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Understanding the trade-offs in tropical reservoir fishery in a socio-ecological perspective

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ABSTRACT

A study involving the assessment of ichthyo-diversity, physico-chemical aspects of reservoir, socio-economics of the reservoir fishers and their sustainability issues was conducted in Peechi Reservoir, in Thrissur District, Kerala, India during 2016-2018. The study indicated the need for developing appropriate reservoir based fishery management measures in protected ecosystems considering the intricate trade-offs between conservation strategies leading to ensuring livelihoods for the resource poor fishers. Fish and water samples collected were analysed on various scales. The study indicated that *Salmostoma novacula* was the major species contributing to the diversity in terms of abundance in the reservoir. The diversity, species evenness (0.92 to 0.95) and species richness index (1.73 to 2.39) were observed to be higher at the sampling site 'Intermediate 1'. Canonical correspondence analysis (CCA) indicated that diversity was positively associated with dissolved oxygen (0.58), pH (0.62) and hardness (0.66) and negatively correlated with conductivity (-0.60). Socio-economics of the reservoir fishers identified very low monthly relative contribution of the species to the fishers' income of the reservoir, which calls for better management measures of the reservoir with respect to supporting the livelihood and sustainable management. Based on fishers' perception on fisheries management, an index called reservoir fisheries management index (RFMI) was introduced, which indicated that management of technical drivers will ensure better fisheries in Peechi Reservoir. The study identified that technological interventions like enclosure-based culture system using indigenous fishes of the reservoir such as *Etroplus suratensis*, hatchery operations and tourism during the lean period to support the livelihood of the fishers are critically needed. Thus, a participatory mode of culture supported sustainable conservative management may be incorporated in this reservoir. This is the first study of its kind in reservoir based aquatic system.

Keywords: Fish diversity, Participatory mode, Reservoir management, SIMPER, Socio-economics

Introduction

The dynamic and diverse tropical freshwater ecosystems are abode to more than 10,000 species of fish (Nelson, 1994), despite being the most stressed (McIntyre *et al*., 2016) aquatic system. Reservoirs (Dudgeon *et al*., 2006) were not primarily constructed for fisheries purposes, but for water development projects such as hydroelectric power generation and agricultural irrigation. Various researchers have studied reservoirs in a fisheries perspective (Fernando and Holcík, 1991; Agostinho *et al*., 1997). Thomas and Abdul Azis (1999), Jyotishi and Parthasarathy (2007) and Tasneem (2011) studied the fishery management aspects of Indian reservoirs. These studies revealed that though fishing and fisher livelihoods remain a low priority activity in Indian reservoirs, they continue to remain as the mainstay in the livelihood sustenance of the underprivileged communities, as a meaningful employment for augmenting income.

Understanding the spatial and temporal fish assemblage structure in tropical reservoirs is relevant, when reservoirs are used as a potential aquatic ecosystem for fish production. In this scenario, studies concerning fish associations may be considered mandatory for the sustainable management of the tropical reservoir ecosystem. But successful management of any reservoir depends on the comprehension of species diversity and knowledge about the associated community and their participation in the management activities. Fishers should be considered the primary stakeholders in developing plans and policies for enhancing the productivity of any fisheries. Scarce information on reservoir fishers hampered the chance of developing sustainable and integrated management measures (linkages between the socio-economic and the environmental dimensions) within fisheries (Liswanti *et al*., 2012; Braveman and Gottlieb, 2014). Realising that the fishers' perception on fisheries management plays a pivotal role in chalking out policies, programmes and plans, an index called reservoir fisheries management index (RFMI) was introduced in this study.

Peechi Reservoir is one of such numerous tropical reservoirs which was not primarily constructed for fisheries purposes, but could serve as a potential water body for fish production in the near future. The present study was taken up in Peechi Reservoir in Thrissur District of Kerala, India with the objective of developing appropriate reservoir based fishery management module in protected ecosystems considering the intricate trade-offs between mandatory ichthyo-faunal conservation strategies and livelihood assurance for the resource poor fishers.

Materials and methods

Study area

Peechi Reservoir (Fig. 1), a medium reservoir built across Manali River was constructed in 1957. This artificial tropical lake having a catchment area of 1300 ha is situated in Thrissur District of Kerala and geographically located between 10.51^0N, 76.39^0E and 10.55^0N, 76.391^0E. Multiple stakeholders are involved in the management of the reservoir. The fisheries and allied activities of the reservoir are effected through Peechi SC/ST Co-operative Society. Nearly 200 people are registered members in the co-operative society. Around 20% of the registered members are active regular fishers whose primary source of income is fishing.

For the present study, Peechi Reservoir was divided into three zones *i. e.* lentic (near to the shutter of the dam), lotic (riverine region) and intermediate zones (between lentic and lotic zones). This sampling strategy was carried out to conduct an in-depth investigation into the hydro-biological variables of this system ensuring an unbiased sampling. Fig. 1 clearly depicts the extent of the reservoir and its connectivity to Manali River and its tributaries at two sites, Lotic 1 and Lotic 2. Lotic zones were predominantly riverine ecotones. The lentic zone (lacustrine region) which was designated as Lentic 1 had no direct connection with the river. In order to ensure unbiased sampling, three sampling sites namely Intermediate 1, 2 and 3 were selected from intermediate zone for the current investigation.

Sampling details

Monthly samples of water and fish were collected from Peechi Reservoir during 2016 to 2018. The physical characteristics of water such as temperature, pH,

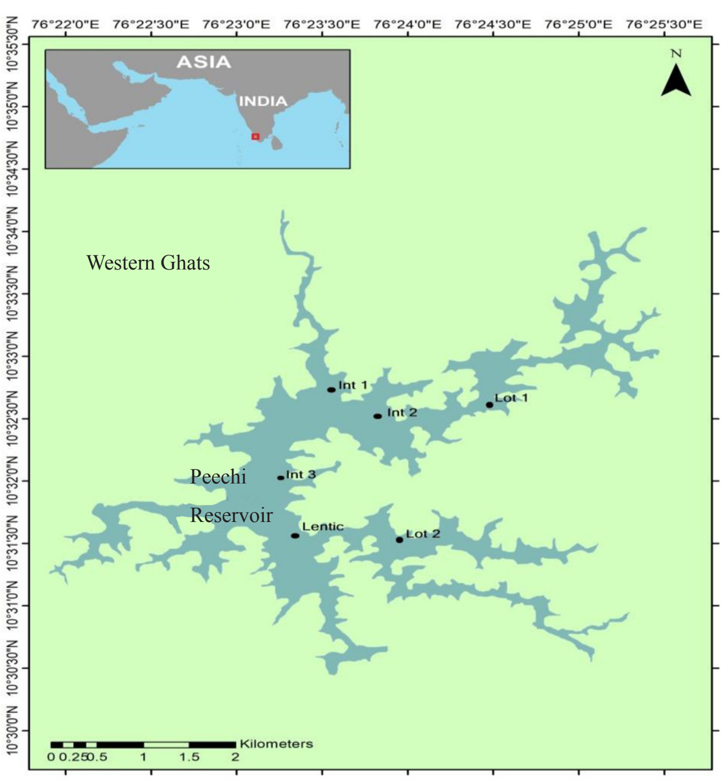

Fig. 1. *Satellite image of Peechi Reservoir*

conductivity and transparency were measured *in situ* using Eu-tech multi-parameter probe. The chemical characteristics of water such as alkalinity, dissolved oxygen (DO) and hardness were measured using titrimetric method (APHA, 2012). Nutrients were determined using spectrophotometric method (APHA, 2012). Monthly fish samples were collected from pre-identified sampling sites in the reservoir by experimental fishing using gillnets (mesh sizes ranging from 20 to 120 mm) and from the landings at the co-operative society site. Fish specimens thus collected were taxonomically identified using Talwar and Jhingran (1991). The spatial data of fish were segregated into three zones as mentioned above and analysed. The temporal data of fish were analysed by segregating the data into three seasons *vis-a-vis* pre-monsoon (February-May), monsoon (June-September) and post-monsoon (October- January).

A reconnaissance survey was carried out to extract details on the socio-economic profile of the fishers of Peechi Reservoir. The prepared schedule extracted information related to demographic information, fisheries, economics and marketing aspects and the various strategies suggested for better management of the fishery in this reservoir were scored based on the method of Garett and Woodsworth (1969). The sample size for socio-economic survey was 20% of the registered members, who were active regular fishers whose primary source of income is fishing. The study segregated the statements provided by fishers for scoring into five drivers (social, technical, economical, institutional and policy drivers) in a fisheries perspective. Each of these drivers had various attributes which were scored on a five point continuum. The continuum addressed the fishers perception on merit, with 5 (strongly agree), 4 (agree), 3 (no opinion), 2 (disagree) and 1 (strongly disagree). Based on the scores provided for each attribute, the cumulative scores were computed for the drivers. Reservoir fishery management index (RFMI) was thus devised as a composite index of all these five drivers. This composite index provided the fishers perception on the priorities for the reservoir fisheries management with fisher participation.

The present study used the statistical package for community ecology and environment namely PRIMER 7.0 (Clarke and Gorley, 2015) for analysing species data and R for statistical computing and graphics (R Core Team, 2020). ArcGIS Desktop 10.0 was used in the mapping of diversity indices on a GIS platform (Biswas *et al*., 2016).

Data analysis

Biodiversity indices, namely Pielou's evenness index, Margalefs richness index and Shannon-Weiner's diversity index were used to estimate the discrepancy of fish communities in this system. ANOVA was carried out to determine whether there existed any statistically significant differences of the means of biodiversity indices between the sampling zones. The temporal and spatial dominance curve across three seasons and three zones were plotted separately using PRIMER 7.0 to find the rate of instability of the system on temporal and spatial scale respectively. Similarity Percentage (SIMPER) analysis was carried out using PRIMER 7.0 on a temporal and spatial scale to identify the species and zone contributing to the diversity of Peechi Reservoir. Canonical correspondence analysis (CCA) was carried out between the hydrological variables and fish assemblage (TerBraak and Smilauer, 2002) to identify the predominant variables impacting the fish assemblages in Peechi Reservoir. Conservation status and fish production scenario of the reservoir was identified from the IUCN listing of fishes (IUCN, 2017) and State fisheries department respectively. Catch composition studies of Peechi Reservoir helped to identify the major single species which formed a fishery in the reservoir. Livelihood analysis was carried out to identify the stability of fishers' income for a sustainable livelihood. The most contributing driver was identified and was recommended as the best management practice that can be adopted for this reservoir.

Results and discussion

Spatial dimension of ichthyodiversity

The diversity studies in Peechi Reservoir recorded 14 species belonging to 11 genera, 6 families and 3 orders. Paul *et al*. (2017) recorded 18 species belonging to 15 genera, 10 families and 4 orders from this reservoir. Table 1 presents the fish species in Peechi Reservoir during the present study. Table 2 depicts the spatial variation in ichthyo-diversity indices such as Shannon diversity index, Margalef's species richness index and Pielou's species evenness index across various zones in Peechi Reservoir. The results of ANOVA for the diversity indices indicated that there existed significant difference between the means of Pielou's species evenness index in three zones. Spatial distribution of diversity in terms of abundance (Table 2) indicated that the number of species is more in the lotic zone (Lotic 2) compared to all other zones. This indicated that the feeder riverine system (tributaries of Manali River) was a major source of ichthyo-diversity in Peechi Reservoir due to its inherent conditions supporting the ingestion of allochthonous food resource into the reservoir system. Hence these zones (Lotic 1and 2) provided suitable feeding (Nogueira *et al*., 2010) and breeding (Hye and Alamgir, 1992) grounds for the fishes in the system and thereby exhibited greater fish diversity.

The diversity, species evenness (0.92 to 0.95) and species richness indices (1.73 to 2.39) were observed to

Table 1. Fish species recorded from Peechi Reservoir

No.	Families	Species	Conservation status (as per IUCN Red List)	Population trend
1	*Cyprinidae*	*Puntiu smahecola*	Endangered	Unknown
2		*P. chola*	Least Concern	Unknown
3		*P. sophore*	Least Concern	Unknown
4		*Salmostoma novacula*	Least Concern	Unknown
5		*Rasbora dandia*	Least Concern	Decreasing
6		*Pethia punctata*	Least Concern	Stable
7		*Garra mcclellandi*	Data Deficient	Unknown
8		*Devario malabaricus*	Least Concern	Stable
9	*Aplocheilidae*	*Aplocheilus lineatus*	Least Concern	Decreasing
10	*Percidae*	*Etroplus maculatus*	Least Concern	Stable
11		*Etroplus suratensis*	Least Concern	Decreasing
12	*Gobiidae*	*Glossogobius giuris*	Least Concern	Unknown
13	*Bagridae*	*Mystus malabaricus*	Endangered	Decreasing
14	*Siluridae*	*Ompok malabaricus*	Endangered	Unknown

Table 2. Spatial variations in diversity indices in Peechi Reservoir

Zones	Species	No. of species	Margalef's species richness index	Pielou's species evenness index	Shannon's diversity index
Lotic 1	12	363	1.87	0.80	2.00
Lotic 2	13	608	1.87	0.70	1.80
Intermediate 1	11	66	2.39	0.95	2.27
Intermediate 2	9	72	1.87	0.92	2.02
Intermediate 3	9	103	1.73	0.93	2.05
Lentic	7	64	1.44	0.88	1.71

be higher in 'Intermediate 1' which may be due to mixing of riverine and lacustrine fish species in these zones. Oliveira *et al*. (2005) attributed the high spatial heterogeneity in intermediate zones to the presence of macrophytes and woody debris which provided suitable substratum for colonisation of planktonic organisms which form a food resource for many species in the intermediate zone. The Lentic zone had the lowest spatial heterogeneity of fishes. This finding may be attributed to the unconducive habitat for fish assemblage in these zones on account of subsidised food ration (Doi *et al*., 2008) brought in by feeder rivers. Similar results were reported by Joy and Death (2004) wherein species diversity was found increasing towards the riverine (lotic) zone.

Temporal dimensions of ichthyodiversity

Table 3 shows that the number of species recorded was maximum (14) during monsoon compared to other seasons. Miranda (2001) explained that the predominance of monsoon-based ichthyo-diversity (14) in Peechi may be due to the increase in food and shelter contributed by flooded vegetation in the reservoir. Decrease in lacustrine water levels (due to scarce rainfall and high water temperature) indirectly resulted in the concentrations of fish populations (Agostinho *et al*., 2007) leading to the high values (2.53) of species richness index during post-monsoon (Miranda, 2001).

K-dominance curves

Spatial and temporal dominance plot was prepared to identify any dominant fishery in Peechi in the spatial and temporal scales. Temporal K-dominance curve (Fig. 2) of the reservoir indicated highly diverse pre-monsoon season with dominance percentage of single species less than 30% and an unstable post-monsoon. Further, the spatial K-dominance study (Fig. 3) indicated that Intermediate 1 zone was the most stable ecotone in the reservoir with no clear dominance by any single species. The stability may be attributed to the intermixing of species in these zones as it provided suitable habitat with macro-aquatic vegetation. The most unstable zone was Lotic 2 zone as indicated by 50% of the single dominant species in the system.

SIMPER analysis

Temporal analysis (Table 4) indicated the endemism and dominance of the species *Salmostoma novacula* followed by *Puntius mahecola* in Peechi across all

Table 3. Temporal variations in diversity indices in Peechi Reservoir

Season	No. of species (s)	Margalef's species richness index (d)	Species evenness (J')	Shannon's diversity index (H')
Post-monsoon	13	2.53	0.83	2.24
Monsoon	14	2.46	0.80	2.26
Pre-monsoon	13	2.37	0.84	2.27

Table 4. Percentage contribution of species on temporal scale in Peechi Reservoir

Percentage species contribution (Temporal scale)							
Season	Similarity	Species	%	Dissimilarity between	%	Major species	%
Post-monsoon	77.75	*S. novacula*	14	Monsoon and post-monsoon	24.69	*Pethia punctata*	15.84
Monsoon	77.04	*S. novacula*	14.8	Post-monsoon and Pre-monsoon	19.95	*P. punctata*	13.60
Pre-monsoon	83.12	*S. novacula*	15.02	Monsoon and Pre-monsoon	18.29	*P. punctata*	15.97

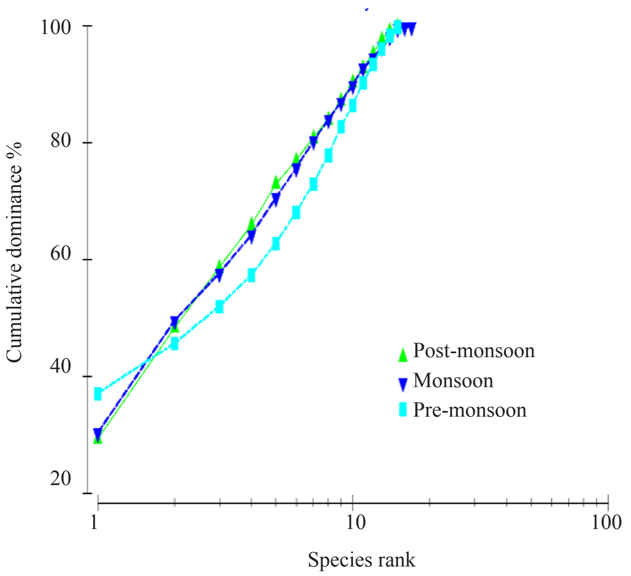

Fig. 2. Dominance plot (Temporal scale)

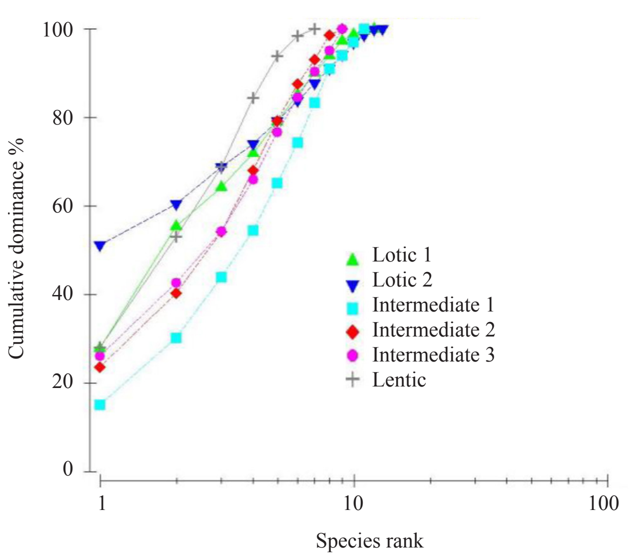

Fig. 3. Dominance curve (Spatial scale)

seasons. The study also indicated that *Pethia punctata* (15.84%) contributed maximum to dissimilarity in terms of abundance on a temporal scale and also reflected the season specific endemism of *Etroplus suratensis* and *Rasbora dandia* in the reservoir. Similarly, spatial SIMPER analysis indicated that *S. novacula* (32.9%) was dominant in the lotic zone where as *P. mahecola* was predominant in the intermediate zone to the tune of 18.81% (Table 5). This clearly explained the dominance and endemism of *S. novacula* in the lotic zone across all seasons. The dominance of *P. mahecola* in intermediate zone was explained by its contribution to the dissimilarity in species abundance between the Lentic and Intermediate zones across all seasons (Table 5).

Canonical correspondence analysis (CCA)

Canonical correlation studies (CCA) between species diversity and hydrological variables indicated that dissolved oxygen, pH, hardness and conductivity influenced the fish diversity in Peechi (Fig. 4). Eigen values and percentage of CCA in Peechi Reservoir was 0.146 (axis 1) and 0.119 (axis 2) explaining 35.92 and 29.2% of the variance between the variables in the components. The first canonical loading (Table 6) was positively associated with dissolved oxygen (0.58), pH (0.62) and hardness (0.66) and negatively correlated with conductivity (-0.60). The study showed that these variables contributed maximum to the first canonical variable and hence most associated with variation in species abundance.

Fig. 4 indicates that majority of the species exhibited wide distribution patterns. Species like *Pethia punctata* and *Devario malabaricus* indicated lower abundances (density <1.0%) and a limited distribution. The herbivorous feeding habit of *Garra mcclellandi* and its occupancy in ecological niche as a bottom feeder substantiated the results of CCA. *Aplocheilus lineatus* inhabited bentho-pelagic ecological niche of the reservoir

Table 5. Percentage contribution of species on spatial scale in Peechi Reservoir

Percentage species contribution (spatial scale)							
Similarity in groups	Similarity	Species	%	Dissimilarity between	%	Major species	%
Lotic	63.23	*S. novacula*	32.9	Lotic and Intermediate	81.9	*S. novacula*	41.51
Intermediate	67.08	*P. mahecola*	18.8	Lotic and Lentic	84.8	*S. novacula*	41.25
				Intermediate and Lentic	66.1	*P. mahecola*	17.17

Table 6. Summary of CCA values and Eigen values of data for biotic and abiotic factors of Peechi Reservoir

Variables	CCA I	CCA II
Water temperature (^{0}C)	0.06	-0.27
Depth (m)	-0.07	0.26
Transparency (m)	0.07	-0.25
Dissolved oxygen (ppm)	0.58	-0.08
Conductivity (µS)	0.22	-0.60
pH	0.62	-0.26
Hardness (ppm)	0.66	0.21
Alkalinity (ppm)	-0.13	-0.46
Nitrate (ppm)	0.01	-0.38
Phosphate (ppm)	0.15	0.15
Silicate (ppm)	0.17	-0.03
Eigen values	0.1464	0.119
Percentage	35.92	29.2

(Froese and Pauly, 2018), which substantiated the species abundance relative to the reservoir depth (Fig. 4). *Etroplus suratensis* exhibited their breeding behaviour in shallow depths where oxygen was abundant between lotic and intermediate zones in the reservoir.

Conservation status of fishery in Peechi Reservoir

The assessment of conservation status of ichthyo-diversity in Peechi Reservoir is relevant in order to envisage the level of conservation to be implemented in this reservoir. The study indicated that 75% of species were in the "Least Concern" category, 18.75% in "Endangered" and 6.25% in "Data Deficient" category of the IUCN (IUCN, 2017). Species such as *Devario malabaricus, Rasbora dandia* and *Etroplus suratensis* were reported of exhibiting decreasing population trends. Species such as *Ompok malabaricus* and *Mystus malabaricus* were included under 'Near Threatened' category (Table 1). *Salmostoma novacula* was a least concerned species indicating the possibility of sustainable exploitation of the species.

The study further showed that the contribution of miscellaneous fish species (Fig. 5) which include *S. novacula* and *P. mahecola* to the fishery of Peechi Reservoir. This shift in the catch from Indian major carps (IMC) to *S. novacula* and *P. mahecola* may be due to the use of small meshed gears. The catch composition study

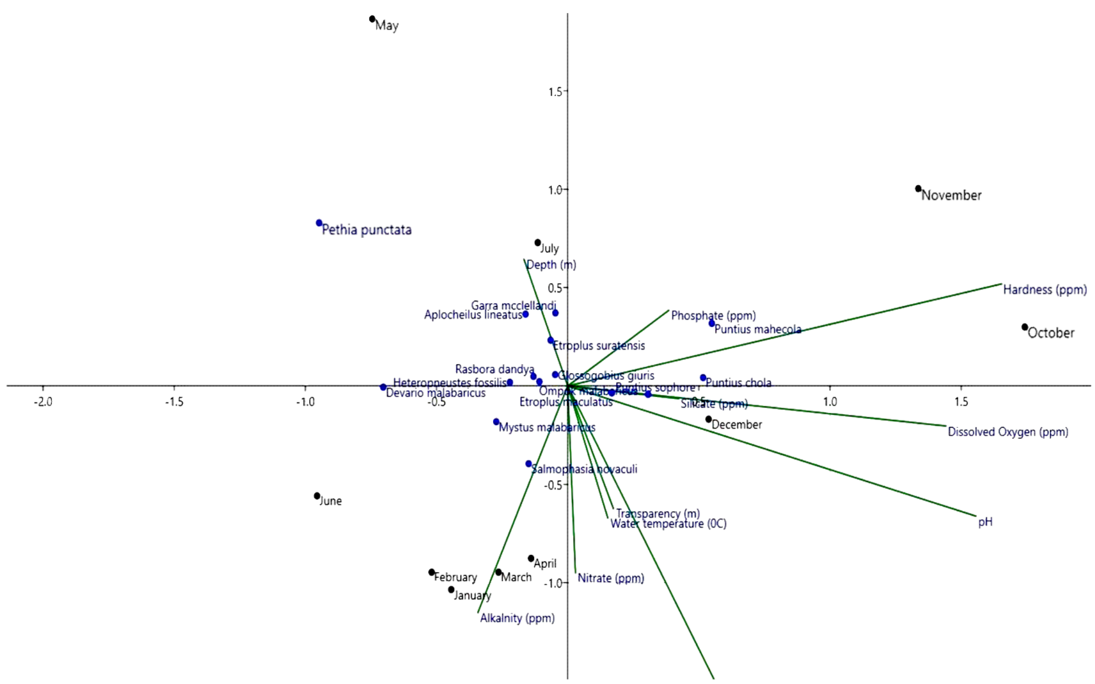

Fig. 4. Ordination diagram of CCA showing relationship between the hydrological variables and species diversity in Peechi Reservoir

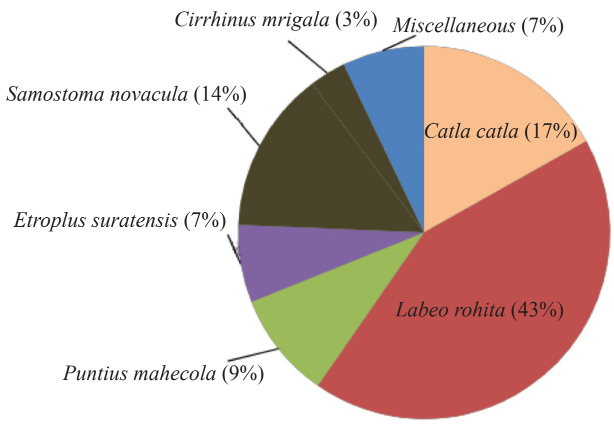

Fig. 5. Catch composition of Peechi Reservoir during 2016-2018

of Peechi Reservoir indicated that *S. novacula* contributed to 14% of the catch whereas the endangered *Puntius mahecola* (Fig. 5) contributed to 9%. The study indicated a need for regulating the fishery in the reservoir as an endangered species form a good portion of the catch from the reservoir.

Fisheries socio-economics

The study identified gender inequity in reservoir fishing in Peechi. Fishing activities were steered by active male members (fishers) of Peechi SC/ST fishery co-operative society. The educational profile indicated that the literacy rate of the fishers was 88% which was very low when compared to Kerala's average literacy rate of 93.91%. Studies on family profile indicated a prominent and periodical shift from joint family to nuclear family system among fishers.

Livelihood income analysis estimated the mean monthly income of fishers from fishing as ₹103 in Peechi (₹1235 a year). The studies (Fig. 6) depicted that out of the 6 seasons observed, fishing was practised only during 4 seasons. After a period of abstinence from fishing for one season (pre-monsoon 2017), the fishery increased to almost thrice the previous period of fishing. This suggested for a possible intervention by practising fishing holidays in Peechi during lean months and substituting the lost income with alternative livelihood programmes. Various management strategies suggested by fishers in Peechi for the maintenance of the reservoir fisheries and betterment of fishers livelihood was evaluated using RFMI in this study (Table 7).

The analysis indicated that RFMI of Peechi was mainly driven by the technical drivers (score being 69.09).

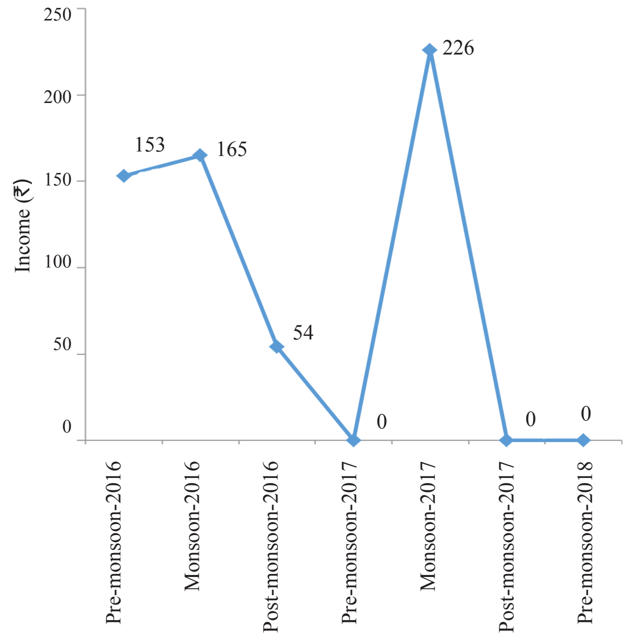

Fig. 6. Mean seasonal fishing income from Peechi Reservoir

Table 7. Reservoir fisheries management index (RFMI) of Peechi Reservoir

Drivers /Reservoir	Values
Policy	65.82
Institutional	52.73
Social	43.18
Technical	69.09
Economic	29.77
Reservoir fisheries management index	52.12

The major technical attribute (Table 8) that contributed to RFMI was the fishers' support to continuous stocking of fishes in the reservoir and construction of hatcheries (score being 78.18). This indirectly indicated a need for alternate livelihood opportunities (construction of hatcheries) in the absence of stocking in the reservoir. The low prices of fishes (economic driver) to which the fishers were vulnerable in Peechi may be mitigated by adding value to the captured fishes on an entrepreneurial mode. The increased competitive nature of fishers (economic driver) created unprecedented juvenile fishery of the endangered *P. mahecola* which also calls for conservation of this fishery. Mesh size regulation and periodic closed seasons in fishing (technical driver) would help in mitigating the vulnerability faced by reservoir fishers. The procurement of fishers identity cards (score being 81.82) indicated their dire need for being enrolled in government sponsored schemes and subsidies exclusively meant for fishers (policy driver). The improved involvement of women in fishing operations (Table 8) and participation in decision making related to reservoir fisheries (social driver) would further raise the index leading the reservoir to be a model reservoir for the state. Alternate livelihood opportunities such as hatchery and tourism based business, cage culture activities involving *E. suratensis* during lean seasons (when fishing holidays were practised) will help in the sustainable increase in the livelihood of the reservoir fishers.

The study focused on identifying an appropriate management strategy for the upliftment of tropical reservoir fishers considering their socio-ecological vulnerabilities. Legal pluralism in reservoir management restricted the resource managers from harnessing the potential of such aquatic resources sustainably. The study also thus proves the essentiality of a comprehensive acknowledgement of all the resources associated with reservoir fisheries in bringing out the most appropriate management measure in a reservoir. Conservatory measures such as self-imposed regulatory fishing, practice of mesh size regulations along with the livelihood improvement strategies such as cage culture, hatchery operations and tourism are needed for the Peechi Reservoir fishery. Reservoir fishery management with respect to modifications in technical drivers would result in conceptualising a model fishery reservoir. The study emphasised the importance of planning at the level of the primary stakeholder for sustainable fisheries, which is otherwise referred to as a bottom up approach.

Table 8. Details of drivers used in Reservoir Fisheries Management Index (RFMI)

Attributes of drivers used in RFMI									
Social drivers	Score	Policy drivers	Score	Technical drivers	Score	Economic drivers	Score	Institutional drivers	Score
Membership to women in co-operative society	23.64	Requirement of fisheries policy	32.73	Implementation of minimum legal size	63.64	Low prices for fishes	87.27	Support of government support in terms of subsidy and other financial benefits	32.73
Participation in fishing operations	41.82	Acceptance of mesh size regulation	70.91	Refrain from fishing during breeding season	74.55	Alternative marketing facility	23.64	Trainings from research institutions/state fisheries departments on advanced fishing practices	72.73
Participation in hatchery operations	36.36	Receipt of minimum support price	69.09	Refrain from growth overfishing	78.18	No competition among fishers	21.82	Regular participation in awareness campaign conducted by various institutes	52.73
Participation in reservoir based decision making	70.91	Promotion of reservoir fisheries by government	74.55	Supporting continuous stocking of fishes	78.18	No alternative livelihood option	32.73		
		Procurement of fishermen identity card	81.82	Construction of hatcheries	78.18	Easy availability of loans	25.45		
				Stocking of exotic fishes	60.00	Easy repayment of loans	27.27		
				Stocking fishes more than 100 mm size	67.27	Price fixation	87.27		
				Emphasis on diversity aspects hindering stocking	52.73				
				Supporting dredging in reservoir	69.09				
				Implementing cage culture	69.09				
				Motorisation of crafts	76.36				
Total scores	43.18		65.82		69.09		29.77		52.73

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