CENTRE FOR AQUATIC RESOURCE MANAGEMENT AND CONSERVATION [CARMC]

Mid-Term Assessment Report.[2017-2020]

Summary Statement

1. Mandate of CARMC: Promotethe Research Activities of KUFOS in the fields of Aquatic Sciences and Polar Science to National/ International standards.

2. Date of start of CARMC: July 2017.

3. Budget allocation: ₹ 7.35 crore for 5 years. [2017 – 2022]

4. CARMC Team: Prof Chair (one) Faculty Members (8) & Project staff (11): Please see *Annexure-1* for details.

5. On-going Research activities of CARMC: (i) Studies on the Vembanad wet-land System (Major project), (ii) Polar Research (minor) & (iii) Coastal biodiversity of Kerala (minor).

6. Major Research accomplishments: Kindly see *Annexure -2*for details.

- First ever comprehensive high resolution (300 X 300 meter grids) bathymetric chart of the South Sector of Vembanad Lake (Alappuzha to Thannermukkom).
- Quantified the depth and area shrinkage of the South Sector between 1930 and 2019.
- Worked out details on the bottom sediments to be dredged to restore optimal circulation pattern of the south sector.
- Evaluated decadal changes in carrying capacity of the Lake from 1930 onwards.
- Quantified the macro-plastic load in the bottom sediments of the South Sector.
- Mapped the clam-beds of the south Sector.
- Participation in the 2017-18 Arctic Expedition of India.
- Participation in the 2019-20 Indian Expedition to Southern Ocean (Antarctic waters).

7. CARMC Annual Reports.

2017 – 2018: *Annexure 3*

2018 - 2019: *Annexure 4*
2019 - 2020: *Annexure 5*

8. Research Papers in High Impact Factor Journals: Total – 24. [*Annexure -6]*.
2017-18 (6);
2018 – 19 (10)
2019 – 2020 (8)

9. Workshops/ Seminars

- National training workshop "Tools for Monitoring, assessment and Management of Aquatic Ecosystems". Held at KUFOS from the 29th to 31st of January 2018.

- National Workshop on "Climate Change and Disaster Management (CCDM)". Held at KUFOS on the 22nd& 23rd of February 2019.

- National Conference "Integrating Biogeochemistry and Ecosystems". Organized jointly by CARMC and INCOIS, Hyderabad on 19th Jan 2019 at KUFOS.

- Seminar on planning and executing taxonomic research. Held on 5th March 2019 at KUFOS.

- Seminar " Monitoring of Vembanad Lake and associated Ecosystems" held on the 16th of October 2019 at Marine Drive, Kochi.

- Workshop on "Somalia-Yemen Development Programme (SYDP). Held at Kochi jointly with MEA, IORA & FICCI on the 28th& 29th of Nov 2019.

- Seminar on " Coastal processes and Biodiversity with reference to Northern Indian Ocean". Organized jointly with Shimane University, France on 5th Feb 2020 at KUFOS.

10. Papers Presented by CARMC Group in Workshops. Members of CARMC Group presented a total of 24 papers in various Seminars/ workshops held in India. Details of papers presented are provided in ***Annexure -7***.

11. Invited Lectures

- Miniature Fishes of the World. Dr.Ralph Britz, British Museum of Natural History. 20th July 2017.

- Building & Management of Crustacean Collection. Dr. Tomoyuki Komai, Natural History Museum & Institute, Japan. 22nd Feb 2018.

- Marine Conservation. Dr.Naveen Namboothri, Director, Dakshin, Bangalore on the 2nd Sept 2018.

- Natural and Human induced Hypoxia: Dr. Lisa Levis, Scripps Institute of Oceanography, US. On the 5th May 2019.

12. CARMC in State/ National and International missions.

State missions: On the request of GoK & its Offices, the CARMC undertook studies on the following aspects and submitted its reports to the concerned authorities;

i. Report on "Fish Ladder at Thannermukom bund and its possible impacts on Fishery" . Prepared and submitted to the Executive Engineer, Kuttanad Development Mission (August 2017).

ii. Report on " Climate Change and possible impacts on Kerala Coast". This Report was prepared in the aftermath of the 29th/30th Ockhi incident following the directions from the State Fisheries Department. Report submitted to Kerala Legislative Assembly on 5.3.2018.

iii. Report on the field study of the 2018 flood hit Kainakary Village in Kuttanad. Submitted to the State Fisheries Department on 2. 9.2018.

iv. CARMC took the lead role in the multi-institutional Task Force constituted by KUFOS under the instructions from Hon'ble State Minister for Fisheries & Ports to investigate the impact of 2018 Kerala Floods. CARMC organised several TF meetings and consolidated the inputs from various agencies to draft the final report. The report entitled " Impact Analysis of 2018 Kerala Floods" (Eds. A.Ramachandran; T.V.Sankar; V.N.Sanjeevan, M.R.Boopendranath & Rajeev Raghavan) was officially released by Ms. Mercykutty Amma, the hon'ble Minister for Fisheries & Ports in November 2019.

v. CARMC heads the State Committee constituted by GoK vide S.O. (ordinary) No.143/2020/MTV dt. 6.3.2020) to study and advise on the rejuvenation of Vembanad Lake System. The Committee had 3 sittings and we hope to finalise the Report by end August 2020.

National missions

i. **Revalidation of potential fishery yield** from Indian EEZ: This is an effort undertaken by ICAR once in a decade to support Indian Marine Fishery management systems. Prof. Chair, CARMC headed the Trophodynamic Group in the Group of Experts. The final report revalidating the fishery potential to 5.45 million tons was prepared and submitted to DARE in April 2019.

ii. **Indian Antarctic Bill**: Prof.Chair, CARMC was a Member in the High-powered Committee constituted by GoI to draft India's Antarctic Legislation, the other Members being Dr. Bimal Patel, VC-GNLU & Member, Niti Ayog; Prof. Sanjay Chaturvedi, Head, International Affairs, Punjab University; Dr.Razik Ravindra, Former Director, National Centre for Antarctic Research and JS, MEA (IR). The Committee had 15 sittings over the years 2017- 2019 and submitted the Bill to the Ministry of Earth Sciences in November 2019, to seek Cabinet clearance on the Bill.

International missions

i. **World Ocean Assessment of Assessments** (WOA II): This is an international effort under the UNGA to assess the state of world Oceans through an analysis of secondary data. Prof.Chair, CARMC is India's official representative to the WG and a Member of the Group of Experts.
ii. Dr.Rajeev Raghavan is Member IUCN.

13. Consultancy Services

Rapid Biodiversity Assessment of the Rivers and Backwaters of North Kerala: The assessment was carried out jointly by the School of Ocean Science & Technology (SOST,KUFOS) & CARMC for KITCO Ltd as a part of the EIA for the River cruise tourism project of Department of Tourism, GoK. Consultancy fee: Rs.10.00 lakh. Field survey conducted in Feb 2020 and the Assessment Report has just been completed.

14. New Projects initiated under CARMC.

i. **Regional Centre of IORA at KUFOS**: Discussions on this were initiated by CARMC/KUFOS from March 2018 onwards with the Ministry of External Affairs (MEA) and the Secretariat of Indian Ocean Rim Association (IORA). Accordingly DPR on " Aquatic Resources & Ocean Information Services [ICE – AROIS] was prepared by CARMC and submitted to MEA/IORA for further considerations. The Regional Centre will serve as an R&D centre of IORA

catering to the 21 Member countries surrounding the Indian Ocean. The Centre is expected to start in 2020 at an estimated cost of **Rs.16.38 crore** for 4 years [2020 – 2024].

ii. **World Bank assisted project on "Marine Biodiversity Inventory** of North Kerala coast". DPR on this was prepared by CARMC and submitted to NCSCM, Chennai in the second week of January 2020 for favour of funding under the ENCORE (Enhancing Coastal and Ocean Resource Efficiency) programme of NCSCM. Estimated project coast for 5 years is **Rs.4.00 crore**.

iii. **World Bank assisted project on " Aquatic Resource Mapping**". The CARMC is preparing the DPR on this and expect to submit the proposal to NCSCM by end August 2020. Project cost: **Rs. 2.00 crore**.

Annexure- 1

CARMC TEAM

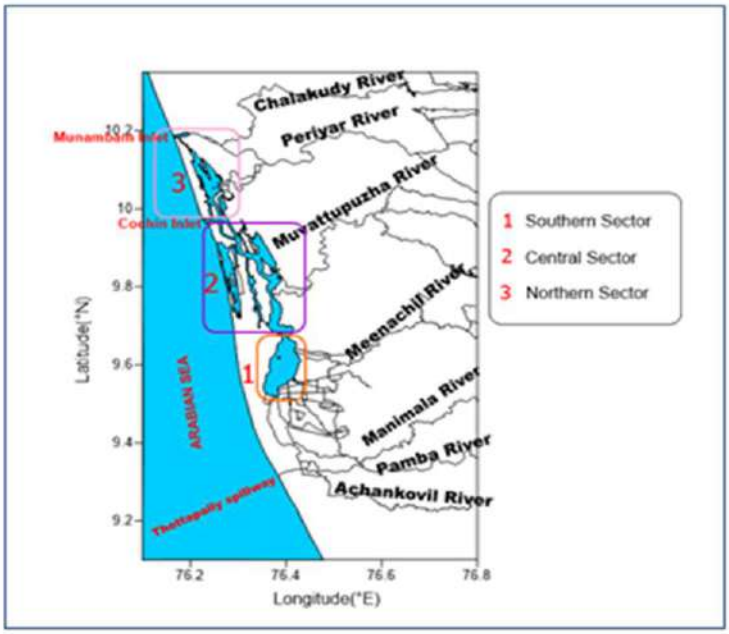
S.N	Name	Position	Functional role
1	Dr.V.N.Sanjeevan	Professor Chair	Project lead
2	Dr.S.Suresh Kumar	Director, SOST	Ecosystem Health
3	Dr.Ranjeet	Assoc. Professor	Mollusc other than bivalves
4	Dr.Rajeev Raghavan	Asst.Professor	Biodiversity
5	Dr.Jayalekshmi	Asst.Professor	Bivalvia
6	Dr.Anu Gopinath	Asst. Professor	Hydrochemistry & Polar Research.
7	Dr.Prabhakaran	Asst. Professor	Benthos
8	Dr. Pramila	Asst. Professor	Mesocosm studies
9	Dr. Anwar Ali	Asst. Professor	Breeding & Rearing of organisms
Project Staff			
1	Dr.Gireesh Raghavan	Project Scientist	Phytoplankton
2	Dr.Vimal Kumar	Project Scientist	Hydrodynamics
3	Mr. Sudarsan	SRF	Macrobenthos & Puffer fish
4	Mr. Sreenath	SRF	Decapod crustacean& Fish community structure
5	Ms. Remya	SRF	Biodiversity& fish community str.
6	Ms.Anju	SRF	Mesocosm studies
7	Ms.Shilpa	SRF	Meiobenthos & Minor Phyla
8	Ms.Princy John	SRF	Hydrochemistry
9	Ms. Nithara	TA	Fish egg & larvae, Jelly fish
10	Ms. Nayana	TA	Ecosystem health & Anchovy
11	Mr. Jayeesh	DTP	Data Assistant

Annexure 2

CARMC Research Accomplishments [2017-2020].

A. Vembanad Wet-Lands

1. **Introduction:** Vembanad lake is South India's largest lake, a Ramsar site (UNESCO, 1981) and an ecologically sensitive zone under the Indian Environmental Protection Act of 1985. The lake extends from Alappuzha in the south to Azhikkode in the north (96 km) along 9^0 30' 46" N to 10^0 11' 11" N and 76^0 09' 48" E to 76^0 25' 45" E coordinates. The lake has 3 sectors that are interconnected (Fig-1) namely; (i) **Southern Sector** (21 km long) extending from Alappuzha to Thannermukkom. This sector receives water from the rivers Achenkovil (128 km in length), Pamba (176 km), Manimala (90 km) and Meenachil (78 km) and drain to the Arabian Sea through the Thottapally spill-way. (ii) **Central Sector** (43 km in length) extending from Thannermukkom to Kochi Bar-mouth receiving water from the Muvattupuzha river (121 km in length) and draining to the Arabian Sea through the Kochi Bar-mouth and (iii) the **Northern Sector** (32 km in length) and receiving waters from Periyar river (244 km) and Chalakuddy river (145 km) and draining to the Arabian Sea through the Munnambam Bar mouth. The 3 sectors differ in their geomorphological, hydrological and biological features.



Though several studies have been carried out at different stand-alone sites of the lake system, a comprehensive study of the entire lake and its associated systems have not been attempted so far.

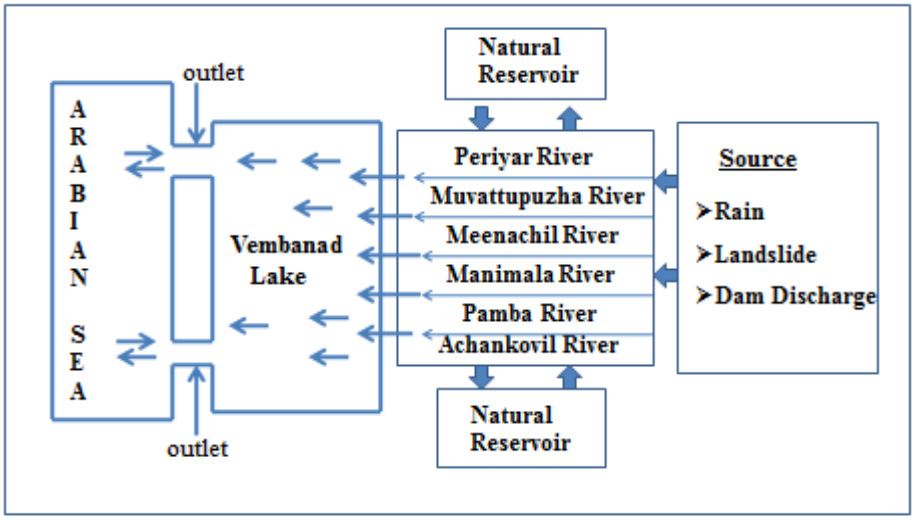


Fig -2: System components of VWS

The present study aim to achieve this, by taking the Vembanad wetland system (VWS) as a single unit (Fig-2) consisting of the 7 rivers that drain to the lake, natural reservoirs (Kuttanad fields, Kol wetlands & Vembanad lake), outlets (Thottappally, Kochi Bar mouth & Munnambam Bar mouth) and tide flux as its system components. The system is considered as a single homogenous pulsating system. Changes in one or more components of the system can upset the dynamics of the system with cascading effects.

Questions that are being addressed through the present work.

Q.1.*What are the long-term geomorphological changes in the system?*

1.1. **Changes in the area extent of the lake:** Preliminary results (needs validation with ground truth data) from the present study indicate an overall decrease of 41% in the area extent and decrease of 76.6% in the carrying capacity of the lake for the period 1930 to 2019 (present study). The shrinkage in area extent is from human interferences (reclamation) for the purpose of agriculture and habitation.

Area Extent (Km^2)

Sector	Area Extent (Km^2)			% decrease
	1930	1980	Present	
South sector	120.0	80.0	76.5	36.3%
Central sector	160.0	100.0	92.0	42.5%
Total	280.0	180.0	168.5	39.8%
North sector	75.0	47.0	41.0	45.3%
Grand total	355.0	227.0	209.5	41.0%

Menon et al., 2000 reported that the south and central sector of Vembanad together had an area of 315 Km^2in 1912 that got reduced to 180 km^2 by 1983 and 130 km^2 by 1998. As per Narayanna et al.,2006, the combined area (South & Central Sector) of Vembanad was 177.29 km^2 in 1973, 169.22 km2 in 1992, 166.29 km^2 in 2005 and 165.01 km^2 in 2015.

1.2. **Depth shrinkage of Vembanad Lake**

Detailed Bathymetry survey of the Lake was undertaken/ is being undertaken through echo-sounding technique for preparation of precise, high resolution (300 X 300 m grid) maps – a mandatory need for modelling efforts. Depths obtained from echo-soundings were post-processed for fixing the datum and removing possible errors from tide influence (de-tiding), and the results were validated by actual field observations.

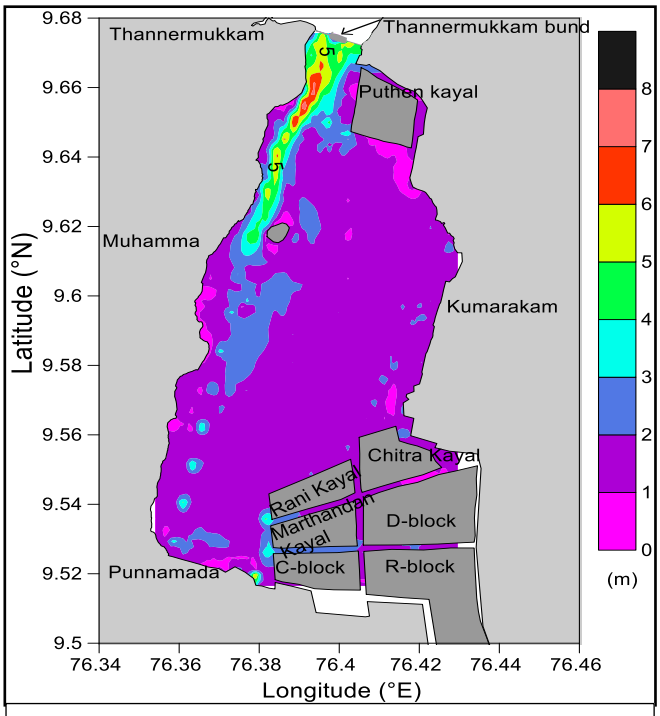


Figure-3: Depth profile map of South Sector

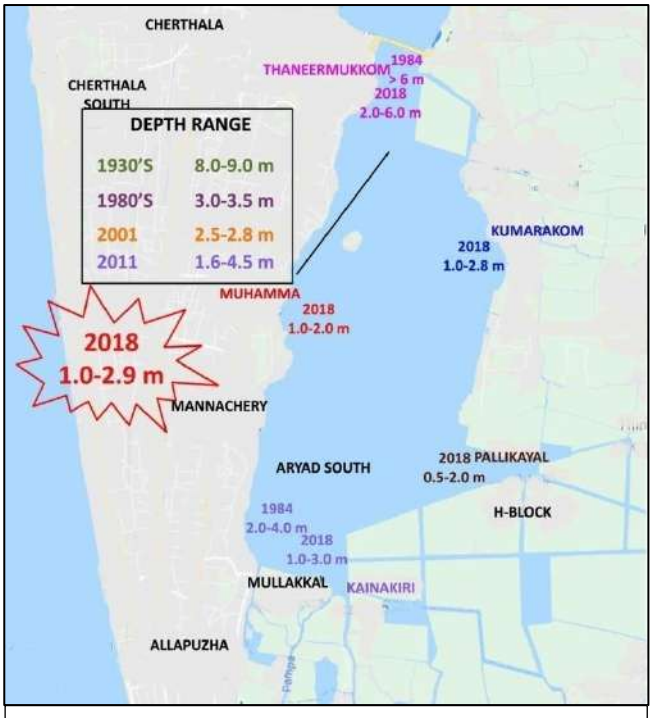


Figure-4: Long-term trend in depth shrinkage

Tidal amplitude is found to be around 80 cm (40 cm high during high tide and 40 cm low during low tide) with a lag period of 2 to 3 hours at different points of the south sector.

In phase-1(2018-19) bathymetric chart for the southern sector (Alappuzha to Thannermukkom) was prepared. Survey work was completed just before the August 2018 floods (highly useful for comparisons) and post processed (de-tided, datum fixed) depth profile maps were generated by April 2019. The survey results show alarming shrinkage (**82% Shrinkage**) in the depth profile of the Southern sector (fig-3).

0 to 1 m depth – 2% area ; 1 to 2 m depth – 85% area; 2 to 3 m depth – 5% area; > 3m depth (mostly the boat channel and northern end) – 8% area.

A comparison of the present depths with depths reported earlier (not sure whether depths are reported after de-tiding) indicates sharp depth shrinkage (82%) between 1930 and 2019 (Fig-4). Several points especially on the eastern side of this sector are < 1m in depth.

Phase -2 of the survey covering the Central sector (Thannermukkom to Kochi) was carried out during 2019 - 2020 (Fig – 5). Post processing of the data is progressing and results are expected to be available by August 2020.

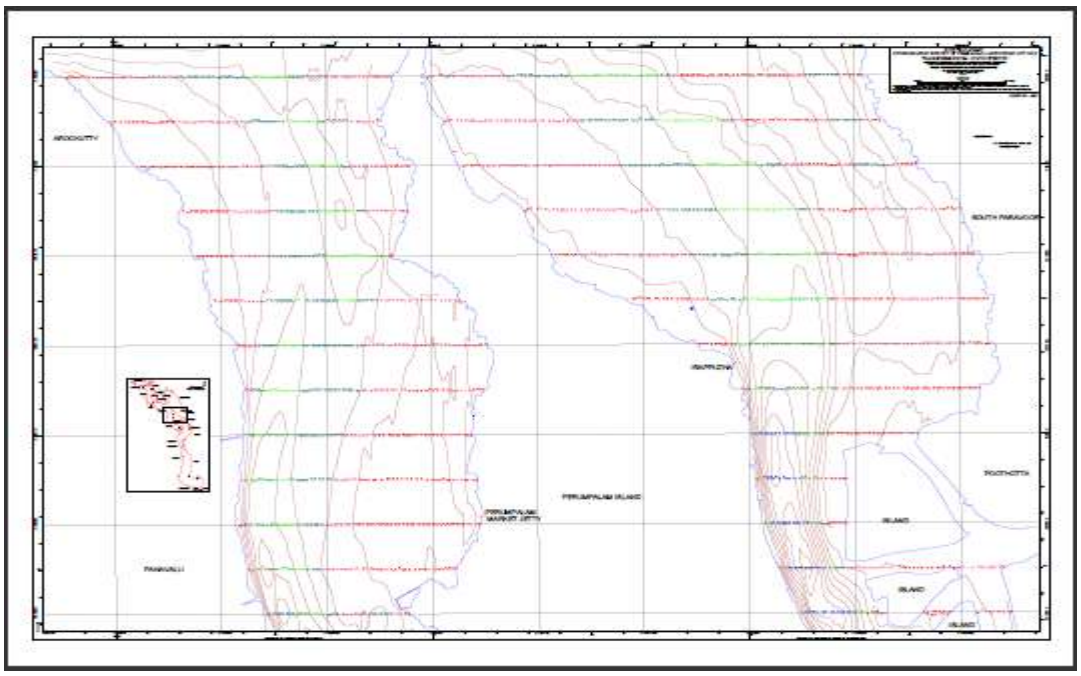


Figure-5: Survey transects (dotted lines) along the Central Sector. Each dot represents one ping or one depth station

The final phase covering the North sector (Kochi – Azhikode) will be considered subject to the project continuity beyond 2022.

1.3. Changes in the Carrying Capacity of the Lake

Spill over carrying capacity is considered as the lowest average bank height from Mean Sea Level (MSL) to which water in the river/ lake can be contained before it spills to the adjacent low lying areas causing flood inundation, multiplied by the area of the natural reservoir (lake/ river).

The estimated (present estimate) carrying capacity of the Lake is 567.7 MCM (Million Cubic Meter) water, of which 505.7 MCM can be contained in the South & Central Sectors and 62 MCM in the North Sector (Table).

Carrying Capacity (MCM)

Sector	Carrying Capacity (MCM)			% decrease
	1930	1980	Present	
South sector	960.0	240.0	137.7	85.7%
Central sector	1120.0	500.0	368.0	67.1%
Total	2080.0	740.0	505.7	75.7%
North sector	338.0	118.0	62.0	81.7%
Grand total	2418.0	858.0	567.7	76.6%

Consistent to the decreases in the area extent and depth of the lake, the Carrying Capacity of the Lake show sharp decline from 2418 MCM in 1930 to 567.7 MCM in 2019 – an alarming 77% overall decrease.

1.4. Carrying Capacity of Kuttanad & Kol wetland systems.

The estimated carrying capacity (CARMC estimate) of Kuttanad and Kol wetlands is approximately 1236.46 MCM which is close to the storage capacity of Idukki the biggest dam in Kerala or the Combined storage capacity of Kallada dam (488 MCM), Kakki dam (447 MCM) and Malampuzha dam (227 MCM).

Table-10: *Carrying capacity (M m^3) w.r.to river dyke elevation of paddy fields adjacent to rivers.*

Rivers	Paddy field Area (sq km)	Elevation (m)	C. Capacity (MCM)
Achankovil	24.85	1.0	24.85
Pamba	11.72	3.0	35.16
Meenachal+Manimala+ Muvattupuzha	525.00	2.0	1050
Periyar & Chalakudy	42.15	3.0	126.45
	603.72		1236.46

However, our estimates based on satellite imageries needs to be validated with data on area extent of paddy fields from concerned local authorities.

Q.2: *What causes the heavy siltation in Vembanad?*

2.1. **River bed Siltation:** Strong bottom flow is necessary for sand formation and keeping the river beds free of silt deposition. Bottom current measurements undertaken by CARMC using current meters show weak bed flow (except during the August 2018 floods) in all the rivers draining to Vembanad Lake. This combined with the heavy sediment load in the water column (measured manually by filtering known volume of water as KUFOS do not have river sonars that can give fast and reliable results) promotes silt deposition on river beds which further reduces bottom flow velocity with cascading effects. Only preliminary works are completed so far and detailed studies on silt deposition (from core samples) and nature of silt (Particle Size Analyser) needs to be completed.

2.2. **Siltation in Kuttanad wetlands:** The wetland system of Kuttanad (dominated by paddy fields) is an efficient buffer to prevent instantaneous floods (pulsates with tide) and removal of silt from river discharges. Before the elevated concrete bunds were constructed under the Kuttanad Development scheme to promote double paddy cropping, the clayey boundary walls of paddy fields used to give way to flood waters maintaining continuity between the river and the paddy field. Water that is stagnant in the paddy field promotes settling of the nutrient rich silt. Large quanta of silt brought by the rivers were removed this way, before the discharge water reach the Vembanad Lake during low tide. With the construction of concrete bunds, this process is almost entirely altered with the result that all the silt brought by the rivers is directly deposited in the lake. This process is greatly accelerated in the South Sector of the Lake due to weak tide flux (Thaneermukkom bund?). Though few sluice gates (approx.one meter breadth) are constructed for exchange of water between rivers and paddy fields these are not efficient or adequate for the system to function normally. These are preliminary results and our inferences need more studies/ analysis for further authentication.

2.3. **Siltation in Vembanad Lake:** Studies by CARMC confirm the alarming decrease in the depth profile of the South sector of Vembanad and attribute it to heavy siltation. Heavy sediment load in the waters discharged to Vembanad by the rivers, Achenkovil, Pamba, Manimala & Meenachel; poor performance of Thottapally spill way (50% of the designed efficiency) and reduced tide flux (Thaneermukom bund) appears to be the prime reasons for this. The growth of periphyton in shallow areas of the Lake further accelerates the process of siltation. The depth up to which the sediment is deposited (multibeam echo sounding)_ and the nature of the sediment (PSA) need to be assessed. This work is nearing completion for the south sector and the other sectors (Central and if possible the North sector) need to be studied.

Q. 3.*What is the role of tide flux and MSL on water discharge and salinity structure of Vembanad Lake?*

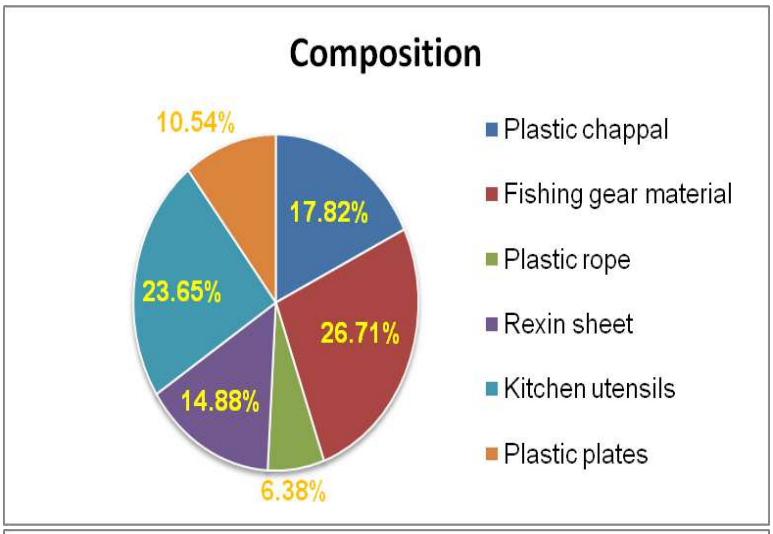
The Vembanad Lake communicates with the Arabian Sea through the Thottapally spill-way, the Kochi Bar-mouth and the Munambam Bar-mouth. The present discharge rates of Thottapally, Kochi and Munambam outlets are 630 CM^{-S}, 1463 CM^{-S} and 387 CM^{-S} respectively. These discharge rates are dependent on Mean Sea Level (MSL), Tidal amplitudes and water levels in Vembanad Lake. In a detailed study on the August 2018 Kerala floods; CARMC has documented the role of MSL, tide amplitudes and lake capacity in intensifying flood inundation and

in sustaining these conditions for a prolonged time. For details kindly refer Chapter-2 Task Force Report: Impact assessment (Eds. Ramachandran et al., 2019).

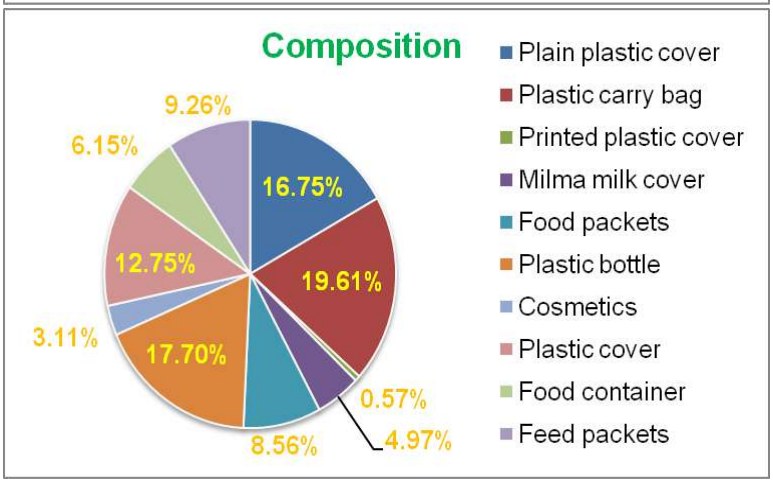
Q.4.*What is the current pollution load in Vembanad Lake?*

The lake is highly polluted by Plastic litter, agricultural wastes (Kuttanad area), Industrial wastes (Eroor area), Wastes from coir retting (Cherthala), Hospital wastes (Ernakulum area), Domestic wastes (Tourism sector etc.). CARMC is undertaking detailed investigations on the Water quality and pollution levels in Vembanad. The work commenced only from 2019 onwards and around 70 samples are undergoing analysis.

Plastic Pollution of Vembanad: Detailed studies were carried out by CARMC to quantify the macroplastic and microplastic load in the sediments of Vembanad South sector. Preliminary results based on 26 stations indicate the presence of 4276 Tons of Macroplastic within the upper two meter sediment of the South Sector (76.5 km^2 area) at the rate of 55.89 T/ km^2 area. The estimated load is composed of both light macroplastic such as plastic cover, covers of food products, plastic bottle etc., and heavy macroplastic such as plastic chapel, Fishing gear materials, plastic plates etc. Light macroplastic accounted for 615 Ton @ 8.04 T/Km^2 and heavy plastic were 3661 T @ 47.85 T/ Km^2 area. Final results covering > 100 stations and representing all the seasons (Pre-monsoon, monsoon & post monsoon) are being



Composition of light macroplastic



Composition of heavy macroplastic

worked out. Sediment samples for microplastic analysis and quantification have been gathered from 70 stations and are being analysed.

Q.5*What are the biological features investigated under this study?*

5.1. **Biodiversity inventory:** Inventory on the biodiversity of rivers (upstream, midstream and downstream) and within the 3 sectors of Vembanad are being studied as part of this project. Biodiversity of rooted plants (periphyton), Phytoplankton (floating plants), Zooplankton (microscopic animals), fishes, crabs, molluscs, fishes, macro and meiofauna are being attempted. Inventory for Achenkovil is nearing completion. Samples have been taken and are being analysed to document the biodiversity in the South sector of Vembanad. Sample collection from the remaining 6 rivers and from the Central and North sector is pending.

5.2. **Food-web dynamics in Vembanad Lake**: This is being attempted through gut content analysis and mesocosm experiments. The work is only in the initial stages.

5.3. **Mapping of Clam beds:** Data from the South sector of Vembanad lake is generated on the basis of extensive dredge sampling. Clam bed maps of the South Sector generated.

5.4. **Community structure of Fishes**: Survey work in the South sector has been initiated through a combination of experimental trawling operations, fish landing survey and market survey.

5.6. **Jellyfish menace and stake net fishery**: Appearance of jellyfish blooms in the South sector of Vembanad is being monitored on a weekly basis. In the Kumbalam stake net fishery, the menace is mainly from *Acromitus flagellates* and the numbers of fishing days lost through the clogging of jelly fish in these nets are being recorded.

Stake Net Fishery at Kumbalam, Kochi.

New record of the Leopard- spot jelly fish from Indian waters.

The leopard-spot jelly fish *Acromatus maculosus* reported by Light, 1913 from Philippine waters is recorded from Indian waters for the first time. The species is reported after 100 years from its original report. CARMC will be communicating this rediscovery to Journal on Marine Biodiversity, UK for publication.

B. Participation in the Indian Arctic Expedition: CARMC (Dr. Anu Gopinath and her team) participated in the Indian Arctic expeditions organized by NCPOR, Goa during 2017-18 & 2018 – 19. Results from these are published top ranking international journals; *Advances in Polar Science* (2019) &*Ecological Indicators* (2019).

C. Participation in the 2019 – 20 Southern Ocean Expedition (Antarctic waters): From 2019 onwards CARMC is taking part in the Southern Ocean Expeditions of India, being organized by the National Centre for Polar and Oceanographic Research (NCPOR), Ministry of Earth Sciences, Goa. Dr. Gireesh Raghavan & Ms. Princy John participated in this year's expedition to SO from 3rd January to 11th March 2020 on-board SA.Ahulas. The topic being investigated by CARMC is the " Salp- Cnidarian-Ctenophore interactions in a Krill centred Ecosystem". Due to Covid -19 samples collected are presently lying in the ice-core laboratory of NCPOR and will be transferred to KUFOS later. The analysis is expected to take 6 to 8 months' time.

Annexure 3

CENTRE FOR AQUATIC RESOURCE MANAGEMENT & CONSERVATION (CARMC).

ANNUAL REPORT 2017-18.

1. CARMC was officially inaugurated on the 12th of September 2017 by Smt.J.Mercykutty Amma, the Honourable Minister of Fisheries, Harbour Engineering and Cashew Industry, Government of Kerala. The CARMC has taken up two major projects for implementation viz; Comprehensive study of the Vembanad Lake and associated ecosystems and (ii) Process studies including biodiversity of the territorial waters of Kerala.

2. The study on Vembanad envisage documentation of the long-term trends in the geomorphology, hydrodynamics, siltation, river discharge and tide flux, water chemistry, pollution loads, biodiversity etc., and to model how these changes have altered the resources availability from the lake. Based on the review of over 200 published papers, the CARMC has designed its work plan and survey protocols to address all areas where data gaps exist. The study area is given in Figure-1. Preliminary field survey of the Northern sector of the lake was undertaken during December 2017 and the downstream part of Manimala River was surveyed in February 2018. Fine resolution bathymetry (250 X 250 m grids) of the Southern sector of Vembanad Lake was initiated in March 2018 and is expected to be completed by June 2018. On completion, this will be the first fine scale bathymetric chart of the Lake, a critical input for modelling studies.

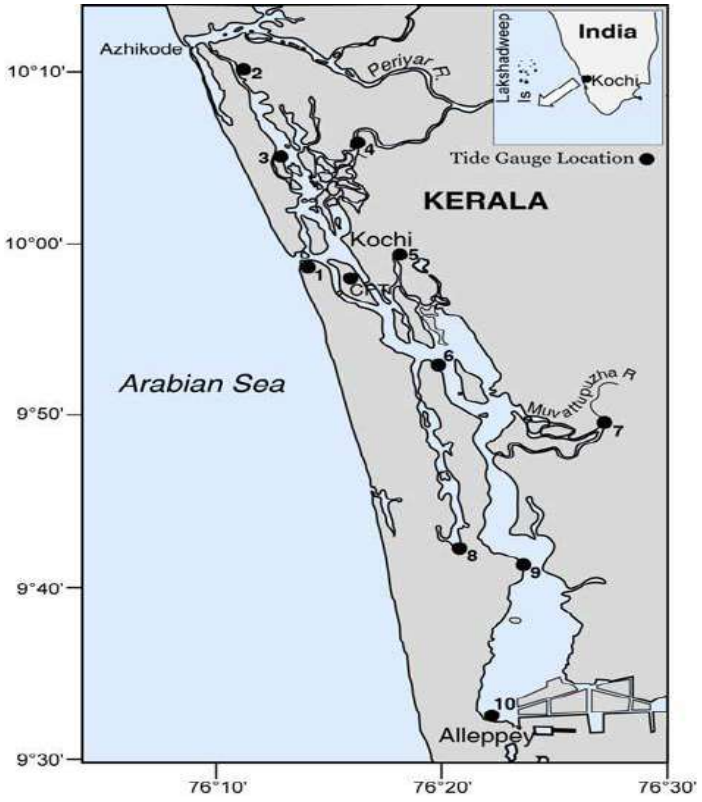


Fig-1: CARMC Study Area.

3. Workshops/ Invited lectures Organized: CARMC organized the National Training Workshop on "Tools for monitoring, assessment and management of aquatic ecosystems" at KUFOS on the 29th, 30th& 31st of January 2018. The workshop was attended by over 150 participants including delegates from many collages in Kerala and the CARMC project team. Invited lectures were taken by experts from within and outside Kerala on the recent updates on measurement protocols to be followed. Lecture sessions were followed by hands-on –training sessions conducted in various laboratories of KUFOS.

   Dr.Ralph Britz, British Museum of Natural History, London delivered an invited talk on " Miniature Fishes of the World" which was arranged at KUFOS by CARMC on 20th July 2017. The lecture was important as it is documented that the rivers discharging into the Vembanad do harbour few miniature fishes.

   An invited talk by Dr.Tomoyuki Komai, curator, Natural History Museum and Institute, Japan on " Building and Management of crustacean collection" was arranged by CARMC at KUFOS on the 22nd of February 2018. The talk explained the procedures for collection, preservation and identification of crustaceans.

The third invited talk organized by CARMC was held at KUFOS on the 27th March 2018. A lecture on " Natural and human induced hypoxia" was delivered by Dr.Lisa Levis, Scripps Institution of Oceanography, USA. This lecture was of special significance, as the Arabian Sea is believed to have the world's largest Oxygen Minimum Zones.

4. Research Papers/ Technical Reports. During the year under report, the CARMC Group published 3 scientific papers in reputed International journals such as Zootaxa (UK)- one published and another accepted for publication and the journal Conservation Genetics Resources (accepted for publication).

   Based on extensive field survey's the CARMC Group prepared a technical report on "Fish ladder at Thaneermukkom bundh and its possible impacts on the fishery" which was submitted to the Executive Engineer, Kuttanad Development Mission.

   Another detailed technical Report on "Climate Change and possible impacts on Kerala coast" was prepared by the CARMC Group consolidating the scientific observations following the November 29/30th Okhi incident which was submitted to the Kerala Legislative Assembly on Environment. This report summarizes the action plan and preparedness to face catastrophic events like Tsunami & OKHI.

5. Science collaborations: Following the brain-storming session with representatives from the Indian National Centre for Ocean Information Services (INCOIS), Hyderabad, held at KUFOS on 21.7.2017 an MOU was signed between KUFOS & INCOIS for collaborative research in the areas of ocean observation and coastal services.

   The KUFOS had one full day discussion with senior officials of the Indian Ocean Rim Association (IORA), India Chapter on the possibility of establishing an IORA regional centre at KUFOS. As a consequence of this, it has been decided to hold a regional workshop for on 'Ways & means to promote Indian fishing industry" at Kochi in May 2018 jointly by KUFOS & IORA.

6. Participation in National/International Committees: Members of CARMC are represented in prestigious committees and have attended meetings of the Committees such as United Nations Assessment of Assessment of World Oceans, Government of India's committee on drafting the Indian Antarctic Act, Working Group on Revalidation of Potential Fishery Resources of Indian EEZ constituted by ICAR etc.

Annexure 4

CENTRE OF EXCELLECNCE IN

AQUATIC RESOURCE MANAGEMENT AND CONSERVATION

ANNUAL REPORT

KERALA UNIVERSITY OF FISHERIES AND OCEAN STUDIES

PANANGAD

1. **Background:**The Centre for Aquatic Resource Management and Conservation (CARMC) was set up at KUFOS in September 2017 with a view to develop technologies for the viable utilization of aquatic resources, develop knowhow on conservation and management of aquatic living resources, facilitate policy research and impact assessment in the coastal and inland waters of Kerala and to provide a platform for information dissemination and

training.As a part of this, the CARMC has initiated studies on (i) the long-term trends in Vembanad lake and its associated ecosystems (ii) the anchovy-sardine coupling and (iii) biodiversity inventorization.

2. **Vembanad lake and associated ecosystems:** The study assumes significance as the system help to (i) mitigate floods and droughts (ii) supply nutrient enrichment to the Kuttanad paddy fields (iii) has rich biodiversity including several endemic species and (iv) is rich in fin-fish, crustacean and bivalve resources. Man-made disturbances and natural changes have drastically affected the ecosystem services from the system, especially from the southern sector (Thaneermukkom bund to Alappuzha). The present study envisage documenting the long-term changes in the system focusing on (i) geomorphology (ii) changes in the river discharges (iii) carrying capacity (iv) siltation (v) community structure (vi) biodiversity and (vii) resource availability. Work progress during 2018-19 are as under;

2.1. **Fine-Scale Bathymetry:** The bathymetry of the Southern sector of Vembanad lake (Alappuzha to Thaneermukkom bund) was carried out on a fine-scale (300 X 300 m grid resolution) from echosoundings. Depth profiles generated were validated with *in-situ* observations on depths. Comparison of depth profiles with past data, indicate an alarming decrease in the depth of this sector over the last 50 years, especially after the construction of the Thaneermukkom bund in 1972. As per reports, in the 1930's the lake had a depth of 8 to 9 meters which reduced to 3 - 3.5 m by 1980's, to 2.5 - 2.8 m in 2001 and to 1.6 - 4.5 m by 2011 (Fig-1). The present survey results indicate a depth range of 1.0 to 2.9 m (except the boat channel) for the lake. The observed depth shrinkage of the lake is likely through heavy siltation in the near absence of tide flux.

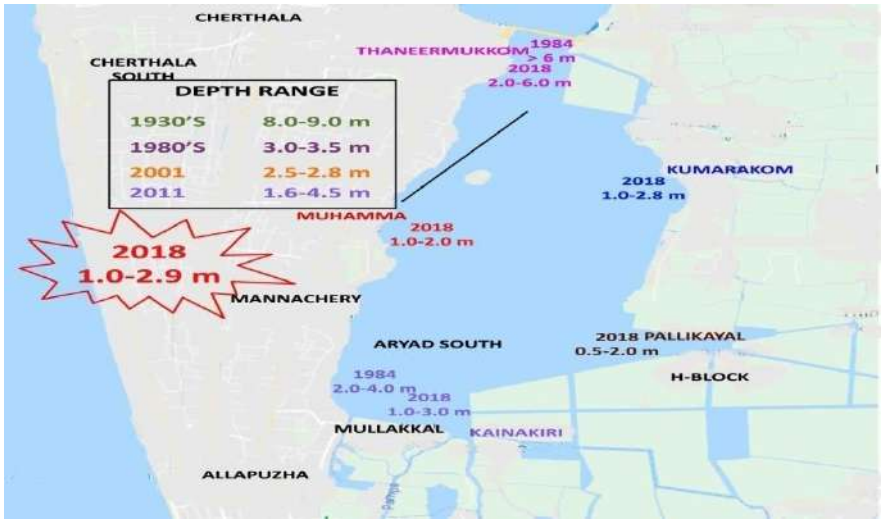


Figure -1: Long-term bathymetric trends in the southern sector (Alappuzha to Thaneermukkom bund) of Vembanad lake.

2.2. **Studies on the August 2018 Kerala Floods:** CARMC team visited the flood affected areas of Kuttanad and Aluva and collected data on the level of inundation, water quality and species composition. Data on Mean Sea Level, tidal amplitudes and discharge rates for the flood period were generated. Data analysis is in progress. Preliminary results indicate considerable increase in the August sea level at Kochi bar mouth (66cm) compared to 2017 (56 cm). . This combined with the unusually heavy precipitation during the Neap tide phase (Fig-2) of August 2018 may the primary reason for the persistence of flood waters in the low lying areas for a prolonged time. Detailed report on this is under preparation and will be submitted to the Task Force on Kerala floods constituted by KUFOS.

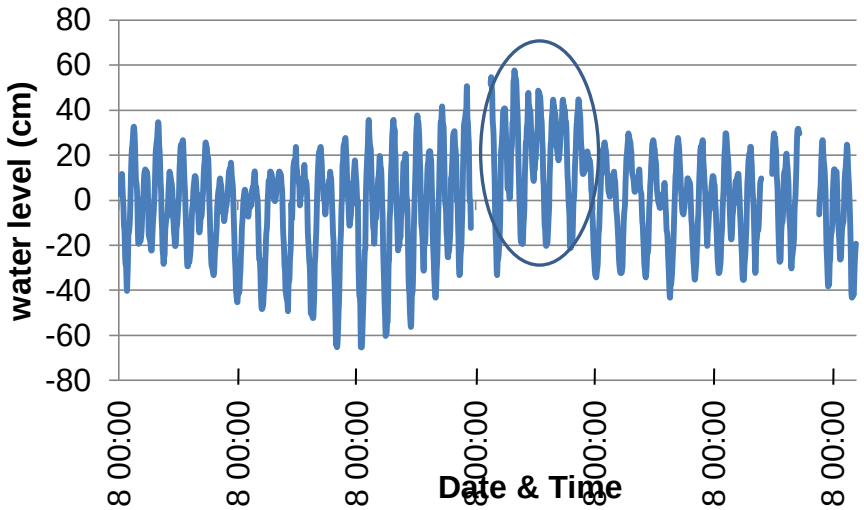


Figure-2: Tidal amplitude for the month of August 2018.

2.3. Environmental monitoring: During the period under report two field surveys were conducted to assess the physical, chemical and biological attributes of the Vembanad lake. The dissolved oxygen ranged from 2.82 to 3.96 mg/l in January 2019, while it was in the range 2.70 to 3.04 mg/l during December 2018. The Lake had typical freshwater characteristics during the survey in most stations except at Aroor – Thevara region where salinity was in the range 19 to 21 ppt. The observed pH of Vembanad lake water varied from 8.65 to 7.98 with an average of 7.63. The sight acidity as well as alkalinity may be due to pollutants from prawn culture field or agriculture fields. The chlorophyll *a* ranged from 0.89 to 2.05 mgC/m^3, while Chlorophyll *b* from 0.42 to 1.79 mgC/m^3 and Chlorophyll *c* from 0.53 to 2.31 mgC/m^3. The temperature (surface water) ranged from 28-31ºC and pH in the range 6.7-7.2. In the phytoplankton composition Chlorophycea was the dominant group (9 Genus) followed by Cyanophycea (6 genus) and Bacillariophyceae (5 genus). The Zooplankton biomass was in the range 0.036 to 0.1 No/m^3. The middle part of all selected sampling sites in the

Vembanad lake had high zooplankton biomass (Figure 3). Copepod was the dominant group (average 78.5%) followed by Gastropod (11.79%), Amphipod (3.60%) and larval forms of Barnacle (3.89%), fish (1.25%), Zoea (0.50%), Mysid (0.21%) and Isopods (0.11%).

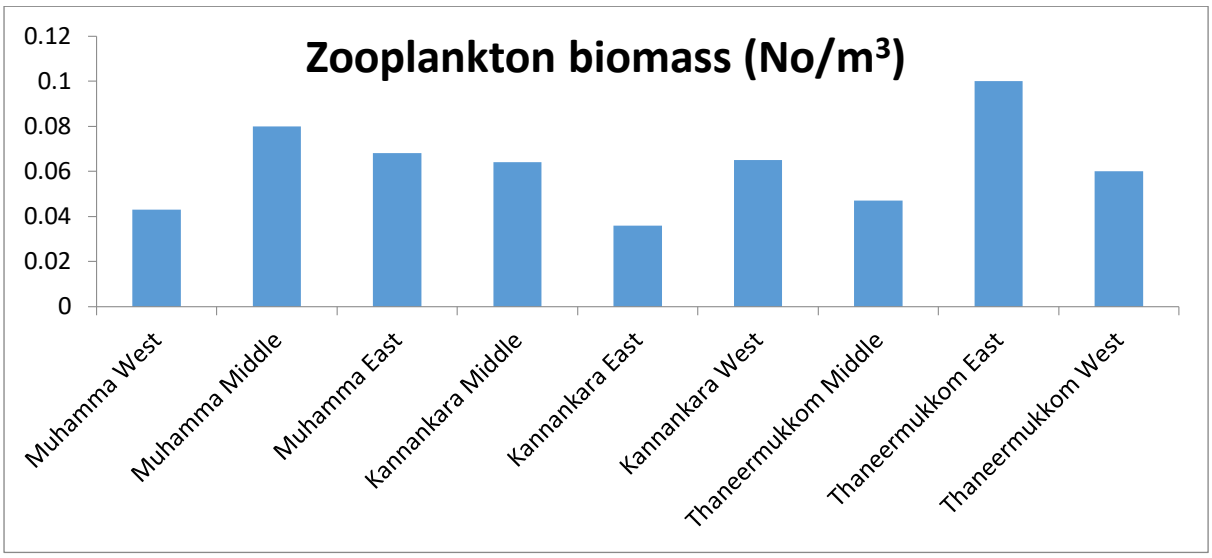


Figure 3. Zooplankton biomass at different stations of Vembanad Lake.

2.4: **Biodiversity & Community Structure:** Completed inventorying the biodiversity of finfish in Achenkovil river. Finfish inventory of Manimala river is in progress. Documentation of crab, mollusk, macrobenthos, sponge and aquatic plant diversity in the two rivers are in progress. Data collection to document the community structure of finfish in the southern sector of Vembanad lake is in progress. Towards this, 5 field visits were undertaken in 2018-19. A total of 31 finfish, 2 crustaceans and 2 mollusks species were identified, so far. Finfish is dominated by *Arius maculatus*, *Heteropneustesfossils*, *Strongylura strongylura*, *Labeo dussumieri*, *Pseudoetroplus maculatus* and *Channa striata* . Crustaceans are dominated by *Macrobrachium rosenbergii* and *M.idella* and mollusks by *Villorita cyprinoides* and *Paphia malabarica*.

Figure-4: Samples of catfish *Arius maculatus* and spot-tail needle-fish *Strongylura strongylura* from Vembanad South sector.

2.5.**Stake-net fishery & Jelly fish menace :** Regular monthly monitoring of the stake-net fishery is being conducted at Aroor, Kumbalam, Perumbalam and Panangad. In few months of the study period, extensive blooms of jelly fish dominated by *Acromitus flagelatus* were observed; forcing the closure of the fishery for few weeks. The study focus on the seasonal trends in the stake-net fishery, the species associated with bloom formation and the environmental set up that promote the appearance and sustenance of jelly fish blooms.

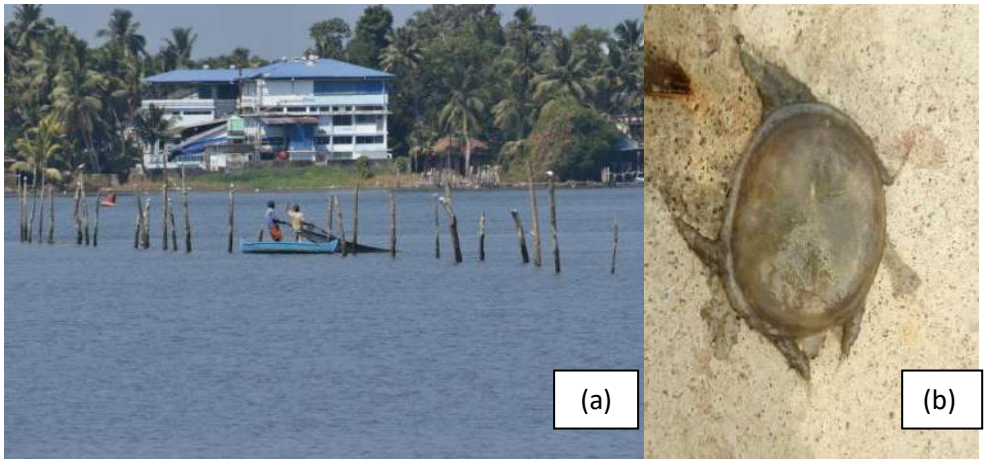


Figure-5: (a) Stake-net fishing at Kumbalam and (b) *Acromitus flagelatus* the dominant bloom forming species.

2.6: **The Anchovy – Oil Sardine Coupling:** Small pelagic fish like anchovy, oil sardine and Indian mackerel support nearly 50% of Kerala's marine capture fishery. Oil-Sardine and anchovies share common coastal habitats and therefore a clear understanding of the niche preferences of these two groups is a mandatory need to explain their responses in a changing climate scenario. CARMC has initiated studies on gonad maturation, spawning and ontogeny of these groups along the Kerala coast. Results from these studies will be available only after three years.

2.7 **Other CARMC activities:** These include (i) publication of seven research papers in high impact international journals (ii) taking a lead role in the tropho-dynamic sub-group on estimation of Potential fish yield from the Indian EEZ, as part of the three working groups constituted by the Ministry of Agriculture, New Delhi for this purpose. The trophodynamic group established the energy flow in carbon terms through trophic levels, using which the potential yield was estimated to be 5.11 million tons (iii) conduct of National Workshop on Climate Change and Disaster Management at KUFOS on the 22nd to 23rdof February 2019. The science and management aspects on extreme weather events were addressed by Dr.P.V.Joseph, Former Director General, India Meteorological Centre; Dr. Mohan kumar, Professor, Radar unit, CUSAT; Dr.J.Sanjay, Scientist, Centre for Climate Change Research, Pune; Dr. Prasannakumar, former Director, National Institute of Oceanography, Goa; Shri. Ajit Kumar, Joint Director General, Marine Mercantile Division; Capt. Rajesh Rana, Southern Naval Command and Dr.A.S.K. Nair, former scientist, CESS, Thiruvananthapuram (Fig- 6). CARMC organized another seminar on Planning and executing taxonomic research at KUFOS on the 5th March 2019 which was addressed by Dr. Graham Oliver, National Museum, Wales.

Figure-6: Dr.P.V.Joseph delivering the lecture on extreme weather events. Seated from right to left are Dr,T.V.Sankar, Director (Research), KUFOS. Dr. Victor George, Registrar, KUFOS; Dr.A Ramachandran, Vice-Chancellor, KUFOS and Dr.V.N.Sanjeevan, Professor Chair, CARMC.

Annexure 5

ANNUAL REPORT: 2019 – 2020.

Centre for Aquatic Resource Management & Conservation [CARMC]

CARMC is a Centre of Excellence (CoE) under the Directorate of Research, KUFOS dedicated for research and analysis on Aquatic systems of Kerala. CARMC is structured around a centre with a Professor Chair, 8 faculty members as Investigators and 9 associated Project staff. From September 2017, CARMC is engaged in a detailed study of the Vembanad Wetland System (VWS). Studies during 2019-2020 focussed on the South Sector of the VWS which include the South Vembanad Lake (Alappuzha to Thaneermukkom sector), the Rivers Achankovil, Pamba, Manimala and Meenachil that drain to this sector, associated wetlands dominated by the Kuttanad Padasekhrams, network of deltaic canals and rivulets, Regulators

at Thottapally & Thannermukkom and outlets /tidal inlets at Thottpally, Andhakaranazhi and Kochi (Fig -1).

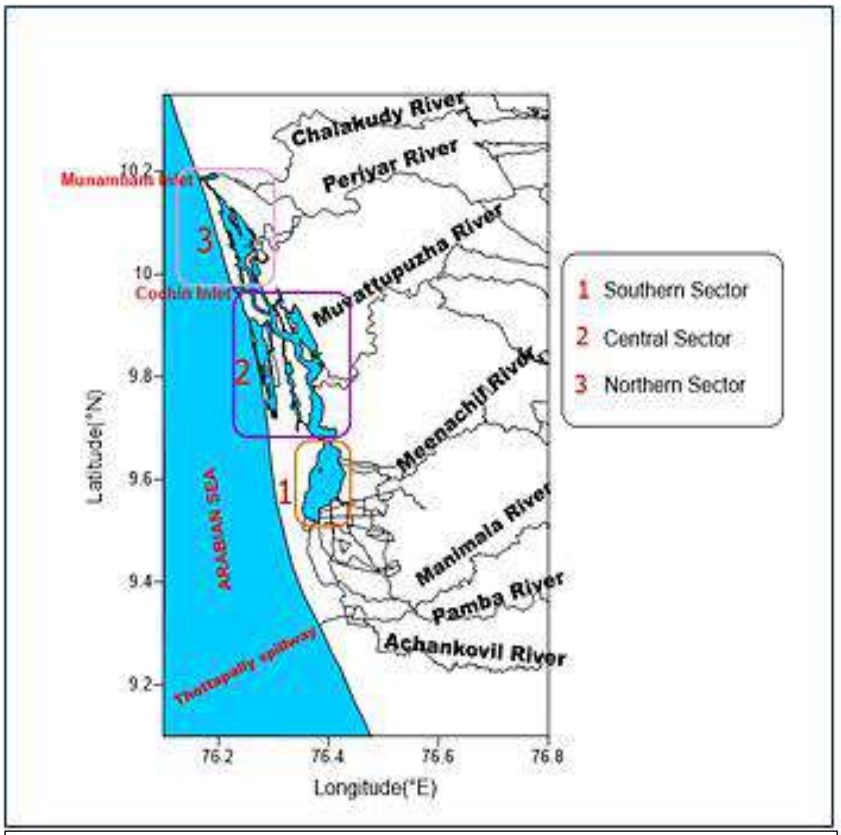


Figure-1:*study area showing the South Sector (1) of VWS*

Activities of the CoE during the year under report are as under;

i. Assessment of sediment deposition in the south sector of VWS:

Sediment deposits in the 76. 5 km^2 area of the South sector was assessed by dividing the area to 856 equal grids of 300 X 300 m and quantifying the sediment in each grid taking 4.5 m as the base floor depth (BFD) of the Lake. BFD was fixed at 4.5 m in consideration to the fact that the sill depth of Thannermukkom regulator is at 4.12m below Mean Sea Level. Our analysis show that 4.4% of the Lake fall below one meter depth, 77.7% between 1 to 2 m, 10.5% in the 2 to 3 m depth range, 2.5% in the 3 to 4m range, 3.0% in the 4 to 5m depth range and the remaining 1.9% had depths above 5 m. Overall the depth of this sector shrunk by 1.8 m over the years 1980 to 2018 at an average deposition rate of 4.75 cm per year. The bottom topography of the Lake showed an east-west sloping (Fig -2) and an uneven floor with deeper depths (>4m) restricted to the western and northern boundaries.

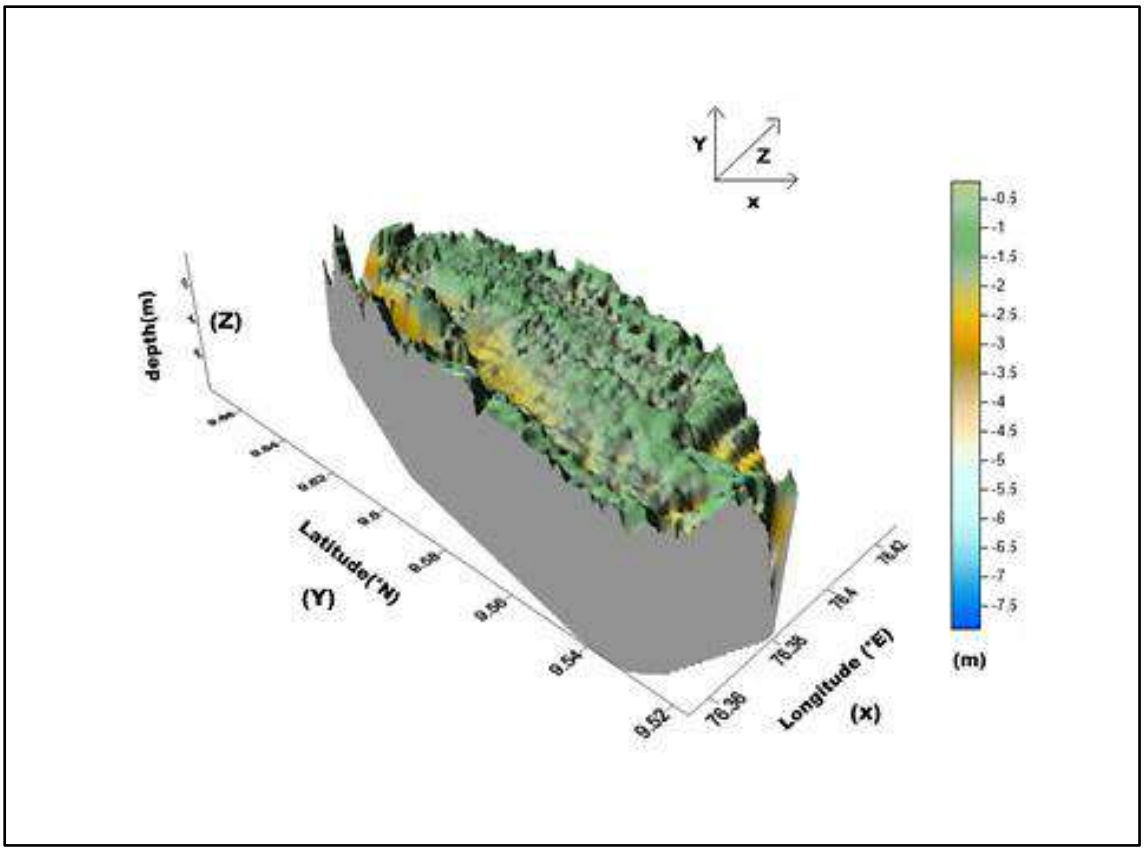


Figure -2*: 3-D view of sediment deposition in the South sector of Vembanad Lake.*

These studies were carried out under the supervision of Dr. V. N. Sanjeevan, Prof. Chair, CARMC. Our estimates indicate the presence of approximately 200 Million Cubic Meters (MCM) of bottom sediment above the BFD which need to be removed by dredging to restore the smooth flow pattern of the Lake. In the near absence of tidal influence in this sector of Vembanad Lake, we attribute this heavy siltation to reduced flood and base flow velocities of the rivers discharging to this sector and the noticeable reduction in the sediment filtering capabilities of Kuttanad Padasekhrams. Reduced flow velocities in the upstream segments of the 4 rivers (CARMC current meter data for 2019 monsoon) combined with loss of river bed roughness leads to less production and transport of sand that further amplify the effects from loss of bed roughness and slow down of flood flow in the mid and downstream stretches of these rivers

ii. High resolution bathymetry of the Central Sector of Vembanad Lake

Fine scale bathymetry charts (300 X 300 m grid resolution) for the south sector of Vembanad Lake (Alappuzha to Thannermukkom) was generated by CARMC during the year 2018 – 19. Following this, during 2019 – 2020 extensive surveys were conducted in the Central sector (Thaneermukkom – Kochi sector) of Vembanad jointly by CARMC and the Hydrographic Survey Department, Govt. of Kerala to generate high precision bathymetry charts. Acoustic

surveys using SY Quest Bathy 500 MF Echosounder were carried out from September to end November 2019 along 100 east –west transects covering the 600 grids (10 seconds) in the Central sector (Figure -3 A & B). For this the Central sector was divided to 10 sub-sectors with each sub-sector representing around 60 grids of 300 X 300 m dimension.

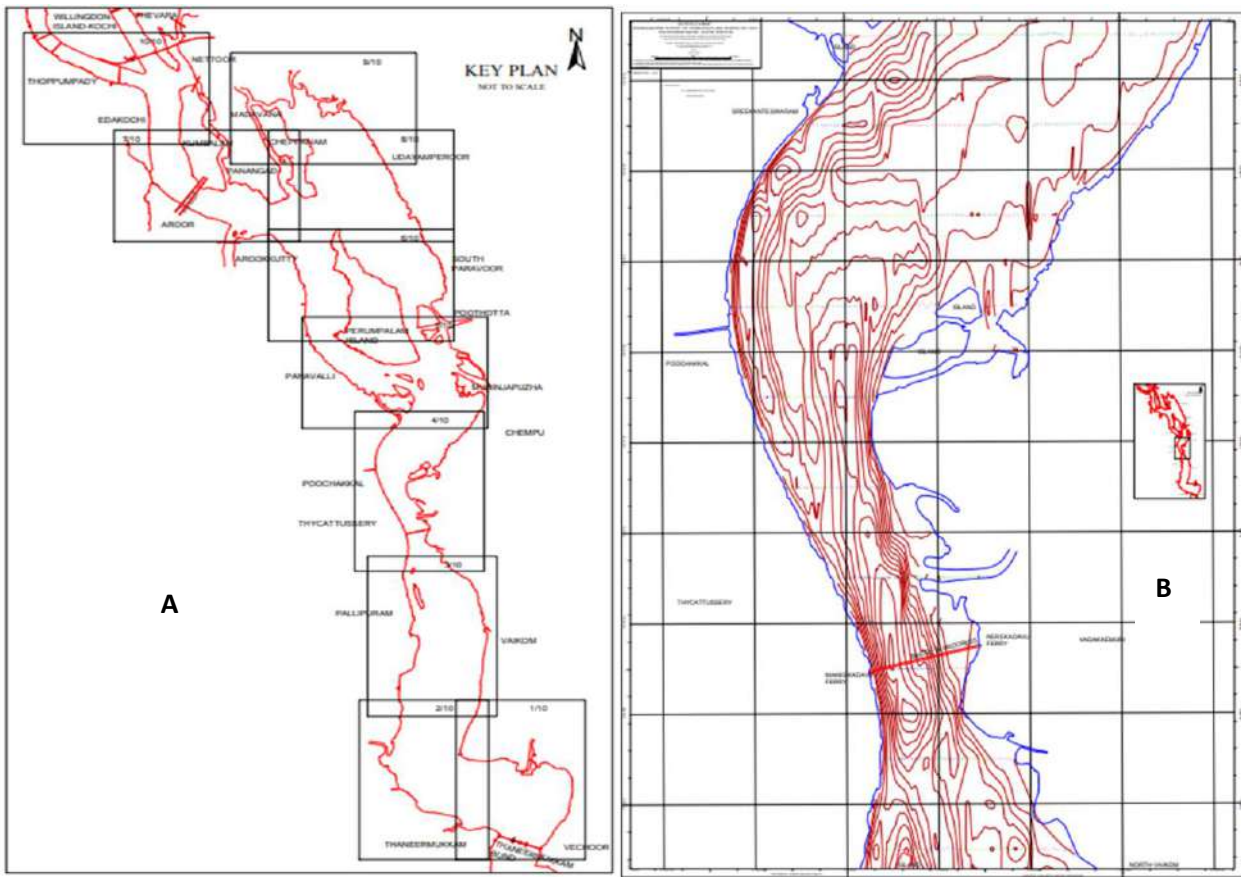


Figure-3 (A): *10 subsectors in the Central sector and* **(B)** *details of the Vaikom sub sector*.

Acoustic depth data were detided making use of *in-situ* tide data from tide poles maintained at Thaneermukkom, North Vaikom and Kochi. Station positions were fixed through DGPS (Tremble SPS 855). Post processing of the data is progressing. Field validations of depths will commence in June/July 2020.

iii. Quantification of Plastic load in the bed sediments of the South Sector

For quantification of Macro and Micro Plastic load in the bottom 1.8 m sediments (estimated to be deposited between 1980 and 2018) of the South Sector, samples were collected from 26 stations during September/October 2019 by Dredge, grab and bottom trawl operations. At each station Dredge and trawl were operated for 20 minutes for collection of macroplastics. Grabs were operated at these stations to check the vertical distribution of macroplastic and to collect sediment sub-samples for microplastic Analysis. Since the grab bites 50cm deep, the grab samples represent plastic accumulation over the last 10 years @

4.8 cm thick sedimentation per year. Studies on macroplastics were coordinated by the CARMC centre and studies on microplastic under the supervision of Dr. Anu Gopinath, Asst. Professor, KUFOS. The study indicates the presence of 4276 tons of macroplastic load in the upper 1.8 meter sediment of the Southern Sector of Vembanad Lake at the rate of 55.89 ton/ km^2 area.

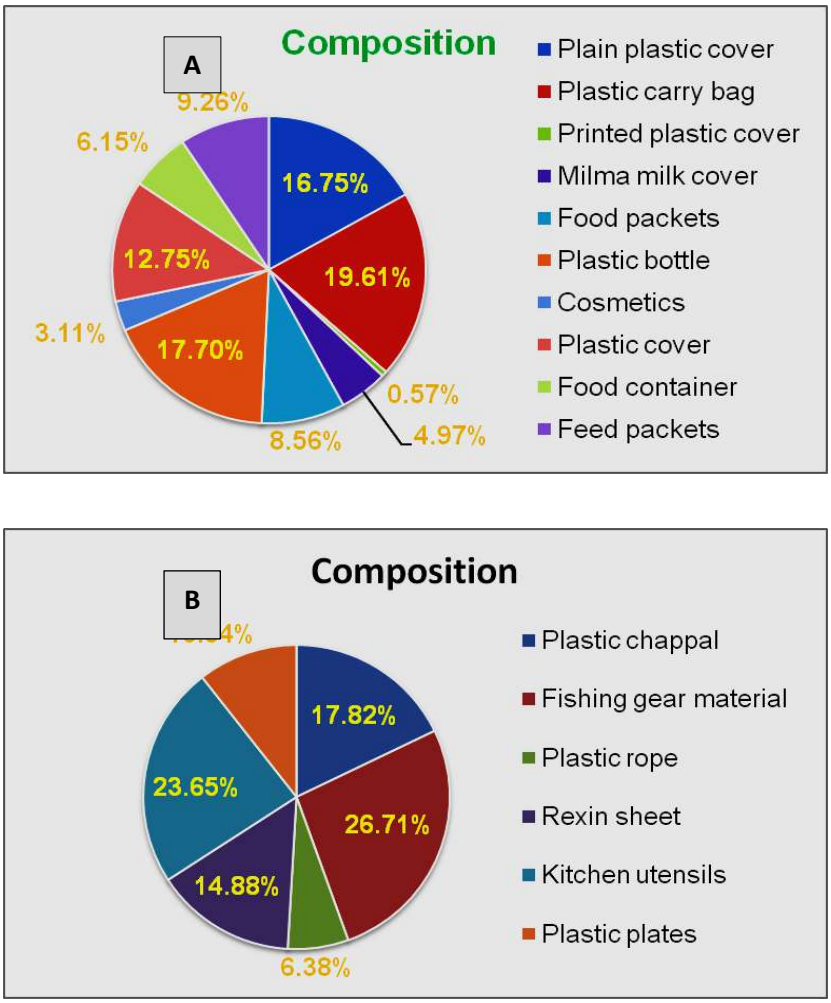


Figure -4:*Macroplastic deposits in the bottom sediments of Vembanad Lake's South Sector. Composition of*(A)*Light and*(B)*heavy macroplastics*.

Light macroplastic (slow sinking plastic) such as plastic sheets, carry bags, milk sachets etc., accounted for 615 tons @8.04 ton/ km^2 (Fig – 4A)and heavy plastic (fast sinking plastic) such as nylon net materials, plastic foot wares, plates, plastic ropes etc., was 3661 tons @ 47.85 ton/ km^2 area (Fig -4 B). The analysis of microplastic in the 76 sediment samples collected (Dr. Anu Gopinath, Asst. Professor) and impact of microplastic on filter feeders (Dr. Pramila, Asst. Professor) are in progress. The CARMC also organized a plastic Awareness meet and a beach clean-up campaign on the 16th October 2019 at the GCDA Grounds, Marine Drive, Kochi as part of Swachatha Hi Seva programme (Figure -5). More than 150 participants from nearby institutions/ colleges and faculty members of KUFOS joined the campaign and the meet.

Figure -5:*Plastic awareness campaign, GCDA grounds, Marine Drive, Kochi*.

iv. Mapping the Black-Clam beds in the Southern Sector of Vembanad Lake.

Studies on the spatial distribution of Black Clams (*Villorita cyprinoides*) in the Southern Sector of Vembanad lake was carried out during the monsoon season of 2019 by the CARMC team led by Dr. Jayalakshmi, Asst. Professor. The distributional pattern of black-clams and their numerical abundance during the monsoon season is represented in Figure -6. Abundance is found to increase northward where the salinity is relatively higher. Maximum abundance recorded was 1857 No's per 1000 sq. meter area. The anterior-posterior length of live clams ranged from 6 to 48 mm. Juvenile clams (<15mm) were abundant towards the northern parts of this sector. Pre-monsoon and post-monsoon survey's needs to be undertaken.

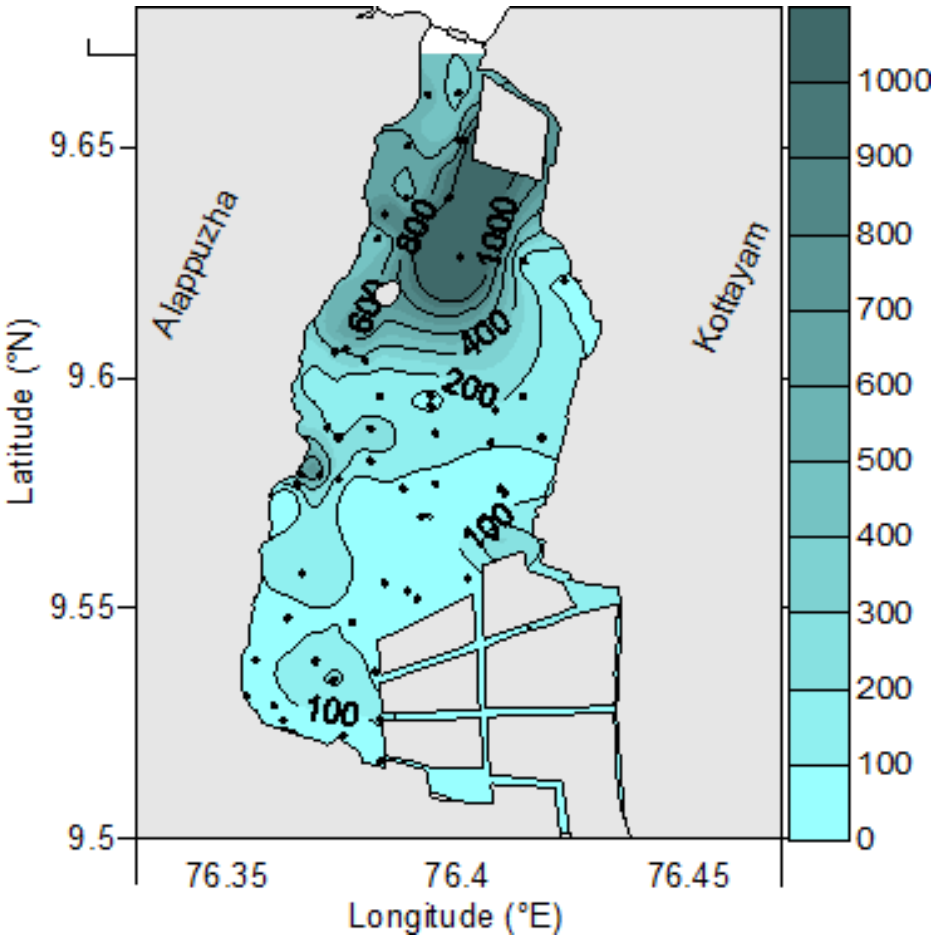


Figure-6:*Numerical abundance of black-clams in the South Sector of Vembanad Lake*.

v. Biodiversity Studies.

CARMC is involved in a detailed investigation on the distribution, abundance and species diversity among Phytoplankton, Periphyton, Zooplankton, Benthos, Crustaceans, Molluscs and fishes in the south sector of the Vembanad lake and along the upstream, midstream and downstream of the Rivers Achankovil, Pamba, Manimala and Meenachil. During 2019 -20 field data were collected from Achankovil and from the South sector of the Lake (Figure 7 A & B) covering the monsoon season. Data of post monsoon 2019 and pre-monsoon 2020 could not be gathered due to logistic reasons. Samples are being analysed as under; Phytoplankton/Periphyton/ Zooplankton (CARMC centre); Benthos (supervised by Dr. Prabhakaran, Asst. Professor); Crustaceans (supervised by Dr. Raffi, Asst. Professor); Molluscs (Bivalves supervised by Dr. Jayalakshmi & other molluscs by Dr. Ranjeet, Associate Professor); Fishes (supervised by Dr. Rajeev Raghavan, Asst. Professor – Riverine fishes and the CARMC Centre (Vembanad Lake). Dr. Rajeev Raghavan has completed the fish biodiversity of Achankovil River including generation of bar codes of important native fish species.

Figure -6A: *Data collection from the Forest area of River Achankovil*.

Figure 6 B:*Collection of Sediment Grab Samples from South Sector of Vembanad Lake.*

CARMC project staff under the guidance of Dr. S. Suresh Kumar, Director, School of Ocean Science and Technology participated in a rapid biodiversity assessment of the rivers and backwaters of North Kerala to evaluate the impact of the proposed Malanad – Malabar River cruise tourism project of Department of Tourism, GOK. Biodiversity of phytoplankton, zooplankton, benthos, microbes and sedentary organisms together with details on the depth, salinity and surface temperature were collected from Mahe river (6 stations), Anjarakandi river (4 stations) Valapattanam River (7 stations), Kuppam river (8 stations) and Valiayaparamba backwaters (5 stations).

vi. Spatio-temporal distribution and numerical abundance of Benthos in the South Sector of Vembanad Lake. **(PI:Dr.Prabhakaran)**

Sediment samples for enumeration of macrobenthos and meiobenthos were collected from the Southern (Kavunkal & Mannancherry transects), Middle (Mohamma & Pathiramanal transects) and Northern (Kannankara & Thannermukkom transects) ends of the south sector using Van Veen Grab (Figure -6 B) during the pre monsoon and monsoon seasons of 2019.

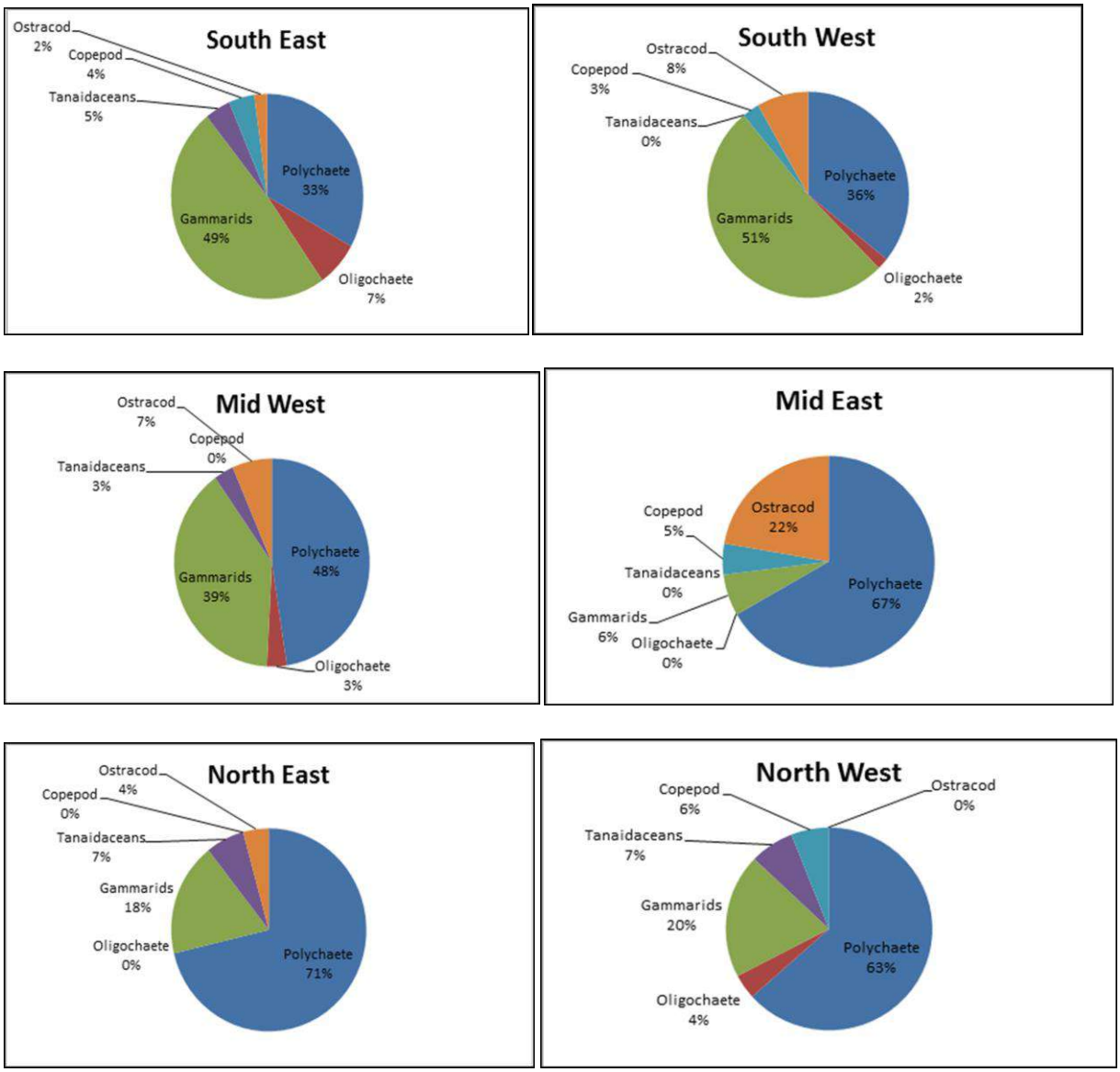


Figure-7:*Percentage contribution of Benthic Groups in the numerical abundance at different zones.*

Post monsoon collections could not be made due to logistic reasons. Similarly the analysis of mid stations (mid-south, mid-central and mid-north) is incomplete. Numerical abundance of macrobenthos varied from 1090 nos/m^2 in the southwest to 940 nos/m^2 in norteast, 927 nos/m^2 in southeast, 808 nos/m^2 in northeast, 630 nos/ m^2 in centraleast and 488 nos/ m^2 in the midwest regions.

Polychaetes dominated all areas of the south sector except the Southeast and southwest areas where Gammaridae were the dominanant group. Percentage contribution of various groups in the numerical abundance of macrobenthos in the study area is presented in Figure -7. In the southeast area, the Peracarid crustacean Gammaridae formed 49% followed by Polychaetes (35%) represented by Nereididae (91.3%). In the Southwest, Gammaridae formed 51% followed by Polychaetes (36%) represented by Nereididae (35.9%), Sebellidae (38.5%) and Capitellidae (25.6%). The mideast area had 67% polychaetes represented by Sebellidae (45.2%), Capitellidae (33.3%) and 21.4% Spionidae. Ostracodes (22%) formed the second largest group in this area. The midwest area had 48% polychaetes [Spionidae (65.5%), Sabellidae (20.7%) & Nereididae (13.8%)] and 39% Gammarids. Highest abundance of polychaetes was in the northeast area [71% represented by Nereididae (29.9%), Capitellidae (28.3%), Spionidae (13.4%), Sabellidae (7.5%), Glyceridae (10.4%) and Nephtyidae (10.4%)] followed by Gammarids (18%). In the northwest Polychaetes formed 63% (Capitellidae-39.1%, Nereididae -34.4%, Glyceridae -14%, Onuphidae -9.4%, & Nephtyidae -3.1%) and Gammarids (20%).

In the meiobenthos, nematodes, foramnifera (*Trilobatus sacculifer*), harpacticoid copepods, polychaetes and oligochaetes were the dominant groups. Nematodes, foramnifera and polychaetes were abundant in silty sediments and Halammohydra in sandy sediments.

vii. New reccord of the leopard-spot jelly fish *Acromitus maculosus*

Since 2018, the CARMC centre is monitoring on a regular basis, the jelly fish menace in the stake-net fishery of Kumbalam, Kochi. Blooms of jelly fish appear in these waters with rise in salinity (> 22 ppt) and clog the nets forcing the fishermen to avoid stake net fishing. Among the scyphozoan jelly fish, *Acromitus flagellatus* (Order: Rhizostomeae) is the main bloom forming species. However in our 2019 collections, in addition to this species, sizeable quantities of the leopard-spot jelly fish *A. maculosus* (Figure -8) were obtained in stake nets when the salinity was higher than normal. The occurrence of this species has not been reported from Indian waters. *A. maculosus* was reported first by Light in 1914 from coastal waters of Philippines. Literature survey show that the species has not been reported from any coastal waters world wide in the last 100 years. A scientific paper titled " New reccord of

the leopard-spot jelly fish *Acromitus maculosus* and its morphotypes from Indian waters" has been communicated to an international journal for publication.

Figure -8:*Acromitus maculosus* – A new reccord of species from Indian waters.

viii Participation in the Indian Expedetion to the Southern Ocean (Antarctic waters)

Starting from 2019-2020, CARMC has initiated studies on " Salp – Cnidarian – Ctenophore trophodynamic interactions in the Krill centered ecosystems of Southern Ocean" as a part of the Indian Expedetion to the Southern Ocean organized on an annual basis by the NCAPOR, Goa. The objective of the study is to (i) elucidate the epipelagic food-web structure in five discrete ecosystems in the Central Indian Ocean sector of Southern Ocean (ii) explain the community structure and abundance of phytoplankton, mesozooplankton and macrozooplankton (iii) study the export flux of Particulate Organic Carbon and faecal pellets (iv) delineate faeal pellets on the basis of size and shape and (v) estimate sinking rates and carbon values of faecal pellets. These studies are carried out under the supervision of

Dr.V.N.Sanjeevan, Professor Chair, CARMC and Dr. Anu Gopinath, Assistant Professor, KUFOS. The 2019 -2020 multi disciplinary Southern Ocean Expedetion commenced on 3rd January 2020 on-board the South African Research Vessel S.A. Agulhas and after detailed survey of the study area covering the austral summer 2019 – 20, the study team returned on 11th March 2020.

Figure -9:*Members of the Indian Expedetion 2019 - 2020 to Southern Ocean*.

Dr.Gireesh, Project Scientist, and Ms. Princy John, Sr. Research Fellow represented CARMC in this expedetion (Figure – 9). Samples collected by CARMC will be brought to the CARMC lab for further analysis after the corona lock down period.

ix Other activities of CARMC.

- Published five scientific papers in National/ International peer-reviewed journals.
- Presented 10 research papers in the international conference on Aquatic Resources and Blue Economy (AquaBE) organized by KUFOS at Kochi from 28th to 30th of November 2019.
- Organized the meetings of the multi-institutional Task Force constituted by KUFOS on the impact analysis of 2018 Kerala Floods. Contributed one full chapter on " Rivers, Lakes and Coastal Zone" in the Task Force Report published in November 2019.

Annexure 6

CARMC PUBLICATIONS IN HIGH IMPACT FACTOR JOURNALS

2017- 2018.

Number of Research Papers -6

1 Chippy Khader, N.Saravanane, B.Kishore Kumar and **V.N.Sanjeevan** (2017). New record of the stalked Crinoid *Saracrinus angulatus* (Echinodermata: Crinoidea: Isocrinida) from Andaman Sea, North Indian Ocean. ***Mar. Biodiv.UK***. DOI. 10. 1007/s 12526-016-0626-7.

2 Anoop, V.K; Neelesh,D., **Anvar Ali, Rajeev Raghavan** (2017) : Taxonomy of the zodiac loaches, *Mesonoema chelius triangularis*, *M. tambarapaeniensis*&*M.periyarensis* endemic to Western Ghats of India (Teleostei: Nemachelidae). ***Zootaxa*** 4341 (1) 124-134.

3 Aneesh Kumar, R.V., K.P.Deepa, Hashim Manjebrayakath, C.P.Rajool Shanis, N.Saravananae, **V.N.Sanjeevan** and M.Sudhakar (2017): Relationships between fish and otolith size of the Indian Ruff *Psenopsis cyanea* (Alcock, 1980) collected from the South Eastern Arabian Sea coast of India. ***J. Mar. Biol. Assn. India.*** Doi: 10.6024/jmbai.2016.58.2.1916-dx.

4 Sree Renjima, G., **V.N.Sanjeevan**, B.R.Smitha, C.B.Lalithambika Devi and M.Sudhakar (2017): Early developmental stages of the Indian mackerel *Rastrelliger kangurta* (Cuvier) along the Kerala-Mangalore coast of South Eastern Arabian Sea. ***J. Mar. Biol. Assn. India.***, doi: 10-6024/ jmbai. 2016.58.2.1958A-ox.

5 Parameswaran, U.V., **V.N.Sanjeevan**, Abdul Jaleel, K.U., Vinu Jacob, Aiswarya Gopal, Anil Kumar Vijayan and M.Sudhakar (2017): An updated check-list of echinoderms of the South Eastern Arabian Sea. ***Mar. Biodiversity,UK*** DOI:10.1007/s 12526-017-0732-1 (IF-1.646).

6 Meera, K.M., M.Hashim, **V.N.Sanjeevan**, J.Jayasankar, T.V.Ambrose, M.Sudhakar (2017): Systematics and biology of the blue laternfish, *Diaphus coeruleus* from the south-eastern Arabian Sea. ***JMBA (UK).*** Doi.10.1017/s 0025315417002004.

2018 -19

Number of Papers - 10

7 Salini,T.C., Smitha B.R., Sajeev Ravindran, **Sanjeevan V.N.**(2018). Upper layer circulation, hydrography and biological response of the Andaman waters during winter monsoon based on in situ and satellite observations. ***Ocean Dynamics***: https://doi.org/10.1007/s 10236-1160-x.

8 Pinder,A.C., Marimekalan, A., Knight, JDM., Krishnankutty P., Britton JR., Philip S., Dahannkar N., **Rajeev Raghavan** (2018) : Resolving the taxonomic enigma of the iconic game fish, the hump-backed mahseer from the Western Ghats, a biodiversity hot-spot, India***. PLoS ONE***, 13 (6): e 0199328.

9 Usha V. Parameswaran, Abdul Jaleel, **V.N.Sanjeevan**, Aiswarya Gopal, Anil Kumar Vijayan, GVM. Gupta and M.Sudhakar. 2018: Diversity and distribution of echinoderms in the South Eastern Arabian Sea shelf under the influence of seasonal hypoxia. ***Progress in Oceanography***. DOI: 10.1016/j.pocean.2018.06.005.

10 Indreesh babu KK., C.R.Rajool Shanis**, S.Suresh Kumar** (2018): First record of the rare furry lobster *Palinurellus wieneckkii* (DeMan, 1881) (Decapoda: Palinuridae). ***Journal of Threatened Taxa***. 10 (15) 12986 -12989.

11 Sammy de Grave, Charambilly PA., **Rajeev Raghavan** (2018): The discovery of Euryrhynchidae (Crustacea: Decapoda) in India with the description of a new genus and species. ***Zootaxa***. 4462 (3): 367 – 378.

12 Anoop VK., Neelesh, D., Sibi, P., Liju, T., **Rajeev R.** (2018): Phylogeny of the hill-stream loach genus *Mesonoemacheilus* reveals widespread diversification through ancient drainage connection in the Western Ghats Biodiversity hotspot. ***Molecular Phylogenetics & Evolution***. 129, 77 – 84.

13 Mohammed Naushad B., KK. Indees babu, Usha VP., **S. Suresh Kumar** (2018): A new record of sea star, *Nardoa frianti* Koechler, 1910 (Echinodermata: Asteroidea: Ophidiasteridae) from the Arabian Sea, Western Indian Ocean. ***Mar.Biol.Assn. India***. Doi 10.6024/mbai/2018-60.2.2056-14.

14 Meleppura Rajeesh Kumar, Kannamkulathil V. Aneesh Kumar, Manjibrayakath Hashim, Narayanane saravanane, **Vellorkirakathil N. Sanjeevan**, Maruthadu Sudhakar (2018): Length weight relationships of five deep-sea angler fishes from Andaman & Nicobar waters. Journal of Ichthyology 34 (5) doi.org/10.1111/jai.13773.

15 Ashwini K., **Rajeev Raghavan**, Paingauleas MS., Pradeep kumar, Umesh K., Shrikant Jadhv, Anand Padhye, Neelesh D. (2018): Molecular phylogeny unveils hidden diversity in hill-stream loaches (Cypriniformes: Cobitoidea) in the north Western Ghats of India. ***Meta Gene*** 17 (2018) 237 -248.

16 C.R. Asha Devi, **K.G. Vimal Kumar**, G.V.M. Gupta, Anilkumar Vijayan, M. Sudhakar (2018)- Implications of stratification on the heterotrophic plankton community (micro- & meso zooplankton) in the South Eastern Arabian Sea -***Regional Studies in Marine Science*** 24 (2018) 66–81

2019-2020

Number of Papers - 8

17 K.S. Sumod, Anil Mohapatra, **V.N.Sanjeevan**, T.G.Kishor & K.K.Bineesh (2019): A new species of white – spotted moray eel, *Gymnothorax smithi* (Muraenidae: Muraeninae) from deep waters of Arabian Sea, India. ***Zootaxa*** 4652 (2): 359 – 366. https://doi.org/10.11646/zootaxa.4652.2.8.

18 Anand Jain, Krishnan, KP., Archana Singh, Femi Anna Thomas, Nazia Begum, Manish Tiwari, Bhaskar, VP., **Anu Gopinath** (2019): Biochemical composition of particles shape particle-attached bacterial community structures in a high Arctic fjord (2019): ***Ecological Indicators***, 102 (2019) 581 – 592.

19 K.V.Aneesh Kumar, K.P.Deepa, M.M.Muhammed Rafeeq, G.Sree Renjima, Hashim Manjeebrayakath, B.R.Smitha, N.Saravananae, M.P.Prabhakaran, **V.N.Sanjeevan** and M.Sudhakar (2020): Near Reef abundance and off-shore distribution of tuna larvae around Minicoy Island in Lakshadweep Sea, India. ***Marine Biology Research, UK***. DOI: 10.1080/17451000.2019.1704018.

20 Anu Joy, Anoop, PP., Rajeesh, R., Jose Mathew, Angel Mathew, **Anu Gopinath** (2019): Spatial variation of trace element concentration and contamination assessment in the coral reef sediments of Lakshadweep archipelago, Indian Ocean. ***Marine Pollution Bulletin***. 146. (2019).

21 Riyas, CA., Idreeshbabu, KK., Marimuthu, N., S. **Suresh Kumar** (2020): Impact of the tropical cyclone on ecological and geomorphological structures of the small low-lying island in the Central Indian Ocean. ***Regional Studies in Marine Science***. 33 (2020) 100963.

22 Jose Mathew, **Anu Gopinath** (2019): Spatial and temporal variations of Arsenic distribution in a tropical estuary along the west coast of India. ***Marine Pollution Bulletin***. 149 (2019) 116567.

23 Mathew, J., Shaji, A., **Anu Gopinath**, Krishnan, KP., Louis, SV., Pradeep, AP. (2019): A characteristic study of humic acid isolated from Arctic fjord sediments. ***Advances in Polar Science***. Vol 30 (1) 24 – 34.

24 Kusum Komal Karati, Ashadevi C.R., Rasheed K., Vineetha G.,Smitha B.R.,**Vimal Kumar K.G**., Sari mol C.N. Sudhakar M (2019)- Influence of the coastal circulation and water-mass characteristics in structuring the zooplankton community of the eastern Arabian Sea- ***Regional Studies in Marine Science*** 31 (2019) 100761

Annexure 7

PAPER PRESENTED IN SEMINAR/WORKSHOP

1. **Sreenath TM,** SM Raffi, W Vinu and VN Sanjeevan, 2020. Length Weight Relationship of freshwater crab Lamella lamellifrons (Alcock, 1909), (Decapoda: Brachyura) from the upper Reaches of Muvattupuzha River. Abstract submitted and published in : International Conference on "Rivers for Future(RFF 2020)"., pp. 63: 5th to 7th Feburary

2. **TM Sreenath**, Akshaya Vijayan, SM Raffi and VN Sanjeevan, 2019. Survey and Inventorisation of brachyuran crabs from the mangrove patches in and around Cochin backwaters. Abstract submitted and published in: International Conference on Aquatic Resource and Blue Economy (AQUABE 2019), 28 – 30 November 2019, pp. 34

3. **Sudarsan K.S**., Nayana Narayanankutty and Sanjeevan, V.N. 2019. Distribution of two endemic species of puffer fishes (*Carinotetradon travancoricus* (Hora and Nair, 1941) and C. imitator (Britz and Kottelat, 1999) of Kerala and Karnataka waters. Abstract submitted in- National conference on Climate Change Disaster Management (CCDM), Kerala University of Fisheries and Ocean Studies: 22-23 Feb 2019

4. **Sudarsan, K.S**., Vimalkumar, K.G., Nithara, C.G., Sreenath, T.M., Jayeesh Saseendran., Shilpa, Asokhan., Nayana, Narayankutty., Milena, V.M., Gireesh, R and V.N. Sanjeevan. 2019. Macroplastic load in the bottom sediments of the southern sector of Vembanad Lake. Abstract submitted and published in: International Conference on Aquatic Resources and Blue Economy (AQUABE 2019) pp 168: 28-30 Nov 2019
5. **Sudarsan KS**, Prabhakaran MP, Sreenath TM, Gireesh R, Shilpa KA, Nithara CG, Jayeesh Saseendran and Sanjeevan VN. 2020. Macro-Benthic Faunal Communities in the Upper Reaches of Achenkovil River, Kerala. Abstract submitted and published in: International Conference on Rivers For Future (RFF 2020) pp 65 :5th to 7th February

6. **KV Anju**, S Pramila, and VN Sanjeevan . lethal concentration (LC_{50}) of Cadmium for juvenile Pearlspot, Etroplus suratensis (Bloch, 1970) Abstract submitted and published in: International Conference on Aquatic Resources and Blue Economy (AQUABE 2019) pp 98: 28-30 Nov 2019

7. Melbin Lal, **KV Anju**,VM Arjunan,Ganesh Raju,PH Anvar Ali. Captive breeding and embryonic development of an endemic ornamental cyprinid, Rasbora dandia(Valenciennes) Abstract submitted and published in: International Conference on Aquatic Resources and Blue Economy (AQUABE 2019) pp 95: 28-30 Nov 2019

8. **Amritha KS**, KJ Jayalakshmi and VN Sanjeevan (2019)- Composition of epibentic macrofaunal community in the Kuttanad region of Vembanad Lake. Abstract submitted and published in: International Conference on Aquatic Resources and Blue Economy (AQUABE 2019) -28-30 Nov 2019

9. **Nithara CG**,VM Milena and VN Sanjeevan (2019)- First record of the leopad jellyfish,Acromitus maculosus from Indian waters. Abstract submitted and published in: International Conference on Aquatic Resources and Blue Economy (AQUABE 2019) -28-30 Nov 2019

10. **Remya L Sundar**, VN Sanjeevan and Rajeev Raghavan (2019)- Fresh water fish diversity of Achankovil River with special reference to endemism, threats and conservation. Abstract submitted and published in: International Conference on Aquatic Resources and Blue Economy (AQUABE 2019) -28-30 Nov 2019

11. **Gireesh Raghavan**,TM Sreenath and VN Sanjeevan (2019)- Composition and diversity of periphtic algae in Achankovil River, Kerala during the monsoon season-Abstract submitted and published in: International Conference on Aquatic Resources and Blue Economy (AQUABE 2019) -28-30 Nov 2019

12. **Nayana Narayananankuty** and VN Sanjeevan (2019)- Phenotypic variations in Anchvies off the south and central Kerala Coast-Abstract submitted and published in: International Conference on Aquatic Resources and Blue Economy (AQUABE 2019) -28-30 Nov 2019

13. **Shilpa KA, Nithara CG** and Sanjeevan VN (2019)- A review o fin fishery in Vembanad Lake-Abstract submitted-National conference on Climate Change Disaster Management (CCDM), Kerala University of Fisheries and Ocean Studies: 22-23 Feb 2019

14.**Shilpa KA** and Sanjeevan VN (2019)- Meiofaunal diversity and abundance in bottom sediments along the southern sector of Vemband Lake-Abstract submitted and published in: International Conference on Aquatic Resources and Blue Economy (AQUABE 2019) -28-30 Nov 2019

15. **Milena VM,** Gireesh R,and Sanjeevan, V.N.(2019)- Phytoplankton and Zooplankton in Vembanad Lake- A review-Abstract submitted -National conference on Climate ChangeDisaster Management (CCDM), Kerala University of Fisheries and Ocean Studies: 22-23 Feb 2019

16**Princy MJ**, Anu Gopinath and Adithya Suthan (2019)- Transitional changes in hydrography of cochin backwaters associated with the August 2018 floods- Abstract submitted and published in: International Conference on Aquatic Resources and Blue Economy (AQUABE 2019) -28-30 Nov 2019

17. Vishnu Murali, **Princy MJ**, Athira P K , PriyaVargheese, Ignatious Joseph, Prabhakaran M P, KunalChakraborty, Aneesh A Lotliker , AnuGopinath)- Influence of Upwelling on Apparent Oxygen Utilization (AOU) and Nutrients in the Offshore Waters Off Kochi - An Evaluation over a Period of Six Month"- MARICON 2019- International conference on frontier in marine science, challenges and prospects -Kochi during 16-20 December 2019.

18. Adithya Suthan,**Princy MJ**,and Anu Gopinath (2019)- Temporal Variations in the Concentration of Metals in Vembanad Lake in Relation to 2018 Flood" in a National Conference on Integrating Biogeochemistry and Ecosystems in a changing oceanic environment organized by KUFOS-INCOIS centre during 17-18 January 2019 at KUFOS.
19. **Princy MJ**, Vigneesh ER, Aflah T, Midhun KT and Anu Gopinath (2019)- "Cadmium in the surface sediments of Vembanad Lake: a comparison of total as well as bioavailable Cadmium" in the 28thSwadeshi Science Congress during 7-9 November 2018.

20. **Princy MJ**, Anu Gopinath and Adithya Suthan (2019)- Nutrient Dynamics of Vembanad Lake in Relation to Flood**"**in the international conference on 'Sustainable Innovations in Green Chemistry and New Technological developments'organized by Maharajas College , Ernakulum during 11-12 December 2018.

21.**Vimal Kumar KG**, Gireesh R, Sudarsan K.S and Sanjeevan, V.N. (2019). Kerala flood 2018-A case study.Abstract submitted -National conference on Climate Change Disaster Management (CCDM), Kerala University of Fisheries and Ocean Studies: 22-23 Feb 2019

22.**Vimal Kumar KG**., Sajeev R., Sanjeevan V.N. (2019)- Characteristics and forcing mechanism of eddies along western Bay of Bengal during spring inter monsoon-Abstract submitted and published in World Ocean Science Congress (WOSC) '19-Visakhapatnam- 25-27 February 2019.

23. **Vimal Kumar KG**. and V.N.Sanjeevan (2019)- Contributory role of tides and sea level in prolonging the flood inundation period- Abstract submitted and published in: International Conference on Aquatic Resources and Blue Economy (AQUABE 2019) -28-30 Nov 2019

24.**Vimal Kumar KG**., Sajeev R., Lix John K, Sanjeevan V.N. (2019) - Observed mesoscale features in the western Bay of Bengal during fall inter monsoon- MARICON 2019-International conference on frontier in marine science, challenges and prospects -Kochi during 16-20 December 2019.