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Post- Flood Changes in the Fish Fauna of Meenachil River, Kerala, South India

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Abstract

Extreme flash floods along with landslides occurring out the expected hydrological range can cause significant consequences in the riverine ecosystems ranging from changes in fish assemblage pattern and diversity to the elimination of a particular species. Kerala state experienced an extreme flash flood on August 15, 2018, which was recorded as the worst in the history of Kerala ever since a similar one occurred in 1924. The forty-four rivers, including Meenachil River, were severely flooded due to the abnormally high rainfall received from June 1, 2018 to August 19, 2018. Analysis of the impact of the major flood on the riverine ecosystem requires observations shortly before and after the event, which are rare because of the unpredictable occurrence of such events. The present study reports the effect of the flood on the fish diversity of Meenachil River, an important riverine system of Kerala. The data on the pre-and post-flood changes in the fish diversity of Meenachil River showed a drastic decline right from the upstream till downstream following the flood. Even though diversity indices showed an immediate reduction after the flood, a rapid recovery was noticed in the upstream and midstream zones except downstream. Majority of the species exhibited a greater relative abundance during post-monsoon of 2018. *Garra mullya* and *Nemacheilus triangularis* were outnumbered in the upstream, *Labeo dussumieri*, *Channa diplogramma* and *C. striata* midstream and *Puntius mahecola*, *Gerres setifer* and *Megalops cyprinoides* in the downstream ensuing the flood. A more or less complete absence of *Parambassis thomassi* and a decline in the number of *Etroplus suratensis* was noticed. Three exotics, including *Piaractus brachypomus*, and the lack of *Clarias gariepinus* were noticed.

Keywords: Extreme flash flood, Meenachil River, Fish Assemblage, Post-flood

1. Introduction

Extreme flash floods and landslides cause significant changes in the earth's natural environment. Though these natural disasters can be devastating to population centers, they have been an integral part of nature's renewal process showing the remarkable ecological resilience. Even though the stream ecologists consider flood as a major disturbance to the riverine ecosystem, the flood can reconfigure the channel morphology and the associated habitats and also reset the riparian along the margins which can be beneficial in the long term to the riverine fauna. (Hupp and Bornette, 2003). Flood Pulse concept (Junk *et al*. 1989) highlights the importance of frequent flooding for lateral transfer of water, organic and inorganic nutrient between a river and its flood plain, and in channel fluctuation of discharge called flow pulses to create a transposing pattern of aquatic and terrestrial habitats in the river (Tockner *et al*., 2000).

Flooding significantly influences the stream fish assemblages, although the immensity and duration of its effect vary among sites and with flood severity (Resh *et al.*, 1988). The greater habitat and resource availability created by the flood induced environmental changes can enhance the productivity, and increase the species abundance, richness, evenness and diversity when compared to the usual flow regimes (Junk *et al*., 1989). Regular and expected floods have little long-term effects on species endurance and assemblage stability. (Pusey *et al*., 1993; Dollof *et al*., 1994; Halls and Welcomme, 2004). Severe floods occurring outside the predictable temporal and hydrological range may be considered as major stochastic events (Delong *et al.*, 2001), the impacts of which may range from variations in species richness, size and age structure of populations to the exclusion of a particular species and the disruption of assemblage structure and diversity. (Puckridge and Walter, 2000). The downslope movement of large landslide masses can drastically alter the habitat conditions of the fishes, which may result in the movement and re-distribution of spawning gravels, addition of new sediment and woody debris to the channel system (Swanston, 2000). Even though this debris flows in the short term can have disastrous effects on fish population in mountain streams, both flora and fauna can recover with time from the temporary damage occurred in their habitats.

The impact of severe floods on population structure and assemblage attributes of fishes remain mostly unknown, although there is evidence that considerable numerical fluctuations may occur in some native species (Pires *et al.*, 1999; Magalhaes *et al*., 2003; Schlosser and Collares Pereira, 2007). The physical habitats of flood plain rivers are significantly altered by severe floods resulting in the re-structuring of the riverine communities (Poff *et al.*, 1997; Ward *et al*., 1999). Study on the impact of an extreme flash flood on the riverine ecosystem requires pre- and post-flood disturbance data, which are very rare due to the unpredictable occurrence of such events (Bischoff and Wolter, 2001; Hajdukiewicz *et al.*, 2018). Very few works have been conducted on the impact of the flood on the riverine diversity of Kerala (Padmakumar *et al.*, 2019; Raghavan, 2019). Kerala, one of the Southern

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states at the tip of the Indian peninsula, experienced an extreme flash flood probably the worst in a century and the history of Kerala ever since a similar one happened in 1924. Kerala received actual rainfall of 2394.1 mm from June 1 to August 22, 2018, which exceeded the normal rainfall of 1701.4 mm by 41% (IIRS, 2018) Idukki district where the major catchments are located received the highest rainfall of 3555.5 mm during the same time with two significant spells of rainfall during July 17 to 20 and August 14-19, 2018) resulted in the formation of two flood waves. The extreme rainfall at 1-15 days duration in August 2018 in the catchment, upstream of the three major reservoirs- Idukki, Kakki and Periyar had the return period of more than 500 years (Mishra *et al.*, 2018). The unprecedented extreme rainfall and almost full reservoirs in the catchments resulted in a significant release of water within a short span of time, which resulted in the severe flooding of almost all the 44 rivers of Kerala. The present study reports the effect of the recent flash flood on the changes in the fish diversity of the Meenachil River.

2. Materials and Methods

2.1 *Study area*

Four major streams fed by several minor tributaries originating from the Cardamom Hills of Southern Western Ghats confluences to form Meenachil River, the lifeline of Central Kerala (Fig. 1). The perennial river with a length of 78 km has a basin area of 1272 km², falling within 57 panchayats and three municipal towns in Kottayam as well as in Vaikom, Kanjirappally, Meenachil and Changanacherry Taluks. The watershed extends from a latitude of 9°25' to 9°55' and longitude of 76°20' to 76°55'. The tributary originating from the northeastern part of the sub water shed Anakunnumudi at an elevation of +922m above MSL flow southwards and joins with the tributary originating from Illikkal kallu to form the Kadapuzha Ar. It continues the southerly flow and joins with the tributary, Konipadu thodu to form the Kalathukadavu Ar. Theekoy stream originating at Vagamon Kurisumala at an elevation of 1050m above MSL confluence with Kalathukadavu Ar and continues its southerly flow. Poonjar stream originating from Kolahalamedu at an elevation of 1156m above MSL joins with Teekovil Ar at the southern side of Erattupetta to form the Meenachil River. After Erattupetta, Meenachil River takes a sharp turn and flow westwards to receive the fourth major tributary, Chittar originating at an elevation of 530m above MSL from Anangampadi. The river continues its westerly flow receiving many minor tributaries connected to floodplains at the midstream zone. Reaching downstream, the river splits up into numerous inter-connecting distributaries and finally joins the Vembanad Lake through a series of crisscrossing channels before emptying into the Arabian Sea.

Unlike the other major rivers of Kerala which confluences to Vembanad Lake, Meenachil is one of the undammed rivers of Kerala and hence the flooding of the river was only due to the abnormally extreme precipitation occurred in the catchment area and not due to the sudden discharge from the reservoirs.

The heavy rainfall started from May 27 onwards reached its peak by July 17 resulted in the first flood wave in Meenachil River. Once these floodwaters receded the second wave, which was flashy with the peak on August 15 occurred. The monsoon season of 2018 has been anomalously wet as the majority of the state received more than 1500-2000 mm rainfall from May 25 to August 21, 2018. From August 8 to August 17 the state received more than 500mm rainfall with a surplus of 40 to 50%. Rainfall occurred on August $15^{th,}$ and 16^{th} was abnormally higher as a large part of Kerala received more than 200mm rainfall each day which created a saturated condition that

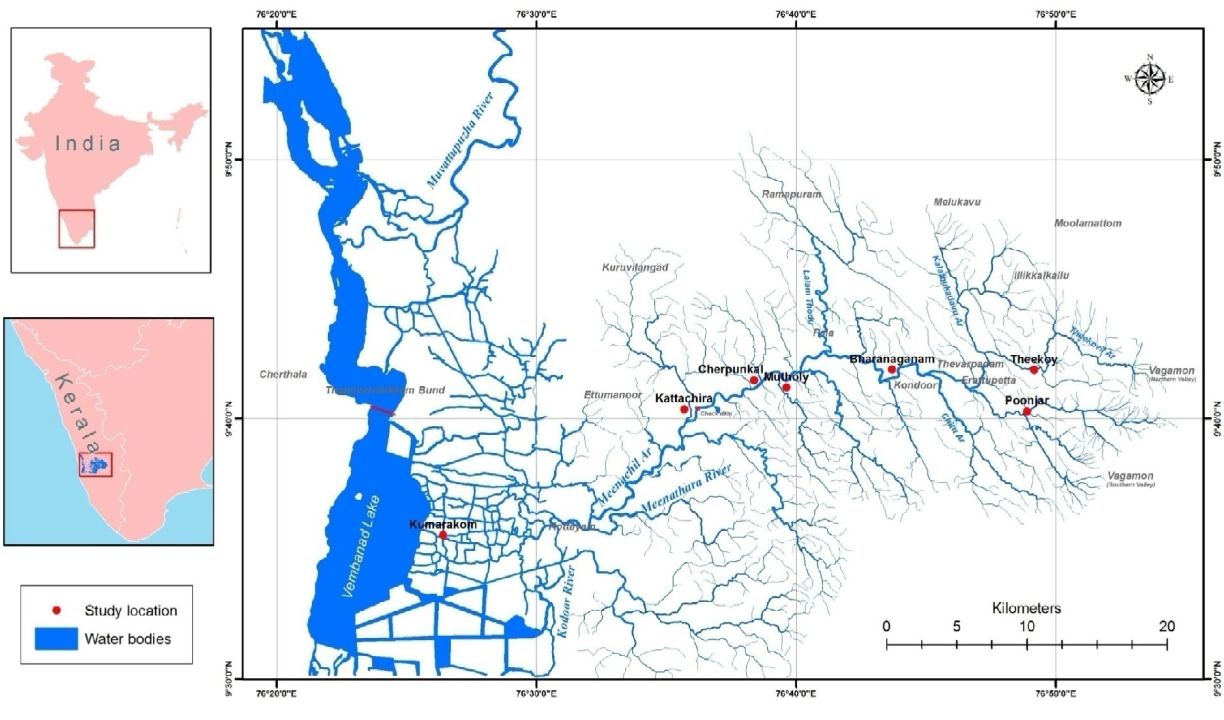

Fig. 1. River map of Meenachil River basin showing the sampling sites

caused the enormous flooding. Landslides occurred in close proximity to the headwaters Theekoy of Meenachil River along with the heavy monsoon showers. Hence the major impact on Meenachil Riverine ecosystem is the combined effect of the extreme flash flood and landslides.

2.2 Fish sampling and diversity assessment

Pre-flood data were obtained from the fish diversity and habitat studies carried out in the study area from 2015 onwards (i.e., 2015-2019). Post-flood sampling started in August 2018 and continued till December 2019. Seven representative sampling sites (Fig. 1) falling in the three different geographical zones of the river include the upstream, midstream and downstream stretches. Pre-monsoon sampling was done from February to May, monsoon from June to September and post-monsoon from October to January every year. Fishing was carried out with the help of fishing expertise, the local fishermen. Sampling was done on a monthly basis in which the upstream and midstream sites were sampled together on one day, and the downstream stretch on the next. Fishing was done early in the morning (5:30-8:30 am) and late in the evening (6:00-9:00 pm) where maximum number of individuals had been successfully sampled. In open areas, the casting was done from the boats or on a special base prepared in the river using bamboo poles. Cast nets (8ft) and gill nets (2-2.5cm mesh size) were used. The cast nets were operated 10 times, covering a distance of about 200m^2 in the sampling area. In addition to the cast nets, gill nets of different mesh sizes were set in specific areas during the late evening hours with the collection being assisted by local fishermen early in the morning. Specially designed traps and unique indigenous methods were also used for species like *Labeo dussumieri* and catfishes. Loaches from the upstream sites were captured using fine-meshed cotton clothes or mosquito nets. Hooks and lines were used to collect the species like *Mastacembelus armatus* and *Wallago attu* from the lower stretches. Nearby landing centers were also surveyed to monitor and look for the presence of any species which were not available during the experimental fishing. Secondary data regarding fishes had been collected from the local fishermen community and those residing at the banks of the major tributaries.

The numbers of species caught during each sampling were recorded. Voucher specimens were preserved in 70% ethyl alcohol, and tissue samples for molecular studies were preserved in 95% ethanol. Remaining fishes had been immediately released into the river. Morphological and morphometrical identification was made using the standard literature by Menon 1993; Talwar and Jhingran1991; Jayaram 2010. Present species names were confirmed with Fishbase (Froese and Pauly 2007) and Eschmeyer's Catalog of Fishes. Local details and names of the species were confirmed using the checklist by Bijukumar and Raghavan, 2015.

3. Results

A total of 57 species belonging 13 orders and 27 families were recorded from Meenachil River during the survey from 2015 to 2019. Of them, cyprinids were the most dominant group in the community. Of these, 36 belonged to the Least Concern, seven were Nearly Threatened, six were Data Deficient and four in the vulnerable category (IUCN, 2018).

The diversity changes in the fish fauna of the Meenachil River in the seven sampling sites are given in the Table 1. The post-monsoon sampling results were analyzed for elucidating the changes in the fish community structure of the Meenachil River after the flood. The number of species represented in the post-monsoon samples of Theekoy, Poonjar, and Bharanganam, ranged between 20-25, Mutholi, Cherpunkal and Kattachira ranged between 27-33 and that of Kumarakom between 25-27. However, the sampling immediately after the flood resulted in the marked decline of the species representation in the samples (Fig. 2). The number of species in Theekoy was 21-23 in 2015-2019 monsoon samples dwindled to 14. The pattern of decline had followed a similar trend in all the seven locations. However, this drastic decline was a temporary phenomenon and the diversity restored before the next post-monsoon season as evidenced from the subsequent sampling during the post-monsoon of 2018 and pre-monsoon, monsoon and post-monsoon periods of 2019 (Fig. 2).

The post-monsoon samples analyzed from different locations of Meenachil River showed a significant increase in the number of species to as high as 39 species in certain locations like Pala Mutholi (midstream) during the year 2018. This was a temporary post-flood phenomenon that lasted for a short period. The fish communities were restored to the normal level after the next monsoon season. The sudden changes due to flood were clearly reflected in the midstream stretch of the river (Fig. 2).

Table 1. Number of Taxa represented in the sampling during pre-monsoon, monsoon and post-monsoon periods of 2015-19 and flood period

	2015			2016			2017			2018			2019			2018
	PR	M	PM	PR	M	PM	PR	M	PM	PR	M	PM	PR	M	PM	Flood
THEEKOY	21	21	23	19	20	23	17	17	21	17	19	21	21	23	22	12
POONJAR	20	20	20	18	19	19	17	18	15	16	21	20	20	20	20	14
BHARANGANAM	23	24	24	22	21	21	14	14	15	17	19	23	22	24	23	14
PALA MUTHOLI	23	34	27	29	35	29	26	30	22	27	37	39	38	36	30	23
CHERPUNKAL	26	33	33	26	31	26	24	32	27	18	35	35	34	32	32	18
KATTACHIRA	32	35	33	32	33	29	32	32	28	28	35	36	36	34	32	25
KUMARAKOM	24	27	25	25	27	26	25	30	27	24	28	26	26	24	20	20

Fig. 3 provides a comparison of the number of fish species in the samples of the monsoon period of 2015-2019 with that of the flood period. It is discernible that there is an apparent decline in the number of species during the flood period compared to monsoon data of 2015-2019.

The species that had notably disappeared from the samples of Theekoy during the flood period was *Macrognathus guentheri*, *Nemacheilus triangularis, Barilius bakeri* and *Mystus montanus* which was common in all the samples during 2015-2018. *Etroplus maculatus*, *Hypselobarbus kurali*, *Pethia ticto, Haludaria fasciata* and *Salmostoma boopis* which were frequent in the samples from Poonjar were entirely absent in the flood samples. *Parambassis thomassi*, *Haludaria fasciata* and *Rasbora dandia* were not represented in the flood sample from Bharanganam, which were quite common in the river site prior and after the flood. The Pala Mutholi section of the river harbours 34 different fish species. *Devario malabaricus*, *Ehirava fluviatilis*, *Horabagrus brachysoma*, *Mastacembelus armatus*, *Nandus nandus*, *Parambassis thomassi* and *Pethia ticto* were not represented in the flood samples from Pala Mutholi. *Puntius mahecola*, *Parambassis thomassi* and *Pethia ticto* which were outnumbered in the samples of Kattachira during 2015-18 periods were absent in the flood samples. *Horabagrus brachysoma*, *Parambassis thomassi* that were quite common both in our samples and catches of fisherfolk of Kattachira were totally absent for a period three months. The occurrence of invasive exotic species**,** *Piaractus brachypomus* and *Oreochromis mossambicus* were represented in post-flood sampling in the midstream and downstream stretch of the river. These species were not present previously in the pre-flood samples.

The (Simpson 1-D) values were taken to evaluate the dominance. An increase in Simpson 1-D value indicates a decrease in diversity. The increased dominance indices of the upstream sites Theekoy and Poonjar during the monsoon of 2019 indicated a higher abundance of certain species (Fig. 4). Post-monsoon of 2019 showed a decrease in the dominance values for the upstream indicating the restoration of fish diversity after the flood (Fig. 5) while the dominance index of Kumarakom continued to increase from post-monsoon of 2018 to monsoon of 2019. This reflected the declining diversity of the downstream stretch of the river. The species outnumbered in the flood samples were *Garra mullya* from the upstream, *Channa diplogramma* from the midstream and *Etroplus suratensis* from the downstream.

The evenness index communicates the degree up to which the abundance is equal among the species present in the samples. Theekoy and Poonjar sites showed the least evenness during the post-monsoon of 2019 corresponding to an increased abundance of the species *Garra mullya*, *Nemacheilus triangularis* and *Haludaria fasciata*. From Fig. 6 and Fig. 7, it is discernible that the evenness and the diversity of the upstream were re-stored to normal as in the previous years. The high evenness indices during the flood period indicated the poor diversity and high abundance of certain individuals. An increasing trend of evenness can be clearly noticed from the post- monsoon of 2018 towards post-monsoon of 2019 except in the Kumarakom downstream zone. In the Kumarakom zone, the evenness was found to be lower than the previous years (2015-2018) indicating a drastic decline in diversity.

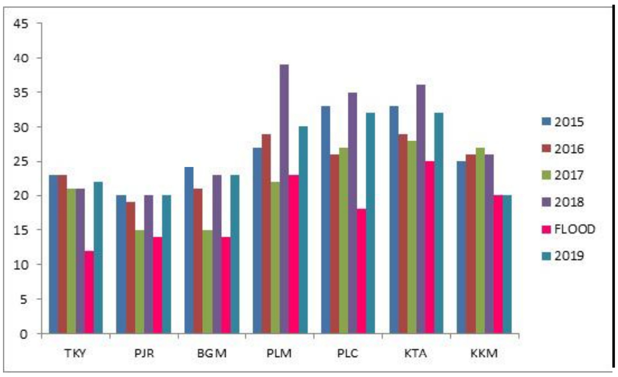

Fig. 2. Comparison of the no. of taxa in the post-monsoon samples of 2015-19 periods with flood

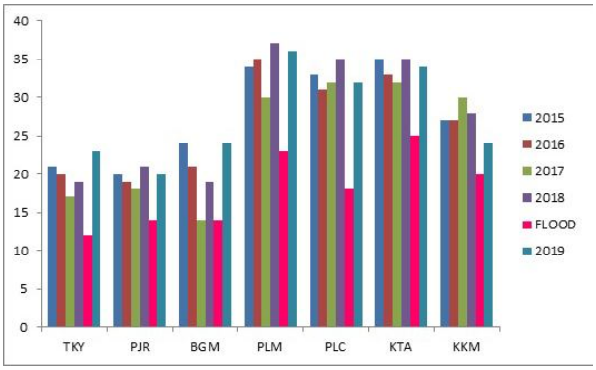

Fig. 3. Comparison of the no. of taxa in the monsoon samples of 2015-19 periods with flood

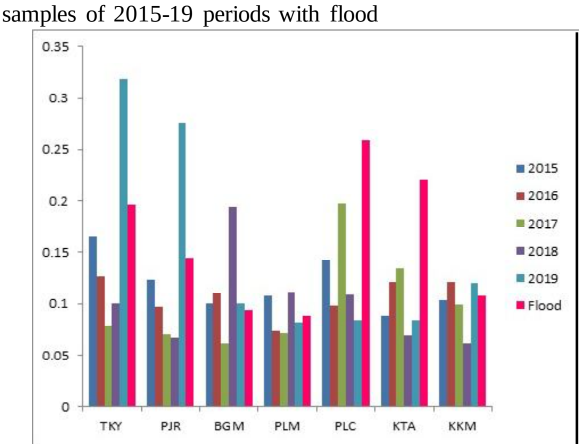

Fig. 4. Comparison of dominance indices during the monsoon 2015-19 and flood

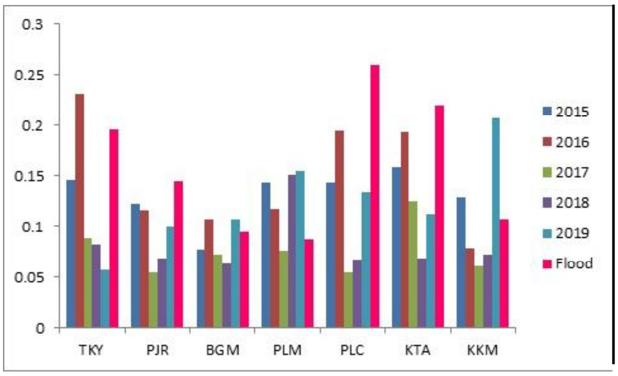

Fig. 5. Comparison of dominance indices during the Post-monsoon 2015-19 and flood

TKY-THEEKOY; PJR-POONJAR; BGM-BHARANGANAM; PLM-PALA MUTHOLI; PLC-PALA CHERPUNKAL; KTA-KATTACHIRA; KKM-KUMARAKOM

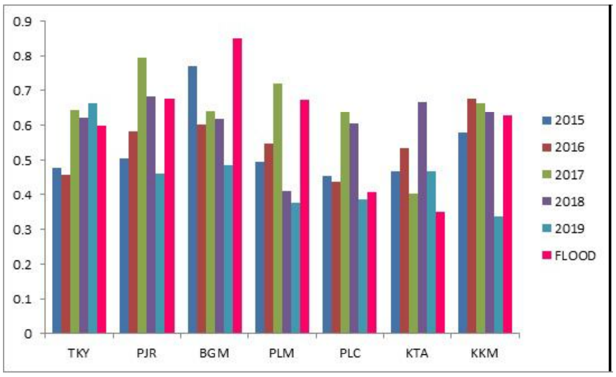

Fig. 6. Comparison of the post-monsoon evenness indices of 2015 – 19 with the flood samples

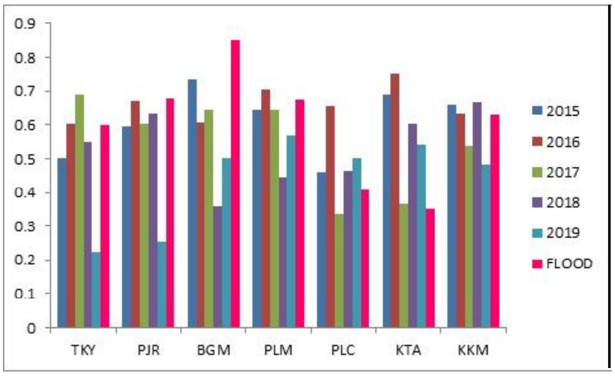

Fig. 7. Comparison of the monsoon evenness indices of 2015-19 with the flood samples

4. Discussion

The effects of single hydrological extreme events are highly context-dependent ranging from deleterious to beneficial, and reliant upon event magnitude, extent and timing relative to the life cycle stage of specific species (Ledger and Milner, 2015) The impact of a severe flood on population structure and assemblage attributes remain primarily unknown. However, there is evidence that considerable numerical fluctuations may occur in some native species (Pires *et al*., 1999;). There is currently no data available to compare the impact of flood or landslides on the fish assemblage of Meenachil River with any of the Indian rivers.

The extreme flash flood and landslide caused an intense disturbance in the ecosystem of Meenachil River leading to a marked decline in the number of species in the sampling from the upstream, midstream and downstream sites immediately after the flood. The river was affected twice by the flood waves; the first one being along with a major landslide at the headwaters during July 17-18 followed by the second extreme and intense flash flood during Aug 15-19. The landslide debris deposited over the river substratum has contributed to a drastic and sudden deterioration of fish habitat, and spawning grounds, and also the water quality of Meenachil River. However, a rapid recovery process- recruitment and re-colonization of the fishes in the upstream and midstream habitats of Meenachil River was evident from the post-flood data (Figs. 8-10). The landslide caused disasters may even have positive effects on the habitats of flora and fauna of a river which allows species recovery in the long term (Robert *et al*., 2001). The present study concludes that the recovery has not taken much time.

Post-flood changes in habitat can be correlated with the fish abundance upstream. 2016-18 showed a gradual decline in the number of the following upstream species *Nemacheilus triangularis, Garra mullya* and *Haludaria fasciata* which showed a remarkable increase in the number during the post-monsoon after flood and is continued till 2019, supports the fact that floods flush out fines from bed material making the river substratum suitable for the spawning of lithophilic fishes (Hajdukiewiez *et al*., 2018). The river course upstream was also re-established by washing out the encroachments re-storing the pebble substratum preferred by hill stream species (Fig. 11, 12).

The post-monsoon samples from different location of Meenachil River showed an increase in the number of species to even 39 species in Pala Mutholi within the mid-stream stretch of the river. The midstream abundance is following the Flood Pulse Concept, which postulates that the fish abundance will increase after floods as river-floodplain connectivity augments habitat and resources availability. (Junk *et al*., 1989) The newly expanded floodplain habitat provided an immediate influx, detritus, and invertebrates. With time, greater nutrient availability and aquatic primary production which might have resulted in highest fish abundance and per-unit- area density, typically occur as the flood water receded. The receding period represented a time of resource abundance which enhanced the piscivore growth and its abundance (Jepsen *et al*., 1999), which were reflected in the outnumbering of *Labeo dussumieri* and *Puntius machecola* in the midstream (Kattachira site) and *Etroplus suratensis* from the downstream site (Kumarkom). Post-flood diversity analysis of mid-stream supported the prediction and previous flood observations (Jurajda *et al*., 2006; Zampatti and Leigh 2013; Stoffels *et al*., 2014)Pala Mutholy, Cherpunkal and Kattachira, connected to the major flood plains of Meenachil River showed a marked increase in the relative abundance of many species after the flood. Flood plain inundation likely promoted movement and provided favourable spawning and foraging conditions for adults (Steffensen *et al*., 2014) which can be related to the tremendous increase in numbers of adult and gravid *Labeo dussumieri, Channa diplogramma, Channa marulius, Channa striata, Heteropneustes fossilis, Anabas testudineus* also showed a notable increase in number in the mid-stream stretch of river. A sudden increase in the number of *Etroplus suratensis* in the mid-stream stretch of river is also a notable change. Floods connect rivers with flood plains and supply nutrients and organic matter to aquatic-terrestrial transition zones, stimulating biological productivity and habitat heterogeneity (Junk *et al*., 1989; Ward and Stanford 1995; Tockner *et al*., 2000). All the large-bodied species occupy the flood plain during their spawning season, a universal increase in relative abundance suggest movement into the flood plains where the flood plain inundation likely facilitated reproduction (Gerking 1950; Trepanier *et al*., 1996; Bice *et al*., 2014). A huge post-flood increases in the number of *Labeo dussumieri* and a marked abundance of cat fishes and the

Fig. 8. Landslide at Theekoy headwaters

Fig. 9. Theekoy headwaters after the landslide and first flood wave

Fig. 10. Restored headwaters after the second flood wave– Theekoy (after flood)

Fig. 11. Poonjar tributary encroached for cultivation (before flood)

dominance of *Channa diplogramma* and *Channa marulius* in the midstream stretch after the flood supports their prediction. Flood generally increased the relative abundance of large-bodied fishes but not the small-bodied ones (Pires *et al*., 2008)

Invasive alien species are considered to be a major cause for species endangerment and extinction in the freshwater system (Sala *et al*., 2000) through the displacement of native species. Invasive alien species reported from Meenachil River after the flood is *Piaractus brachypomus, Oreochromis mossambicus and Cyprinus carpio.* Raghavan (2019) reported the presence of eleven alien species from the natural waters of Kerala after the flood; many are illegally introduced and farmed for the aquarium pet trade as they are not listed in the species allowed to be imported to the country. Much of the freshwater

Fig. 12. Poonjar tributary (after flood)

aquaculture system in Kerala is located in the vicinity of the major river system, with the farming system having very little or no infrastructure to prevent the escape of fish into the adjoining natural water bodies.

Although the river flood plain connectivity can benefit a few species by increasing the vegetation availability, the flood can also decrease or wipe away certain species (Puckridge and Walter 2000; Thieme *et al*., 2001). The complete absence of *Parambassis thomassi* which were abundant in all the zones of the entire river is noticed after the flood. The abundance of the common cyprinid *Dawkinsia filamentosa* and *Etroplus maculatus* decreased drastically after the flood across the entire stream network which is in accordance with the observation of Pires *et al*., 2008 where an extreme flash flood across a Mediterranean catchment had no such measurable impact on the assemblage composition. Still, they only caused a reduction in the abundance of small cyprinids and a local abundance for certain species.

The abundance of individual species in Kumarakom (downstream*)* showed a decline during the year 2019 preceding the flood when compared to the previous years. All the species showed a drastic decrease except a few outnumbered species, *Megalops cyprinoides, Puntius mahecola* and *Gerres setifer. Etroplus suratensis* and *Hyporhamphus limbatus,* which were abundant during the pre-flood years showed a drastic decline after the post-monsoon of 2018. George *et al.*, 2015 have reported the direct effect of severe flooding, which includes displacement-related mortality and destruction of incubating eggs in streams. Indirect effects include the destruction of habitats affecting the carrying capacity, which favours one species or guild over the others. Padmakumar *et al*., 2019 reported the drastic decline of the endemic fish *Etroplus suratensis* from all the major landing sites of Vembanad Lake. *Etroplus suratensis* is a visual breeder, and the high suspended sediment load and turbidity of the flood waters appeared to have affected their breeding. The paired *Etroplus suratensis,* during breeding, utilize benthic solid objects, submerged in water for the attachment of their adhesive eggs which were hindered by the habitat disturbances possible in flood (Padmakumar *et al.*, 2019). It is also inclined to believe that the general decline of fish abundance in the downstream could be due to the accumulation of pollutants due to the retention of flood waters. The abnormally extreme rainfall rushing down upstream with very high velocity flushed out the anthropogenic wastes which were found to disturb the river substratum downstream (Kerala State Biodiversity Board Flood Report 2018). The opening of the reservoirs to the over flooded rivers caused a tremendous rise in the flood levels of Vembanad lake were the rivers confluence. The perigean spring tides and the strong offshore winds in the Arabian Sea prevalent during the time worsened the flood situation in the low-lying areas which delayed the receding of flood waters from Kerala Rivers to Arabian Sea (INCOIS, 2018). These phenomena caused the temporary retention of flood waters in the downstream with all the anthropogenic wastes flushed out from the upstream of the river including non-biodegradable plastics, effluents from factories and pesticides washed out from the rubber and pineapple plantations.

The effects of the flash flood on aquatic habitat provide insight for interpreting the fish community trends in riverine ecosystems. Most aquatic systems have a "self-purification capacity". So long as there is a limit to the pollutant input, natural purification works well.

The undammed Meenachil River experienced a natural extreme flash flood and landslides which have re-figured the channel morphology and re-stored the deteriorated riverine ecosystem as a part of Nature's resilience. Even though the main channel, tributaries and backwaters got re-figured by the flood and landslides, a change in the habitat complexity was not detrimental to the structurally resistant fish community. Further investigations are needed to determine the long-term effects and ecological implication of floods on Kerala Rivers, which is urgently needed for the implementation of restoration strategies for conserving our nation's riverine ecosystem and its unique and endemic fauna.

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