Advances in life science research

Fish community dynamics of the downstream estuarine zone of Meenachil River, Southern Western Ghats, Kerala, India

Letha P Cheriyan[a*]|Manu Oommen[b]

[a]Post Graduate and Research Department of Zoology, Mar Thoma College, Thiruvalla 689103, Pathanamthitta affiliated to Mahatma Gandhi University, Kottayam, Kerala, India
[b]Research and Post Graduate Department of Zoology, Catholicate College, Pathanamthitta, Mahatma Gandhi University, Kerala, India
Corresponding author email:lethapc@hotmail.com
Phone: +91 9497487331

ABSTRACT

Fish assemblages are one of the most sensitive and reliable indicators of the ecological status of streams and rivers. Fish composition and abundance pattern of the downstream estuarine zone of Meenachil River were studied from 2015 to 2019, along with assessing water quality parameters. A total of forty-one species of fish belonging to 20 families, 11 orders, and 33 genera were documented from the downstream zone of the Meenachil River during the study period. A continuous and drastic decline of the native species *Etroplussuratensis* and *Dawkinsiafilamentosa* was seen from 2018 to 2019, along with an unusual abundance of the secondary species *Megalops cyprinoides* and *Gerressetifer*. A complete shift in dominance and species re-ordering was noticed in the downstream fish community composition of the river after the extreme flash flood of 2018 occurred in Kerala. *Channa diplogramma* showed an increasing trend in abundance in the lower stretches of Meenachil River from 2017 to 2019. Higher values for TDS and conductivity, significantly fluctuating values for salinity, and lower values for dissolved oxygen were noticed in the downstream distributaries besides the drastic changes that happened in the community composition. The difference in ranks of the different species reflected a significant change in the community pattern resulting in a re-ordering of species. Re-ordering the position of a dominant species may be a significant driver of community change than species abundance or losses, which cannot be revealed by species richness or dissimilarities alone.

KEYWORDS

Urbanized river, Community dynamics, Species re-ordering, Estuarine zone, Species abundance

INTRODUCTION

Globally ecologists are now focusing on the causes of variability and how communities respond to these causes, the environmental stressors like climate change and anthropogenic disturbances over time. According to Fausch et al. (1990), fish assemblages represent one of the most sensitive and reliable indicators of the ecological status of streams and rivers. To develop and implement stream management strategies, it is essential to comprehend the natural variation of fish assemblage compositions (Ross, 1986).

Ecological communities are both fascinating and challenging to explore due to their dynamic nature, in which the abundances of co-occurring species vary throughout space and fluctuate over time. The species that are solely found in a particular area, combined with information on the gradient of habitat disturbance, may serve as bio-indicators to assess the ecological integrity of that region (Lasne et al., 2007). Community composition may gradually track subtle environmental changes or shift abruptly as environmental drivers approach ecological thresholds, potentially crossing a tipping point (Scheffer et al. 2001; Bestelmeyer et al. 2011). Many aspects of communities may change in response to natural or anthropogenic environmental disturbances that are the well-known causes of community dynamics.

Understanding how fish assemblages respond to the disturbances is critical in deciding species-specific conservation strategies. Hence the local fish conversationalists are eager to determine the species composition and spatial patterns of fish assemblages in ecologically sensitive regions. Smith et al. 2015 proposed that communities will exhibit either linear or nonlinear responses to chronic changes in environmental drivers through multiple processes, including phenotypic plasticity of individuals at relatively short time period, as well as through a re-ordering of species dominance patterns along with changes in species composition through colonization and local extinction. Presently, the anthropogenic influences on the aquatic systems go far beyond the natural variations, leading to a drastic reduction in water volume and the quality of water in Indian rivers (Ittekkot& Arain, 1986). Due to their limited capacity to dilute the toxins, riverine systems are particularly vulnerable since they lack the volume of open marine waters (Dudgeon et al., 2006).

Meenachil River, originating from Western Ghats, has a vibrant fish faunal diversity despite its short length span of 78kms. In addition to many ecologically unique and endemic species, the lower stretches of the Meenachil River support the state's economy by contributing food fish of high demand in Kerala and fish with high ornamental value. Since Meenachil is the only river in Kerala with human settlement from its source to its mouth, the entire river is overexploited. As the downstream estuarine zone of Meenachil River falls in the most densely populated houseboat tourism hub of Kerala, the Kumarakom village, the downstream fish fauna, and the waters of the region are forcefully subjected to indiscriminate human interventions.

The changes in community patterns over the years can be studied using the rank abundance curves. RACs provide additional insights into community dynamics, which cannot be revealed by species richness or dissimilarities alone (Avolio et al., 2015). Over time, rank of a species can change, which was particularly important as it reflects a large change in the community pattern resulting in re-ordering of species, which may re-order the position of a dominant species, may be a large driver of community change than species abundance or losses (Jones et al., 2017). Rank abundance curves visually depict species richness and evenness while representing assemblage variations contributed by the dominance of individual species during different seasons of the year.

Despite a few fish diversity surveys conducted by The River Research Centre, Thrissur, Kerala (2013) as a part of a general survey of the fish fauna of Kerala, and the "Meenachil Fish Count" of 2004 (Padmakumar et al., 2006) no such attempts have been made to study the fish assemblage patterns or the community composition of the fishes of Meenachil River. The present study aims at revealing the diversity, changes in fish community composition, and water quality parameters of the downstream confluence estuarine zone of Meenachil River from 2015 to 2019.

MATERIALS AND METHODS

Study Area

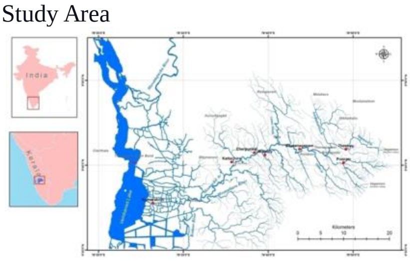

Figure 1 River map of Meenachil River showing the study location Kumarakom with several distributaries

The study area comprises the different distributaries of the Meenachil River in the downstream confluence zone, Kumarakom station, with longitude 76°26’07’’E and latitude 9°35’34” N (Fig. 1). Fish community composition was studied along with the water quality parameters from 2015 to 2019 during the pre-monsoon, monsoon and post-monsoon seasons. Fish sampling was done from the different distributaries of the downstream zone using cast nets and gill nets of varying mesh sizes specific to other species. Morphological identifications were made using the standard literature by Talwar and Jhingaran (1991), Tekriwal and Rao (1999) and Jayaram (2010). Present names of species were confirmed with the Eschmeyer’s Catalog of Fishes (Eschmeyer et al., 2017) and the Fishbase (Froese & Pauly 2020). Changes in the fish community composition and abundance from 2015 – 2019 were studied using evenness and dominance indices and the Rank Abundance Curves. Water quality parameters - TDS, conductivity, pH, dissolved oxygen, and salinity of the region during different seasons were studied using a Multiparameter portable meter, HANNA, Model HI 2020-02.

Diversity and species abundance assessment
Shannon's index, H' (Diversity index)

The Shannon index (H') was used to study the fish diversity. This average uncertainty increases with an increase in the number of species as the distribution of individuals among species become even.The equation for the Shannon function uses natural logarithms and is defined by the following function.

$$H' = -\sum_{i=I}^{S^*} (P1 \text{ In } pi)$$

Where H' is the average uncertainty per species in an infinite community made up of 'S' species with a non-proportional abundance P 1, P2, P3.. . . . . , PS
H’ = value of S-W diversity index.
pi = proportion of individuals in the ith species.
ln = natural logarithm.
S = Number of species in community
Evenness index
The evenness index is the measure of how equally abundant species are in a community. The evenness index used is J' of Pielou. This expresses H' relative to the maximum value that H' can attain when all of the species in the sample, S, are perfectly even with one individual per species.

$$J = H'/H'_{max} = H'/\log S$$

Simpson’s index (d) (Dominance Index)

Simpson’s index is based on the probability of any two individuals drawn randomly from an infinitely large community belonging to the same species. The Dominance Index is derived from the formula.

$$D = \frac{\sum ni\ (ni - 1)}{N(N - 1)}$$

Abundance models – Rank Abundance Curves (RAC)

In RAC, species are plotted on the horizontal axis according to their abundance rank, giving the most abundant species rank 1, the second most abundant rank two, and so on. This is plotted against the relative abundance on the Y- axis. The rank abundance curve visually reflects both species richness and species evenness. Species richness can be depicted with the number of different species on the chart, i.e., the number of species rank. Species evenness is depicted according to the slope of the line that fits the graph. A steep gradient indicates low evenness due to considerable differences between high-ranking and low-ranking species. A shallow gradient indicates high evenness as the abundances of different species is more similar.

RESULTS

Table 1 Fish community composition of the downstream estuarine zone of Meenachil River with taxa representations (2015-19).IUCN Status NT- Nearly Threatened, VU- Vulnerable DD- Data Deficient, NE- Not Evaluated, LC- Least Concerned. Distribution Status WG- Western Ghats, KL- Kerala, EX-Exotic. * Secondary species

SPECIES COMPOSITION		IUCN Status	Endemicity
	ORDER: CYPRINIFORMES		
	Family: Danionidae		
1	*Amblypharyngodonmelettinus* (Val, 1844)	LC	
2	*Horadandiabrittani* (Menon &RemaDevi, 1992)	LC	
	Family: Cyprinidae		
3	*Hypselobarbuskurali*(Menon &RemaDevi, 1995)	LC	WG
4	*Labeodussumieri* (Val, 1842)	LC	
5	*Dawkinsiafilamentosa* (Val, 1844)	LC	WG
6	*Puntius mahecola* (Val, 1844)	DD	KL
7	*Puntius vittatus* (Day, 1865)	LC	WG
8	*Systomussubnasutus* (Val, 1842)	LC	
9	*Puntius parrah*(Day, 1865)	LC	WG
10	*Puntius bimaculatus* (Bleeker, 1863)	NE	
11	*Gibelioncatla*(Hamilton, 1822)	LC	EX
	Family: Cobitidae		
12	*Lepidocephalichthysthermalis* (Val, 1846)	LC	
	ORDER: PLEURONECTIFORMES Family:Soleidae		
13	**Brachirusorientalis*	NT	
	ORDER:SILURIFORMES		
	Family: Horabagridae		
14	*Horabagrusbrachysoma* (Günther, 1864)	VU	WG
	Family: Bagridae		
15	*Mystusoculatus* (Val, 1840)	LC	WG
16	*Mystusgulio* (Hamilton, 1822)	LC	
	Family: Siluridae (buttercatfishes)		
17	*Ompokbimaculatus* (Bloch, 1794)	NT	
18	*Wallago attu* (Bloch & Schneider, 1801)	NT	
	Family: Heteropneustidae (stinging catfishes)		
19	*Heteropneustesfossilis* (Bloch, 1794)	LC	
	ORDER: CYPRINODONTIFORMES		
	Family: Aplocheilidae (panchax)		
20	*Aplocheiluslineatus* (Val, 1846)	LC	
21	ORDER:BELONIFORMES Family :Belonidae *Xenentodoncancila*	LC	
	Family: Hemiramphidae		
22	*Hyporhamphuslimbatus* (Val, 1847)	LC	WG
	ORDER: SYNBRANCHIFORMES		
	Family: Mastacembelidae (spiny eels*)*		
23	*Macrognathusaral* (Bloch & Schneider, 1801)	LC	
	ORDER: PERCIFORMES		
	Family: Ambassidae (Asiatic glassfihes/perchlets)		
24	*Parambassisranga* (Hamilton, 1822)	LC	
25	*Parambassisdayi* (Bleeker, 1874)	LC	WG
26	*Parambassisthomassi*(Day, 1870)	LC	WG
	Family: Scatophagidae		
27	**Scatophagus argus* (Linnaeus, 1766)	LC	
	Family: Gerreidae		
28	**Gerressetifer*(Hamilton, 1822)	NE	
	Family: Sillaginidae		
29	**Sillagosihama*(Forsskal, 1775)	NE	
	ORDER: CICHLIFORMES		
	Family: Cichlidae (pearl spot)		
30	*Etroplussuratensis* (Bloch, 1790)	LC	
31	*Pseudetroplus maculatus* (Bloch, 1795)	LC	
32	*Oreochromis mossambicus* (Peters, 1852)	LC	EX
	ORDER: GOBIIFORMES		
	Family: Gobiidae (gobies)		
33	*Glossogobiusgiuris* (Hamilton, 1822)	LC	
	ORDER: ANABANTIFORMES		
	Family: Nandidae (Leaf fishes)		
34	*Nandus nandus*(Hamilton, 1822)	LC	
	Family: Anabantiae (climbing perch)		
35	*Anabas testudineus* (Bloch, 1792)	DD	
	Family: Channidae (snakeheads)		
36	*Channa marulius* (Hamilton, 1822)	LC	WG
37	*Channa striata* (Bloch, 1793)	LC	WG
38	*Channa diplogramma* (Day, 1865)	VU	WG
	ORDER: ELOPIFORMES		
	Family: Megalopidae		
39	**Megalops cyprinoides* (Broussonet, 1782)	DD	
	ORDER: CLUPEIFORMES		
	Family: Clupeidae		
40	**Ehiravafluviatilis*(Deraniyagala, 1929)	DD	
	ORDER: CHARACIFORMES		
	Family: Serrasalmidae		
41	*Piaractusbrachypomus*(Cuvier, 1818)	NE	EX

Table 1 shows the community composition of the fishes of the downstream stretch of the Meenachil River from 2015 to 2019 with taxa representations. A total of forty-one species belonging to 20 families, 11 orders, and 33 genera were collected during the study, which included three nearly threatened (NT), two vulnerable (VU) species, four data deficient (DD), four nearly evaluated (NE) and 28 least concerned (LC) species (Table 3). Order Cypriniformes ranked first with 11 species, followed by Siluriformes with six species and Anabantiformes with five species (Figure 8). Out of the forty-one species reported, 12 were endemic to the Western Ghats (WG), and one was endemic to the Kerala region (KL). The study reported three exotic species (EX): Gibelion *catla, Oreochromis mossambicus,* and *Piaractusbrachypomus*.

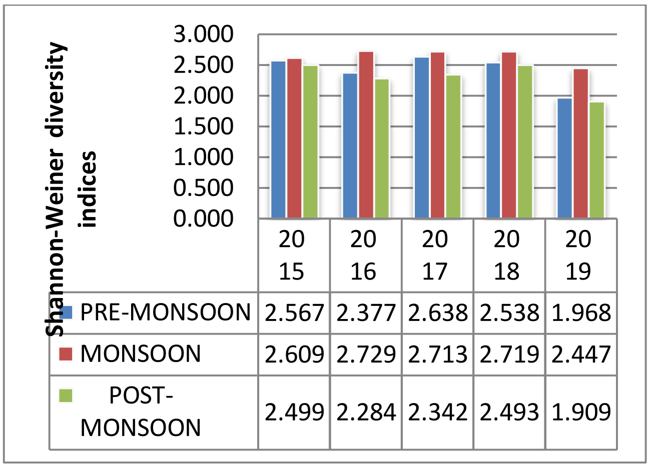

Figure 2 Shannon- Weiner diversity indices represented in the systematic sampling from the downstream zone of the Meenachil River during the different seasons (2015-2019)

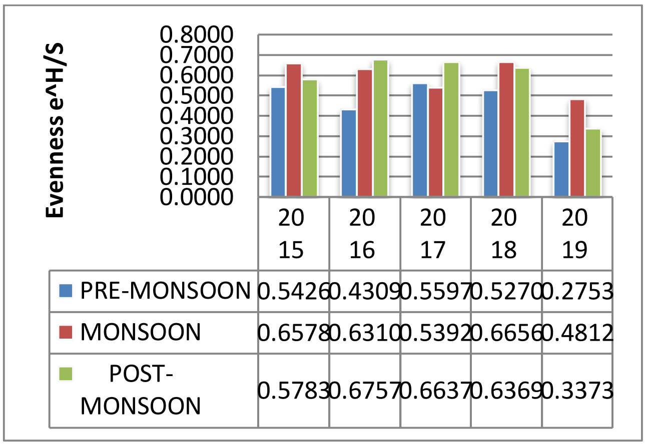

Figure 3 Evenness indices represented in the systematic sampling from the downstream zone of the Meenachil River during the different seasons (2015-2019)

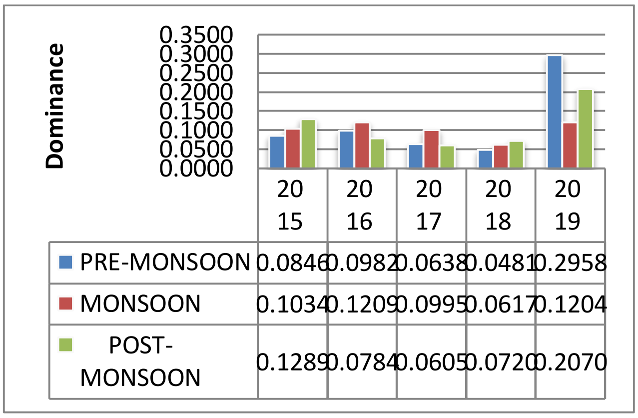

Figure 4 Dominance indices represented in the systematic sampling from the downstream zone of the Meenachil River during the different seasons (2015-2019)

The diversity and fish composition studies conducted in the downstream zone of the Meenachil River clearly showed a declining trend in the abundance of the native species of the region from 2018 to 2019, without a significant change in species richness (Fig 2.). A maximum diversity index of 2.729 was noticed in 2016, and a minimum of 1.909 during the post-monsoon of 2019. A more or less constant diversity value was maintained till 2018, after which a drastic decline was noticed. Along with the declining trend in diversity and abundance, another notable change was the re-structuring of the community composition with a change in the existing dominance pattern of the species (Fig. 4). Dominance indices varied significantly from a minimum of 0.0481 during the pre-monsoon of 2019 to a maximum of 0.2958 during the pre-monsoon of 2019. Minimum evenness of 0.2753 was recorded during the pre-monsoon of 2019 and a maximum of 0.6757 during the post-monsoon of 2016 (Fig 3.). A drastic decline in the abundance of *E. suratensis* and *D. filamentosa* is noticed from 2018 to 2019 (Fig. 5.4 & Figs 5.5). An unusual abundance of the secondary species *M. cyprinoides* and *G. setifer* during 2019 was also noticed (Fig 5.5). Among the native species, *E. maculatus* showed an unusual abundance in 2019 (Fig 5.5). *C diplogramma* showed an increasing trend in abundance from 2017 onwards.

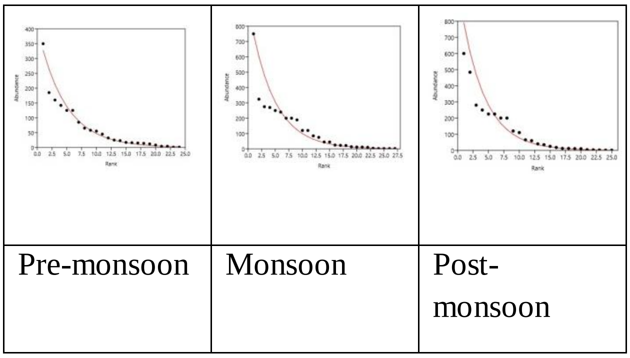

Figure 5.1 The abundance of fishes in Kumarakom showing the rank order during different seasons of 2015

D. filamentosa with 750 individuals showed highest abundance ranking first during the monsoon followed by *P. thomassi* with 324 individuals. *P. thomassi*ranked second throughout the seasons. *E. suratensis with 600 individuals ranked first during the postmonsoon and with 350 individuals during the pre monsoon.*

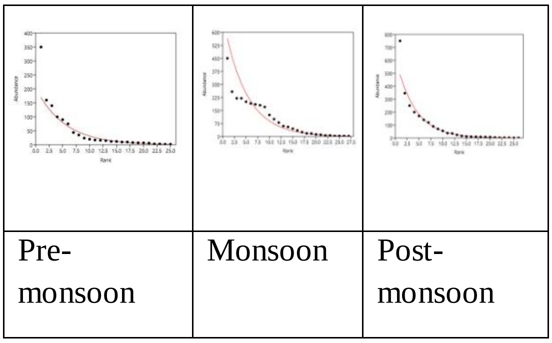

Figure 5.2 The Abundance of fishes in Kumarakom during different seasons of 2016

E. suratensis during pre monsoon and post monsoon outnumbered all other species with 350 and 750 induviduals respectively and *P. thomassi*with 160 individuals during the pre monsoon and 346 induviduals ranked second followed by *D. filamentosa.*

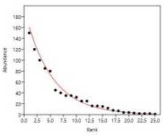	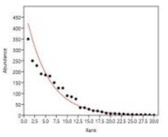	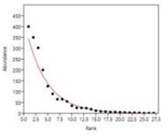
Pre-monsoon	Monsoon	Post-monsoon

Figure 5.3 The Abundance of fishes in Kumarakom during different seasons of 2017

A gradual decline in the abundance of *E. suratensis* with the shifting of the rank was noticed. *D. filamentosa* with 400 and 350 individuals during monsoon and post monsoon seasons ranked first followed by *P. thomassi*. All the other species showed a decreasing trend .The unevenness of abundance was reflected in the RACs of the three seasons.

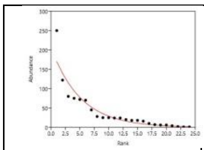	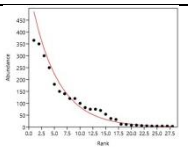	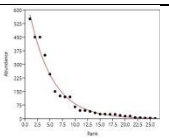
Pre-monsoon	Monsoon	Post-monsoon

Figure 5.4 The Abundance of the fishes in Kumarakom during different seasons of 2018

A sharp decline in abundance is noticed for *E. suratensis*and *D. filamentosa*with the complete absence of *P. thomassi* post monsoon after the flood of 2018 with increased abundance of *G. setifer* and *M. cyprinoides*. *P. maculatus* ranked first with 550 individuals during the post monsoon.

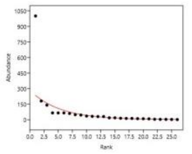	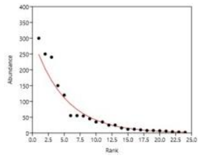	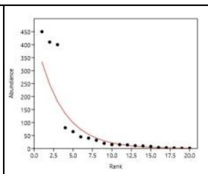
Pre-monsoon	Monsoon	Post-monsoon

Figure 5.5 The Abundance of fishes in Kumarakom during different seasons of 2019

E. maculatus showed an unusually high abundance outnumbering all other species with rank one during pre-monsoon and soon declined during the monsoon and post-monsoon seasons. An overall decline in all the native species was noticed throughout the year; this was clearly denoted by the drastic decrease in the species *E. suratensis* and *D. filamentosa*. A notable variation in abundance was reflected in the sudden increase of secondary species such as *G. setifer* and *M. cyprinoides* in the monsoon and post-monsoon periods. A complete restructuring of the fish assemblage downstream with the unexpected rank change was noticed, with *G. setifer* shifting to rank one and *M. cyprinnoides* to rank two. An increase in the abundance of *C. diplogramma* in the downstream stretch was noticed; scoring the 4th position outnumbering all other species.

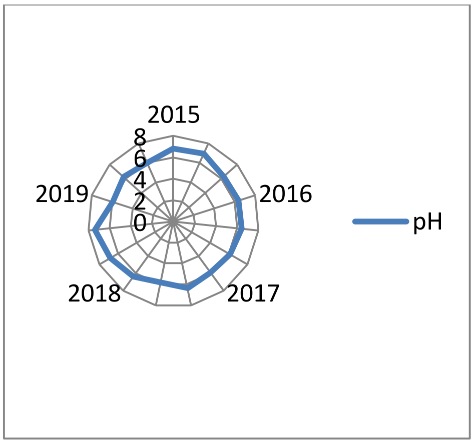

Figure 6.1 Spider graph representing changes in pH from 2015 to 2019

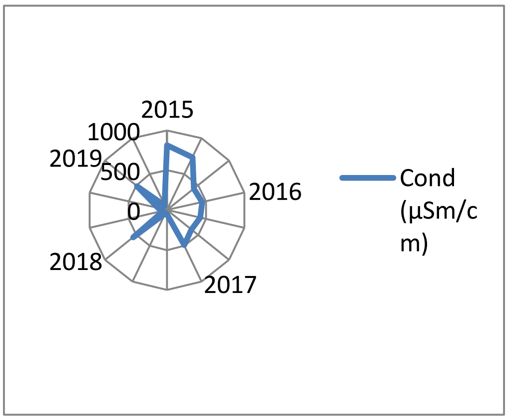

Figure 6.2 Spider graph representing changes in Conductivity from 2015 to 2019

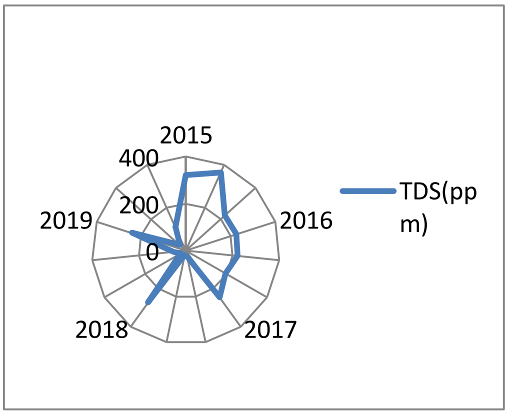

Figure 6.3 Spider graph representing variation in TDS levels from 2015 to 2019

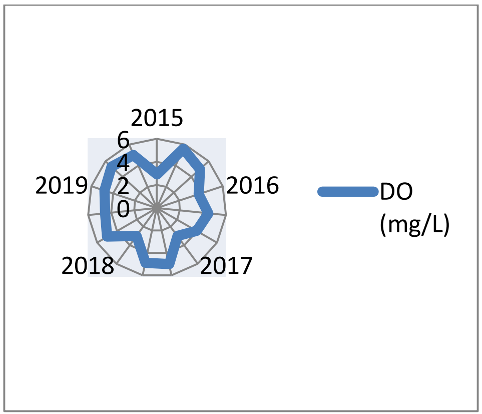

Figure 6.4 Spider graph representing changes in dissolved oxygen from 2015 to 2019

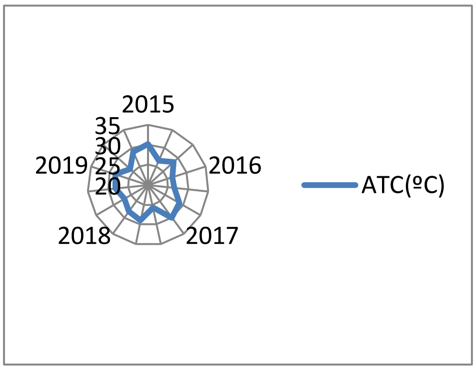

Figure 6.5 Spider graph representing changes in temperature from 2015 to 2019

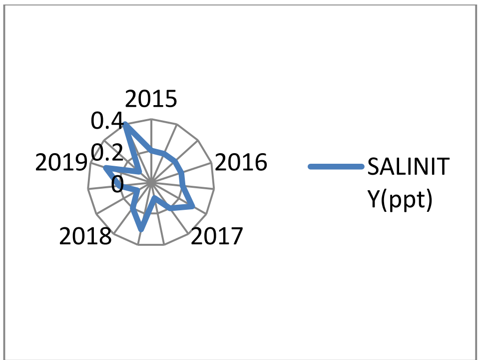

Figure 6.6 Spider graph representing changes in Salinity from 2015 to 2019

Water quality parameters studied showed significant fluctuations during the study period from 2015 to 2019. pH values varied between a minimum of 5.84 during the post-monsoon of 2017, and a maximum of 7.40 during the post-monsoon of 2018 after the flood (Fig. 6.1). Conductivity and Total dissolved solids (TDS) showed significant variations during different seasons from 2015 to 2019. A maximum conductivity of 815µSm/cm was noticed at Kumarakom during the pre-monsoon of 2015 and a minimum of 42.5µSm/cm during the post-monsoon of 2017 (Fig. 6.2). Maximum value of TDS was 365ppm during the monsoon of 2015 and a minimum of 21.3ppm during the post-monsoon of 2017 (Fig. 6.3). Minimum dissolved oxygen concentration of 2.64mg/L was recorded during the pre-monsoon of 2015 and a maximum of 5.6mg/L during the monsoon of 2015 (Fig. 6.4). Maximum water temperature of 30.1ºC was recorded during the pre-monsoon of 2015 and 2017 and a minimum of 25.8ºC during the monsoon of 2017 (Fig. 6.5). Salinity was found to be 0.1ppt during the monsoon of 2017, 2018, and 2019 and a maximum of 0.4ppt during the post-monsoon of 2019 (Fig. 6.6).

DISCUSSION

The fish fauna of the Meenachil River is affected by the alterations in their habitats due to indiscriminate human activities. Unpredictable climatic shifts, salinity intrusion, and stochastic events like landslides and floods exacerbated the outcome of anthropogenic interventions.

The continuously declining species abundance and diversity noticed in the downstream zone in the present study follow the above findings. Alterations in water quality parameters downstream of the Meenachil River due to various pollutants are further enhanced by the opening and closure of Thanneermukhom Bund at the Vembanadu confluence zone of the Meenachil River. The closure of the Thanneermukkom barrage constructed across the Lake every six months a year to prevent saltwater intrusion causes a temporary stagnation in the lower stretches of the river and the Lake with all the washed-out pollutants from the upper stretches brought downstream by the heavy monsoon showers.

From the year 2018 onwards, after the occurrence of an extreme flash flood in Kerala, a drastic and continuous decline in abundance of the native species, *Etroplussuratensis*, *Dawkinsiafilamentosa*, *Horabagrusbrachysoma*, and *Hyporhamphuslimbatus* was noticed in the downstream stretches of the Meenachil River (Cherian &Oommen, 2020). Habit et. al. (2006) and Oberdorff et. al. (2019) pointed out the significant deviation from the typical riverine fish diversity gradient pattern that existed in the past in tropical rivers as a response of the fish community to the human-induced habitat alterations that happened, especially in the lower stretches of the rivers. The decline in diversity and abundance of the native species, specifically *E. suratensis* and *D.filamentosa* in the lower stretches of rivers, were consistent with the habitat destruction and deterioration in water quality over these years due to anthropogenic interventions (Patton et al., 1998).The major threat for the drastic decline of *E. suratensis* in their home range is the rapid degradation of their natural habitats, which in turn might have impacted the recruitment and parental caring of this mouth-brooding cichlid. Roshni et al., 2017 reported the downturn of the state fish *Etroplussuratensis* in Vembanadu Lake due to over-exploitation. Biological characteristics of the species too, including low fecundity, smaller clutch size and comparatively average resilience makes its survival difficult in degrading ecosystems like the deteriorated downstream stretch of the river. Another significant change in the fish community composition downstream was the unusual abundance of the secondary species, *Megalops cyprinoides* during 2019 post-monsoon, which was reflected in the high dominance and shifting of ranks re-structuring existing community order. A perusal of the literature revealed that the Pacific Tarpon *M. cyprinoides* are highly adapted fishes with a modified air bladder that enables them to inhale atmospheric oxygen and tolerate oxygen deficiency (Seymour et al., 2004), allowing them to live in highly polluted environments.The migratory spawners entering the estuarine downstream might have flourished well due to their peculiar adaptive features, setting them at an advantage over the resident native species *H. limbatus*, *D.filamentosa*, *P.*

thomassi, *Systomussarana*, *M. oculatus*, *M. gulio, and H. brachysoma*, which were abundant in the previous years but were sharply declined from 2018-2019.

The downstream contamination had turned it into an 'organic plunk' in the past few years, as described by Kurup and Samuel (1985), favored only the proliferation of omnivorous fishes as they have surplus dietary material. The only native species that showed a consistent increase over the years, while all other species that declined, was *Channa diplogramma.* The dominance of Anabantiformes could be attributed to the presence of accessory respiratory organs, which enable them to survive in a wide range of environmental conditions and utilize atmospheric oxygen (Munshi, 1968). Food is also not a limiting factor as they were generalist feeders. The unusual abundance of *Etroplus maculatus* during the pre-monsoon of 2019 showed the salinity tolerance of the euryhaline species when salinity reached the highest value reported in the region during the entire study period. Extreme tolerance of the euryhaline species *E.maculatus* was reported by Shilta et al., 2016. Kurup (2010) reported reduced diversity in the lowermost stretch of Kallada River due to habitat interventions.

CONCLUSION

The current trend of decreasing native fish abundance and richness in the river's downstream zone reflects the magnitude of habitat changes and pollution imposed by anthropogenic activities. A complete shift in dominance and species re-ordering was noticed in the downstream fish community composition. The change in rank of the different species reflected a significant difference in the community pattern resulting from the re-ordering of the species, which may re-order the position of a dominant species, which may be a considerable driver of community change than species abundance or losses. It is possible to evaluate the ecological status of the riverine fish fauna by looking at deviations from the intended structural pattern in the community composition to implement effective conservation plans.

Acknowledgment

The authors are deeply indebted to the Principals, Dr. Varughese Mathew of Mar Thoma College Tiruvalla and Dr. Mathew P. Joseph of Catholicate College Pathanamthita for providing the necessary work facilities. We are greatly indebted to the fishing craft and gear operators Mr. Thankakuttan, Mr. Jony, Mr. Saji, and the "Meenachil River Restoration Forum" officials Mr. Philip Mani for their support during the fieldwork and data collection.

Conflict of Interest

The authors declare that they have no conflicts of interest

REFERENCES

Avolio M, La Pierre K, Houseman G, Koerner S, Grman E, Isbell F, Johnson D, Wilcox K (2015) A framework for quantifying the magnitude and variability of community responses to global change drivers. Ecosphere 6. Art 280.

Bestelmeyer BT, Ellison WR, Fraser KB, Gorman SJ, Holbrook CM, Laney MD, Ohman DPC, Peters FC, Pillsbury A, Rassweiler, RJ, Schmitt, Sharma S (2011) Analysis of abrupt transitions in ecological systems. Ecosphere 2, 12:129.

Cherian, L. P., Oommen M (2020) Post–flood changes in the fish fauna of Meenachil river, Kerala South India. Journal of Aquatic Biology & Fisheries, 8, 53-61.

Dudgeon D, Arthington AH, Gessner MO, Kawabata ZI, KnowlerDJ,LévêqueC, Naiman RJ, Prieur-Richard AH, Soto D, Stiassny ML, Sullivan CA (2006) Freshwater biodiversity: Importance, threats, status and conservation challenges. Biological Reviews 81, 163:182.

Eschmeyer, W. N., Fricke, R., & Van der Laan, R (2017) Catalog of fishes: genera, species, references

Fausch KD, Lyons J, Karr JR, Angermeier PL (1990) Fish communities as indicators of environmental degradation.American Fisheries Society Symposium 8, 123:144.

Froese, R., Pauly, D (2020) FishBase. World Wide Web Electronic Publication. www.fishbase.org, version (3/2020)

Habit E, Belk M, Tuckfield C, Parra O (2006) Response of the fish community to human-induced changes in the Biobío River in Chile. Freshwater Biology 51, 1:11.

Ittekkot V, Arain R (1986) Nature of the particulate matter in the river Indus, Pakistan. Geochim.Cosmochim.Acta 50, 1643:1653.

Jayaram KC (2010) The Freshwater Fishes of the Indian Region. Narendra Publishing House, Delhi.

Jones SK, Ripplinger J, Collins SL (2017) Species reordering, not changes in richness, drives long-term dynamics in grassland communities. Ecology Letters 20, 1556:1565.

Kurup BM (2010) Freshwater Fish Diversity of Kerala: Status, Threats, and Conservation Needs. In sonnenschein L, Benziger, A (Ed.) Conservation of Fishes in Kerala, India, pp. 116--121.

Kurup BM, Samuel CT (1985) Fish and fishery resources of Vembanad Lake. Proc. Symp. Harvest Post harvest Tech. Fish., Society of Fisheries Technologists 77:82.

Lasne E, Bergerot B, Lek S, Laffaille P (2007) Fish zonation and indicator species for the evaluation of the ecological status of rivers: example of the Loire basin (France). River Research and Applications, 23(8), 877-890.

Munshi JSD (1968) The accessory respiratory organs of *Anabas testudineus* (Bloch) (Anabantidae, Pisces). Proceedings of the Linnean Society of London 179, 107:126.

Oberdorff T, Dias MS, Jézéquel C, Albert JS, Arantes CC, Bigorne R, Carvajal-Valleros FM, De Wever A, Frederico RG, Hidalgo M, Hugueny B, Leprieur F, Maldonado M, Maldonado-Ocampo J, Martens K, Ortega H, Sarmiento J, Tedesco PA, Torrente-Vilara G, Zuanon J (2019) Unexpected fish diversity gradients in the Amazon basin.*Science Advances*5, 9:eaav8681

Padmakumar KG, Bindu L, Joseph N, Sreekumar B, Sunil G, Unnikrishnan N, Kurien JS (2006) River Fish Inventory under Participatory Approaches ‘Meenachil Fish Count 2004. Environment and Ecology 24, 584:590.

Patton TM, Rahel FJ, Hubert WA (1998) Using historical data to assess changes in Wyomings fish fauna. Conservation Biology 12, 1120:1128.

Roshni K, Cr Renjithkumar, Madhusoodana K (2017) The downturn of the state fish, Etroplussuratensis in vembanad lake-a ramsar site, Kerala, India.

Ross ST (1986) Resource partitioning fish assemblages: a review of field studies. Copeia 352:388.

Scheffer M, Carpenter S, Foley J (2001) Catastrophic shifts in ecosystems. Nature 413, 591:596.

Seymour R, Christian K, Bennett, Michael, Baldwin J, Wells R, Baudinette, R (2004) Partitioning of Respiration between the Gills and Air-Breathing Organ in Response to Aquatic Hypoxia and Exercise in the Pacific Tarpon, *Megalopscyprinoides*. Physiological and biochemical zoology: PBZ 77, 760:777.

Smith WE, Kwak T (2015) Tropical insular fish assemblages are resilient to flood disturbance. *Ecosphere 6*, 1:16.

Talwar PK., Jhingran AG (1991) Inland Fishes of India and Adjacent Countries, Vol. I, II. Oxford and IBH Co., Pvt. Ltd., New Delhi.

Tekriwal KL, Rao AA (1999) Ornamental and aquarium fish of India. Kingdom Books, England.