“DIVERSITY AND ABUNDANCE OF MICRO-FAUNA AT KUMBALAM MANGROVES IN RELEVANCE TO PHYSIO - CHEMICAL PARAMETERS”

DISSERTATION SUBMITTED TO ST. TERESA'S COLLEGE, ERNAKULAM IN PARTIAL FULFILLMENT OF THE REQUIREMENT

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SUBMITTED BY,

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CERTIFICATE

This is to certify that the dissertation entitled **"Diversity and abundance of micro-fauna at Kumbalam mangroves in relevance to physio - chemical parameters"** is an authentic record of original project work carried out by **"MEGHA MERIN DAS" (Reg. No.:SM21ZOO008)**, during the academic year **2021-2023**, under the external guidance of Dr. Limnamol V.P. Assistant professor at KUFOS, Kochi and the internal guidance of Mrs. Indu Vasudevan, Assistant Professor, Department of Zoology, St. Teresa's College, for the partial fulfilment of the requirement of the Degree of Masters of Science in Zoology from St. Teresa's College, Ernakulam.

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I hereby declare that this dissertation entitled **"Diversity and abundance of micro-fauna at Kumbalam mangroves in relevance to physio - chemical parameters"** submitted to Mahatma Gandhi University, Kottayam in the partial fulfilment for the award of Master of Science in Zoology, is a record of original project work done by me, and no part thereof has been submitted to any other course. To the best of my knowledge, this project does not include any content that has been previously published or written by someone else, unless proper acknowledgment has been given to the original source.

MEGHA MERIN DAS

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MEGHA MERIN DAS

LIST OF ABBREVIATIONS

SL. NO	ABBREVIATION	EXPANSION
1	%	Percentage
2	&	And
3	°C	Degree Celsius
4	µg/l	Microgram per litre
5	µm	micrometre
6	A	Absorbance
7	ANOVA	Analysis of variance
8	b	blank
9	BOD	Biological oxygen demand
10	BR	Burette reading
11	C	Chlorophyll
12	DO	Dissolved Oxygen
13	E	Equivalent weight
14	g	Gram
15	g/l	Gram per litre
16	hrs	Hours
17	km	kilometre
18	Km^2	Kilometre square
19	L	Length
20	m^3	Meter cube

21	mg L^{-1}	milligram per litre
22	mg/l	Milligram per litre
23	ml	millilitre
24	mm	millimetre
25	N	Normality
26	nm	Nanometre
27	Nos/l	Numbers per litre
28	ppt	Parts per thousand
29	r	regression
30	Sp	species
31	Sq.km	square kilometre
32	St	Standard
33	v	Volume
34	Viz.	videlicet
35	WP	Vertical plankton net

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ABSTRACT

The present study was carried out in the mangrove field of the kumbalam region near Panangad adjacent to the Cochin backwater system to find out the diversity, distribution, abundance, and composition of zooplankton and to correlate them with the variations in physio - chemical conditions. Samples were collected from 6 stations during the period of December to January randomly. Physio - chemical features like temperature, salinity, pH, dissolved oxygen, chlorophyll, nitrate-N, phosphate-P and nitrite - Ni were observed. A total of 20 species of zooplankton were identified, including copepods, Rotifers, cladocerans, and Ostracods. The most abundant species were copepods, which accounted for 81% of the total zooplankton abundance. 15 species of copepods which are belonging to three Orders were noticed. they consist of six species of Order Cyclopoida, 7 species of Order Calanoida and 2 species of Order Harpacticoida. List of copepods species recorded in the Kumbalam mangrove showed that Order Calanoida was the dominant group followed by Cyclopoida and Harpacticoida. They must be the most ecologically significant animals at the first consumer level of the marine plankton and are also the most prominent among the primary carnivores. The copepods diversity and abundance are closely related to water quality parameters and it also related the fish fauna of the water body. The statistical analysis for the influence of physio - chemical parameters showed zooplankton communities in mangrove ecosystems are shaped by a variety of environmental factors, including temperature, salinity, nutrient availability, DO etc and the variations in the zooplankton abundance may be due to the combined effect of all these factors. It is found that temperature and salinity plays significant role in the diversity and abundance of zooplankton community. Highest abundance of zooplankton community was observed from station 6 which had the optimum conditions for their growth and propagation like high salinity&DO, low pH,chlorophyll&nutrients and optimum temperature. Similarly lowest abundance was observed from station 1&2 which had the unfavourable conditions for their growth. The presence of pollution indicator species from study sites lays light upon the fact that anthropogenic activities lead to the destruction of faunal communities.

AIM AND OBJECTIVE

AIM:

To assess the micro-fauna diversity of Kumbalam mangroves and to correlate them with the variations in hydro-graphical conditions.

OBJECTIVE:

- To study the diversity, distribution, abundance, and composition of micro-fauna associated with the mangroves of the Kumbalam wetland ecosystem.
- To estimate the water quality parameters of the study area.
- To estimate the relation of these parameters with the diversity of micro-fauna.

RELEVANCE OF THE STUDY:

Zooplankton is an important link in the aquatic food chain affecting organisms at the different trophic levels either directly or indirectly. They play a significant role in the microbial loop and nutrient cycling, in addition, zooplankton is one of the four selected bio-indicators (benthic diatom, zooplankton, littoral macro-invertebrate, and benthic macro-invertebrate), used for assessment in ecological health monitoring. Studies on the occurrence and abundance of such organisms in relation to hydrographical conditions would be useful for evolving methods for improving the fishery potential of cultural fields. This would also generate necessary information for quantifying the requirements of supplementary feed in the field and also useful in managing the hydro-graphical conditions for obtaining optimum production in the cultural fields. Ecological observations on zooplankton communities are important in assessing the health of coastal ecosystems since pollution can reduce species diversity and abundance and may allow for increases in the population of pollution-tolerant species.

Data obtained from this study will help in the assessment of the quality of individual mangrove ecosystems and highlight the importance of mangrove propagation along the coastline which is important to protect against coastal erosion and also for the development of the mangrove system.

INTRODUCTION

Wetlands are defined as lands transitional between terrestrial and aquatic systems where the water table is generally at or near the face or the land is covered by shallow water (Mitsch and Gosselink, 1986). Wetlands are among the most productive ecosystems in the world and play a vital part in flood tide control, aquifer recharge, nutrient immersion, and corrosion control. In addition, wetlands give habitat for a huge diversity of wildlife suchlike as birds, mammals, fish, frogs, insects, and plants (Buckton, 2007). Therefore, wetlands help in maintaining the biodiversity of flora and fauna. Wetlands in India cover an area of 58.20 million hectares (Prasad et al., 2002). Of 1340 bird species found in India (Ali and Ripley, 1987; Manakandan and Pittie, 2004), 310 species are known to be dependent on wetlands (Kumar et al.,2005). Wetlands in India, aside, are facing tremendous anthropogenic pressures (Prasad et al., 2002), which can greatly impact the structure of the bird community (Kler, 2002; Verma et al., 2004; Reginald et al., 2007).

Mangroves are stress-tolerant species occupying coastal intertidal zones (along shores, rivers, and estuaries) in the tropics and subtropics worldwide (Twilley & Day, 2013). Mangroves are valuable ecological and economic resources, being important nursery grounds for birds, fish, crustaceans, shellfish, reptiles, and mammals, as well as a renewable resource of wood. They also are accumulation sites for sediment, contaminants, carbon, and nutrients, and offer protection against coastal erosion. Mangrove areas are ecologically important coastal environments and act as a "buffer zone" between the marine and terrestrial ecosystems, characterized by the high variation of physicochemical, morphological, and hydrological conditions (Carter 1988; Ysebaert et al. 2002). Mangrove ecosystems have a considerable number of organic compounds and hence are known as biologically rich ecosystems with a variety of living organisms attracting other life forms for various purposes. Increasing anthropogenic stress in coastal areas, however, has resulted in increased pressure on mangrove ecosystems, resulting in the depletion of many valuable floral and faunal species.

Mangrove ecosystems are found all over the world in tropical and semitropical regions. Biodiversity is prevailing in the tropical estuarine system, particularly in the intertidal forested foliage known as Mangrove (Mooney et al. 1995), which covers about 240 x 103 km^2 (Lugo et al. 1990; Twilley et al. 1992). The mangrove foliage possesses numerous structural and physiological peculiarities and is composed of species with firmly pronounced characteristics grouped under “true mangroves”. There are also plants with lower strongly pronounced characteristics, which are known as semi-mangrove (Tansley & Fritch, 1905). There's yet another group of plants, which grow adjoining the mangrove areas but thrive on the land which doesn't submerge by brackish water even during the high currents but can repel some measure of brackish water recession for the short period. These can be grouped as mangrove-associated species (Basha, 1992). India has only 2.66 of the world’s mangroves, covering an estimated area of, 827sq. km.

Kerala along the west seacoast of India has a coastline of 590 km and presently the mangrove area is estimated to be about 17 sq. km, of which 36 % is either completely degraded or degrading (Ram & Shaji, 2013). From the Cochin estuary, the presence of *Acanthus ilicifolius, Avicennia alba, Rhizophora sp,* and *Bruguiera sp* in small numbers has been reported by Kurien (1980). Kerala coast reported 39 mangroves and mangrove-associated species, also found that the mangroves of Kerala were degraded and then grew in isolated patches Ramachandran et al (1985, 1986), there are 32 species under 24 genera of 19 families reported from Kerala (Banerji, 1982). About 70,000 hectares of mangroves once fringed the backwaters of Kerala which now has become reduced to a few isolated patches consisting of a few species (Basha, 1992). The important mangrove patches existing now in Kerala are mangroves of Veli, Quilon, Kumarakom, Kannamali, Mangalavanam, Chetwai, Nadakkavu, Edakkad, Pappinisseri and Kunjimangalam which have been singled out for the conservation and rehabilitation (Suma, 1995). In Cochin, mangrove Islands are increasingly threatened by population pressure and aquaculture operations (Thomas and Fernandes, 1994). Formerly, thriving shrimp production in Cochin backwaters has fallen almost to zero as the after-effects of extensive mangrove clearance (Mastaller, 1996). The flora is now restricted to small isolated strands along the sides of estuaries and backwaters (Joy and Ammini, 1998). The total area of mangroves now existing in Kerala is estimated to be 1671 hectares (Suma, 2000).

The mangrove environment has been considered a plankton-rich area (Robertson and Blaber 1992), and it acts as a feeding and nursery ground for a variety of secondary consumers like fish and invertebrates (Chong 2007). The carbon source of mangrove vegetation is the main factor for their high productivity which has always been linked to the detritus-based food web (Odum and Heald 1975). Zooplanktons are small organisms that were abundantly available in all depths of the ocean. While going into the mangrove-associated fishes, their main primary food is zooplankton, and also there is a need to study their community structure and abundance in relation to the environment (Chong 2007). Some researchers have made an attempt at zooplankton ecology previously in the mangrove ecosystem worldwide (Robertson et al, 1988; McKinnon and Klumpp 1998; Krumme and Liang 2004). Studying about zooplankton diversity is an important feature of biological oceanography because of their important role in the marine food chain of the aquatic environment. The Zooplankton community dominantly occupied the intermediate level between the primary and tertiary producers. The distribution and life cycle of zooplankton has been determined by the physical and chemical characteristics of the environment.

The complex structure of the mangrove system may provide zooplankton populations with shelter, substrate, food, and protection from predation. These factors could impact zooplankton survival, retention, and habitat selection within mangroves, resulting in differences in the composition of zooplankton communities among different coastal habitats. The zooplankton community, a taxonomically heterogeneous group of organisms, play a major role in the food chain of mangrove ecosystems, and the abundance and composition of zooplankton species is influenced by physical, chemical and biological ecosystem parameters. The fluctuations in these parameters are more pronounced in mangrove habitats than in estuaries and the open ocean. The role of zooplankton in such ecosystems is getting increasing attention attributable mainly to their phytoplankton grazing coupled with nutrient recycling and limiting conditions, and factors associated with carbon cycling. There are several reports on the distribution and diversity of zooplankton from Indian mangroves (Kundu et al.,1987; Ramanamurty & Kondala Rao 1993; Karuppasamy & Perumal 2000). Scientific information on mangroves of Kerala, however, is still lacking, especially on the ecology and community structure of biotic communities.

Zooplankton constitutes a diverse assemblage of microscopic organisms that occupy a crucial intermediate position in the food webs of freshwater, estuarine, and marine ecosystems. In transferring energy from primary producers (photosynthetic protists, bacteria, and singlecelled plants) to macroscopic invertebrates and fishes, zooplankton has the capacity to shape the dynamics of entire ecosystems. Zooplankton is one of the four selected bio-indicators (benthic diatom, zooplankton, littoral macro-invertebrate, and benthic macro-invertebrate), used for assessment in ecological health monitoring, (MRCEP (Mekong River Commission Environmental Programme) (2015). They serve as a good indicator of changes in water quality because it is strongly affected by the environmental quality (Gannon, J.E. &

Stemberger, R.S., 1978). The relationship between phytoplankton and higher trophic levels is not straightforward, as zooplankton is the main energy pathway from phytoplankton to fish (Carlotti, F. and Poggiale, J.C., 2010). Zooplankton floats in the water and cannot progress against currents and it is represented by all marine phyla, either permanently as holoplankton (e.g., copepods) or temporarily as meroplankton (e.g., fish larvae). Zooplankton is also critical in the transfer of energy between pelagic and benthic systems (Lassalle et al., 2013), and for carbon export from surface waters to the deep ocean (Steinberg, D.K. and Landry, M.R., 2017). The rate of zooplankton production can be used as a tool to estimate the exploitation of fish stocks in an area (Tiwari, L.R. and Nair, V.R., 1991).

Studies related to the estuarine zooplankton population have broadly been made by various researchers from the both east and west coasts of India (Dalal, S.G. and Goswami, S.C., 2001). However, an understanding and interpretation of zooplankton diversity in the mangrove ecosystem in relation to environmental variables are still scanty and as a result, such studies are warranted. To this end, this study presents important information on the abundance, diversity, and community structure of zooplankton in the diverse mangrove habitats of Cochin, India. Overall, the present study dealt with the assessment of the diversity and abundance of zooplankton from the Kumbalam mangrove wetland ecosystem, in relation to the environmental parameters.

REVIEW OF LITERATURE

MANGROVE DIVERSITY

Mangrove species are one of the most important and productive ecosystems on the planet. Perhaps no other group of plants has evolved to such a degree to withstand conditions as harsh as high salinity, high tides, vigorous winds, hot temperatures, and muddy anaerobic soils. Mangroves are significant for the ecosystem and safeguarding coastal regions from hurricanes, storms, flooding, and soil erosion. In terms of economic benefits, mangroves support marine and coastal fisheries, produce forest products, and provide ecotourism opportunities (Hochard et al., 2019).

The first systematic study of (Heald & Odum, 1970), reported that mangrove ecosystems are self-sufficient coastal landscape units that have developed due to a prolonged Geo-morphological process closely linked with the nearby aquatic environment. From the perspective of a marine biologist, the most crucial roles of mangrove communities are those of supplying food and shelter for a wide range of fish and shellfish. Very little of the mangrove leaf is consumed by grazing animals because it contains significant volumes of stiff, relatively indigestible cellulose and wax-like secretions.

According to (Odum & Heald, 1975) more than 95% of the leaf matter from the red mangrove *Rhizophora mangle* in the mangroves of south Florida enters the nearby sea environment.The microorganisms contribute to the process of transforming food by converting indigestible plant matter into digestible, protein-rich microbial protoplasm. Fish and invertebrate larvae absorb this material at the same time, assimilate the digestible portion, and excrete it as smaller particles in the digestible fraction. The process is repeated until all of the food energy in the particles has been used. These particles are then quickly recolonized by microorganisms for further breakdown. This leaf debris serves as an essential source of nutrients and forms the foundation of the main food chain in the mangrove population, but also acts as a significant food source in the nearby water masses where it is moved by the currents and tides.

Several studies demonstrated that due to their intricate aerial root systems, mangroves around estuaries and backwaters serve a significant role in protecting numerous species of commercial fish and shellfish, especially when they are young and vulnerable to predators (FeIiciano, 1962; Austin, 1971; Austin & Austin, 1971; Olsen et al., 1973; Sambasivan, 1986). Mangroves create a buffer zone between land and shallow seaward communities such as coral reefs and seagrass. Mangrove plants are recognized to reduce the impact of the sea on land by trapping terrestrial organic sediments (Davis, 1940; Macnae, 1968; Scoffin, 1970; Sacage, 1972). Since the deep penetrating root system is especially good at binding sediments and significantly slows down current velocities, it significantly lessens coastal erosion.This may in turn lead to shore-building processes. Thus, the mangrove environments are considered nature's gift, which is known to maintain the equilibrium between the terrestrial and aquatic ecosystems, with regard to physio-chemical and biological aspects (Scoffin, 1970).

According to (Kathiresan & Bingham, 2001), the mangroves produce a distinctive ecological habitat that supports many species assemblages. The mangrove environment serves as a repository for various plant and animal species (Gopinathan & Selvaraj, 2005). In their 2005 survey of India's coastal and marine biodiversity, (Venkataraman & Wafar, 2005), discovered 1862 species of mangrove-associated wildlife. There have been reports of roughly 41 genera and 29 families of mangrove plants in India (Duke, 1992).

Numerous studies on the microbial processes in mangrove communities have been conducted, including those by Australian researchers (Robertson, 1987; Odum & Heald, 1975) Florida's (Teas, 1986) Malaysia's (Sasekumar & Loi, 1983), the Philippines' (Primavera, 1996), and India's Kakinada mangroves (Rao, 1997), it has been suggested that energy is transferred across several trophic levels in the mangrove ecosystem as part of a complicated biochemical mechanism that works together with the physical process of maintaining equilibrium. The phytoplanktons, mangrove plants, zooplanktons, fishes, and benthic population, along with several microbial organisms, all participate in the metabolic process that transfers energy. The zooplanktonic organisms play a significant part in this energy transfer mechanism between different trophic levels and serve as secondary producers. The zooplanktonic creatures can absorb plant energy from phytoplankton and convert it, at a secondary level, into animal protein. Understanding this complicated process of energy transformation and translocation at different trophic levels in the mangrove ecosystem is important for understanding the food chain, which is a key component of the ecosystem.

In the mangrove regions of India, significant studies have been done by several researchers including (Shanmugam, 1986; Sambasivan,1985; Palaniappan & Baskaran, 1985) from the Pitchavaram mangroves of Tamil Nadu, (Sarkar et al.,1985; Baidy & Choudhury, 1985), from the Sunderbans of Calcutta, (Goswami, 1992), from Goa.

ZOOPLANKTON IN MANGROVES

Research on zooplankton distribution and seasonal change in mangrove ecosystems sheds light on the area's potential for fishing as well as nutrient cycles and energy transfer. There has been a significant amount of work done in mangrove habitats in tropical locations, including the works of (Sawamoto, 1986), from Iriomote Island in Ryukyru (Japan) and (Reviews, 1988), from Turdor Creek in Kenya. (Ambler et al., 1991), Villete in the Mundaka estuary, Biscay Bay. (Osore, 1992), from the mangrove creeks of Kenya.

Seminal contributions have been made by (Shaikh et al., 2017), the study aimed to examine the affluence of zooplankton population in Kali Estuary Karwar, Karnataka, India. Water samples were collected from 6 different stations monthly from February 2016 to February 2017 to know the abundance of zooplankton in various seasons. A total number of 42 species of zooplankton were identified and they belonged to 11 groups. The dissenting group is Copepoda with 17 species. Station 6 was found to have the highest zooplankton mangrove-rich area. The zooplankton community of the mangrove region was relatively high.

The exploration of phytoplankton and zooplankton diversity of the mangrove environments of the Gulf of Mannar biosphere reserve, specific to Karapad Bay and Korampallam Creek of Tuticorin was carried out from March 2010 to February 2011.

Regular samples were collected from the study area monthly and were subjected to plankton identification and biomass estimation. In the light of report by (Jebarani & Mohanraj, 2018), it is conceivable that, a total of 14 phytoplankton and 12 zooplankton species were identified. *Thallasiothrix sp., Rhizosolenia sp., and Cossinodiscus sp.* were found to be the dominant forms of phytoplankton from the study area.

In a study conducted by (Karuppasamy & Perumal, 2000), the population density, species diversity, species evenness, and species richness of zooplankton were studied in the Pichavaram mangroves (South East Coast of India), covering 2 stations, from September 1996 to August 1997, It has been suggested that the zooplankton density varied from 200 to 61650 individuals per liter, with the maximum in the summer season. Out of 55 species of zooplankton recorded, the copepod was the dominant group (36.5%). The biodiversity index ranged between 3.61 to 4.28 with the summer maximum. The observed maximum density and diversity during summer could be related to the recorded high salinity and stable hydro graphical features.

In the kali estuary (Kumar, Roopa & Gangadhar, 2013), conducted a study of the mangrove ecosystem. Samples were collected from three fixed stations for a period of thirteen months from January 2008 to January 2009 at the regular interval to identify and quantify the affluence, nomenclature, and relative ratio of phytoplankton and zooplankton.In the current study of species, the copepods, which have roughly seventeen species, play a significant role in the diversity of zooplankton groups in the mangrove system, which is made up of twelve groups and fifty-two species. The protozoa taxa correspond to five species, *Coelenterata and cladoceran* with two species each, *ctenophore* contained single species whereas the larval forms comprised fourteen species in aggregate.

The zooplankton was assessed quantitatively and qualitatively remarking on their superabundance in runlet waters at three spots along the western mangrove of Kachchh, the west shore front of India, for a period of two times (1999- 2000). Totally 69 forms of zooplankton were recorded from 3 stations. Of these, copepods were the most abundant group. . Surface water temperature varied from 17 to 37°C. Salinity ranged from 34.0 to 44.0% and the pH varied between 7.0 and 8.9. Variations in dissolved oxygen content ranged from 3.42 to 5.85 mg L^{-1}. These semi-arid region mangrove networks possessing high consistence were attained during the winter season (Saravanakumar et al., 2007)

Research conducted using seventeen groups of zooplankton was recorded from nine stations located in the Cochin backwaters during the period from August 2000 to July 2002 by (Varghese & Krishnan, 2009) The nine stations' quantitative and qualitative distributions of these groupings are shown. 16 of the 17 zooplankton groups were reported from station I (Vypeen) and station VI (Cochin Fisheries Harbour), with station V recording the fewest groups (9) overall (Eloor). Zooplankton density was highest at station II (Puthuvypu), followed by station III (Narakkal), with 42% and 39% of the total density correspondingly, and lowest at station V (Eloor), with 0.66% of the total density. The highest percentage of rotifers, which made up 52% of the various zooplankton groups present in this region, was followed by copepods, which made up 40%. Rotifers predominated at stations II, III, and VIII, whereas copepods made the most contribution at each of the other six stations, according to station studies. The differences in zooplankton between sites were extremely significant, according to the ANOVA results.

KUMBALAM MANGROVES

A study has been carried out for determining the various physicochemical and biological parameters prevailing in Vembanad Lake of Panangad region, Kochi. During 10 months, water samples were taken from the Panangad-Kumbalam area every two weeks. The analysis revealed that the mean maximum temperature during the post-monsoon was 30.75°C, the mean maximum pH during the post-monsoon was 7.99, the mean maximum DO during the post-monsoon was 6.22mg/l, the mean maximum alkalinity during the southwest monsoon was 144.5mg/l, the mean maximum transparency during the northeast monsoon was 73.37°C, the mean maximum nitrite during the southwest monsoon. Among phytoplankton, diatoms are the most dominant species in this region. Among zooplankton, copepods are dominantly seen in the study region (Rajeswari et al.,2018).

The analysis by Mogalekar et al. (2015; Kochi's Panangad-Kumbalam mangrove patches) revealed the hydrobiological state of Vembanad Lake. Distinct variations of the hydro graphic state and its influence on zooplankton abundance were observed. The study area revealed the presence of 13 mangrove species belonging to 7 families and 9 genera. Salinity showed wide fluctuation, indicating mesohaline nature. The average annual temperature was comparatively normal. The average pH during the study period was (7.38) on the alkaline side. Dissolved oxygen was high (7.7 mg/l) during October compared to March (3.9 mg/l). Nitrate values ranged from 2.40 µg/l to 35.90 µg/l. Phosphorus concentrations varied from 0.90 g/l to 9.0 g/l, with an average of 3.0 g/l. Copepod densities varied from 2013 to 5347 per cubic metre of space. There were 8 to 471 cladocerans per cubic metre of water overall. A total of 306 to 1263 rotifers per cubic metre were present. The onset of monsoon appeared to be a major factor influencing the hydrography, primary productivity, and zooplankton abundance in the backwater.

ZOOPLANKTON DIVERSITY IN RELATION TO HYDROGRAPHICAL PARAMETERS

In the Cochin backwaters, the pioneering study on plankton was of (George, 1958), who enumerated the common groups and brought to light the relation existing between the seasonal changes of the zooplankton population and some of the environmental factors.

There are several reports on the seasonal and spatial changes of zooplankton of the Vembanad Lake and its connected backwaters (Nair & Tranter, 1971; Menon et al*.*, 1971; Haridas et al*,* 1973; Wellershaus, 1974; Madhupratap, 1978).

Variations in the relative proportions of specific groups such as copepods, chaetognaths, hydromedusae, siphonophores, decapod larvae, and cladocerans have been studied by various authors (Wellershaus, 1969, 1970; Abraham, 1970; Pillai, 1970, 1972; Pillai et al*,* 1973; Srinivasan, 1972; Santhakumari & Vannucci, 1972; Mohammad & Rao, 1972; Pillai & Pillai, 1973).

(Menon et al.,1971) investigated the total biomass and faunistic composition of the zooplankton in Cochin backwaters from January to December (1971) and found that three groups viz. copepods, decapod larvae, and cladocerans dominated the total zooplankton. He observed that no single group continued to dominate the community though copepods were the major component of the community for most of the year and an abundance of cladocerans was noted only during the low salinity period.

Studies by several authors including (Nair & Tranter, 1971; Haridas et al., 1973; Wellershaus, 1974; Madhupratap & Haridas, 1975; Rao et al., 1975; Madhupratap, 1978; & Silas & Pillai, 1975) revealed that the composition and intensity of zooplankton are influenced mainly by salinity. These studies also show that the diversity and abundance of zooplankton are more during the pre-monsoon period' which is characterized by high salinity.

(Pillai & Pillai, 1973) reported that the tidal influence is significant in the diel variations in the intensity of zooplankton.

(Madhupratap & Haridas, 1975) observed that the organisms characterized by high salinity are eliminated during the monsoon and those characterized by low salinity occupy the middle and upper reaches of the estuary.
During the post-monsoon season, the animals of high saline water begin to appear in the plankton. During the peak of the monsoon the backwaters enjoy freshwater conditions and the total biomass of zooplankton is greatly reduced (Rao et al., 1975; Silas and Pillai, 1975).

(Silas & Pillai, 1975) reported that the majority of the zooplankton in the backwater belongs to the inshore population, some to the freshwater environment and a few are endemic. They also found that the food potential of zooplankton for plankton-feeding fishes and their larvae is high. The influence of seasonal variations in environmental conditions on the distribution of zooplankton in the backwaters has also been studied by them.

(Gopalakrishnan et al.,1988) who studied the zooplankton of some paddy-cum-prawn culture fields in and around Cochin reported that there is a scarcity of zooplankton in these fields. They also found that the seasonal culture fields had a greater abundance of zooplankton compared to the perennial fields.

(Jose et al., 1988) studied the zooplankton of a brackishwater fish farm in the area and reported that it is mainly composed of copepods with an annual mean of 170 nos/1, which is 62,68% of the total plankton. The copepods were dominant during the saline period from January to May(1988) (140-1021 nos/1) whereas during the low saline phase from June to October, their number was low and it ranged from 12 to 18N nos/1.

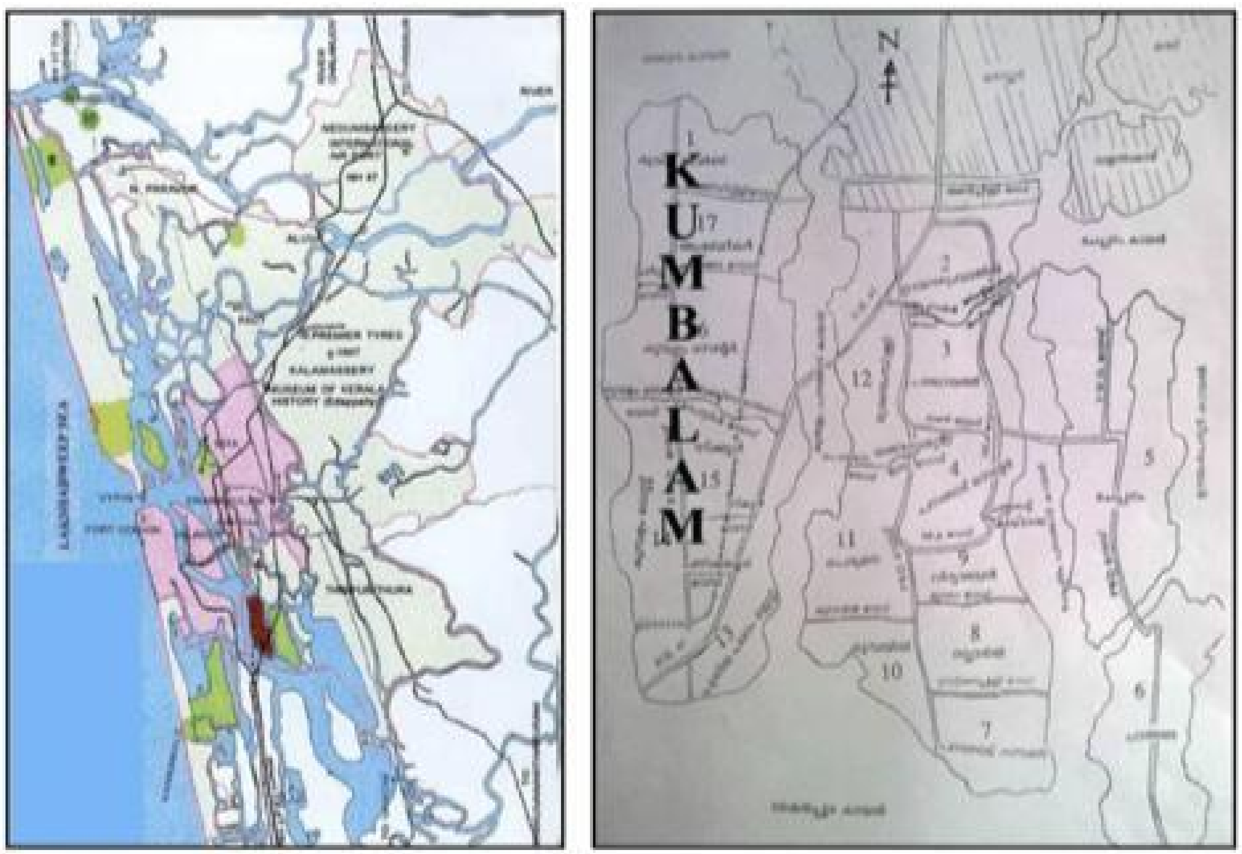
(Joseph, 1988) reported that in the culture fields the zooplankton are constituted mainly of copepods, rotifers, and crustacean larvae.

(Modoosoodun et al., 2010) also noted a positive correlation between phytoplankton and zooplankton density with pH and salinity. A study by (Saifulla et al., 2010), reported the estuarine water of Sarawak mangrove estuaries to be ideal for the growth and sustenance of phytoplankton. High phytoplankton density in mangrove ecosystems means a higher density of its predators which are mostly zooplankton.

Mangrove sites thus provide a highly beneficial environment for zooplankton in terms of food.

MATERIALS AND METHODOLOGY

Figure 1: Map showing the study area



Kumbalam

Kumbalam is a coastal region situated in the 90 54’ 41.96” North and 760 18’ 32.36” East of Ernakulum district. The Kumbalam is surrounded by Cochin backwaters, and is extended up to Panangad. This area is thickly populated, and the mangrove ecosystem of this region is subject to population pressure. The extensive land filling has affected the mangrove vegetation. This wetland is situated in the banks of Vembanad Lake, a RAMSAR site, which meet the Arabian Sea in the West. Kumbalam is a group of islands surrounded by Thevara in the in North, Wellington Island in the Northwest, Edakochi in West, Kumbalangi in Southwest, Aroor in the South, Panangad in the Eastern side, Nettoor in the Northeastern side.

PHYSICO-CHEMICAL PARAMETERS

1. Temperature

The temperature of the collected sample was measured using a calibrated 10-150° C mercury thermometer (Jennson Deluxe) with 0.1° C accuracy.

2. pH

pH of the samples was recorded using a calibrated pH meter (Oakton pH 550- benchtop pH meter) with 0.1 aaccuracies

3. Salinity

Salinity is the measure of saltiness or amount of salt dissolved in a body of water, it is measured using a digital refractometer (Atago Mera Pal Pocket Digital Refractometer) with a brix range of 0.0-53.0.

4. Dissolved oxygen

Dissolved oxygen (DO) is the amount of oxygen that is present in the water. It is measured in milligrams per liter (mg/L), the number of milligrams of oxygen dissolved in a liter of water. DO is calculated using Winkler's method.

Calculation

$$\text{Dissolved oxygen, mg } L^{-1} = \frac{BR * V/v * N * E * 1000}{\text{The volume of sample titrated}}$$

BR = Burette reading (volume of thiosulphate used in titration)

N = Normality of thiosulfate solution

E = Equivalent weight of Oxygen (8)

1000 = To express per liter

$$V/v = \frac{\text{Volume of bottle}}{\text{Vol. of bottle} - \text{Vol. of reagents}}$$

5. Chlorophyll

Chlorophyll is a common and abundant pigment in all photosynthetic organisms and was estimated using Strickland and Parsons (1972). It is used widely for estimating phytoplankton biomass. The samples were stored in clean bottles and are filtered as soon as possible using 0.45µm 47mm diameter cellulose nitrate membrane filter paper. The suction pressure was below 0.5 atm. The pigments retained on the filter paper were extracted with 90% acetone and were kept for 24 hours in darkness -4°C. The extract was centrifuged (~4000 rev/minute, for 10 minutes). The absorbance of the supernatant was measured using a spectrophotometer with selected wavelengths at 750nm, 664 nm, 647 nm, and 630 nm. 1 cm clean cuvette was used for spectrophotometric analysis. 90% acetone was used as a blank in the spectrophotometer. The absorbance of 750 nm was subtracted from the other three wavelengths to give the turbidity corrected value. *Calculation*

$$(C_a)\ \text{Chlorophyll } a = 11.85 * E664 - 1.54 * E647 - 0.08 * E630$$

Where E stands for the absorbance at different wavelengths (corrected by the 750 nm reading).

$$\text{mg chlorophyll}/m^3 = \frac{C \times v}{V \times L}$$

Where,

v is the volume of acetone in mL

V is the volume of the sample filtered in liters

L is the Cuvette length (cm)

6. Nutrients

(A) *Phosphate*

Phosphate in water is allowed to react with acid–ammonium molybdate, forming a phosphomolybdate complex, which is reduced by ascorbic acid in the presence of antimonyl ions (to accelerate the reaction) to a blue coloured complex containing a 1:1 atomic ratio of phosphate and antimonyl ions. The extinction of the blue colour is measured at 880 nm using a 5 cm cell.

Calculation

$$F = \frac{\text{Concentration of standard}}{\text{An (st)-A (b)}}$$

A(st)-A(b) ; Where A (st) = Means absorbance of standards, A(b) = Means absorbance of blanks.

(B)Nitrite

The method of nitrite determination depends on a reaction with an aromatic amine, sulphanilamide, which is then coupled with N-(1-naphthyl) – ethylene diamine dihydrochloride, to form an azo dye. The absorbance of the dye is measured at 540 nm

Calculation

$$F = \frac{\text{Concentration of standard}}{\text{A(st)-A(b)}}$$

A(st)-A(b) ; Where A (st) = Means absorbance of standards, A(b) = Means absorbance of blanks.

(C) Nitrate

The nitrate in seawater is reduced, almost quantitatively to nitrite, by passing through a column containing copperized cadmium filings. Diazotising with sulfanilamide and coupling with N(1-naphthyl)-ethylene diamine as described for NO2-N determine the nitrite thus produced. Nitrite in the sample will pass through the reduction column without change. Hence the total nitrate plus nitrite will be determined by the method. Nitrate can be found by difference.

Calculation

$$F = \frac{\text{Concentration of standard}}{A(st)-A(b)}$$

A(st)-A(b) ; Where A (st) = Means absorbance of standards, A(b) = Means absorbance of blanks.

COLLECTION METHOD

Water is filtered by net and collected in bottles or water samplers as part of the zooplankton collection process. The correct equipment, netting material mesh size, time spent collecting, water depth in the study area, and sampling procedure will all have a significant impact on the sampling's success. The most popular way to capture zooplankton is with a net. The equipment can be used for both qualitative and quantitative studies, and the amount of water that is filtered is greater.. Several sizes and types of plankton nets are employed. The collection container needs to be sturdy and simple to untangle from the net. Bolting silk, nylon, or another synthetic material is used to make the netting of the filtering cone. The material should have precise and constant pore size and be long-lasting. The mesh should be square and the aperture uniform.The type of zooplankton that a net will gather will depend on the mesh size of the netting material.. While larger plankton and fish larvae are collected using nets with coarser netting material, smaller organisms, larval stages, and fish eggs are caught using nets with finer mesh.. The mesh size of 0.2 mm (200 µm) of monofilament nylon is usually used for collecting zooplankton for the study of production, abundance, distribution and population dynamics. The kind, length, and mouth area of the net, as well as the towing speed, the period of collection, and the type of haul, will also affect the quality and amount of zooplankton that is collected.

Vertical plankton net - (WP2).

The offshore water samples for the estimation of zooplankton were collected using a WP2 net (Hydro Bios), (mesh size 200 µm, mouth area 0.28 m^2). The net is closed off with a cylinder (cod-end) at the end, which collects the sample. The net was equipped with a digital flow meter (Hydro Bios, model 438110) for determining the amount of water passing through the plankton net. The net was towed horizontally just below the water surface for 10 min, the initial and final reading of the flow meter were noticed. It is mostly used to determine the abundance and distribution of mesozooplankton.

The inshore zooplankton sample was collected using 200 µm bolting silk. 2 liters of water is collected and filtered through the net and then back washed and collected in the sample bottles.

Figure 2: zooplankton collection

FIXATION AND PRESERVATION

Fixation

There is no need to emphasise the importance of correctly fixing and preserving zooplankton. The poorly fixed and preserved samples would render their subsequent analysis difficult.The improperly fixed samples show the white precipitate and ruptured exoskeletons. In order to prevent bacterial action and autolysis from damaging animal tissue after sampling, samples should be fixed as soon as possible, ideally within 5 minutes.. The most common fixing and preserving reagent is (4-5%) formaldehyde (formalin). The zooplankton samples may be preserved for a number of years, and it is the least expensive fixative. Since commercial formalin is frequently contaminated with iron compounds, which results in an iron hydroxide brow precipitate that makes zooplankton identification challenging, analytical grade formalin should be used for fixation. To prevent unfavourable osmotic effects, the concentrated formalin should be diluted with fresh water, seawater, or ideally water from the sampling region.One component formalin is mixed with nine parts fresh water or seawater to create the dilution.. The pH of the fixative should be approximately 8.0. The collected micro fauna sample was fixed using 5% formalin.

Preservation

Following fixation, the zooplankton is moved and kept in airtight containers with an adequate amount of preservative. Due diligence should be exercised to ensure that the zooplankton sample is not lost in the transfer process.. Various types of preservatives are available. The buffered formalin (4 to 5%) is mostly used both as fixative and as the preservative. The preserved zooplankton samples should ideally be kept at a temperature of less than 25 °C in a room with good ventilation. The wide opening glass jars are where the samples should be stored. The jars should contain high-quality pre-printed labels with the collector's name, the fixative and preservative used, and other field data inscribed on them for easy access during sample analysis.

BIOVOLUME ESTIMATION

Biomass

The amount of living matter contained in the zooplankton sample is referred to as biomass. The value obtained is used to assess the research area's potential for secondary productivity and fisheries. The zooplankton biomass was measured following the standard displacement volume method after removing large detrital particles (Harris et al. 2000). The displacement volume of zooplankton was first translated to dry weight using a factor of 0.075 g dry weight ml1, and then to carbon biomass using the industry-standard conversion factor of Madhupratap et al. (1981).

Volumetric (displacement volume and settling volume) method

The volume measurements are easy to make in the field or laboratory.The displacement volume method is used to calculate the volume of all zooplankton. Using this technique, a piece of clean, dried netting material filters the zooplankton sample. The size of the mesh in the netting material should match or be smaller than the size of the mesh in the net used to collect the samples. The blotting paper is used to remove the interstitial water that exists between the organisms.The filtered zooplankton is then moved with a spatula into a measuring cylinder that has a known volume of 4% buffered formalin. The displacement volume is calculated by keeping track of how much fixative the zooplankton moved around in the measurement jar. Before calculating the settled volume, the plankton is allowed to settle for at least 24 hours.

FAUNAL ENUMERATION

Counting the plankters in the samples provides data on the faunal composition and relative abundance of various zooplankton taxa and their species. It is advised to take a subsample or an aliquot for the common taxa in order to count them. The total counts of the specimens in the samples should be made, though, for the rare groupings. The subsample or aliquot of 10 to 25% is often investigated for zooplankton enumeration. Yet, the percentage of the aliquot can change depending on how much zooplankton is present in the sample.

Faunal enumeration is done after dividing them into subclasses, grouped them into different organisms,then the abundance and diversity is calculated.

Subsample (aliquot)

There are tools available to divide the sample into fractions. They typically have internal barriers and are composed of plastic. The Folsom plankton splitter is frequently employed. The drum is filled with the zooplankton sample that will be subsampled, and the drum is slowly moved back and forth. The samples are divided into equal portions by internal partitions. The fraction can be poured into the drum once more to split it even more. Until a countable subsample is obtained, the procedure is repeated. The splitter is thoroughly rinsed to recover the organisms, which may be sticking onto the wall of the drum. The sample is generally splitted into 4 subsamples. One subsample is used to calculate dry weight, another to count the specimens of common taxa, a third to calculate relative species abundance, and a fourth is saved as a reference collection. Pipettes made of glass or plastic may also be used to collect the subsample for counting.. After splitting, the specimens are sorted and counted as the next step in the study.

Counting

Both primary and secondary sorting are used. The sample in the first kind is divided into 30 to 40 taxonomic categories (Appendix II). The major groups of organisms or specimens are further divided or sorted into their various families and genera at the secondary stage, however. According to Lawrence and Mayo, the counting should be done with a stereo microscope, and a tally mark should be written on the sheet whenever a specimen from a given group is visible. The multiple counter is used when numerous groups need to be counted at once. The data sheet contains accurate counts of each specimen included in the subsample. Depending on the proportion of subsamples analysed, the total number of specimens for the entire sample is then computed.

Species identification

A group of individuals capable of interbreeding is referred to as a species. Understanding the distributional pattern, seasonal variability, and community structure of zooplankton in an aquatic ecosystem requires accurate species identification. Illustrated checklists could assist with the first identification of common species. Thereafter, the identity should be verified by taxonomic specialists. The specimens that have been labelled and identified should be stored safely for future use. A stereo microscope (Lawrence & Mayo) and binocular microscope are used to view the specimens beneath the microscope (Zeiss, Primostar 1).

Data Computation

Biomass (standing stock)

After estimation of zooplankton biomass the standing stock values are converted into per cubic meter and is calculated as follows:

a. Volume of zooplankton = $\frac{\text{Total volume of zooplankton}}{\text{Volume of water filtered (V)}}$ (ml/m^3)

Faunal Composition

a. Total number of zooplankton specimens/ individuals of all groups

$$= \frac{\text{Total counts of the specimens (say x)}}{\text{Volume of water filtered (V)}}.$$

$No/m^3 = x/y$ (No. can also be expressed/ 100 m^{-3} or 1000 m^{-3})

b. Total number of specimens of a particular zooplankton taxon

$$= \frac{\text{Total counts (x)}}{\text{Volume of water filtered (Y)}}$$

STATISTICAL DATA

- EXCEL - preliminary data interpretation

Microsoft Excel is one of the most popular tools for data analysis. They are without a doubt the most sought-after analytical tool available since they include built-in pivot tables.. Using this allin-one data management application, you can easily import, explore, clean, analyse, and visualise your data. ANOVA is a statistical method used to determine whether the means of two or more groups differ from one another significantly. To investigate the impact of one or more factors, ANOVA analyses the means of various samples.. In other words, ANOVA analyses two or more groups concurrently and determines whether or not there is a link between the groups of the data set.

- PRIMER - diversity analysis

The statistical toolkit Plymouth Routines In Multivariate Ecological Research (PRIMER) consists of a number of specialised univariate, multivariate, and graphical routines for the analysis of species sampling data for community ecology. Species abundance, biomass, presence/absence, and percent area cover are among the common types of data that are examined. In the scientific community, investigations of the environment and ecology are its main uses.

HERBARIUM PREPARATION

A herbarium was prepared which were used for the identification of mangrove species later, photographs were taken from the site and also sample species were brought along for preparation of herbarium and further identification.

RESULTS

This study was carried out to record the diversity of zooplankton (micro fauna) in the mangrove habitats of Kumbalam. The following stations were selected for the study (table 1):

Table 1: Description of study sites

Station	Description
Station 1	characterized by no influx of fresh water into mangrove, surrounded by native resident ships, hence, highly polluted mainly due to household effluents.
Station 2	represents the luxuriant mangrove growth were good number of fishing practices occurs.
Station 3, 4 & 5	represents offshore open area associated to the station 2 where waves predominate.
Station 6	represents a luxuriant and abundant and diverse mangrove area.

Table 2: Geographical features of stations

SL NO	STATION	DATE	TIME	LAT	LONG
1	Station 1	13/12/22	12.51 pm	9.916915 N	76.309102 E
2	Station2	15/12/22	7.15 am	9.919967 N	76.305150 E
3	Station 3	17/12/22	7.34 am	9.924671 N	76.30954 E
4	Station 4	17/12/22	7.53 am	9.930818 N	76.314338 E
5	Station 5	17/12/22	8.11 am	9.930336 N	76.301869 E
6	Station 6	05/01/23	3.45 pm	27.2046 N	77.4977 E

Table 3: True mangroves observed from the study site

No.	Genera	Family	Site
1	*Acanthus ilicifolius L.*	Acanthaceae	1,2,3,4,5,6
2	*Avicennia officinalis L.*	Avicenniaceae	1
3	*Rhizophora mucronate*	Rhizophoraceae	2,3,4,56
4	*Sonneratia caseolaris L.*	Rhizophoraceae	6
5	*Exoecaria agallocha L.*	Euphorbiaceae	6
6	*Brguiera gymnorrhiza*	Rhizophoraceae	6

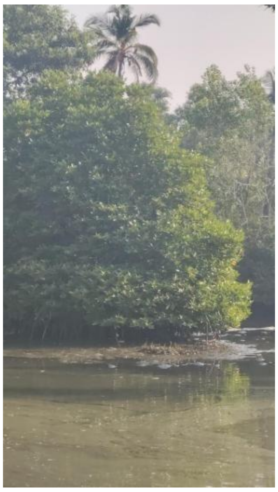
Table 4: Semi-mangroves observed from the study site

No.	Semi mangroves	Family	Site
1	*Acrostichum aureum L.*	Acrostichaceae	1,2,3,4,5,6
2	*Derris trifoliata L.*	Papilionaceae	1,6

Table 5: Mangrove associates observed from the study site

No.	Associate species	Family	Site
1	*Cayratia carnosa L.*	Vitaceae	1,6
2	*Salvinia molesta*	Salviniaceae	2,3,4,5
3	*Cerbera odollam G.*	Apocynaceae	1,6
4	*Fimbristylis ferruginea L.*	Cyperaceae	1,6
5	*Mariscus javanicus H.*	Cyperaceae	1,6
6	*Thespesia populnea*	Malvaceae	1
7	*Hibiscus tiliaceus L.*	Malvaceae	1

Figure 3: mangrove species (3a): ***Rhizophora mucronate*****, (3b):** ***Exoecaria agallocha*****, (3c):** ***Acrostichum aureum*****, (3d):** ***Cayratia carnosa*****, (3e):** ***Avicennia officinalis*****, (3f):** ***Brguiera gymnorrhiza*****, (3g):** ***Acanthus ilicifolius***



(a)

(b)

(c)

(d)

(e)

(f)

(g)

PHYSIO - CHEMICAL PARAMETERS

Several physio - chemical factors were analysed in the current study to provide a clear image of the study site's environment and to project the exact relationship that exists between the physio - chemical condition and the faunal community residing in the mangrove ecosystem.

Table 6: physio - chemical results

Station	pH	Temp ℃	Salinity ppt	DO mg/l	Chlorophyll mg/l	Nitrite µm/l	Nitrate µm/l	Phosphate µm/l
1	6.7	28.6	2.24	0.955	30.0784	1.655	6.79	29.82
2	7.05	20	8.99	5.277	4.4074	2.4505	8.347	12.613
3	7.11	23	14.97	5.803	4.4319	1.393	4.818	10.268
4	7.41	22	11.98	5.111	4.53118	0.425	1.962	9.354
5	7.6	22.5	11.98	6.134	4.51844	0.409	4.376	7.342
6	7.71	24	17.95	5.9	4.78	0.078	3.027	8.347

The water temperature did not vary significantly during the study period or between the stations of the study. It ranged from 20 to 28.6. The salinity ranges from 2.24 to 17.9, The study stations except station I was found to be mesohaline (5-18ppt) while station I was oligohaline (0.5-5 ppt). Dissolved oxygen showed much fluctuation between the study stations. Dissolved oxygen concentration fluctuated between stations, from 0.955 (station 1) to 6.134 (station 5). The DO content of station 1 (0.955) suggests the lowest abundance of zooplankton. The pH concentration did not vary much between the stations. In the present study, the pH values ranged from 6.7 to 7.71. The average chlorophyll is found to be about 4.45 except from site 1 which contained the chlorophyll as 30.07. Nitrite value ranged from 1.39 to 2.45 with average value of 1.06. Phosphate value showed fluctuation and ranged between 12.14 and 29.82 with average value of 12.957. The nitrate value ranged between 1.962 to 8.347 with average value of 4.886. Results showed that water temperature and chlorophyll was high in station 1, pH was high in station 6, nutrient contribution was high in station 1 & 2 and dissolved oxygen were highest in station 5 & 6.

MICROFAUNA

During the study period, 15 species of copepods belonging to three Orders were noticed. Six species of Order Cyclopoida, 7 species of Order Calanoida and 2 species of Order Harpacticoida. List of copepods species recorded in the Kumbalam mangrove showed that Order Calanoida was the dominant group followed by Cyclopoida and Harpacticoida. They are probably the most ecologically significant animals at the first consumer level of the marine plankton and are also the most prominent among the primary carnivores. The copepod diversity is closely related to water quality parameters and it also related the fish fauna of the water body.

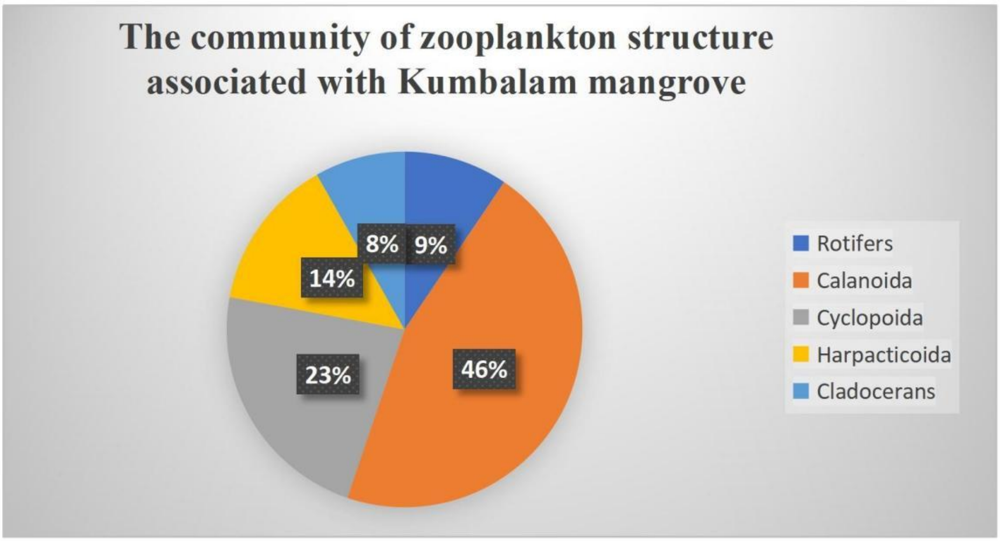
- From site 1 the presence of a pollution indicator has been noted.

Figure 4: *Ischunura elegance* larvae of blue tailed damsel fly

Zooplankton community structure

A total of 20 species of zooplankton were identified, including copepods, rotifers, cladocerans, and ostracods. The most abundant species were copepods, which accounted for 81% of the total zooplankton abundance. The community structure of zooplankton varied significantly between the six sampling sites, with station 6 having the highest diversity and abundance, while station 1 & 2 had the lowest. Physio chemical parameters also varied significantly between these study stations, with salinity and temperature being the most important drivers of zooplankton community structure.

Figure 5: Chart showing abundance of zooplankton from kumbalam mangrove region

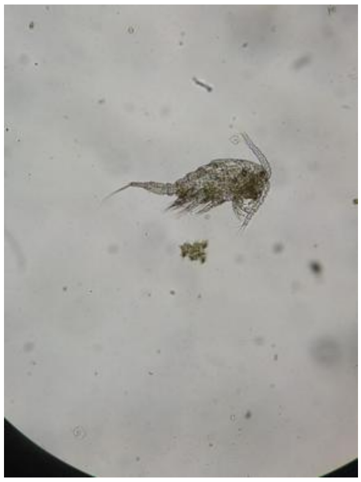


Copepods, Rotifers, Cladocercans & Ostracods

Figure 6: showing zooplankton (a)-(g): copepods, (h): rotifer, (i): cladocerans, (j)-(k): Ostracods



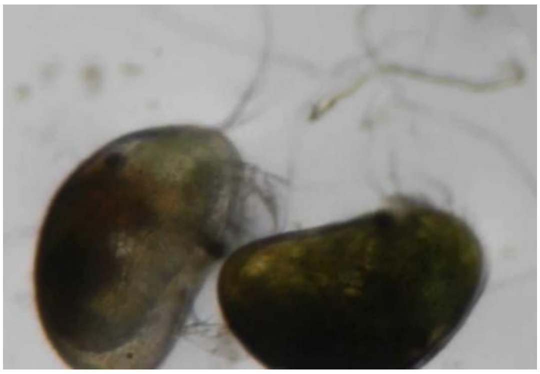
(a) (b) (c)

(d) (e) (f)

(g) (h) (i)

(j) (k)

Abundance of zooplankton from sample stations

Table 7: Number of zooplankton observed from each station

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
Rotifers	4	4	5	6	5	6
Calanoida	16	20	27	28	24	30
Cyclopoida	9	12	12	13	11	15
Harpacticoida	4	4	8	8	9	11
Cladocerans	2	2	4	5	5	8

Figure 7: Abundance of zooplankton observed from station 1

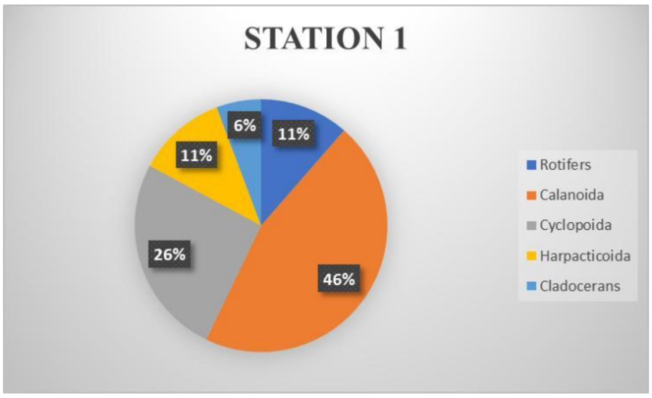


Figure 8: Abundance of zooplankton observed from station 2

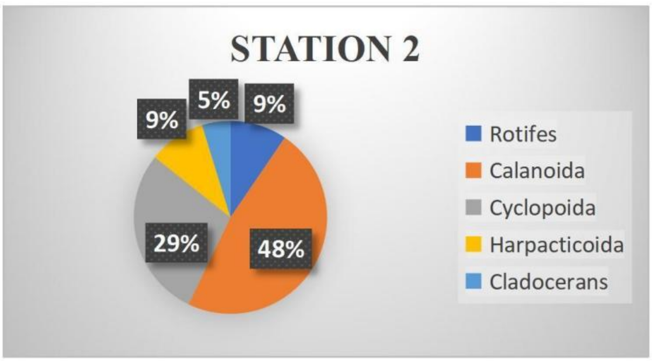


Figure 9: Abundance of zooplankton observed from station 3

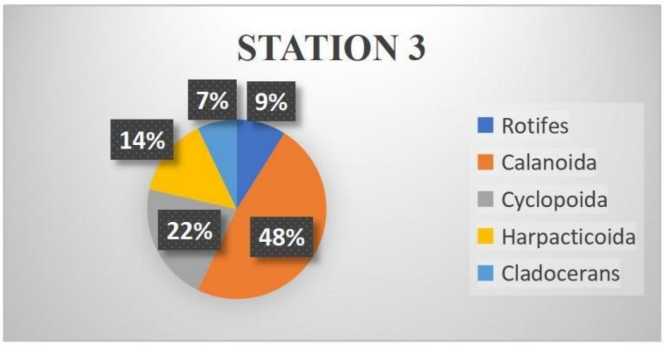


Figure 10: Abundance of zooplankton observed from station 4

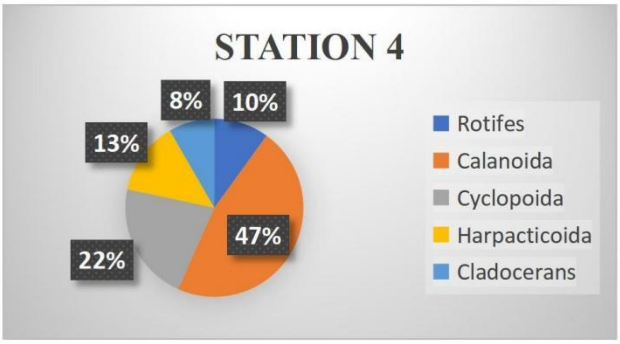


Figure 11: Abundance of zooplankton observed from station 5

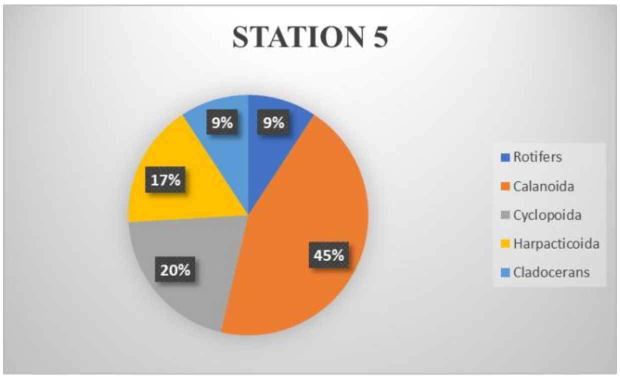
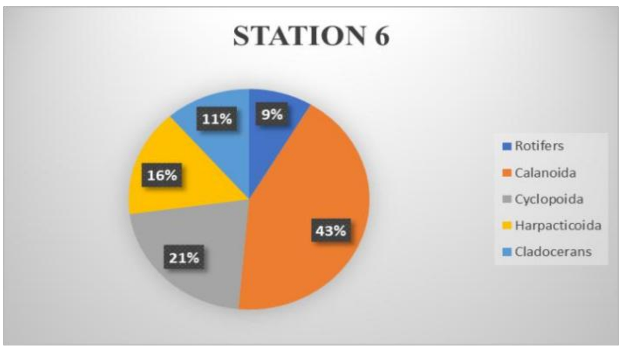


Figure 12: Abundance of zooplankton observed from station 6



CORRELATION BETWEEN ZOOPLANKTON AND PHYSIO - CHEMICAL PARAMETERS

Figure 13: Diagram showing abundance of zooplankton in relation to pH

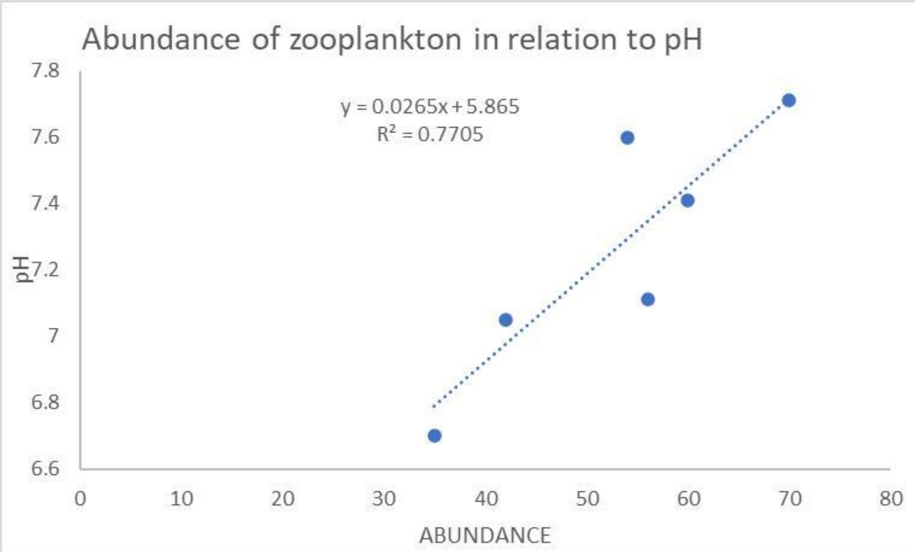


Figure 14: Diagram showing abundance of zooplankton in relation to temperature

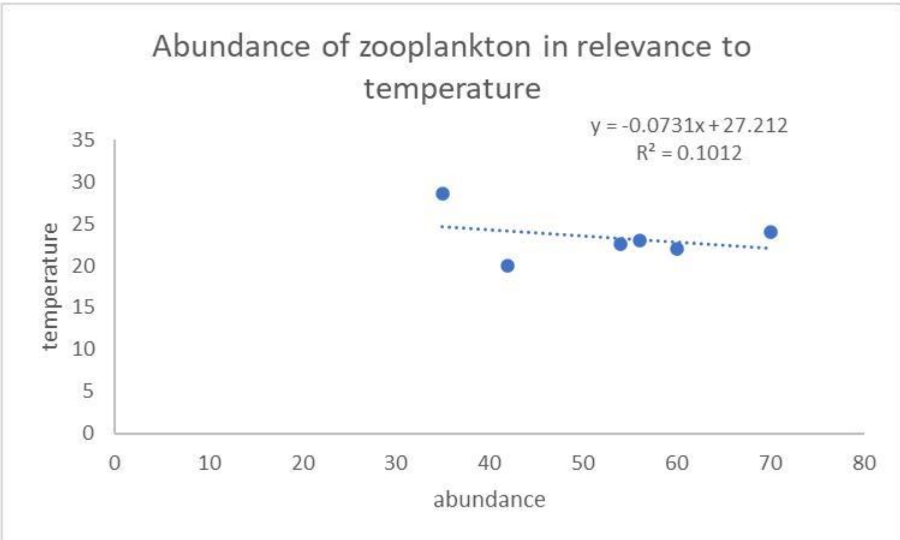


Figure 15: Diagram showing abundance of zooplankton in relation to salinity

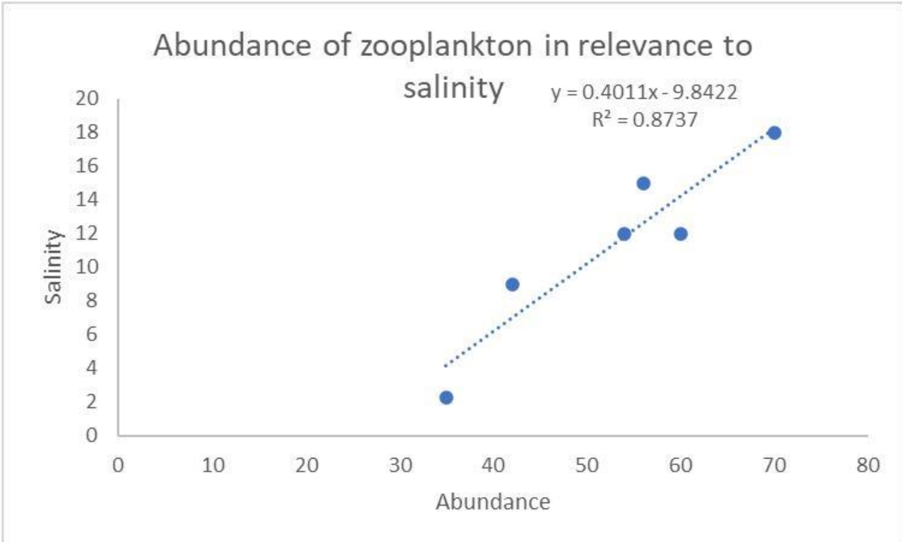


Figure 16: Diagram showing abundance of zooplankton in relation to dissolved oxygen

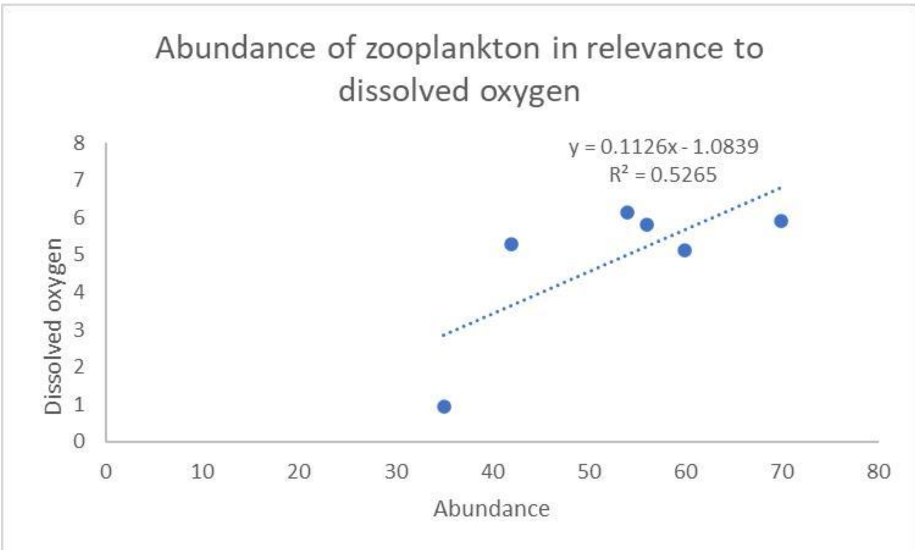


Figure 17: Diagram showing abundance of zooplankton in relation to chlorophyll

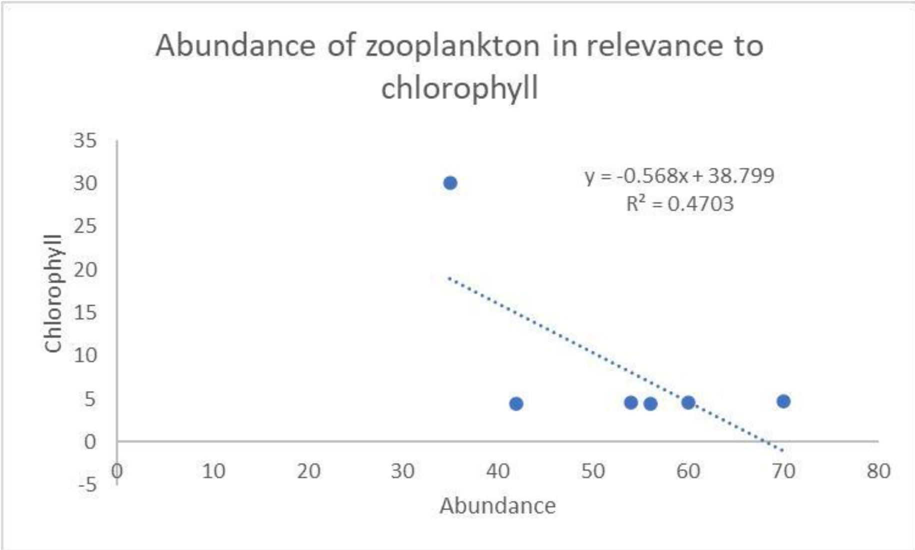


Figure 18: Diagram showing abundance of zooplankton in relation to nitrite

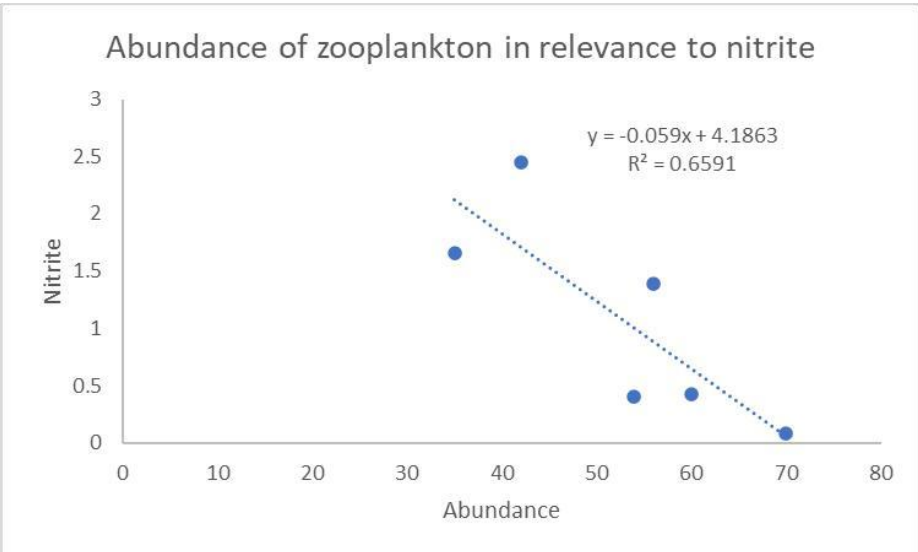


Figure 19: Diagram showing abundance of zooplankton in relation to nitrate

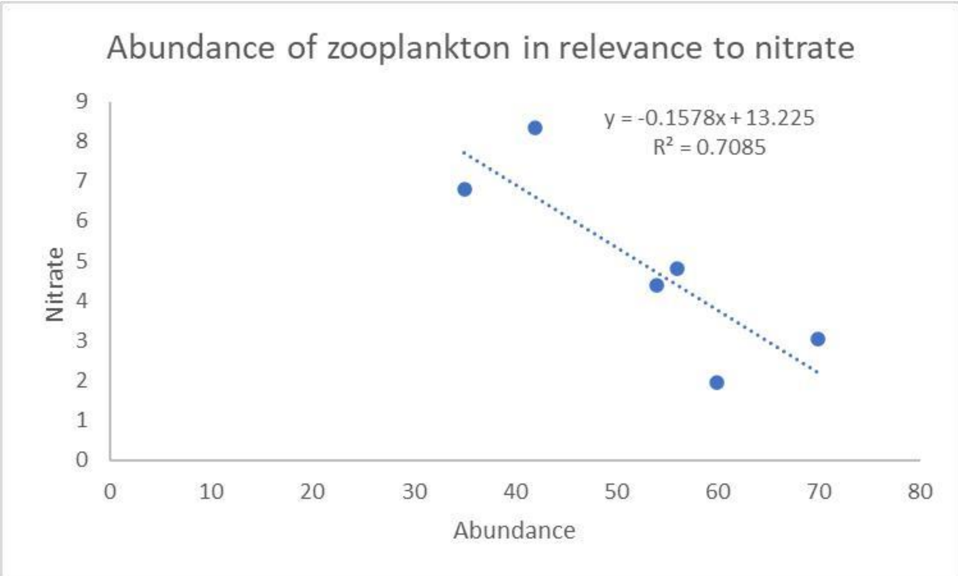
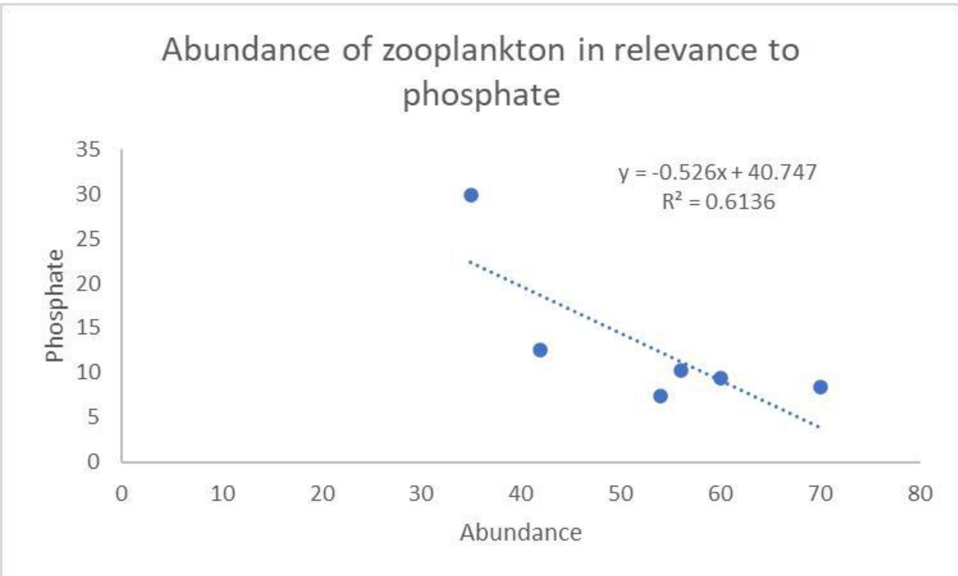


Figure 20: Diagram showing abundance of zooplankton in relation to phosphate



DISCUSSION

The present study focuses on species composition and abundance of micro fauna in relation to environmental variations in the mangrove ecosystem of Kumbalam. The composition of zooplankton in Cochin Backwaters have been studied by Antony & Selvaraj., 1993; Haridevi et al., 2004; Madhu et al., 2007. The study on composition, abundance and diversity of zooplankton associated with mangroves with special emphasize on Kumbalam region which is a part of Vembanad Wetland system is scarce. The present study have documented a wide range of species, including Copepods, Rotifers, Ostracods, and Cladocerans. The diversity of zooplankton in mangrove ecosystems is thought to be influenced by a number of factors, including the availability of food resources and the presence of predators.

Zooplankton are an important group of organisms in aquatic ecosystems. They play a critical role in the food chain, serving as a primary food source for many fish and other aquatic organisms. Zooplankton diversity and abundance can provide insights into the health and productivity of aquatic ecosystems. Here we focus on the diversity, abundance, and community structure of zooplankton in mangrove ecosystems. Zooplankton communities in mangrove ecosystems are shaped by a variety of environmental factors, including temperature, salinity, nutrient availability, and tidal fluctuations. As a result, these communities are highly diverse and dynamic, with species composition and abundance varying over time and space.

The high abundance of copepods in this mangrove ecosystem is consistent with previous studies of zooplankton in other mangrove habitats. Copepods are known to be highly adaptable to changes in salinity and temperature, which may explain their dominance in this ecosystem. The large abundance of copepods among the zooplankton groups was reported by many of the researchers earlier (Wellershaus, 1974; Sarkar et al., 1984; Nagarajaiah and Gupta, 1985; Nair and Azis, 1987; Padmavati and Goswami, 1996; Mishra and Panigraphy, 1999; Karuppasamy and Perumal, 2000; Madhu et al., 2007). Qasim (2005) reported that “within the zooplankton community, copepods constitute the dominant group of all the Indian estuaries”. The large amount of a specific group among the zooplankton can be considered due to the type of ecosystem under study or can be due to the mesh size of the net used for collecting zooplankton. Also, in the present study it is found that different groups of zooplankton prefer specific environments. Since some zooplankton like rotifers are excellent live feed organism in aquaculture practices, detailed studies on species abundance and their relationships with the environmental characteristics are necessary.

The significant variation in zooplankton community structure between the six sampling sites suggests that local environmental conditions play an important role in shaping zooplankton communities. The higher diversity and evenness of species at station 6 may be due to the more favorable physio - chemical conditions at this location, which included higher salinity and higher dissolved oxygen levels.

Rao et al. (1975) observed that the species diversity of zooplankton is high during the high salinity regime at the mouth region of the estuary and there is a progressive diminution towards the head similarly, from the present investigation it was observed that the number of groups contributing to the zooplankton was high during the high salinity regime and it gradually decreased with decreasing salinity in the study area.

In the present study high dissolved oxygen value are obtained from station 5 & 6 which showed higher zooplankton diversity, Haridevi et al. (2003) also observed similar trend from the present study area. Qasim et al.(1969) stated that the higher oxygen concentration during this period could be due to the higher primary production occurring in the surface layers.

One important factor influencing zooplankton abundance in mangrove ecosystems is the availability of phytoplankton, which serves as a primary food source for many zooplankton species. Mangrove ecosystems are highly productive and support a diverse array of phytoplankton species, which in turn support a diverse zooplankton community. A study by Saifulla et al. (2010) reported that the estuarine water of Sarawak mangrove are ideal for the growth and survival of phytoplankton. High phytoplankton density in mangrove ecosystems results in higher density of its predators which are mostly zooplankton. Mangrove sites thus provide a highly beneficial environment for zooplankton in terms of food.

Another important factor influencing zooplankton abundance in mangrove ecosystems is predation. Many fish species that are found in mangrove ecosystems feed on zooplankton, and the presence of these predators can have a significant impact on zooplankton abundance and community structure. Additionally, anthropogenic impacts such as pollution and habitat degradation can also impact zooplankton communities in mangrove ecosystems. In the present study, from station 1 with lower dissolved oxygen rate and high temperature, chlorophyll and phosphate level, showed least abundance and diversity of zooplankton, the site was polluted with anthropogenic wastes from nearby households.

In terms of community structure, zooplankton communities in mangrove ecosystems tend to be dominated by small, fast-reproducing species. This is thought to be due to the high levels of predation and environmental variability in these ecosystems, which favor species with short life cycles and rapid reproductive rates.

The study revealed that the zooplankton community in the mangrove ecosystem was moderately diverse and dominated by a few taxa. The variation in abundance among months could be attributed to several factors, including changes in environmental conditions, food availability, and predation pressure. The physio - chemical parameters of the study area also showed significant variation, which could be attributed to factors such as tidal influence, rainfall, and nutrient inputs from adjacent land areas.

Temperature is a critical environmental factor that influences the physiology and behavior of zooplankton. The highest abundance of zooplankton in station 6 could be attributed to the optimal temperature (24 ℃) conditions that favored the growth and reproduction of zooplankton. Similarly, the lowest abundance of zooplankton in station 1 &2 could be attributed to the unfavorable temperature (28.6 ℃& 20℃) conditions that limited their growth and reproduction. The surface temperature of any aquatic ecosystem is an important factor for the distribution and relative biomass of plankton species. Thus increasing temperature also increases the metabolic rates of algal cells and the growth rate of phytoplankton species. The growth rate is faster at higher temperature but drops considerably beyond an optimal temperature (Eppleyet al., 1979; Schoemannet al., 2005). At Karapad Bay, the least numbers of phytoplankton were observed during the month of June and zooplankton during the months of September to December, which may be due to coupled effect of warm coolant water from nearby Tuticorin Thermal Power Station aided by the atmospheric temperature. All zooplankton are poikilothermic and therefore the rate of physiological processes and is of overall growth rate are highly sensitive to temperature (Huntley and Lopez, 1992).

Salinity is another critical environmental factor that influences the physiology and behavior of zooplankton. The highest and lowest salinity recorded in station 6 (17.95) and station 1 (2.24) respectively could have affected the distribution and abundance of zooplankton in the study area. Gopinathan et al. (1982) reported low salinity values from the fields adjacent to the part of the Cochin backwaters south of the Cochin bar mouth whereas relatively high values were recorded in the fields of the part of the backwaters north of the bar mouth having two connections with the sea. Josanto (1971), Gopinathan et al. (1974), Pillai et al. (1975), Varma et al. (2002) and Haridevi et al. (2003) also have reported similar salinity variations in the Cochin backwaters.

The pH of the study area was generally within the optimal range for most zooplankton taxa, although the lowest pH recorded in station 1 (6.7) could have affected the physiology and behavior. Modoosoodun et al. (2010) also noted positive correlation of phytoplankton and zooplankton density with pH and salinity.

The nutrient content showed negative correlation with abundance of zooplankton. Nitrate ($r = -0.84$), phosphate ($r = -0.78$) and nitrite ($r = 0.81$) content were analyzed, It showed that, as the nutrient content increases the abundance of organism decreases.The value of present findings agrees with the observations made by Sarmah (2011).

CONCLUSION

The present report on Kumbalam mangrove patches indicated the favourable range of physio chemical parameters for the normal distribution and abundance of zooplankton diversity. Salinity and water temperature seem to have a great influence on the distribution and abundance of zooplankton. As the salinity increases the abundance of zooplankton is found to be increasing. Similarly, at an optimum temperature, the zooplankton abundance was high and when temperature fluctuates above or below the optimum range, the abundance tends to decrease. The increased amount of dissolved oxygen showed an increase in abundance, and as the oxygen level decreases the abundance of the organism also decreases. The low oxygen content leads to a high BOD value and indicates that it is polluted. A pollution indicator *ischnura elegance,* the larvae of blue-tailed damsel fly have been observed from station 1 which had the lowest amount of dissolved oxygen. Thus, the study revealed the presence of pollution on mangrove patches due to anthropogenic wastes and its influence on the distribution and abundance of zooplankton, which will result in the loss of abundance and diversity of higher organisms as zooplankton are the primary consumers. The lowest abundance of zooplankton was observed from station 1&2 which showed low DO (0.955) & salinity (2.24), high temperature (28.6) & nutrient values, also the chlorophyll content (30.078) from these sites were higher compared to other stations. Water present on the surface which consists of high chlorophyll content are generally high in nutrients, usually phosphorus and nitrogen. These nutrients cause the algae to grow or bloom and it indicates low quality of water. Thus, these stations showed a low abundance of zooplankton. The higher abundance was observed from site 5&6 which had all the optimum conditions for the growth of zooplankton with optimum temperature (24℃) & pH (7.71), high salinity (17.95) & DO (5.9) and low chlorophyll (4.78) &nutrient values.

A total of 20 species of zooplankton were identified, including copepods, Rotifers, cladocerans, and Ostracods. The most abundant species were copepods, which accounted for 81% of the total zooplankton abundance. The community structure of zooplankton varied significantly between the six sampling sites, with station 6 having the highest diversity and abundance, while station 1 & 2 had the lowest. During the study period, 15 species of copepods which are belonging to three Orders were identified, they consist of six species of Order Cyclopoida, 7 species of Order Calanoida and 2 species of Order Harpacticoida. List of copepods species recorded in the Kumbalam mangrove showed that Order Calanoida was the dominant group followed by Cyclopoida and Harpacticoida.

This study analyzed the diversity, distribution, abundance, and composition of zooplankton associated with kumbalam mangroves. The various physio - chemical parameters associated with the study sites and the influence of these data on abundance and diversity of micro-fauna in the region were analyzed. The data obtained from this study will help in the assessment of the quality of individual mangrove ecosystems and highlight the importance of mangrove propagation along the coastline which is important to protect against coastal erosion and also for the development of the mangrove system. Studies on the occurrence and abundance of such organisms in relation to physio - chemical conditions would be useful for evolving methods for improving the fishery potential of cultural fields. Also as they are considered as bio-indicators the abundance and diversity of zooplankton will give an account on the health of ecosystem.

Research works associated with understanding and interpretation of zooplankton diversity in the mangrove ecosystem in relation to environmental variables are still scanty and as a result, such studies are warranted. To this end, this study presents important information on the abundance, diversity, and community structure of zooplankton in the diverse mangrove habitats of kumbalam wetland ecosystem. Even though further studies are required for assessing the complete details regarding the diversity and abundance of zooplankton of kumbalam mangroves region.

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Appendix - 1

NUTRIENTS- REAGENT

Phosphate Reagents

- Sulphuric acid (9.0 N)
- Ammonium molybdate solution
- Potassium antimonyl tartrate solution
- Mixed reagent
- Ascorbic acid solution
- Phosphate standard solution

Nitrite Reagents

- Sulfanilamide solution (1%)
- N-(1-naphthyl) – ethylene diamine dihydrochloride (1%): Dissolve
- Nitrite standard solution

Nitrate Reagents

- Ammonium chloride buffer
- Sulfanilamide solution (1%)
- N-(1-naphthyl) – ethylene diamine dihydrochloride (1%)
- Cadmium metal filings
- Copper sulphate solution $CuSO_4 \cdot 5H_2O$ (1%)
- Nitrate standard solution