IMPACT OF FLOOD AND DELUGE ON HYDROBIOLOGY AND BIODIVERSITY ENDOWMENTS OF KUTTANAD WETLAND ECOSYSTEM, KERALA : A RAPID ASSESSMENT

A PROJECT SPONSORED BY
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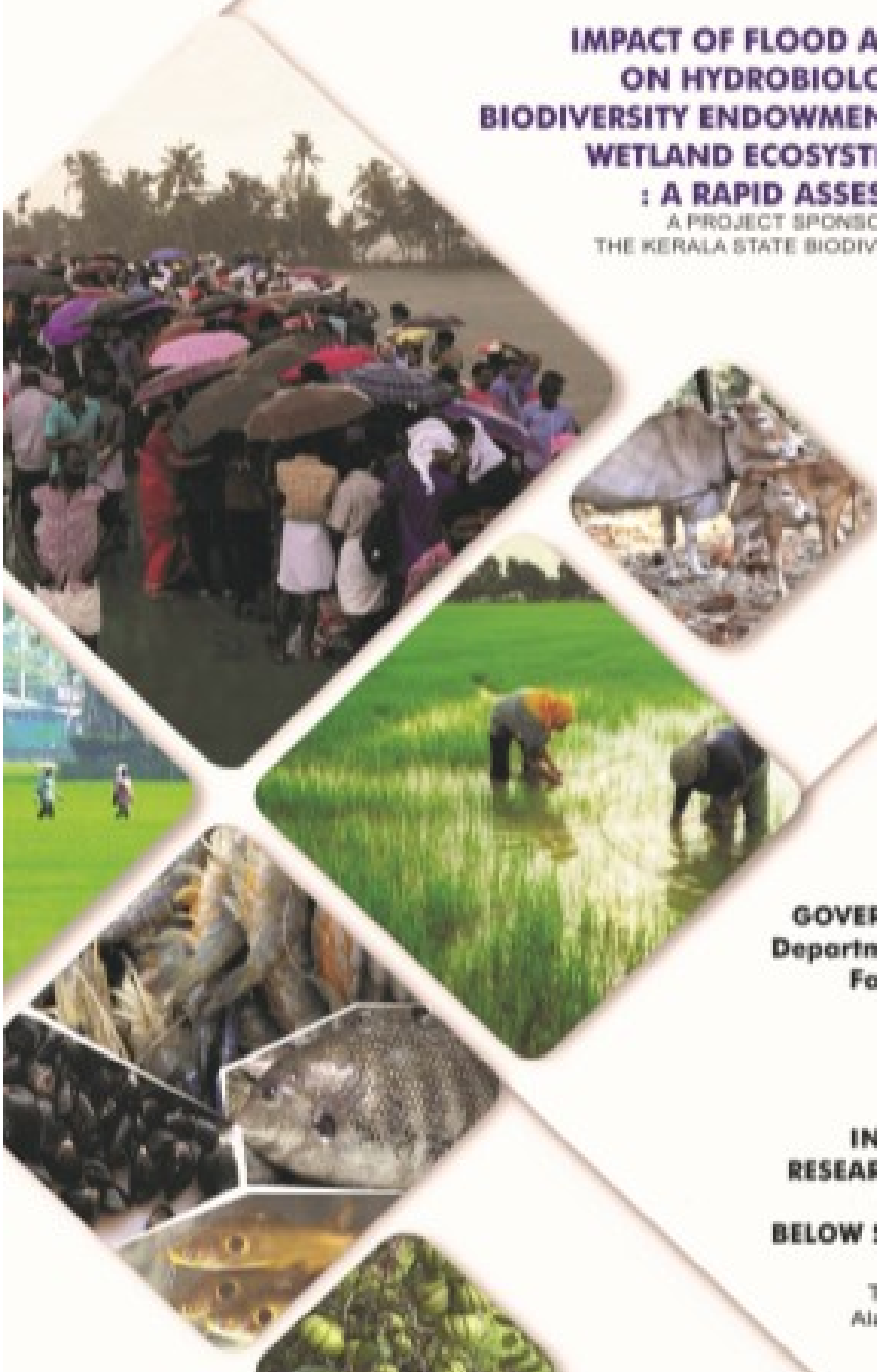

GOVERNMENT OF KERALA
Department of Agriculture & Farmers Welfare

INTERNATIONAL RESEARCH AND TRAINING CENTER FOR BELOW SEA LEVEL FARMING, KUTTANAD
Thottappally, P.O.
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Introduction

Kerala experienced the worst ever floods in its history since 1924, during July-August 2018 when the south west monsoon unleashed its fury over the State. During this period, the state received a cumulative rainfall that was 42 per cent in excess of the normal average. The post disaster needs assessment estimated by the Government put the total damage at Rs. 10, 842 crores and loss at RS. 16,154 crores amounting to total disaster effects of around Rs. 26,996 crores (GOK 2018).

To the surprise of all, flood remained for longer periods in Kuttanad than other places in Kerala. It is not necessary that it should rain in Kuttanad itself; even when it rains in the eastern hills, the water will reach this low lying region in no time, through the rivers that flow into the region. The 5 rivers, Pampa, Ache coil, Manimala Meenachil and Moovattupuzha that open in to Kuttanad floodplains together are estimated to bring in a total of 10,074 mm^3

water into the Vembanad Kayal, 67 % of which is during the southwest monsoon and 12 % during the northeast monsoon

Located below sea level, floods are a common feature in Kuttanad. An extreme natural event becomes a disaster when it has a large impact on human settlements and activities. Kuttanad has been going through noticeable changes in its physical features, as well as, in the livelihood patterns. The green paddy fields are shrinking and disappearing. However, the plight of Kuttanad remains the same with all its perils and troubles.

The principal reason for the large scale flood damages in Kuttanad may not be directly related to any point source; rather it is a mixture of anthropogenic activities and the natural processes. Unfortunately, there has been an administrative unwillingness to mainstreaming the crucial issues of Kuttanad; there is an apparent lack of preparedness for such a calamity of this dimension.

Food and Agriculture organization has recognized the Agricultural Heritage systems of coastal Kerala ie. the below sea level coastal farming in Kuttanad region as a Globally Important Heritage Site(GIAHS), developed and masterminded by the adventurous farmers of these places. This is a recognition of the farming tradition of the region and appreciation of the stupendous contribution of the adventurous farmers and local communities, in preserving protecting unique biodiversity endowments in the past, considered as model coping strategy to the anticipated problems of sea level rise and climate change.

Consequences of floods, both negative and positive, vary greatly depending on the location and extent of flooding, and the vulnerability and value of the natural resources. Flooding can have a variety of direct impacts on the environment and ecosystems. Some of these impacts are positive, and others negative. Flooding is also considered a natural ecological process that plays an integral role in ensuring biological productivity and diversity in the flood plain.

Landscape is not simply what we see with our eyes, but what we see through it - interpret it with our minds and its memorial past. Kuttanad, a landscape made by man has been going through noticeable changes in its physical features, as well as, in the livelihood patterns. Changes in Landscape slowly or profoundly in the course of human development and unnatural.

It is estimated that more than one third of the water spread area in this wetland has been lost due to land reclamation and the expanse of the Vembanad Lake is reduced by two thirds. Further, the depth of the lake is also substantially reduced due to deposition of silt and sediments so that various ecosystem services have been threatened. Water quality in the lake and water channels has been highly degraded. The rich biodiversity supported by it, has been increasingly eroded, the livelihoods of dependent communities are challenged and sustainable development of the region is at stake.

For improving agricultural production below sea level, and as part of effort to increase cropping intensity, for conversion of single crop paddy field in to double crop system, two important engineering interventions were taken up in Kuttanad, the one started during 1951 is Thottappally spillways and another in 1955, is the Thannermukkom Barrage (TMB). TMB is a 1252 m long structure, a road cum water regulator constructed at a narrow segment across the Vembanad. It was designed to prevent salinity ingress in to Kuttanad during the dry season when inflow from the river systems are low and also to retain freshwater from the inflowing rivers in to Kuttanad region and prevent the entry of saline waters from the coastal seas to Kuttanad so as to enable a late puncha crop, extending beyond the month of

December every year. The commissioning of the barrage was beset with severe ecological consequences. This has been triggered largely by changes in the natural hydrological processes and salinity regimes in the estuary. An important outcome has been the total elimination of tidal flushing which has exponentially enhanced pollution levels in Kuttanad. The most serious repercussion has been the rapid decline of estuarine fish production and the livelihoods of the dependent people, consequent to changes of the estuarine system into a totally fresh water ecosystem. This has also resulted in the prevention of fish migration and ecological disturbances to natural breeding and recruitment of several commercially important fish and prawn species.

The gross failure of the spillway during the deluge days was most apparent which enhanced flood miseries partly due to poor design and poor management; the laxity has come to the fore during the flood period. Consequently, floods persisted in Kuttanad for longer period, though the coastal sea was very kind to absorb the fury with tidal heights less than normal. The threat to farming during rainy season in Kuttanad remained unchecked.

Consequent to the utilization of the below sea level paddy fields for rainy season cropping, popularly called 'additional crop' without allowing flood water entry to the vast stretch of polder system ,flood fury got augmented. This was largely because the large quantum of water that enter the Kuttanad floodplains has to flow to the open Vembanad lake through myriad of narrow meandering canals between the padasekharams . These canal systems, about 1500 km were heavily silted up with blockages and exposed to encroachment, which also impeded drainage.

The increasing extent of rainy season cropping area up to 46% during 2017 also directly contributed to floods lasting longer in Kuttanad .This is largely due to a tendency to enhance area under rainy season cropping, despite threat from floods, to enhanced acidity of soil affecting, the post monsoon puncha season cropping.

Being most exposed to coastal seas, we have to, further, prepare the land to face the long term impacts of global warming and climate change. The deluge of 2018 and the drought that follows indicate that we will need more water in summer than we have today. At the same time, we have to drain away more water in monsoon to reduce flooding, - a balance has to be struck. At present there are conflicting interests to be resolved by helping to improve people's livelihood by adopting more suitable and sustainable cropping patterns.

Several studies have demonstrated the influence of the river flood pulse on the biota of floodplain aquatic habitats. Primary productivity, algal species composition and diversity are also closely related to hydrologic regime (Brinson et al. 1981)

Impacts of the land use and farming practices, on the ecosystem on account of the heavy use of fertilizers, and the resultant Eutrophication effects need to be subject to investigations. Cumulative consequence of the increasing Eutrophication in the backwaters of Kuttanad leading to heavy infestation of aquatic weeds is a matter of great concern. Inland fisheries have been the primary activity of the people before rice farming started in Kuttanad and are the most important livelihood enterprise for the indigenous people.

Kuttanad was well known for its fish diversity, which included 149 species of fishes until early 1980s (Kurup et al., 1990). Fishing was an important source of livelihood for over 17000 households, in and around Vembanad Lake. The status of fish populations and their dismal situation in Kuttanad has been described in many studies (Kurup et.al, 1992, 1993, Unnithan et.al.2001, Padmakumar et al 2002, Anon 2007, Asha et.al, 2014). The catch of the endemic prawn *Macrobrachium rosenbergii* of lake Vembanad which was (429 t) in 1960,(Raman ,1967) has come down to 26.72 t during 2000-2001and to 57.69 tons in 2014(Padmakumar et.al, 214). The salinity barrier was responsible for the alarming depletion of *M. rosenbergii*.

Significant decline in fish diversity, and availability have reduced its potential reducing the number of fishing households by about three fourths. Some of the commercially important fishes like milkfish, *Chanos chanos*, marine catfish, (*Tachysurus*) pearlspots,(Eroplus surantenis) giant fresh water prawns *(Macrobrachium rosenbergii*) have either vanished or became rarity .This has been attributed to changes in the prevailing water regimes, in the wetlands caused by change in salinity regimes and disruption in the physical and biological continuity of the lake with the coastal waters. The wetlands have also been an important habitat for rich varieties of birds, including several migratory species. The avian population have declined sharply by more than 40 % since early 1990's (Narayanan and Sreekumar, 2012).

In the context that the agro based economy practiced below sea level in Kuttanad wetland agricultural system has been declared by FAO as Globally Important Agricultural Heritage system (GIAHSs), and given parallels between the Kuttanad below sea level ecosystem and the submergence caused by climate change induced sea level rise, the Kuttanad model is being promoted for designing adaptation in island states, like Maldives, Bangladesh and coastal countries. However, before applying the Kuttanad model in blanket as an adaptation model, there is a dire need to make an assessment of its potential and limitations, from the perspective of water management and sustainable development to avoid the risk of 'maladaptation'.

In fact, rapid human colonization on a faster pace in Kuttanad happened after the great deluge of 1924, the creation of massive polders for agriculture itself gained momentum during this period, and this itself signified an onslaught on the ecology of the wetland .However, the flood of 1924 apparently turned to be a blessing with the improvement of natural fertility linked to the silt and humus deposited in the deluge. With the deposited fertile silt, enriching the 'impoverished' acidic soils, there was an exodus of settler farmers from midlands of Kerala to Kuttanad giving way for formation of extensive *kayal padasekharams* with huge investment and this paved way for commercial rice cultivation in Kuttanad.

This bountiful wetland was able to provide necessary support for the livelihoods of people's needs and culture with utilization of water as a central resource. The ecosystem could continue efficiently until these remained in balance with nature till late sixties with several physical and technological interventions presumably for increasing cropping intensity of rice

Kuttanad, the biodiversity paradise harboured unique species with known endemicity , be it Kuttanadan konchu, Karimeen, golden catfish, the black clam- kakka, the smallest breed of vechoor cow , the hardiest breed of Kuttanadan buffalo, the uniquely adapted breeds of endemic water fowls, chara or chemballi ducks, apart from the myriad of unique rice cultivars including the saline tolerant pokkali rice, the wetland taro, several flora and fauna and agro biodiversity components

The consequences of flood both negative and positive vary greatly depending on location, duration, as well as the vulnerability of the affected environments. Some of these impacts are positive; as flooding is a natural ecological process in the lowland that plays an integral role in ensuring biological productivity and diversity in the flood plain. Bio diverse ecosystems have a complexity and resilience that can take on more of the knocks of nature than eroded and heavily utilized or human-altered environments.

Certain species of life forms like fishes benefit from floods and actually depend upon, seasonal or periodic flooding. Seasonal flooding coordinates natural systems by providing environmental cues for spawning and migration (Leitman et al., 1991). Bayley (1991) coined the term "flood pulse advantage" to describe the increase in fish yield per unit water area during natural flood pulses. More often than not, flooding has a positive effect on fisheries in large low-gradient rivers. This is in contrast to documented population declines of fish in high-gradient river systems after extreme events.

Large numbers of young fish are even lost during average seasonal flooding in systems where the timing of high flows coincides with fragile life stages This severe population drop was attributed to an immediate reduction in food availability, due to depressed invertebrate populations, and the destruction of suitable aquatic habitat .Native fish that are naturally adapted to floodplain areas for spawning and flood protection etc far better than exotic species during floods (Adler, 1996).

The environmental impacts of extreme flooding are more complex, and interesting. Investigation on the nutritional status of soil and its variability in different flood prone areas is one of the important environmental aspects of floods. Floods may reduce the fertility of soil in certain areas to a great extent through sand casting. In certain cases, on the other hand, floods reduce the productivity of agricultural land, with direct impacts on the economy. It is difficult to estimate recovery time for each ecosystem following the floods because monitoring programs are mostly short term and typically do not extend beyond one post-flood measurement.

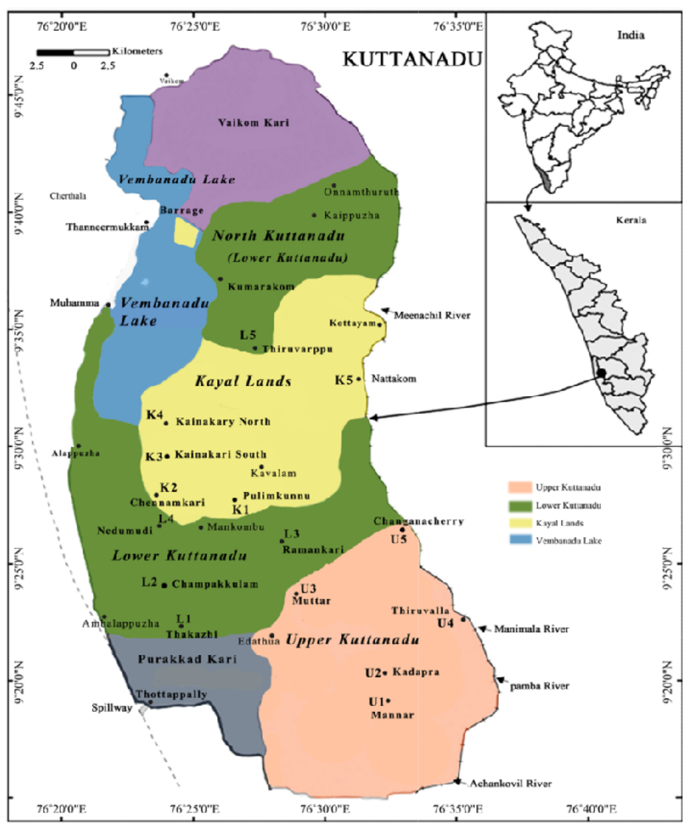
Eutrophication of river water and flood plain wetlands after a flood is expected to lead to undesired dominance of algae, cyanobacteria etc. Lower oxygen concentrations, affecting biodiversity and human health is another problem. It is inferred that the temporal inundation of fertilized flood plains will lead to increased nutrient mobilization, especially phosphates and such other nutrients, deteriorating river water quality leading to Eutrophication.

Undoubtedly, flood disaster like the one Kerala witnessed shows the necessity of investigations on new solutions, as raising dikes or barrages does not seem to support efficient protection to people or property anymore. New strategies have to be proposed that include re-creation of more natural riverine systems, by allowing more space for the rivers. The disaster has to trigger efforts to recognize the role our farmers, and the civil society in evolving, conserving, and diversifying our genetic resources. Impact studies are therefore designed to communicating our knowledge to help shape decision-making at all levels, especially in the context that the Government desire to rebuild the state into a really new Kerala.

Investigations on the impacts of the flood on aquatic ecosystems therefore demands a holistic perspective that assess the diverse influences of floods on each components of the ecosystem parameters viz., primary production, soil quality, water quality, biodiversity, drinking water availability, weed coverage, etc in the wetland ecosystem .

Materials and Methods

Area of study



The study covered the upstream reaches of Vembanad wetlands covering the Kuttanad agro ecosystem, extending from Vaikkom on the north to Thrikkunnapuzha on the south. The sampling stations include three distinct reigns 1.Open Vembanad lake 2.flood plain paddy lands covering upper Kuttanad, Lower Kuttanad, Kayal lands, North Kuttanad and Karilands and the downstream riverine locations of four river system viz., Pampa, Achencoil Manimala and Meenachil River in Kuttanad. Investigations on post flood environmental conditions of the open lake, flooded farmlands, and riverine regions of Kuttanad, falling within Alappuzha, Kottayam and Pathanamthitta districts were covered. The study was undertaken from November 2018 to March 2019 for post flood investigations and the data gathered for period round the year collected for 2018 and the previous years .The baseline data utilized for comparison included the one generated as part of a long term investigation, covering the same stations since 2010 as part of an Kuttanad Environment Surveillance study taken up by the same at Kerala Agricultural University and International Research and Training centre for Below Sea level farming, Kuttanad covering the same sampling sites.

Environmental variables monitored

Physicochemical and biological factors monitored include temperature (air, water), pH, transparency, Salinity, Dissolved Oxygen, Biological Oxygen Demand (B.O.D.), Phosphate (PO4-P) and NO_3-N (Nitrate) Primary productivity, Soil Organic carbon, Sediment grain size distribution (sand, silt & clay)etc

Biological parameters studied to investigate the effects of flood on biodiversity include qualitative and quantitative estimation of Phytoplankton, Zooplankton, Macro benthos, Fish and Fisheries.

The post flood environmental variable studied was compared with the data collected prior to the flood event from as part of continuing environmental surveillance program covering the same stations and locations. The stations covered include Open water lake stations viz. Vaikkom, Thykkattusserry, Thanneermukkom, Pathiramanal, Kumarakom, Muhamma, Punnamada, Pallathuruthy, Thottappally and Thrikkunnapuzha and paddy lands representing different agro ecological regions Upper Kuttanad, lower Kuttanad ,North Kuttanad and

Karilands ie., Edathuva, Pandamkari, Kainakari, Narakathara, Kumarakom, Kuruvappadam, Mankombu, & Mannar and riverine stations, Pamba and Manimala , Achencoil and Meenachil river systems.

Sampling locations

Location	Lat	Long	River/ padam
Edathuva	9.35693	76.4766	River
Kainakari	9.48069	76.38031	padam
Kanjippadam	9.40302	76.37241	River
Kidangara	9.42336	76.50331	padam
Kumarakom	9.64165	76.41949	river
Kuruvappadam	9.46352	76.36137	padam
Mancombu	9.43681	76.42789	padam
Mannar	9.3260796	76.536597	padam
Muhamma	9.60509	76.36566	kayal
Muttar	9.39191	76.49183	padam
Narakathara	9.46955	76.48138	Padam
Pallathuruthy	9.46315	76.36366	River
Pandamkari	9.3258216	76.5759543	River
Punnamada	9.52204	76.35663	Kayall
Thanneermukkom	9.67536	76.3931	Kayal
Thavanakkadavu	9.74255	76.36906	Kayal
Thavanakkadavu - mattel church	9.75354	76.37097	Kayal
Thykattussery	9.78905	76.36154	Kayal
Vaikom	9.75454	76.38853	Kayal
Veeyapuram	9.31525	76.45825	River

For position fixing and location of transects methods described by Holme (1971) were followed. In each station samples for water, plankton, benthos and sediments /soil were collected at monthly intervals. Water samples were collected, away from the shore and from subsurface level from mid-depths in all stations. Approximately 500 ml of water was collected in a wide mouth polythene bottle and stored tightly stopperd for subsequent physicochemical analysis. Care was taken to avoid air bubbling during the sampling and also during transporting of water samples. Chemical constituent like DO, pH, free carbon dioxide, were analysed in the field itself while sample for alkalinity, hardness, salinity, nitrates, phosphates organic carbon etc were analysed in the laboratory within 24 hours following standard methods as per procedures prescribed by APHA (1985).

Field observations of post flood environmental conditions of the lake, paddy fields, and river ecosystems were carried out. The stations covered include Open water lake stations viz.

Vaikom, Thykkattusserry, Thanneermukkom, Pathiramanal, Kumarakom, Muhamma, Punnamada, Pallathuruthy, Thottappally and Thrikkunnapuzha and paddy lands representing different agro ecological regions Upper Kuttanad, lower Kuttanad ,North Kuttanad and Karilands viz. Edathuva, Pandamkari, Kainakari, Narakathara, Kumarakom, Kuruvappadam, Monkombu, & Mannar and riverine stations namely Muttar, Pamba and Manimala from November 2018 to March 2019. For position fixing and location of transects methods described by Holme (1971) were followed. In each station samples for water, plankton, Benthos and soil samples were collected at monthly intervals.

Water Samples were collected for estimation of nutrients where stored in refrigerator and analysis done in 24 hrs.

The data was compared with the findings reported by this centre immediately preceding year during 2017-18 and previous reports. The water sampling stations already being monitored for since 2010 will form the baseline situations for the study. Secondary information was also collected with reference of previous studies from IRTCBSF and other workers. Compared with long term meteorological data (1901-2015) from Kuttanad region reported previously (Shajeesh Jan et. Al, 2017).

Materials and Methods

Surface and bottom water samples were collected from seven stations of Vembanad Lake during November 2018 to march 2019. Surface water samples were collected by clean bucket and bottom water by a Vandron sampler. Sediment samples were obtained by a Quadrat 0.1.m^2 to a penetration depth of 15cm. After the collection the samples were preserved at 4^oC till analysis.

Meteorological data obtained from Regional Agricultural Research station Kumarakom and Rice Research Station Moncompu was utilized and compared with long term data (1901-2015) from Kuttanad region (Shajeesh Jan et. al, 2017).Temperature was measured using a Mercury Thermometer. The temperature of air was recorded first, followed by that of surface water. Transparency of water was measured with the help of Secchi disc and turbidity, estimated directly from transparency values as per standard methods. pH of both surface and bottom water was measured using Universal pH indicator solution in the field and in the lab by electrometric method. Salinity of water sample was measured by salinity meter (Oakton SALT 6+) and the same by titrimetric method .Salinity expressed in ppt. Salinity was calculated by Mohr-Knudsen method. Dissolved Oxygen (DO) was determined by the modified Winkler method. Nutrient samples were refrigerated. The concentrations of N and P in the samples were determined. Phosphate was estimated by APHA (2005) method , Determination of dissolved inorganic phosphates by Fonselius, S.H. and S. Carlberg .1972). Nitrates were estimated as described by Mullin, J.D. and J.P. Riley. 1955

Core soil samples were taken for sediment analysis by drilling a metallic corer up to a penetration depth of 50 cm closed to the points were Benthos samples were collected. The sediment samples where temporary stored in wide mouth jars and a portion of this was used for granulometry and another portion is for the estimation of organic carbon .Grain size analysis was performed after Inman (1963). For mud samples appropriate amount of air dried sediment containing about 25 g of silt and clay fraction where used. The sediment was treated with hydrogen peroxide (6%) to remove organic matter and filtered the filtrate was soaked in distilled water and treated with sodium hexa Meta phosphate. The sand fraction was split on a 62 micron sieve by wet and dry sieving .The dispersed silt clay fraction was suspended in 1 litre cylinder ,after repeated shaking pipette samples of 25 ml where withdrawn at timings and depths based in settling velocity appropriate to their individual diameters, core silt (62-15.6µ),fine silt(15.6-3.9µ) and clay 3.9µ.The samples withdrawn were dried at 100 degree centigrade and the weight percentage of sand silt and clay fractions in the sediment where plotted on triangular graph paper.

Total organic carbon in soil was estimated by dichromate oxidation method described after Walkley and Black, after Buchanan (1971) .Organic carbon in the sediment described as the percentage of the oven dried sediment.

Water samples for phytoplankton primary productivity were collected using a water sampler from fixed reference point in the Vembenad Lake. The water collected were poured into triplicate bottles (one dark and two light bottles) The sample in one of the light bottles was fixed immediately according to Winkler's method to determine the initial level of dissolved oxygen content (APHA, 1998), while the other light and dark bottles were then suspended in a vertical position under water in the euphotic zone of the sampling station for four - six hours. After incubation time, the bottles were taken out and fixed prior to Dissolved Oxygen determination in the laboratory. The light and dark bottles method (Trivedi and Goel, 1986) was used for measuring the primary productivity (GPP, NPP and Community respiration). Gross primary production, Net primary production and Community respiration were calculated based on this formula (NOAA, 2000). The targeted fish production potential (TFPP) of the wetland system covering diverse aquatic habitats was estimated from the GPP values following the method described by Das, et al., (2010).

Zooplanktons were collected by filtering 200 litres of water. Random water sampling from the sampling station channels through a bolting silk having a mesh aperture of 100µ was also collected. The samples were immediately preserved by adding 5% buffered formalin prepared in filtered water. The total count, qualitative composition and numerical abundance of individual species were determined by counting the whole sample when the numbers were less. However, when planktons were abundant, aliquot samples were made with a Stempel pipette and counting was done under a stereo microscope.

Samples for Phytoplankton counts were collected from mid depths using a 500 ml plastic bottle. The empty bottle was lowered to mid depths and the stopper removed allowing bottle to fill. The sample was immediately preserved in 'Lugols solution' as per methods described by Saraceni and Ruggiu (1969) and Throndsen (1978) for samples, enough fixing agents (about 1 to 2ml) was added to give a weak brown colour. The samples were stored in clean glass bottle confirming from colour that required amount of fixative is added. The bottles were transported to the laboratory and kept in darkness till analysis. Phytoplankton samples preserved in Lugols Iodine were allowed to settle for a week and then slowly decanted The concentrated sample was allowed to further settle for 24 hours and decanted down to a volume of 50 ml. When the samples were found to be poor in plankton, the samples were centrifuged at 1500 rpm for 20min. after Margalef (1969). Counts were made by using a modified Sedgwick-Rafter cell. A minimum of 100 cells as recommended by Lund et al., (1958) and Frontier (1972) and maximum of 1000 cells were counted. Counting a minimum of 20-30 fields each of S-R cell as suggested by Mc Alice (1971) and Woelkerling et al (1976) was also followed. The counts were computed to cell number per litre. Filamentous algae were counted as

single units while for chain forming diatoms each cell was considered a replicating unit. The cells were identified during counting.

Benthic samples were collected from an area of $0.1m^2$ from three locations and benthic animals biomass ($g/0.1m^3$) and population density ($no/0.1\ m^3$)were estimated after methodology described by IBP Handbook No.16(Holmes and Mc Intyru et al ,1971).

Fish catch data was collected by conducting field surveys from different landing centers Kuttanad areas. Catch composition was analyzed and monthly fish exploitation was estimated (FAO (2002)). Random samples of fishes were collected for species occurrence from diverse ecosystems viz, open lake, rivers and inundated paddy fields and the same was compared with reports published earlier and list of species and their abundance were evaluated. The species occurrence was identified up to species level.

Estimates of the post flood abundance and distribution of fish stocks representing commercial fish species from the open lake and the adjoining wetland locations were monitored through surveys on landings registered at identified landing centres covering the entire Kuttanad region. Landing data was collected on from the landing centres through primary fish traders and fishermen co-operative societies operating therein. This inventory covered all the landing centers on the southern stretches of the Vembanad Lake in Kuttanad, from north and south of Thannermukkom barrage from Vaikkom to Veeyapuram. The landing sites covered specific fish landing data available on long term basis for commercially important fish species in the lake were also monitored .Based on actual data registered by fish vendors. Relative changes in the landings of selected endemic fish species of commercial value, viz., Pearlpot, 'Karimeen' *Etroplus suratensis* and

Kuttanadan Konchu, *Macrobrachium rosenbergii* were monitored based on landing registered by select fisher groups in major landing centers, consequent to deluge catch per unit effort.

Field survey of Black Clam were carried out in Vembanad lake to identify the areas of spat fall and established clam beds.100 numbers of black clam were collected and utilized on a monthly basis for size frequency distribution studies and other biometric relationships to assess the spawning and recruitment details .

Surveys covered locations on either side of the Thanneermukkom barrage where the clam fishing is an important occupation .Out of 11 registered lime shell co- operative societies in the Vembanad area; all the 8 societies dealing with black clam were included in this study. The Clam beds include regions covered by 4 societies on the west, 3 on the eastern shoreline and one at Kavalm in Kuttanad. They include viz. Vaikom Vechoor , Kumarakom, Kuthiathode, Thycauttussery ,Thanneermukkom North, Muhamma, Aaryad and Kavalam.

In order to assess the effect of flood on the rice productivity in Kuttanad, the realised paddy yield during 2017 puncha season and the yield registered after the deluge during punja 2018 were assessed. The study covered 19 Krishi Bhavans in Alappuzha and 18 krishibhavans in Kottayam districts in Kuttanad. Information on number of farmers, cropped area under each Krishi Bhavan , realised paddy production/ yield etc were evaluated village-wise. This data was also cross checked with the data available with paddy procurement data available with civil supplies corporation engaged in paddy procurement with reference to PRS datasheet maintained. Cropping intensity has been computed by dividing total cropped area of the region by the net area sown i.e. Cropping Intensity = Total Cropped Area X 100 / Net Area Sown. The primary purpose of this study on cropping pattern of a region is to undertake a geographical enquiry into the regional differences, spatial variations and suitable combinations of the crop and its geographical and human associations

RESULTS AND DISCUSSION

Flood and Physico Chemical factors

1. **Temperature**

Air temperature varied from 25-32°C and water temperature followed the same trend and it varied from 25-32°C.Surface temperature did not show any significant variation between stations.

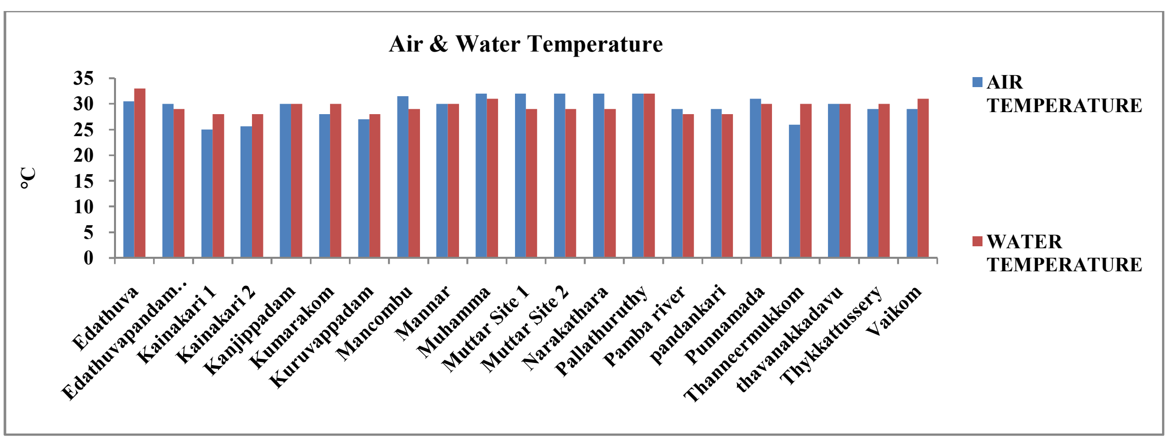


Fig.1

2. Tidal Fluctuations

This coastal strip of Kerala wedged between the Arabian Sea and the Western Ghats mountain chain is prone to inundation, the water levels in Kuttanad were very slow to decline after the deluge as the vast basin has its floor lying below mean sea level. It is inferred that the delayed discharge of flood has aggravated the flood effects in Kuttanad and this has been attributed to tidal floods. However an analysis of tidal fluctuations on the coastal flood it is evident that Kuttanad has been facing fresh session of flood since August 10 after the one in July

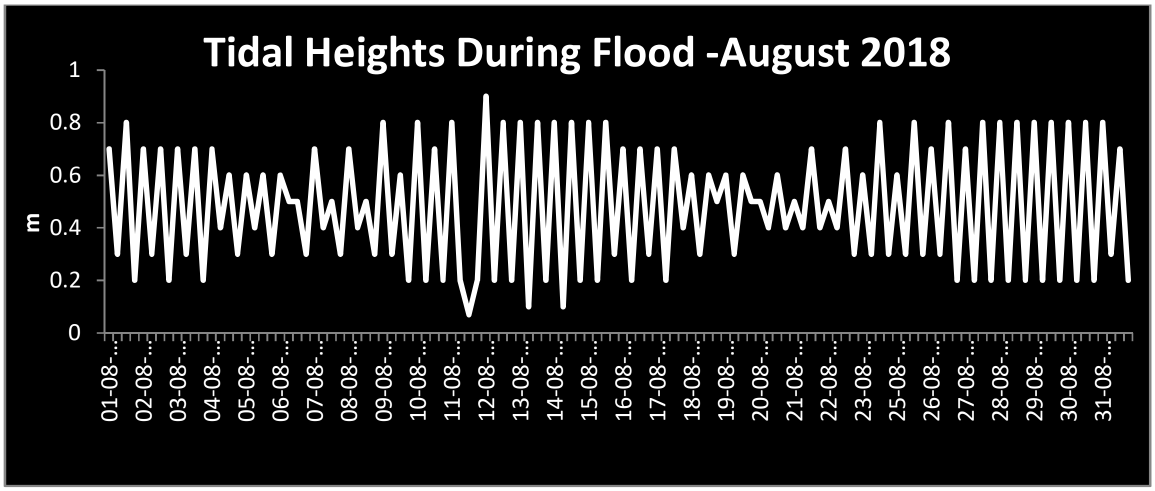


Fig.2

The tidal pattern revealed that the disastrous nature of the deluge was not apparently related to tidal floods as the highest tidal height during the month was observed on 12th August (0.95m) almost 4-5 days prior to deluge .This gradually receded to 0.60 m on 19/ 20 th August 2018 indicating that during the peak flood period, on 17/18, tidal heights were receding to 0.70 m which gradually reduced further during subsequent days with the neap tide.

3. Meteorological Data

Months	**Max (^{o}C)**	**Min (^{o}C)**	**TotalRainfall (mm)**
18-Apr	**33**	**24.6**	**71.6**
May	**33.5**	**24.4**	**303.8**
June	**30.4**	**24.4**	**573.2**

July	**30.2**	**23.6**	**683.3**
August	**29.9**	**23.4**	**621.3**
September	**33.1**	**24.7**	**108.8**
October	**32.7**	**24.5**	**273.9**
November	**33.5**	**24.5**	**88.2**
December	**33.6**	**24.3**	**67.2**
19-Jan	**33.7**	**21.63**	**0**
February	**34.9**	**24.7**	**0**
March	**35.6**	**25.87**	**58.4**

Highest monthly rainfall during the deluge year was recorded for August 2018 and it was 683.3 mm. This was higher by 27 percent than the monthly maximum recorded in Kuttanad, during the month of July based on the recorded data since the turn of the last century. The average annual rainfall over Kuttanad based on data for 125 years from 1901 to 2015 is 2594 mm (Shajish et al., 2017). As per IMD data, Kerala received 2346.6 mm of rainfall from 1 June 2018 to 19 August 2018 in contrast to an expected 1649.5 mm of rainfall. The annual rainfall during 2018, based on records at Rice Research Station Moncompu, Kuttanad region was 2849.70 mm, of which 1877 mm i.e. 64 percent was received during June to August.

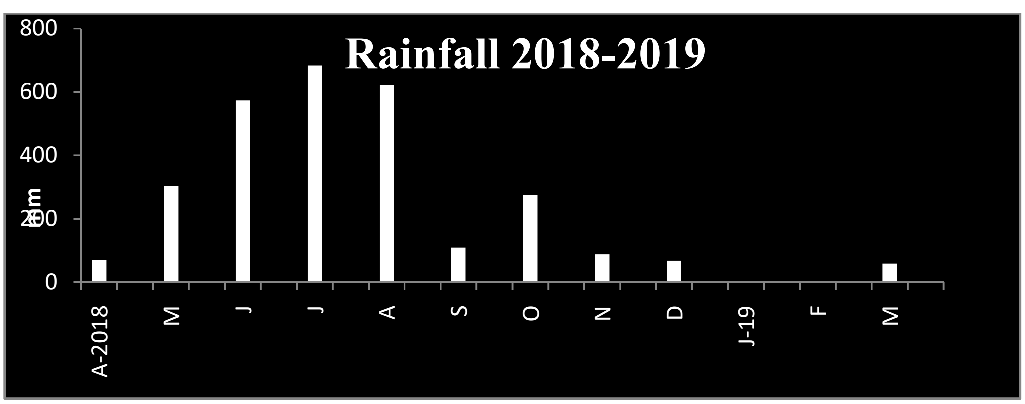


Fig.3

4. Transparency

Transparency of water, measured in meter by Secchi disc (m) method was perceptibly reduced since June 2018 and the trend continued throughout the deluge period. At Punnamada region where organic loading was high, turbidity was perceptibly high throughout the period of study as compared to open lake sites. Higher transparency was observed at Thanneermukkom region. Transparency of water relates to the depth of light penetration. The transmission of light into a body of water is extremely important since the sun is the primary source of energy for all biological phenomena. Transparency of water, which indicates the concentration of dissolved and particulate material in the water, is also correlated to the biological activity in a water body. Transparency decreases as algal abundance and/or suspended sediments increases. Clarity of water can be affected by soil erosion, runoff from urban and agricultural areas, waste water and storm water inputs, algae and plant materials, and abundant bottom feeders stirring up sediment is important in evaluation of tropic state at aquatic ecosystems. Low transparency observed throughout is apparently linked to the high turbidity caused by flood and deluge.

	J-18	J	A	S	O	N	D	J-19	F	M
Thanneermukkom	0.1	0.2	0.45	0.38	0.2	0.18	0.15	0.28	0.3	0.22
Punnamada	0.05	0.1	0.22	0.1	0.05	0.2	0.18	0.19	0.2	0.15

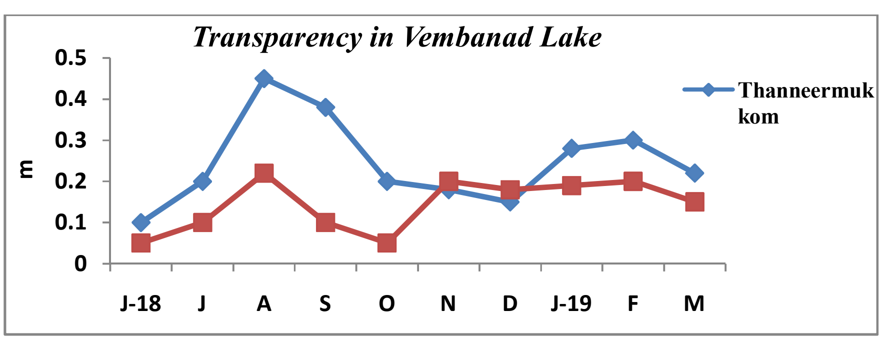


Fig.4

5. **Salinity**

In all stations monitored there was an increase in salinity during post monsoon and pre monsoon months, During the Post flood investigations salinity of surface water ranged from 0 -18.5 ppt (Fig.5a). During post flood studies the highest (18.5 ppt) was observed in Vaikom on the north of the Thanneermukkom barrage during February 2019. Salinity during the same period (2018) fluctuated between 0.086-23.1ppt. Salinity recorded highest value of 16.8ppt at Thrikkunnappuzha on the south during February 2019. The highest value of 4.3 ppt was reported during March 2019 at Thannermukkom south of the barrage although the barrage was closed indicating rapid incursion of saline waters into Kuttanad region consequent to decline of water levels after the devastating deluge. Maximum salinity variations were observed in Vaikom North of Thanneermukkom barrage.

Salinity is one of the most important abiotic stresses, limiting crop production in arid and semi-arid regions, where soil salt content is naturally high and precipitation can be insufficient for leaching (Zhao et al., 2007). Salinity is one of the most important abiotic stresses, limiting crop production in arid and semi-arid regions, where soil salt content is naturally high and precipitation can be insufficient for leaching (Zhao et al., 2007). According to the FAO Land and Nutrition Management Service (2008), over 6% of the world's land is affected by either salinity or sodicity which accounts for more than 800 million ha of land (Table 1)Salinity in rivers, lakes, and the ocean is conceptually simple, but technically challenging to define and measure precisely. Conceptually the salinity is the quantity of dissolved salt content of the water. Salts are compounds like sodium chloride, magnesium sulphate, potassium nitrate, and sodium bicarbonate which dissolve into ions. The concentration of dissolved chloride ions is sometimes referred to as Chlorinity. Seawater typically has a mass salinity of around 35 g/kg, although lower values are typical near coasts where rivers enter the ocean.

	S-2018	O	N	D	J-2019	F	M
Vaikom	**0**	**0**	**0**	**0**	**13.5**	**18.5**	**15.8**
Thanneermukkom	**0**	**0**	**0**	**0**	**2.8**	**4.1**	**4.3**
Punnamada	**0**	**0**	**0**	**0**	**0.8**	**4.2**	**3.8**
Pathiramanal	**0**		**0**	**0**	**3.1**	**4.1**	**4**
Pallathuruthy	**0**	**0**	**0**	**0**	**0**	**2.8**	**2.3**
Thrikkunnappuzha	**0**	**0**	**0**	**0**	**9.8**	**16.8**	**13.8**
Thottappally	**0**	**0**	**0**	**0**	**0**	**1.8**	**1.48**

Comparison of the salinity value with that reported during previous years indicated a rapidly increasing trend in surface waters year after year which could be linked to saline incursion effects due to climate change, and sea level rise and to reduced inflow from the river systems. Rise in salinity up to 23.1ppt during February 2018 (Vaikom) is a distressing trend. However, after the flood and deluge, there has been a marginal reduction (18.5ppt) during 2019. The incursion of saline water to upstream regions of Thannermukkom barrage during 2018 prior to the flood indicate that despite closure of the barrage saline incursion beyond permissible levels can only be attributed to extreme reduction of water level. The situation calls for efforts for maintaining a minimum seaward environmental flow in the wetland by storage of water in the flood plains. The suggestion to utilize the uncultivated Padasekharams in Kuttanad seasonally as water storage structures during rainy season assumes relevance in the context of climate change related water stress.

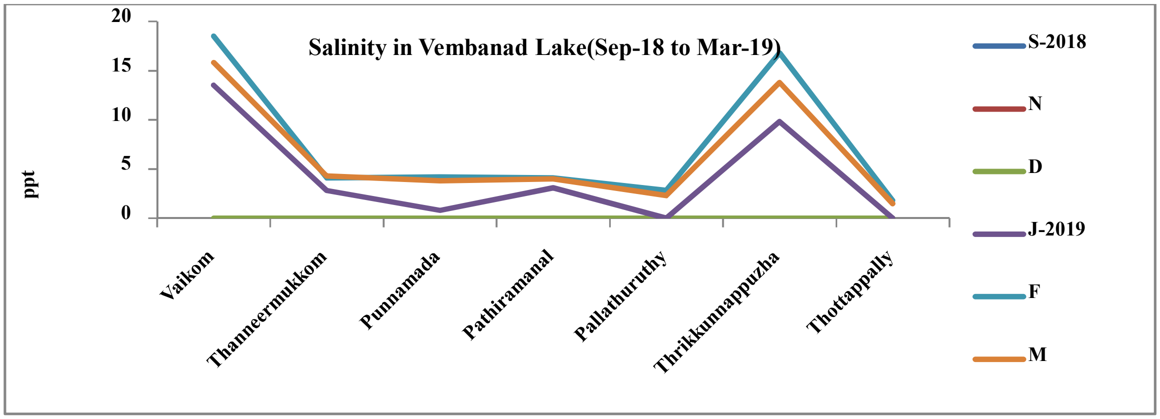


Fig.5a

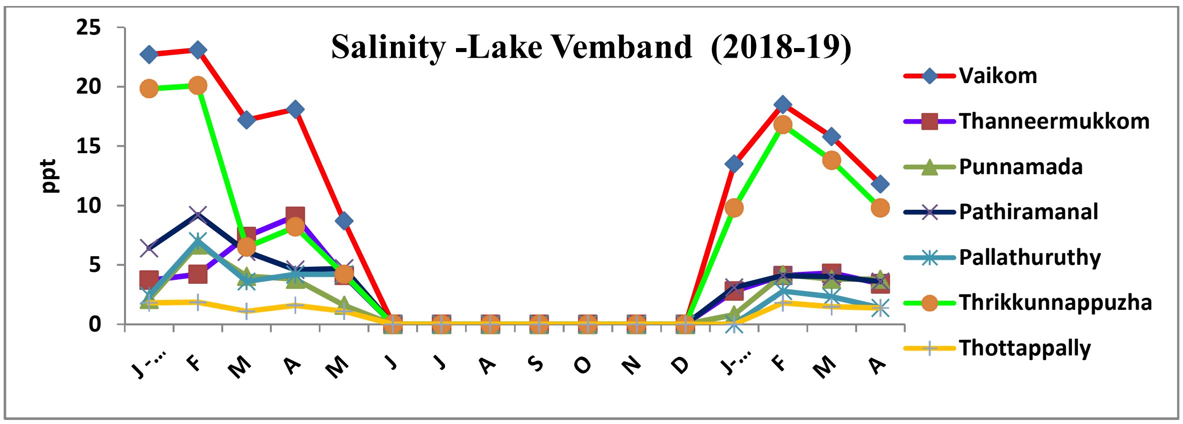


Fig.5b

The salinity values reported from southern regions of the Vembanad Lake is much higher than that reported in almost all previous studies. (Padmakumar et al, 1988, V. K Unnithan, 2001, Anon, 2011). Salinity variations observed were also lesser than that reported from northern side of the lake Aroor at downsteam, north in the lake. (Sujatha et al 2009, Retina et al 2016). Prior to commissioning of the Thanneermukkom barrage (Josanto 1971) observed maximum salinity of *Vembenad lake ,* A similarly increasing trend in salinity was also reported in previous studies (Padmakumar et al 2017).According to CGIAR report the extend and intensity of salinity in the coming years are likely to increase due to climate change induced salt water intrusion (Pethak et al, 2018) a clear indication of the distressing trend of saline incursion in coastal wetlands.

6. pH

In post flood evaluations, pH of sub surface water ranged from 6 to 7 in open Vembanad Lake, and 6.3-6, in floodplain padasekharams while it ranged from 6.5-6.9 in riverine stations. During the previous years (2017& 2018) lower pH values (5 to 8) in the open lake was observed. Apparently there is no significant variation in pH in open lake water and soil due to flood. Comparison of the pH value with that reported during previous years indicated that there is no significant change.

The pH is a measure of ionized hydrogen in a liquid system. For every fall of unity in pH there is a tenfold increase of active acidity. Its increase of every unit over 7 raises the active alkalinity tenfold.

WATER

	S-2018	**O**	**N**	**D**	**J-2019**	**F**	**M**
Vaikom	7	6.5	6.8	6.4	6.8	7	6.8
Thannermukkom	6.8	6.8	7	7	6.8	6.5	6.6
Punnamada	6.8	7	6.9	6.9	6.4	6.6	6.4
Pathiramanal	6.5	6.9	6.5	6.7	7	6.9	6.8
Pallathuruthy	7	6.8	7	6.9	6.8	6	6.1
Thrikkunnappuzha	6.8	7	6.9	7	6.8	6.7	6.9
Thottappally	6.7	6.4	6.7	6.7	6.8	6.8	7

SEDIMENT

Padasekharams		**Rivers**	
Edathuva pandamkari	6.7	Muhamma	6.8
Kainakari	6.6	Pallathuruthy	6.8
Narakathara	6.4	Pamba river	6.7
Kumarakom	6.3	Punnamada	6.8
Kuruvappadam	6.5	Thanneermukkom	6.5
Moncombu	6.9		

The pH values which measures the acidity or alkalinity of the water are the most discussed parameter during flood events. pH value drops immediately after flood and with the second wave of flooding after the big flood events, pH condition improve to near normality as observed by Ching et al.,2011. A similar situation of increased pH in post flood situation was reported in surface horizons of potential acid sulphate soils (Carla et al.1994). The main driver for this change in flooded soils is reactive Phosphates ,Nitrates and Potassium in sediment that bring about a clear shift in pH presumably associated with redox changes in the soil(Guppy and Moody,2018).Apparently the benefit of rapid cleansing effect by the flood waters was evident in this study.

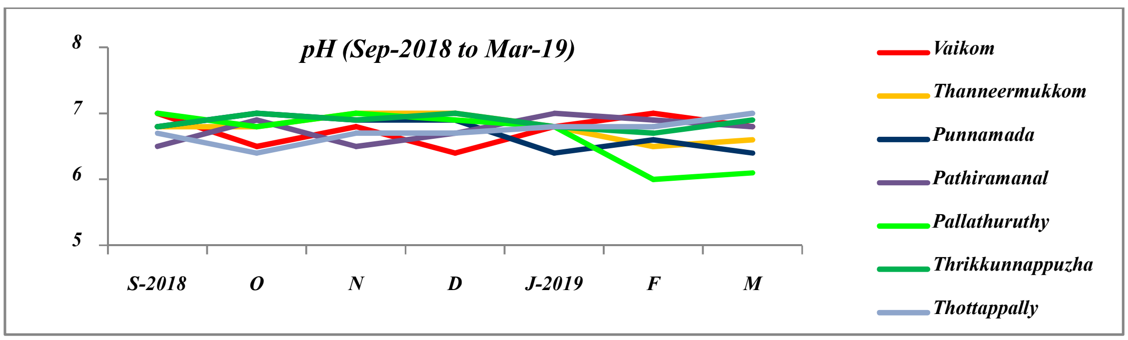
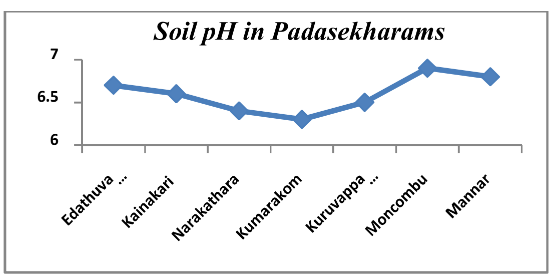


Fig.6 a



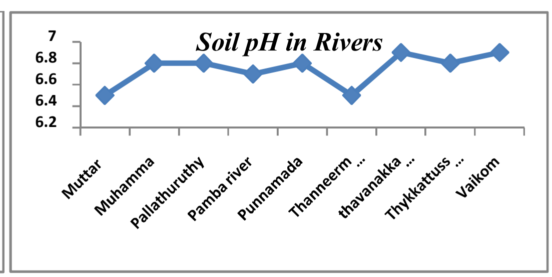


Fig.6 b

Fig.6 c

7. Dissolved Oxygen

Dissolved oxygen in surface water during the post flood period ranged from 0.8 to 7 mg/l with an average of 3.2 mg/l. The observed low value was significantly lower than the desired level of DO for sustenance of aquatic organisms. Immediately after the flood, during October 2018, the concentration of dissolved oxygen, almost reached hypoxia (0.8mg/l) in Thrikkunnapuzha region, the flood water discharge point close to the Kayamkulam estuary. A similar decline to drastically lower level up to 1.2 mg/l and 1.3 mg/l was observed at Vaikom, and Thottappally sector respectively, both locations representing the exit points for flood waters. The highest DO (7mg /l) concentration was observed in Pathiramanal region in the open lake during September 2018. The observed DO concentration during post flood was lower than that observed in year round surveys closed to the in urban sewage influx point at Punnamada where a very low DO was characteristic. Decline in DO concentration continued as a characteristic feature in almost all locations even after the deluge. This could only be attributed to the high organic loading consequent to flood and deluge. In the year round monitoring during the pre flood period (2017&18) the average DO was significantly higher (4.08 mg/l) which further explains that the low DO is linked to the influx of organic matter during floods.

Dissolved oxygen is a critical parameter in aquatic ecosystems and one of the important chemical parameter for water quality. The optimum value of DO for survival of aquatic life is known to be 4-6 mg/l. Oxygen levels below 1-2 mg/L even for a few hours can result in fish kills. The depressing concentration of DO is a negative effect of the flood event, linked to breakdown of organic matter.

	S-2018	**O**	**N**	**D**	**J-2019**	**F**	**M**
Vaikom	6	4	4	4.6	3.2	1.6	1.2
Thanneermukkom	5.2	3.8	6	2	4.2	3.2	3.6
Pathiramanal	7	3.6	4.2	3.8	3.6	2.1	4.2
Punnamada	4	3.2	2.1	3.2	4.6	3.8	2.4
Pallathuruthy	4.1	4.5	3.2	2.4	6.8	4.2	3.1
Thottappally	1.2	1.8	3.8	1.6	1.8	4.2	3.2
Thrikkunnappuzha	2.6	0.8	1.6	2.1	3.2	3.4	1.6

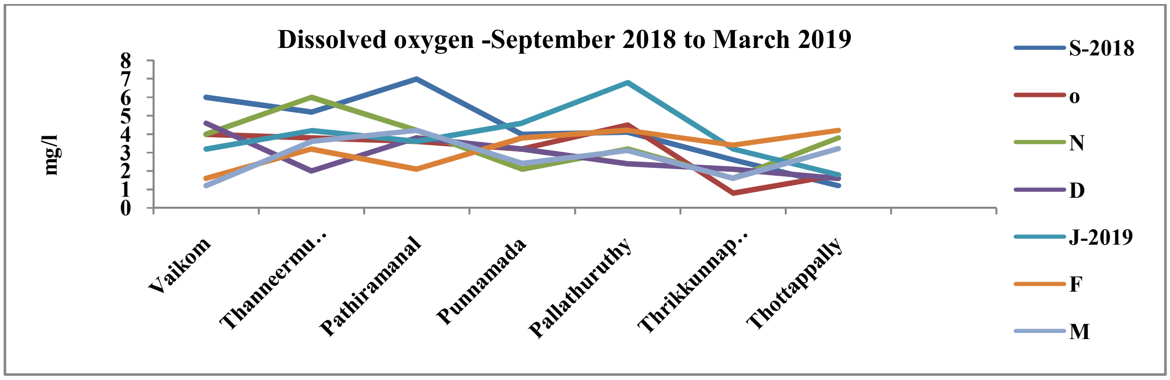


Fig.7a

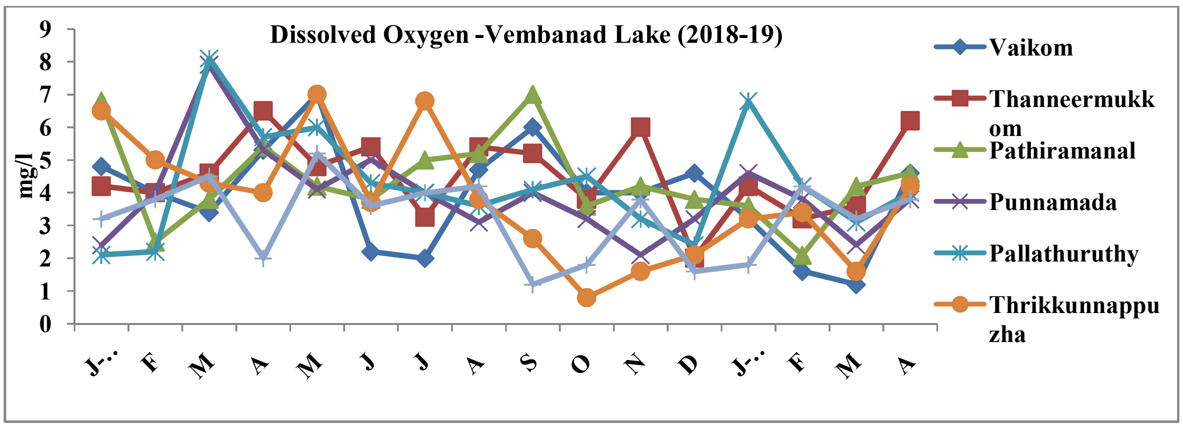


Fig.7b

8. Phosphate (PO_4-P)

Phosphate (PO_4P) concentration in water ranged from 0.43mg/l to 8.67 mg /l with an averge of 2.85mg/l in the open lake waters during the post deluge period. Immediately after the deluge, the concentration of phosphate in the open waters rose to 10.5mg/l in the open lake region in pathiramanal during september 2018. However its concentration rapidly reduced to as low as 0.43 mg/l in the same location by March 2019.

Phosphate in the lake waters fluctuated between 1.2-7.8 mg/l, highest values observed during April 2017 with Average 3.6 mg/l. A similar increase in concentration was observed during monsoonal flooding during previous years where the highest value was high as 12.9 mg/L,detected in locations close to at the sewage influx points and houseboat terminals at Punnamada and Pallathuruthy. Apparently flood inundation led to increased nutrient mobilization in all stations particularly for phosphate which reached very high concentrations.

Phosphate (PO_4-P) is critical nutrient that limits the organic production in esturine environment.Nutrient enrichmment consequent to floods is a characteristic phenomenon. In esturine systems Phosphate is an essential element for plant life, but when there is too much of nutrient in water, it can speed up Eutrophication. The natural levels of total phosphorus are generally less than 0.03 mg/L. Many bodies of freshwater are currently experiencing increases of phosphorus and nitrogen from outside sources. High phosphates in water cause , algal blooming which prevents light and oxygen from getting into the water, leading to hypoxia and death of organisms in the ecosystem.

	S-2018	O	N	D	J-2019	F	M
Vaikom	9.1	7.2	6.1	3.2	0.9	0.92	0.56
Thanneermukkom	8.85	6.03	7.6	1.9	1.2	1.5	0.9
Punnamada	8.4	7.4	8.67	4.6	1.6	0.64	0.72
Pathiramanal	10.5	8.2	7.9	4.1	0.8	0.73	0.43
Pallathuruthy	4.475	6.325	6.41	3.9	0.68	0.94	0.61
Thottappally	5.9	6.8	5.2	2.7	1.1	0.76	0.51
Thrikkunnappuzha	5.38	3.9	2.1	1.9	0.9	0.82	0.95

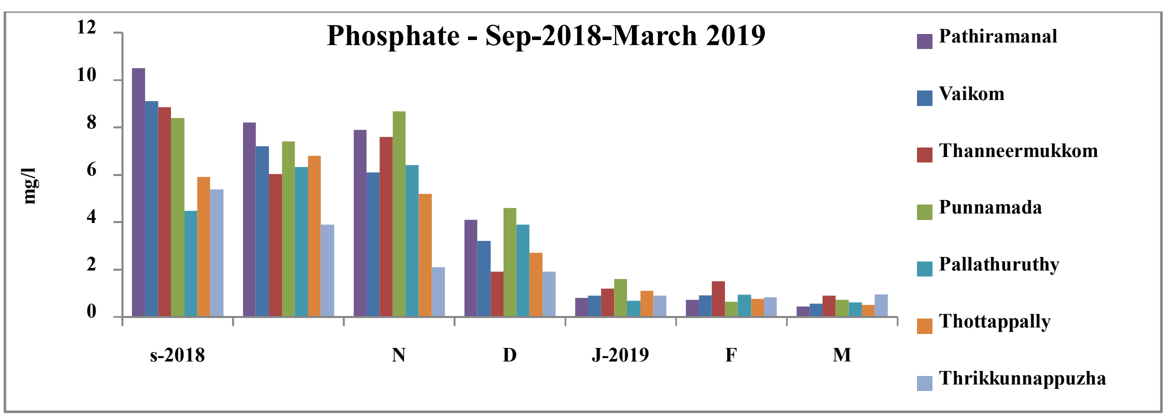


Fig.8a

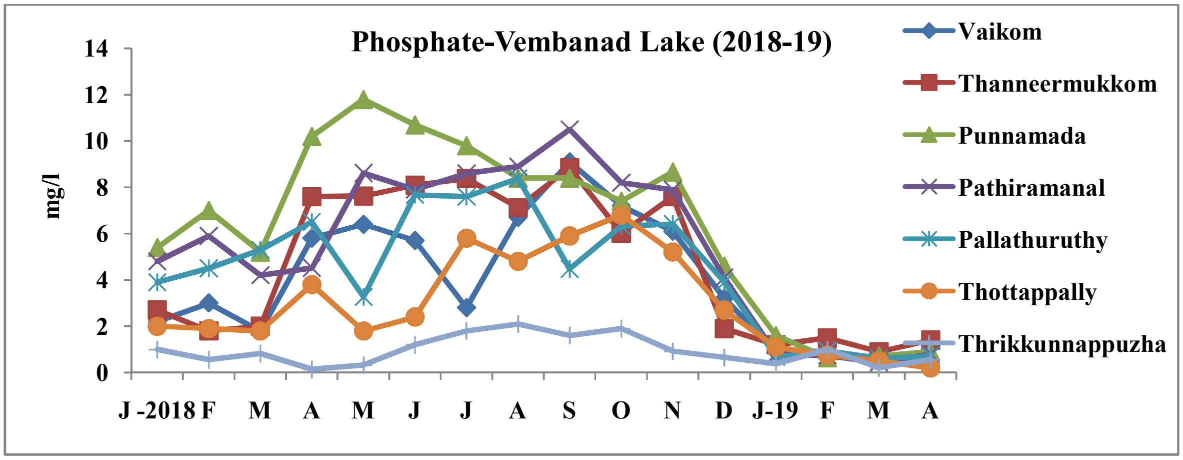


Fig.8b

9. Nitrate-Nitrogen (NO_3-N)

Nitrate concentration in the surface waters post deluge ranged from 0.7mg/l to 5.0 mg/l. Highest values (6.5 mg/L) were observed during September 2018 immediately after the deluge especially locations closed to sewage influx areas of urban discharge points near Punnamada. Obseved nitrate nitrogen though higher than normal, was apparently lesser than that of phospahtes. In all stations nitrate concentration was high during post flood period as compared to that observed during previous years.

Nitrates and phospahtes are known as critical plant nutrients. In open Vembanad lake, its concentratin has been exhibiting abnormal trends during different years. The Nitrate concentration during previous years ranged from 0.04-2.5 mg/l with an average of 1.05mg/l(Fig.9 b) .During 2017&18 its concentration was relatively lower (0.045-6.5 mg/L) , average 1.32 mg/l as compared to the flood year.

Nitrate nitrogen is a decissive parameter linked to the productivity in aquatic systems. Excessive Nitrate -N can cause eutrophication of surface waters primarily by stimulating algae production. Agriculture has been identified as a potential contributor of Nitrate Nitrogen to surface water. Abnormal concentration of nutrients in Kuttanad waters can only be attributed to incessant human interventions and organic enrichment through diverse infringements in the ecosystems. Omernik (1977) reported that total Nitrogen concentrations were nearly 9 times greater downstream agricultural lands than forested areas especially in ground waters. Apparently, after flooding, nitrate accumulated to very high levels. This type of Eutrophication resulting from increased mobilization within the system is called internal Eutrophication, a characteristic feature observed during post flood in Kuttanad waters.

	S-2018	O	N	D	J-2019	F	M
Vaikom	9.1	7.2	6.1	3.2	0.9	0.92	0.56
Thanneermukkom	8.85	6.03	7.6	1.9	1.2	1.5	0.9
Punnamada	8.4	7.4	8.67	4.6	1.6	0.64	0.72
Pathiramanal	10.5	8.2	7.9	4.1	0.8	0.73	0.43
Pallathuruthy	4.475	6.325	6.41	3.9	0.68	0.94	0.61
Thottappally	5.9	6.8	5.2	2.7	1.1	0.76	0.51
Thrikkunnappuzha	5.38	3.9	2.1	1.9	0.9	0.82	0.95

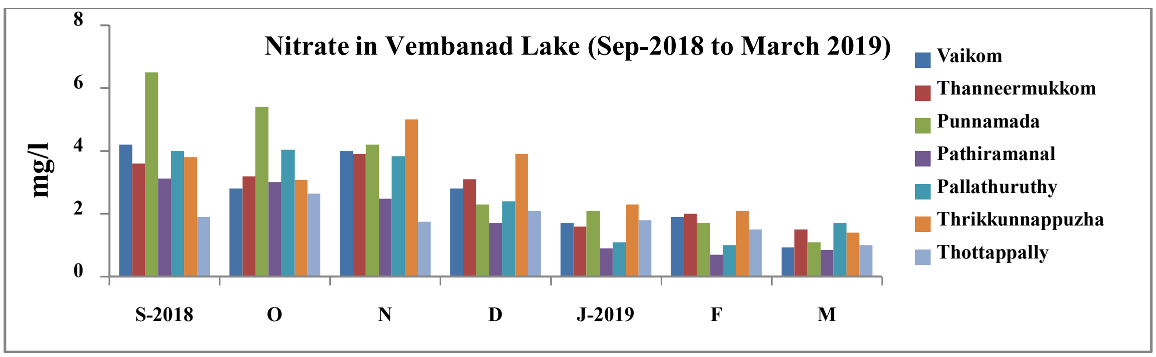


Fig.9a

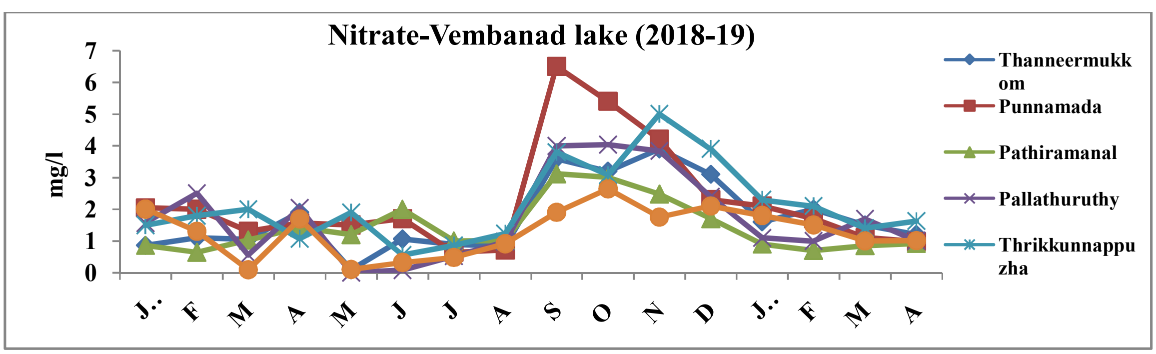


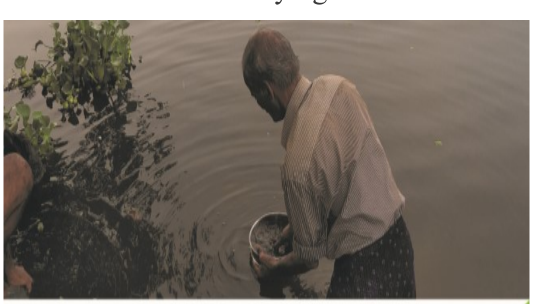
Fig.9b

10. Total Organic Carbon

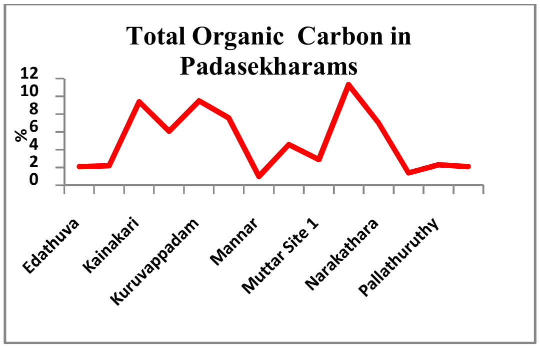
Total Organic Carbon in sediments during post flood period ranged from 0-2.8% in open lake stations,1.4-11.33% in floodplain Padasekharams and 1.9-11.08 % in riverine sediments. Highest concentration of total organic carbon was characteristic to riverine locations and flood plain polders as compared to open lake stations. The highest value in lake sediments 2.8% was observed close to Thannermukkom barrage during October 2018. Organic Carbon immediately after flood in Muttar padasekharam adjacent to Manimala river reached highest percentage during November (11.3%). A similarly high value of 11.08 mg/l, was observed in the flood plain sediments at Edathuva- Pandamkari reaches in the Pampa river system during November 2018. Total organic carbon content in open lake locations during previous years indicated highest value as 2.8 % and almost a similar level was observed in the post flood. We may infer that open lake locations did not show any appreciable increase or decrease due to floods unlike riverine locations and floodplain polders.

Organic carbon and the other nutrients in soil play a key role in soil-forming processes, in addition to contributing to soil fertility and quality. Organic compounds found in soil is a stable reservoir and carbon sink that limit CO_2 release to the atmosphere and hence wetlands are rich in deposited carbon sinks that help combat climate change .Studies in Kuttanad reveal that the wetlands receive 1 to 26 tons of organic matter annually and the present study indicated that after the deluge quantum of silt and sediments deposited in riparian zone of river Pampa near Mannar was as high as over 130 tons/ ha.

Soils tend to be more acidic in zones with presence of thicker litter, which contributes to acidifying the surface horizons. Degradation and humification of organic matter produces acidifying substances. However such a serious problem of acidification was not



discernible in open surface waters in Kuttanad after the flood probably due to fast flood washing off acidifying substances.



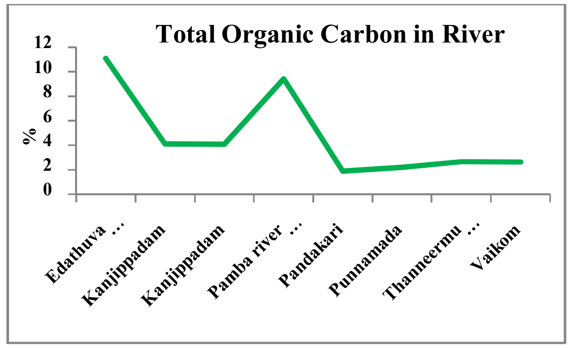


Fig.10a

Fig.10b

11. Flood and Sediment Grain Size

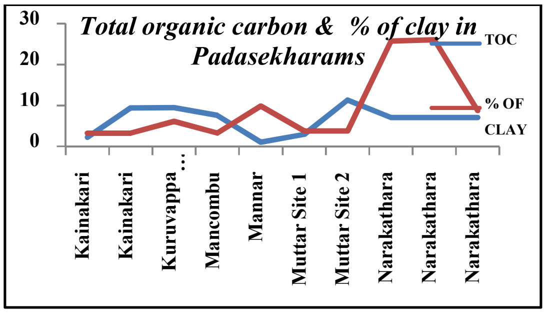
Grain size distribution in the sediments during post flood evaluation indicated that median grain size fluctuated from sandy loam to sandy clay loam and to silty clay in different stations. In almost all padasekharams and river systems the textural class was predominantly sandy loam. In riverine zones apparently highest percentage of sand fraction was evident, possibly linked to deposition of sand consequent to massive floods. In riverine sediments, percentage of clay fluctuated between 5.3-44.96% and silt from 12.6 to 44.4% and percentage of sand ranged high from 57.2 to 61.3%. In padasekharams, percentage of clay ranged from 3.2-25.68% and percentage of silt from18.72-35.2% and sand fraction from 52.24- 74.3%. Clay fraction dominated in few stations also in river soils (44.96 %) in Kanjippadam areas close to the sewage impounded site and minimum 5.3 % in Pamba river site. In Padasekharams highest clay content 25.68% was observed in Narakathara padasekharam and minimum 3.2 % at Moncombu and Kainakari. . The textural class of floodplain regions after the floods indicated that flood plays an important role in soil profile dynamics and development. A significant negative correlation of Total Organic Carbon and sediment clay fractions was evident in Narakathara and Mannar padasekharams and upstream locations of Pamba.

Sediment composition and particle size are very important flood impact parameters. The rate of sediment deposition and erosion processes occurring between the river and flood plain affect soil formation on flood plains. It is apparent that floods recharged farmland soils and increases suitability for farming. Therefore, the net positive or negative impacts of flooding on soil formation depend on the volume of sediment transported and deposited. When silt carried in suspension by rivers in flood, is allowed to be a deposited in fields specifically by adding layers of silt it is called warping. Warping makes the land fertile. The observed conditionings of rice polders after flood indicate that rice field soils have become good for cultivating rice. However, in locations higher concentration is observed ,it might reduce porosity and it is recommend that farmers in such floodplains plough immediately after the onset of flood recession when the soil is still moist and rich in nutrients availability (Ubuoh1, ,et al., 2016). More studies are however needed to identify the impact of flood events on soils in Kuttanad.

Soil Texture in Rivers				
Flood soil	% clay	% slit	% sand	Soil texture
Pamba	5.3	33.4	61.3	sandy loam
pandankari 1	32.72	10.08	57.2	sandy clay loam
Pandankari 2	28.3	12.6	59.1	sandy clay loam
Kanjipadam	44.96	44.4	10.64	silty clay

Soil Texture in Padasekharams				
Flood soil	% clay	% slit	% sand	Soil texture
Moncomb	3.2	26	70.8	sandy loam
Narakathara	8.7	23.4	67.9	sandy loam
Narakathara 2	25.68	18.72	55.6	sandy clay loam
Narakathara 2	26	21.76	52.24	sandy clay loam
Kainakari	3.2	25.7	71.1	sandy loam

Muttar	3.7	35.2	61.1	sandy loam
Kuruvapadam	6	19.7	74.3	sandy loam
Mannar	9.8	21	69.2	sandy loam



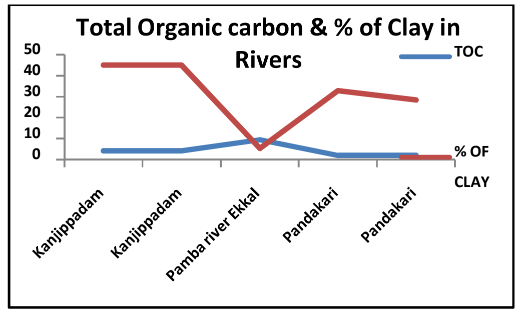
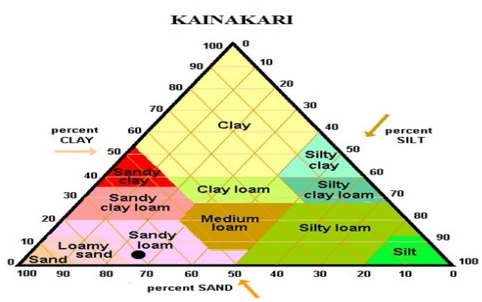
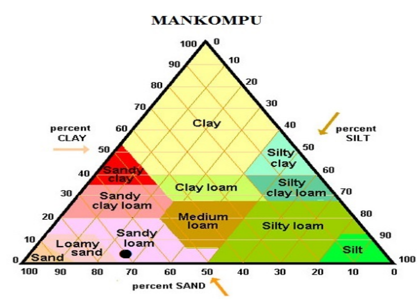
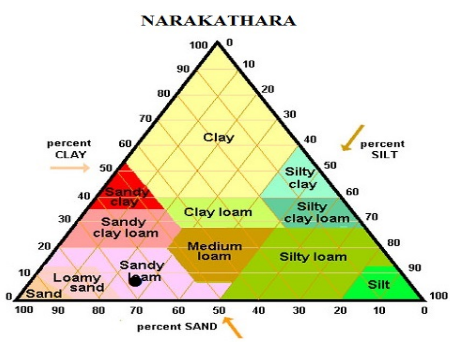


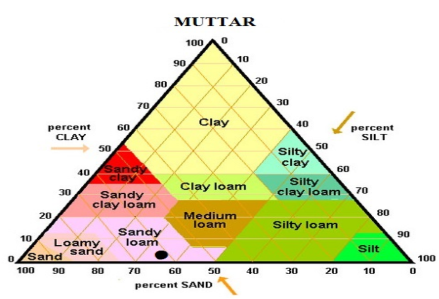
Fig.11a

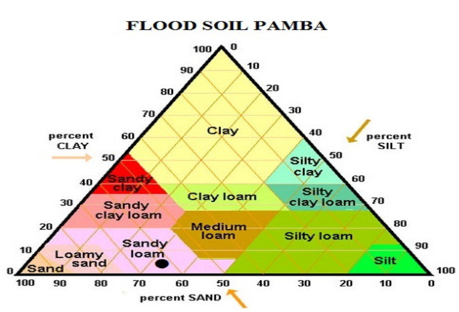
Fig.11b

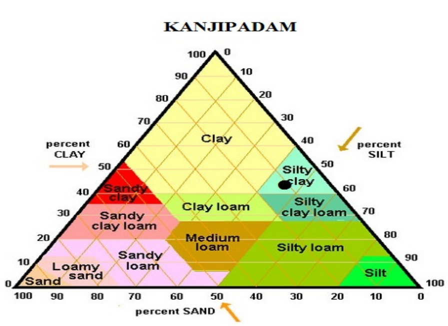


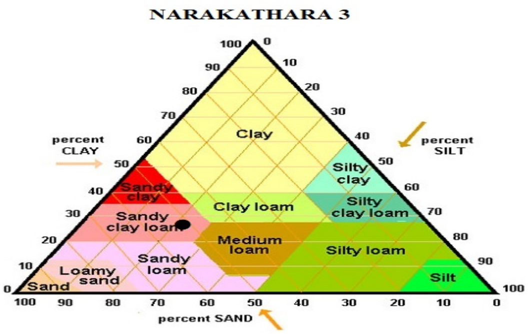


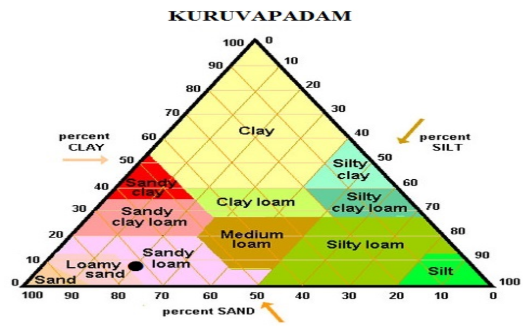


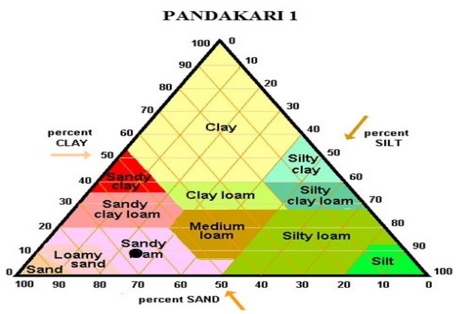


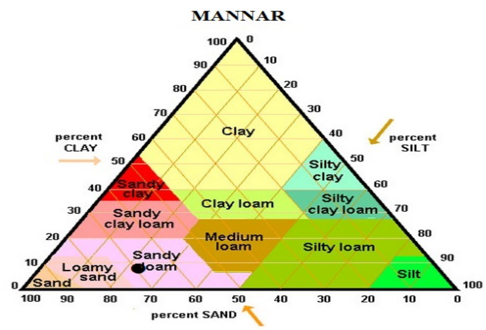


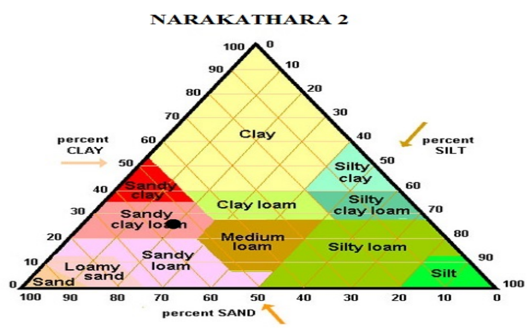












12. **Gross Primary Productivity**

Gross primary productivity at different stations fluctuated from 45 (September)-315 (November) mg C/m^3/hr (av.195.83mgC/m^3/hr) during the post flood period . The average GPP values for the flood year 2018 was 148.89 mg C/m^3/hr. The Gross Primary Productivity (GPP) of lake water was several fold higher than that reported during 1999-2001(Padmakumar, 2001, 2002). The highest productivity 315 mg C/m^3/hr was recorded during 2018 in open lake stations in Pathiramanal and the lowest 45 mg C/m^3/hr in Punnamada waste water impounded tourist terminal site during September. Evidently there is a perceptible decrease in productivity during the months of flooding in all stations, which gradually picked up during the post flood period. Conversion of the GPP values with Targeted Potential Fish Yield (TPFY) computed (Das et.al, 2008) indicated Potential Fish yield, on the south of the Thanneermukkom barrage (13000 ha) at 774 tones. This when compared to previous year, 835 tones is lower than that of the previous year. The actual realised fish yield from 13000 ha in Kuttanad on south of barrage during 2011 has been 633 tons of fin fish and 128 tons of prawns and shrimps (Padmakumar et al., 2017.) A recent estimate of annual fish catch in Vembenad lake (Asha et al.,2014) indicate total annual landing from the southern sector as 480.98 tons and 4387.31 tons from the whole lake. As 30% of the TPFY is predicted as possible yield (Das et.al, 2008).The predicted potential appear to be realistic however the important contribution of detritus and such other allochothanous sources of food resources are not included in this. Utilization of GPP or NPP as a dependable index for predicting targeted fish yield (TPFY) in water bodies has been suggested in various studies (Das et al., 2008).

Productivity is of great importance in ecosystem as it integrates the cumulative effects of many physiological processes, which occurs simultaneously within the ecosystem. Primary productivity of aquatic ecosystems is essential for a proper assessment of the biological potential of that habitat. Primary productivity refers to the fixation of inorganic carbon and the gross or net production of organic matter by the photosynthesis process.

The light intensity and nutrient availability are important factors to primary productivity in aquatic ecosystems, because they constitute limiting factors to photosynthesis. However, there are certain physicochemical and biological factors which control the rate of production in a marine ecosystem. Higher production is not governed by a single factor (Singh and Singh, 1999)

Floods may initially inhibit primary production while when water is high but nutrients mobilized during storms may be processed in ecosystems later, when water levels. Primary production benefit aquatic ecosystems up to a certain tipping point. Therefore, increased primary production post-flood is considered an ecosystem service net gain but if primary production is excessive then flooding results in a net loss. If flushing rates exceed algal growth rates, large flood events could reduce algal biomass, regardless of nutrient enrichment.

	S	O	N	D	J-19	F	M
Thanneermukkom	135	225	160	195	120	300	130
Pathiramanal	105	300	315	165	240	165	255
Punnamada	45	155.76	163.5	161.5	196.1	121.15	144.23
Pallathuruthy	187.5	175	200.6	240	255	240	300
Thottappally	208	104	167	104	156	313	208

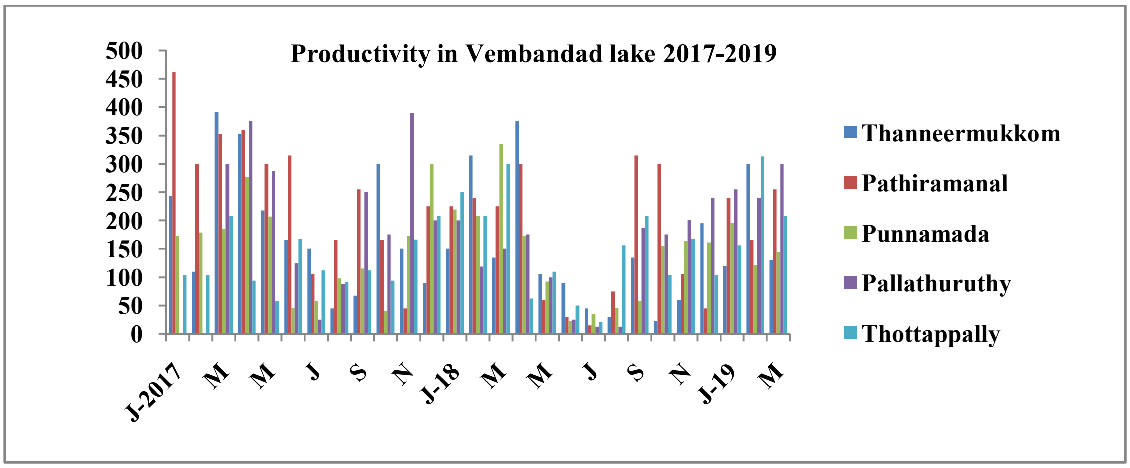


Fig.12 a

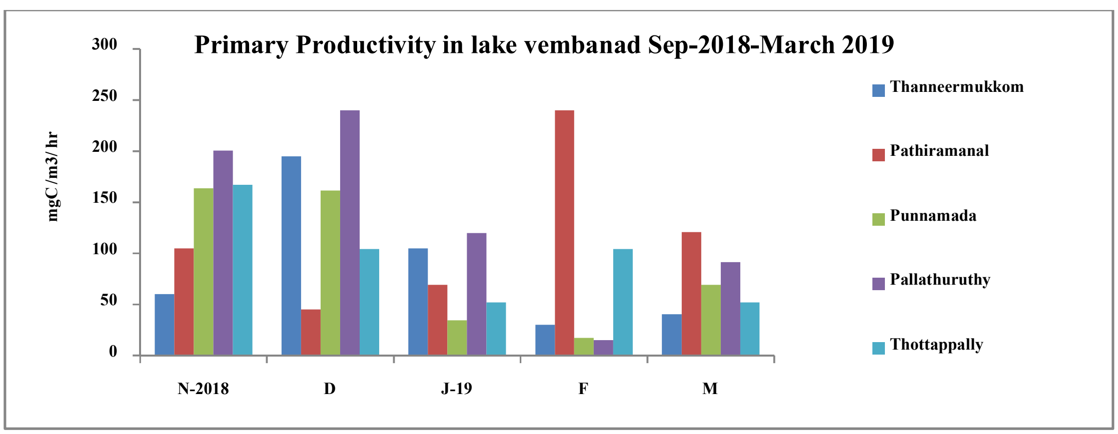


Fig.12 b

Impact on Flood on Aquatic Biodiversity

13. Phytoplankton

A total of 34 taxas of Phytoplankton were identified as dominant taxa in the post flood inventory in Kuttanad waters. The highest incidence phytoplanktons were observed in open lake waters in Kumarakom and riverine station and at the riverine stations in Muttar region of the Manimala river .The relative abundance of various genera are summarised in Table.

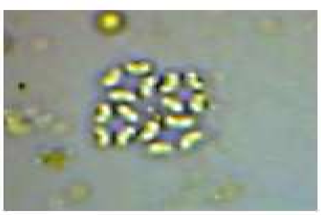
Species abundance in different locations is given in table.

Actinastrum sp., Pediastrum sp., Coelastrum sp., ,Scenedesmus sp., ,Tetraedron sp., Navicula sp, Nitzschia closterium, Spirulina sp., Asterionella sp, Pleurosigma sp., Euglena sp., Cosystis, Peridiniumsp., Ankistrodesmus falcatus , Anacystis sp., Anabaena sp., Cosmarium sp., Volvox sp., Hyalotheca sp., Melosira sp., Oscillatoria sp., Nodularia sp,. Stauroneis sp., Cymbella sp., Cyclotella sp., Synedra sp., Mallomonas sp,Closterium kiietzingii, Peridinium sp., Chlorella sp.

In the year round study, covering the same stations in the open lake prior to the flood, a long list of plankters could be identified They include *Actinastrum sp., Characiumsp., Chlamydomonas sp., Chlorella sp., Cladophora sp., Closteridium sp., Closerium sp., Cosmarium sp., Elakatrothrix sp., Melosira sp., Microspora sp., Oedogonium sp., Scenedesmus sp., Spirogyra sp., Spirotaenia sp., Staurastrum sp., Tetraedron sp., Ulothrix sp. Zygnema sp. ,Achananthes sp., Amphora sp., Asterionella sp., Biddulphia sp., Ceratulina sp., Cheatoceros sp., Climacosphenia sp., Coscinodiscus sp., Cyclotella sp., Cymbella sp., Diatoma sp., Diploneis sp., Fragillaria sp., Frustulia sp., Gyrosigma sp., Grammatophora sp., Isthmia sp., Leptocylindrus sp., Licmophora sp., Navicula sp., Nitzschia sp., Pinnularia sp., Pleurosigma sp., Rhizosolenia sp., Skeletonema sp., Stauroneis sp., Streptotheca sp., Synedra sp., Tabellaria sp., Thalassionema sp., Thalassiosira sp., Thalassiothrix sp. Triceratium sp., Coscinodiscus, Anabaenopsis sp., Anabaenasp., Lyngbya sp., Oscillatoria sp., Phormidium sp., Spirulinasp. and Trichodesmiumsp.*

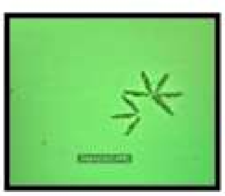
Phytoplankters are the primary producers of the pelagic marine ecosystems and some of the phytoplankton species may also reflect the ecological changes in the environment. Planktonic primary production provides the base upon which the aquatic food chains culminating in the natural fish populations. They are primarily responsible for 50 percent of the world's primary productivity (Longhurst, Sathyendranath, Platt, & Caverhill, 1995).

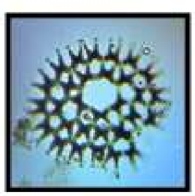
Phytoplanktons are the major producers in the aquatic ecosystems; their role in the food chain is of paramount importance. Phytoplankton forms the foundation stone of world fishery. The distribution and abundance of the commercially important fish and shellfish and their larvae are dependent on some species of the phytoplankton, forming food for majority of juveniles as well as many adult fishes. Not only that in aquatic ecosystems plankton are indictors of water quality, for eg., chaturvedi et al., (1999) reported that some planktons like *Chlorella* and *Closterium* grew well in polluted waters and acts as indicators of organic pollution (Borse et al., 2003) observed that, presence of genus *Ankistrodesmus sp* and *Scenedesmus* in significant numbers According to Round (1965), epilethic algae such as *Oscillatoria sp*. and *Phormidium* sp. are excellent indicators of water pollution. *Ankistrodesmus* and *Scenedesmus*, was considered as the eutrophicated environment (Jose and Kumar, 2011). This eutrophication resulted not only the proliferation of aquatic weeds but also blooming of indicator algae viz., *Tetrastrum sp, Staurastrum sp and Closterium gracille* in Vembenad lake at locations close to waste influx zones with desmid, *Closterium gracile* blooming to most detrimental level, 19.04 lakhs per litre *(*Padmakumar etal*.*, 2017*)*


Crucegenia sp.


Scenedesmus sp.

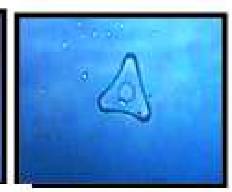

Merismopedia sp.


Actinastrumum


Pediastrum

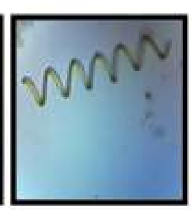

Coelastrum

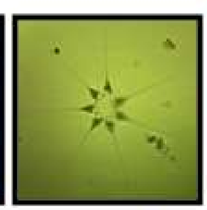

Scenedesmus

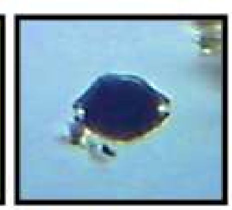

Tetraedron


Navicula


Nitzschia closterium


Spirulina

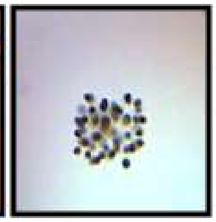

Asterionella


Peridinium


Chlorella


Chaetocerus

Ankistrodesmus falcatus


Anacystis


Anabaena

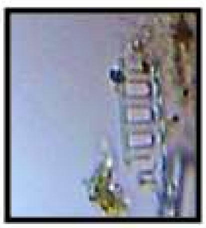

Cosmarium sp

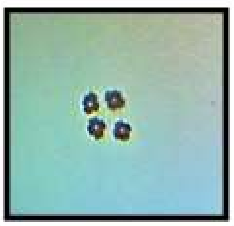

Nitzschia sp


Navicula sp

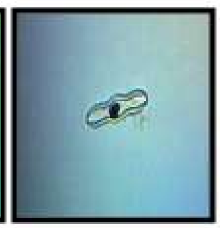

Scenedesmus sp


Volvox


Hyalotheca sp


Crucegenia

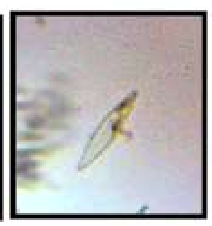

Actinastrum


Diploneis

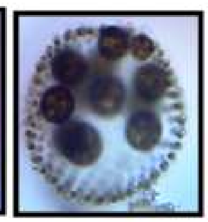

Cymbella


Cosmarium sp


Nitzschia sp

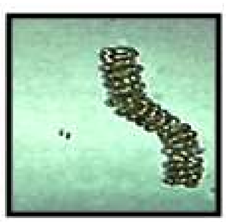

Navicula sp

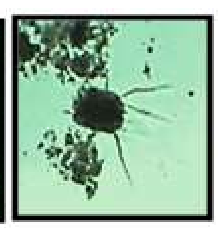

Scenedesmus sp

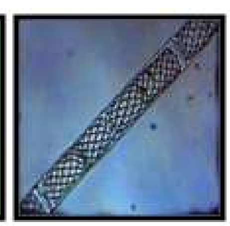

Volvox


Cyclotella sp


Lyngbya


Spirulina


Mallomonas

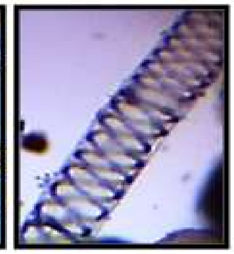

Melosira

Closterium kiietzingii

Nodularia

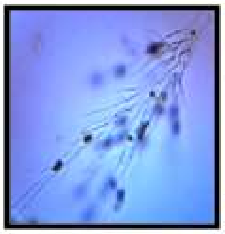
Oedogonium sp

Oscilatoria



Spirogyra

Cyclotella sp



Dinobryon

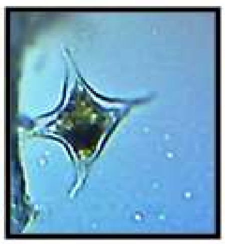
Pediasrum sp

Microcoleus sp

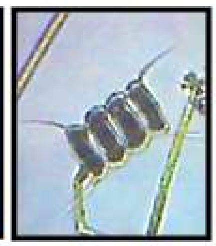
Nitzschia frigida

Fragilaria sp

Desmodium



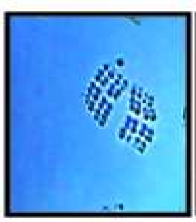
Arthrodesmum sp



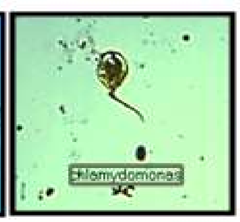
Scenedesmus perforatus

Ulothrix

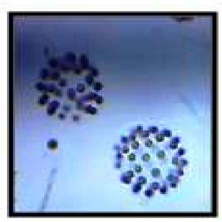
Phacus sp



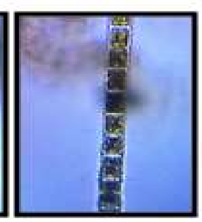
Agmenellum sp



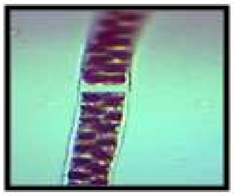
Chlamydomonas sp



Gomphosphaeria sp



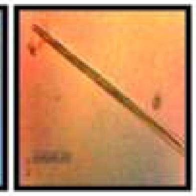
Zygnema


Microspora

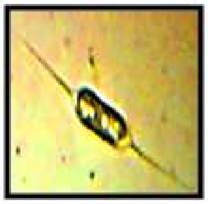

Closterium sp


Chlorococcum sp


Closteriopsis

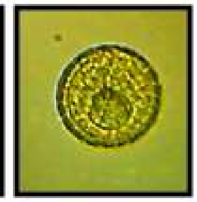

Synedra

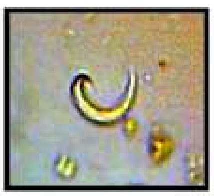

Actidesmium sp

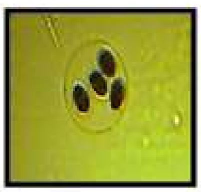

Centritractus sp

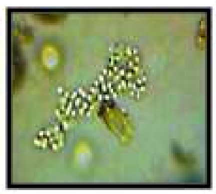

Aphanizomenon sp


Botryococus sp

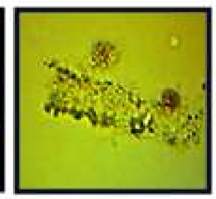

Melosira sp


Selanastrum sp


Sphaerocystis sp

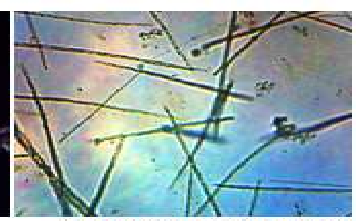

Gloeocapsa sp


Rhizosolenia sp


Desmidium sp


Tetrastrum bloom

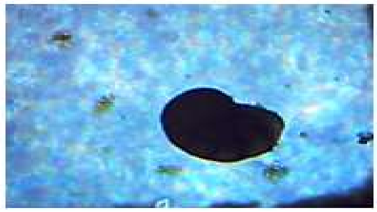

Sturastrum bloom


Closterium gracile bloom

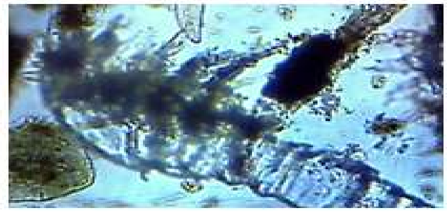
14. Zooplankton

The component elements of Zooplanktons in the year round study conducted from the same stations in the open lake prior to the flood is indicated as under. Zooplanktons were represented by *Trichocerca, Brachionus, Brachionus forficula, Brachionus plicatilis, Brachionus falcatus, Brachionus quadridentatus, Platyias, Keratella tropica, Keratella cochlearis , Filinia opoliensis, Bosmina longirostris, Moina macrocopa, Moina rectirostris, . Daphnia lumholtzi, Ceriodaphnia cornuta, Bosminopsis ,Moinodaphnia, Euryalona orientalis, Pseudodiaptomus trihamatus, Pseudodiaptomus incises, Pseudodiaptomus speciosus, Pseudodiaptomus annandalei, Heliodiaptomus elegans, Acartiella sinensis,* *Limnoithona sinensis, Tropocyclops prasinus, Microcyclops varicans, Mesocyclops, Thermocyclops, Hemicypris, Stenocypris, Bestionila similis, Heliodiaptomus cinctus, Allodiaptomus mirabilipes, Acartiella gravelyi, Acartia southwelli, Acartia spinicauda, Centropages tripinos, paracalanus indicus, Paracalanus crassirostris and Bestionella similis*

Cyprius larva



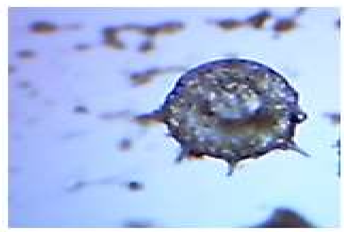
Gastropod larva



Harpaticoid

Daphnia

Brachionus

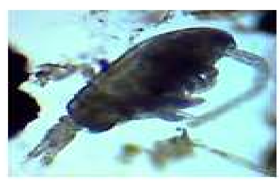


Centeropyxis

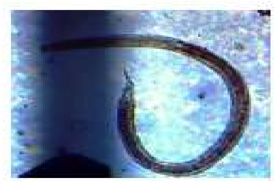
Keratella

Cyclops

Copepod nauplii



Paracalanus



Hook worm

15.Ichthyofauna

Short term inventory of fish species post deluge in the lake indicated occurrence of following species .Fish species inventory included incidence of 80 species of fishes and 10 species of prawns and 1 species od crab in the survey, the list include viz., *Anguilla bicolor* –mananjil, *Anguilla bengalensis* ,menanlil), *Xenentodon cancila*- Kolan, Kola, *Hyporhamphus xanthopterus*-Morasu, *Hyporhamphus limbatus*-Morasu, *Dayella malabarica*-Paral, *Stolephorus indicus-choodan, Chela dadyburjori*-Ooppaparal, *Danio malabaricus*-Vayampu), *Rasbora daniconius*-Thuppalukutiyan, *Amblypharyngodon melettinus*-Vayampu, *Amplypharyngodon mola*-Vayampu, *Amplypharyngodon microlepis*-Vayampu, *Puntius ambhibius*- Urulanparal, *Dawkinsia filamentosa*-poovaaliparal,*Puntius mahecola,*-kothichi paral, *Puntius sarana*-kuruvaparal, *Labeo rohita*-rohu, C*atla catla*-katla, *Cyprinus carpio*-karp, *Ctenopharyngodon idella* - pulcaarp, *Hypophthalmus molitrix*- silver Carp, *Heteropneustis fossilis*, *Aplocheilus lineatus,* -Poonjan, *Aplocheilus lineatus* -poonjan, Manathukanni, *Aplocheilus panchax*- poonjan, *Poecilia reticulata*-Guppy, *Megalops cyprinoides*-palan Kanni, *Chanos chanos*-Poomeen, *Mugil cephalus*-Thirutha ,*Liza parsia* - Kanampu,*Ambassis ambassis*-Arinjil, *Parambassis dayi*-Arinjil, *Parambassis thomassi*-Arinjil, *Parambassis ranga*-Nandan, *Anabas testudineus*-chempalli, karoop, *Channa striata* - Varal, Bral, *Channa Marulius*-cherumeen, *Channa diplograma*-Manal vagha/ pulivaaha, *Channa orientalis* vattan, *Labeo dussumieri*-Thooli, Pullan, *Etroplus Suratensis*-Karimeen, *Etroplus maculatus*-pallathi ,*Oreochromis mossambicus*-silapia, *Oreochromis niloticus*-silapia, *Gerres setifer* –prachil, *Nandus nandus*- Urakkamthoongi, *Glossogobius giuris*-Poolan, *Pristolepis rubripinnis*-Pannakarimeen/ kallurutti, *Pseudosphromenus cupanus*, -Karinkannachi, *Scatophagus argus*-Nachukarimeen, *Johnius dussumieri*- kaayaklchempalli, *Brachirus orientalis*-vatta Nank, *Cynoglossus sp*.-Nanku, *Mystus gulio*-vazha koori/chattithalayan, *Mystus vittatus*-ChillanKoori, *Mystus oculatus*-chillan koori, *Mystus malabaricus*-koori, *Horabagrus brachysoma*-Manjakoori, *Wallago attu*-Attu vaala, *Ompok malabaricus*- Dharmaan, *Ompok bimaculatus*-Thlaappan, *Pangasianodon hypophthalmus*--Malasian vala, *Pangasius pangasius*-koori vaala , *Clarias gariepinus*- African mushi, *Clarias dussumieri* -NaadanMuzhi, *Arius maculates*- Eata koori, *Macrognathus guentheri*-Panayakaran, *Mastacembelus armatus*-Aarakan, *Carinotetraodon travancoricus*-thavalappottan, *Carinotetraodon imitator*-oothiveerpan*,* *Chelonodon patoca*-puffer fish, *Lates calcarifer*-kaalanchi*,Gerres filamentosus*-prachil,*Carangoides malabaricus*-vatta and *pterygoplichthys multiradiatus*-sukerAmong crustaceans *Metapenaeus dobsoni ,Fenneropenaeus indicus, Metapenaeus monoceros, Macrobrachium idella, Macrobrachium rosenbergii, Scylla serrata and Penaeus monodon, Macrobrachium equidens, Caridina nanderjoni,and Caridina pseudogarcilirostris* were observed .

Although more number of species was reported from the whole lake covering marine entrants, estuarine residents and freshwater species, there was no noticeable reduction in number of fish species consequent to floods. On the contrary more fishes were noticeable and local fishing activity was very high, during the floods. Kurup (1982) made a list of 150 species of fishes belonging to 100 genera under 56 families in the whole Vembanad backwater, which included several marine fishes also. During the period 1988-1989, only 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 in their studies. Kurup et al (1993). Padmakumar et al.(2004) reported 50 finfish species in a one day fish count in freshwater river systems in Kuttanad. In a detailed study Narayanan and Sreekumar , 2012 reported 88 fish species and 10 prawn species form Vembenad lake. Asha et.al (2014) reported a total of 80 species of fin fishes from the whole lake apart from 8 species of shrimps, and prawns from the whole lake covering both south and northern reaches. A short survey on Kuttanad's river system indicated a total of 62 freshwater species of fishes from 17 families (Jayasree, and Radhakrishnan, 2014).

Riverine fisheries are a mirror of riverine health. Flowing water is the essential feature of any river system and changes to a river's flow regime therefore are likely to have profound consequences. The fish species incidence is related to the ecosystem changes and such changes due to regulation are manifest in several ways (Simons, 1979).Increasing number of studies are highlighting that dams and barrages are perhaps the most important reasons behind hydrological modification, obstacle to migration, changes in salinity, changes in sediment and loss of riparian areas affect floodplain biodiversity worldwide. Prior to commissioning Farakka Barrage in 1975, the fish migrated from Bay of Bengal upto Allahabad. Post Farraka, the yield of Hilsa dropped from 91 kg/km in 1960s to near zero in 2006 in Allahabad. Decreased river flows tremendously affect the flushing property and increased sedimentation. This results in sharp decrease in fish population due to loss of breeding and nursery grounds ultimately affecting their breeding process.

Kurup et al. (1993)estimated an annual yield of 7202 t in Vembanad during 1988-1989 and from the southern stretches annual landing was estimated at 500 tons (KWBS,1987) During 1999-2000 and 2000-2001 (Padmakumar et al., 2002) reported annual fish catches, from regions south of Vaikom 838 t and 687 t respectively and form south zone south of Thanneermukkom barrage as 584 t and 507 t respectively . Annual landing from the southern zone during 1988-1989 and 1995 - 1999 were 500 tons ((KWBS,1989) and 486 tons (Unnithan etal.,2001). Padmakumar et al.(2017) in later studies estimated annual fish landings from southern Vembanad and adjoining lowlands based on data during 2011-12 as 762 tons of which finfish alone constituted 633 tons. Asha et al, (2014) reported annual fish production of 4387.31 tons from the whole Vembenad lake, of which 480.98 tons was reported from the south zone. The depletion of the fish stock of southern portion of the backwater was mainly attributed to man-made impacts on the ecosystem alterations, such as habitat modifications, reduction of natural grow out area due to various activities such as intensification of rice cultivation and cropping pattern changes depriving space for fish groth and physical barriers such as Thaneermukkom barrier that disrupted the migratory pattern, coupled with over fishing and pollution hazards due to excessive use of chemicals and pesticides in the paddy fields of Kuttanad.

. Fish of different species and life stages display unique sets of characteristics including abiotic tolerances, habitat preferences, feeding and spawning habits, physical appearance, and physical capabilities. Certain fish species, especially those that are monsoon breeders were apparently benefitted from, seasonal or periodic extreme flooding Individual features allow certain species of fish, particularly those that are adapted to a wide range of conditions, to better cope with flood conditions. In effect there was no perceptible decline in fish abundance consequent to floods, although fishing as .

Survey on entry of alien fishes

During the floods, a few alien species of fishes were seen abundant in the Kuttanad river systems and padasekharams , our team could record maximum number of such escape fishes from farms and hatcheries in Kuttanad paddy fields and at flood exit points at Thottappally spillways during flood period.. Even after 6 months, large numbers of fishes that have escaped have intruded in the ponds and water bodies and are caught in normal catches. Small and large specimens of ornamental fish like gouramis, sucker fishes that escaped form aquarium centres were also spotted. Maximum number of food fishes, *Pangasianodon hypophthalmus* and Tilapias were encountered at flood exit points in Thottappally spillway at Alappuzha during the deluge days and later from almost all inundated padasekharams in Kuttanad, *Piaractus brachypomus* and *Oreochromis niloticus* were caught in considerable numbers during dewatering of the polders for annual punja rice farming. Atleast over 100 fishers were continuously engaged in fishing for such escapee fishes using diverse gears, almost round the clock for over 25-30 days during the flood period The dominant invasive fish species caught were *Cyprinus carpio, Gambusia affinis, poecilia reticulata Oreochromis mossambicus, Oreochromis niloticus, Ptergoplichthys sp. and Clarias gariepinus* and alien species without any confirmed report of invasion ,*Ctenopharyngodon idella, Hypophthalmichthys molitrix, Xiphophorus hellerii, Xiphophorus maculatus, Piaractus brachypomus, Oncorhynchus mykiss, Pangasianodon hypophthalmus, and Osphronemus goramy*, but no records of two specimen escaped from aquarium keepers viz., *A gigas* and A. *spatula* that were not spotted at all in Kuttanad available prior to the floods.

Our observation highlight the need for prevention of unlawful introductions and fish keeping and breeding in natural river systems with utter disregard to lack of bio security measures coupled with non existence of enforcement mechanisms to bring to book the offenders and measures for prohibition for sale and farming of alien fish species are the reasons for their unlawful farming and proliferation. Rather than the many number of publications on the problem no serious effort has been taken to allay the damages and the concern is limited to reporting the observation. Some scientists even treat Indian major carps that were introduced officially as exotics. Equating such species with other predacious species without considerations on biological attributes is misleading and will help justify the offenders promoting such species. Continuous neglect of this crucial problem is a serious threat to the endemic fish biodiversity.

Alien species exotic to the lake encountered during the study were *Poecilia reticulate (rainbow fish), Oreochromis mossambicus (mozhambique tilapia), Oreochromis niloticus(nile tilapia), Pterygoplichthys (Janitor fish), Clarias gariepinus(African sharptooth catfish),Xiphophorus hellerii,((Green swordtail),X. maculatus(Moonfish), Piaractus brachypomus (pirapitinga /pacu/piranh)Pangasianodon hypophthalmus(Iridescent shark/shark catfish), Osphronemus goramy (Giant gourami)Piaractus brachypomus (Red-Bellied Pacu), Pterygoplichthys multiradiatus(sailfin catfish), Poecilia reticulata (guppy), Pterygoplichthys pardalis(amazon sailfin catfish), Pygocentrus nattereri (red bellied piranha), Clarias gariepinus (Africancatfish), Oreochromis niloticus(Nile tilapia), Piaractus brachypomus (Pacu /piranha), Pangasianodon hypophthalmus (Sutchicatfish), Helostoma temminckii (Kissing gourami) Osphronemus goramy (Giant gourami),* Trichopodus leerii *(Pearl Gourami)*,Trichopodus trichopterus *(Opaline Gourami*).

Floodplains supported a high number and diversity of fishes and that several species had extremely successful spawning years in flood basins. More often than not, flooding has a positive effect on fisheries in large low-gradient rivers. This is a major contrast with documented short and long-term fish population declines in high-gradient systems after extreme events. Another example of contrasting dynamics involves benthic species, fishes that reside primarily in the substrate of the riverbed. In high-gradient systems, these fish suffer extremely high mortality as

the bed shifts (Erman et al., 1988). In large low-gradient rivers, benthic fish may actually be more likely to survive floods due to a higher tolerance for suspended sediment (Whitfield and Paterson, 1995).The natural diversity of fish species complicates the impacts of extreme flooding on riverine fish assemblages. Certain fish species benefit from, and actually depend upon, seasonal or periodic extreme flooding. Seasonal flooding appeared to coordinates natural systems by providing environmental cues for spawning and migration processes.

16. Flood: Effects on Endemic fish

As an integral part of the study, it was considered prudent to investigate the effects of the deluge on selected fish species of economic importance. We studied the production trends and population abundance of 3 commercially important species, vz., Pearlspot, *Karimeen,* Giant freshwater prawns, *Kuttanadan Konchu* and Black clam, *Kakka,* the thre e brand species of Kuttanad as they are considered endemic to Kuttanad waters.. Relative changes in the landings of the above species were monitored based on landing data registered in major landing centres, consequent to deluge and before, including catch per unit effort.

. 16. 1.Effects of flood and deluge on Pearl spot (*Etroplus suratensis)*

Pearlspot, *Etroplus suratensis*, 'Karimeen', the *State Fish of Kerala*, is a high valued table fish endemic to Kerala and parts of Sri Lanka. Owing to its wide salinity tolerance and omnivorous feeding habits it is ecologically important candidate species adapted to coastal lowlands in the context of climate change. The Vembanad Lake is considered as the home ground for this species and support a very rich natural fishery for this species since long. Being a culinary delicacy, with the boom in backwater tourism, the demand for pearl spot has been steadily on the rise and its fishery in the Vembanad therefore has been subject to increasing pressures. In this context it was considered prudent as a typical case to investigate in the effects of the great deluge on the endemic fish, Karimeen in consideration of its great ecological ad commercial significance

The landings of Pearl spot (*Etroplus suratensis)* fluctuated between 6045-14125 kg, 9518-1956kg, 1813-4150kg, 47117-136988kg, 2466-4938kg, 6175-13913 kg in Punnamada, Pallathuruthy, Thottappally, Vaikom, Ambikamarket Kumarakom respectively during 2015-2018. The highest average landings were observed at Vaikom (136.9 ton) and the lowest at Thottappally. After flood, Karimeen production decreased in almost all places except at Punnamada. The reduction in catches may be due to high turbidity of water that do not favour fishing of this species specially by scare line fishing popularly known as ‘vellavali’ fishing.Average annual landing during 2015-18 varied from 2584.5 to 91949.25kg. Catch per unit effort/month was 34 kg which has come down to 17.3 kg during the flood year. Karimeen is a visual breeder and the high suspended sediment load and turbidity appeared to have affected the landings. As the water quality improved, production gradually picked up after December. The abundant generation of filamentous algae after the flood also seemed to have favoured the production of pearl spot as *E.suratensis* voraciously feed on filamentous algae. In nature, the fish prefer a predominantly herbivorous diet comprising filamentous algae (43%) and detrital matter (42%). (Bindu and Padmakumar, 2008.)

The disappearance of the once luxuriant mangroves that fringed the Vembanad shores and ecosystem alterations consequent to construction of saltwater exclusion barrage at Thannermukkom barrage. Their breeding and recruitment has been impaired. The annual landings of *E.suratensis* in Vembanad lake, south of Cochin backwater, which constitute approximately 50 % of the total lake expanse has been reduced to 200-300 tons as compared to 1252 tons reported during the 1960’s (Padmakumar, 2004) . Breeding behaviour is also unique with ‘pair-bonding as a characteristic feature.. The paired couple utilizes benthic solid objects, submerged in water for attachment of their adhesive eggs. Natural recruitment of this species will be hindered by habitat disturbances possible in the floods. The exploited annual landings of Karimeen (Pearlspot) varied from 2015-2018 is summarised in Table.

Flood Effects on major Endemic Fish Karimeen				
	2015	2016	2017	2018
PUNNAMADA				
J	1365	1085	430	640
F	1100	930	860	690
M	1310	875	890	815
A	1420	940	940	700
M	1485	860	825	800
J	920	1040	1010	685
J	1030	1210	675	1015
A	865	1900	890	215
S	1405	960	985	0
O	1205	840	630	0
N	1120	1100	680	0
D	900	630	790	485
Total	**14125**	**12370**	**9605**	**6045**

PALLATHURUTHY				
J	1705	1525	1458	1205
F	1540	1385	1305	1150
M	1700	1526	1507	1220
A	1650	1490	1437	1208
M	1650	1300	970	1140
J	1689	1359	1205	1205
J	1605	1350	1260	1238
A	1659	1486	1548	215
S	1643	990	1200	200
O	1590	1428	1260	196
N	1425	950	1105	185
D	1300	1250	1208	356
Total	**19156**	**16039**	**15463**	**9518**
Thottappally				
J	520	300	350	300
F	430	220	170	95
M	480	260	200	190
A	420	200	220	198
M	300	100	260	210
J	160	70	65	60
J	180	90	60	50
A	200	130	200	150
S	220	160	230	175
O	390	200	150	130
N	400	200	160	125
D	450	180	200	130
Total	**4150**	**2110**	**2265**	**1813**
Vaikom				
J	13354	7963	6589	3600
F	12241	10425	6452	4800
M	12557	10524	7584	5020
A	11240	9978	6984	4000
M	9587	8996	5562	3300
J	6994	5672	4560	2400
J	9674	4010	3541	2070
A	12547	9840	4994	2230
S	12654	9998	6857	5421

O	13241	10874	6908	4800
N	10543	9611	6987	4050
D	12356	10934	7849	5426
Total	**136988**	**108825**	**74867**	**47117**
Ambikamarket				
J	597	390	326	300
F	450	320	290	260
M	464	330	290	286
A	406	280	260	240
M	481	340	279	256
J	365	260	240	160
J	403	300	250	186
A	450	325	248	198
S	425	300	258	150
O	447	350	245	190
N	450	350	282	240
Total	**4938**	**3545**	**2968**	**2466**
Kumarakom				
J	1450	1200	900	1000
F	1360	950	800	900
M	1280	900	680	780
A	1320	910	700	520
M	1380	840	780	480
J	958	620	430	310
J	825	580	610	280
A	850	590	580	210
S	950	620	570	330
O	1100	790	630	315
N	1130	880	710	450
D	1310	980	860	600
Total	**13913**	**9860**	**8250**	**6175**

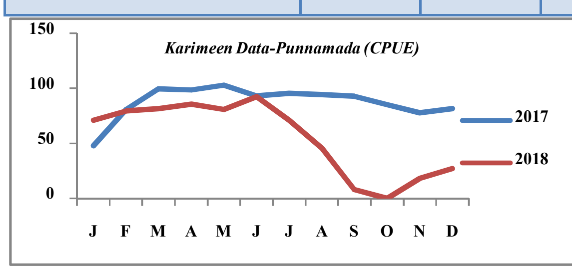


Fig.16a

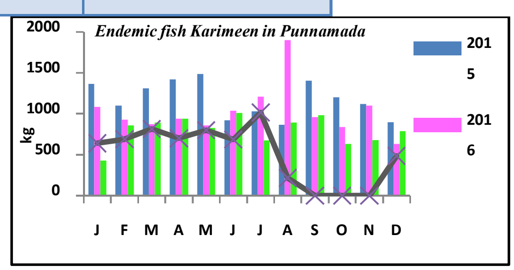


Fig.16b

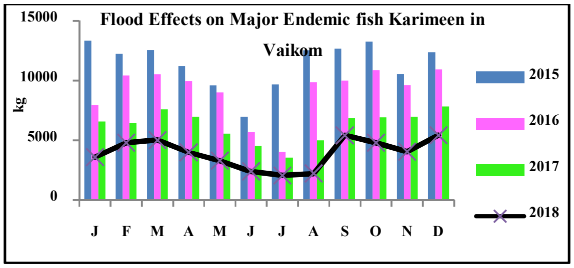
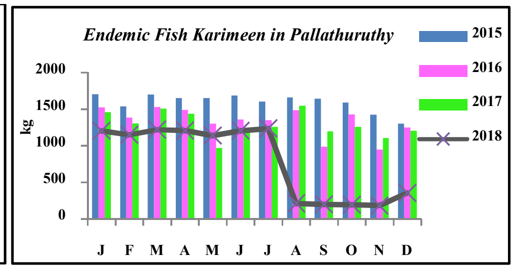


Fig.16c



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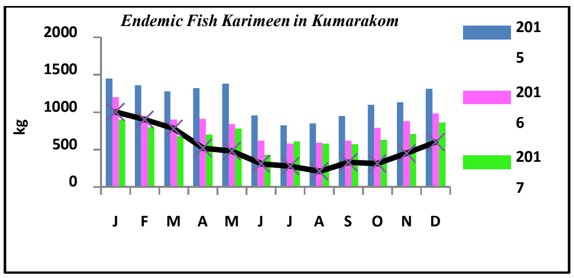

Fig.16e

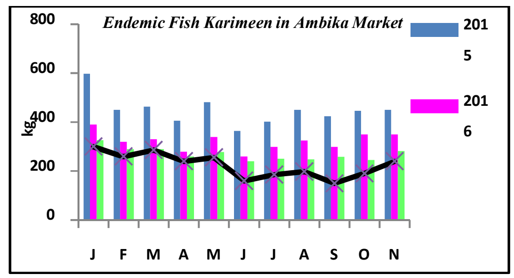

Fig.16f

16.2 Flood Effect on endemic prawn (*Macrobrachium rosenbergii*)

During previous years, comparison of the landings between 2015-2018 productions of Endemic prawn in Kumarakom ranged from 332.95 to 2226.35 kg and Ambikamarket prawn production ranged from 1062-6961 kg during different months. During flood year (2018) at Kumarakom there was a significant increase in yield of prawn as compared to previous years. Immediately after the rain there is perceptible increase in landings of Konchu in Kumarakom region. Investigations revealed that, prawns with poor swimming ability was washed downstream in the flash floods. Catch of prawn in Ambikamarket close to the barrage was however, significantly reduced long term effects of this phenomenon due to flood on the recruitment species already hindered by environmental alterations need to be further investigated.

The physical obstruction by the barrage and its effect on the fishery of the endemic freshwater prawn, *Macrobrachium rosenbergii* has been highlighted in several studies.. The annual recruitment of this species was totally disrupted in its home ground due to physical hindrance to their migration. The annual catch of this species during the pre-barrage days was as high as 429 tones (Raman et al.,)which declined to less than 40 tons (Kurup et al., in the late eighties and further down to 27 tons (Padmakumar et al, 2002) on the southern stretches after a brief spell of recovery during the late 90's. The physical obstruction of the barrage also led to the near decimation of its fishery in their home grounds. The upstream and downstream migration of the giant river prawn, *Macrobrachium rosenbergii,* (*Kuttanadan konchu)* was totally disrupted due to ecosystem alteration. In this context a detailed investigation on the effect of the flood and deluge on this species was attempted. The investigations revealed that the prawns with poor swimming ability was washed downstream locations in the flash floods.

Flood Effect on endemic prawn									
KUMARAKOM (Konchu)					**AMBIKAMARKET (Konchu)**				
	2015	2016	2017	2018		2015	2016	2017	2018
J	6.3	4.4	2.8	3.65	J	550	350	258	75
F	1.8	2.5	1.6	2.3	F	436	254	200	56
M	3.4	1.3	0	0	M	335	225	150	40
A	0.8	0	0	3.5	A	325	200	150	38
M	6.2	4.2	3.4	7.9	M	320	240	150	15
J	26.7	12.3	9.6	11.6	J	950	900	750	225
J	33.6	17.5	13.6	26.5	J	1000	775	698	195
A	33.8	34.6	28.7	69.5	A	930	620	558	155
S	48.9	141.7	92.8	780.9	S	600	290	216	60
O	260.5	193.4	89.95	960.9	O	465	370	279	78
N	235.8	113.25	73.65	245.8	N	550	360	270	75
D	170.25	12.6	16.85	113.8	D	500	280	150	50
Total	828.05	537.75	332.95	2226.35		6961	4864	3829	1062

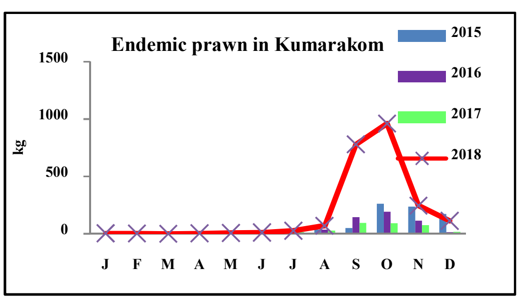

Fig.17a

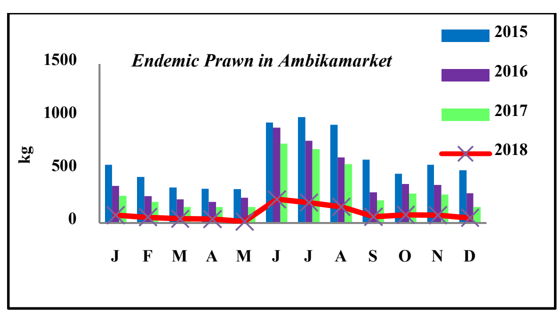

Fig.17b

16.3. Black Clam *Villorita cyrpinoides* landings

The exploited landings of black clam data available from the 8 black clam societies. Animal production of black clam during 2018 was reported 32005.98. The highest landing was reported in March 2018 and the lowest was reported in September. The production of black clam has not affected the deluge. The average annual landings of black clam calculated for the period 2009 to 2018 was 29115.14 ton. During the flood year, the annual landing based on landings reported from 8 black shell societies is 28683.97 ton. Evidently, there is an increase over the average production previous years. However, immediately after the deluge; there was a drastic decline of landings which was compensated by an increase during subsequent months. The deluge has no significant effect on the clam production. Highest landings were observed in northern side of the barrage. Annual production was close to what was achieved during previous year. During the year 2017 it was 28893.16 ton. Suja and Mohaed production of black clams, about 25,000 tonnes

A comparison with earlier reports showed that the live clam resources of the lake exhibit a diminishing trend over the years. Rasalam and Sebastian (1976) reported that about 26,858 tones of live clams were fished from the Vembanad Lake in 1968. Achary (1987) observed that the average annual clam production from the lake during the period from 1979 to 1984 was 21,490 tones. In 1983 it was reportedly 13,804.48 tons. However, since then the yield was increasing and annual yield was varying from 25000 to 30000 tons. Monthly average production has been reported as 2619 t during 2000 (Laxmilatha and Appukuttan, 2002) Suja and Mohamed (2012) observed annual landing as 25000 tons, although a very low production of 7025 ton has been reported earlier during 1988-89 by Kurup et al.,(1990) . Evidently the clam landing during the flood year remains almost unaffected. The fisheries for the clams and the finfish provide the major livelihood for coastal communities around the lake (Sathiadhas et al., 2004). Laxmi latha and Appukuttan (2002), Sathiadhas et al. (2004), Arun (2005), Ravindran et al. (2006), and others have also are summarized these aspects earlier. The major coastal villages where prominent include clam fishery is predominant were Chempu, Vaikom, Vechoor, Kuthiathodu, Thycattussery, Muhamma, Aryad, and Kavalam distributed among the districts of Kottayam and Alappuzha. All these locations except Kavalam being open lake locations on the northern sector, apparently, any deleterious effects of silt debris deposition to the bottom communities were not perceptible. The trend is evident ine Fig .

	J	F	M	A	M	J	J	A	S	O	N	D
Vechoor												
2015	132.84	145.06	177.82	152.34	208.7	109.56	96.06	151.84	57.46	169.12	89.44	146.7
2016	159.4	171.16	124.74	121.04	152.18	158.88	101.78	24.48	22.88	118.5	90.7	86.28
2017	47.66	68.28	98.86	85.34	149.26	72.12	134.55	81.04	73.21	296.18	142.04	213.38
2018	276.2	244.62	323.02	259.38	327.7	422.6	235.84	288.56	149.28	201.56	99.86	103.74
Muhamma												
2015	1383.08	925.2	989.12	618.14	830.56	1015.36	814.04	890.98	574.8	845.34	725.26	854.9
2016	1197.18	1263.98	1003.4	1063.4	583.94	719.42	981.42	773.34	807.86	340.12	784.38	850.76
2017	668.52	635.04	787.26	478.76	653.82	788.72	937.86	1421.54	175.84	1281.5	1800.3	1298.4
2018	1607.7	1786.48	178.06	370	1740.46	2191.88	1546.42	807.84	762.24	1125.4	1088.6	1088.4
Thykkattusserry												
2015	400.78	281.65	342.05	391.72	648.59	647.625	636.65	691.405	202.88	462.16	431.52	497.75
2016	435.64	524.15	505.50	401.2	586.885	459.355	541.025	385.655	311.84	298.59	316.2	447.58
2017	367.29	300.59	422.08	245.7	464.825	325.63	307.165	460.845	172.79	462.21	484.63	460.3
2018	348.24	335.42	497.59	111.23	707.16	475.28	281.5	189.41	97.35	357.77	334.47	383.97
Kavalam												
2015	157	208	276	75	107	48.13	239.85	0	0	0	0	136.25
2016	88.558	135.03	168.228	0	44.565	42	0	0	5	0	0	47
2017	198.18	146.99	291.94	0	0	48	54	45	45	71	81	197
2018	100	30	129	0	64	48	201	196	199	0	24	47
Kumarakom												
2015	15	15.3	25.44	25.8	21.32	17.52	0.54	21.78	14.24	0	7.2	33.04
2016	3.2	15.44	50.74	16.28	14.14	15.24	9.36	8.92	15.82	5.36	25.8	7.24
2017	19.42	7.82	405.72	9.08	17.52	7.02	1.84	37.64	32.4	24.86	26.4	28.66
2018	10.48	28.22	7.46	27.2	29.88	47.56	21.94	1.4	29.28	10.86	53.16	24.16
Kuthiathodu												
2015	56	41	125	15	73	93	46	129	37	91	55	29
2016	45	46	70	32	30	79	70	39	71	80	85	130
2017	64	47	118	74	55	129	51	136	43	67	77	64
2018	38	30	81	26	46	28	86	72	31	62	32	81
TV puram												
2015	267	270	919	592	492	459	312	110	112	182	231	**132**
2016	257	243	415	0	257	516	274	232	172	134	119	**395**
2017	43	364	457	0	385	453	298	259	384	620	653	**512**
2018	377	410	363	601	661	300	199	173	107	211	198	**188**

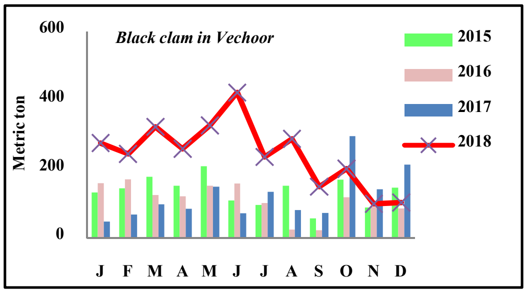

Fig.16.3a

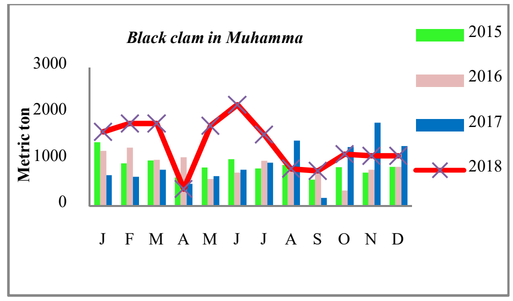

Fig.163b

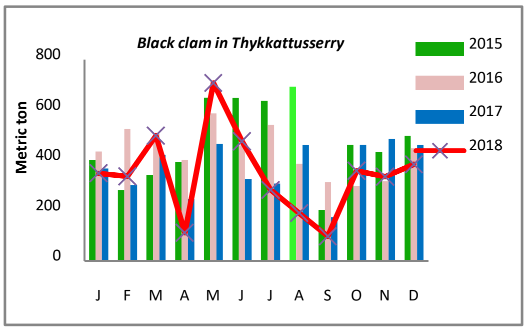

Fig.163c

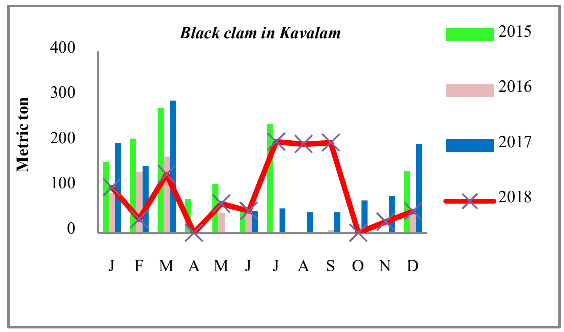

Fig.16 3d

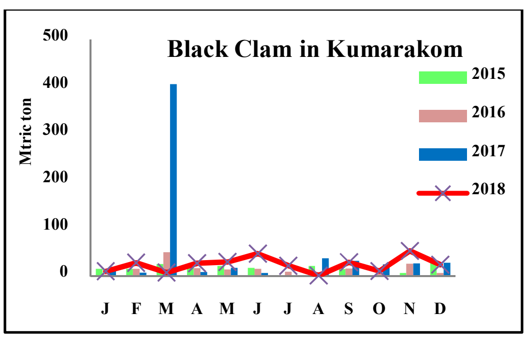

Fig.16 3e

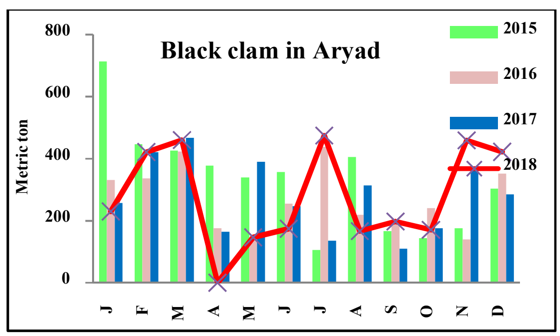

Fig.16 3f

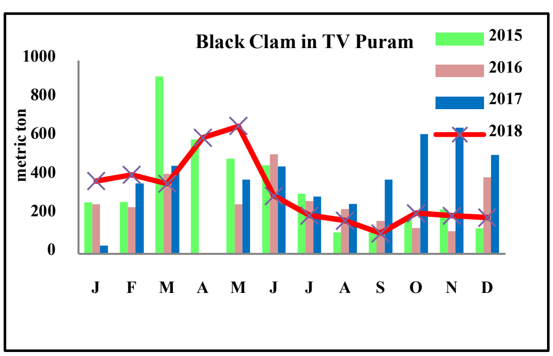

Fig.16 3g

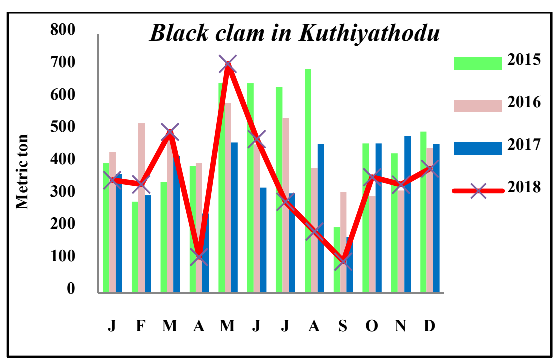

Fig.16 3h

16.4Black clam population size and distribution

The highest size group predominantly represent in Kayippuram region, while the lowest group is in Muhamma.The landing size varied from 2.1 to 4cm. Smallest groups was observed in Aryad and Muhamma region during November. Clams generally breed twice a year; May- August, January- March. The lowest size groups were noticed in Thaykkattussery region, although the data for the same is not available due to regulations on fishing of "mallikkakka" at this breeding site.

	ARYAD	MUHAMMA	THANNEER MUKKOM	KAYIPPURAM	PUTHANANGADI
1.5 - 2.0cm	8	13.3	0	0	0
2.1 - 2.5cm	41.67	45.67	15	18	79
2.6 - 3.0cm	27.67	29	56.5	25	18
3.1 - 3.5cm	16	10.3	17	53	3
3.6 - 4.0cm	6.67	1.67	11.5	43	0
4.0 – 4.5 cm	0	0	0	0	0

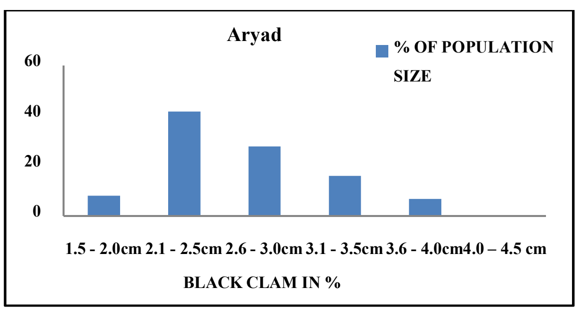

Fig.16 4 a

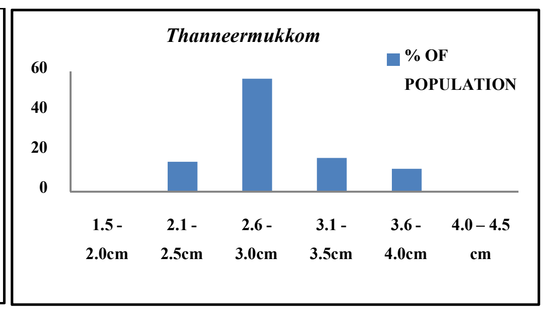

Fig.16 4b

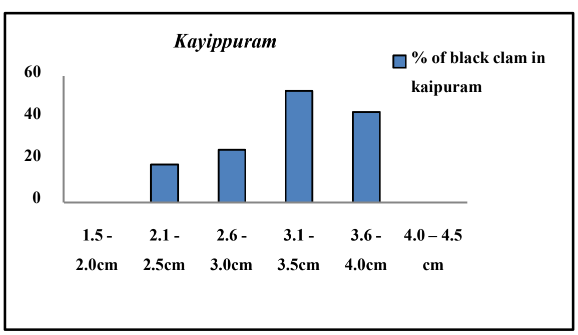

Fig.16 4c

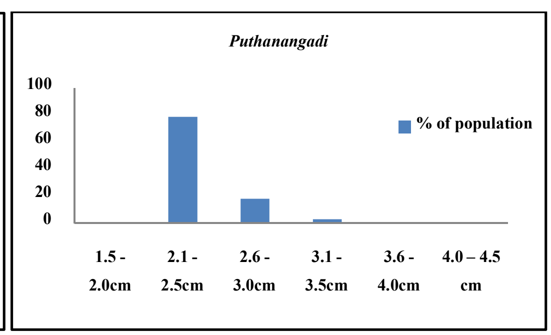

Fig.16 4 d

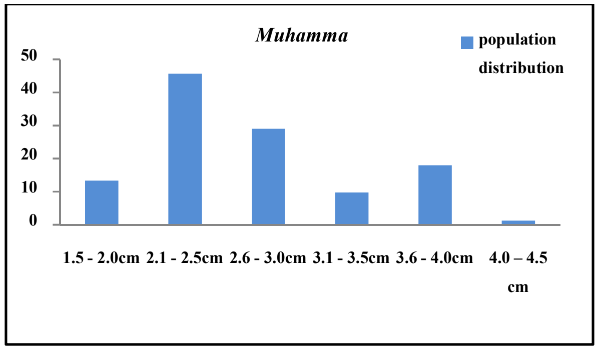

Fig.16 4 e

16.5Clam whole weigh to meat ratio

Meat shell ratio of different size group indicated that, the highest meat ratio was observed between 2-3 cm sizes. Meat percentage was lower for large sized group; 3-4cm. The flood and deluge did not seem to have any significant effect of breeding and recruitment of clams. Environmental factors /land use changes that contributed to the flood enhancement in Kuttanad.

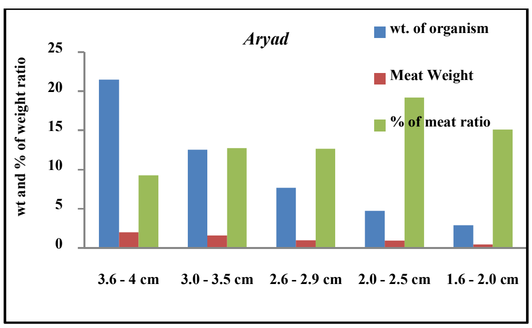

Fig.16.5 a

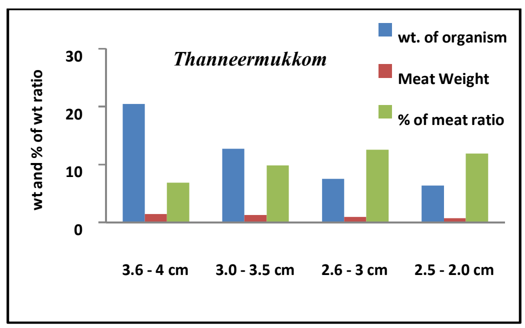

Fig.16.5b

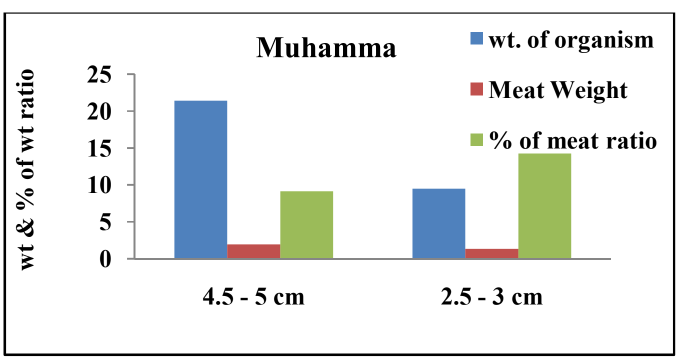

Fig.16.5c

17. Land use changes and Flood

Agricultural land use and cropping patterns often undergo remarkable change from time to time due to natural consequences of the influence of physical, cultural, technological and economic factors. The analysis of variations in agricultural land use over a period of time gives us an insight in to the type and magnitude of transformation of an agrarian rural society. An analysis of agricultural land use is essential for a meaningful understanding of the agricultural system prevailing in a region.

The specific objectives of this study were (a) to assess spatial and temporal variation in rice yield, cropping intensity in Kuttanad the rice bowl of Kerala and (b) to evaluate the relative importance of spatio-temporal change in climate and cropping intensity on rice yield.

Cropping being the part of land use pattern has always been a dynamic phenomenon. The cropping pattern is in fact, a reflection of the interplay of the complex social, economic and physical factors. On account of dynamic socio-economic factors, the cropping pattern also changes in a long run sometimes it may get replaced totally

The probable effect of land use in Kuttanad on flood incidence was investigated. The study reveals that the land area under varsha*krishi* in Alappuzha &Kottayam has been on the increase lately. The area under *varshakrishi* in Alappuzha was 8237ha during 2013 and this increased to 13225ha during 2017. In Kottayam region the area under *Varsha krishi* was 5306 ha during 2012.This had increased to 9809 ha during 2017. This indicates that over 45% of the land area under rice is put to use for *Varshakrishi* lately in Kuttanad. The trend is given in Fig17 b.

Varshakrishi	**Alappuzha(ha)**	**Kottayam (ha)**
2010	10312	6653
2011	9493	6761
2012	11219	5306
2013	8237	6558
2014	10449	6736
2015	10013	6415
2016	9948	6485
2017	13225	6809

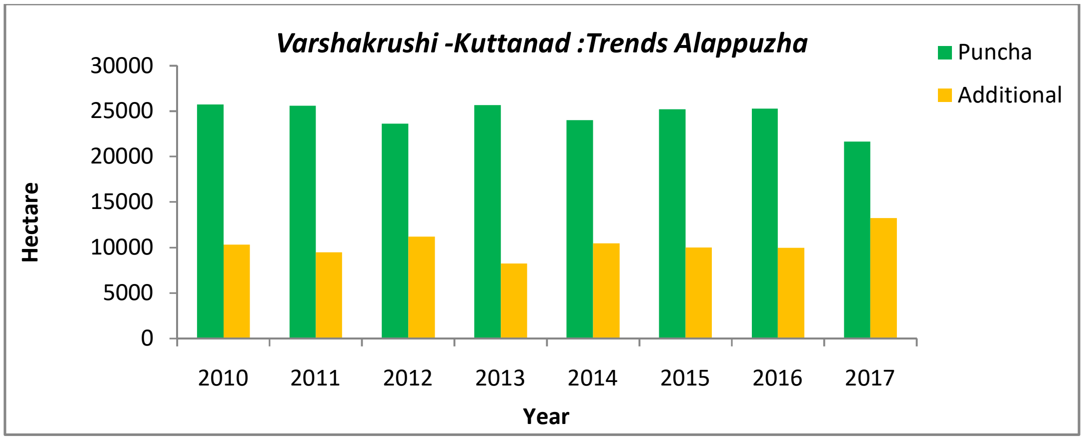

Fig.17a

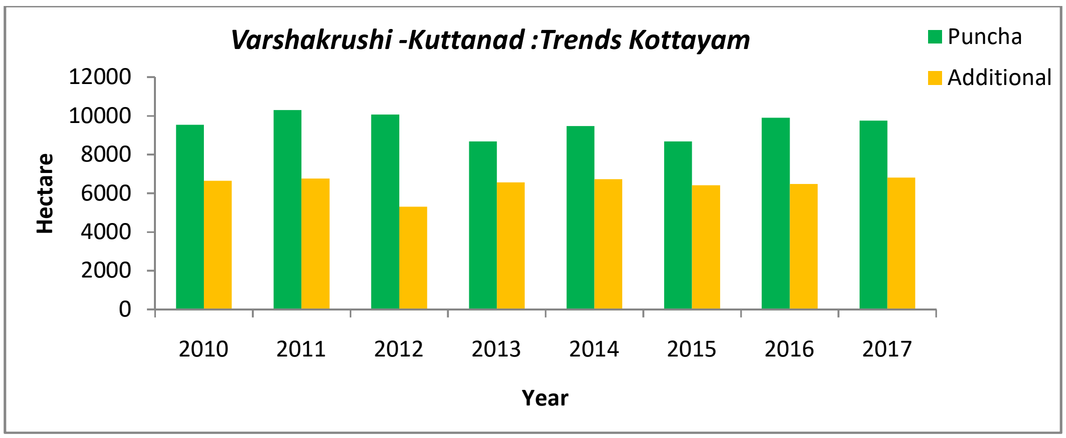

Fig.17 b

During 2018 also a similar trend was perceptible. Although all these area has come under *vashakrushi,* the crop was lost during the July floods itself leaving practically no space in the floodplains for flood waters to spread and flow. Although the standing recommendation has been to limit the land area in Kuttanad under *varshakrushi* to not more than 30 percent, this is not followed, partly because of the declining yield in punja crop, increasing soil related problems and soil acidity during post monsoon punja season high pest incidence and crop loss and threat of salinity intrusion during fag end of the punja crop season. Consequently the trend is to skip punja cropping and raise v*arshakrushi* in large are reducing space for flood waters, augmenting the severity of floods. .

18. Rice Productivity in Kuttanad-Puncha Post flood Season

Evaluation of rice productivity covering 19 krishibhavans in Alappuzha District viz., Ambalappuzha South,Ambalappuzha North, Champakkulam, Cheruthana, Harippad (M), Kainakary, Karuvatta, Kavalam, Mannancherry ,Muttar, Nedumudi, Neelamperoor, Pallippad, Pulikkunnu, Punnapra south, Purakkad, Ramankary, Thalavadi,Veeyapuram) and 18 krishi bhavans in Kottayam district viz.,Thiruvarpu, Kumarakam, Arpookara, Vechoor, Neendoor, Kurichy, Panachikadu, Nattakam, Kottayam, Vazhapally, Changanasseri, Thalayazham, Udayanapuram, TV Puram, Thalayolaparambu, Kallara, Kadathuruthy during 2016-2018.The average rice productivity in Kottayam was 6.75 ton/ha and 6.72 ton/ha in Alappuzha during 2018-19.

During 2018-19 the highest yield was recorded at Kainakary (8.75 tons/ha) in Alappuzha and in Kottayam yield found at Thiruvarppu, Kumarakom(8.25).The average productivity of rice productivity in Alappuzha district during previous years was 4.4 ton/ha & 4.65 ton/ha in 2016-17, 2017-18 respectively. In Kottayam district average productivity of rice was 5.14ton/ha in 2016-17, 4.94 ton/ha in 2017-18.

Evidently, the flood has improved the soil fertility of Kuttanad partly due to deposition of fertile humus and silt, and due to inundation for long period under flood waters. High phosphate in the overlying water possibly due to rapid mobilization of P within the system as evident in this study. In flood plain soils containing high amounts of organic matter, sulphate is known to increase the mobilization of phosphate (Artur *et al*., 2009) and inundation led to increased nutrient mobilization particularly phosphates which reached very high concentrations in both soil water and overlaying surface water. Long term inundation apparently favoured release of phosphates bound in sediment and increased its availability for the crop. The washing of acidity improved pH condition of the soil to the benefit the crop. Improved microbial soil activity in the soil is another factor that apparently helped to improve the farm soils.

Puncha(Ton/ha)	2016-17	2017-18	2018-19
Alappuzha	4.4	4.65	6.72
Kottayam	5.14	4.94	6.75

2018-19				
Block	Paddy procured(Kg)	Area(ha)	Yield Kg/ha	ton/ha
Ambalappuzha	21886548	3578.42	6116.26	6.1
Kuttanad	139626170	32657.06	4275.528	4.27
2018-19				
Block	Paddy procured(Kg)	Area(ha)	Yield Kg/ha	ton/ha
Changanachery	17253059	2600.46	6634.618	6.6
Kottayam	50506978	8380.35	6026.834	6.03
Vaikkom	21979478	4329.74	5076.397	5

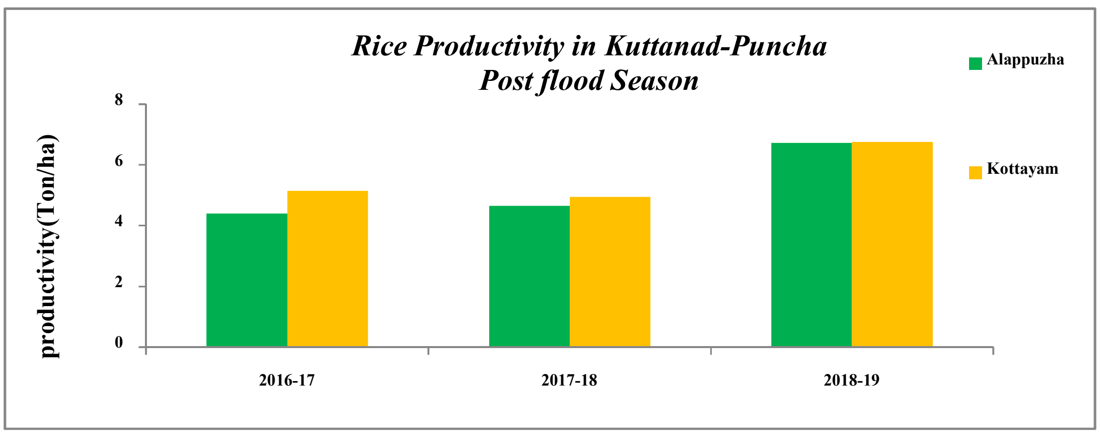

Fig.18

- In this study, we examined the aftereffects of the devastating flood event of 2018 in Kuttanad, by evaluating their effects on aquatic ecosystem and biodiversity endowments.
- Kuttanad suffered from 3 floods in succession since July 2018. Although the present study on t flood effects was started in November 2018, as we were engaged in an ongoing year-round surveillance program, as part of institutional project, year round data was available to decipher the effects of flood.
- Most studies on such disasters is based on fortuitous events and often lacks pre-disaster data. In contrast we utilized our current understanding based on long term monitoring data generated by our own team during the past few years..
- The important ecosystem parameters monitored in the study include, water and soil quality primary production, secondary aquatic production, rice productivity and effects on biodiversity including fish and fisheries
- Extremely distressing trend has been the observed on increasing trend in salinity, year after year in the Vembanad system and in the Kuttanad region after monsoon months every year. This can only be attributed to consistently declining inflow from river systems during post monsoon months and could be due to the environmental effects of the hydrological modifications made at Cochin sea mouth as part of the Vallarpadam Container Terminal Project (VCTP) for berthing large vessels. .
- Utilization of polders as water harvesting structures that enable seaward flow to hold up salinity ingression after monsoons is a valuable proposition
- During the deluge period, when flood waters entered Kuttanad, the vast padasekharams were already inundated due to the previous floods in July The deluge resulted in further re inundation over the ring dykes.
- Fishes in very large numbers were caught from numerous rivulets and inundated paddy fields. The consequences of the floods, negative and positive, varied greatly depending on the location. Regions exposed to human interventions were more vulnerable.
- Flood had both short term as well as long term impacts on biodiversity. The observations support the view that small foods lead to gains in aquatic ecosystem services, while effects of extreme episodes like the one we experienced in 2018, last longer lead to more economic losses.

- Extreme organic loading consequent to floods and prolonged water logging apparently led to anoxic conditions in water which has been critical to all life forms.
- Besides influx of large quantum of plant nutrients, N and P, the low DO due to influx of organic matter apparently favored mobilization of more P within the system by ' *internal eutrophication*' due to release of P from sediments. Long term inundation apparently favored release of P bound in sediments.
- Despite high nutrient influx, algal abundance was reduced and primary production suffered initially because waters were more turbid as light was a serious limiting factor, and flushing rates apparently exceeded algal growth rates.
- As transparency of water increased slowly, after a few months, algal growth was stimulated. This increases in primary production is attributed to increased availability of phosphorus (P) and high nitrogen N) loading, facilitated by the flood.
- We cannot consistently conclude that flooding increased or decreased primary production as productions of algal biomass are dependent also on other interacting variables as well, viz water clarity, flushing rates etc
- Pelagic fishes that lay their eggs in the inundated paddy fields in the cold floodwaters were benefitted. Evidently large schools of fishes were found abounding the polders during and after the flood. This highlights the role of flooded padasekharams as natural fish nurseries.
- The study further points to the dire need for utilizing the Kuttanad polders at least seasonally as flood water storage systems, and fish reproduction protection zones to sustain endemic fish biodiversity.
- During the flood, paddy fields were also teeming with exotic fishes, mostly escapee fishes from aquaculture farms, like *Oreochromis*, *Pangassius, Piaractus sp.* Etc. Spread of such exotics can be a serious threat to endemic ichthyofauna But huge quantiy of such estranged fishes were caught from the systems due to very active fishing during flood periods.
- The study highlights the dire need for effective measures for prevention of unlawful introductions of fishes.
- Some farms take up fish breeding in net enclosures in the flowing river itself with no checks. Breeding of such alien fish species in natural river systems with utter disregard to biosecurity shall be forbidden, invoking strict legal provisions against such offenders.

- Fish species that are dependent on bottom substratum for feeding and breeding behaved differently than seasonal breeders. The cleansing effects of the flood flows in post flood months provided them high transparency; this is evident from the catch up in yield of *Karimeen* in later months after the floods.
- Kuttanadan Konchu, *Macrobrachium rosebergii*, with poor swimming ability were encountered in large numbers in downstream regions, apparently washed down in the heavy currents, They reached the natural breeding ground, downstream early in their annual migratory route. Implications of their early arrival at the breeding grounds before salinity build up to desired level, in the heavy floods can affect their recruitment process. This need to be investigated.
- It is inferred that the extreme events that was destructive for humans was a blessing for natural populations. We may agree with the contention that flooding generally create a production boom for fish and shell fishes in oligotrophic waters and especially those that survive well in clean waters with low turbidity etc.
- The stable water quality conditions and the less turbid waters after initial pulse of flood favored the profuse growth of filamentous algae. This in effect benefitted the endemic algal browser *Etroplus suratensis*, and the known filter feeding pelecipod, *Villorita cyprinoides* both being important to the livelihoods of the ecosystem people in Vembanad.
- The study indicated that floods created a near homogenous water conditions but and highly heterogeneous habitat situations. As habitat situation changed, floral and faunal communities and biodiversity is bound to change. Changes in substratum characterizes were visible in our study.
- Annually, floods bring about silt deposition, estimated at around 1-25 tons per ha in Vembenad lakes and rivers of Kuttanad. Our study indicated that the silt deposition was as high as, 13 kg / sq m, ie., 130 tons per ha in some locations in the flood plains of Pampa river near Mannar region, Alappuzha. The situation calls for more detailed and long term investigations to capture changes in benthic biodiversity in the wetland system in days to come.
- Floods have increased the fish diversity partly due to more diverse habitats becoming available to fishes.

- Flooding improved agricultural soils by depositing sediments on floodplains, helped recharge farmland soils and significantly increased suitability of soils for farming. The increased productivity of rice is a testimony to this. This was facilitated in part by enhanced nutrient availability.
- Floods improved soil condition due to long inundation, helped washing of acidity and removal of residual salts like sodium from soils. These observation points to the benefit of inundation of lowland rice soils at least for a few months before every cropping season..
- Flooding improved soil formation by depositing sediment on flood plains and increased deposition of particulate organic carbon. This underlines the role of wetlands behaving as carbon sink, a very significant role of wetlands in the context of climate change.
- Unlike other places in Kerala, flood inundation lasted for a long period in Kuttanad. .This cannot be attributed to sea level remaining high, as the tidal heights on the dates of flooding remained low. If the flood happened 5 days prior to 16th August, coinciding with the highest high tides, and tidal floods, the disaster would have been more catastrophic.
- Long period of inundation in Kuttanad with flood water not receding fast can only be ascribed to physical hindrance to outflow and the failure due to very poor management of the Thottappally spillways system (TSW), constructed exclusively for flood control in Kuttanad..
- Evidently this indicates that structural engineering mechanisms such as spillways and ring bunds around polders or saline exclusion barrages constructed to master nature by altering hydrologic regimes cannot be solutions as such civil structures create hurdles to smooth natural flow.
- These observations indicate that river floods synchronized by tidal floods, in the context of climate variability, will lead to a seriously grave situation in Kuttanad if it merges with coastal seas, situations most disastrous and catastrophic to Kuttanad.
- The study highlights the need for nonstructural alternatives, for flood management by integration of the natural dynamics of flooding, restoration of wetland areas and reconnection of key floodplain areas etc.
- Apparently, more than anything, there is a dire need to rethink on the extent of area for rainy season rice cropping allowable in Kuttanad , as increase in area under rainy season cropping

like 45 % of the expanse as of now is a significant factor that contribute to and magnify flood damages, in Kuttanad.

- Flood cushioning role in Kuttanad paddy fields are different from paddy fields in valley bottom paddy lands in midlands of Kerala
- In valley bottom paddy lands, in midlands of Kerala, reduction in paddy field area increase flood hazards, where as in Kuttanad increase in area under rainy season rice farming enhance floods. Hence Increase in varshakrushi shall not be allowed to increase beyond 30 percent of the area. Kuttanad padasekharams to be viewed different from paddy fields in other areas, owing to its unique below sea level location and its natural role of flood water storage during rainy season.
- This also means that we cannot afford to drain away all the monsoon waters to the seas in order to avoid flooding. We have to store some of it for dry seasons, atleast for about six months. We have to satisfy the water demand.
- The present study underlines that seasonal inundation of Kuttanad padasekharams improve soil quality, in terms of algal and microbial biodiversity, and enhances rice yield, and endemic fish and other biodiversity.
- The study calls for an institutional system for continuous and systematic evaluation and corrections in land and water use in Kuttanad by giving more room for water.

  We should also explore the possibility of 'controlled flooding' as a tool to accommodate floods by applying an entirely different science and response strategy in Kuttanad.

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References:

Achary, G.P.K. 1988. Characteristics of clam resources of Vembanad Lake - a case study. Bull. Cent. Mar. Fish. Res. Inst., 42 (10): 10-13.

Agostinho, A. A., S. M. Thomas, C. V. Minte-Vera, and K. O. Wine miller. 2000. Biodiversity in the high Parana´ River floodplain. p. 89–118. In B. Gopal, W. J. Junk, and J. A. Davis (eds.) Biodiversity in Wetlands: Assessment, Function and Conservation, Volume 1. Backhuys Publishers, Leiden, The Netherlands.

Anon,2018.Kerala Floods and Landslides- Post Disaster Needs Assessment Floods and Landslides August 2018: Draft Report for Consultation - 11 October 2018, UN, EU & GOK., 262 p.

APHA, 1980. Standard methods for the examination of water and waste water including bottom sediments and sludges. 11th Edition. American public health association Inc. Newyork, 626pp

APHA(2005); Standard methods for the examination of water and waste water, American Public Health Association, Washington, DC, APHA-AWWA-WEF, 167 (2005)

ATREE (2008) Report of the Participatory Fish Resources Survey of the Vembanad Lake, Kerala. Vembanad Fish Count Report, Alappuzha.

ATREE (2009) Report of the Participatory Fish Resources Survey of the Vembanad Lake, Kerala. Vembanad Fish Count Report, Alappuzha.

Artur M. Banach, Katarzyna Banach Eric J. W. Visser, Zofia Ste˛pniewska ,Antoine J. M. Smits Æ Jan G. M. Roelofs, Leon P. M. Lamers.(2009). Effects of summer flooding on floodplain biogeochemistry in Poland; implications for increased flooding frequency. *Biogeochemistry 92:247–262.*

Arun. A. U. 2005. Impact of Artificial Structures on Biodiversity of estuaries: A case study from Cochin estuary with emphasis on Clam beds. , Applied ecology and Environmental Research 4(1): 99-110.

Bayley, P.B. (1991). “The flood pulse advantage and the restoration of river-floodplain systems”, Regulated Rivers: Research and Management, 6:75-86.

Biju Kumar, A., Smrithy Raj, C. P. Arjun, UnmeshKatwate and Rajeev Raghavan.2019. Jurassic invaders., *CURRENT SCIENCE, VOL. 116, NO. 10, 1628-1629.*

Bindu . L. and K. G. Padmakumar. 2008. Food of the pearlspot Etroplus suratensis (Bloch) in the Vembanad Lake, Kerala .J. Mar. Biol. Ass. India, 50 (2) : 156 – 160

Borse, S.K., Lohar, P.S., Bhave, P.V., 2003. Hydro biological study of algae of Aner River, Jalgaon (Maharashtra). J. Aqua. Biol., 18(1), 15

Buchanan,J B 1971.sediments In IBP handbook No.16 Methods for the study of marine benthos (EDS) N.A. Holme and A.D. Mc. Intyre. Blackwell scientific publication, Oxford 3052

Chaturvedi, R.K., Sharma, K.P., Kamayani Sharma, Bharadwaj S.M., Subhasini Sharma, 1999. Plankton community of polluted waters around Sanganer, Jaipur. J. Env. Poll. 6(1), 77-84.

ChingYun Chen, YookHeng, Lee1 Mohd, EkhwanToriman,Maimon Abdullah,Baharudin Bin . Yatim1. 2015. Effect of the big flood events on the water quality of the Muar River, Malaysia. Water Resource. Manag. (2015) 1:97–110

Chris Guppy and Phil Moody., 2018. Reserve phosphorus (P) and potassium (K) availability and release in northern region soils; effects of flooding and fertilizer bands, ***ChrisGuppy*** *. Agronomy and Soil Science,* NSW 2351.

Das.K.K., N.P. Shrivastava, K.K. Vassand B. L. Pandey. 2008. Management strategies for Enhancing fish production in Madhyapradesh reservoirs.Proc. ofTaal, Twelth World Lake conference, Sengupta, M and Dalwani. R (Eds.) pp. 1295-3000

Erman et al., 1988). In high-gradient systems, these fish suffer extremely high mortality as the bed shifts (Erman et al., 1988).

FAO (2002) Sample-Based Fishery Surveys—A Technical Handbook. FAO Fisheries Technical Paper, 425, Rome, 132.

Fonselius S.H. and S. Carlberg. 1972. Determination of dissolved inorganic phosphates. In co operative Research Report, Series, A No.29

Frontier E.1972**.**Calculdel'erreur Sur unconptage de zooplancton*.J.Exp.Mar.Biol.ECOL***,** 8; 121-132.

Gwo-Ching Gong,1,2 Kon-Kee Liu,3 Kuo-Ping Chiang,1,4 Tung-Ming Hsiung,5 Jeng Chang,1,6 Chung-Chi Chen,7 Chin-Chang Hung,1 Wen-Chen Chou,1 Chih-Ching Chung,1 Hung-Yu Chen,8 Fuh-Kwo Shiah,1,9 An-Yi Tsai,1 Chih-hao Hsieh,10 Jen-Chieh Shiao,10 Chun-Mao Tseng,10 Shih-Chieh Hsu,9 Hung-Jen Lee,8 Ming-An Lee,4 I-I Lin,11 and Fujung Tsai8. 2011. Yangtze River floods enhance coastal ocean phytoplankton biomass and potential fish production.GEOPHYSICAL RESEARCH LETTERS, VOL. 38, L13603, doi:10.1029/2011GL047519

Harikrishnan M., Vipin, P.M. and Kurup, B.M. (2011) Status of Exploited Fishery Resources of Azhikode Estuary, Kerala, *India. Fishery Technology*, 48, 19-24.

Holme N.A 1971 Position fixing. In IBP handbook No.16 Methods for the study of marine benthos (EDS) N.A. Holme and A.D. Mc. Intyre. Blackwell scientific publication, Oxford 1229

Inman D. L, 1963.Submarine Geology, sediments. In Physical properties and mechanics of sedimentation, Harper and Row, Newyork, 104 P

Josanto V. 1971. The bottom salinity characters and the factors that influence the salt water penetration in the Vembanad Lake. *Bull. Dpt. Mar. Biol. Oceanogr*. , 5, 1- 16.

Jose, L. and Kumar, C. 2011. Evaluation of Pollution by Palmer's Algal pollution index and physico chemical analysis of water in Four Temple ponds of Mattanchery, Ernakulam, Kerala. : Nature Environment and Pollution Technology 10(3): 471-472

Jyotsna K, Rajeswari1, G. Suresh2, P. Srikanth3 and N. N. Raman1.2014.Study of temporal variations in physico-chemical parameters of Vembanad Lake at Panangad- Kumbalam region, Kochi, Kerala, India. *Int.J .Curr. Microbiol. App.Sci*. 7(6): 2905-2917.

Kumar Ranjith P, Raman NN, Pranav P, Pamanna D, Adnan Amin and Sumanjali SS. 2017.The physico-chemical characteristics of Vembanad backwaters at Eramalloor region, Alappuzha district, Kerala, India, *International Journal of Fisheries and Aquatic Studies*; 5(5): 258-262

Kurup B.M. and Harikrishnan, M. (2000) Reviving the Macrobrachiumrosenbergii (de Man) Fishery in Vembanad Lake, India. Naga, the ICLARM Quarterly, 23, 4-9.

Kurup M.B, M.J. Sebastian, T.M.Sankaran and P. Rabindranath. 1990. Exploited fishery resources of the Vembanad Lake, part - I. Clam Fisheries, Mahasagar, Vol.23, No.2, 1990, pp. 127-137

KWBS, 1989.Kuttanad Water Balance Study- Kingdom of the Netherlands, Ministry of Foreign Affairs and Republic of India, State of Kerala, Vol II, , 37.

Laxmilatha P. and K.K. Appukuttan.2002.A review of the black clam (*Villorita cyprinoides*) fishery of the Vembanad Lake, Indian *J. Fish.,*49(1) : 85-91,

Laxmilatha, P., Velayudhan, T. S., Kripa, V., Jenny Sharma and Alloycious, P. S. 2005. Biology of the black clam, Villorita cyprinodes (Gray) in the backwaters of Vembanad Lake. *Indian J. Fish.,* 52(3): 361-366.

Leitman, H.M., Darst, M.R., and Nordhaus, J.J. (1991). "Floodplain of the Ochlockonee River, Florida, during flood and drought conditions", U.S. Geological Survey, *Water-Resources Investigations*, (90-4202), Tallahassee, Florida

Madhupratap .M..1976. Studies on the Ecology of Zooplankton of Cochin backwaters(a tropical estuary),Ph. D thesis, Cochin University, 196 p.

Mc Intyre, A.D.1971. Introduction design of sampling programs in method for the study of marine benthos, IBP Handbook No.16, N.A Holme and A.D. Mc Intyre. Blackwell publication Oxford, 1-11

Moody.Chris Guppy and Phil, 2018.Reserve phosphorus (P) and potassium (K) availability and release in northern region soils; effects of flooding and fertiliser bands,***ChrisGuppy*** *.. Agronomy and Soil Science*, , NSW 2351.

Mullin, J.D. and J.P. Riley. 1955. The Spectrophotometric determination of nitrate in natural waters, with particular reference to sea water. Anal. Chem. Acla, 12, 464-480.

Nandan Bijoy. S, K. and Sajeevan. 2018. Distribution and abundance of phytoplankton in vembanad estuary, a Ramsar site on south west coast India. International Journal of Engineering Technologies and Management Research. Vol.5 (3): March, 2018, 75-87.

Nandan Bijoy S, Jayachandran PR and Sreedevi O K, Spatio-Temporal Pattern of Primary Production in a Tropical Coastal Wetland (Kodungallur-Azhikode Estuary), South West Coast of India. 2014. Journal of Coastal Development. J Coast Dev. 2014, 17: 1000392

Narayanan, S.P and B Sreekumar, 2012.A Decade of Vembanad Water bird Counts- Fishes of Kuttanad,. Department of Forests and Wildlife, Government of Kerala..p.171.

Padmakumar, K.G., Anuradha, K., Manu, P.S., Shiny, C.K. and Radhika, R. (2002) Thaneermukkom Barrage and Fishery Decline in Vembanad Wetlands, Kerala. Proceedings of the Fifth Kerala Science Congress, Kottayam, 28-30 January 1993, 27-36

PadmakumarK.G., N.K. Santhosh , Shanu Raveendranath, C.G. Rakesh, K.B. Bindusha and B. Jasmine, 2017.A study on the fish catch from vembanad lake, south ofThannermukkom barrage during the period from March,2011 to February 2012, Natl. Sem., Biodiv. Farming Syst.Wetland ecology, 22-23 February, pp, KAU, 35-36

Padmakumar,K.G, Shanu Raveendranath, N.K Santhosh, K.B Bindhusha, B. Jasmine and C.G Rakesh,2017.Phytoplankton Distribution and Nutrient Dynamics in Vembenad lake, India. Poc. Natl. Sem., Biodiv. Farming Syst. Wetland ecology, 22-23 February, pp, KAU, 33-34

Padmakumar, K.G., Anuradha Krishnan,L.Bindu, P.S. Sreerekha, Nitta Joseph. 2004.. Pearlspot,*Etroplussuratensis*, Captive breeding for conservation and of endemic fishes of Western Ghats, India, Kerala Agricultural University,pp.47-63.

Padmakumar K.G., L Bindu, Nitta Joseph, B.Sreekumar, G.Sunil, N.Unnikrishnan and J.Sabu Kurien,2006. River Fish Inventory Under Participatory Approaches: *'Meenachil Fish Count 2004',Environment and Ecology*, 24(3):584-590.

Pillai, K., K. J. Joseph and a. Kesavan Nair. 1975, The plankton production in the Vembanad Lake and adjacent waters in relation to the Environmental Parameters. *Bull. D.pl. Mar. Sci. Univ. Cochin,* Vll, I, 137-150.

Raman, K (1967) Observation on the Fishery of Giant Fresh Water Prawn Macrobrachium rosenbergii (De Man). Proceedings of the Symposium on Crustacea. Part II. Symposium Series 2, Marine Biological Association of India, B.S., 33, 253-279.

Rasalam, E. J. and Sebastian, M. J. 1976.The lime-shell fisheries of the Vembanad Lake, Kerala. J. Mar. Biol. Ass. India, 18(2): 323-355.

Ravindran, K., Appukuttan, K. K., Pillai, V. N. Sivasankara and Boopendranath, M. R, 2006.Report of the committee of experts on ecological and environmental impact of dredging at VaduthalaKayal and VaikamKayal, Kerala, Submitted to The Government of Kerala, Thiruvananthapuram, September 2006.

Round, F.E. 1965.*The biology of the algae*. Edward Arnold Publications. London 269 pp Round, F.E. 1965.The biology of the algae .Edward Arnold Publications. London 269 pp.

ShajeeshJan.P.S. Paneerselvam, V. Geethalakshmi, K.P. Ragunath,Ga.Dheebakaran and R. Jagannathan,(2017).Centurial Rainfall Variability in Below Sea Level Farming Region of Kerala, India.Int.J.Curr.Microbiol.App.Sci (2017) 6(12): 2414-2422.

Singh A.K and Singh D.K.,.A comparative study of the phytoplanktonic primary production of river Ganga and Pond of Patna (Bihar). India. J. Environ. Biol.: 1999. Pp. 263-27

Sreejith, K.A. 2013. Human Impact on Kuttanad wetland ecosystem - An overview, International Journal of Science, Environment and Technology, Vol. 2, No 4, 2013, 679- 690

Strickland, J.D.H. and T.R. Parsons. 1968. A practical handbook of sea water analysis. Fisheries Research Board of Canada, Ottawa, 311p

Suja. N and K. S. Mohamed.2012. Biometric Relationships of Villorita cyprinoides (Gray) from Vembanad Lake, Kerala, India, Asian Fisheries Science 25 (2012):29-39

Sujatha, C.H, Nify Benny, Renjitha Raveendran, Fanimol, C.L., Samantha, N.K., 2009. Nutrient Dynamics in the two lakes of Kerala, *Indian J. Mar. Sci*., 38(4), 451-456.

Ubuoh, E.A, Uka, A. Egbe1, C. Michael,2016.Effects of flooding on soil quality in abakalikiAgro Ecological zone of South-Eastern state, Nigeria,, *International Journal of Environmental Chemistry and Ecotoxicology Research,* Vol 1, No.3, pp. 20-32,

Unnithan, V.K., BijoyNandan, S. and Vava, C.K. (2001) Ecology and Fisheries Investigation in Vembanad Lake. Bul- letin No. 107, CICFRI, Barrackpore, 1-38.

Vidya, V., Sumathy, K. and Prasad, G. 2014.Phytoplankton -Pollution indicators: A Case study from Wetland areas of Vembanad Lake adjacent to Sea food Processing Facilities. *Journal of Aquatic Biology and Fisheries,* Vol. 2. pp. 835 to 842.

Vijayasree, T.S. M.V. Radhakrishnan, 2014. Fish Diversity of Kuttanad's River System, Kerala State, India, *International Journal of Fisheries and Aquatic Studies* 1(6): 55-58

Vijayan Dhanya & J. G. Ray. 2016. Ecology and Diversity of Diatoms in Kuttanadu Paddy Fields in Relation to Soil Regions, Seasons and Paddy-Growth-Stages. Journal of Plant Studies; Vol. 5, No. 2; 7-21.

Yun Chen Ching1 • Yook Heng Lee1 • MohdEkhwan Toriman2,3 • Maimon Abdullah1 • Baharudin Bin . Yatim1. 2015. Effect of the big flood events on the water quality of the Muar River, Malaysia. Water Resour. Manag. (2015) 1:97–110

Walkley, A., & Black, I. A. (1934).An examination of Degtjareff Method for determining soil organic matter and a proposed modification of the chronic acid titration method. Soil Science, 37, 29-37.

Whitfield, A.K. and Paterson. Q.W. (1995). "Flood-associated mass mortalities of fishes in the Sundays Estuary", Water SA, 21(4), 385-389.