity index was performed to classify seasons according to species composition. The dendrogram (Fig. 5) indicated that the fish assemblage during the monsoon season formed a distinct cluster compared to the other seasons. The hierarchical clustering resulted in two major clusters, separated at a cluster distance of approximately 7000. This demarcation clearly distinguished monsoon from other seasons and emphasised the impact of deluge during the monsoon, in 2018.

The assessment of the conservation status of the Chaliyar fishery (Fig. 6) indicated that the majority of fishes belonged to the least concern category. Species such as *Horabagrus brachysoma* (yellow spotted catfish) and *Bhavana australis* (Western Ghats loach), which are categorised as endangered, contributed around 2% of the ichthyodiversity (Table 1). *Bhavana australis* was known to inhabit rapids and clear water streams, which are characteristic of high-altitude ecosystems. *Horabagrus brachysoma* is a freshwater amphidromous fish and was observed at the Areecode Station in the lower stretch of the river.

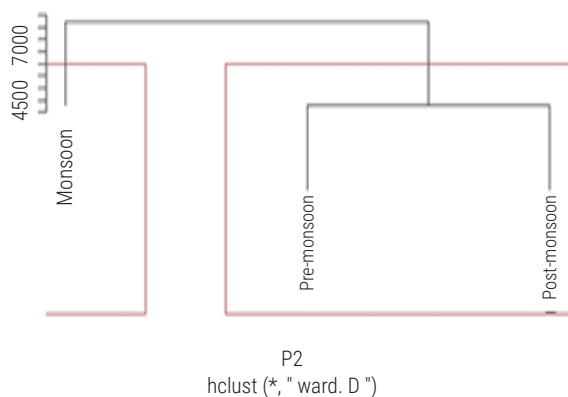


Fig. 5. Seasonal cluster analysis of the Chaliyar River fish assemblage

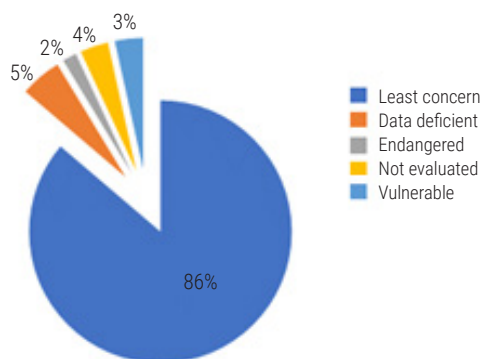


Fig. 6. Conservation status of the Chaliyar fishery

Approximately 2% of the fish diversity was also contributed by vulnerable species such as *Hypselebarbus curmuca*, which is a freshwater, benthopelagic, and potamodromous species. The analysis indicated the need to devise conservation programmes and awareness campaigns, particularly in the upper stretches of the river.

The paper highlights a pragmatic approach for implementing management measures in the Chaliyar River based on the scientific findings of the present study. It recommends community mobilisation through awareness, empowerment, and participation as an ongoing process rather than a one-time effort. Integrating indigenous knowledge into conservation planning and training communities in resource monitoring and sustainable practices are also proposed as key management strategies.

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