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Decline in Diversity and Production of Exploited Fishery Resources in Vembanad Wetland System: Strategies for Better Management and Conservation

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Abstract

This paper describes the fishery catch structure of Vembanad wetland system during August 2012 to July 2013. The estimates of fishery production indicated an annual landing of 4387.31 t, in which 480.98 t and 3906.33 t contributed by southern and northern zone of Vembanad respectively. Eighty species of finfishes, five species of penaeid shrimps, three species of palaemonid prawns and two species of crabs were identified from the study period. The catch per unit effort (CPUE) value was maximum for gill net (3.04 kg·h^{-1}) followed by stake net (2.43 kg·h^{-1}), Chinese dip net (2.01 kg·h^{-1}), seines (1.2 kg·h^{-1}), cast net (0.72 kg·h^{-1}) and hook and line (0.34 kg·h^{-1}). Biological integrity and fishery production of estuaries in the country are declining mainly due to various man induced activities. Thaneermukkom barrage, the salinity barrier, constructed across the Vembanad wetland system in 1976, transforming the water body into two distinct ecosystems, a fresh water zone on the south and a brackish water zone on the north, resulting in gross changes in physical, chemical and biological entity of the aquatic ecosystem. In the southern zone of Vembanad the marine fish species were less available with the closure of the barrage period. There are signs of decline of the Vembanad fishery resources, evident in the lesser number of species and decline of fishery production. This will lead to biodiversity loss, fish stock reduction and will ultimately affect the livelihood support of the traditional fishers to a large extent, besides affecting other ecological services. A better conservation measure must be implemented for maintaining the sustainable fishery resources in Vembanad.

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Keywords

Fishery Production, *Macrobrachium rosenbergii*, Ramsar Site, Vembanad Wetland System

1. Introduction

The fish resources of tropical estuaries, mostly in developing countries, constitute a vital source of food and employment for millions of people. Hence, in most cases, there are no effective alternatives to maintain the viability of tropical estuarine fisheries, despite threats to their sustainability from overfishing, industrial and agricultural practices [1]. Habitat deterioration mainly from anthropogenic activities, including destructive fishing, pollution and irresponsible coastal development and natural disturbances are declining the fishery with collapse beyond the recovery [2]. Knowledge on the status and trends of inland fisheries is the key to sound policy development, better decision-making and responsible fisheries management. It is necessary at the national level for the maintenance of food security and for describing social and economic benefits of fisheries [3]. The declining biological integrity and fishery production in the aquatic environment lead to biodiversity loss, fish stock reduction and eventually affect the livelihood support of traditional fishers. An ecosystem approach is important in large catchment area for large lakes and river systems [4]. Fluctuations and trends in fish stocks are difficult to assess. So to facilitate fisheries management the stock assessment process in which the collection of fishery production estimation including multispecies and multi gear fishery is important.

Fisheries activities of the inland sector of India are traditional in nature and fishermen generally carry out the fishing operations without any consideration to sustainability of the resources, which is leading to dwindling catches and poor returns. The fish and fisheries play a crucial role in the Kerala's economy, particularly among the communities along the coastal belt. The backwaters in Kerala form a habitation for over 200 resident and migratory fish and shellfish species and fishing activities in this water body provide the livelihood to about 200,000 fishers and provide full time employment to over 50,000 fishermen [5]. Fish communities of coastal estuarine environment possess a mixture of ecological groupings that contain euryhaline species adapted to brackish environments, along with true marine and fresh water species. Hence fish assemblages in estuaries are very diverse and are composed of marine, estuarine, freshwater and migrating species [6]. Considering the major contributing species of estuarine fishery, the current knowledge of stock status is poor or missing. Even for those species about which something is known, considerable caution will be needed when making assumptions, at least until stock assessments are better developed. Only with increased monitoring, assessment and research of species will improve the existence of the fishery management system. In this context the present study made an attempt to quantify the fishery resources and propose a management plan for the Vembanad backwater system.

In Vembanad wetland system, the fishery diversity and distribution were studied initially by Shetty [7]; Kurup [8]; Kurup *et al.* [9]-[11] and Unnithan *et al.* [12]. The crustacean resources in the Vembanad backwater was studied by Menon and Raman [13]; George [14], Kuttyamma [15]; Kuttyamma and Antony [16] and Kurup [8] made a systematic list of 150 species of fishes belonging to 100 genera under 56 families in the Vembanad backwater. Kurup *et al.* [11] examined the seasonal and spatial variations in fishing intensity and gearwise landings of the Vembanad backwater. Menon *et al.* [17] pointed out the impact of fluctuations of temperature from premonsoon to monsoon on the seasonal distribution and abundance of fishes in the Vembanad estuarine system. Padmakumar *et al.* [18] documented the fishery decline in Vembanad wetlands. In Azhikode estuary, the status of exploited fishery resources was studied by Harikrishnan *et al.* [19] and temporal pattern of fish production was observed by Bijoy Nandan *et al.* [20]. Fisheries and socio-economic aspects of Vembanad backwater were observed by Anon [21].

2. Materials and Methods

2.1. Study Area

Kerala has diverse aquatic ecosystem like network of rivers, backwaters and natural lakes, supporting high biodiversity and a rich commercial fish fauna. Vembanad wetland system, an important Ramsar site on the South West coast of India, forms a complex, shallow estuarine network running parallel to the coastline of Kerala with two permanent opening to the Arabian sea—one at Cochin and the other at Azhikode. After intruding from Arabian sea, it extend to an area of 200 km^2 boarded by Alappuzha, Kottayam and Ernakulam districts. In 1976, the Thaneermukkom barrage (salinity barrier) was constructed for regulating the salt water from entering the southern most areas and adversely affects the agricultural operation in the low-lying Kuttanad, which is the rice bowl of the state. There are several disputes connected the opening and closing of shutters of the Thaneermukkom barrage. The barrage kept closed during the summer months, and there are no salt water intrusions as well as tidal flow in the upper reaches, leading to an unfavourable environment for marine fauna. The agriculture operations cause delay on opening of shutters; long closure period adversely affects the fishery as well as livelihood of thousands of fishermen. Continuous conflicts happened between fishermen and farmers over opening and closing of shutters. Six rivers, the Periyar, Muvattupuzha, Pamba, Achankovil, Meenachil and Manimala and small streams bring large amount of freshwater into the backwater system, especially during summer monsoon (June-September) with an estimated annual runoff of 22.41 × 103 Mm^3/year [22].

2.2. Sampling Method

Estimation of fishery catch in Vembanad backwater has been made by monthly fishery surveys in the fish landing centres from August 2012 to July 2013. Landing centre based data collection method and catch yield was used for the fish landing estimation (Sparre and Venema [23]; FAO [24]; Gupta *et al*. [25]. Fish landing data was collected from twenty centers situated around the wetland (9˚30'069"N & 76˚21'268"E to 9˚53'519"N & 76˚18'139"E) (**Figure 1**). Alappuzha, Pallam, Kumarakam, Muhamma, Thaneermukkom, Cherthala, Vaikkom, Chembu, South Paravoor, Aroor, Arookutty and Thevara were the major fish landing centres. Total catch in the landing centre were sorted into fin fish and shell fish. Catch composition and gear wise catch were also estimated. Gear details such as length, mesh size and twine size were also recorded. Total number of each category of fishing gears were enumerated and the fish catches were examined in detail from not less than 30% of each type of gear. Species level identification was made with help of standard references Talwar and Jhingran [26]; Bijoy Nandan [27] and Fish Base [28]. For the purpose of fishery estimation, we divide the aquatic system into two, the estuarine northern zone and fresh water, southern zone.

2.3. Data Analysis

We examined the trend in total catch and the important species groups in relation to changes in fishing. Catch per unit effort (CPUE) was defined as the catch obtained in one tow of the net operated once per site, and is expressed as $kg \cdot hr^{-1}$. The CPUE is calculated for monthly and annual values and used as index of relative abundance [23] [24]. Landings from all gears and fishing methods were computed by following equations Kurup *et al*. [10] and Gupta *et al*. [25].

$$W = (w/n) \times N$$

where W = total weight of fish

w = total weight of fish from gear sampled

n = number of gear sampled

N = total number of similar gears operated.

Monthly catch was calculated by multiplying the daily catch with total number of fishing days and pooled to arrive at seasonal trends. Based on the South West monsoon and North East monsoon pattern along the west coast of India, there are three well defined seasons, pre monsoon (February to May), monsoon (June to September) and post monsoon (October to January). To check for similarity among fish production in months, CLUSTER analysis using PRIMER vs. 6 was performed. In the cluster analysis, hierarchical agglomerative clustering (Bray-Curtis similarity) was performed [29].

3. Results

3.1. Fishery Production

The fishery resources comprised of eighty species of finfishes, five species of penaeid shrimps, three species of palaemonid prawns, two species of crabs (**Table 1**). The estimates of annual fishery production indicated an annual landing of 4387.31 t, in which 480.98 t and 3906.33 t contributed by southern and northern zones respectively. The finfishes contributed 26.7% (1192.17 t) to the total fishery; cichilids, cyprinids, mullets, cat fishes,

Table 1. List of species composition, family, habitat, IUCN status, environment and migration of finfishes from Vembanad wetland during August 2012 to July 2013 period.

Species Name	Family	Habitat	Status	Environment	Migration
Ambassis ambassis	Ambassidae	M F B	LC	Demersal	Oceanodromous
Parambassis thomassi	Ambassidae	M F B	LC	Demersal	-
Parambassis ranga	Ambassidae	F B	LC	Demersal	Potamodromous
Parambassis dayi	Ambassidae	F B	LC	Demersal	-
Anabas testudineus	Anabantidae	F B	DD	Demersal	Potamodromous
Anguilla bengalensis	Anguillidae	M F B	LC	Benthopelagic	Catadromous
Aplocheilus panchax	Aplocheilidae	F B	LC	Benthopelagic	Non migratory
Horabagrus brachysoma	Bagridae	F B	VU	Demersal	Amphidromous
Mystus oculatus	Bagridae	F B	LC	Demersal	-
Xenentodon cancila	Belonidae	M F B	LC	Pelagic-Neritic	-
Brachirus orientalis	Bonthidae	M B	NE	Demersal	Oceanodromous
Megalaspis cordyla	Carangidae	M B	NE	-	-
Rhizoprionodon acutus	Carcharhinidae	M F B	LC	Benthopelagic	Amphidromous
Chaca chaca	Chacidae	F	LC	Demersal	Potamodromous
Chanos chanos	Chanidae	M F B	NE	Benthopelagic	Amphidromous
Oreochromis mossambicus	Cichilidae	F B	NT	Benthopelagic	Amphidromous
Etroplus maculatus	Cichilidae	F B	LC	Benthopelagic	Amphidromous
Etroplus suratensis	Cichilidae	B	LC	Benthopelagic	-
Clarias batrachus	Claridae	F B	LC	Demersal	Potamodromous
Sardinella longiceps	Clupidae	M	LC	Pelagic-Neritic	Oceanodromous
Sardinella gibbosa	Clupidae	M	NE	-	-
Cynoglossus microlepis	Cynoglossidae	F	LC	Demersal	Potamodromous
Cynoglossus cynoglossus	Cynoglossidae	M B	NC	Demersal	-
Puntius sarana	Cyprinidae	F B	LC	Benthopelagic	Potamodromous
Puntius filamentosus	Cyprinidae	F B	LC	Benthopelagic	-
Puntius amphibius	Cyprinidae	F B	DD	Benthopelagic	-
Puntius melanostigma	Cyprinidae	F	NE	Benthopelagic	-
Rasbora daniconius	Cyprinidae	F B	LC	Benthopelagic	-
Labeo dussumeri	Cyprinidae	F B	LC	-	Potamodromous
Labeo rohu	Cyprinidae	F B	LC	Benthopelagic	Potamodromous
Amblypharyngodon mola	Cyprinidae	F	LC	Benthopelagic	-
Amblypharyngodon microlepis	Cyprinidae	F	LC	Benthopelagic	-
Cata catla	Cyprinidae	F B	LC	Benthopelagic	Potamodromous
Himantura uarnak	Dasyatidae	M B	VU	-	Amphidromous
Nematalosa nasus	Dorossomidae	M F B	LC	Pelagic-Neritic	Anadromous
Anatondostoma chacunda	Dorossomidae	M F B	NE	Pelagic-Neritic	Anadromous
Eleotris fusca	Eleotridae	M F B	LC	Demersal	Amphidromous
Elops machanta	Elopidae	M B	LC	Pelagic-Neritic	Oceanodromous

Continued

Stolephorus commersonnii	Engraulidae	M B	NE	Pelagic-Neritic	Oceanodromous
Stolephorus indicus	Engraulidae	M B	NE	Pelagic-Neritic	Oceanodromous
Thryssa malabarica	Engraulidae	M B	NE	Pelagic-Neritic	Amphidromous
Thryssa dussumeri	Engraulidae	M B	NE	Pelagic-Neritic	Amphidromous
Gerres setifer	Gerridae	M B	NC	Benthopelagic	Amphidromous
Gerres filamentosus	Gerridae	M F B	LC	Demersal	Amphidromous
Glossogobius giurius	Gobidae	M F B	LC	Benthopelagic	Amphidromous
Oxyurichthys formosanus	Gobidae	M B	NE	Demersal	Amphidromous
Oxyurichthys tentacularis	Gobidae	M B	NE	Demersal	Amphidromous
Hyporhamphus xanthopterus	Hemirhamphidae	M F B	VU	Pelagic-Neritic	-
Heteropneustus fossilis	Heteropneustidae	F B	LC	Demersal	-
Lates calcarifer	Latidae	M F B	NE	Demersal	Catadromous
Leiognathus equulus	Leiognathidae	M F B	LC	Demersal	Amphidromous
Leiognathus dussumieri	Leiognathidae	M B	NC	Demersal	-
Leiognathus brevirostris	Leiognathidae	M B	NC	Demersal	Amphidromous
Macrognathus guentheri	Mastacembelidae	F	LC	Benthopelagic	-
Megalops cyprinoides	Megalonidae	M F B	DD	Benthopelagic	Amphidromous
Mugil cephalus	Mugilidae	M F B	LC	Benthopelagic	Catadromous
Valamugil speigleri	Mugilidae	M F B	NE	Demersal	Catadromous
Liza parsia	Mugilidae	M F B	NE	Demersal	Catadromous
Liza microlepis	Mugilidae	M F B	LC	Demersal	Catadromous
Chelon planiceps	Mugilidae	M F B	NE	Demersal	Catadromous
Muraenesox cinereus	Muraenesocidae	M F B	NE	Demersal	Oceanodromous
Nandus nandus	Nandidae	F B	LC	Benthopelagic	-
Pristolepis fasciata	Nandidae	F	LC	Demersal	Potamodromous
Channa striatus	Ophiocephalidae	F B	LC	Benthopelagic	-
Channa marulius	Ophiocephalidae	F	LC	Benthopelagic	Potamodromous
Channa orientalis	Ophiocephalidae	F B	NE	Benthopelagic	Potamodromous
Platycephalus indicus	Platycephalidae	M B	DD	Reef associated	Oceanodromous
Eleutheronema tetradactylum	Polynemidae	MFB	NE	Pelagic-Neritic	Amphidromous
Scatophagus argus	Scatophagidae	M F B	LC	-	Amphidromous
Johnius coitor	Sciaenidae	M F B	LC	Demersal	Amphidromous
Pygocentrus nattereri	Serrasalmidae	F	NE	Pelagic	-
Siganus javus	Siganidae	M B	NE	-	Oceanodromous
Sillago sinhama	Sillaginidae	M B	NE	-	Amphidromous
Wallago attu	Siluridae	F B	NT	Demersal	Potamodromous
Ompok bimaculatus	Siluridae	F B	NT	Demersal	-
Cynoglossus bilineatus	Soleidae	MB	NE	Demersal	-
Arius subrostratus	Tachysuridae	M B	NC	Demersal	-
Arius maculatus	Tachysuridae	M F B	NC	Demersal	Potamodromous
Plicofollis platystomus	Tachysuridae	M B	LC	Demersal	Amphidromous
Tricanthus brevirostris	Tricanthidae	M B	NE	Demersal	-

Note: F: Fresh Water; B: Brackish Water; M: Marine; LC: Least Concern; DD: Data Deficient; VU: Vulnerable; NE: Not Evaluated; NT: Near Threatened.

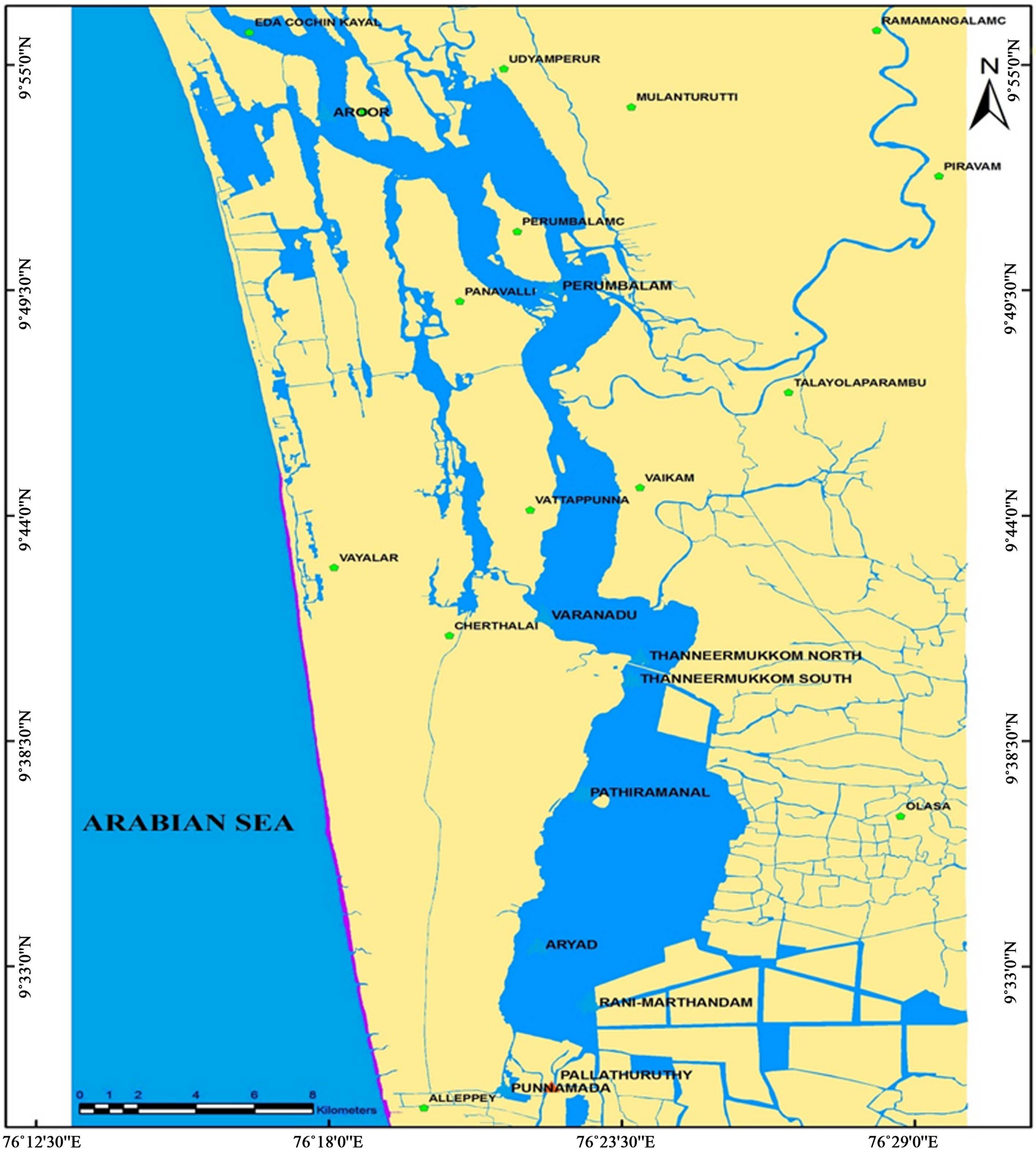

Figure 1. Map showing the study area in Vembanad backwater system (Courtesy: Satellite imagery—LISS and PAN as November 2004-July 2006).

ambassids, scaenids and half beaks were the major groups in the exploited finfishes. The estimated landings of various groups of finfish and shellfish are given in **Table 2**. In cichilids, *Etroplus suratensis* and *Etroplus maculatus* formed the major fishery. Cyprinids were represented by species such as *Labeo dussumieri*, *Puntius filamentosus* and *Amblypharyngadon microlepis*. Mullets were represented the species such as *Mugil cephalus*, *Liza parsia* and *Liza macrolepis* in which *Mugil cephalus* contribute maximum (61.5%). *Arius maculatus*, *Arius subrostratus*, *Plicofollis platystomus* formed the principal species among cat fishes. Crustaceans contributed 73.29% to the (3195.14 t) total fishery. In penaeids, *Metapenaeus dobsoni* dominated the catch (77.86%) followed by *Metapenaeus monoceros* (14.7%), and *Fenneropenaeus indicus* (5.99%). Among crab species *Scylla serrata* and *Portunus pelagicus* were the dominant ones, in which *Scylla serrata* contributed 79% to the fishery. In the case of *Macrobrachium rosenbergii* the highest abundance was observed during monsoon (66.7%), followed by premonsoon (21%). The monthly fish catch in the backwater showed that maximum production occurred during May 2013 and minimum during June 2013. The pre monsoon period showed the highest landings (51.16%), followed by postmon-

Table 2. Estimated finfish and shell fish production (tonnes) from Vembanad wetland during August 2012 to July 2013 period.

Finfishes	Ton	**Shellfishes**	Ton
Cichilids	339.52	*Metapenaeus dobsoni*	2412.61
Cyprinids	124.64	*Fenneropenaeus indicus*	185.353
Mullets	194.41	*Metapenaeus monoceros*	455.767
Cat fishes	229.52	*Penaeus monodon*	11.172
Ambassis sp.	68.43	*Macrobrachium rosenbergii*	57.69
Gerres sp.	20.4	*Macrobrachium idella*	9.7644
Leiognathus sp.	12.88	*Scylla serrata*	49.4441
Half beaks	64.92	*Portunus pelagicus*	7.84
Scaenids	37.09	Others	5.5
Chanos chanos	7.54	**Total**	**3195.14**
Megalops cyprinoides	4.69		
Anchovies	31.32		
Flat fishes	9.62		
Channasps.	11.34		
Scatophagus argus	8.24		
Others	27.61		
Total	**1192.17**		

soon (35.77%) and monsoon (13.07%). In the southern zone an overall similarity of 65% was observed in the monthly fishery production (**Figure 2**). Highest similarity of fish production was observed between April 2013 and May 2013 (92.51%). An overall similarity of 55% was observed in the total landings in the northern zone having highest similarity of 81.43% that was observed between February 2013 and April 2013 months; followed by June and August with 76.54% of similarity. A separate cluster was formed in post monsoon months (**Figure 3**).

In the southern sector 88.5% of fishery was contributed by finfishes followed by crustaceans (11.5%). *Etroplus suratensis* dominated the landings (36.18%) followed by *Labeo dussumieri* (18.86%), *Puntius sp.* (9.64%), *Hyporhamphus xanthopterus* (6%), *Amblypharyngodon microlepis* (6.5%), *Etroplus maculatus* (5.4%), Channa sp. (3.6%). In the northern sector 37.66% of fishery was contributed by finfishes. The species such as *Etroplus suratensis* (35.8%), Mullets (29.9%), Tachysuridae (19.1%), Scinaeid sp. (6.2%) and Ambassid sp. (5.6%) contributed maximum biomass to the fishery. In crustaceans *Metapenaeus dobsoni* contributes 64.82% to the fishery followed by *Fenneropenaeus indicus* (14.84%), *Metapenaeus monoceros* (10.29), *Macrobrachium idella* (2.97%), *Macrobrachium rosenbergii* (2.2%), *Scylla serrata* (2.64%) and *Penaeus monodon* (0.84%). In Vembanad backwater, the high number of species not reflected in the fish species dominance. Only a few dominant species contribute to the maximum fishery landings in the system. During the present study most of the fish species were estuarine dependent (69 species) which showing migration. Less saline, southern zone was reflected by fresh water species such as *Amblypharyngodon microlepis*, *Hyporhamphus xanthopterus*, *Labeo dussumeri*, *Puntius sarana*, *Puntius filamentosus* more abundant. The species such as *Mugil cephalus*, *Etroplus suratensis*, *Chanos chanos*, *Johnius coitor*, *Gerres setifer*, *Arius subrostratus* and *Arius maculates* formed the dominant species contributing to the northern zone fishery (**Table 3**). During the closure period of the barrage, the average fishery production of southern zone declined from 53.25 t to 31.76 t. During monsoon the average fishery production was very less (29.23 t) compared to the barrage closure period. The unfavourable environmental condition connected with monsoon season and the heavy rain fall makes the area unapproachable for fishing.

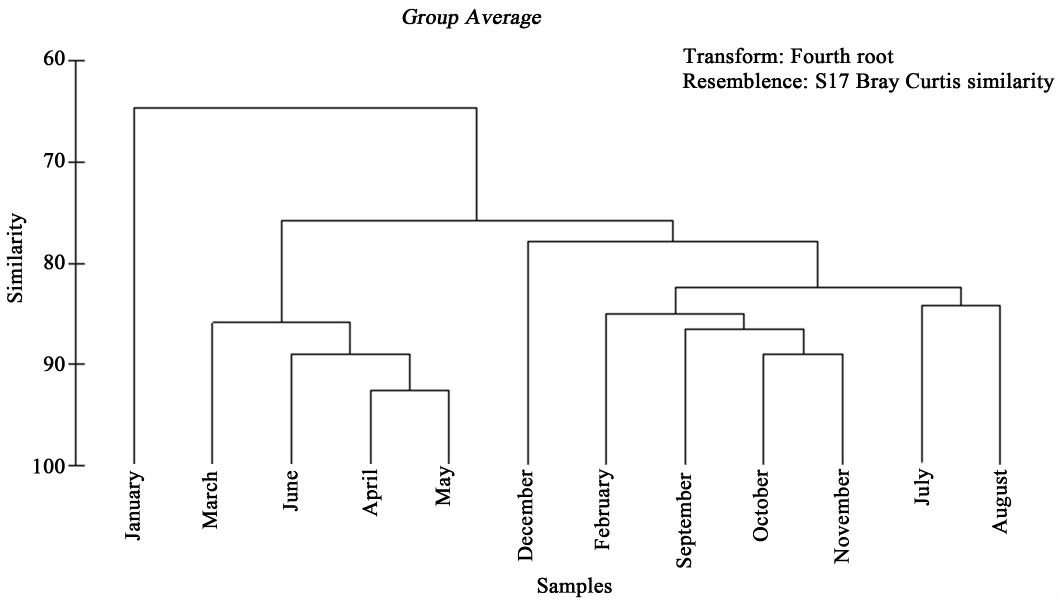

Figure 2. Dendrogram based on monthly fishery production in the southern zone of Vembanad backwater.

Table 3. List of major fish species contributing maximum landings in Vembanad during August 2012 to July 2013 period.

Southern Zone	Northern Zone
Amblypharyngodon microlepis	*Ambassis ambassis*
Amblypharyngodon mola	*Arius maculatus*
Anabas testudineus	*Arius subrostratus*
Channa marulius	*Chanos chanos*
Channa orientalis	*Cynoglossus cynoglossus*
Channa striatus	*Etroplus suratensis*
Etroplus maculatus	*Johnius coitor*
Heteropneustus fossilis	*Leiognathus brevirostris*
Horabagrus brachysoma	*Leiognathus dussumieri*
Hyporhamphus xanthopterus	*Liza parsia*
Labeo dussumeri	*Mugil cephalus*
Puntius amphibius	*Parambassis thomassi*
Puntius filamentosus	*Stolephorus commersonnii*
Puntius melanostigma	*Thryssa dussumeri*
Puntius sarana	*Valamugil speigleri*
Macrobrachium rosenbergii	*Metapenaeus dobsoni*
	Fenneropenaeus indicus
	Metapenaeus monoceros

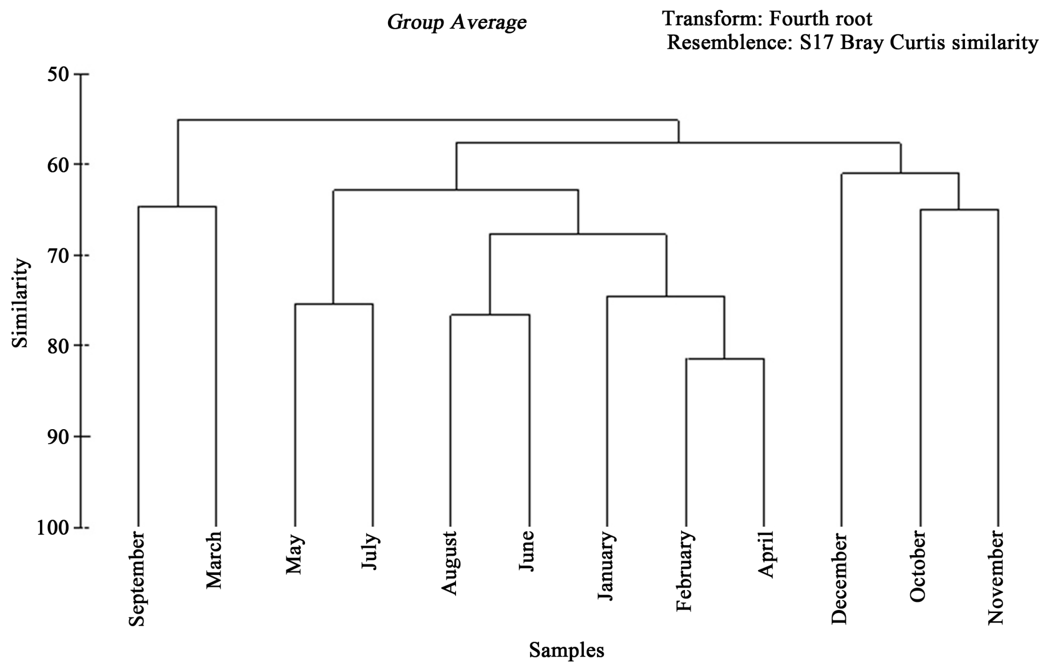

Figure 3. Dendrogram based on monthly fishery production in the northern zone of Vembanad backwater.

3.2. Gear wise Production and CPUE

In the southern zone gill nets (77.3%), seines (12.5%), cast net (5.1%), trap (3.2%) and hook and line (1.8%) was the dominant gear whereas in the northern zone stake net (46.5%), gill net (26.8%), Chinese dip net (14.8%) and seines (9.6%) formed the major gear (**Figure 4**). The Gill net of varying mesh size was employed along the southern zone contributing 76.3% of the catch. More than 50% of fish production in the northern zone of backwater was contributed by fixed gears such as stake nets and Chinese dip nets. Gill net, seines, hook and line, cast net and crab ring also contributed to the annual fishery. The stake net operated in the northern zone of Vembanad backwater had a cod end mesh size of less than 10 mm and it broadly filter out the incoming prawns and fishes irrespective of their size and destroy outwardly migrating fishes, this agrees with the studies by Kurup *et al.* [11]. Gill net showed highest CPUE of 3.04 $kg \cdot h^{-1}$ followed by stake net having 2.43 $kg \cdot h^{-1}$,Chinese dip net 2.01 $kg \cdot h^{-1}$, seine net with 1.2 $kg \cdot h^{-1}$, cast net with 0.72 $kg \cdot h^{-1}$, hook and line with 0.34 $kg \cdot h^{-1}$ and traps with 0.26 $kg \cdot h^{-1}$.

4. Discussion

Information regarding the fish production revealed that a drastic decline occurred in the fish production system of Vembanad backwater. It revealed that, fisheries in the Vembanad backwater will eventually collapse due to the unscientific operation of barrage along with illegal fishing activities such as operation of unfriendly gears, poison and other anthropogenic activities. An alarming decline (4387.31 t) in fishery production was observed in the present study. Kurup *et al.* [10] estimated an annual yield of 7202 t in Vembanad during 1988-1989. He suggested that the northern zone of the backwater having marine and estuarine influences yielded comparatively high production than the southern zone, the fresh water sector of the backwater. Similar trend was obtained during the present study. This may be due to the influence of salinity on fishery. Barletta *et al.* [30] noted that salinity and distance to the bar mouth were most important in structuring the fish species in an estuary. It was estimated that the annual landing from the southern zone during 1988-1989 and 1995 - 1999 were 500 t [31] and 486 t [12] respectively. During 1999-2000 and 2000-2001 Padmakumar *et al.* [18] estimated fish landings from southern Vembanad and adjoining lowlands that were 838 t and 687 t respectively. The production from southern zone exclusively from the water body, south of barrage was 584 t and 507 t respectively. The depletion of the fish stock of southern portion of the backwater was mainly due to man-made impacts on the ecosystem such as habitat alteration, reduction of natural grow out systems due to various activities such as intensification of rice cultivation and cropping pattern, physical barriers caused in the migratory pattern, over fishing and pollu-

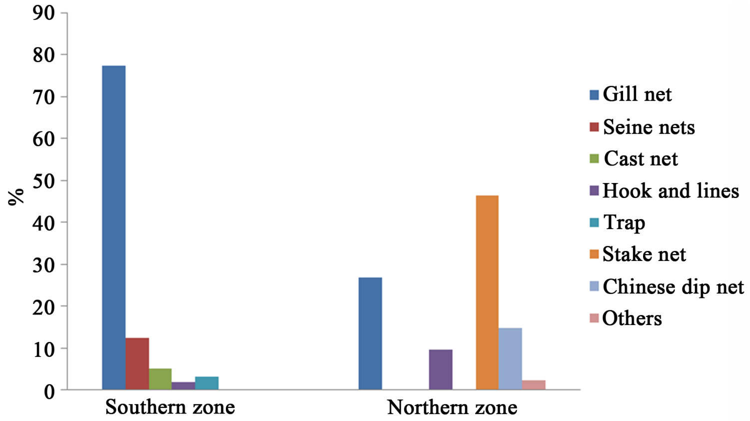

Figure 4. Percentage contribution of various gears operated in southern and northern zone of Vembanad backwater.

tion hazards due to excessive use of chemicals and pesticides in the paddy field of Kuttanad [9]. A stagnant water condition in the southern zone during the closure period of barrage stimulated the intensification of sewage and agriculture wastes in the southern zone causing threats to fisheries. According to Anon [32], obstruction to the natural and free flow of the river-backwater system and the ensuing interruption to the seasonal mixing of saline and fresh water have affected the natural cleansing mechanism of backwaters. It was reported that opening of Thaneermukkom barrage after the closure period benefited fishermen in the southern area from marine fish catch, Anon [33]. During the period 1988-1989, 115 species of fishes belonging to 84 genera, 6 species of penaeid prawns, 4 species of palaemonid prawns and 3 species of crabs were reported by Kurup *et al.* [11]. But in the present study only eighty species of finfishes, five species of penaeid shrimps, three species of palaemonid prawns and two species of crabs were reported, in which three species were classified vulnerable. The modification in the ecology of Vembanad backwater due to Thaneermukkom barrage is believed to have lost about 23 species of fishes, preventing migration of about 13 other species [32]. During 2008, Atree [34] reported 51 species of finfish representing 26 families and 35 genera, as well as 11 species of shell fish belonging to 6 families and 7genera from the southern part of Vembanad. It includes two species of critically endangered, four species of endangered and five species of vulnerable fish. In 2009, Atree [35] reported a total of 65 finfishes and 14 shell fishes from the southern part of Vembanad backwater.

Comparing the previous studies in the southern sector, the fishery contribution by major species has changed over the years. The Channa species (27.1%) and *Etroplus suratensis* (27.5%) followed by *Metapenaeus dobsoni* (12.06%) and *Macrobrachium rosenbergii* (6.01%) formed the dominant fishery in the Vembanad backwater during 1990s. Now the fisheries of Channa sp., *Macrobrachium rosenbergii*, Metapenaeus sp. were dominated over by cyprinids, Hemirhamphidae, ambassids, and Bagridae. In cyprinids, *Labeo dussumeri*, *Amblypharyngodon microlepis* and *Puntius* sp. formed the major fishery. The catch of *Macrobrachium rosenbergii* in Vembanad declined over a period of 4 decades (**Figure 5**). In the early period, the highest catch (429 t) was recorded in 1960 and lowest (189 t) in 1962. The average for the period 1960-1964 was 300 t [36]. During 1988-1989, the catch declined to 39 t [9]. During 1994-1995 and 1995-1996 the exploited stock from Vembanad backwater were 112.85 t and 129.44 t respectively [37]. During 1995-1996 and 1996-1997, the catch of *M. rosenbergii* in the southern zone was reported to be 57.93 and 36.33 t respectively [12] whereas in 1999 to 2000 it was 65.2 t and it reduced to 26.72 t during 2000-2001 [18]. In the current study the exploited stock of *M. rosenbergii* from the whole backwater was 57.69 t. The landing of *M. rosenbergii* increased from July onwards and the maximum occur on September. Compared to the northern zone (39%), the southern zone (61%) contributed maximum production. *M. rosenbergii* has been exposed to various changes over the years in Vembanad backwater mainly due to the operation of Thaneermukkom barrage. The salinity barrier was responsible for the alarming depletion of *M. rosenbergii*. After commissioning of barrage over the backwater in 1976, fisheries at upstream of the barrage was negligible in most of the fish landing centres. It obstructs downstream migration of berries and the upstream migration of post larvae of *M. rosenbergii* and found that recruitment over fishing of *M. rosenbergii* occur in the backwater and also responsible for the depletion in fishery [37]. They proposed suitable management practice for *M. rosenbergii* fishery, which include ban on fishing in the breeding ground, creating sanctuaries and hatcheries

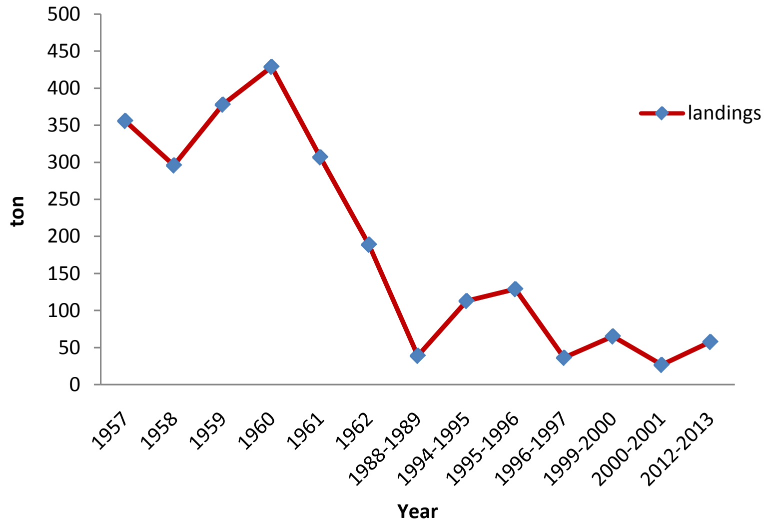

Figure 5. Trends in the landings of *Macrobrachium rosenbergii* in Vembanad backwater during 1957 to 2013 period.

near the breeding ground etc. The present study reveals that fishermen capture berried female during their breeding migration. This has a tremendous adverse impact on population recruitment and declining of *M. rosenbergii* fisheries. Comparing the seasonal fishery production it was observed that during monsoon season a reduction in the catch was observed. The heavy rainfall during the South West monsoon and associated physical stress made fishing activity difficult for the fishermen, which reflected the decreased fishing days and production during monsoon period.

In the northern sector the stake net operation during monsoon was not much prominent. Strong under water current in the monsoon season may damage the fishing gear. The rapid proliferation of the aquatic exotic weed, water hyacinth, *Eichhornis crassipes* during the monsoon season had negative impact on fisheries in the whole backwater. The fishes were subjected to overfishing and under sized fishing by stake net, which negatively impacts the fish population. Over exploitation of fishery resources due to its high economic value leads to the vulnerability of the population in different ecosystems [38]. "Padal fishing", an illegal fishing method was employed in Vembanad backwater during the monsoon season. It is the most destructive fishing method caused to the destruction of juvenile population of commercially important fish, such as *Etroplus suratensis* (pearlspot), mullet, shrimp and perch [39]. The Vembanad backwater has been reclaimed over the past 150 years for various purposes such as agriculture expansion for paddy cultivation, aquaculture, urban development activities and for public and private uses. The progressive shrinkage of the estuarine system has resulted in the decline of fishery areas and estuarine dependent fishery resources particularly the migratory fishes and shrimps.

Humans have profoundly altered the aquatic environment in many regions of the world, in the form of hydroelectric dams and barrages for power generation, irrigation, drinking water and shipping. The opening and closing of barrages adversely affect the migratory organisms. The building of the High Aswan dam in Egypt had important impacts on the marine life in the south eastern Mediterranean Sea. The decrease in sardine catch is generally attributed to alterations in Nile outflow, in which the total catch of sardines declined by 90% (Halim [40]; Dowidar [41]) and 75% reduction in Egypt's annual shrimp landings was reported by Wadie and Abdel Razek [42]. According to Quraishee [43], the catch rate of all fish species in Pakistan dropped significantly in the late 1950s due to the completion of the first large barrage across Indus River. Before the construction of the Thanneermukkom barrage the entire estuarine area was saline or brackish during the pre-monsoon period. The barrage divide the estuary into two zones, where the southern area was rich in estuarine fish fauna earlier, consisting of species originating from the sea, fresh water species and true estuarine species. The latter reproduce in the estuarine environment and find their physiological optimum in brackish water. The marine fish and prawns reproduce in the saline waters of sea and migrate to the estuary after completing their pelagic development. Some of the commercially important species of this area were Mugil sp., *Chanos chanos*, *Tachysurus* sp., *Etroplus suratensis*, *Macrobachium rosenbergii*, *Scylla serrata*, in which some of these species have now vanished from the area, while others have become a rarity. The native fish species such as *Horabagrus brachyso-*

ma and *Hyporhamphus xanthopterus* of Vembanad estuary were vulnerable and other species suffered a decline in both number and distribution. The operation of Thaneermukkom barrage and its impact on the depletion in catch of *Macrobrachium rosenbergii* was reported by Kurup and Harikrishnan, 2000 [37]. They pointed out the obstruction of barrage on the downstream migration of berries and the upstream migration of postlarvae of *M. rosenbergii*. It was confirmed by releasing marked post larvae into the estuary north of the barrier during the period of its closure. *M. rosenbergii* requires both freshwater and saline areas for the completion of its life history. Regular conflicts occur between farmers and fisherman on the issue of regulating the operations of the iron shutters of Thaneermukkom barrage; the fisher folk demanded entry of salt water in the southern part of barrage and fishes to enter for breeding and for better catch. A complete barrage operation strategy was needed for the ecosystem balance of Vembanad estuarine fishery.

5. Summary

The present study revealed that a drastic reduction of capture fishery in the Vembanad wetland system. The declining fish stocks in the estuary could be recognised due to the lack of sufficient fishery resource management in the system. Adequate enforcement or acceptance of both fishery management and conservation laws is important for the protection of fishery resources. To achieve the optimal ecological balance, the implementation of fish ways in the barrage and special design features helpful to enable migration of fish and other aquatic organisms. Among these are fish ladders or other device which allow the passage of fishes. Harvesting fish in an unsustainable manner also means that harvesting them inefficiently. In order to protect the lake fisheries a holistic approach must be needed. It should include habitat protection; prevent the unfriendly activities in the ecosystem avoiding further degradation. So establishment of protected areas has been considered as the most effective means to mitigate the impacts of overfishing and arrest further deterioration of coastal ecosystems [44]. Apart from establishment of protected areas, reducing the number of fishers through the economic assistance and other livelihood programs, strengthening law enforcement against destructive and unsustainable fishing practices seemed to be more urgent. The fishing pressure could be alleviated by promoting transition of fishers into alternative livelihood [45]. Capacity building and livelihood programs must be followed to increase chances of fishers to shift from fishing to alternative occupations. Ultimately ecosystem modification, stock assessment, harvest management, declaration of closed fishing season, closed area provision and ban on negative fishing methods and a strong evaluation measures are needed for the better fishery management.

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