DIVERSITY AND ABUNDANCE OF ZOOPLANKTON IN RELATION WITH PHYSICO-CHEMICAL PARAMETERS OF THRISSUR KOLE WETLAND WITH SPECIAL EMPHASIS ON ROTIFERA (EUROTATORIA)

Thesis submitted in partial fulfilment of the requirements for the Degree

of

DOCTOR OF PHILOSOPHY IN ZOOLOGY

Under the Faculty of Science

University of Calicut

by

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NOVEMBER 2021

DECLARATION

I, FATHIBI K, hereby declare that the work embodied in the thesis "**DIVERSITY AND ABUNDANCE OF ZOOPLANKTON IN RELATION WITH PHYSICO-CHEMICAL PARAMETERS OF THRISSUR KOLE WETLAND WITH SPECIAL EMPHASIS ON ROTIFERA (EUROTATORIA)**" submitted to the University of Calicut in partial fulfilment of the requirements for the Degree of Doctor of Philosophy in Zoology is a bonafide record of the research work carried out by me under the supervision of Dr. Aneesh E. M., Assistant professor, Department of Zoology, University of Calicut and Dr. Sudhikumar A. V., Assistant professor, Research and Post-Graduate Department of Zoology, Christ College, Irinjalakuda. No part of the thesis has formed the basis for the award of any degree, diploma or other similar titles of any university.

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This is to certify that **Ms. FATHIBI K** has completed the research work for the full period prescribed under the Ph.D. ordinance of the University of Calicut. This thesis **"DIVERSITY AND ABUNDANCE OF ZOOPLANKTON IN RELATION WITH PHYSICO-CHEMICAL PARAMETERS OF THRISSUR KOLE WETLAND WITH SPECIAL EMPHASIS ON ROTIFERA (EUROTATORIA)"** embodies the results of her investigations conducted during the period at which she worked as a research scholar. I recommend the thesis to be submitted for the evaluation for the award of the degree of Doctor of Philosophy in Zoology of the University of Calicut.

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ABSTRACT

Physico-chemical Parameters and WQI of Thrissur Kole Wetland

The Kole wetland, recently designated as a Ramsar site, is one of Kerala's largest, most productive, and unique wetlands. However, the pollution, construction of buildings, new bunds and roads are adversely affecting the wetland. The study on Thrissur Kole wetland's physical and chemical parameters and Water Quality Index was conducted during October 2017- September 2019. Surface water samples were collected monthly from six sampling sites to cover the entire topography of the wetland. Air temperature, Water temperature and field pH was measured in the field itself and other parameters were measured separately for all the samples in the laboratory. All the physical and chemical parameters showed seasonal variation and all the parameters seem to be correlated. Parameters such as iron and turbidity were very high, which led to high WQI value and low water quality. Turbidity was above the permissible limit of BIS standard and Iron was above the acceptable limit during the pre-monsoon and post-monsoon season, above the permissible limit during the monsoon. Turbidity in the water is due to organic or inorganic suspended particles and high turbidity indicates the presence of large amounts of suspended solids. The main reason for the increase in turbidity during the monsoon season was the surface runoff and wastewater intrusion; this makes the water severely deteriorate. This study will help to improve the water quality and maintain sustainable use by understanding the condition of the Kole wetland water.

Diversity and Abundance of Zooplankton in Thrissur Kole Wetland

Zooplanktons are heterotrophic planktonic animals floating in the water. They are the crucial food source to many fishes and act as an important indicator of water quality. A total of 77 species of Zooplankton belonging to 2 phyla, 20 families and 44 genera were identified from the study area. Rotifers were the most dominant and diversified group comprising 52% of the zooplankton community; Cladocera, Copepoda and Ostracoda constituted 27%, 13%, 8%, respectively. Canonical Correspondence Analysis (CCA) was used to integrate the Zooplankton abundance with water's physical and chemical parameters. Different species prefer different concentrations of environmental variables. The major factors influencing the Zooplankton abundance were dissolved oxygen, iron, water temperature, COD, BOD, sulphate, and electrical conductivity. Genus *Brachionus* is regarded as a pollution indicator found abundant in the study area throughout the study period. The Molecular Phylogenetic Analysis of Rotifera (Eurotatoria) by the Maximum Likelihood Method revealed that species under the same genera exhibited a prominent range of similarity. In contrast, the species from the different genera are known to illustrate an extensive range of genetic changes.

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ACRONYMS AND ABBREVIATIONS

ACD	-	Acidity
ALK	-	Alkalinity
ANOVA	-	Analysis of Variance
APHA	-	American Public Health Association
AT	-	Atmospheric temperature
BIS	-	Bureau of Indian Standards
BOD	-	Biochemical Oxygen Demand
Ca	-	Calcium
CCA	-	Canonical Correspondence Analysis
Cl	-	Chloride
CO_2	-	Carbon dioxide
COD	-	Chemical Oxygen Demand
CV	-	Coefficient of variation
DO	-	Dissolved oxygen
EC	-	Electrical conductivity
EDTA	-	Ethylenediamine tetraacetic acid
Fe	-	Iron
FpH	-	Field pH
HCl	-	Hydrochloric acid
KCl	-	Potassium chloride
KI	-	Potassium iodide
LpH	-	Lab pH
MBR	-	Mean burette reading
Mg	-	Magnesium
$MnSO_4$	-	Manganese sulphate
NaCl	-	Sodium chloride
NaOH	-	Sodium hydroxide

NO_3	-	Nitrate
NTU	-	Nephelometric Turbidity unit
pH	-	potential hydrogen
SO_4	-	Sulphate
TASA	-	Total Anions of Strong Acids
TDS	-	Total suspended solids
TH	-	Total Hardness
TUR	-	Turbidity
WHO	-	World Health Organization
WQI	-	Water Quality Index
WT	-	Water temperature

Seasons

MON	-	Monsoon
PRM	-	Pre-monsoon
MON	-	Monsoon

Chapter I

General Introduction

1.1. Introduction

Population growth has become a significant problem in the world and in our country today. This is because a growing population needs a growing economy, and demand is also increasing on a daily basis. Population growth is one of the primary reasons for all environmental problems, as it needs significant amounts of non-renewable resources for its survival. Water scarcity is an insurmountable obstacle to human survival as the population increases. One of India's major causes of environmental degradation is rapid population growth, which adversely affects natural resources and the environment. Increasing population and environmental degradation pose the challenges of sustainable development without environmental damage. If the world's population continues to grow, the impact on the environment will be catastrophic. It will put severe pressure on land expansion in the forests and pastures, as food demand cannot be significantly increased and met with the increase in population.

1.1.2. Water

Life on earth depends on water for survival. Wells, rivers, lakes, and oceans are full of water and are important components of the body fluids of all living things. A water molecule is a combination of one oxygen and two hydrogen atoms, which are found in three states: solid, liquid and gaseous. The term ‘water’ is used to denote ‘liquid state.’ The solid state of water that changes shape with temperature is called ice and the gaseous state is called vapour. Fresh water is a particularly colourless and transparent substance, and the presence of certain elements changes the colour of the water. The presence of limestone gives water a greenish-blue (turquoise) colour, the iron compounds give water a reddish-brown colour, the copper compounds a dark blue colour, and the presence of algae gives water a green colour. Water is not stagnant; it passes through the water cycle from one place to another, changing from one form to another.

About 71% of the earth's surface is covered by water, and over 96% of this water is in the oceans, with the remaining 3% being freshwater, three-quarters of which is found in icebergs and glaciers, the rest is in surface water (0.3%) and groundwater. Renewable water resources are scarce in many parts of the world, with India accounting for 4% of the world's renewable water resources (Manju & Sagar, 2017). Lakes, rivers, and swamps contain 87% of the surface water; only 1% of the water on earth is usable to humans. 71% of fresh water is used for agricultural purposes and only 10% is used for domestic purposes.

Water pollution caused by organic or volatile substances is a major threat during this period as all living organisms in this world are directly or indirectly related to water. Water is an excellent solvent and dissolves substances even in small quantities, which increases the risk of water contamination. As the amount of dissolved matter increases, the amount of oxygen in the water decreases. This significantly affects the various functions of the organisms depending on the amount of dissolved matter. Due to transportation, fishing, tourism, sports and power generation, water use and pollution have increased manifold in addition to conventional uses. Protection of water resources is all the more essential than any matter of immediate concern because polluted water kills more lives than war. Eutrophication is a major stressor of the aquatic habitat as the primary productivity of phytoplankton increases due to nutrient load in the water (Uitto & Hällfors, 1997).

1.1.3. Wetlands

Wetlands are important components of the landscape. About 6% of the earth's surface is covered by wetlands, with the United States alone accounting for 12% of the world's wetlands. Wetlands are defined as swampy or waterlogged by a resolution of the 1971 conference in Ramsar, Iran. Wetlands are natural, man-made, permanent, temporary, flowing, still, freshwater, lagoon or saltwater tidal flats with a depth of less than six meters. Wetlands are the most productive habitats covered by water and are constantly or periodically flooded, with more aquatic vegetation (Gerakis & Kalburtji, 1998). Wetlands have unique ecological characteristics and are seen on all continents, and they play vital roles in water purification, flood control and coastal protection for ecological balance. Deltas, mangroves, coral reefs, swamps, low-lying paddy fields, dams, reservoirs, and seasonally flooded plains and forests are defined as wetlands. Scientists describe the wetlands as the earth's kidneys (Zhang, Zhang, Xia, & Wang, 2005), which are richer in biodiversity than any other habitat and are home to many flora and fauna.

Wetlands are found on all continents except Antarctica. The United Nations Millennium Habitat Assessment estimates that the environmental degradation that occurs in wetlands in modern times is far more significant than in any other habitat. According to a 2001 public study, there are 157 wetlands in Kerala, excluding reservoirs. Most of the wetlands in Kerala are waterlogged, and there are few freshwater lakes in Kerala. Kuttanad paddy fields in Alappuzha, Pokkali fields in Ernakulam, Kole fields in Thrissur, and the swamps in Kollam and Thiruvananthapuram districts are the unique wetlands of Kerala. According to a 2007 study, wetlands in Kerala earn an annual income of 157.97 crores and provide 231.15 crores to Kerala, including paddy fields.

The production of grains like paddy is mainly dependent on wetlands. In addition, many types of grasses and mosses used as fodder are obtained from wetlands. About 90% of the total fish consumption of mankind comes from wetlands. Flood control is mainly carried out in wetlands, collecting excess run off during heavy rains. Wetlands are natural dams that enrich groundwater and reclaim it as needed. The unique topography of wetlands is suitable for groundwater recharge (Acharya & Barbier, 2000); freshwater seeps into the aquifer through microscopic holes in the sandy loam. Wetlands are less prone to summer droughts, and wetland vegetation strengthens lakes and riverbanks and is important for sustainability (Junk et al., 2014). Special plants that grow along the shores of wetlands help to keep the eels and the coastal structure intact. The most important of these are mangroves; they provide opportunities for the feeding and breeding of various fish species and protect the land from sea swells and floods. The tide regulates the flow of water during low tide. Growing wetlands play an important role in protecting the coast from tsunamis and hurricanes (Alongi, 2008).

Wetlands are areas with serious environmental damage and are endangered worldwide due to human-centered and natural causes, including urbanization, encroachments on agricultural, domestic and industrial purposes, and reclamation.

Natural phenomena such as drought, storms, erosion, the elevation of the ocean floor and eutrophication cause the destruction of wetlands (Chambers, Steinmuller, & Breithaupt, 2019). These disturb the soil structure, the nature of the elements, the distribution, the biodiversity and the groundwater supply in the wetlands. The influx of exotic species leads to the extinction of native species, while weed growth threatens the survival of other species.

Excessive exploitation of natural resources, urbanization, industrial development, tourism and agriculture are the major human interventions in wetlands. Excessive use of fertilizers and pesticides in agriculture lead to the destruction of wetland biodiversity (Verhoeven & Setter, 2010). Large-scale dumping of household and industrial effluents into wetlands, effluents from streams and untreated industrial effluents contaminate wetlands. Excessively dissolved solids reduce the amount of oxygen in the water and lead to the extinction of the species, especially the endangered fish species. Horizontal or vertical changes in Zooplankton caused by hypoxia can affect trophic interactions, which may later change the community structure (Decker, Breitburg, & Purcell, 2004). Household wastes, nutrients, excessive algae and microbial growth cause odours from wetlands (Sehar, Naeem, Perveen, Ali, & Ahmed, 2015). Weeds and algae growing on the water surface due to overnutrition in the wetlands interfere with the distribution of sunlight and kill the bottom-growing organisms. The construction of dams and reservoirs obstructs the circulation of water in watersheds and reduces water availability. This undermines the natural environment of the wetlands. Pollution from houseboats and hotels is one of the major threats to tourism-based wetlands.

Wetlands are invaluable resources that provide many vital functions for the environment and human beings (Reddy & Gale, 1994). By educating the people about the activities that adversely affect them, the major problems currently faced such as mining, pollution, and reclamation can be prevented to a definite extent.

1.1.4. Plankton

Planktons are small, immobile, fragile swimmers found in the ocean and freshwater, providing food for a wide variety of aquatic life. The word ‘plankton’ comes from the Greek word *planktos*, which means ‘drifter’ or ‘wanderer’ that can’t swim very well against the water current. With the exception of some crustaceans and jellyfish, most planktons are microscopic and form the bottom of every aquatic food web. There are two main groups, phytoplankton and Zooplankton. Like terrestrial plants, phytoplankton performs photosynthesis in water, and they are biological indicators of pollution because they are very sensitive to changes in the environment. Zooplanktons are the animal component of the planktonic community (Greek word *zoo*- animal, *planktos*- drifter).

1.1.4.1. Zooplankton

Zooplanktons are heterotrophic organisms drifting in the water. They have an irreplaceable position in the aquatic ecosystem. They act as important food sources for many of the fish larvae, and are great consumers of bacteria and phytoplankton. They act as a cost-beneficial indicator of water quality (Jeppesen et al., 2011). They stay deep in the water during the day to stay away from predators, and at night they come to eat phytoplankton (Hays, 2003). Zooplankton can help prevent algal bloom through the top down effect that it consumes toxic cyanobacteria (Andersen, 1991; Wilson, 2006) and the abundance of Zooplankton can be enhanced by eliminating the planktivorous fishes (Boon, 1994). The aquatic macrophytes help the Zooplankton as a shelter from predators (Thomas, 2003). The size of the feed is not related to the size of Zooplankton; smaller species not only feed smaller cells; for example, *K. cochlearis* can eat cells having <17μm (Bogdan, 1984), and the lipid profile of Zooplankton changes with the season as a result of dietary variation (Gonçalves, 2012). Zooplanktons are widely used in toxicological studies because they are more sensitive to chemicals (Hanazato, 2001) and are easier to handle. Pesticides and insecticides affect the life of Zooplankton differently; *Daphnia* (large-sized Cladoceran) showing high sensitivity to certain pesticides, followed by medium-sized Cladoceran (*Moina* and *Diaphanosoma*). Small-sized Cladoceran (*Bosmina*) and

Rotifers are less sensitive to these chemicals (Hanazato, 2001). Zooplanktons are classified according to their size, such as MicroZooplankton (20-200µm), MesoZooplankton (0.2-20mm) and MacroZooplankton. If Zooplankton lives as plankton for only a certain period, it is called meroplankton, and Zooplankton that lives entirely as plankton is called holoplankton. Freshwater Zooplanktons are composed of Rotifers, Cladocerans, Copepods and Ostracods. Protozoa are rare in Zooplankton studies because they require different sample techniques and equipment than others, making it difficult for taxonomists (Pace, 1981). The diversity and abundance of freshwater Zooplanktons depend entirely on the biotic and abiotic components. Biotic factors include quality and availability of food, competition (Intra and interspecific) and predation, and abiotic factors include water temperature, pH and oxygen content of the water. Zooplankton also show a strong affinity for macrophytes, and the composition of the Zooplankton species of a particular area occurs as a result of the interaction of the surrounding macrophytes (Choi et al., 2014). Zooplankton reacts rapidly to environmental conditions (Gyllström, 2004), and the reaction may be both morphological (spinal formation in Daphnia) and behavioural (distribution, swimming).

Zooplankton is distributed in the aquatic environment through human and animal vectors, wind and running water (Cohen, 2003; Havel, 2004), and the density, biomass, and nutrient cycling of aquatic ecosystems are mainly met by Rotifera, Cladocera, Copepoda and Ostracoda. Zooplankton can withstand adverse environmental conditions and can produce resting eggs and disperse from one area to another.

The organism which passes through dormancy has the power to preserve the egg for decades (De Stasio Jr, 1990; Hairston Jr, Van Brunt, Kearns, & Engstrom, 1995) and conserve its genetic variation like seed dormancy (Hairston & Cáceres, 1996). The breaking of diapause occurs when it gets cues from biotic and abiotic factors during the favourable conditions (Brendonck, 2003). Copepods take the signal from abiotic factors, Rotifers take the signal from biotic factors and Cladoceran takes both (Gyllström, 2004). Zooplanktons are important model organisms in evolutionary ecology (especially *Daphnia*) because they are manageable and their cyclic parthenogenetic reproduction produces clones at high frequencies (De Meester, 1996).

1.1.4.1.1. Rotifera

Rotifers (Wheel Animalcule) are short-lived multicellular microscopic, mostly aquatic organisms that represent free-living and parasitic organisms, living alone or colonially. They play an important role in the aquatic food web. The body of the rotifer is spherical, bag-like, flattened or wormlike, and consists of head, trunk and foot. Phylum Rotifera is composed of three groups; Monogononta, Seisonidea and Bdelloidea.

Monogononta represents the major portion of the phylum Rotifera (more than 77% of the global Rotifers (Segers, 2007) and above 90% of the Indian Rotifers (B. K. Sharma, 1998) belongs to the subclass Monogononta). They are both free-swimming and sessile forms and have only one gonad as the name Monogononta indicates. Males of Monogononta are small; hence the name dwarf males developed from small haploid eggs (Shiel, 1995) and males are not observed in many of the Monogononts. Collothecacea, Flosculariacea and Ploimida are the orders coming under the subclass Monogononta (Smith, 2001).

Rotifer is a filter feeder (feed algae, microscopic organisms and dead materials); some are generalized feeders and specialized feeders. The filtration capacity of rotifers is not based on the microorganism type; it is based on the size. Based on the filter-feeding, the rotifers are divided into three groups (Chen, 2020). The first group feeds on suspended material up to 1–15µm in size (*Conochilus* and *Keratella*), the second group preys on large grain-sized species (*Ascomorpha, Gastropus, Polyarthra, Synchaeta* and *Tricocerca*) and the third group feeds based on the nature of the food that is dominant in the water. *Brachionus, Colurella, Cephalodella*, *Lecane*, *Lepadella, Macrochaetus, Monostyla* and *Trichocerea* were the most common rotifers seen in nutrient rich water.

Environmental factors influence the sex determination of rotifers, which show sexual, asexual, and cyclically parthenogenetic mode of reproduction. The Seisonidea

Rotifers are amphimictic and reproduce sexually. Bdelloid Rotifers (males not found) reproduce asexually by parthenogenesis (Welch & Meselson, 2000) and Monogonont Rotifers reproduce both sexually and asexually and show alternation of generations. Amictic females produce daughters (mictic/amictic) by parthenogenesis, mictic females produce males through parthenogenesis; when mictic females are not fertilized by males, resting eggs are produced which hatch into amictic females. Production of mictic females is higher during high temperature (Birky Jr, 1971). Rotifers consist of both sensitive and tolerant groups, many of them are least sensitive to the pesticide and acidification.

Rotifers e.g., Genus *Brachionus* (Grosell, Gerdes, & Brix, 2006; Janssen, Rodrigo, & Persoone, 1993; Preston, Snell, Robertson, & Dingmann, 2000) and *Lecane* (Pérez-Legaspi & Rico-Martínez, 2001) are widely used in the toxicological study because of their short life cycle, easy handling and its high sensitivity to toxins.

1.1.4.1.1.1. Morphology of Rotifers

Corona: The head bears a two-segmented wheel-like organ called corona (ciliated or funnel-shaped), which helps in locomotion and food collection. Ciliary lines at the anterior margin called trochus and at the posterior margin called cingulum are important features for species-level identification.

Integument: The rotifers may be loricate or illoricate. A lorica is a strong integument that covers the body of rotifers. There are different shaped loricas that vary from one species to another, making it easier for taxonomists to identify rotifer species.

Feet and toes: The majority of the rotifers have a foot with one or two toes for attachment and locomotion. Feet and toes are also important for their species-level identification.

Mastax: Pharynx with jaws (trophi) is called mastax. It is an important calcified part involved in the digestion of food particles and having a rod-like structure called fulcrum located below the trophi and it supports two rami. Unci is located on the outer surface of the rami and is attached to the two manubria.

Trophi: Trophi is located just below the mouth and found in almost all rotifers. Seven types of trophi are seen in rotifers (Shiel, 1995), and are an important systematic character for identification.

a. **Malleate:** Short fulcrum with 4-7 toothed unci. Powerful rami and manubria help to cut and chew the food.

b. **Virgate:** This is often asymmetrical with long fulcrum and manubria. Rami broad, unci broad with small teeth.

c. **Cardate:** Broad fulcrum with lyre shaped rami and having numerous epipharynx elements.

d. **Forcipate:** Seizing type, looks like pincers and can be expelled from the mouth. Curved rami, long and flat manubria, unci with teeth.

e. **Incudate:** Seizing type, pincer like, rami long and curved. Fulcrum slender and short, manubria and unci are absent.

f. **Uncinate:** Tearing type, well developed rami, unci bear 3-5 pairs of teeth, weak or degenerate fulcrum and manubria.

g. **Ramate:** Grinding type, unci broad, curved, toothed and grooved. Manubria and rami are absent.

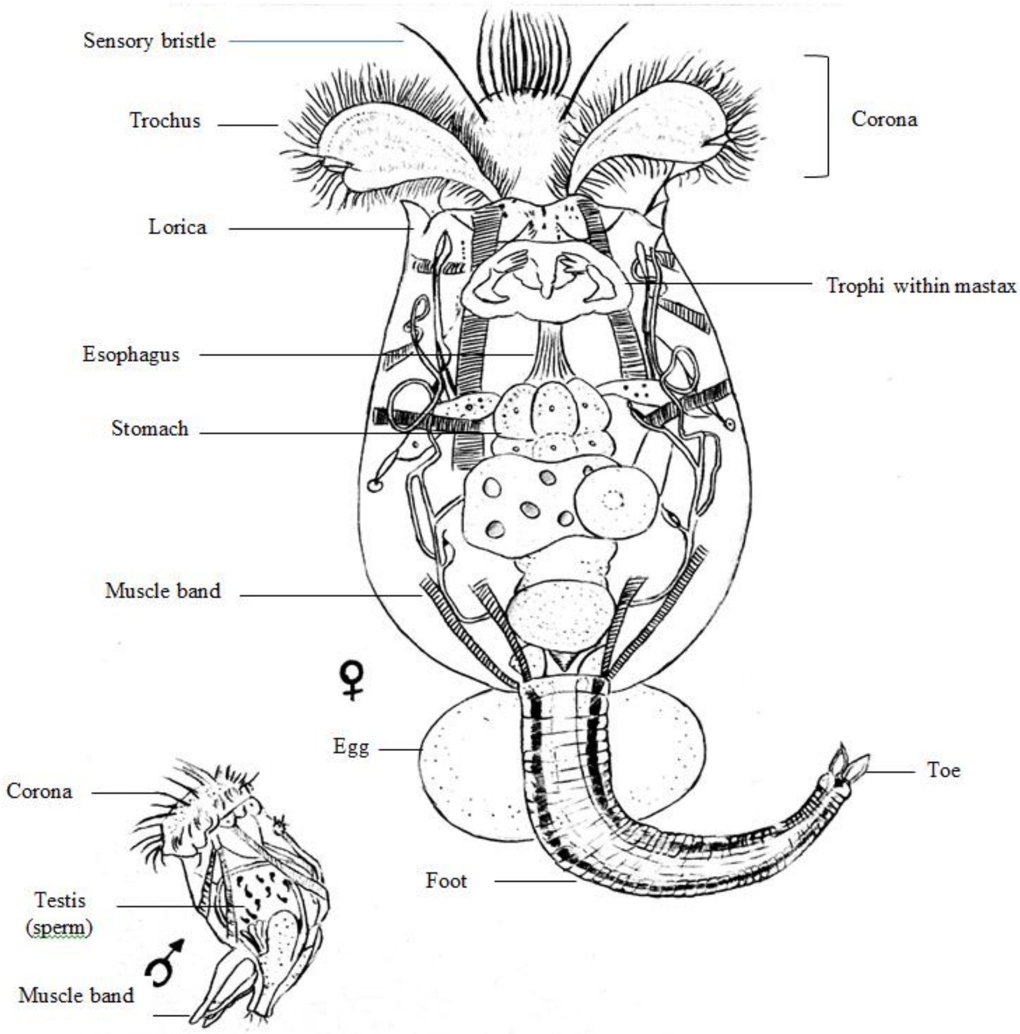


Figure 1.1. Morphology of a Rotifer modified from W Koste, 1980

1.1.4.1.2. Cladocera

The Order Cladocera belongs to the class Brachiopoda, a group of primitive micro crustaceans that occupy a central place in the aquatic food web and acts as an active grazer and plant food for planktivorous animals and fishes. Cladocera, commonly called "water fleas," constitutes a dominant group of Zooplankton (mostly freshwater) size ranging from 0.2-0.5 mm (majority of them are transparent). The order Cladocera is divided into 4 suborders; Anomopoda, Ctenopoda, Onychopoda and Haplopoda (Dodson & Frey, 1991), and consists of 11 families; Sididae, Daphniidae, Moinidae, Bosminidae, Macrothricidae, Chydoridae, Holopedidae, Polyphemidae, Cercopagidae, Podonidae, and Leptodoridae (Michael & Sharma, 1988).

Dispersal capacity and the ability to survive environmental stress are the main factors controlling the distribution of Cladocera (Brooks & Dodson, 1965). The mode of reproduction and the ability to produce dormant eggs stimulate dispersal capacity (A. Korhola, & Rautio, M., 2001). Cladocera reproduces both sexually (gamogenesis) and asexually (parthenogenesis); parthenogenetic females lay eggs, store them in their brood pouches, and release juveniles. Gamogenesis releases resting eggs, which are covered by a thick chitinous envelope forming "ephippium" (A. Korhola, & Rautio, M., 2001; Michael & Sharma, 1988) and it enhances the dispersal rate. Different stages are seen in the life cycle, juveniles look like adults (omit their size) and undergo a series of moulting. The Cladocera developed from diapausing eggs is always female, except for *Daphniopsis ephemeralis*.

Cladocera are more sensitive to trophic changes, and many researchers use them as a model organism to study eutrophication because some species are abundant in such waters. Branchiopoda are tools for studying past climate and environmental changes, so researchers are also making the possibility of studying paleontology using Cladocera (A. Korhola, & Rautio, M., 2001).

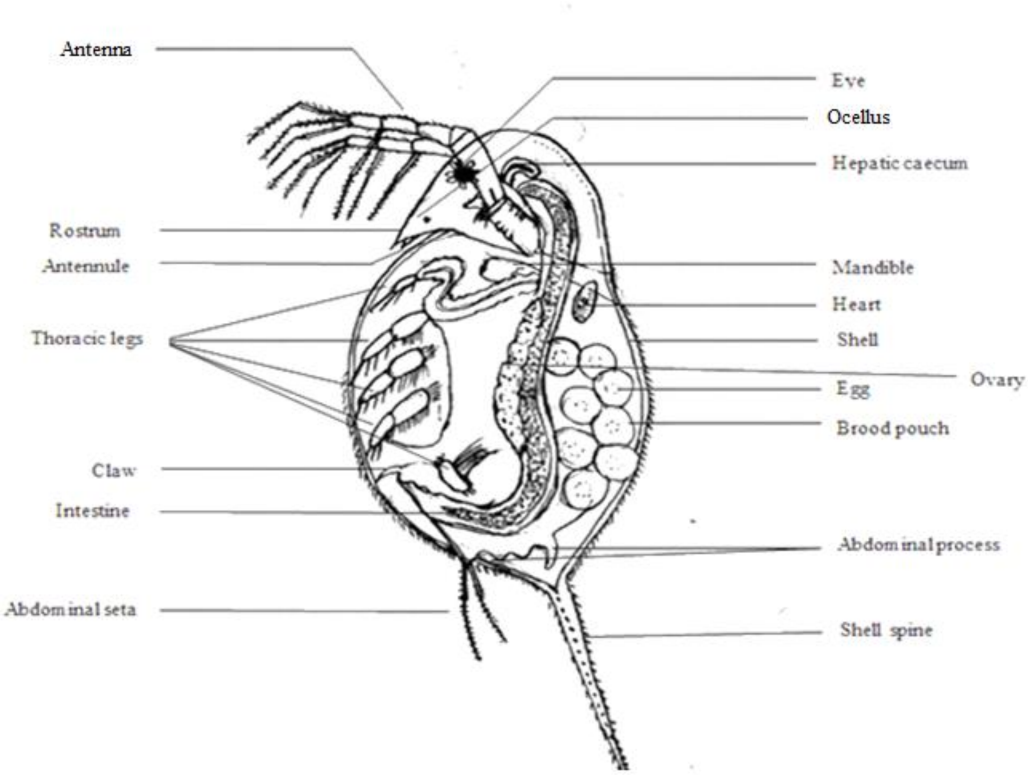


Fig 1.2: Morphology of a Daphnid

1.1.4.1.2.1. Morphology

Carapace: The majority of Cladocera's body is covered with a carapace (except the head), which exists in a different shape, and some taxa have spines or hairs. The family Polyphemidae, Leptodoridae, Podonidae and Cercopagidae have carapace that covers only the brood chamber (A. Korhola, & Rautio, M., 2001).

Head: Head extends anteriorly and contains a conspicuous organ, **compound eye**. **Ocellus** is present in some genera and the size and position of the ocellus in relation to the eye and rostrum is the key feature for the identification of some taxa.

Antennule: It is a simple structure containing olfactory setae. The size, position of the antennule is different in different families. For example, the antennule of the family Moinidae is in the ventral side of the head and that of the Macrothricidae is in the anterior region. The antennule of the family Daphnidae is small and immobile, while that of Moinidae and Macrothricidae is long and mobile.

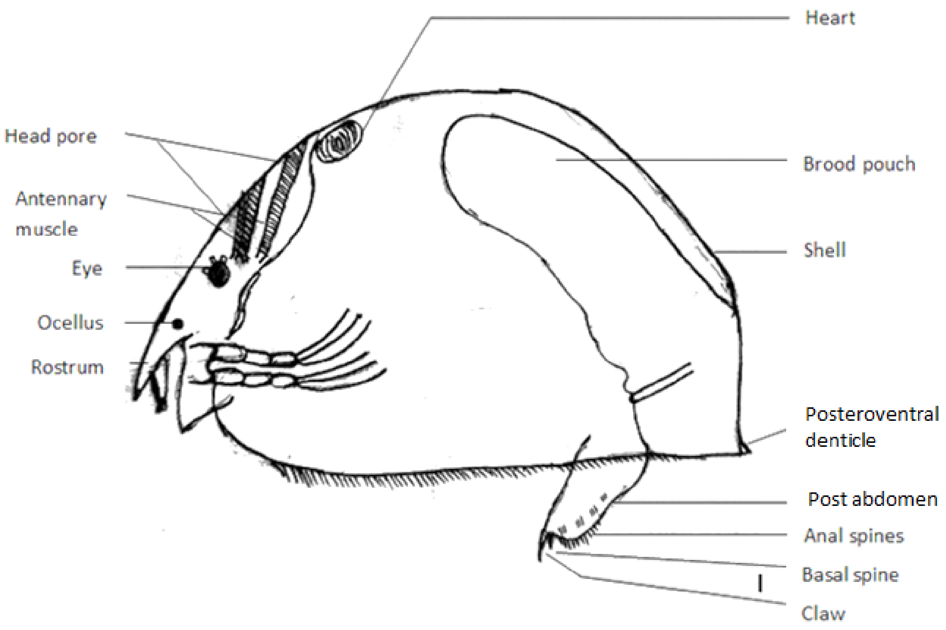


Fig 1.3: Morphology of a Chydorid

Antennae: The antennae, mostly biramous, is located at the posterior margin of the head. The number of segments, its organization per ramous and the number of setae are consistent in each species and vary from species to species. Therefore the position, arrangement and number of segments are important in the taxonomic identification.

Fornix and vertex: Fornix is a furrow at the area of insertion of the antenna which bolsters the head and the antenna and is an important feature for species level identification. Vertex is the anterior-most part of the head prior to the eye.

Post abdomen: The trunk forms a broad part called the post abdomen; it bears the anus. It also contains claws and abdominal setae, the size and structure of which also serves the taxonomic importance. It is an essential part for the identification, the majority of the taxonomic identification at the species level requires the clear examination of the shape, arrangement and number of the anal spines, number and location of the lateral setae.

Appendages: Normally, the Cladoceran have 5 or 6 pairs of trunk appendages; the first pair of legs are modified and contain hooks in males (Michael & Sharma, 1988). In some families (e.g. Sididae), the legs are similar, differences are found in other families.

1.1.4.1.3. Copepoda

Copepods are small crustaceans that inhabit almost all freshwater and marine habitats, either free-living, symbiotic, or parasites. They are an important group that plays a significant role in the aquatic food web as a source of food for commercially important fish, especially larvae. The diet of most free-living Copepods includes phytoplankton, bacteria and other planktonic animals such as protozoans, Rotifers and small Cladocerans (Brandl, 2005; Sommer, 2005). Only sexual reproduction occurs, and fertilized eggs are usually carried in a pair of sacs attached to the abdomen.

The body of the Copepoda is covered with a thin transparent exoskeleton, and is divided into metasome and urosome. Metasome consists of head and thorax and the head contains two pairs of antennae [first antennae (antennule) and second antennae], mandibles, maxillae and maxillulae. The thorax contains six pairs of appendages, maxillipeds. The subclass Copepoda has 10 orders, of which only five orders namely Calanoida, Harpacticoida, Cyclopoida, Gelyelloida and Siphonostomatoida, have been reported in freshwater (Boxshall, 2008). Freshwater Copepod of the world consists of 552 species of Calanoida, 1124 species of Harpacticoida, 1096 species of Cyclopoida, 40 species of Siphonostomatoida and only two species of Gelyelloida.

1.1.4.1.3.1. Order Calanoida

Calanoids are an important part of the diet of fish larvae or adults and act as an excellent indicator of water quality. They can be easily distinguished from other Copepods by the presence of the antennae, which are about half the length of the body, and the biramous fifth leg. Freshwater Calanoid Copepod contains four families; Diaptomidae, Centropagidae, Temoridae and Aetideidae. Family Diaptomidae is the dominant family, 80% of the Calanoid Copepods belong to this family. 14% of freshwater Calanoid Copepod of the world belongs to the family Centropagidae and only 5% belongs to Temoridae. Family Aetideidae is the smallest family having only two species worldwide (Boxshall, 2008).

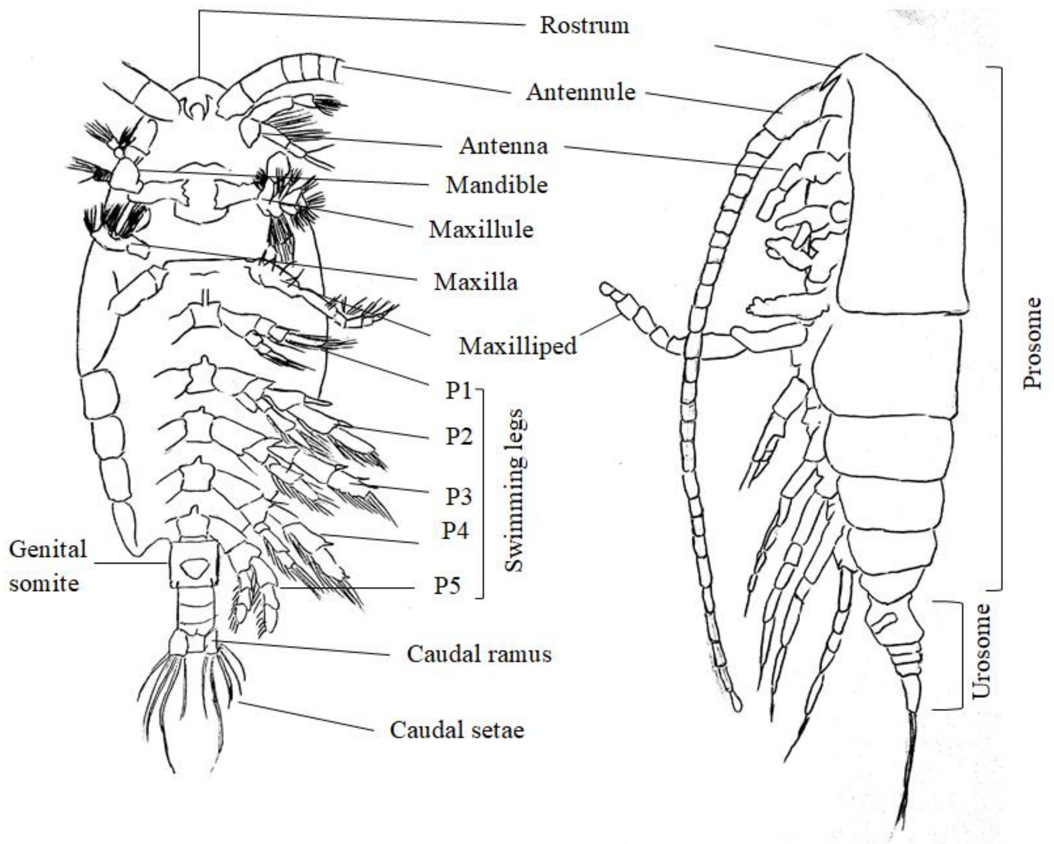


Fig 1.4: Morphology of Calanoid Copepod

1.1.4.1.3.2. Order Harpacticoida

There are 1124 species of freshwater Harpacticoids belonging to 12 families in the world: Canthocamptidae, Parastenocarididae, Ameiridae, Miraciidae (Diosaccidae), Ectinosomatidae, Phyllognathopodidae, Harpacticidae, Chappuisiidae, Huntemanniidae, Laophontidae, Cletodidae and Darcythompsoniidae are the families. Canthocamptidae is the largest family. 56% of the identified Harpacticoid Copepods belong to this family. Family Darcythompsoniidae is the smallest family with only one representative species (Boxshall, 2008).

1.1.4.1.3.3. Order Cyclopoida

Order Cyclopoida is the dominant group of Zooplankton having 1096 freshwater species worldwide in 5 families (Cyclopidae, Oithonidae, Ozmanidae, Lernaeidae and Ergasilidae). Cyclopidae is the dominant family constituting 73% of the total freshwater Cyclopoid Copepods. Ozmanidae is the smallest family with only two representatives (Boxshall, 2008). Genus Mesocyclops of the family Cyclopidae is now being exploited by scientists to control mosquitos.

1.1.4.1.3.4. Order Siphonostomatoida

Siphonostomatoida contains 40 freshwater species in 3 families (Lernaeopodidae, Caligidae and Dichelesthiidae) worldwide, and are found only as parasites in fish. 95% of the freshwater Siphonostomatoida belongs to the family Lernaeopodidae, other two families have only one freshwater representative (Boxshall, 2008).

1.1.4.1.3.5. Order Gelyelloida

Order Gelyelloida contains only two global freshwater representatives in a single-family called Gelyellidae (Boxshall, 2008).

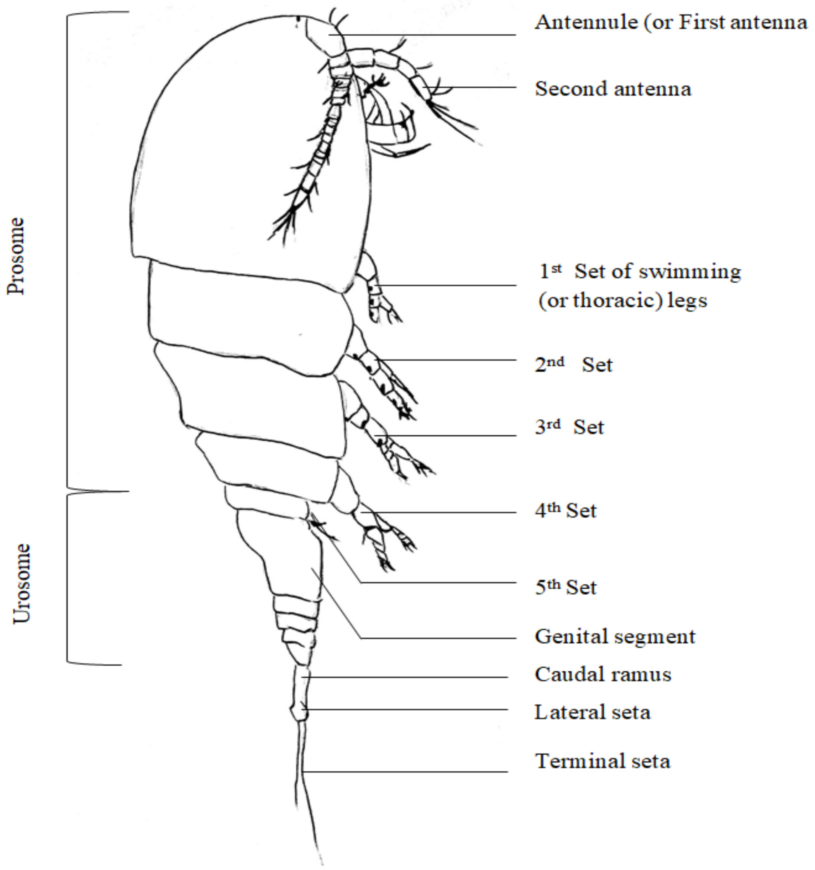


Figure 1.5. Morphology of Cyclopoid Copepod

1.1.4.1.4. Ostracoda

Ostracoda belongs to the class Crustacea of the phylum Arthropoda, and is highly diverse, living in all types of marine and freshwater habitats. The body of Ostracoda is compressed laterally, and is covered with bivalve carapace, the head is indistinguishable, and has seven or fewer thoracic legs. Adult Ostracods range in size from 0.5 mm to 3 mm. They have excellent fossil records as they have a calcified, bivalaved carapace. About 2000 species of Ostracoda belonging to 13 families, Cyprididae, Candonidae, Ilyocyprididae, Notodromadidae, Limnocytheridae, Leptocytheridae, Xestoleberidae, Cytheruridae, Loxoconchidae, Hemicytheridae and Terrestricytheridae have been recorded from the world's freshwater habitat (K. Martens, Schön, I., Meisch, C., & Horne, D. J., 2007). About 50% of the reported global freshwater Ostracoda belong to the Cyprididae family and 25% to the

Candonidae family. The other 11 families represent only 25% of the global freshwater ostracod diversity.

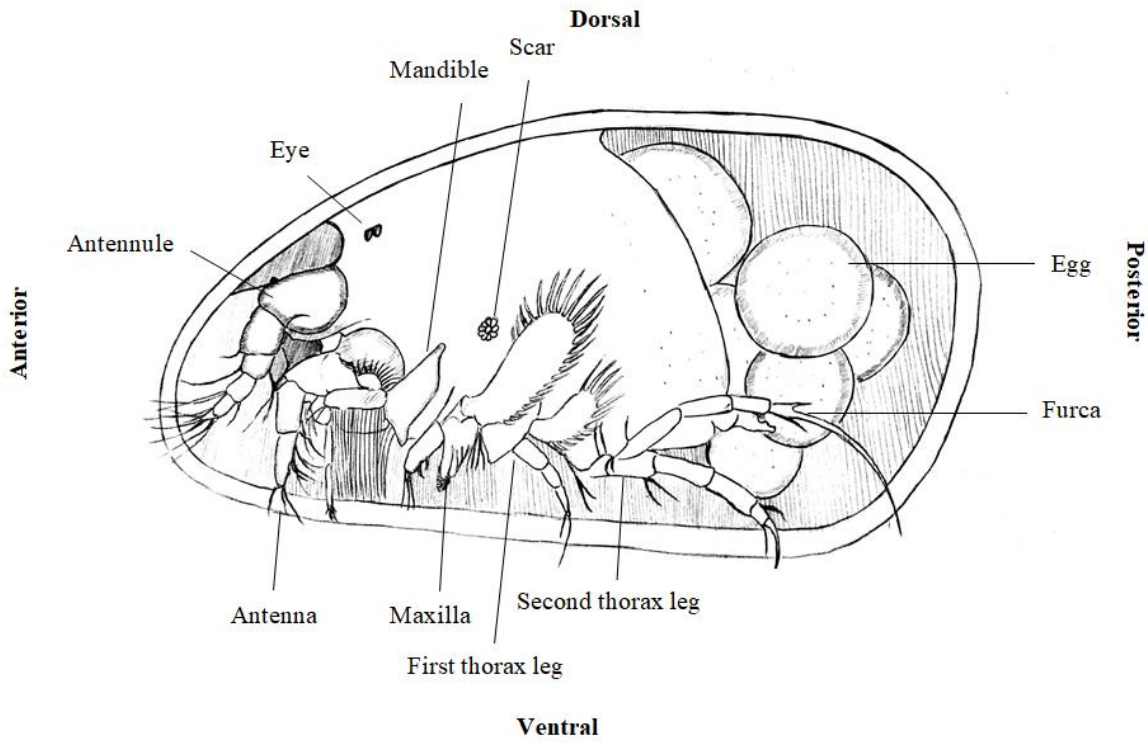


Figure 1.6. Morphology of Ostracod

1.1.5. Physical and Chemical Parameters of the Water

Water quality is the measure of water quality compared to the needs or purposes of living things. The most popular definition of water quality is "the physical, chemical and biological properties of water." Physical parameters of the water include colour, taste, temperature, turbidity, electrical conductivity and total dissolved solids. pH, acidity, alkalinity, chloride, calcium, magnesium, iron, sulphate, nitrate, dissolved oxygen, biochemical oxygen demand and chemical oxygen demand are important chemical parameters.

1.1.5.1. Water Temperature

Water temperature is an important factor that regulates the metabolism of aquatic organisms and all organisms have a preferred range of temperature. The water temperature increases with an increase in air temperature. This in turn alters the dissolved oxygen level (Morrill, Bales, & Conklin, 2005), which is harmful to the fauna. Colder temperature holds more dissolved oxygen than warmer temperature and higher temperature eliminates certain cold-water organisms (Lessard, 2003). The alteration in the water temperature changes the chemical and biological processes; it affects the photosynthetic rate, organism's metabolic rate, reproductive success and responsiveness. Higher temperature increases the electrical conductivity by dissolving more minerals from surrounding rocks. Certain compounds are noxious to aquatic fauna at higher temperature by reducing the tolerance limit of organisms. Turbidity is also a factor that influences the water temperature, which increases the temperature of the water because the suspended particle absorbs more heat from sunlight, which reduces the amount of dissolved oxygen in the water and adversely affects the organism.

1.1.5.2. pH

pH means "potential for hydrogen." All the organisms have a certain range of pH, most of the aquatic organisms adopt a pH range of 6.5 - 9.0 (Boyd, Tucker, & Somridhivej, 2016). The freshwater pH usually lies between 6 - 8, pH variation noticed throughout the day due to the photosynthesis and respiration (Wurts, 1992). When the pH is too high or low, it affects the solubility and toxicity of chemicals (Thurston, Russo, & Vinogradov, 1981) and stresses the organisms, thereby lessening the survival rate. The metals such as copper and zinc toxicity to the algae *chlorella sp.* increased with increase in pH (Wilde, 2006), an example of pH-based toxicity.

1.1.5.3. Turbidity

Turbidity is a measure of the transparency loss through the existence of suspended particles; we can predict the quality of water by measuring the turbidity. Turbidity can be caused by a number of factors which include deposits from erosion, algal growth, phytoplankton and waste discharge. Turbidity induces the water temperature because the suspended particle absorbs more heat from the sunlight, which reduces the dissolved oxygen content of water which adversely affects the organisms. Due to the presence of large amounts of suspended particles, plants do not get enough sunlight to photosynthesis (Jewson & Taylor, 1978), which further decreases the dissolved oxygen (Lloyd, Koenings, & Laperriere, 1987).

1.1.5.4. TDS

TDS (Total Dissolved Solids) is a measure of total inorganic salts and some organic matter that is dissolved in water. Inorganic salts mainly include calcium, magnesium, sodium, potassium, bicarbonates, chlorides and sulphates. These salts come from both natural and manmade sources like agricultural runoff, urban runoff and waste discharge. The higher concentration of TDS is not a serious concern (except the presence of copper/lead), but it causes aesthetic problems. The higher TDS affects the taste and hardness of water and low TDS indicates the good quality of water.

1.1.5.5. Electrical Conductivity

The measurement of ionic activity of a solution in terms of its capacity to conduct current is the electrical conductivity; this power is brought by the conductive ions present in water. It is a good indicator of salinity and increases with an increase in temperature. The presence of contamination and salt increases the conductivity of water. The distilled water is having a conductivity 1 to 5 µ mho and sudden increase in the water conductivity is an indication of the pollutant addition. Conductivity also gives information about the suitability of the water for various purposes, water having above 20 µ mho conductivity is not suitable for irrigation purposes (Trivedy & Goel, 1984).

1.1.5.6. Acidity

Acidity is a measure of the ability of water to neutralize bases mainly due to the existence of acids (carbonic acid, acetic acid) and the salts of weak bases and strong acids (aluminium sulphate, ferrous sulphate etc.). Acidity of the water is mainly increased by the addition of acid-producing wastes (Trivedy & Goel, 1984). Acidity normally increases during rain due to the runoff.

1.1.5.7. Alkalinity

Alkalinity is a measure of the ability of water to neutralize strong acids due to the existence of hydroxyl ions which can unite with the hydrogen ion. The higher level of alkalinity helps to buffer the rapid pH changes and save aquatic life. Dissolution of CO_2 is the main reason for alkalinity in natural waters. Runoff during the rain decreases the alkalinity through increase in acidity. Human activities like mining, construction et cetera alters the alkalinity of water; higher alkalinity in water than the soil makes the water unfit for irrigation.

1.1.5.8. Total Hardness

Hardness is a property of water in which the amount of dissolved minerals is high, especially calcium and magnesium. Strontium, iron and manganese make water hard to some extent. This increases the boiling point of the water and prevents lather formation with detergent/soap. Therefore, household cleaning with hard water feels unsatisfactory. However, hard water is not dangerous; instead, it gives some amount of calcium and magnesium to the human diet.

1.1.5.9. Calcium

Calcium is found naturally in water, which leaches from rocks. It is an important determinant of hardness and the quantity gets varied based on the nature of rocks. Sewage disposal and other industrial effluence increase the calcium of water. There is no adverse effect on humans reported due to the high calcium level; instead, it adds some calcium to human dietary needs.

1.1.5.10. Magnesium

Magnesium is present together with calcium in all types of water and its concentration is less than calcium. The main source of magnesium is rock. Industrial wastes and sewage increase the magnesium level hazardously. A higher amount of magnesium in the drinking water causes some health hazards (Kožíšek, 2003).

1.1.5.11. Chloride

Chloride is present in small concentrations in all types of water. The main man made source of chloride in water is domestic sewage, industrial effluents and fertilizers; the higher concentration of chloride content of water is an indicator of pollution by sewage (Kelly, Panno, & Hackley, 2012). It induces the electrical conductivity and corrosivity of water. There are no reports on the health effect of a higher concentration of chloride, but a concentration above 250 mg/L makes a difference in taste.

1.1.5.12. Iron

Iron occurs in two forms; insoluble ferric iron and soluble ferrous iron. The high concentration of iron in water makes the metallic taste and colour change in water. Iron in the water is considered as a secondary contaminant by the Environmental Protection Agency (Colter & Mahler, 2006).

1.1.5.13. Nitrate

As a component of protein, nitrogen is essential for all living things and is found in different forms in the environment. Nitrate is the highest oxidized form of nitrogen, and its source in water is both natural and anthropogenic (domestic sewage, fertilizers, human and animal wastes etc.). Nitrate in the drinking water leads to Methemoglobinemia in infants (Avery, 1999). The higher concentration of nitrate causes eutrophication which inhibits the growth of many organisms through decreasing dissolved oxygen and prevents light from entering into the water (Lund, 1972).

1.1.5.14. Sulphate

Sulphate is naturally found in water through the decomposition and combustion of organic matter, the oxidation of sulfides, volcanic activity, and mineral weathering. The discharge of domestic sewage and industrial wastes increases its concentration. Sulphate accelerates the biochemical movement of carbon, nitrogen, and phosphorus, and land use and climate change disrupt the global sulphur cycle. As a result, sulphate pollution can seriously affect aquatic flora and fauna (Zak et al., 2020).

1.1.5.15. Carbon Dioxide (CO_2)

CO_2 enters the water through biological processes such as photosynthesis, in situ respiration and organic carbon digestion (Duarte & Agustí, 1998; Mayorga et al., 2005), and it reacts with water forming carbonic acid (Tho & Ha, 1984). It is intimately connected to the water pH. pH decreases as the concentration of CO_2 increases (Tucker & D'Abramo, 2008). Water with a pH greater than 8.5 contains no CO_2.

1.1.5.16. Dissolved Oxygen (DO)

Dissolved Oxygen is a measure of the amount of free oxygen available in the water for living organisms. Oxygen enters the water through photosynthesis and dissolution from the atmosphere (Oswald & Gotaas, 1957). Aquatic organisms require different DO concentrations. Some are sensitive to changes in DO concentration, and some can tolerate variations. A large decrease or increase in the DO content of water is harmful to all aquatic organisms. Eutrophic lakes contain a lot of organic matter, with a lot of decomposition at the bottom (Lund, 1972). This decomposition uses oxygen and reduces the amount of free oxygen in the water (Viet, Bac, & Huong, 2016). Higher temperature, high turbidity and the presence of oxygen-requiring wastes are other causes of depletion of dissolved oxygen in the water.

1.1.5.17. Biochemical Oxygen Demand (BOD)

BOD is the amount of oxygen required to break the organic matter by the aerobic microorganisms and it is a good measure of water quality (Mohamed, 2015). When the amount of organic matter such as manure, sewage, wastes, dead plants and leaves are more, aerobic bacteria use the majority of the dissolved oxygen of water to decompose the matter, reducing the amount of free oxygen, thus changing the structure of aquatic life.

1.1.5.18. Chemical Oxygen Demand (COD)

COD is defined as the equivalent amount of oxygen needed to oxidize aquatic organisms, which can be used to monitor the biological contamination of water (Latif & Dickert, 2015). It gives more accuracy than BOD because it measures oxygen required to convert almost all organic substances to carbon dioxide. Oxygen demand testing measures the effect of a combination of substances and conditions rather than determining the concentration of a particular substance. Since the need for oxygen is not pollution, it is not a direct threat to fish or other organisms. However, depleted oxygen levels pose an indirect threat to organisms (Boyles, 1997).

1.2. Review of Literature

Aquatic biodiversity has great economic and aesthetic value and is primarily responsible for maintaining and supporting overall environmental health. Water use, water scarcity as well as pollution are increasing as the population grows; so many scientists and researchers around the world have been studying water and related problems. Zooplankton has a close relationship with the surrounding environment throughout their life cycles and shows rapid changes in their population when there are disturbances such as eutrophication. Numerous studies have been examined and reported on Zooplankton and the physical and chemical parameters of water in various parts of the world.

1.2.1. International Status

Hanazato (2001) studied the effect of toxic chemicals to the Zooplankton, large-sized Cladocerans (*Daphnia*) shows more sensitivity to carboryl insecticide and small-sized Cladoceran and Rotifers are less sensitive. DDT and arsenate are more sensitive to *Bosmina* (small Cladoceran) than larger Daphnia. Havel (2004) studied the mechanism of dispersal in the Zooplankton; he proposes four ways of Zooplankton distribution; human-mediated, animal-mediated, through wind and dispersal along with the water flow. A similar study was done by Cohen (2003) in the artificial pool to monitor the rate and process of dispersal. Gyllström (2004) conducted an overview of the dormancy of freshwater Zooplankton and clearly defined the cause and advantages of dormancy of freshwater Zooplankton, Copepoda, Cladocera, and Rotifera. Boxshall (2008) analyzed the zoogeographical distribution of global freshwater Copepod (2814 species) and provided a clear list of Copepod orders that we can easily understand. K. Martens, Schön, I., Meisch, C., & Horne, D. J. (2007) did a similar job of listing the global freshwater Ostracoda's zoogeographical distribution. Rautio (2010) studied the effect of UV radiation on the Zooplankton ecology to monitor the global change to the aquatic ecosystem. Jeppesen et al. (2011) studied the importance of the Zooplankton as an indicator of water quality from published works.

Like all living things, the survival of the Zooplankton is closely linked to the surrounding biotic and abiotic components. An (2012) studied the community structure of Zooplankton and the physical and chemical parameters of water, including the phosphate content of Lake Hulun in China, and based on the results they classified the lake as mesotrophic/eutrophic. Gonçalves (2012) estimated the seasonal and structural patterns of Zooplankton using a fatty acid profile. They found that the difference in fatty acid composition was due to differences in food sources. Choi et al. (2014) studied the influence of macrophytes on Zooplankton diversity and found the obvious relationship of Zooplankton with submerged and free-floating plants.

Azevêdo (2015) used Zooplankton as a tool to monitor the trophic status of subtropical reservoirs, as Zooplankton is a water quality indicator. Abdulwahab and Rabee (2015) studied the Zooplankton diversity and factors affecting the distribution of Zooplankton in the Tigris River in Baghdad region, Iraq. Rotifers were found to be the most abundant Zooplankton, and it was noted that water temperature, electrical conductivity, TDS, and oxygen were the major factors controlling their survival. Diel (2020) conducted a study on the predator-prey interaction of Zooplankton and found that Zooplankton had an irresistible resistance to reacting to the kairomones produced by the predator. Karpowicz (2020) reported abnormal changes in the structure of Zooplankton species in low oxygen areas and some Zooplanktons were found to live in anoxic conditions. Eskinazi-Sant'Anna (2020) examined the local and regional factors that make up the Zooplankton community. They found that the diversity, richness and abundance of Zooplanktons were affected by the area of the lake and the macrophyte cover. Freiry (2020) noticed a change in the diversity pattern of the Zooplankton based on the vegetation type in the Southern Brazilian Coastal Plain.

Da Silva Brito et al. (2020) studied the beta diversity of Rotifers and Cladocerans in the littoral and pelagic zones of the 50 different floodplain lakes in Brazil, with the highest racial richness in the littoral zone and the lowest in the pelagic zone. This study reveals the importance of adding samples from the littoral zone for accuracy in the study of Zooplankton biodiversity, as the inclusion of the littoral zone is rare in studies. P. Liu, Xu, S., Lin, J., Li, H., Lin, Q., & Han, B. P. (2020) studied the impact of urbanization on the Zooplankton community by estimating the beta diversity in 25 permanent reservoirs over three seasons, and noted the homogenization of the Zooplankton community as a result of urbanization. Tiang-Nga, Sinev, and Sanoamuang (2020) studied the diversity of Cladocera at a Ramsar site in Thailand and identified 58 species of Cladocera, three (*Chydorus idrisi*, *Karualona kwangsiensis* and *Streblocerus serricaudatus*) of which were recorded for the first time in Thailand. Freiry (2020) evaluated the community structure, examined the integrated patterns between the active and inactive life stages of Zooplankton, and recorded 77 species of Zooplankton. It was found that active communities have higher species abundance and richness compared to dormant communities.

Shurin (2020) studied the fluctuations in Zooplankton diversity as a result of chemical and thermal changes in 56 temperate lakes in North America and Europe. They found an increase in the abundance of species as a result of climate change and the extinction of some Zooplankton species due to climate change. Florencio (2020) also studied the influence of climate change on the diversity, and abundance of Zooplankton in Mediterranean temperate pools. Da Silva, Lansac-Tôha, Lansac-Tôha, Sales, and Rocha (2020) estimated the beta diversity pattern of Rotifers, Cladocerans and Copepods in a semiarid river ecosystem. They used variation partitioning and distance-based redundancy analysis to explain the relationship between beta diversity and variables, and concluded that spatial and environmental factors alter the beta diversity pattern of Zooplankton in aquatic habitats. Qin (2020) conducted a comparative study of the diversity of Zooplankton and fungus in six sub-lakes (2 eutrophic, 3 mesotrophic, and 1 oligotrophic sub-lakes) in the Poyang Lake watershed, China. They found that anthropogenic activities endanger biodiversity and induce harmful contents and pathogens into the water. N. Kuczyńska-Kippen (2020a) studied the impact of anthropogenic activity on Zooplankton diversity and the survival of rare species, and reported high Zooplankton abundance and rare species in pools of low human activity. Sendek (2020) estimated the diversity of Zooplankton and weed bed macro invertebrates in a floodplain with high anthropogenic influence. Eighty-eight percent of the collected Zooplanktons are group Copepoda, and the rest are Cladocera and Rotifera, all of which show seasonal variation. Islam (2020) studied the diversity and abundance of Zooplankton in relation to the physical and chemical parameters of three pools and identified 33 species of Zooplankton. The dominant group is Rotifers, which have been found to correlate with certain quality parameters and the high water temperature favours Zooplankton growth.

N. Kuczyńska-Kippen (2020b) studied the diversity of Zooplankton in Polish waters, identified some pollution indicator species, and concluded that water was on the verge of pollution due to its presence. Setubal (2020) conducted a study on the effect of salt on the diversity and biomass of freshwater Zooplankton by adding sea salt. They opined that high Zooplankton productivity is determined by functional diversity and that environmental factors positively affect even in saline conditions. Patterson (2020) studied the anthropogenic activity and the effects of hurricanes and floods on the structure of the Zooplankton community. They also assessed the number of dormant eggs in the study area. They found that the number of dormant eggs was low, preventing the community from re-establishing itself after environmental stress. Espinosa-Rodríguez (2020) observed the productivity of plankton after the removal of a macrophyte (*Egeria densa*) from water and found that Zooplankton was depleted due to changes in habitat and fluctuations in turbidity, carbonates, dissolved oxygen, and nitrates. Amaral (2020) conducted an experimental study on the diversity of Zooplankton, epipelon and phytoplankton, and found that oligotrophication causes significant changes in plankton diversity. Goździejewska (2020) studied the effects of recreational fishing on the Zooplankton community composition of three mine drainage system reservoirs. They estimated the diversity of Zooplankton in areas with three different fishing methods. High diversity of Zooplankton has been recorded in the sustainable fisheries sector, while diversity in the catch-and-release area has been found to be low.

Yang (2020) studied variations in the structure of Zooplankton using the eDNA-based method to improve the environmental condition assessment of aquatic ecosystems. Chen (2020) compared the Zooplankton biodiversity of the restored and unrestored area of a lake. It has been found that the number of macrophytes increases after the restoration of the lake, which increases the Zooplankton biodiversity and water quality. Xiong (2020) proposed advanced methods to avoid current technical problems in order to make the biodiversity survey more accurate, using the DNA-based method. Divya et al. (2020) conducted a study on the Zooplankton diversity of two water storage lakes to monitor the impact of a water transfer project on biodiversity. 133 species Zooplankton found; the dominant species were different in the two lakes. The study also examined the habitat preferences, changes in community structure, and the extinction of certain taxes.

Schmidt (2020) studied the impact of dam construction on aquatic biodiversity by observing changes in Zooplankton diversity and found that changes in topography alter the Zooplankton species composition. Bazzuri (2020) studied the impact of saltwater intrusion on aquatic habitats due to the construction of drainage canals, observing changes in the Zooplankton species composition. 166 species of Zooplankton were recorded, Rotifer was the most diverse group, and the saltwater made a significant difference in Zooplankton abundance, species structure, and reproduction. Temperature and conductivity further influence the Zooplankton community of the Salado River. N. Kuczyńska-Kippen, Špoljar, M., Zhang, C., & Pronin, M. (2020) used Zooplankton as a tool for assessing latitudinal differences in northern and southern temperate European countries. Water transparency has become a more critical factor than variation in latitudes, which positively affects littoral species and adversely affects Zooplankton abundance.

Zooplankton serves as an important food source for fish larvae. To determine the suitability of the pond for fish culture, Iloba and Arebun (2020) measured the abundance of Zooplankton and the quality of water in the pond and found that the pond contained enough plankton to obtain the best fish production. Obuid-Allah, S Moustafa, HM Hussien, M Gaber, and A Mohammad (2020) studied the distribution of Zooplankton in the Nile and found that it has the highest diversity in the winter and the lowest in the summer. Temperature, turbidity, pH, and dissolved oxygen were found to be the factors limiting the distribution of Zooplankton. Almeida (2020) reported that the quality of the four reservoirs located in the northern part of Portugal, which is free of human intervention, was improved based on the Zooplankton assessment and hydrological parameters and that minor changes in hydrological parameters were found due to natural phenomena.

Mojumder, Kibria, and Bhuyan (2020) studied the diversity of Zooplankton in the Halda River in Bangladesh and identified 35 species. They reported high Zooplankton levels in non-polluted areas and dangerously low levels near the industrial area as wastewater from industrial plants is discharged into the river. F. Tóth, Zsuga, K., Kerepeczki, É., Berzi-Nagy, L., Jakabné Sándor, Z., & Körmöczi, L. (2020) studied the effects of different feeds (fish-based, plant-based feeds, grains) given to fish in the Zooplankton species composition. Different feeds were found not to permanently change the structure of the Zooplankton community, suggesting plant-based feed as a more suitable alternative to fishponds than other supplementary feeds.

1.2.2. National Status

Studies related to Zooplankton are ongoing in India, some of which are mentioned here. Ahangar, Saksena, and Mir (2012) recorded 23 species of Zooplankton from Lake Anchar in Kashmir, which did not find the sensitive species recorded in the previous study, and found that the eutrophication of the lake eliminates sensitive species. Karuthapandi, Xavier Innocent, and Siddiqi (2012) studied the diversity of Zooplankton in a temporary pond in Hyderabad, Andhra Pradesh. 26 species of Zooplankton were recorded and found to be strongly related to light, pH and water temperature. P. Kumar, Wanganeo, Sonaullah, and Wanganeo (2012) studied the plankton diversity of two highlands, Himalayan ponds in Uttarakhand and reported 131 species of phytoplankton and 51 species of Zooplankton. High diversity of planktons was recorded as a result of the optimum range of environmental factors such as temperature and pH. Dalal and Gupta (2013) discovered 26 species of Zooplankton in two temple ponds in Assam.

Amsha Devi, Baskaran, and Suresh Kumar (2013) reported that the physical and chemical parameters of water significantly influence the Zooplankton abundance in the temple pond at Virudhunagar in Tamil Nadu. Negi and Mamgain (2013) estimated the biodiversity of Zooplankton in the Tons River in Uttarakhand and identified 23 species of Zooplankton, with Rotifers being reported as the dominant group among them. Nimbalkar, Kamtikar, Shinde, and Wadikar (2013) studied the Zooplankton diversity of Ambe Ghosale Lake in Maharashtra and found 36 species of Zooplankton, of which Rotifer was the richest group. Chari, Mahender, Kumar, and Rajashekhar (2013) Jose studied the diversity and abundance of Zooplankton in different seasons in the Nagulakunta water tank in the state of Telangana and reported that there was a lot of Zooplankton in the pre-monsoon period. P. Pandey, Sahu, Jha, and Shrivastava (2014) studied the diversity of macrobentic and algal fauna in the Limha Pond in Bilaspur as well as the biodiversity of Zooplankton. High diversity of Zooplankton was observed in June and low diversity in December.

Balai, Sharma, and Ujjania (2014) conducted a survey on the physical and chemical parameters of Jaisamand Lake, a man-made lake in Udaipur, and on the Zooplankton variety. Fifty-one species have been reported, of which Rotifer is the dominant group. Zooplankton shows maximum abundance from September to February as a result of increased phytoplankton abundance. Banerjee, Nur, and Barat (2014) conducted a comparative study of the Zooplankton in an animal waste integrated aquaculture pond with a nonintegrated pond in West Bengal, and found that adding cow dung and duck manure increased the abundance of Zooplankton, thereby increasing fish production. Bhanja et al. (2014) observed the plankton community in two uncontrolled ponds in West Bengal, pointing out that the two genera of Rotifera, *Keratella* and *Brachionus*, indicate eutrophication. Gadekar (2014) studied the chronological variation of the Zooplankton variety in a railway pond and identified 20 types of Zooplankton, including eutrophic indicators, and concluded that the pool was eutrophic. N Manickam et al. (2014) recorded 55 Zooplankton species from the Thoppaiyar Reservoir in southern India, and Rotifer was found to be the most dominant group.

S. M. Pawar (2014) studied the diversity and density of Zooplankton from three freshwater bodies around Satara in Maharashtra and recorded 66 species, with the highest Zooplankton population recorded during the summer. Jaiswal, Ahirrao, and Shejule (2014) conducted a survey on the diversity of Zooplankton at the Rangavali Dam in Nandurbar, Maharashtra, and reported 20 species, including 8 species of Rotifera, 6 species of Cladocera, 4 species of Copepoda and 2 species of Ostracoda. Biswas (2015) found that certain Physico-chemical parameters such as water temperature, dissolved oxygen, biological oxygen demand, chemical oxygen demand, phosphate, sulphate, and total hardness affected the entire Zooplankton population in Rabindra Sarobar, Kolkata. The Copepod was the most dominant, and the Rotifers showed high diversity and species richness.

Manickam et al. (2015) studied the Zooplankton diversity of Barur Lake in Tamil Nadu and recorded 47 species. They suggested the importance of understanding the density of Zooplankton for the success of aquaculture practices, and found that the lake was suitable for aquaculture due to the high productivity of Zooplankton. Dede and Deshmukh (2015) identified Rotifera as the most abundant group in the Zooplankton from Bhima River in the Solapur district of Maharashtra. H. K. Kumar, Kiran, and Narayana (2015) studied the diversity of Copepods in a sewage fed tank Bhadravathi taluk, Karnataka and documented 7 types of eutrophication indicator Copepods. Mahesh, Balakrishna, Surender Reddy, and Ravinder Reddy (2015) found seasonal variation in Zooplankton diversity in Kandlapally Lake, Telangana and the most common species are *Brachionus falcatus*, *Mesocyclops leukarti*, *Bosmina longirostris* and *Hemicypris fossulata*. M. Pandey, Shukla, Mishra, and Rai (2015) studied the diversity of Zooplankton in the Narmada River in Madhya Pradesh and observed the Copepod as the dominant group among the 42 species recorded.

Majumder et al. (2015) studied how water pollution in six different ponds in the town of Bankura in West Bengal affects the population of Zooplankton. Pollution has been found to significantly affect the survival of Zooplankton, and diversity is more in unpolluted water than in polluted water. Eighteen species were recorded and Cladocera was found to be the most abundant group. Ghosh and Biswas (2015) studied the diversity of Zooplankton in Ox-Bow Lake in West Bengal and identified Rotifer as a dominant group. S. Kar and Kar (2016b) conducted a similar study on a freshwater wetland in Assam and recorded 37 Zooplankton species. Harkal and Mokashe (2015) studied the diversity of Zooplankton along with all the peripheral fauna of Lake Kagzipura in Maharashtra and reported 38 species of Rotifera, 28 species of Cladocera, 9 species of Copepoda and 4 species of Ostracoda. Indur, Reddy, and Vijaykumar (2016) studied the diversity of Zooplankton in freshwater reservoirs in Yadgiri district of Karnataka and reported 13 species of Rotifera, 5 Cladocera, 4 Copepoda and 2 Ostracoda, the abundance of Zooplankton was found to be high during monsoon season.

Manikandan, Selvakumar, and Ezhili (2016) studied the biodiversity and density of Zooplankton in three lakes in Coimbatore and recorded 30 species of Zooplankton. They noticed that the Zooplankton density increased during the summer and decreased during the rainy season. Mruthyunjaya, Venkateshwarlu, Kiran, and Somashekar (2016) reported 17 species of Zooplankton from Ayyanakere Lake in Karnataka, with the highest diversity being found in summer and the lowest in winter season. Bhavan, Udayasuriyan, Vadivalagan, Kalpana, and Umamaheswari (2016) studied the abundance and population density of Zooplankton in four perennial ponds in the city of Coimbatore, and he isolated four species by DNA barcoding of the mt-CO1 gene.

Das and Kar (2016) reported 24 species of Zooplankton from the Siang River in Arunachal Pradesh. Zooplankton population was observed to be high during the rainy season and low during winter. Rai (2016) reviewed the work published by Arjun

Shukla *et al* and estimated the fauna diversity of the Narmada River in the Jabalpur region during the period 2014-2015. Of the 260 species observed, 42 species belonging to the Zooplankton group and the importance of Zooplankton studies were mentioned in the study. Kadam (2016) studied the diversity of Zooplankton in the Bhogaon Reservoir in Maharashtra and found six species of Copepoda, five species of Cladocera, 13 species of Rotifera and two species of Ostracoda. The abundance of Zooplankton was found to be high during the post-monsoon season and low during the monsoon. S. Kar and Kar (2016a) studied the abundance and diversity of freshwater Zooplankton in perennial ponds in the city of Silichar in Assam, 29 species of Zooplankton reported, and found that Rotifer is the most abundant group. They also reported 42 species of Zooplankton from freshwater wetland in a Cachar district of Assam (S. Kar, Das, P., Das, U., Bimola, M., Kar, D., & Aditya, G., 2018). Water temperature, turbidity, alkalinity, calcium and magnesium were found to affect the Zooplankton community. The population density was high during the winter season and low during the summer season. The presence of the Zooplankton community is strictly controlled by water temperature (R. T. Pawar, 2016).

Adhikari, Goswami, and Mukhopadhyay (2017) studied the diversity of Zooplankton in a polluted pond and the physico-chemical parameters of the water and revealed that changes in the physical and chemical parameters of the water are anthropogenic. He also observed that the presence of Cladoceran, Copepods, and predatory Rotifers influenced the abundance of Rotifera. Dutta (2017) identified 16 species of Zooplankton from the freshwater wetlands of Cachar in Assam, with the highest number of Zooplankton diversity found during the monsoon season. Litvinchuk (2018) conducted a study on the Zooplankton community in 9 mountains and lowland water bodies of northwestern India and identified 46 species of Zooplankton, eight species of Rotifera, five Cladocera, and 2 Copepoda were new in the area. Cladocera was widespread in most studied waters; based on the bio-indication characteristics of Zooplankton organisms, 2 out of 9 water bodies studied were found to be clean.

Narasimman Manickam *et al*. (2018) found an increase in Zooplankton abundance during the summer season in Ukkadam Lake in Coimbatore due to high temperature and rich nutrients. S. D. Kumar, & Rakhi, U. (2018) studied the diversity of Zooplankton in the Pagara Dam in Madhya Pradesh and discovered 23 species of Zooplankton, and a higher abundance of Rotifera, Cladocera and Copepoda were found during summer season. Sinha (2018) conducted a survey on Zooplankton diversity in Arunachal Pradesh from available literature and reported 66 species of Zooplankton, including 45 Rotifers, 20 Cladocerans and one Copepod species. Prabhakar (2019) found that sand mining reduces the diversity of species and the abundance of Zooplankton in the river Ganga. Sand mining reduces water transparency by increasing turbidity, which changes the equilibrium of the habitat.

B. K. Sharma, & Noroh, N. (2020) studied the diversity of Zooplankton in three floodplain lakes located in Assam, and found that 67% of the collected Zooplankton (118 species) belongs to the phylum Rotifera, and that the abiotic components in the ponds affect the diversity of Zooplankton. Niyoyitungiye (2020) found only 12 species of Zooplankton from Lake Tanganyika in Burundian Littoral, Assam, and Zooplankton in the lake are found to be related to certain water quality parameters. Rotifera, the most abundant group of Zooplankton in the Indian freshwater habitat, was found to be absent in the lake. Padhye (2020) studied the seasonal variation of Cladocera species in a highly eutrophic lake and observed the presence of Moina species during the highly polluted months. It was concluded that the genus Moina may be an indicator of pollution, indicating that further studies are needed to find the exact cause.

P. A. Kumar, Balakrishna, D., & Jangir, O. (2020) studied the abundance of Zooplankton along with the physical and chemical parameters of Lake Kamareddy in Telangana and identified fifteen species of Zooplankton and identified the Rotifer as the most abundant group. S. Singh, & Sharma, R. C. (2020) assessed water quality as part of a study on Zooplankton diversity in the high-altitude wetland located at Dodi Tal in the Garhwal Himalayas. They found strong pollution indicator species, including *Brachionus caudatus, B. patulus, Colurella obtusa* and *Cephalodella gibba.*

Totawar (2020) recorded high Zooplankton density from the Godavari River near the city of Nanded and demonstrated the suitability of the wetland for aquaculture practices. K. Singh (2020) studied the diversity of Zooplankton along with water quality standards to check the pollution level of a river located near an industrial area. They found low levels of Zooplankton and high value of physical and chemical parameters (BOD, COD, TSS, chloride, nitrate) and low value of DO, which clearly indicates terrible pollution in the river.

Kamboj and Kamboj (2020) studied the impact of mining on the Zooplankton biodiversity of the Ganges River and identified pollution indicator species. Water velocity, water temperature, mean depth, turbidity, dissolved oxygen, and biochemical oxygen demand all influenced diversity, abundance, reproduction, and richness of Zooplankton. Sankhala and Nama (2020) surveyed the diversity of microscopic crustacean Zooplankton (Cladocera, Copepoda, Ostracoda) in a eutrophic pond located in the city of Pipar in Rajasthan and identified 17 pollution tolerant species. R. Sarkar, Ghosh, and Mondal (2020) conducted a comparative study on the Zooplankton diversity of two urban ponds. Based on the presence of more Rotifers, one of the studied ponds was found to be contaminated.

Nath (2020) studied the diversity of plankton in the Kumri Beel, a beel with human intervention. Zooplankton was most noticeable during the rainy season and it had been found that Zooplankton abundance depends on phytoplankton. A. K. Verma, & Prakash, S. (2020) observed a bimodal pattern of periodic variation of plankton, with one primary peak in July and a second peak in January. Srivastava (2020) studied the relationship of Zooplankton to the surrounding environment and found that water temperature, phosphate and dissolved oxygen in water were the most limiting factors in Zooplankton abundance. A study conducted by Shruthi (2020) at the Boranakanive Reservoir in Tumakuru district of Karnataka found that Zooplankton density fluctuates due to environmental changes. Watkar (2020) studied the diversity of Rotifers on the Kolar River in Nagpur. Maximum Rotifers found in winter, minimum in rainy season, and water temperature were found to strongly influence the population density of Rotifers.

1.2.3. Regional Status

Studies on the diversity of freshwater Zooplanktons are rare in Kerala. S. George and Martens (2002) and S. George, & Martens, K. (2003) discovered two new species of Ostracoda from Chalakudy river in Thrissur, *Potamocypris narayanani* and *Newnhamia dumonti* sp. Sheeba S. (2005) identified 27 species of Zooplankton from the Ithikkara River, with Copepoda and Rotifera being the most dominant group of Zooplankton. R. Jose and Sanalkumar (2012) studied the biodiversity of Zooplankton in the Achenkovil River; of the 29 Zooplankton species collected, Cladocera was found to be the most abundant and diverse group. D. Jose, & Senthilkumaar, P. (2015) conducted a preliminary study on the diversity of Zooplankton in a perennial pond, Anicadu Chira, and identified 28 species of Zooplankton, which are abundant during the summer and lowest during the monsoon.

Cleetus (2016) discovered some freshwater Zooplankton from the Vembanad estuarine system. Water temperature, dissolved oxygen, salinity, nitrate and phosphate are the major factors that have been found to affect the Zooplankton abundance in the Vembanad estuarine system. Reju J. (2019) assessed the diversity of Zooplankton in seven ponds in Vengannur Grama Panchayat and identified 32 species, with the maximum variety being found before monsoon and the minimum during monsoon. Roshan (2020) studied the diversity of Zooplankton in a threatened wetland, identified 38 species of Zooplankton, and the main group as Rotifers. Zooplankton diversity and abundance show seasonal variation and some Rotifers have been found to indicate pollution.

1.2.4. Local Status

To date, only one study has been conducted on Zooplankton in the Thrissur Kole wetland. John Thomas (2003) studied the diversity of Zooplankton using a few samples and discovered 64 species of Zooplankton as part of his study of environmental change and human impacts at Muriyad Kole, part of Thrissur Kole, Wetland. It was only a short-term study of diversity, and they excluded abundance and seasonal variations from the study. My study regularly focuses on diversity, abundance, seasonal occurrence, and the relationship of Zooplankton to hydrological parameters for two years. Our study involves the relationship of hydrological parameters to the diversity, abundance, and seasonality of Zooplankton from different parts of the wetland.

1.3. Objectives

- ❖ To study the diversity and abundance of Zooplankton in selected sites of Thrissur Kole Wetlands, Kerala, at least for two years.
- ❖ To study the seasonal fluctuations in the abundance and diversity of Zooplankton in Thrissur Kole Wetland.
- ❖ To study the relations, if any, between the abundance of Zooplankton with the physicochemical parameters of Thrissur Kole Wetlands.
- ❖ To prepare a water quality index of Thrissur Kole Wetlands.

Chapter II

Physico-chemical Parameters and WQI of Thrissur Kole Wetland

2.1. Introduction

Decades ago, water was seen as an unlimited natural resource, and the misuse and abuse of water resources changed the situation. Satisfying the water needs of mankind along with protecting freshwater systems, will be one of the most difficult challenges of the 21st century. As the population and consumption levels increased, water scarcity spread rapidly in many parts of the world. Further efforts are needed to conserve water to maintain environmental activities and to return water to natural systems when needed (Pereira, Cordery, & Iacovides, 2009; Postel, 2000).

Water quality is based on the physical, chemical and biological properties and standards of its usage. Water quality is measured by a number of factors, including the concentration of dissolved oxygen, the amount of salt, the number of bacteria or the amount of material suspended in the water. In some waters, the concentration of microscopic algae and the amount of heavy metals, pesticides, herbicides, and other contaminants can be used to determine water quality. Quality determination is usually related to the purpose of the water. Good water quality is essential for a healthy ecosystem (Gleick, 1993); too many nutrients in the water can cause an overgrowth of algae. In addition, contaminant particles such as fertilizers, pesticides, metals and oils flow from the land into the water, causing the growth of excess algae and other harmful effects.

Wetlands around the world help reduce the concentration of nutrients in running water. Numerous studies have shown that wetlands have a long-term and high potential to improve water quality, which has led many to come forward to restore or create wetlands. Freshwater wetlands receive water from rain, groundwater, runoff, rivers, lakes, and human wastewater. Currently, wetlands receive most of their water from man-made sources (mainly sewage discharge, flow from urban and agricultural lands), and only a tiny amount of water from rain and groundwater (Johnston, 1991).

The change in the physical and chemical aspects of the water causes a similar change in the relative structure and abundance of the organisms. Thus studying exactly how organisms react to the physical and chemical changes of water determines the quality of the environment (Desrosiers, Leflaive, Eulin, & Ten-Hage, 2013; Resh

& Unzicker, 1975). Therefore, an attempt was made to evaluate the water quality of the Thrissur Kole wetland through the analysis of 21 physical and chemical parameters and further calculation of the water quality index using all these parameters.

2.2. Materials and Methods

2.2.1. Sampling Sites

The word ‘Kole’ is a Malayalam word that means ‘bumper yield,’ which indicates a cultivation practice once a year, probably from December to May. It is a part of Vembanad Kole wetland ecosystem. The Kole wetlands, recently designated as a Ramsar site, spread over Thrissur and Malappuram districts of Kerala, having 13,632 hectares. It is one of the largest, most productive and unique wetland lies between 10° 20' and 10° 40' N latitudes and 75° 58' and between 76° 11' E longitudes and lies between the Chalakudy River in the south and Bharathapuzha in the North, Karuvannur and Kecheri river drain the Kole lands and finally discharge into the Arabian Sea (John Thomas, 2003). The Kole wetlands run parallel to the sea and are low-lying tracts located 0.5 to 1m below mean sea level and remain submerged for about six months (June to November) in a year (Johnkutty & Venugopal, 1993). There is an alternative culture of fish and paddy practice in some of the areas of Kole lands**.**

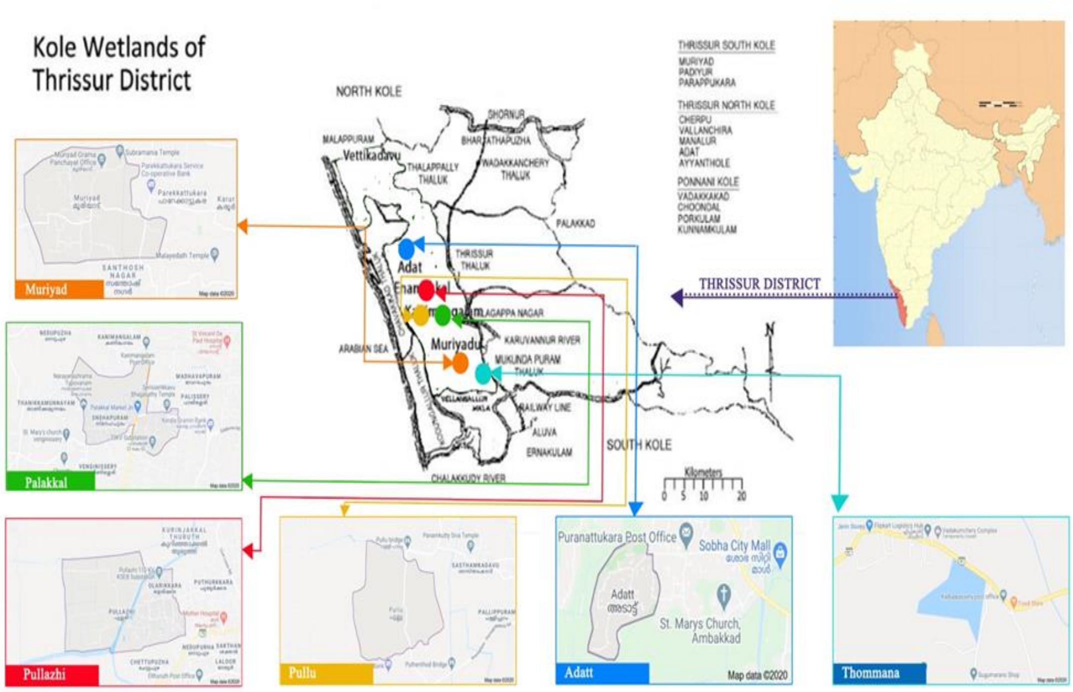


Figure 2.1. Location of the Study Area

2.2.2. Determination of Physical and Chemical Parameters of the Water

2.2.2.1. Sample Collection

To determine the water's physical and chemical parameters, surface water samples were collected early in the morning between 6 AM to 9 AM monthly from the six sampling stations (Figure 2.1). Air temperature, water temperature and field pH were measured in the field itself. Lab pH, Conductivity, Turbidity, Calcium, Chloride, Magnesium, Iron, Hardness Acidity, Alkalinity, Nitrate, Sulphate, TDS, TASA, DO, CO_2, BOD, COD were measured separately for all the samples in the laboratory by employing standard methods described in the APHA (1992) and Trivedy and Goel (1984).

2.2.2.2. Physical Parameters

2.2.2.2.1. Temperature

Air temperature and water temperature were measured by using mercury thermometer. A water sample was taken in a beaker, a good grade mercury thermometer (0^0C) was immersed, and then the water temperature was recorded.

2.2.2.2.2. Turbidity

Turbidity was measured using a digital Nephelo-Turbidity metre (Systronic 132). The instrument was set up using distilled water as zero and calibrated by using standard NTU solutions with respective ranges (10 and 100 NTU). The readings were expressed in the Nephelo Turbidity Unit (NTU).

2.2.2.2.3. Conductivity

The surface water samples' conductivity were measured in the laboratory using a microprocessor-controlled conductivity metre (Systronic 306). The instrument probe was previously calibrated with 0.1m KCl solution at 25^oC; the readings were expressed in µS/cm.

2.2.2.3. Chemical Parameters

2.2.2.3.1. pH

The field pH was recorded with the help of pH metre (Hanna Hi 96107) with a glass electrode, and the equipment was calibrated against pH 7 buffer each time before measurement. Lab pH was recorded using a pH metre with both reference and glass electrodes (Systronics 32). The instrument was calibrated with pH 4 and pH 7 buffer solutions at the laboratory temperature before measurement.

2.2.2.3.2. Total Dissolved Solids

50 ml of surface water samples (after stirring) were filtered through a previously weighed, rinsed and dried filter paper and rinsed three times with deionized

water. Transfer this filter to an evaporating dish, allow it to cool and then reweigh the filter.

$$\text{TDS (mg/L)} = \frac{(\text{A - B}) \times 100}{\text{ml of sample}}$$

Wherein:

A = weight of filter + dried residue (mg)

B = weight of filter (mg)

2.2.2.3.3. Dissolved Oxygen

The DO of the surface water samples was determined by Winkler's method. The DO was fixed in the field itself; for this 300 ml of BOD bottles were filled with surface water samples without air bubbles and 2ml of manganese sulphate ($MnSO_4$) and 2ml of alkaline potassium iodide (KI) were added to this and the bottles were closed with glass stopper. On return to the laboratory, 2 ml sulphuric acid was added to dissolve precipitation. 90 ml of sample was titrated against 0.025 N Sodium Thiosulphate using 1% freshly prepared starch solution as an indicator. The disappearance of the blue colour determined the endpoint. The concentration of DO was calculated by using the formula,

$$\text{DO (mg/L)} = \frac{\text{MBR} \times \text{N} \times 1000}{\text{V2 (VI} - \text{V/VI}}$$

Wherein,

MBR = Mean Burette Reading

N = Normality of Sodium Thiosulphate (0.025N)

V1 = Volume of BOD Bottle (300ml)

V2 = Volume of Part of the Content Titrated (90ml)

V = Volume of $MnSO_4$ and KI Added (2+2ml)

2.2.2.3.4. Biological Oxygen Demand (BOD mg/L)

To determine BOD, the surface water samples from each sampling site were aerated for 10 minutes and transferred into two 300 ml capacity BOD bottles. One BOD bottle for each sampling site was incubated in a BOD incubator set at 20^{o}C for five days. The DO of the other BOD bottle was determined in the laboratory with modified Winkler's method. This gave DO_0 value. DO content of the incubated sample was determined using the same procedure after five days of incubation and this gave DO_5 value. The differences between the initial and final DO concentration, i.e., $DO_0 - DO_5$ gave the BOD value.

2.2.2.3.5. Chemical Oxygen Demand (COD mg/L)

The COD of the surface water samples was determined by the Di-Chromate method described by APHA (1992). 50 ml of the water samples were taken in a conical flask and to this, 5ml of potassium dichromate was added. Three copy samples were used for each site. In another conical flask, 50ml of distilled water was taken, which serves as blank. All the conical flasks were incubated for 1hr; after cooling add 5ml of 10% KI and then 10 ml of 2M sulphuric acid. This was titrated against 0.1N sodium thiosulphate using 1% starch solution as an indicator, and the end point is the disappearance of blue colour. The COD of water samples were determined by using the following formula,

$$\mathrm{COD\,(mg/L)} = \frac{\mathrm{N \times (B - A) \times 8 \times 1000}}{\mathrm{ml\ of\ Sample\ taken\ (50ml)}}$$

Wherein,

N = Normality of Sodium Thiosulphate (0.1N)

B = Burette Reading of Blank

A = Burette Reading of Sample

2.2.2.3.6. Free Carbon Di-Oxide (CO_2 mg/ L)

To determine the CO_2 of the water samples, 100ml of the sample was taken in a conical flask and 2 drops of phenolphthalein indicator were added. These samples were titrated against 0.05N sodium hydroxide and titration was continued till the pink colour appeared. However, in some of the water samples, the pink colour appeared immediately after adding the phenolphthalein indicator. These indicated the complete absence of free CO_2 in the water sample. CO_2 of the surface water samples were calculated by using the following formula,

$$\text{Free } CO_2 \text{ (mg/L)} = \frac{\text{MBR} \times \text{N} \times 44 \times 1000}{\text{ml of sample taken (100ml)}}$$

Wherein,

MBR= Mean Burette Reading

N= Normality of NaOH (0.05)

2.2.2.3.7. Acidity (mg/L)

100 ml of surface water samples were taken in a conical flask and added two to three drops of methyl orange as an indicator. If the solution turns yellow, the methyl orange acidity is absent. If it turns pink, titrated against the 0.05 N NaOH. Colour changes from pink to yellow are the end point. Then added a few drops of phenolphthalein indicator and titrated again with NaOH until the content turned pink.

$$\text{Methyl Orange Acidity (mg/L as Ca CO3)} = \frac{\text{A} \times \text{N of NaOH} \times 1000 \times 50}{\text{ml of sample taken}}$$

$$\text{Phenholpathalein Acidity (mg/L as Ca CO3)} = \frac{\text{B} \times \text{N of NaOH} \times 1000 \times 50}{\text{ml of sample taken}}$$

$$\text{Total Acidity (mg/L as Ca CO3)} = \frac{(\text{A} + \text{B}) \times \text{N of NaOH} \times 1000 \times 50}{\text{ml of sample taken}}$$

Wherein,

A = Volume of NaOH used with methyl orange in titrating the sample to pH 3.7.

B = Volume of NaOH used with phenolphthalein in titrating the sample from pH 3.7 to 8.3.

2.2.2.3.8. Alkalinity (mg/L)

The Alkalinity of the surface water samples was determined by the titrimetric method. 100ml of surface water samples in triplicate was taken into 250 ml conical flask, and two drops of phenolphthalein indicator was added. If the solution remains colourless, phenolphthalein alkalinity is zero; if the colour changes to pink, titrate with 0.1N HCl, till the colour disappears. To this solution, 2-3 drops of methyl orange were added and titration continued until the yellow colour changed to pink colour. The total alkalinity was calculated using the formula,

$$\text{Total Alkanity (mg/L)} = \frac{\text{MBR} \times \text{N} \times 1000 \times 50}{\text{ml of sample taken}}$$

Wherein,

MBR = Mean Burette Reading

N = Normality of HCl (0.1N)

2.2.2.3.9. Hardness (mg/L)

The hardness of the surface water sample is determined by the titrimetric method. 50 ml of the surface water samples in triplicate for each site were taken in 250 ml conical flask, 1ml of ammonia buffer solution and 100-200 mg of Eriochrome Black T indicator were added to this. The content in the flask was titrated against 0.01M Ethylenediamine tetraacetic acid solution (EDTA) and titration was continued until the end point indicated by colour changed from wine red to blue colour. The hardness of the surface water samples was calculated by using the formula:

$$\text{Hardness (mg/L)} = \frac{\text{MBR} \times \text{N} \times 1000 \times 50}{\text{ml of sample taken}}$$

Wherein,

MBR = Mean Burette Reading

2.2.2.3.10. Calcium (mg/L)

The calcium content of the surface water samples was determined by the titrimetric method. 50ml of the surface water sample in triplicate for each sample was taken in 250 ml conical flasks. 2ml of sodium hydroxide and 100mg of Murexide indicator were added to this. The content was titrated against 0.01M Ethylenediamine tetraacetic acid (EDTA) solution and titration was continued until the end point indicated by a colour change from pale pink to purple. The calcium content of the surface water samples was calculated by using the following formula,

$$\text{Calcium (mg/L)} = \frac{\text{MBR} \times 400.8}{\text{ml of sample taken (50ml)}}$$

Wherein,

MBR = Mean Burette Reading

2.2.2.3.11. Chloride (mg/L)

The chloride content of the surface water samples was determined by the titrimetric method. 50ml of the surface water sample in triplicate, for each sample, was taken in 250ml conical flasks and 2ml of 5% potassium chromate was added to each of them. The content was titrated against 0.02N silver nitrate solution. The titration was continued till the end point indicated a colour change from yellow to brick red. The chloride content of the surface water sample was calculated by using the formula,

$$\text{Chloride (mg/L)} = \frac{\text{MBR} \times \text{N} \times 35.5 \times 1000}{\text{ml of sample taken (50ml)}}$$

Wherein,

MBR = Mean Burette Reading

N = Normality of Silver Nitrate (0.02N)

2.2.2.3.12. Magnesium (mg/L)

The magnesium content of the surface water sample was determined by the titrimetric method, magnesium concentration is calculated using the following formula, based on the amount of EDTA solution taken to determine hardness and calcium.

$$\text{Hardness (mg/L)} = \frac{\text{MBR} \times \text{N} \times 1000 \times 50}{\text{ml of sample taken}}$$

$$\text{M}g^{2+} \text{ (mg/L)} = \frac{\text{y - x} \times 400.8}{\text{Volume of sample } x 1.645}$$

Wherein,

y= EDTA used in hardness determination

x= EDTA used in calcium determination for the same volume of the sample

2.2.2.3.13. Iron (mg/L)

The iron content of the surface water sample was determined by the spectrophotometric method. 50 ml of surface water samples were taken in a conical flask. Add 10ml sodium acetate, 2ml hydroxylamine hydrochloride, 5 ml phenanthroline solution and make up to 100 ml with distilled water. Take a spectrophotometric reading at 510 nm after 10 minutes. The blank was prepared by using a 10 ml buffer, 2 ml hydroxylamine hydrochloride, 5 ml phenanthroline solution and make up to 100 ml with distilled water. For the preparation of the standard graph, standard iron solutions were prepared by using iron (II) ammonium sulfate hexahydrate. Five different concentrations (2, 4, 8, 10, 12 ml) were taken into a conical flask and make up to 50 ml with distilled water. The same chemical solution was added, employing the same procedure as per the samples. The concentration of the iron content of the surface water sample gets directly from the standard curve.

2.2.2.3.14. Nitrate (mg/L)

The nitrate content of the surface water sample is determined by the Brucine method. 10 ml surface water samples were taken in a test tube. 2 ml NaCl, 10 ml of 2M H_2SO_4 and 0.5 ml brucine reagent were added and mixed thoroughly. Blank was also prepared in a similar manner using 10ml of distilled water and these test tubes were heated in the water bath for 20 minutes. The optical density of the sample was measured at 410 nm using a photo electric calorimeter.

For the preparation of the standard graph, the standard nitrate solution of 1 mg per litre was prepared using potassium nitrate. 10 different concentrations (0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, and 1.0mg/L) of standard nitrate solution were taken in 10 different test tubes. Volume in these test tubes was made up to 10ml using distilled water and the same chemical solution was added employing the same procedure as per the samples. The optical density of these solutions was measured. The standard curve was plotted using concentration against absorbance. The concentration of the nitrate was determined from the standard graph and also nitrate content of the surface sample was calculated using the following formula

$$\text{Cocentration of nitrate (mg/L)} = \frac{\text{OD of sample x concentration of standatd}}{\text{OD of standarad}}$$

2.2.2.3.15. Sulphate (mg/L)

The sulphate content of the surface water sample was determined by the Turbidimetric method. 100ml of surface water sample from each site was taken in a 250ml conical flask. 5ml of conditioning reagent (75g of NaCl+3ml of concentrated Hcl+100ml of 90% ethyl alcohol+300ml of distilled water+50ml of glycerol) and 10mg barium chloride crystals were added to this flask. A blank was also prepared in a similar manner using 100ml distilled water. The optical density of these samples was measured at 420 nm using a photoelectric calorimetre.

For the preparation of the standard graph, standard sulphate solution was prepared by using anhydrous disodium sulphate. 10 different concentrations

(5,10,15,20,25,30,35,40,45, and 50 mg/L) of the standard sulphate solution were taken in 10 different conical flasks and volume in these flasks was made up to 100ml using distilled water. The same chemical solution was added, employing the same procedure as per the samples. The standard curve was plotted using concentration and absorbance. The concentration of the sulphate was determined from the standard graph and also sulphate content of the surface sample was calculated using the following formula,

$$\text{Cocentration of Sulphate (mg/L)} = \frac{\text{OD of sample x concentration of standatd}}{\text{OD of standarad}}$$

2.2.2.3.16. Total Anion of the Strong Acids (TASA)

The TASA was calculated by adding chloride, nitrate, and sulphate concentrations of the surface water sample.

2.2.3. Water Quality Index (WQI):

Water Quality Index **(WQI) = ΣQnWn/Wn**

Wherein,

Qn = (Water Quality Rating) 100 X (Vn/Sn)

Wn = (Unit Weight) K/Sn

Sn = Recommended Standard for nth Parameter

Vn = Observed Value of the nth Parameter

Vo = Ideal Value (zero for all parameters except pH and DO which are 7.0 and 14.6 mg/L respectively

K = (Constant) 1/ (Σ1/Sn)

Estimated WQI values are classified into five categories (Sahu & Sikdar, 2008):

Water Quality Index Level	Water Quality Status
>50	Excellent Water
50-100	Good Water
100-200	Poor Water
200-300	Very Poor Water
> 300	Unsuitable for Drinking

2.2.4. Statistical Analysis

The following statistical analysis was performed using SPSS 19.0. version to determine the significance of the seasonal variation and the correlation between the parameters.

One-way Analysis of Variance (ANOVA) was used to examine the significance of seasonal variation of physical and chemical parameters.

Pearson's Correlation Analysis was performed to determine the correlation between the physical and chemical parameters.

2.3. Results

2.3.1. Physical Parameters

A summary of physical and chemical parameters tested from October 2017 to September 2019 is shown in Table 2.1. As shown in Table 2.2, most of the water quality parameters show significant seasonal variation. Pearson's correlation coefficient between Physico-chemical parameters is shown in Table 2.3. The monthly variations of the physical and chemical parameters are shown graphically in Figures 2.2 to 2.22.

Physico-chemical Parameters	Mean ±SD	Range	CV (%)

Air Temp (^{0}C)	27.37 ±2.66	24-33	10
Water Temp (^{0}C)	26.58 ±1.72	24.3-30	6
Field pH	6.67 ±0.27	6.2-7.4	4
Lab pH	6.68 ±0.29	6.3-7.5	4
Turbidity (NTU)	10.81 ±6.26	4.0-25	58
Electrical Conductivity (µS^{-cm})	150.53 ±37.49	101-232	25
TDS (mg/L)	90.35 ±41.05	32.5-188	45
Acidity (mg/L)	11.93 ±3.13	6.7-19	26
Alkalinity (mg/L)	31.87 ±9.01	15-48	28
Total Hardness (mg/L)	34.54 ±16.45	2.0-72	48
Calcium (mg/L)	10.45 ±4.53	4.0-22.4	43
Magnesium (mg/L)	3.63 ±1.17	1.9-5.5	31
Chloride (mg/L)	32.39 ±14.44	13-75.5	45
Fluoride (mg/L)	0.09 ±0.04	0.02-0.17	51
Iron (mg/L)	0.98 ±0.17	0.81-1.5	17
Nitrate (mg/L)	4.57 ±0.95	6.0-3.2	21
Sulphate (mg/L)	8.2 ±.02	4.5-13.1	37
CO2 (mg/L)	10.61 ±3.03	4.0-20	29
DO (mg/L)	5.98 ±1.4	4.0-8	23
BOD (mg/L)	1.43 ±0.58	0.7-2.7	40
COD (mg/L)	6.83 ±2.57	3.0-11	38
TASA (mg/L)	42.4 ±15.17	24.5-84.9	36

Table 2.1. Physical and Chemical Parameters of Thrissur Kole Wetlands (Oct 2017 to Sep 2019). NTU= Nephlo Turbidity Unit, TDS= Total Dissolved Solids, DO=Dissolved Oxygen, BOD= Biochemical Oxygen Demand, COD=Chemical Oxygen Demand, TASA=Total Anions of Strong Acids.

Parameter	PRM	MON	POM	F-value	P-value
Air Temp (0^0C)	30.4	25.5	26.4	22.81	0.000*
Water Temp (0^0C)	28.2	25.4	26.0	9.62	0.001*
Field pH	6.7	6.5	6.8	1.90	0.174
Lab pH	6.8	6.5	6.8	2.10	0.147
Turbidity (NTU)	8.0	10.8	14.1	1.67	0.213
Electrical Conductivity (μS^{-cm})	182.7	116.0	156.0	12.94	0.000*
TDS (mg/L)	93.3	68.9	116.8	2.12	0.145
Acidity (mg/L)	11.8	13.6	10.2	2.46	0.110
Alkalinity (mg/L)	33.8	32.8	28.5	0.60	0.558
Total Hardness (mg/L)	26.1	35.7	43.1	2.02	0.158
Calcium (mg/L)	9.0	11.5	11.5	0.64	0.537
Magnesium (mg/L)	4.2	3.7	2.8	3.01	0.071
Chloride (mg/L)	34.2	22.8	42.4	3.64	0.044*
Iron (mg/L)	0.91	1.15	0.87	13.40	0.000*
Nitrate (mg/L)	4.6	5.1	4.0	3.80	0.039*
Sulphate (mg/L)	12.3	6.6	6.1	206.75	0.000*
CO2 (mg/L)	12.4	8.5	11.3	4.32	0.027*
DO (mg/L)	4.2	7.3	6.5	85.90	0.000*
BOD (mg/L)	1.8	0.9	1.6	8.55	0.002*
COD (mg/L)	7.6	4.3	8.5	13.13	0.000*
TASA (mg/L)	42.7	34.6	52.5	2.28	0.127

Table 2.2. Seasonal Comparison of Physical and Chemical Parameters of Thrissur Kole wetland, Oct 2017- Sep 2019

Each parameter represents an average of 8 months. *=significant, -= <*.*5. NTU= Nephlo Turbidity Unit, TDS= Total Dissolved Solids, DO=Dissolved Oxygen, BOD=Biochemical Oxygen Demand, COD=Chemical Oxygen Demand, TASA=Total Anions of Strong Acids.

	AT	WT	FPH	LPH	TUR	EC	TDS	ACD	ALK	TH	Ca	Mg	Cl	Fe	NO_3	SO_4	CO_2	DO	BOD	COD	TASA
AT	1																				
WT	.789**																				
FpH	0.119	0.012																			
LpH	0.196	0.159	.931**																		
TUR	-0.351	-.485*	0.025	-0.088																	
EC	.613**	.565**	0.200	0.232	-0.146																
TDS	0.296	0.196	0.142	0.165	-0.047	0.331															
ACD	0.016	-0.103	-0.026	-0.019	-0.081	-0.355	-0.373														
ALK	0.326	.424*	-0.053	0.099	-.675**	0.177	-0.125	0.210													
TH	-0.117	-0.011	0.364	.409*	-0.166	-0.033	0.296	-0.126	.442*												
Ca	-0.229	-0.269	.535**	.535**	-0.112	-0.205	0.103	0.189	0.225	.592**											
Mg	0.362	.526**	-0.129	0.030	-0.377	.488*	0.005	-0.009	.493*	0.018	-0.073										
Cl	0.085	0.071	0.319	0.286	0.221	0.356	.544**	-0.260	-.448*	0.014	0.079	0.062									
Fe	-0.337	-0.295	-.497*	-.429*	0.043	-.439*	-0.324	0.039	0.023	-0.055	-0.051	0.164	-.419*								
NO_3	0.052	0.033	-0.265	-0.202	0.147	-0.074	-0.306	.465*	0.120	-0.117	-0.023	0.363	-0.075	0.195							
SO_4	.814**	.652**	0.084	0.169	-0.295	.631**	0.065	-0.049	0.175	-0.373	-0.234	.462*	0.090	-0.186	0.146						
CO_2	.546**	.473*	0.146	0.265	-0.145	0.258	0.177	0.186	0.274	0.077	-0.126	-0.074	-0.010	-.447*	0.015	0.345					
DO	-.760**	-.676**	-0.372	-0.398	0.335	-.659**	-0.174	0.101	-0.104	0.233	0.166	-0.294	-0.260	.539**	0.170	-.827**	-0.397				
BOD	.466*	0.216	0.131	0.112	0.336	.520**	0.107	-0.040	-0.318	-.454*	-.456*	-0.038	0.241	-.432*	0.047	.446*	.425*	-.465*			
COD	0.271	0.108	.509*	.444*	0.190	0.293	-0.028	-0.091	-0.044	0.138	0.086	-0.278	0.260	-.564**	-0.375	0.100	0.390	-0.394	.454*		
TASA	0.031	-0.020	0.398	0.334	0.242	0.287	0.390	-0.152	-0.228	0.299	0.311	-0.034	.823**	-0.344	-0.148	0.003	0.035	-0.127	0.026	.422*	

Table 2.3. Pearson's Correlation Coefficient between Physico-chemical Parameters

AT= Air Temperature, WT= Water Temperature, FpH= Field pH, LpH= Lab pH, TUR= Turbidity, EC= Electrical Conductivity, TDS= Total Dissolved Solids, ACD= Acidity, ALK= Alkalinity, TH= Total Hardness, Ca= Calcium, Mg= Magnesium, Cl= Chloride, Fe= Iron, NO_3= Nitrate, SO_4= Sulphate, CO_2= Carbon Dioxide, DO= Dissolved Oxygen, BOD= Biochemical Oxygen Demand, COD= Chemical Oxygen Demand, TASA= Total Anions of Strong Acids

2.3.1.1. Air Temperature

The mean air temperature of Thrissur Kole wetland was 27.4^{0}C ranged between 24-33^{0}C with 10% variation. The mean air temperature was 26.8 in the first year and 27.9 in the second year. The highest temperature was recorded in May 2018 and May 2019 (33^0 C) and lowest during July 2018 (24^{0}C). The mean air temperature showed seasonal variation; the temperature was high during the pre-monsoon season (30.4^{0}C) and low during the monsoon season (25.5^{0}C). The air temperature ranged between 27-33^{0}C during the pre-monsoon season, 24-26.3^{0}C during monsoon season and 25-28^{0}C during the post-monsoon season. The graphical representation of the air temperature of the Thrissur Kole wetland is shown in Figure 2.2. Air temperature shows significant positive correlation with water temperature (r= 0.789, p= 0.000), electrical conductivity (r= 0.613, p= 0.001), sulphate (r= 0.814, p= 0.000), CO2 (r= 0.546, p= 0.006) and BOD (r= 0 .466, p= 0.022), and negative correlation with dissolved oxygen (r= 0. -.760, p= 0.000).

2.3.1.2. Water Temperature

The mean water temperature of Thrissur Kole wetland was 26.6^{0}C and ranged between 23.8^{0}C- 30^{0}C, with 6% variation. The mean water temperature was 26 in the first year and 27.2 in the second year. The highest temperature (30^{0}C) was recorded during May 2019 and the lowest during August 2018 (23.8^{0}C). On a seasonal basis, the highest water temperature was recorded during the pre-monsoon season (28.2^{0}C) followed by the post-monsoon season (26.1^{0}C) and monsoon season (25.4^{0}C). The water temperature ranged between 26-30^{0}C during the pre-monsoon season, 23.8-27.5^{0}C during monsoon season and 24.3-28^{0}C during the post-monsoon season. The graphical representation of the monthly variation in the water temperature of the Thrissur Kole wetland is shown in Figure 2.3. Water temperature shows strong positive correlation with air temperature (r= 0.789, p= 0.000), electrical conductivity (r= 0.565, p= 0.004), alkalinity (r= 0.424, p= 0.039), magnesium (r= 0 .526, p= 0.008), sulphate (r= .652, p= 0.001), CO2 (r= 0.473, p= 0.020) and negatively with dissolved oxygen (r= -0.760, p= 0.000).

2.3.1.3. Turbidity

The mean turbidity of the Thrissur Kole wetland water was 10.81 NTU in the range of 2.7-25 NTU with 58% variation. Mean turbidity was 13.9 NTU in the first year and 7.7 NTU in the second year. The highest turbidity was recorded during December 2017 and the lowest during January 2019. Seasonal data revealed significantly higher turbidity during the post-monsoon season (13.8 NTU) and lowest during the pre-monsoon season (8.0 NTU). The turbidity ranged between 4-13 NTU during the pre-monsoon season, 5-20 NTU during monsoon season and 2.7-25 NTU during post-monsoon season. The graphical representation of the monthly variation in the turbidity of Thrissur Kole wetland is shown in the Figure 2.4. Turbidity shows significant negative correlation with water temperature (r= -0.485, p= 0.016) and alkalinity (r= -0.675, P= 0.000).

2.3.1.4. Electrical Conductivity

The mean electrical conductivity of Thrissur Kole wetland was 150.5 μS^{-cm} ranging between 98 to 232 μS^{-cm} with 25% variation. Mean electrical conductivity was 154.0 μS^{-cm} in the first year and 147.1 μS^{-cm} in the second year. The highest electrical conductivity was recorded during May 2019 and the lowest during June 2018. Seasonal data revealed significantly higher conductivity during the pre-monsoon season (182.7 μS^{-cm}) and lowest during the monsoon season (116 μS^{-cm}). The conductivity ranged between 123-232 μS^{-cm} during the pre-monsoon season, 98-132 μS^{-cm} during monsoon season and 124-175 μS^{-cm} during post-monsoon season. The graphical representation of the monthly variation in the electrical conductivity of Thrissur Kole wetland is shown in Figure 2.5. Electrical conductivity shows strong positive correlation with air temperature (r= 0.613, p= 0.001), water temperature (r= 0.565, p= 0.004), magnesium (r= 0.488, p= 0.016), sulphate (r= 0.631, 0.001) and BOD (r= 0.520, p= 0.009), and strong negative correlation with iron (r= -0.439, p= 0.032) and dissolved oxygen (r= 0. -.659, p= 0.000).

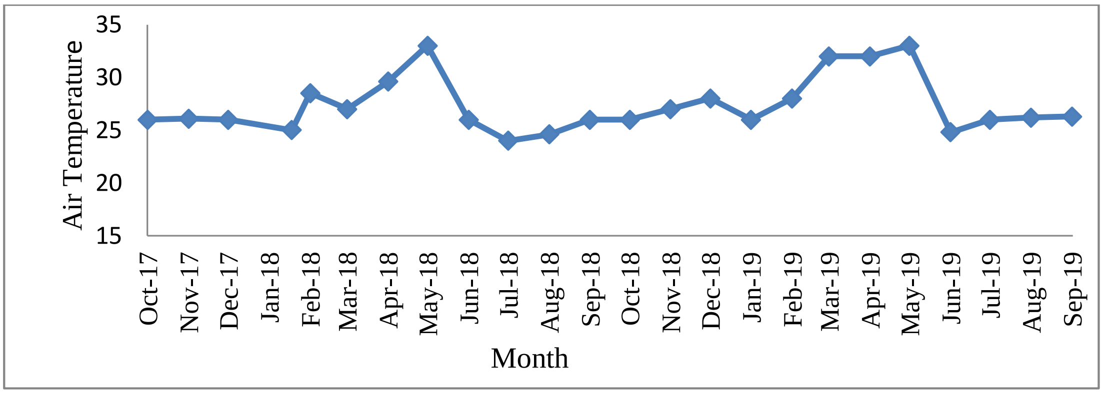


Figure 2.2. Monthly variations in Air Temperature (^{0}C) of Thrissur Kole wetland, Oct 2017-Sep 2019

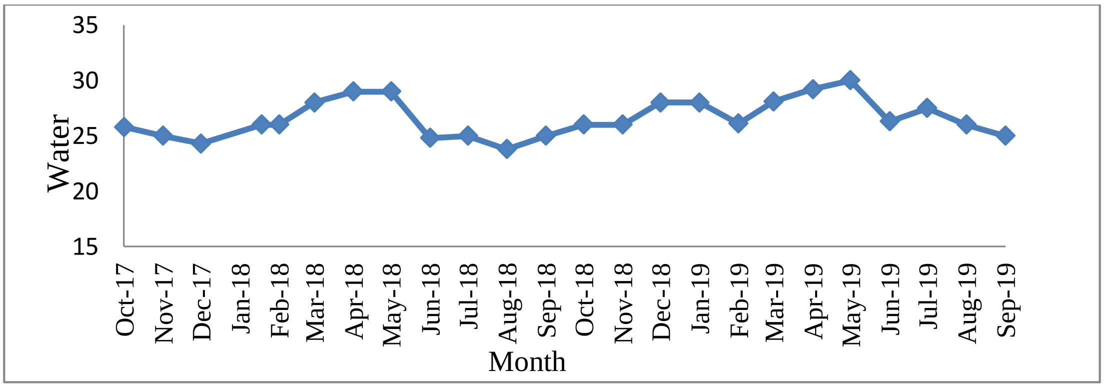


Figure 2.3. Monthly variations in Water Temperature (^{0}C) of Thrissur Kole wetland, Oct 2017-Sep 2019

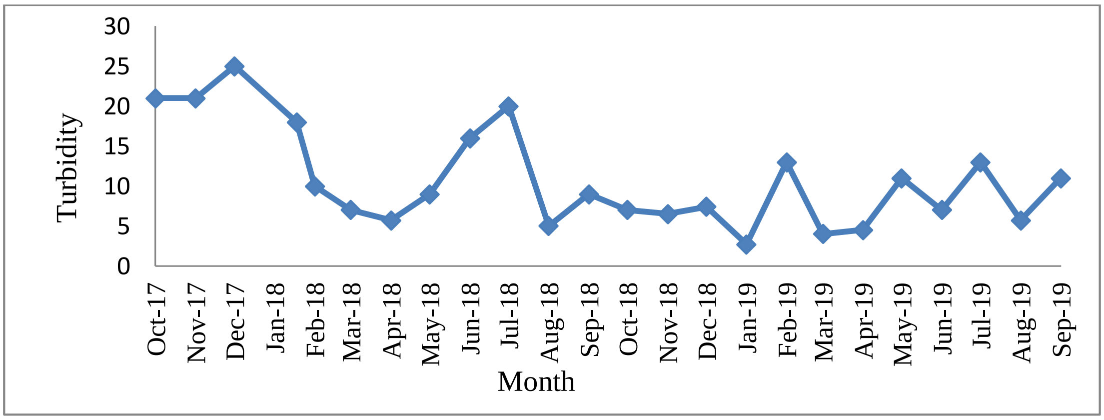


Figure 2.4. Monthly variations in Turbidity (NTU) of Thrissur Kole wetland, Oct 2017-Sep 2019

2.3.2. Chemical parameters

2.3.2.1. Field pH

The mean-field pH of Thrissur Kole wetland was 6.67 ranging between 6.2-7.4 with 4% variation. Mean-field pH was similar (6.7) in the first and second years. The highest field pH was recorded during Oct 2018 and lowest during June 2018. In the seasonal data, the field pH was higher and significantly similar during the pre-monsoon (6.74) and post-monsoon (6.75) season and low during the monsoon season (6.53). The field pH ranged between 6.5-7 during the pre-monsoon season, 6.2-6.9 during monsoon season and 6.3-7.4 during the post-monsoon season. The graphical representation of the monthly variation in the field pH of Thrissur Kole wetland is shown in Figure. 2.6. Field pH shows significant positive correlation with the laboratory pH (r= 0 .931, p= 0.000), Calcium (r= 0 .535, p= 0.007) and COD (r= 0 .509, p= .011) and significant negative correlation with iron (r= -0.497, p = 0.013).

2.3.2.2. Laboratory pH

The mean laboratory pH of Thrissur Kole wetland was 6.69, ranging between 6.1-7.55 with 4% variation. Mean lab pH was similar (6.7) in the first year and in the second year. The highest value was recorded during October 2018 and the lowest during November 2017. On a seasonal basis, the highest and significantly similar value was during pre-monsoon (6.79) and post-monsoon (6.76) seasons and lowest during monsoon season (6.5). The lab pH ranged between 6.5-6.9 during the pre-monsoon season, 6.3-6.8 during monsoon season, and 6.1-7.6 during the post-monsoon season. The graphical representation of the monthly variation in the Lab pH of Thrissur Kole wetland is shown in Figure 2.7. Laboratory pH shows significant positive correlation with field pH (r= 0.931, p= 0.000), total hardness (r= 0.409, p= 0.047), calcium (r= 0 .535, p= 0.007) and COD (r= 0.444, p= 0.030) and negative correlation with iron (r= -0.429, p= 0.036).

2.3.2.3. TDS (mg/L)

The mean TDS value of Thrissur Kole wetland water was 90.4 mg/L ranged between 46-188 mg/L with 45.4% variation. Mean TDS was 95.3 mg/L in the first year and 85.4 mg/L in the second year. The highest value was recorded during May 2018 and the lowest during March 2018. On a seasonal basis, the highest value was recorded during the post-monsoon season (108.9 mg/L), followed by pre-monsoon (93.3 mg/L) and the lowest during monsoon season (68.9 mg/L). The TDS ranged between 32.5-188 mg/L during the pre-monsoon season, 46-83 mg/L during the monsoon season and 67-168 mg/L during the post-monsoon season. The graphical representation of the monthly variation in the TDS of the Thrissur Kole wetland is shown in Figure 2.8. TDS shows strong positive correlation with chloride ($r= 0.544$, $p= 0.006$).

2.3.2.4. Acidity

The mean acidity of Thrissur Kole wetland was 11.9 mg/L ranged between 6.7-19 mg/L with 26.2% variation. This was 10.8 mg/L in the first year and 13.1 mg/L in the second year. The highest value was recorded during July 2019 and the lowest during April 2018. On a seasonal basis, the highest value was recorded during the monsoon season (13.6 mg/L), followed by the pre-monsoon season (11.8 mg/L) and the lowest during the post-monsoon season (10.4 mg/L). The acidity ranged between 6.7-16.7 mg/L during the pre-monsoon season, 9.0-19 mg/L during monsoon season and 7.0-14 mg/L during post-monsoon season. The graphical representation of the monthly variation in the acidity of the Thrissur Kole wetland is shown in Figure 2.9. Acidity shows significant positive correlation with nitrate ($r= 0.465$, $p= .022$).

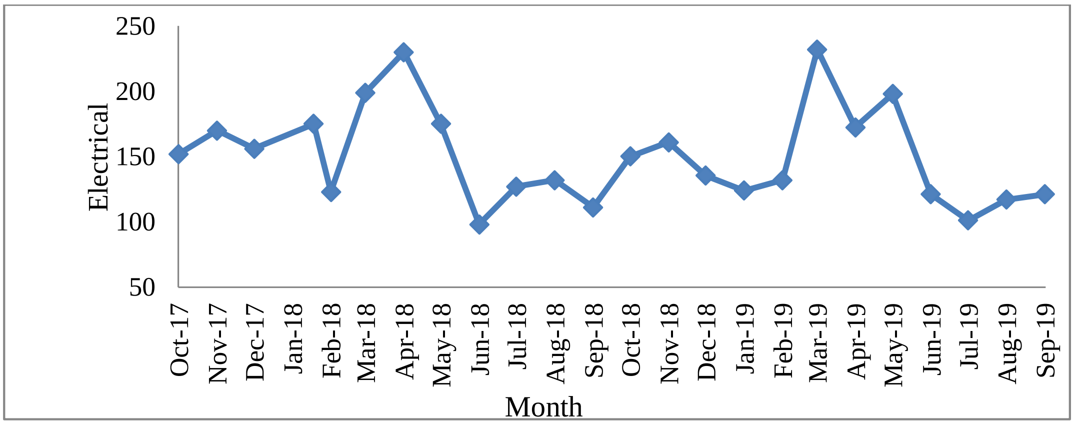


Figure 2.5. Monthly variations in Electrical conductivity (µS^{-cm}) of Thrissur Kole wetland, Oct 2017-Sep 2019

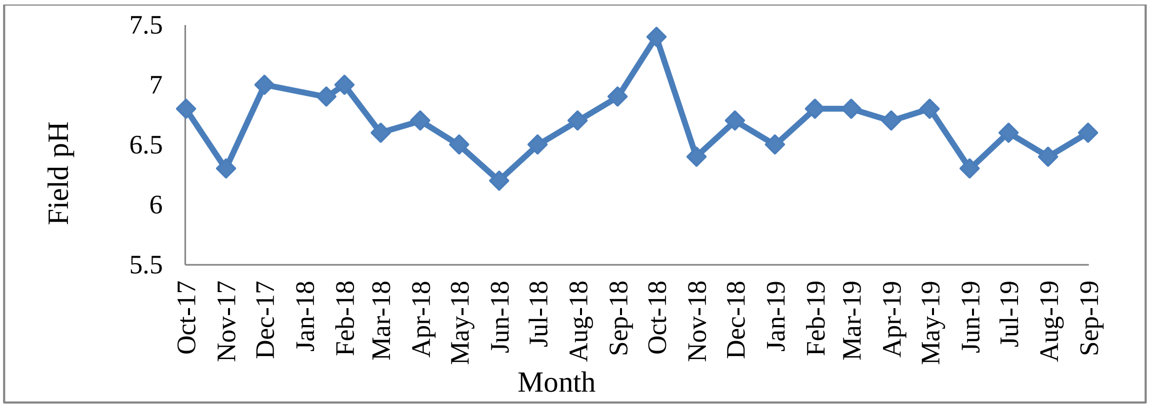


Figure 2.6. Monthly variations in Field pH of Thrissur Kole wetland, Oct 2017-Sep 2019

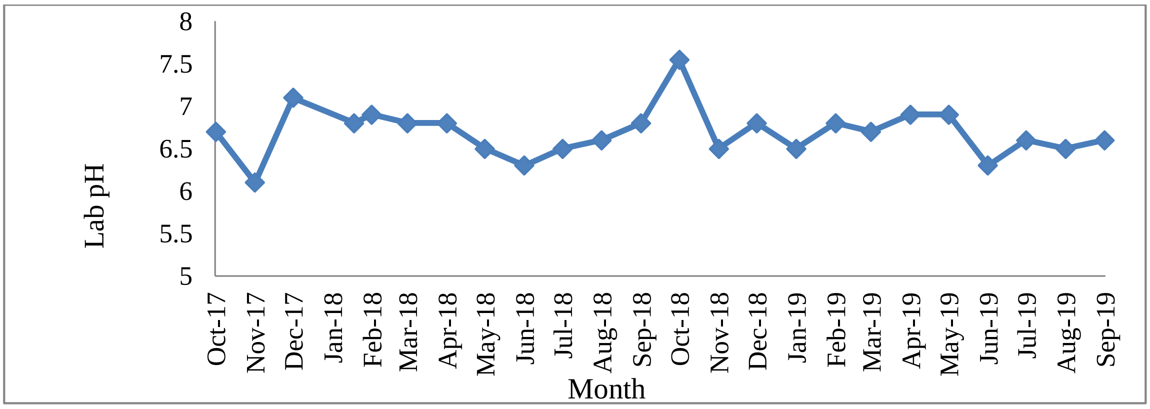


Figure 2.7. Monthly variations in Lab pH of Thrissur Kole wetland, Oct 2017-Sep 2019

2.3.2.5. Alkalinity

The mean alkalinity of Thrissur Kole wetland was 31.9 mg/L ranging between 15-48 mg/L with 28.3% variation. This was 27.2 mg/L during the first year and 36.6 mg/L during the second year. The highest value was recorded during April 2019 and the lowest during November 2017. On a seasonal basis, the mean alkalinity during pre-monsoon (33.8 mg/L) and monsoon (32.8 mg/L) season were significantly similar and higher, and lowest (29 mg/L) during post-monsoon season. The alkalinity ranged between 19-48 mg/L during the pre-monsoon season, 21-39 mg/L during monsoon season and 15-45.3 mg/L during post-monsoon season. The graphical representation of the monthly variation in the alkalinity of Thrissur Kole wetland is shown in Figure 2.10. Alkalinity shows significant positive correlation with water temperature (r= 0.424, p= 0.039, total hardness (r= 0.442, p= .031), magnesium (r= 0.493, p= 0.014) and significant negative correlation with turbidity (r= -0.675, p= 0.000) and chloride (r= -0.448, p= 0.028).

2.3.2.6. Total Hardness

The mean total hardness of Thrissur Kole wetland was 34.5 mg/L ranging between 2.0-72 mg/L with 47.6% variation. This was 29.3 mg/L during the first year and 39.8 mg/L in the second year. The highest value was recorded during October 2018 and the lowest during March 2018. On a seasonal basis, the highest mean water hardness was recorded during the post-monsoon season (41.8 mg/L) followed by monsoon season (35.7 mg/L) and pre-monsoon season (26.1 mg/L). The hardness ranged between 2.0-55 mg/L during the pre-monsoon season, 12-41 mg/L during monsoon season and 23-72 mg/L during post-monsoon season. The graphical representation of the monthly variation in the total hardness of the Thrissur Kole wetland is shown in Figure 2.11. Total hardness shows significant positive correlation with laboratory pH (r= 0.409, p= 0.047), alkalinity (r= 0.442, p= 0.031), calcium (r= 0.592, p= 0.002) and significant negative correlation with BOD (r= -0.454, p= .026).

2.3.2.7. Calcium (mg/L)

The mean calcium content of the Thrissur Kole wetland water was 10.5 mg/L ranging from 4.0-22 with 43.3% variation. This was 9.3 mg/L during the first year and 11.6 mg/L in the second year. The highest value was recorded during October 2018 and lowest during November 2017, March, May, June 2018. On a seasonal basis, the highest value was recorded during monsoon season 11.5 mg/L, followed by post-monsoon season (10.9 mg/L) and lowest during the pre-monsoon season (9 mg/L). The calcium ranged between 4-12 mg/L during the pre-monsoon season, 4-19 mg/L during monsoon season and 4-22 mg/L during post-monsoon season. The graphical representation of the monthly variation in the calcium of the Thrissur Kole wetland is shown in Figur: 2.12. Calcium shows significant positive correlation with pH (r= 0.535, p= 0.007) and total hardness (r= 0.592, p= 0.002), and negative correlation with BOD (r= -0.454, p= 0.026).

2.3.2.8. Magnesium

The mean magnesium content of the Thrissur Kole wetland water was 3.6 mg/L ranging between 1.9-5.9 mg/L with 30.8% variation. This was 3.58 mg/L during the first year and 3.69 mg/L during the second year. The highest value was recorded during May 2019 and the lowest during February 2018. On a seasonal basis, the highest concentration was recorded during the pre-monsoon season (4.23 mg/L) and the lowest during the post-monsoon season (2.97 mg/L). The magnesium ranged between 1.9-5.9 mg/L during the pre-monsoon season, 3.0-4.3 mg/L during monsoon season and 1.9-4.05 mg/L during post-monsoon season.

The graphical representation of the monthly variation in the magnesium concentration of Thrissur Kole wetland is shown in the Figure 2.13. Magnesium shows significant positive correlation with water temperature (r=0.526, p= 0.008), electrical conductivity (r= 0.488, p= 0.016), alkalinity (r= 0.493, p= 0.014) and sulphate (r= 0.462, p= 0.023).

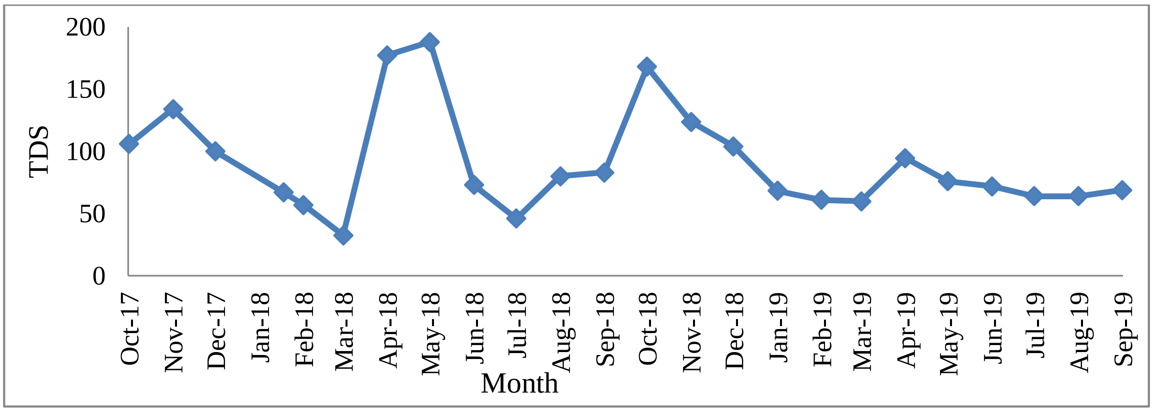


Figure 2.8. Monthly variations of TDS (mg/L) of Thrissur Kole wetland, Oct 2017-Sep 2019

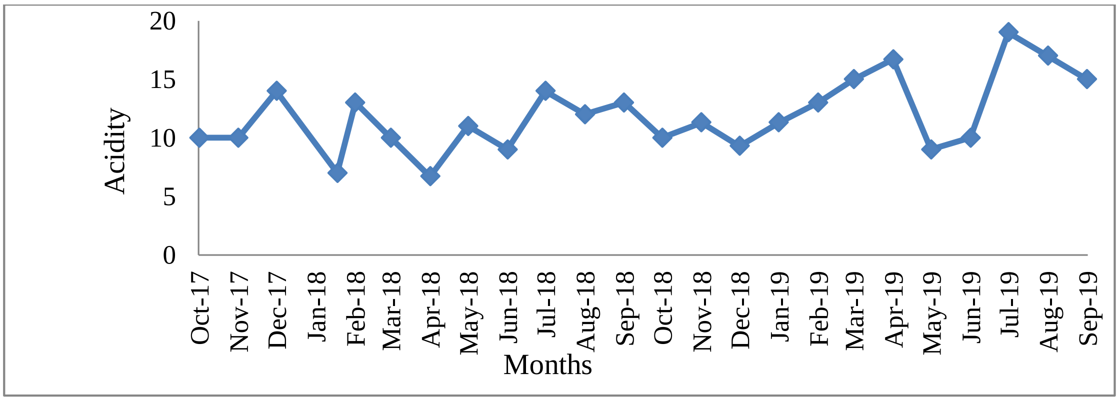


Figure 2.9. Monthly variations of Acidity (mg/L) of Thrissur Kole wetland, Oct 2017-Sep 2019

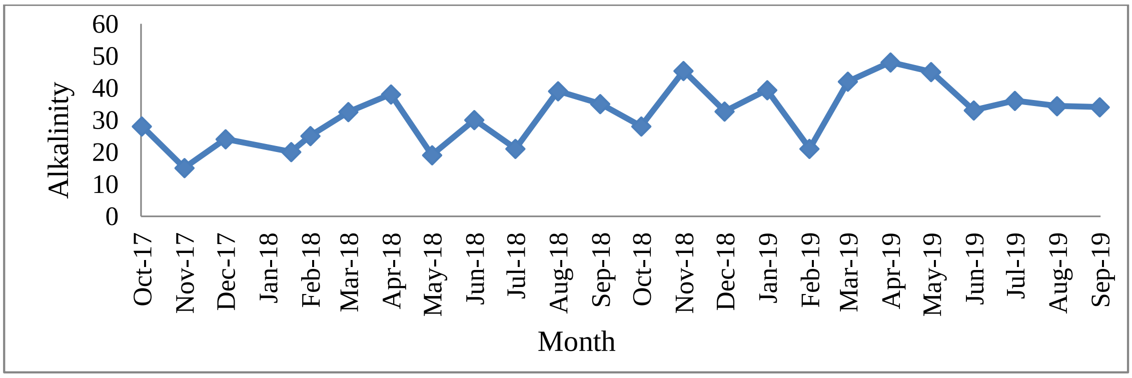


Figure 2.10. Monthly variations of Alkalinity (mg/L) of Thrissur Kole wetland, Oct 2017-Sep 2019

2.3.2.9. Chloride

The mean chloride content of the Thrissur Kole wetland water was 32.4 mg/L ranging between 13-75.5 mg/L with 44.6% variation. This was 34.5 mg/L during the first year and 30.3 mg/L in the second year. The highest value was recorded during October 2018 and the lowest during August 2018. On a seasonal basis, the highest chloride concentration was recorded during the post-monsoon season (40.1 mg/L), followed by pre-monsoon season (34.2 mg/L), and least during the monsoon season (22.8 mg/L). The chloride ranged between 29-45 mg/L during the pre-monsoon season, 13-40 mg/L during monsoon season and 24-75.5 mg/L during post-monsoon season. The graphical representation of the monthly variation in the chloride of the Thrissur Kole wetland is shown in Figure 2.14. Chloride shows significant positive correlation with TDS (r= 0.544, p= 0.006) and TASA (r= 0.823, p= 0.000), and significant negative correlation with alkalinity (r= -0.448, p= 0.028) and iron (r= -0.419, p= .042).

2.3.2.10. Iron

The mean iron content of the Thrissur Kole wetland water was 0.98 ranging between 0.81-1.5 mg/L with 17.4% variation. This was 0.98 mg/L during both sampling years. The highest value was recorded during June 2018 and the lowest during November 2017. On a seasonal basis, the highest concentration of iron was recorded during monsoon season (1.2 mg/L) and lowest and similar during pre-monsoon and post-monsoon season (0.9 mg/L).

The iron ranged between 0.84-0.99 mg/L during pre-monsoon season, 1.0-1.5 mg/L during monsoon season and 0.81-0.91 during mg/L post-monsoon season. The graphical representation of the monthly variation in the iron of Thrissur Kole wetland is shown in Figure 2.15. Iron shows significant positive correlation with dissolved oxygen (r= 0.539, p= 0.007) and significant negative correlation with laboratory pH (r= -0.429, p= 0.036), electrical conductivity (r= -0.439, p= 0.032), chloride (r= -0.419, p= 0.042), CO_2 (r= -0.447, p= 0.029), BOD (r= -0.432, p= 0.035) and COD (r= -0.564, p= 0.004).

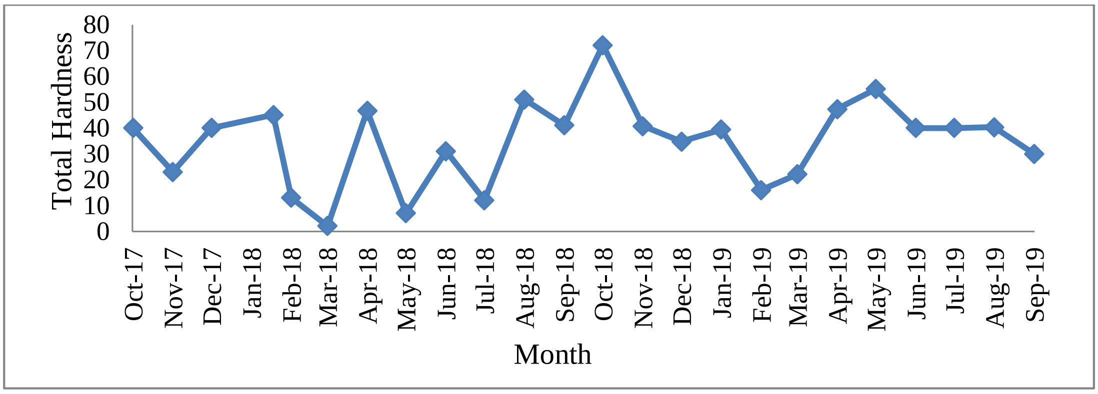


Figure 2.11. Monthly variations Total hardness (mg/L) of Thrissur Kole wetland, Oct 2017-Sep 2019

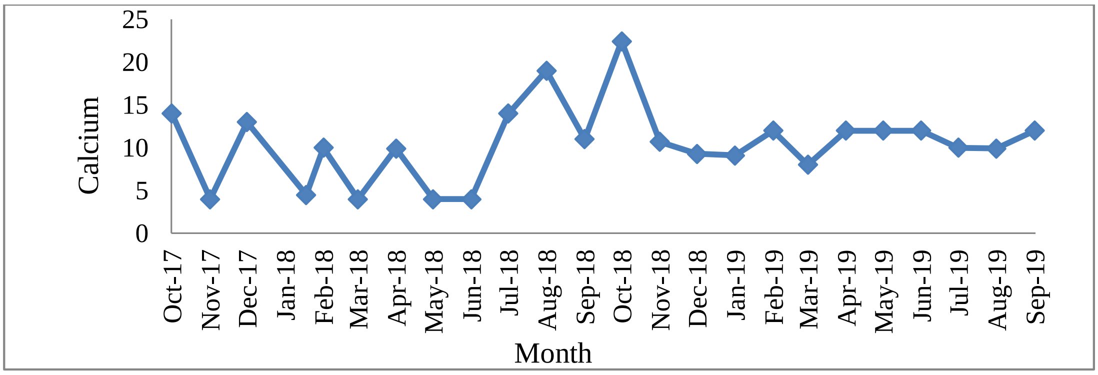


Figure 2.12. Monthly variations Calcium (mg/L) of Thrissur Kole wetland, Oct 2017-Sep 2019

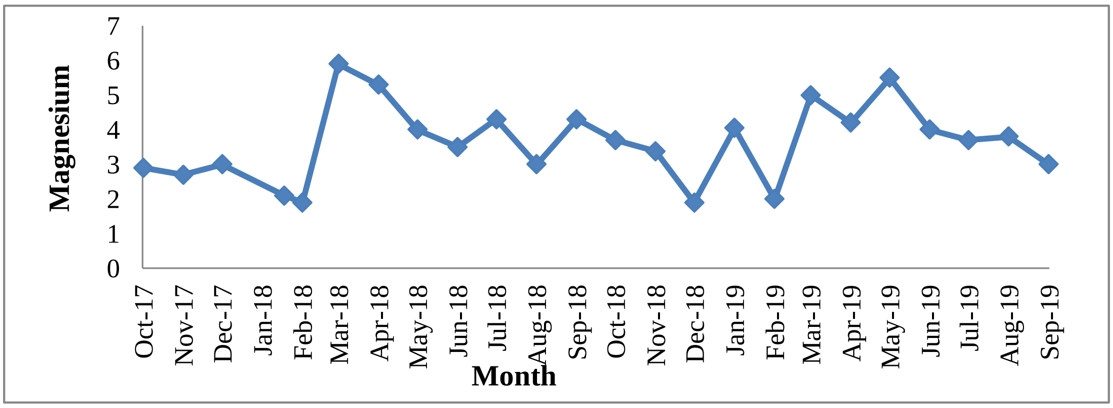


Figure 2.13. Monthly variations Magnesium (mg/L) of Thrissur Kole wetland, Oct 2017-Sep 2019

2.3.2.11. Nitrate

The mean nitrate content of the Thrissur Kole wetland water was 4.57 mg/L ranging between 3.03-6.0 mg/L with 20.8% variation. This was 4.5 mg/L during the first year and 4.6 mg/L during the second year. The highest value was recorded during May and July 2019 and the lowest during April 2018. On a seasonal basis, the highest concentration of nitrate was recorded during monsoon season (5.1 mg/L), followed by pre-monsoon (4.6) and lowest during the post-monsoon season (4.0 mg/L). The nitrate ranged between 3.03-6 mg/L during the pre-monsoon season, 4.0-6.0 mg/L during monsoon season and 3.1-5 mg/L during the post-monsoon season. The graphical representation of the monthly variation in the nitrate of the Thrissur Kole wetland is shown in Figure 2.16. Nitrate shows significant positive correlation with acidity (r= 0.465, p= 0.022).

2.3.2.12. Sulphate

The mean sulphate concentration of Thrissur Kole wetland water was 8.24 mg/L ranging between 4.5-13.1 mg/L with 36.7% variation. It was 8.3 mg/L in the first year and 8.1 mg/L in the second year. The highest value was recorded during May 2019 and the lowest during January 2019. On a seasonal basis, the highest concentration of sulphate was recorded during the pre-monsoon season (12.3 mg/L) followed by monsoon (6.6 mg/L) and lowest during the post-monsoon season (5.8 mg/L). The sulphate ranged between 11-13.1 mg/L during the pre-monsoon season, 5.9-7.9 mg/L during monsoon season and 4.5-7.0 mg/L during post-monsoon season. The graphical representation of the monthly variation in the sulphate of the Thrissur Kole wetland is shown in Figure 2.17. Sulphate shows significant positive correlation with air temperature (r= 0.814, p= 0.000), water temperature (r= 0.652, p= 0.001), electrical conductivity (r= 0.631, p= 0.001), magnesium (r= 0.462, p= 0.023) and BOD (r= 0.446, p= 0.029) and significant negative correlation with DO (r= -0.827, p= 0.000).

2.3.2.13. CO_2

The mean CO_2 content of the Thrissur Kole wetland water was 10.6 mg/L ranging between 4.0 -20 mg/L with 28.6% variation. This was 9.8 mg/L in the first year and 11.4 mg/L in the second year. The highest value was recorded during April 2019 and the lowest during July 2018. On a seasonal basis, the highest concentration of CO_2 was recorded during the pre-monsoon season (12.4 mg/L), followed by the post-monsoon season (11. mg/L) and the lowest during monsoon season (8.5). The CO_2 ranged between 10.0-20 mg/L during the pre-monsoon season, 4.0-12 mg/L during monsoon season and 8.8-15 mg/L during post-monsoon season. The graphical representation of the monthly variation in the CO_2 of the Thrissur Kole wetland is shown in Figure 2.18. CO_2 shows significant positive correlation with air temperature (r= 0.546, p= 0.006), water temperature (r= 0.473, p= 0.020) and BOD (r= 0.425, p= 0.038), and significant negative correlation with iron (r= -0.447, p= 0.029).

2.3.2.14. Dissolved Oxygen

Thrissur Kole wetland's mean dissolved oxygen content was 6.0 mg/L ranging between 4.0-8.0 mg/L with 23.5% variation. This was significantly similar in both sampling years in the first year. The mean DO is 6.0 mg/L and 5.9 mg/L in the second year. The highest value was recorded during June 2019 and the lowest during February, March, May 2018 and May 2019. On a seasonal basis, the highest concentration of dissolved oxygen was recorded during monsoon season (7.3 mg/L) followed by post-monsoon (6.4 mg/L) and lowest during pre-monsoon season (4.2 mg/L). The dissolved oxygen ranged between 4.0-5 mg/L during the pre-monsoon season, 6.5-8 mg/L during monsoon season and 5.5-7 mg/L during post-monsoon season. The graphical representation of the monthly variation in the dissolved oxygen of the Thrissur Kole wetland is shown in Figure 2.19. Dissolved oxygen shows significant positive correlation with iron (r= 0.539, p= 0.007) and significant negative correlation with air temperature (r= -0.760, p= 0.000), water temperature (r= -0.676, p= 0.000), electrical conductivity (r= -0.659, p= 0.000), sulphate (r= -0.827, p= 0.000) and BOD (r= -0.465, p= 0.022).

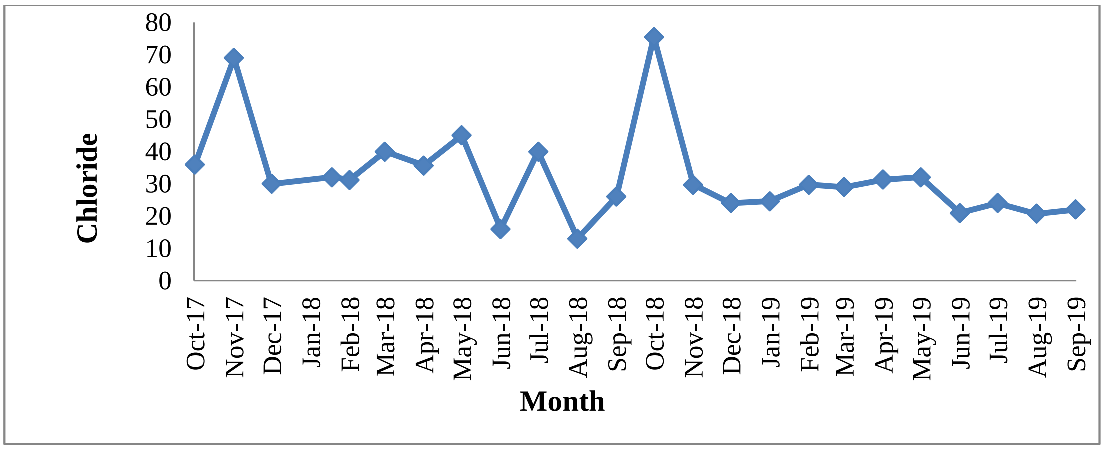


Figure 2.14. Monthly variations Chloride (mg/L) of Thrissur Kole wetland, Oct 2017-Sep 2019

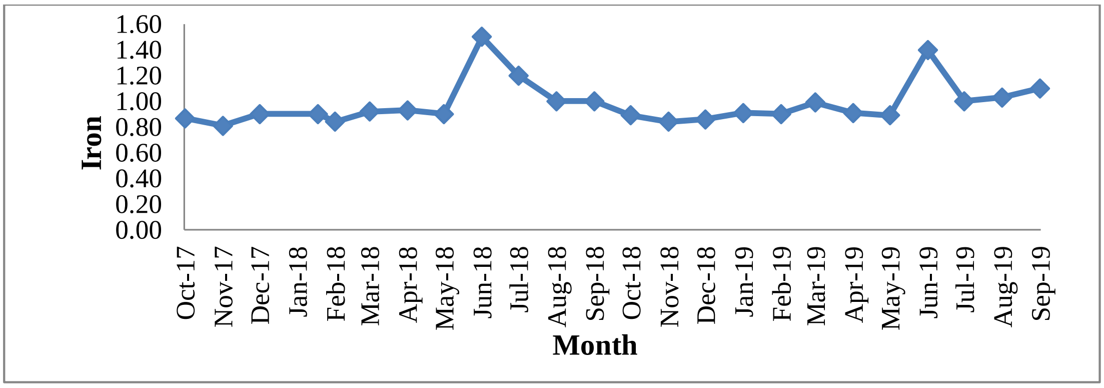


Figure 2.15. Monthly variations Iron (mg/L) of Thrissur Kole wetland, Oct 2017-Sep 2019

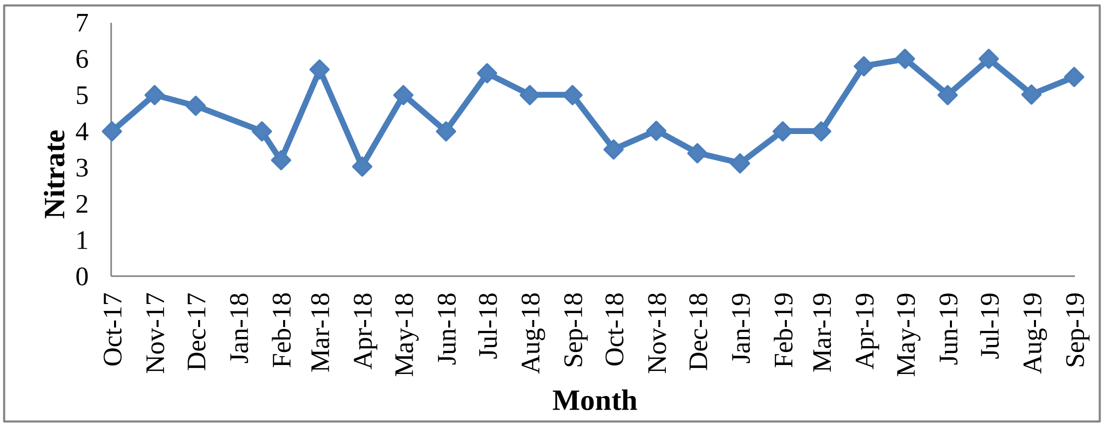


Figure 2.16. Monthly variations Nitrate (mg/L) of Thrissur Kole wetland, Oct 2017-Sep 2019

2.3.2.15. BOD

The mean BOD of Thrissur Kole wetland was 1.44 mg/L ranging between 0.7 to 2.7 mg/L with 40.1 % variation. This was 1.6 mg/L in the first year and 1.3 mg/L in the second year. The highest value was recorded during December 2017 and lowest during August and October 2018. On a seasonal basis, the highest concentration of BOD was recorded during pre-monsoon season (1.8 mg/L) followed by post-monsoon (1.6 mg/L) and lowest during the monsoon season (0.9 mg/L). The dissolved oxygen ranged between 1.1-2.5 mg/L during pre-monsoon season, 0.7-1.2 mg/L during monsoon season and 0.7-2.7 mg/L during post-monsoon season. The graphical representation of the monthly variation in the BOD of Thrissur Kole wetland is shown in Figure 2.20. BOD shows significant positive correlation with air temperature (r= 0.466, p= 0.022), electrical conductivity (r= 0.520, p= 0.009), sulphate (r= 0.446, p= 0.029), CO2 (r= 0.425, p=0.038) and COD (r= 0.454, p= 0.026), and significant negative correlation with total hardness (r= -0.454, p= 0.026), calcium (r= -0.456, p= 0.025), iron (r= -0.432, p= 0.035) and dissolved oxygen (r= -0.465, p= 0.022).

2.3.2.16. COD

The mean COD of Thrissur Kole wetland was 6.8 mg/L ranging between 3.0-11 mg/L with 37.5% variation. This was 6.3 mg/L in the first sampling year and 7.3 mg/L during the second sampling year. The highest value was recorded during February 2019 and the lowest during June 2019. On a seasonal basis, the highest concentration of COD was recorded during the post-monsoon season (8.6 mg/L) followed by pre-monsoon (7.6 mg/L), and lowest during monsoon season (4.3 mg/L). The COD ranged between 4.0-11 mg/L during the pre-monsoon season, 3.0-5 mg/L during monsoon season, and 7.0-10 mg/L during post-monsoon season. The graphical representation of the monthly variation in the COD of the Thrissur Kole wetland is shown in Figure 2.21. COD shows significant positive correlation with pH (r= 0.509, p= 0.011), BOD (r= 0.454, p= 0.026) and TASA (r= 0.422, p= 0.040), and negative correlation with iron (r= -0.564, p= 0.004).

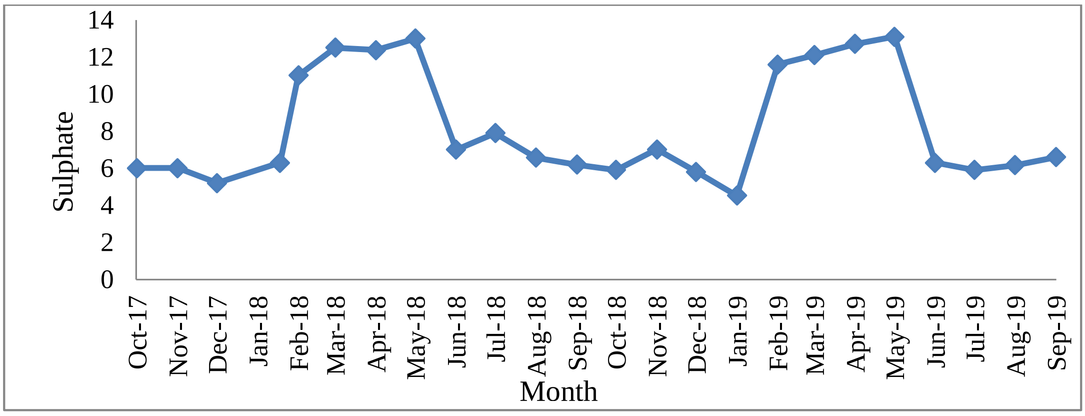


Figure 2.17. Monthly variations of Sulphate (mg/L) of Thrissur Kole wetland, Oct 2017-Sep 2019

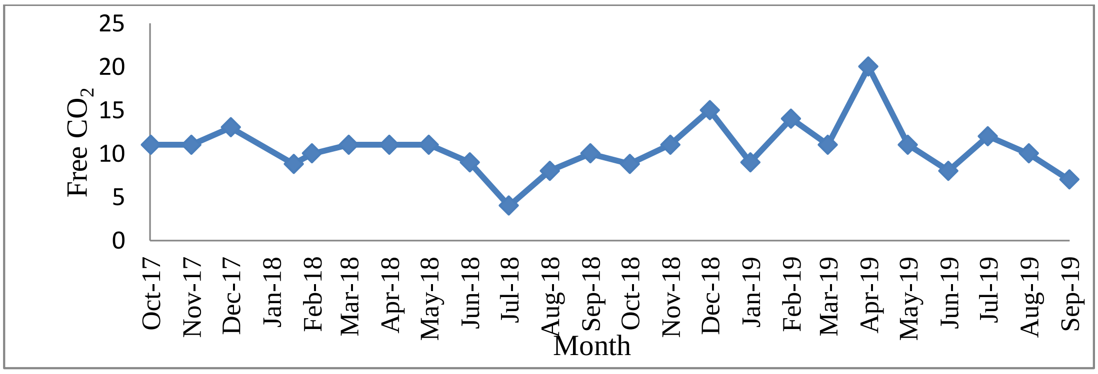


Figure 2.18. Monthly variations of free CO_2 (mg/L) of Thrissur Kole wetland, Oct 2017-Sep 2019

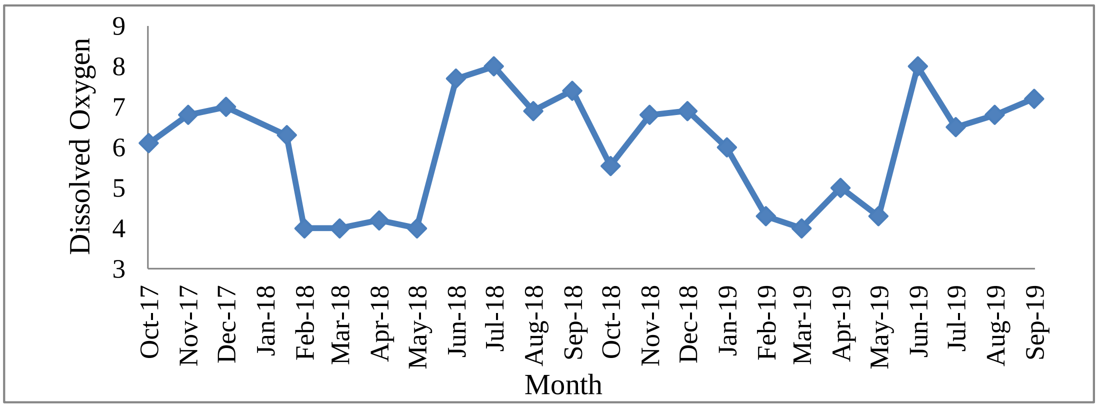


Figure 2.19. Monthly variations of Dissolved oxygen (mg/L) of Thrissur Kole wetland, Oct 2017-Sep 2019

2.3.2.17. TASA

The mean TASA value of Thrissur Kole wetland was 42.4 mg/L ranging between 24.6-85 mg/L with 35.8% variation. This was 41.7 mg/L in the first year and 43 mg/L in the second sampling year. The highest value was recorded during October 2018 and the lowest during May 2018. On a seasonal basis, the highest concentration of TASA was recorded during the post-monsoon season (49.9 mg/L), followed by pre-monsoon (42.7 mg/L) and lowest during monsoon season (34.6 mg/L). The TASA ranged between 24.6-53.5 mg/L during the pre-monsoon season, 24.6-53.5 mg/L during monsoon season and 33.2-84.9 mg/L during post-monsoon season. The graphical representation of the monthly variation in the TASA of the Thrissur Kole wetland is shown in Figure 2.22. TASA shows significant positive correlation with Chloride (r= 0.823, p= 0.000) and COD (r= 0.422, p= 0.040).

Pearson's linear correlation matrix was created using 24-month data of 21 parameters (Air Temperature, Water Temperature, Field pH , Lab pH, Conductivity, Turbidity, TDS, Calcium, Chloride, Magnesium, Hardness, Alkalinity, Acidity, Iron, Nitrate, Sulphate, TASA, DO, CO_2, BOD and COD), to define any co-variation (Table 2.3). The results obtained indicate strong positive relationships between AT, WT and SO_4; Cl with TASA, and very strong negative relationships between AT and DO; SO_4 with DO. AT shows weak positive correlation with EC, CO_2 and BOD; WT with EC, ALK, Mg, CO_2 and SO_4; pH with Ca and COD; EC with Mg, SO_4 and BOD; TDS with Cl and TASA; ACD with NO_3; ALK with TH and Mg; TH with Ca; Mg with SO_4; Fe with DO; SO_4 with BOD; CO_2 with BOD; and BOD with COD. WT shows a weak negative correlation with TUR and DO; pH with Fe; TUR with ALK; EC with Fe and DO; ALK with Cl; TH with BOD; Ca with BOD; Cl with Fe; Fe with CO_2, BOD and COD and DO with BOD.

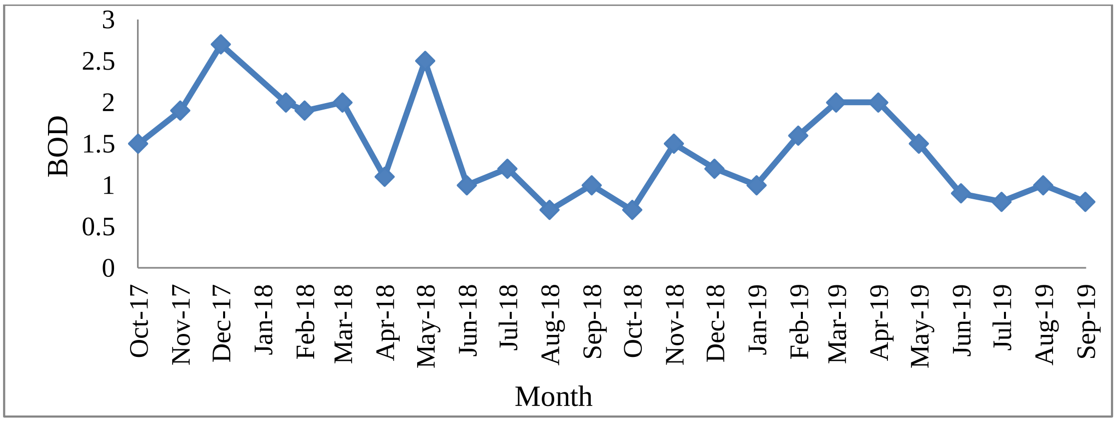


Figure 2.20. Monthly variations of BOD of Thrissur Kole wetland, Oct 2017-Sep 2019

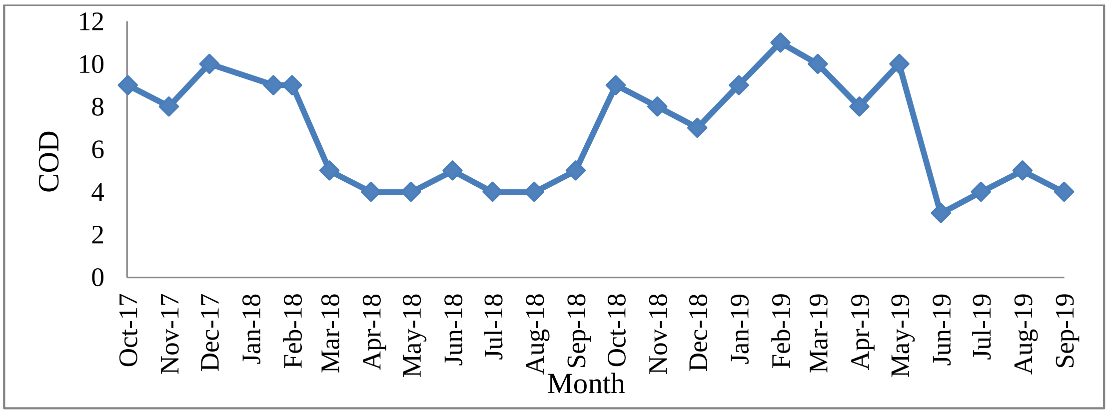


Figure 2.21. Monthly variations of COD of Thrissur Kole wetland, Oct 2017-Sep 2019

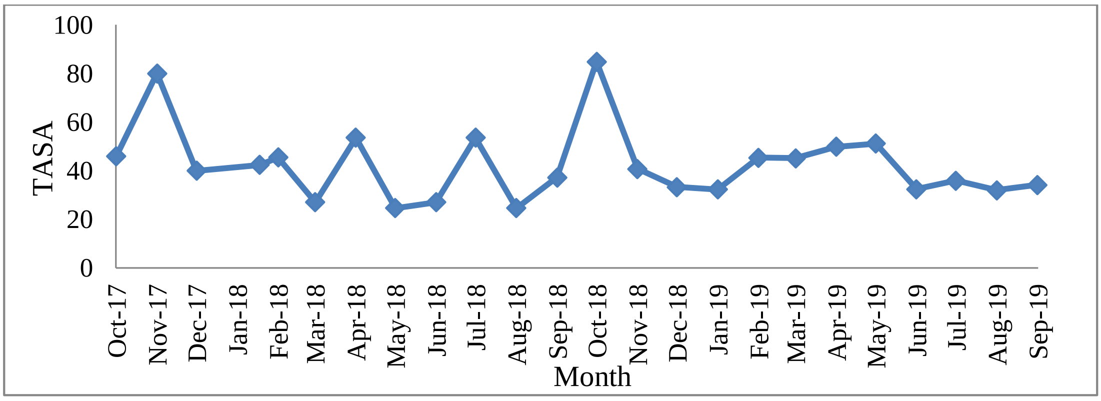


Figure 2.22. Monthly variations of TASA of Thrissur Kole wetland, Oct 2017-Sep 2019

2.3.3 Water Quality Index (WQI)

The mean value of each physical and chemical parameter was used to calculate WQI. The monthly fluctuation of WQI is shown in Table 2.4. The WQI value of Thrissur Kole wetland water was 222 (very poor water), which was above 190 every month (>190: not good). The maximum value was in June 2018 (335.2) and the minimum in February 2018 (190.7). The seasonal difference in the WQI values of first and second year is given in Fig 2.23. The higher WQI value was noted in the monsoon season (257) and the WQI values of pre-monsoon and post-monsoon season were significantly similar and values indicate very poor water. Therefore, there was only a small difference in the WQI value in the seasons of the first and second years respectively.

Month	WQI Value	Water Type	Month	WQI Value	Water Type
Oct 17	206	Very Poor Water	Oct 18	197	Poor Water
Nov 17	197	Poor Water	Nov 18	191	Poor Water
Dec 17	216	Very Poor Water	Dec 18	196	Poor Water
Jan 18	211	Very Poor Water	Jan 19	201	Very Poor Water
Feb 18	191	Poor Water	Feb 19	206	Very Poor Water
Mar 18	206	Very Poor Water	Mar 19	220	Very Poor Water
Apr 18	208	Very Poor Water	Apr 19	202	Very Poor Water
May 18	204	Very Poor Water	May 19	202	Very Poor Water
Jun 18	335	Unsuitable for Drinking	Jun 19	308	Unsuitable for Drinking
Jul 18	275	Very Poor Water	Jul 19	227	Very Poor Water
Aug 18	221	Very Poor Water	Aug 19	229	Very Poor Water
Sep 18	224	Very Poor Water	Sep 19	247	Very Poor Water

Table 2.4. WQI Values and Water Types from October 2017 - September 2019

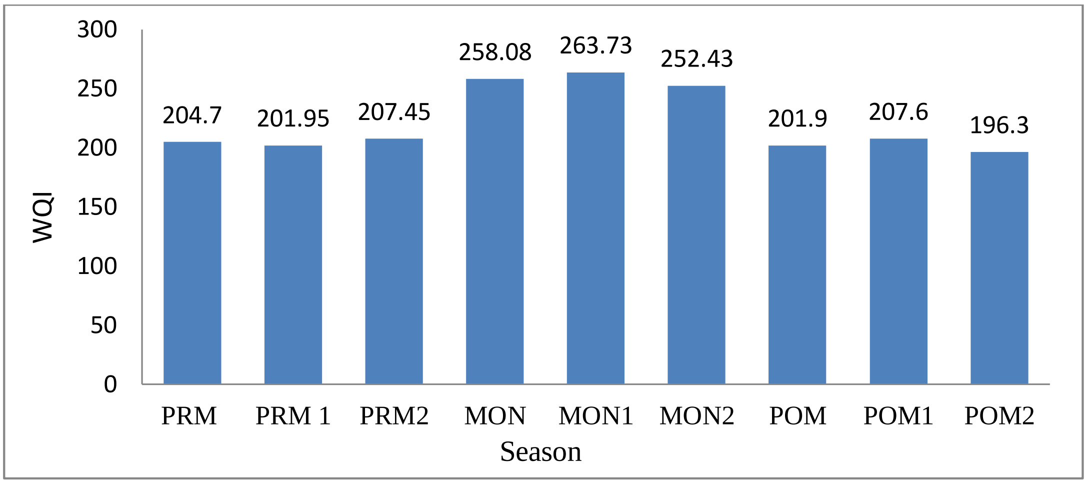


Figure 2.23. Seasonal Variation in WQI Value. WQI= Water Quality Index, PRM= Pre-Monsoon, MON= Monsoon, POM= Post-Monsoon 1= First Year 2= Second Year

2.4. Discussion

Temperature is an important factor (Heinle, 1969) that can alter whole alone in the aquatic ecosystem. Livingstone (1998) reported that global warming is the major reason for increased heat uptake by rivers, lakes, and reservoirs. The current study revealed a change in the air and water temperature every month due to the different collection times and seasonal influences. Sentis, Hemptinne, and Brodeur (2012) reported that temperature is one of the most important environmental parameters affecting all biological processes and functions of living things. Our results also agree with these findings, as all the Zooplankton groups show a correlation with the temperature. In the present study, temperature was significantly correlated with electrical conductivity, sulphate, CO_2 and BOD, and negative correlation with dissolved oxygen. Eliku and Leta (2018) reported the influence of conductivity, and dissolved gases on water temperature. This agrees with the current investigation. The air and water temperature were linearly related; this has been proved in a number of studies (Benyahya, Caissie, St-Hilaire, Ouarda, & Bobée, 2007; Langan, Donald, Donaghy, Hay, & Soulsby, 2001; Mohseni & Stefan, 1999; Vajravelu, Martin, Ayyappan, & Mayakrishnan, 2018).

The water temperature was lower during the monsoon season due to the decreased solar radiation, rainfall and cloudy sky and higher during the pre-monsoon season due to the higher atmospheric temperature (Perumal, Rajkumar, Perumal, & Rajasekar, 2009). Higher temperature during pre-monsoon season and minimum during monsoon season were also reported by a number of authors (Dhanasekaran, Bhavan, Manickam, & Kalpana, 2017; Guevara, Lozano, Reinoso, & Villa, 2009; kumar Dutta & Patra, 2013; Ladipo, Ajibola, & Oniye, 2011; Manickam et al., 2015; Perumal et al., 2009). The increase in water temperature has been shown to increase the chemical-biological reaction in the water and reduce gases' solubility, thus decreasing the dissolved oxygen (Antonopoulos & Gianniou, 2003; R. Sarkar et al., 2020).

pH is an important measure that depends on biological activity and changes in the temperature of the atmosphere. Most aquatic organisms prefer a certain pH, usually 6.5-9. Increasing or decreasing the pH causes stress and increases or decreases toxicity, thus affecting the survival and reproduction of organisms (W.-N. Wang, Wang, Chen, Liu, & Sun, 2002), so pH maintenance is the most important characteristic of any water system. Changes in pH is due to the photosynthetic and microbial activity (Nayak, Acharya, Panda, Nayak, & Acharya, 2004); higher pH increases the risk of the absorption of toxic chemicals by increasing the mobility of the toxic chemicals. Although the normal range of pH of the surface water is 6.5 to 8.5, the mean pH in the current study was slightly acidic, but within the acceptable limit of BIS and WHO standards, this acidic pH may be due to the environmental influence. pH shows a significant positive correlation with calcium and COD and a significant negative correlation with iron. The pH value varies slightly from season to season, with the same value for both pre-monsoon and post-monsoon seasons, and decreases during monsoon. Riddhi et al. (2011), Chennakrishnan, Stephen, Manju, and Raveen (2008) reported relatively low pH during the monsoon season, which is consistent with the current study that low pH during the monsoon season is mainly due to rainwater. According to K. Sharma, Devi, Arti, and Neha (2013), the main reason for the high values of pH in winter is the decrease in temperature and high values of DO and carbonate. According to Trivedy (1989), low water and high photosynthetic activity cause the pH to rise in pre-monsoon because the production of high carbon dioxide makes the water slightly alkaline.

Conductivity is the measure of the ability of the water to conduct electricity; it is an indirect measure of water quality. It tells you how many soluble substances, chemicals and minerals are in the water. This was related to the TDS content, and its value would increase as the level of pollution increased. The conductivity in this study was very high and varied greatly from month to month, indicating more volatile solids in the water. Conductivity below 750µS/cm is satisfactory and the growth is favourable to the growth of the organism. In the current study, maximum electrical conductivity was recorded during the pre-monsoon season and minimum during the monsoon season. The increased conductivity of salt due to evaporation is the reason for the high conductivity in the pre-monsoon and dilution of water reduces the electrical conductivity during monsoons due to the addition of rainwater. A similar seasonal trend was observed by Rahman and Huda (2012), P. Verma, Chandawat, and Solanki (2011), Pradeep, Deepika, Urvi, and Hitesh (2012). Riddhi et al. (2011) reported higher electrical conductivity during the pre-monsoon months due to the increase in the concentration of salt due to the discharge effluent and organic matter. Ayoade, Agarwal, and Chandola-Saklani (2009) found low electrical conductivity during monsoon; this agrees with the current investigation. Electrical conductivity is related to a number of other factors, including temperature, magnesium, sulphate, dissolved oxygen, BOD and iron. Electrical conductivity shows a strong positive correlation with air temperature, water temperature, magnesium, sulphate and BOD, and strong negative correlation with iron and dissolved oxygen.

Turbidity in the water is due to organic or inorganic suspended particles and high turbidity indicates the presence of large amounts of suspended solids. Seasonal data revealed significantly higher turbidity during monsoon season and less during pre-monsoon season. The mean turbidity of the study area was above the acceptable limit of BIS and WHO standards during the pre-monsoon season and above the permissible limit during the monsoon and the post-monsoon seasons. The main reason for the increase in turbidity during the monsoon season was the influx of suspended solids, rain water and clay, organic matter, silt, and microscopic organisms, making the water unfit for domestic purposes. El-Feky, E Alprol, MM Heneash, A Abo-Taleb, and Y Omer (2019) found minimum turbidity during the pre-monsoon season. Turbidity shows strong negative correlation with water temperature and alkalinity.

Total Dissolved Solids (TDS) contain inorganic salts (mainly calcium, magnesium, sodium, potassium, bicarbonates, sulfates, chlorides) and some water-soluble organic matter. TDS is used as an indicator of the aesthetic characteristics of drinking water and as an overall indicator of the presence of extensive chemical contaminants, which is generally not considered a primary contaminant. In the current study, the TDS was maximum during the post-monsoon season and minimum during the monsoon season. It was below the BIS standard, and shows strong positive correlation with chloride. Similar seasonal trend was noticed by Ayoade et al. (2009) in two high altitude rivers and R. Sarkar, Ghosh, A. R., & Mondal, N. K. (2020) in two urban ponds of Chandannagar. El-Feky et al. (2019) found high amounts of TDS during the post-monsoon season and P. Verma et al. (2011) found low amounts of TDS during the monsoon season as a result of the dilution of water, this agrees with the current investigation.

Alkalinity is a measure of the ability of water to neutralize acidity. An alkaline test measures the amount of carbonates, bicarbonates and hydroxides in water. Alkalinity is important; it protects aquatic organisms from rapid pH changes. In the current study, the mean alkalinity was significantly similar in the pre-monsoon and monsoon seasons and lower during the post-monsoon season. The sources of alkalinity in the water are the rocks and soils, salts, some plant activities and some industrial effluents. Ramzan, Zafarullah, Ahmad, Ali, and Malik (2020), Manjare, Vhanalakar, and Muley (2010) reported a lower level of alkalinity during the post-monsoon season; this agrees with the current study. Pradeep et al. (2012) recorded more alkalinity in the pre-monsoon period due to increased decomposition rate. Alkalinity shows a significant positive correlation with water temperature, total hardness, magnesium and a significant negative correlation with turbidity and chloride. A significant positive correlation of alkalinity and total hardness was also noticed by Ayoade et al. (2009) and El-Feky et al. (2019)**.** Acidity is the ability of water to neutralize an alkali, the highest value was recorded during the monsoon season followed by pre-monsoon season and lowest during post-monsoon season. Acidity shows a significant positive correlation with nitrate. High nitrate concentrations make water more acidic.

Calcium is naturally found in water. It may melt from rocks such as limestone, marble, calcite, dolomite, gypsum, fluorite and apatite. Calcium is one of the determinants of water hardness. In the current study, the calcium content was significantly similar in all the seasons; monsoon season shows a comparably higher concentration of calcium and pre-monsoon season shows minimum concentration. Calcium shows a significant positive correlation with pH and total hardness, and negative correlation with BOD. Magnesium, along with calcium, is responsible for water hardness. In the current study, magnesium was higher during the pre-monsoon season and lower during the post-monsoon season. A similar observation has been made by Bhatia and Nair (2020) in Shivnath river in Durg. Magnesium shows a significant positive correlation with water temperature, electrical conductivity, alkalinity and sulphate.

Chloride is one of the leading indicators of pollution. Chlorides are discharged into the water along with wastewater and agricultural runoff. Pure and salty water contains chlorides, which are essential components of life. The highest chloride concentration was recorded during the post-monsoon season, followed by the pre-monsoon season and lowest during the monsoon season. Chloride shows a significant positive correlation with TDS and TASA and a significant negative correlation with alkalinity and iron. Higher chloride concentration during the post-monsoon season is also noticed by El-Feky et al. (2019). Iron is considered a secondary or aesthetic contaminant and is not harmful to health. However, high levels of iron in water have several notable effects on odour and taste. The concentration of iron was recorded high during monsoon season and low and similar during pre-monsoon and post-monsoon season. Iron shows a significant positive correlation with dissolved oxygen and a significant negative correlation with laboratory pH, electrical conductivity, chloride, CO_2, BOD and COD. The iron content was above the acceptable level during the pre- and post-monsoon seasons and above the permissible limit during the monsoon.

Hardness is an important parameter for detecting water pollution. The water's total hardness indicates the water's quality only in terms of calcium and magnesium. In the present study, the total hardness of the water was below 60 mg/L, so it was considered as soft. The highest mean water hardness was recorded during the post-monsoon season, followed by monsoon season and lowest during pre-monsoon season. Similar observations have been made by El-Feky et al. (2019), and higher total hardness during the post-monsoon season was noticed by Ayoade et al. (2009) and Bora and Goswami (2017). Total hardness shows a significant positive correlation with laboratory pH, alkalinity, calcium and a significant negative correlation with BOD. Ayoade et al. (2009) noticed the significant positive correlation of hardness with alkalinity and Rahman and Huda (2012) found a significant positive correlation with pH, a similar correlation has been found in the present study.

Nitrate can occur naturally on the surface and in groundwater, which is usually harmless, and high levels of nitrate in the water are often caused by agricultural runoff or human and animal wastes. In the present study, the highest concentration of nitrate was recorded during the monsoon season, followed by the pre-monsoon and lowest during the post-monsoon season. Similar seasonal trends in the amount of nitrate were also noticed by P. Verma et al. (2011). Bhatia and Nair (2020) recorded high concentration of nitrate during the monsoon season in the Shivnath river in Durg, this agrees with the current finding. The amount of nitrate was below the acceptable limit and shows significant positive correlation with acidity. High levels of nitrate are obtained during the monsoon season due to the flow of fertilizers and rainwater (Savci, 2012). This could be a reason for the higher amount of nitrate during the monsoon season in this study.

Sulphate is one of the major constituents of rainwater (Efe, Ogban, Horsfall, & Akporhonor, 2005), and found in almost all natural waters. When combined with the two most common components of hardness, calcium and magnesium, the high concentration of sulphate in water makes it a laxative effect and organisms are sensitive to high sulphate levels. In the present study, the highest concentration of sulphate was recorded during the pre-monsoon season followed by monsoon and lowest during the post-monsoon season. Furthermore, sulphate shows significant positive correlation with air temperature, water temperature, electrical conductivity, magnesium and BOD and a significant negative correlation with DO.

Dissolved Oxygen (DO) is an important parameter of water quality, important for all living things. It is formed in water by diffusion directly from the air and by the photosynthetic action of autotrophs. DO is one of the most important parameters for indicating water purity. Some species prefer certain levels of DO, so it plays an important role in determining the distribution and abundance of organisms. In the present study, the highest concentration of dissolved oxygen was recorded during the monsoon season followed by post-monsoon and lowest during the pre-monsoon season, and this agrees with the finding of Datta (2011) in Gajoldoba beel and D. Jose, & Senthilkumaar, P. (2015). Dissolved Oxygen shows a significant positive correlation with iron and a significant negative correlation with air temperature, water temperature, electrical conductivity, sulphate and BOD. The lowest DO concentration is mainly due to the increase in temperature (Kumar Dutta & Patra, 2013); an increase in water temperature increases the chemical-biological reaction of the water and reduces the solubility of the gases, thus reducing the dissolved oxygen (Antonopoulos & Gianniou, 2003). In the present study, high temperatures may be one of the reasons for the decrease in DO in the pre-monsoon season.

Carbon dioxide is highly soluble in water and is one of the main constituents of aquatic organisms and is a major source of carbon footprint in nature. It is an important parameter required for the photosynthesis process in plants, as carbon dioxide in water reacts with water to form carbonic acid, which is rapidly broken down into carbonates and bicarbonates, which changes the pH of the water (Lower, 1999). The CO_2 of the water was normal during the study period. In the present study, the highest concentration of CO_2 was recorded during the pre-monsoon season, followed by the post-monsoon season, and lowest during monsoon season. Datta (2011) found a similar seasonal variation in Domohani beel. This agrees with the current investigation. CO_2 shows a significant positive correlation with air temperature, water temperature, and BOD, and a significant negative correlation with iron.

Biochemical Oxygen Demand (BOD) represents the amount of oxygen used by bacteria and other microorganisms that decompose organic matter under aerobic conditions. High levels of BOD are the best indicators of water pollution, as they directly affect dissolved oxygen and thereby imbalance the aquatic habitat. In the current study, the highest concentration of BOD was recorded during the pre-monsoon season, followed by post-monsoon, and lowest during the monsoon season. Similar seasonal differences in the BOD were noticed in Datta (2011), P. Verma et al. (2011), and D. Jose, & Senthilkumaar, P. (2015). BOD shows a significant positive correlation with air temperature, electrical conductivity, sulphate, CO_2, and COD and a significant negative correlation with total hardness, calcium, iron and dissolved oxygen.

Chemical Oxygen Demand (COD) is an important parameter for measuring the extent of water pollution; it measures the amount of oxygen needed to oxidize water-soluble and particulate matter. In addition, it is an indication of the amount of oxygen that can be used for different reactions in water. In the present study, the highest concentration of COD was recorded during the post-monsoon season followed by pre-monsoon and lowest during the monsoon season, and values were below the desirable limit. COD shows a significant positive correlation with pH, BOD and TASA, and a negative correlation with iron. In this study, it was found that the physical and chemical parameters of the tested water were not detrimental to the survival of the Zooplankton, but rather they were important in improving productivity. The concentration of all parameters except the value of iron and turbidity were within the permissible limit.

The Water Quality Index (WQI) is used to assess the condition of the water table, designed to understand the appropriateness of water for certain uses. The WQI is defined as an index that reflects the combined influence of different water quality parameters that are calculated and taken into account to calculate the water quality index. A simple number provided by WQI describes the level of water pollution. The

WQI value revealed that the water in the study area was abysmal. This is mainly due to the increased turbidity and iron content, above the acceptable level of BIS standard every month. The WQI value was relatively high during the monsoon season, while the pre-monsoon and the post-monsoon WQI values were low and similar, with very poor water in all the seasons. WQI in June during both years was above 300, which indicates that the water was unsuitable for drinking during these months. Wetland water becomes more polluted during monsoons due to flood, increased erosion, heavy household and agricultural discharge due to rainfall; a similar result was reported by Rubio-Arias, Contreras-Caraveo, Quintana, Saucedo-Teran, and Pinales-Munguia (2012). High WQI during the monsoon season was also observed by Bora and Goswami (2017) from Kolong River, Jomet and Yamakanamardi (2013) in Cauvery and Kapila rivers. Oberholster, Botha, and Cloete (2008) reported that increasing urbanization, industrialization, agricultural influx, and rapid human settlement increased sewage, agricultural, and residential flow in the wetland, leading to greater pollution.

2.5. Summary and Conclusion

The study concluded that there were seasonal and monthly differences in all physical and chemical parameters and that all parameters correlated with each other. Although WQI showed poor water quality in all the seasons, severely deteriorated conditions were detected during the monsoon due to surface runoff and wastewater discharge. Parameters such as iron and turbidity were very high, which led to high WQI value and low water quality. An important finding of this study is the changes in water quality according to the seasons. Disposal of organic waste from chicken farms, PET bottles, other plastics, and wastes from washed vehicles, oil and grease continue to be an unsolvable problem in various parts of the Kole land. The water quality index used in this work is based on 21 parameters. Inclusion of additional parameters, especially microbiological data, is recommended. Local background conditions must be taken into account when establishing a parameter rating for a WQI. Do not use WQIs indiscriminately, regardless of their features and limitations. This study helps to improve the water quality and maintain sustainable use by understanding the condition of the Kole Wetland water. As the Vembanad-Kole wetland was recently designated as a Ramsar site (Tuesday, November 19, 2002), it is the responsibility of the state and national authorities to protect and preserve the wetland.

Chapter III

Diversity and Abundance of Zooplankton in Thrissur Kole Wetland

3.1. Introduction

Zooplanktons are heterotrophic planktonic animals composed of primary consumers, consuming free-floating algae and secondary consumers, feeding on other Zooplanktons. Thus, it acts as a predator and indirectly affects resource competition between algae and bacteria. The main forms of P and N released from Zooplankton are easily absorbed by phytoplankton and sometimes act as an important nutrient supply to primary producers. Freshwater Zooplanktons are mainly composed of Rotifers and Crustacean Zooplanktons. Crustacean Zooplankton includes Cladocera, Copepoda and Ostracoda. Rotifera is a phylum, and other Zooplankton groups belong to the subphylum Crustacea of Phylum Arthropoda. Cladocera is an order coming under Class Brachiopoda, Copepoda is a subclass coming under class Maxillopoda and Ostracoda is a class under Subphylum Crustacea.

The Phylum Rotifera are microscopic Zooplanktons with short (∼1 to a few weeks) lifespans, containing about 2,000 species of unsegmented invertebrates, most of which are found in freshwater (Wallace, 2015). Rotifers are commonly called wheel animals or wheel animalcules because of crown-like cilia around the mouth. Rotifers are an important link in the food chain, crucial food source and contribute to the decomposition of soil organic matter and many other organisms. Rotifers' diets consist of dead or rotting organic matter, unicellular algae, and other phytoplankton, the primary producers of aquatic organisms. Most of the Rotifers are cosmopolitan. From a practical point of view, Rotifers are important in aquaculture and eco-toxicological studies. The main reason for the use of Rotifers in the eco-toxicological study is the very short life cycle, ease of handling and affordability.

Rotifers are considered as water quality indicators, and various Rotifer taxa act as bio-indicators of water quality. Reports from around the world confirm this fact (B. K. Sharma, 1998). The species composition of Rotifers are influenced by ecological changes (Fathibi, 2020). Phylum Rotifera is divided into three classes: Monogononta, Bdelloidea, and Seisonidea. The largest group is the Monogononta, followed by the Bdelloidea. There are only two known species in Seisonidea, and they are generally considered "primitive". Strictly bisexual reproduction is found only in the class Seisonidea in Rotifers (Ricci, Melone, & Sotgia, 1993). The study of Bdelloidea is very rare, the species can only be identified by observing active and living specimens, and there are no anaesthetic components available, so the analysis of Bdelloidea taxonomy features is challenging (Örstan & Plewka, 2017).

Rotifers have sexual, asexual, and cyclically parthenogenetic reproduction, and environmental factors influence sex determination. For example, Seisonidea Rotifers are bisexual, Bdelloid Rotifers shows asexual parthenogenesis and Monogononta Rotifers shows heterogony. Amictic females produce daughters (mictic/amictic) and mictic females produce males through parthenogenesis. When males do not fertilize the mictic female, they produce dormant eggs, hatch into amictic females. Production of mictic females is higher during high temperature (Birky Jr, 1971).

Cladocera is an older group of microscopic branchiopod crustaceans found in almost all freshwater habitats (A. Korhola, & Rautio, M., 2001). It is an important component of the micro crustacean fauna of freshwater ecosystems, which play multiple roles in aquatic habitats. About 620 species of Cladocera have been found in the world so far (Forró, 2007). Today only a few species of Cladocera can be found in the ocean, but the evolutionary history of many ancestral branchiopods began at sea. Dispersal capacity and tolerance to various environmental conditions are factors influencing the distribution of Cladocera. Except in Polyphemidae, Leptodoridae, Cercopagidae, and Podonidae, the whole body of the Cladoceran species is covered by a carapace, so there is no external proof for body division.

Cladocera is a filter feeder and the large Cladocera is very effective in removing algae from the water. Variation in the abundance and taxonomy of Cladocera is an indicator of various environmental changes and disturbances, such as climate change, trophic oscillations, acidification and changes in water level. The species composition of Cladocera is different across all continents, some species are very widespread and some are found only in small geographical areas (Smirnov, 2017). Reproduction in Cladocera is unusual. Most of the time, reproduction takes place through unfertilized female-bearing eggs. In adverse conditions like high temperature, lack of oxygen, lack of food, and overcrowding, males are produced by parthenogenesis and the diapausing eggs by gamogenesis. Paired diapausing eggs are covered with numerous protective membranes and form an “ephippium,” enhancing the dispersion.

Copepods are a group of small crustaceans found in all freshwater and saltwater habitats. Copepods are dominant members of the Zooplankton, used as biodiversity indicators. Some species are planktonic (floating in water), some are benthic, many species are parasitic, and some continental organisms live in limno-terrestrial habitats and other wetlands. Most Copepods have a body length of 0.5–1.5 mm. Adults of certain parasitic Copepods can grow up to several centimetres. Copepods are ecologically important and are a key component of biomass and secondary productivity of freshwater systems. They are important in the aquatic food web as primary and secondary consumers or as predatory species. Some Cyclopoids feed on fish larvae and other small animals, larger or smaller than themselves (Fryer, 1957). Compared to other Zooplankton, Copepods have more complex life cycles and a long generation time.

The subclass Copepoda consists of 10 orders, of these only five orders; Calanoida, Harpacticoida, Cyclopoida, Gelyelloida and Siphonostomatoida have been reported in freshwater (Boxshall, 2008). Copepods have short cylindrical bodies that are clearly divided into several segments. The head section is usually circular and prominent, often with long antennae that slow down when kept away from the body. The anterior parts carry the swimming appendages while the posterior segments, ending in a pair of caudal ramies at the base of the abdomen. The degree of segmentation of the pereiopod’s endopods, the number of spines on the metasome and the number of setae in the caudal rami are the important features for taxonomic identification. Males are slightly smaller than females and have modified antennae (first antennae) that are used to perceive females during mating. Some Copepods act as a biological control agent, which feeds on mosquito larvae (Früh, Kampen, Schaub, & Werner, 2019).

The world's freshwater Copepoda includes 552 species of Calanoida, 1124 species of Harpacticoida, 1096 species of Cyclopoida, 40 species of Siphonostomatoida, and two species of Gelyelloida. The basic factors for distinguishing groups are the body's shape, length of the first antenna and the position of the body constriction (Reid & Williamson, 2010). The two most important freshwater Copepods in Kerala are Calanoids and Cyclopoids (Cleetus, 2016). The antenna size helps identify three orders of Copepods in adults, with the lowest antenna being the Harpacticoids. Calanoids have antennae that are as long as the body. The antennae of Cyclopoids extend beyond the cephalothorax, so they are shorter than the Calanoids and longer than the Harpacticoids.

Ostracoda, also known as seed shrimp, are small aquatic crustaceans similar to small bivalve molluscs. The Ostracods are protected by a seed-shaped or mussel shaped carapace, which varies greatly in shape even within families; they can be spheroidal, elongated, enlarged, or compressed. The lateral view may be approximately square, triangular, ‘bean-shaped’ or ‘kidney-shaped’, or have anterior, posterior and dorsal extensions (DJ, 2009). This protective coating is composed of calcite and chitin. Almost all Ostracods are free-living filter feeders, most are herbivores or detritivores and are eaten by fish and various benthic and planktonic invertebrates.

Ostracods are very small (usually 0.5–2.0 mm) with two pairs of antennae (antennules, antennae), two mouthparts, three pairs of leg-like thoracic appendages, and a pair of furcal claws. The first and second antennas are well developed and extend beyond the carapace. The rest of the Ostracoda body is short and ends in a multi-spiked furca. Males can be larger or smaller than females, reproducing sexually and some species through parthenogenesis. Class Ostracoda in Crustacea contains marine and freshwater forms. The order Podocopida of the subclass Podocopa contains all the freshwater Ostracods in two suborders Metacopina and Podocopina.

3.2. Review of Literature

Studies are being conducted around the world on Rotifer species composition, morphologic and Genetic diversity, functional properties and interactions with other organisms. Saksena (1987) conducted a comprehensive survey of the literature on the use of Rotifers as bio-indicators to measure water quality. *Brachionus angularis, Polyarthra euryptera, Pompholix sulcata, Trichocerca cylindrica, Filinia longiseta* and *Rotaria rotatoria* were designated as indicators of heavy pollution (eutrophication). *Asplanchna herricki, Ascomorpha ovalis, Anuraeopsis fissa, Synchaeta grandis, Monostyla bulla M. hamata* and *Ploesoma hudsoni* are indicators of clean and pure water (oligotrophy), a variety of Rotifers, including *Brachionus, Keratella* species, live in moderately pure (mesotrophy) waters. B. Sharma (2017) studied the diversity of Rotifers in northeastern India, a hotspot for metazoan diversity. They found 150 species of Rotifers, two new to India and 38 new to Nagaland.

B. K. Sharma, Noroh, N., & Sharma, S. (2017) studied the diversity and distribution of Rotifers and observed 141 species of Rotifers from three Beels, including 31 genera and 17 families. They explained the influence of individual abiotic factors through canonical correspondence analysis. B. K. Sharma, & Sharma, S. (2018) provide clear information on the biodiversity, distribution and ecosystems of 14 species of Testudinella, a genus of Rotifera in India. Dastgeer et al. (2020) found 14 species of Rotifers from Lake Marala and some fish ponds in Pakistan, with more diversity in the lake than in fish ponds, and reported higher diversity during the summer season.

Singh (2020) studied the diversity of Zooplankton in high altitude wetland of the Dodi Tal in the Garhwal Himalaya and found the presence of certain pollutant indicator Rotifers such as *Brachionus caudatus, B. Patulus, Colurella obtusa* and *Cephalodella gibba.* Studies on Bdelloid Rotifers are rare in Asia. Zeng (2020) studied the diversity of Bdelloid Rotifers in China and documented 59 species, 39 of which were new to China. Mantovano et al. (2021) studied the major climatic and environmental variables suitable for the distribution of the exotic Rotifer, *Kellicottia bostoniensis* across the world. *Kellicottia bostoniensis* enters accidentally when importing commercially interested exotic fish such as tilapia into aquaculture, which they find to be the main reason for their distribution in new areas.

A. Korhola, & Rautio, M. (2001) studied the possibility for the paleontological study of two families of the Cladocera. Two of the 11 families, Chydoridae and Bosminidae, are well protected by its fortified carapace, while the others are not well preserved. For example, Daphnidae's exoskeleton, a major family of Cladocera, is very vulnerable to decomposition. Makino, Machida, Okitsu, and Usio (2020) studied different habitat selection in Cladocera using the genus *Moina*, and identified 7 species of *Moina* based on morphology and genetic analysis. It has been observed that the smaller species are mostly distributed in agricultural ponds followed by natural lakes and the larger variety in the paddy fields.

To find out how the high chloride concentration caused by road salt affects the Cladocera, Valleau (2020) studied the changes in the Cladoceran assembly of the five lakes affected by the road salt. The studied lakes showed different taxonomic shifts, including an increase in the abundance of *Chydorus brevilabris*, *Eurycercus* sp., and *Daphnia pulex* complex, and a decrease in the relative richness *Bosmina spp*, which was found to be more abundant before the application of road salt. The *Diaphanosoma* has a reproductive mode similar to that of *Daphnia*, but its dormant eggs are rarely observed, and dispersal is limited due to the absence of the ephippium. P. Liu, Xu, S. L., Liao, J., Dumont, H. J., & Han, B. P. (2020) developed microsatellite markers for a Cladocera *Diaphanosoma dubia* and used 11 microsatellite markers to analyze the spatial and temporal diversity of four sub-tropical waters, two large reservoirs and two temporary pools. Variation partitioning revealed that water storage and depth are important factors in genetic variation.

Padhye (2020) studied seasonal variation in diversity and functional composition of Cladoceran fauna in the Lotic habitat of India and was able to distinguish two seasonal clusters by a variety of faunal and functional patterns. Despite the severe pollution, the presence of the *Moina* was suspected to be an indicator of local pollution. Etile et al., (2020) reported 39 species of Cladocera from the Ivory Coast and found that Chydoridae was the most diverse family. Klemetsen (2020) studied the diversity and abundance of littoral Chydorids in a low-vegetation oligotrophic lake in Takvatn. The lowest abundance of Chydorid Cladocera was found in summer and maximum abundance was found in autumn. Da Silva Brito et al. (2020) explored the abundance and taxonomic structure of the Cladocera in the lakes of Pantanal from the state of Mato Grosso. In addition, they listed the known Cladocera in each hydrographic region of the state and recorded 120 species from eight families.

Desert lakes are one of the most endangered ecosystems globally, but studies of desert lakes are scarce compared to lakes in more humid regions. Li, Zhao, Hu, and Leppänen (2020) studied the Cladocera species composition of 40 lakes located in the Badain-Jaran Desert, with several megadunes and more than a hundred small lakes in China. Cladocera was completely absent in more salty water; some salt-tolerant species have been found in sub-saline lakes. Although a total of 8 species of Cladocera were found, and the remains of Cladocera were rarely seen, the most interesting finding is the ability of these species to grow in high alkalinity.

Copepods are an important component of the aquatic habitat and have been the subject of numerous studies worldwide. Novichkova and Azovsky (2017) studied the distribution and diversity of micro-crustacean fauna in 27 water bodies at high altitudes, and species abundance of Cladocera and Copepoda was found to increase significantly with temperature. Corgosinho et al. (2019) revised Copepod diversity in various parts of Ecuador and found a total of 27 species, of which Cyclopoids predominate. Perbiche-Neves et al. (2019) studied the impact of local environmental or climatic changes on the life strategies of Cladocera and Copepoda in the La Plata Basin. A total of 104 species of micro-crustaceans were identified. The distribution of Cladocera was regulated by local processes strongly related to the trophic state of the sites; similarly, localization and climate adaptation have influenced the distribution of Copepods.

Lopez and Papa (2020) studied the diversity and distribution of Copepods in groundwater habitats throughout Southeast Asia, and found a total of 47 species of Copepods in the order Calanoida, Cyclopoida, and Harpacticoida. Some species that were previously considered rare and endemic have actually been found to be common in some parts of the region.

Studies on freshwater Ostracoda are rare in India. Külköylüoĝlu and Vinyard (2000) identified fourteen freshwater Ostracoda species from 24 springs in Nevada, Idaho, and Oregon. The effects of water parameters, including temperature, dissolved oxygen, pH, and conductivity, were also studied. Külköylüoğlu (2003) studied the diversity of Ostracods from the lakes and reservoirs of Bolu, Turkey. No species were found in the reservoirs, and five species of Ostracods were found in the lakes. Temperature, pH, Salinity, and redox potential were the four factors that mostly influenced the preference of the organisms in these lakes. Akdemir and Kulkoyluoglu (2011) studied the summer diversity of Ostracoda from the province of Diyarbakir and found 23 species, one of which was new to Turkey.

From 141 reservoirs studied, 40 species of Ostracoda were reported by Külköylüoğlu and Sarı (2012). pH, air temperature, water temperature, and electrical conductivity were the most influential factors, and the effect of dissolved oxygen on the Ostracoda species composition was minimal. Külköylüoğlu, Yavuzatmaca, Akdemir, and Sari (2012) randomly selected 95 different locations from the southern Kahramanmaraş, recorded 48 Ostracoda species from 68 reservoirs, and reported water temperature as the most influential factor.

3.3. Materials and Methods

3.3.1. Sampling Period

Plankton samples were collected monthly for two consecutive years, as follows:

1. First year - from October 2017 to September 2018

2. Second year - from October 2018 to September 2019

3.3.2. Sample Collection

3.3.2.1. For Qualitative Analysis

Zooplankton samples were collected monthly from six different sites of Thrissur Kole wetland by using a Nylon plankton net having mesh size 60µ. A concentrated plankton sample was collected by towing the plankton net horizontally for about 10 minutes. Large crustacean larvae, tadpole larvae and some aquatic insects that entered the sample bottle were removed with the help of forceps during collection. In this way, samples collected from all sites were labelled and stored separately.

3.3.2.2. For Quantitative Analysis

For quantitative analysis, Zooplankton samples were collected monthly from six different sites of Thrissur Kole wetland by filtering 100 L of water through 60 µ mesh plankton net. Quantitative water samples were stored in special sample bottles of 100 ml capacity, with the site name, date and time labelled accurately.

3.3.3. Fixation and Preservation

The samples were preserved in 4% formalin, and a few drops of glycerin were added to prevent the samples from shrinking, drying the material, and retaining the colour of the Zooplankton.

3.3.4. Zooplankton Analysis

The number of Zooplankton was calculated using Sedgwick Rafter Counting Chamber, which can calculate the number of Zooplankton present in a 1 ml sub-sample of a well-mixed standard sample. The number was then converted to the number of organisms per litre of water.

3.3.4.1. Sedgwick-Rafter Cell Method

The Sedgwick-Rafter cell is the most common device to count the phytoplankton and Zooplankton. The Sedgwick rafter cell is a slide with a 50 mm x 20 x 10 mm compartment with a capacity of 1 ml.

For counting,

1. Stir the sample to distribute the organisms evenly, transferring exactly 1 ml of the sample to the cell with a pipette. Carefully place the cover slip on the cell, avoiding air bubbles. Allow the plankton to settle for a while.

2. When the sample is too concentrated, many organisms will cling to each other, get too close, and follow the wrong results. To avoid this difficulty, proper dilution of the plankton sample is essential.

3. The cell was moved horizontally and vertically to cover all areas and the total Zooplankton in the 1 ml sample was calculated. Take another drop and repeat the procedure until about 10 copies are counted.

3.3.4.2. Abundance of Zooplankton:

$$\text{Organisms/m}^3 = \frac{C \text{ x } V_1}{V_2 \times V_3}$$

Where,

C= No. of Organisms Counted

V_1= Volume of Concentrated Sample (50 ml)

V_2= Volume of Sample Counted (1 ml)

V_3= Volume of Grab Sample ($0.1m^3$)

Finally, to obtain organisms per litre, the no. of organisms per m^3 was divided by 1000.

3.3.4.3. Qualitative Analysis

Species composition of all the four groups of Zooplankton was scored after determining the abundance. Individual organisms are carefully placed on a glass slide with water and glycerin using a fine pipette or forceps. The water evaporated and only Zooplankton and glycerin remained on the slide, and then all parts of the body were carefully monitored under a compound or dissecting microscope according to their size.

3.3.4.4. Identification of Zooplankton

As most Zooplanktons are microscopic, their identification is an important part. The identification of each organism is done after careful observation of every part of the body based on morphological and taxonomic key characters described by Altaff (2004); Battish (1992); Shiel (1995); Y. R. Reddy (1994); Michael and Sharma (1988); Victor (2004); Victor and Fernando (1979).

3.3.5. Species Diversity

3.3.5.1. Shannon-Weaver Diversity Index (H)

The Shannon-Weaver Diversity Index, H, was calculated based on the number of taxa and individual abundance of organisms present in the sample (Wiener, 1949). The Shannon-Weaver index is the most widely used diversity index for examining the diversity of species derived from activity. It is used in the field of information in relation to describing the degree of uncertainty in predicting species. The Shannon diversity increases as the number of species increases.

Shannon Weiner Diversity Index is calculated as,

$H = -\sum(ni/N)\log(ni/N)$ or $H = -\sum P_i \log P_i$

Wherein,

H = Shannon-Weaver Diversity Index

ni = Important Value for Each Species

N = Total Number of Important Value

Pi = Important Probability for Each Species $Pi = ni/N$

3.3.5.2. Evenness Index (E)

Species evenness indicates how close each species is to an environment. Mathematically, it is defined as a diversity index, a measure of biodiversity that determines how equal the community is.

$E = H/LogS$

Wherein,

H = Shannon index (H)

S = Number of Species

3.3.5.3. Simpson Diversity Index (1-D)

Simpson's **Diversity** Index is a measure of diversity that considers the number of species present and the relative abundance of each species. As species' richness and evenness increase, diversity also increases.

$D = \sum (n(n-1)/N(N-1)$

n = the total number of organisms for particular species

N = the total number of the organism of all species

With this index, 0 represents infinite diversity and 1 represents zero diversity. That is, as the value of D increases, the diversity decreases. This is not intuitive or logical, so to overcome this problem, D is often subtracted or divided by 1 to give D. Here Simpson's Reciprocal Index 1/D was used to calculate Simpson's Diversity.

3.3.6. Statistical Analysis

The following statistical tests were carried out with the help of SPSS 21.0 version.

3.3.6.1. Rank Abundance Distribution

The rank abundance curve method (Avolio et al., 2019) was used to measure the species abundance (e.g., the number of individuals) relative to the abundance of other species. Rank abundance curve is used to depict species' richness and species' evenness visually. The Rank Abundance Curve is a chart used by ecologists to display the relative species abundance, a component of biodiversity.

X-axis: The abundance rank, most abundant species - rank 1, the second most abundant - 2, et cetera.

Y-axis: The relative abundance, usually measured on a log scale, is a measure of species abundance (e.g., the number of individuals) relative to the abundance of other species.

3.3.6.2. Pearson's Correlation Analysis

Pearson correlations were used to obtain the relationship of Zooplankton groups with the physico-chemical parameters of the water.

3.3.6.3. Regression Analysis

Based on the highly correlated physico-chemical parameters for each Zooplankton species, appropriate regression models were developed. Using the developed regression models, each Zooplankton species can be predicted by physico-chemical parameters. The normality of all the data was checked by using P-P Plot.

3.3.6.4. Canonical Correspondence Analysis

Canonical Correspondence Analysis (CCA) is a multivariate method for clarifying the relationship between the biological assemblies of organisms and their environment. To illustrate the relationship between environmental variables and Zooplankton species, a Canonical Correspondence Analysis (CCA) was performed using 21 environmental variables.

3.3.6.5. Molecular Phylogenetic Analysis

The applicability of molecular strategies in analyzing the evolutionary perspectives of the identified specimens has been investigated using the nucleotide sequences retrieved from NCBI (National Centre for Biotechnology Information). The species name has been designated as the keyword for downloading the COI sequences from NCBI. The evolutionary perspectives of this investigation's identified specimens were inferred using the Maximum Likelihood Method based on the Tamura 3-parameter model (Tamura, 1992).

The initial tree for the heuristic search was acquired automatically by employing Neighbor-Join and BioNJ algorithms to a matrix of pairwise distances computed using the Maximum Composite Likelihood (MCL) strategy and then choosing the topology with superior log likelihood value. The tree is drawn to scale along with branch lengths calculated in the number of substitutions. The analysis encompassed 25 nucleotide sequences of the identified specimens. The following codon positions were included in the analysis; 1st+2nd+3rd+Noncoding. The final dataset possessed 828 positions. All the steps required for the evolutionary analyses of the Class Monogononta of the study area were conducted in MEGA7 (S. Kumar, Stecher, & Tamura, 2016).

3.4. Results

3.4.1. Total Zooplankton

3.4.1.1. Diversity of Zooplankton

The Zooplankton of the study area is very rich and diversified, with 77 species, including Rotifera, Cladocera, Copepoda and Ostracoda. These belong to 2 Phylum, 20 families and 44 genera. Rotifera, the largest group (Figure 3.1.) constituted 52% of the collected species; Cladocera, Copepoda and Ostracoda constituted 27%, 13%, 8%, respectively. The species diversity of Zooplankton of the study area is shown in Table 3.1. A systematic list of Zooplankton of Thrissur Kole wetland is given in Tables 3.2 & 3.3. There was a significant diversity of Rotifers in the Thrissur Kole wetland. Rotifers had a higher Shannon, Simpson, and Evenness index, so they showed greater diversity and evenness than other Zooplankton groups, followed by Cladocera. The diversity indices of the Copepoda were relatively low compared to the others. The evenness index was seen less in Ostracoda, so this group showed less evenness than others. More species and families have been recorded in the Rotifera group, while more genera have been found in Cladocera (Figure 3.2.).

Period	Number of Species	Number of Genera	Number of Families	Number of Orders	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)

Rotifera	40	14	10	2	3.338	0.954	0.411
Cladocera	21	16	6	-	2.424	0.857	0.3121
Copepoda	10	8	2	2	1.5433	0.6965	0.2329
Ostracoda	6	6	2	-	1.713	0.808	0.056

Table 3.1. The Diversity of all the Four Group of Zooplankton in Thrissur Kole Wetland Oct 2017- Sep 2019

The species diversity of Zooplankton in the study area showed seasonal variations; the Rotifera and Ostracoda showed significant seasonal variations in a number of species, while Cladocera and Copepoda were significantly similar in all the seasons (Figure 3.3.). The number of species of Rotifera was more during the pre-monsoon season and less during the monsoon season. The number of Cladocera species was similar during the pre-monsoon and monsoon season, with one species more in the post-monsoon season. Similar seasonal variation in the number of species was also noticed in Copepoda. The Ostracoda was absent during the pre-monsoon period. One more species was observed during the post-monsoon period than during the monsoon.

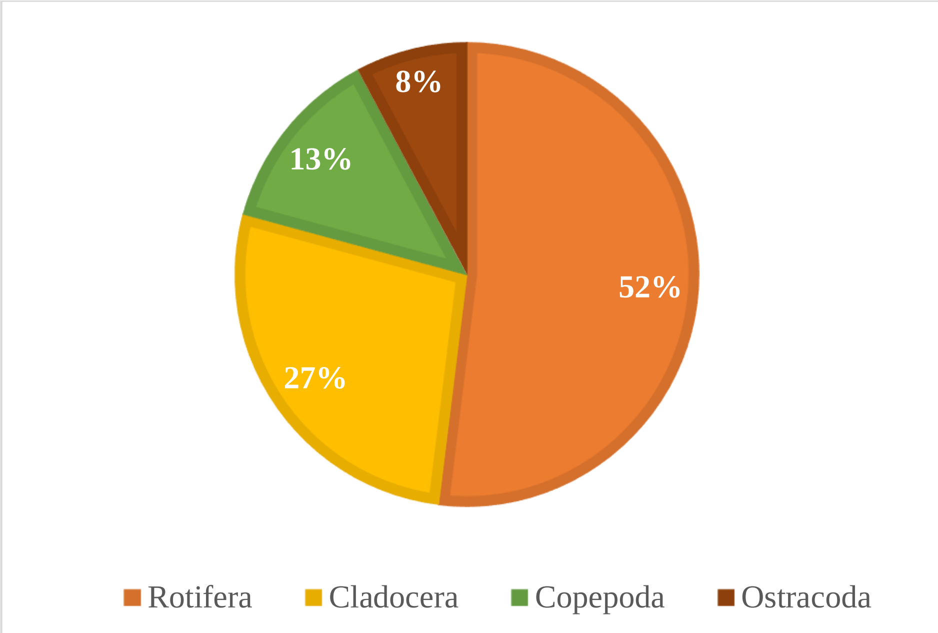


Figure: 3.1. Pie chart showing the percentage composition of Zooplankton groups

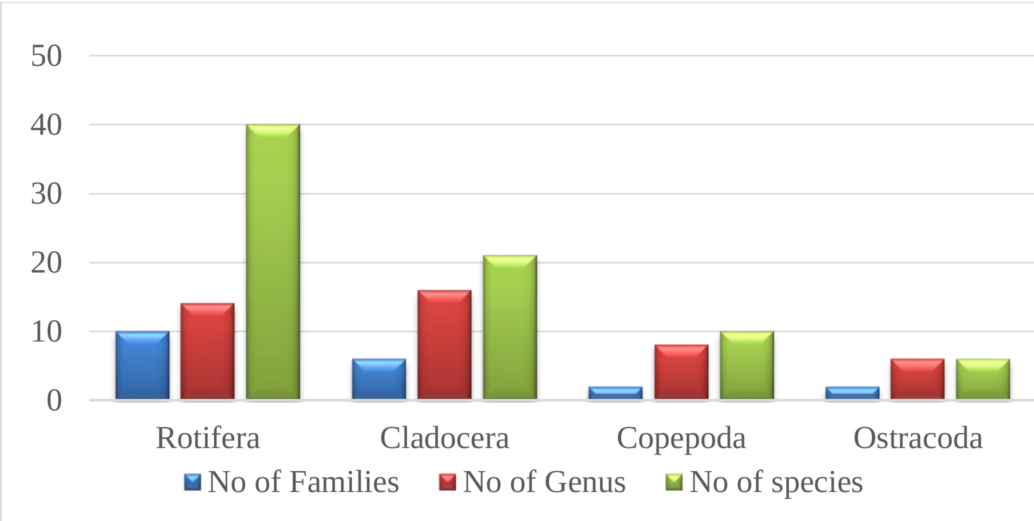


Figure 3.2. Bar Diagram Showing the Number of Families, Genera and Species in Different Groups of Zooplankton

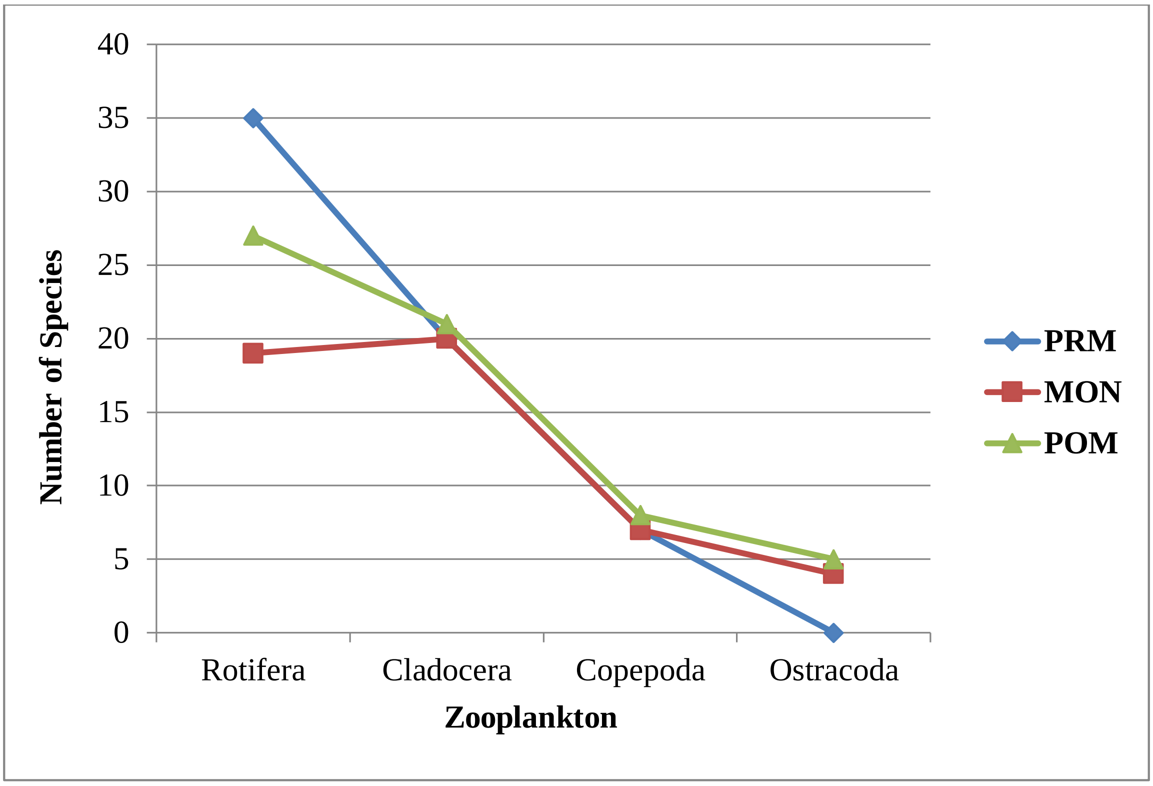


Figure 3.3. Seasonal Variation in the Diversity of Zooplankton in Thrissur Kole Wetland during the Study Period

Phylum: Rotifera Cuvier, 1817
Class: Eurotatoria De Ridder, 1957
Subclass: Monogononta Plate, 1889
Order: Ploimida Hudson & Gosse, 1886
Family: Brachionidae Wesenberg-Lund, 1899

Genus *Anuraeopsis* Lauterborn, 1900

1. *A.fissa* Gosse, 1851
2. *A. navicula* Rousselet, 1911

Genus: *Brachionus* Pallas, 1766

3. *B. angularis* Gosse, 1851
4. *B. forficula* Wierzejski, 1891
5. *B. Calyciflorus* Pallas, 1766
6. *B. falcatus* Zacharias, 1898
7. *B. dichotomus* Shephard, 1911
8. *B. sessilis* Varga, 1951

Genus: *Platyias* Harring, 1913

9. *Platyias quadricornis* Ehrenberg, 1832
10. *Platyias patulus* O. F Mullar, 1786

Genus: *Keratella* Bory de St. Vincent, 1822

11. *K. Cochlearis* Gosse, 1851
12. *K. tropica* Apstein, 1907

Family: Asplanchnidae Harring & Myers, 1926

Genus: *Asplanchna* Gosse, 1850

13. *A. brightwelli* Gosse, 1850
14. *A. herricki* De Geurne, 1888
15. *A. priodonta* Gosse, 1850

Family: Mytilinidae Bartos, 1959

Genus: *Mytilina* Bory de St. Vincent, 1822

16. *Mytilina sp.*

Family: Lecanidae Bartos, 1959

Genus: *Lecane* Nitzsch, 1827

17. *L. cornuta* O. F. Muller1786
18. *L. bulla* Gosse, 1851
19. *L. aculeata* Jakubski, 1912
20. *L. furcata* Murray, 1913
21. *L. monostyla* Daday, 1897
22. *L. luna* Müller, 1776
23. *L. lateralis* Sharma, 1978
24. *L. inopinata* Harring & Myers, 1926
25. *L. pyriformis* Daday, 1905
26. *L. sp1*
27. *L. sp2.*

Family: Trichocercidae Remane, 1933

Genus: *Trichocerca* Lamarck, 1801

28. *T. cylindrica* Imhof, 1891
29. *T. kostei* Segers, 1993
30. *T. longiseta* Schrank, 1802
31. *T. similis* Wierzejski, 1893
32. *T, rattus* Müller, 1776

Family: Synchaetidae Remane, 1933

Genus: *Polyarthra* Ehrenberg, 1834

33. *P. vulgaris* Carlin,1943
34. *Polyarthra sp.*

Genus: Synchaeta Ehrenberg, 1832

35. *Synchaeta sp.*

Order: Flosculariacea Ramane, 1933
Family: Trochosphaeridae Harring, 1913

Genus: *Horaella* Donner, 1949

36. *H. brehmi Donner, 1949*

Family: Conochilidae Remane, 1933

Genus: *Conochilus* Ehrenberg, 1834

37. *C. unicornis* Rousselet, 1892
38. *C. hippocrepis* Schrank, 1803

Family: Filinidae Bory de St. Vincent, 1824

Genus: *Filinia* Bory de St. Vincent, 1824

39. *F. opoliensis* Zacharias1898

Family: Testudinellidae Harring, 1913

Genus: *Testudinella* Bērziņš, 1973

40. *T. patina* Hermann, 1783

Table 3.2. Systematic List of Rotifers of Thrissur Kole Wetland Identified during the Study Period

Phylum: Arthropoda Latreille, 1829
Subphylum: Crustacea Brunnich, 1772
Class: Maxillopoda; Dahl, 1956
Sub class*:* Copepoda H. Milne Edwards, 1830
Order: Calanoida; Sars1903 ,
Family: Diaptomidae Sars, 1903

1. Genus: *Heliodiaptomus Kiefer*, 1932
   Heliodiaptomus cinctus Gurney, 1907

Genus: *Allodiaptomus* mieni Dang & Ho, 1985

2. *Allodiaptomus* mirabilipes Kiefer, 1936

Genus: *Neodiaptomus* Kiefer, 1932

3. *Neodiaptomus sp.*

Order: Cyclopoida Burmeister1834 ,
Family: Cyclopidae Rafinesque, 1815
Genus: *Eucyclops* Claus, 1893

4. *Eucyclops serrulatus* Fischer, 1851

Genus: *Mesocyclops* Sars, 1914

5. *Mesocyclops leuckarti Claus, 1857.*
6. *Mesocyclops ogunnus Onabamiro, 1957*

Genus: *Microcyclops* Claus, 1893

7. *Microcyclops varicans* Reid, 1992.
8. *Microcyclops rubellus* Lilljeborg, 1901

Genus: *Thermocyclops* Kiefer, 1927

9. *Thermocyclops crassus* Fischer, 1853

Genus: *Ectocyclops* Brady, 1904

10. *Ectocyclops rubescens* Brady, 1904.

Class: Ostracoda Latreille, 1802
Order: Podocopida Sars1866 ,
Family: Cyprididae Baird, 1845
Genus: *Cyprinotus* Brady, 1886

1. *Cyprinotus cingalensis* Brady, 1886

Genus: *Stenocypris* Sars, 1889

2. *Stenocypris sewelli* Klie, 1927

Genus: *Strandesia* Stuhlmann, 1888

3. *Strandesia flavescens* Klie, 1932

Genus: *Cypreta* Vavra, 1895

4. *Cypreta fontinalis* Hartman, 1964

Genus: *Eucypris* Vávra, 1891

5. *Eucypris sp.*

Family: Notodromadidae
Genus: *Indiacypris* Hartmann, 1964

6. *Indiacypris dispar* Hartman, 1964

Class: Brachiopoda Latreille, 1817
Subclass: Phyllopoda Preuss, 1951
Order: Cladocera Latreille, 1829
Family: Sididae Baird, 1850
Genus: *Diaphanosoma* Fischer, 1850
1. *D. excisum* Sars, 1885
2. *D. sarsi* Richard, 1894
Genus: *Latonopsis* Sars, 1888
3. *L. australis* Sars, 1888
Genus: *Pseudosida* Herrick, 1884
4. *Pseudosida szalayi* Daday, 1898
Family: Daphnidae Straus, 1820
Family: Daphnidae Straus, 1820
Genus: *Ceriodaphnia* Dana, 1853
5. *Ceriodaphnia cornuta* Sars, 1885
Genus: *Simocephalus* Schoedler, 1858
6. *Simocephalus acutirostratus* King, 1853
7. *Simocephalus serrulatus* Koch, 1841
Family: Moinidae Goulden, 1968
Genus: *Moina*, Baird, 1850
8. *Moina micrura* Kurz, 1874
Family: Bosminidae Sars, 1865
Genus: *Bosminopsis* Richard, 1895
9. *Bosminopsis deitersi* Richard, 1895
Family: Macrothricidae Norman & Brady, 1867
Genus: *Macrothrix* Baird, 1843
10. *Macrothrix triserialis* Brady, 1886
11. *Macrothrix goeldii* Richard, 1897
Genus: *Ilyocryptus* Sars, 1862
12. *Ilyocryptus spinifer* Herrick, 1882
Family: Chydoridae Stebbing, 1902
Subfamily: Chydorinae Stebbing, 1902
Genus: *Alonella* Sars, 1862
13. *Alonella sp.*
Genus: *Chydorus* Leach, 1816
14. *Chydorus sphaericus* O. F. Muller, 1776
15. *Chydorus barroisi* Richard, 1894
Subfamily: Aloninae Frey, 1967
Genus: *Alona* Baird, 1843
16. *Alona rectangula* Sars, 1862
17. *Alona monacantha* Sars, 1901
Genus: *Biapertura* Smjrnov, 1971
18. *Biapertura affinis* Leydig, 1860
Genus: *Oxyurella* Dybowski & Grochowski, 1894
19. *Oxyurella singalensis* Daday, 1898
Genus: *Kurzia* Dybowski & Grochowski, 1894
20. *Kurzia longirostris* Daday, 1898
Genus: Euryalona Sars, 1901
21. *Euryalona orientalis* Daday, 1898

Table 3.3. Systematic List of Crustacean Zooplankton Identified during the Study Period

3.4.1.2. Abundance of Zooplankton

The abundance of all the four Zooplankton groups during the study period is shown in Figure 3.4. The average abundance in Figure 3.5. Rotifera was more abundant, 51% of the individual Zooplankton collected during the study period belonged to this Phylum. Cladocera recorded 34% of the total, Copepod 12% and Ostracoda only 3%. The average abundance of Rotifera was 18 times more than that of Ostracoda. Zooplankton abundance showed monthly (Figure 3.6.) and seasonal variation (Figure 3.7 & 3.8). Rotifera, Cladocera and Copepoda showed more abundance in the pre-monsoon season followed by monsoon and less during the post-monsoon season. There was no Ostracoda during the pre-monsoon season, and the Ostracoda abundance was significantly similar during the monsoon and the post-monsoon seasons.

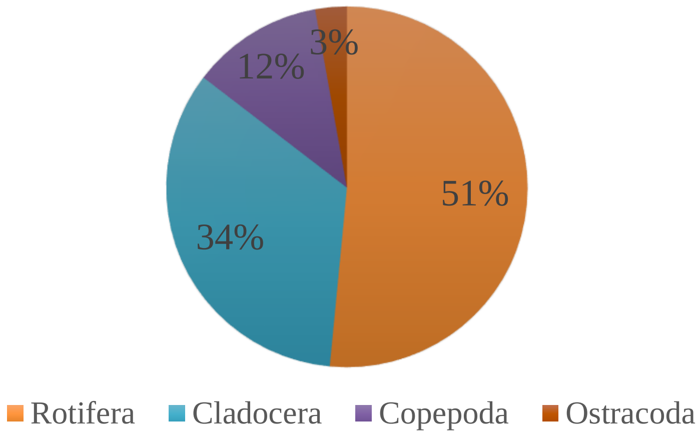


Figure 3.4. The Abundance of the Zooplankton Groups during the Study Period

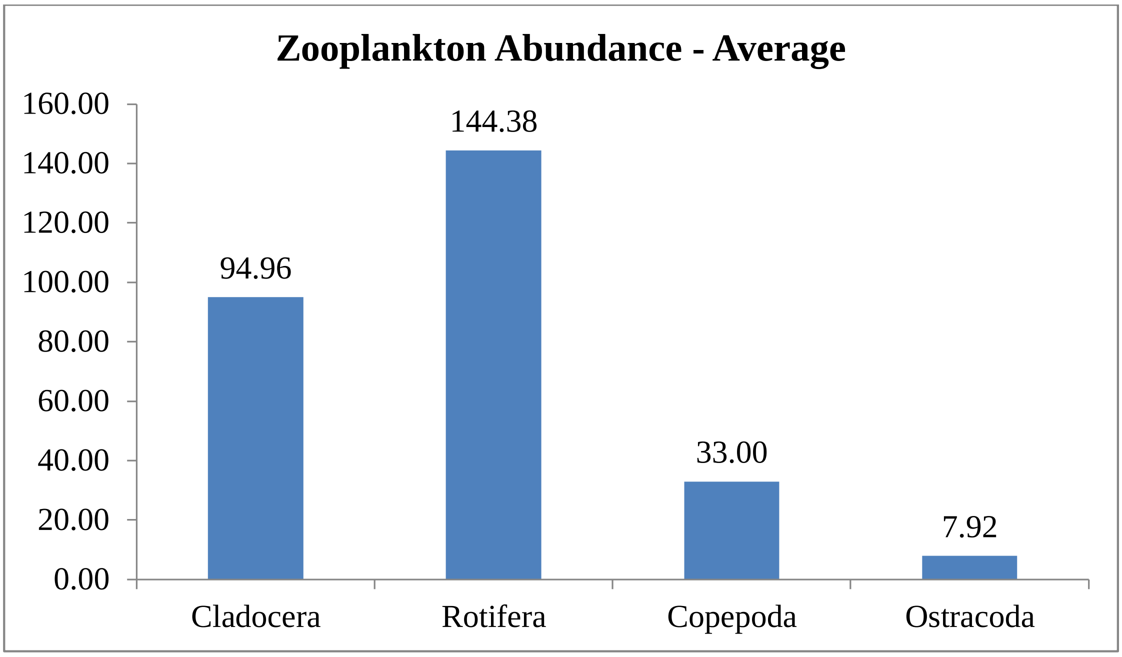


Figure 3.5. Average Abundance of Zooplankton Groups during the Study Period

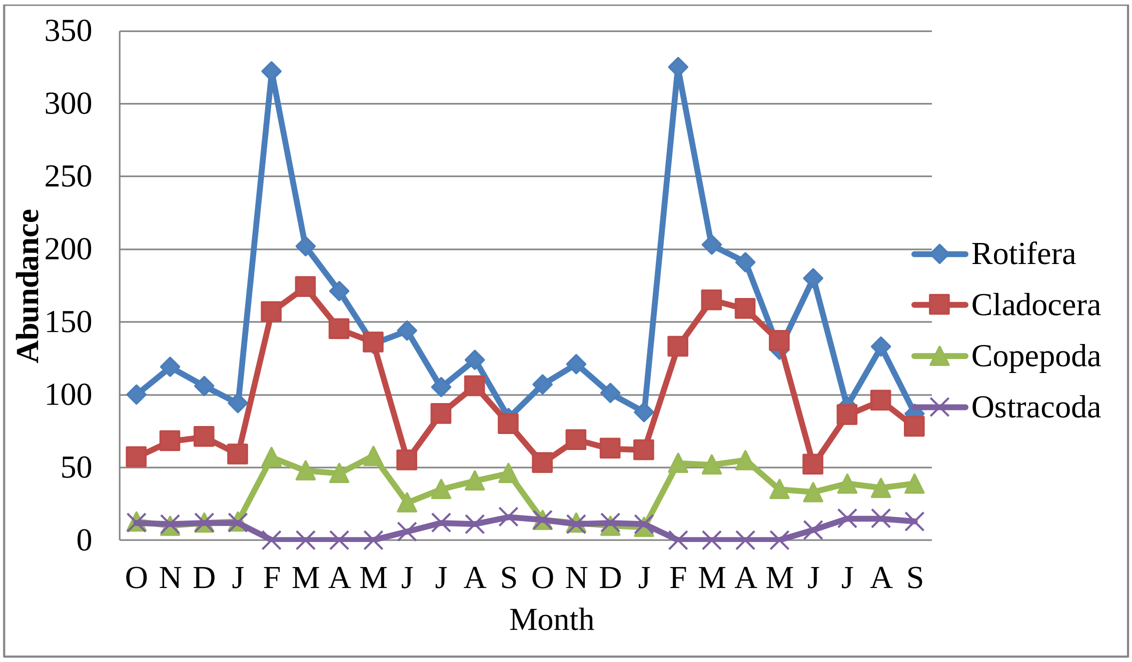


Figure 3.6. Monthly Variation in the Abundance of Zooplankton Groups

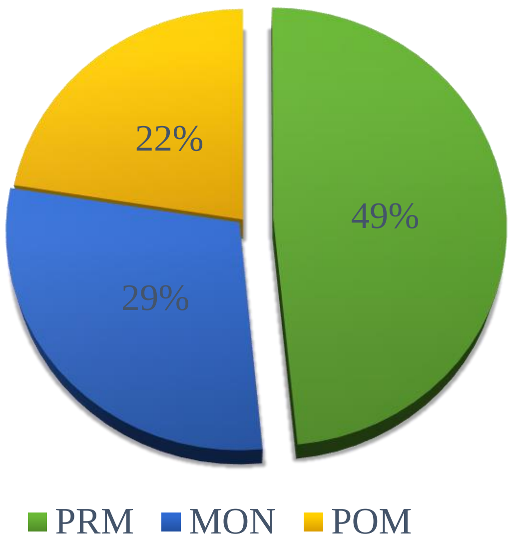


Figure 3.7. Seasonal Variation in the Abundance of Zooplankton during the Study Period

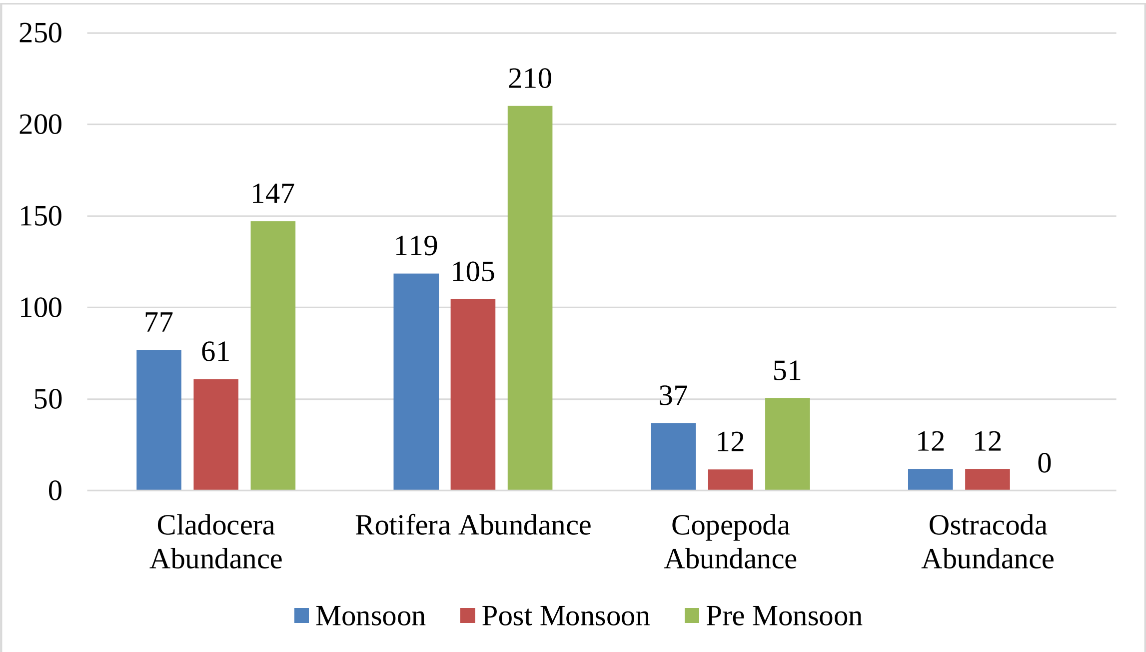


Figure 3.8. Mean Abundance of Zooplankton Groups in Different Seasons

3.4.1.3. Relationship with Environmental Parameters

3.4.1.3.1. Correlation Analysis

As shown in Table 3.4., the abundance of all the four groups of Zooplanktons were found to show a correlation with more than two physico-chemical parameters of water. Cladocera was found to be associated with more variables than other groups. Sulphate and dissolved oxygen are the main factors influencing all four groups. Air temperature, water temperature, electrical conductivity, magnesium, sulphate and BOD were found to positively affect the abundance of Cladocera, and total hardness and dissolved oxygen affect the abundance of Cladocera negatively. Rotifers and Copepods showed positive association with sulphate and negative association with total hardness and dissolved oxygen. In addition to that, Copepods also showed a positive relationship with air temperature. Ostracoda showed a positive association with dissolved oxygen and negative association with air temperature, water temperature, electrical conductivity, sulphate and BOD. The relationship of Ostracoda to water parameters was inversely proportional to that of Rotifera; factors that positively affect the abundance of Rotifera were found to adversely affect Ostracoda abundance and vice versa, except for total hardness and magnesium, both variables do not significantly affect Ostracoda.

3.4.1.3.2. Canonical Correspondence Analysis (CCA)

CCA was used to integrate overall abundance of Zooplankton groups with the physical and chemical parameters of the water. The scree plot of the CCA analysis is illustrated in Figure 3.9. The resulting biplot is presented in Figure 3.10. The permutation test was insignificant for all canonical axes ($p > 0.05$), indicating that the physical and chemical parameters of the water were not linearly related to the abundance. Within the Canonical Correspondence Analysis eigenvector analysis, the eigenvalue for CCA axis 1 and axis 2 explained an 87.44% variation, of which Axis 1 represents 48.17% of the total variable. This means that the two-dimensional Canonical Correspondence Analysis map will be enough to analyze the relationships between the month, variables and overall abundance of Zooplankton groups.

Parameter	Cladocera Abundance	Rotifera Abundance	Copepoda Abundance	Ostracoda Abundance
Air Temperature	**0.704**	0.350	**0.506**	**-0.749**
Water Temperature	**0.550**	0.167	0.309	**-0.603**
Field pH	0.138	0.108	0.029	0.009
Lab pH	0.191	0.108	0.038	-0.069
Turbidity	-0.381	-0.199	-0.380	0.274
Electrical Conductivity	**0.564**	0.155	0.150	**-0.579**
TDS	-0.107	-0.223	-0.166	-0.032
Acidity	0.187	0.064	0.372	0.188
Alkalinity	0.241	-0.076	0.155	-0.130
Total Hardness	**-0.412**	**-0.444**	**-0.417**	0.397
Calcium	-0.187	-0.099	-0.085	0.307
Magnesium	**0.434**	-0.086	0.337	-0.344
Chloride	-0.013	-0.045	-0.208	-0.019
Iron	-0.291	-0.064	0.099	0.082
Nitrate	0.174	-0.201	0.309	0.046
Sulphate	**0.909**	**0.635**	**0.752**	**-0.923**
CO2	0.360	0.286	0.146	-0.355
DO	**-0.820**	**-0.599**	**-0.527**	**0.793**
BOD	**0.422**	0.296	0.127	**-0.474**
COD	0.080	0.272	-0.282	-0.187
TASA	-0.081	0.011	-0.260	0.051

Table 3.4. Correlation between Physico-chemical Parameters and Zooplankton Abundance

Dissolved oxygen, turbidity, total hardness, and calcium were positively correlated, while sulphate, air temperature, water temperature, BOD and electrical conductivity were negatively correlated with axis 1. Therefore, this axis was interpreted as a gradient of increasing dissolved oxygen, turbidity, total hardness, and calcium, and decreasing sulphate, air temperature, water temperature, BOD, and electrical conductivity. Axis 2 was positively associated with COD and TASA, and negatively associated with nitrate and magnesium. Therefore, this axis was interpreted as a gradient of increasing COD and TASA and decreasing nitrate and magnesium. Rotifera showed a positive association with axis 2, high concentrations of COD and TASA and low concentrations of nitrate and magnesium promote the abundance of Rotifera.

Cladocera and Copepoda showed a negative association with both axis, that is, the abundance of both favoured by the higher value of air temperature, water temperature, electrical conductivity, sulphate, BOD, nitrate and magnesium, and low concentration of COD, TASA, dissolved oxygen, turbidity, total hardness and calcium. On the other hand, Ostracoda showed a positive association with axis 1; higher concentration of dissolved oxygen, turbidity, total hardness and calcium favours the growth of Ostracoda, whereas sulphate, air temperature, water temperature, BOD and electrical conductivity disfavour the abundance. The CCA also confirmed the spatial order of the sampling months based on the environmental variables. Post-monsoon months were positively associated with axis 1, whereas pre-monsoon months were negatively associated with axis 1, and monsoon months showed a negative association with axis 2.

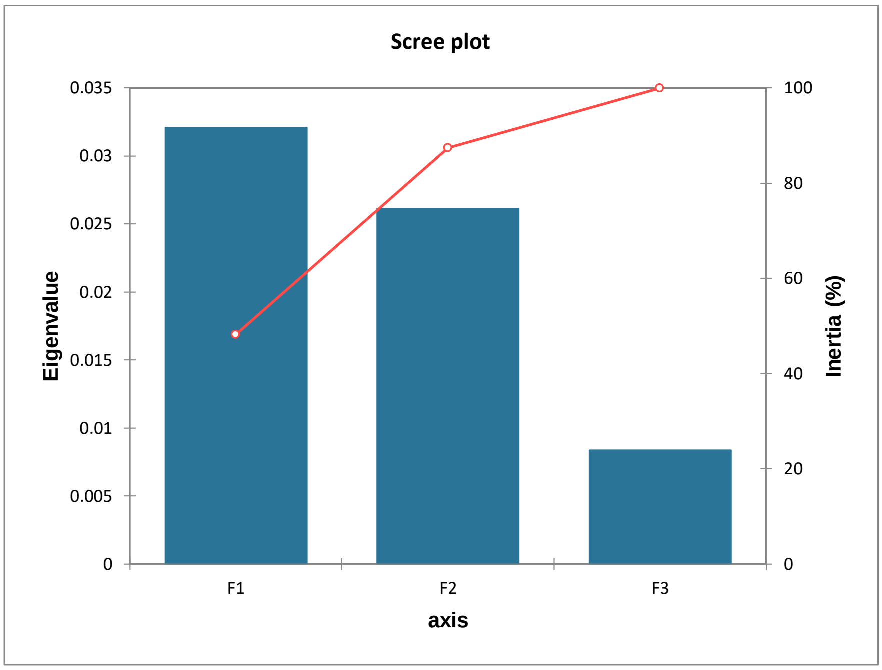


Figure 3.9. The Scree Plot Represents the Eigenvalues for Each Component

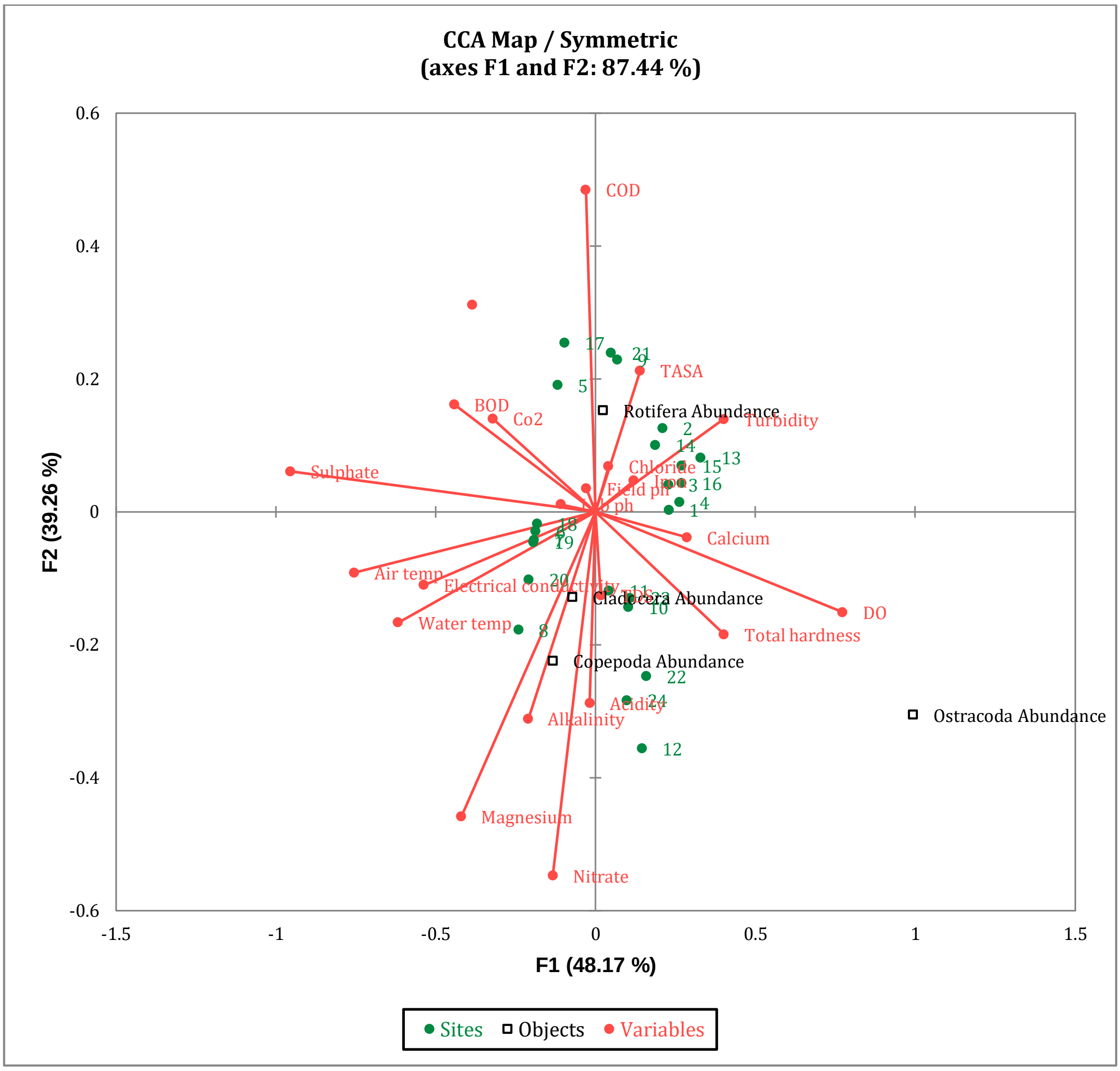


Figure 3.10. Ordination Diagram (CCA) of Descriptive Variables and Zooplankton Groups

3.4.2. Rotifera

3.4.2.1. Diversity of Rotifers

During the study period from October 2017 to September 2019, 40 species of Rotifers belonging to 10 families and 14 genera belonging to the two orders Ploimida and Flosculariacia were identified from the Thrissur Kole Wetland. Systematic list of Rotifers of Thrissur kole wetland is given in Table 3.5. There was a significant diversity of Rotifer in the Thrissur Kole wetland (H = 3.338, 1-D = 0.954). Ploimida was the largest order, accounting for 88% of the Rotifera of the study area. The diversity showed a clear seasonal variation (Table 3.6), with the pre-monsoon season being much more diverse than the other two seasons (H = 3.274, D = 0.952). The lowest diversity was during the monsoon season (H = 2.507, 1-D = 0.885), and the post-monsoon diversity was more than the monsoon (H = 2.997 1-d = 0.937). Rotifers showed more species evenness in the post-monsoon season (0.449) and the pre-monsoon season (0.443) and less in the monsoon season (0.368).

The Rotifers of the Thrissur Kole wetland belong to 10 families; Brachionidae, Asplanchnidae, Mytilinidae, Lecanidae, Trichocercidae, Synchaetidae, Conochilidae, Filinidae, Testudinellidae and Trochosphaeridae. Of these, only one species has been identified in each family: Mytilinidae, Filinidae, Testudinellidae and Trochosphaeridae. The diversity indices of the Rotifer family is given in Table 3.7. Brachionidae was the largest family of 12 species, with 11 species in the family Lecanidae. In terms of diversity, Lecanide was the most diverse family (H = 2.322, 1-D = 0.919), followed by Family Brachionidae (H = 2.269, 1-D = 0.881). The diversity index of families with only one species cannot be calculated, and among families representing more than one species, Family Synchaetidae showed the least diversity (H = 0.664, 1-D = 0.406).

From October 2017 to September 2019, 14 genera were found in the Thrissur Kole Wetland. Multiple species have been identified in eight genera: *Anuraeopsis, Brachionus, Keratella, Asplanchna, Lecane, Conochilus, Trichocerca* and *Polyarthra*. Of the remaining 6 genera, only one species exists, so it is impossible to estimate the diversity of such genera. Diversity indices of the Rotifer genera of Thrissur Kole Wetland is given in Table 3.8. The largest genus was *Lecane*, which contained 11 species. Genera *Anuraeopsis*, *Keratella*, *Conochilus* and *Polyarthra* were the smallest genera. The most diverse genus was *Lecane* (H = 2.322, 1-D = 0.919) and the least diverse genus was *Polyarthra* (H = 0.479, 1-D = 0.336). Similarly, species evenness showed more in *Lecane* and less in *Polyarthra*. The diversity of Rotifers showed a clear seasonal variation. Of the 40 species identified, 11 species (27.5%) were found in all seasons, 19 species (47.5%) were found in two seasons and 10 species (25%) were restricted to a single season.

Order	**Family**	**Species**	**PRM**	**MON**	**POM**
Ploimida	Brachionidae	*Anuraeopsis fissa*	+	+	+
		Anuraeopsis navicula	-	+	+
		Brachionus angularis	+	-	-
		Brachionus calyciflorus	+	+	+
		Brachionus dichotomous	+	-	-
		Brachionus falcatus	+	+	+
		Brachionus forficula	-	+	-
		Brachionus sessilis	+	-	-
		Brachionus patulus	+	+	+
		Platyias quadricornis	+	+	-
		Keratella cochlearis	+	+	+
		Keratella tropica	+	+	-
	Asplanchnidae	*Asplanchna brightwelli*	+	+	+
		Asplanchna herricki	+	+	+
		Asplanchna priodonta	+	-	+
	Mytilinidae	*Mytilina sp.*	+	-	+
	Lecanidae	*Lecane bulla*	+	+	+
		Lecane cornuta	+	-	+
		Lecane aculeate	+	-	+
		Lecane furcata	+	-	+
		Lecane monostyla	+	+	-
		Lecane luna	+	-	+
		Lecane lateralis	-	-	+
		Lecane inopinata	+	-	+
		Lecane pyriformis	+	-	+
		Lecane sp1	+	-	+
		Lecane sp2.	_	_	+
	Trichocercidae	*Trichocerca cylindrica*	+	+	-
		Trichocerca kostei	+	-	+
		Trichocerca longiseta	+	-	+
		Trichocerca similis	+	+	+
		Trichocerca rattus	-	+	-
	Synchaetidae	*Synchaeta sp.*	+	-	-
		Polyarthra vulgaris	+	+	+
		Polyarthra sp.	+	-	-
Floscularíacea	Conochilidae	*Conochilus unicornis*	+	+	+
		Conochilus hippocrepis	+	+	-
	Filinidae	*Filinia opoliensis*	+	-	-
	Testudinellidae	*Testudinella patina*	+	-	+
	Trochosphaeridae	*Horaella brehmi*	+	-	+

Table 3.5. The Seasonal Occurrence of the Rotifers of Thrissur Kole Wetland

11 species of Rotifera such as *A. fissa, B. calyciflorus, B. falcatus, B. patulus, K. cochlearis, A. brightwelli, A. herricki, L. bulla, T. similis, P. vulgaris* and *C. unicornis* were found in all seasons. *F. opoliensis, B. sessilis, B. dichotomous, B. angularis, Synchaeta sp.,* and *Polyarthra sp.,* were only found in the pre-monsoon season, *T. rattus* and *B. forficula* in monsoon, and *L. lateralis* and *Lecane sp.,* in the post-monsoon season.

Period	**Number of Species**	**Number of Genera**	**Number of Families**	**Number of Orders**	**Shannon Index (H)**	**Simpson's Index (D)**	**Evenness Index** (E)
Whole Study Period	40	14	10	2	3.338	0.954	0.411
PRM	35	14	10	2	3.274	0.952	0.443
MON	19	9	6	2	2.507	0.885	0.368
POM	27	11	9	2	2.997	0.937	0.449
PRM1	35	14	10	2	3.268	0.952	0.489
PRM2	35	14	10	2	3.278	0.953	0.489
MON 1	19	9	6	2	2.565	0.894	0.420
MON 2	19	9	6	2	2.472	0.875	0.401
POM1	27	11	9	2	3.046	0.941	0.505
POM2	27	11	9	2	2.211	0.937	0.370

Table 3.6. The Diversity of Rotifers of Thrissur Kole Wetland Oct 2017- Sep 2019

PRM= Pre-monsoon, MON= Monsoon, POM= Post-monsoon, 1= First Sampling Year, 2= Second Sampling Year

Family	Number of Species	Number of Genera	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)
Brachionidae	12	4	2.269	0.881	0.308
Asplanchnidae	3	1	1.041	0.665	0.201
Lecanidae	11	1	2.322	0.919	0.394
Conochilidae	2	1	0.671	0.478	0.109
Trichocercidae	5	1	1.290	0.666	0.221
Synchaetidae	3	2	0.664	0.406	0.136

Table 3.7. Diversity Indices of Rotifer Family of Thrissur Kole Wetland Oct 2017- Sep 2019

Genera	Number of Species	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)
Anuraeopsis	2	0.579	0.390	0.100
Brachionus	7	1.705	0.788	0.254
Keratella	2	0.629	0.437	0.105
Asplanchna	3	1.041	0.665	0.201
Lecane	11	2.322	0.919	0.394
Conochilus	2	0.671	0.478	0.109
Trichocerca	5	1.290	0.666	0.221
Polyarthra	2	0.479	0.336	0.099

Table 3.8. Diversity of Rotifer Genera of Thrissur Kole Wetland Oct 2017- Sep 2019

3.4.2.1.1. Pre-monsoon Season

The diversity of Rotifera of Thrissur Kole Wetlands was high in the pre-monsoon season, with 35 species of 14 genera and 10 families. All Rotifer genera and families found from the study area were found during this pre-monsoon season as well. Five species of Rotifera *A. navicula*, *Brachionus forficula*, *Lecane lateralis*, *Lecane sp2.* and *T. rattus* found in other seasons were not present during this season.

The Brachionidae was the largest family of 10 species, followed by the Lecanidae family of nine species. Rotifer family diversity indices during the pre-monsoon season were given in Table 3.9. The family Brachionidae (H = 2.161, 1-D = 0.873) and Lecanidae (H = 2.068, 1-D = 0.882) were the most diverse family, and the Conochilidae was the least diverse family (H =. 0.693, 1-D).

The largest genus *Lacane*, had nine species, followed by the genus *Brachionus* with 6 species. Genus *Anuraeopsis, Filinia, Horaella, Testudinella, Platyias, Mytilina* and *Synchaeta* represent only one species, so it is impossible to calculate such genera's diversity indices. The diversity indices of Thrissur Kole wetland during the pre-monsoon period are given in Table 3.10. *Lecane* was the most diverse genus (H = 2.069, 1-D = 0.8821), of the genera containing more than one species, the *Polyarthra* was the least diverse genus (H = 0.653, 1-D = 0.460). Species evenness was higher in the genus *Lecane* (0.399) and lower in *Keratella*.

Family	Number of Species	Number of Genera	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)
Brachionidae	10	3	2.161	0.873	0.319
Asplanchnidae	3	1	1.068	0.647	0.221
Lecanidae	9	1	2.068	0.882	0.399
Conochilidae	2	1	0.693	0.499	0.148
Trichocercidae	4	1	1.226	0.682	0.253
Synchaetidae	3	2	0.914	0.563	0.215

Table 3.9. The Diversity Indices of Rotifer Family in the Thrissur Kole Wetland during the Pre-monsoon Season

There was no significant difference in the Rotifer diversity between the pre-monsoon seasons of the two sampling years. The number of species, genus, and families were all the same, the only difference was abundance (Table 3.11.). The Shannon Diversity Index showed a minimal annual difference of 0.01, and there was no difference in the Simpson's index and evenness index. The Rotifer family's diversity indices for the two sampling years are shown in Table 3.12 & 3.13. The diversity index of Rotifer families was significantly similar, with very small differences in the value observed as the difference was only in abundance. The most diverse family was Brachionidae, followed by Lecanidae.

Genus	Number of Species	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)
Anuraeopsis	1	NIL	NIL	NIL
Brachionus	6	1.692	0.801	0.267
Keratella	2	0.660	0.467	0.12
Asplanchna	3	1.068	0.647	0.221
Lecane	9	2.069	0.8821	0.399
Conochilus	2	0.693	0.499	0.148
Trichocerca	4	1.226	0.682	0.253
Polyarthra	2	0.653	0.460	0.158

Table 3.10. The Diversity of Rotifer Genera of Thrissur Kole Wetland during the Pre-monsoon Season

Period	Number of Species	Number of Genera	Number of Families	Number of Orders	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)
PRM1	35	14	10	2	3.268	0.952	0.489
PRM2	35	14	10	2	3.278	0.953	0.489

Table 3.11. Annual Variation in Diversity of Rotifers of Thrissur Kole Wetland Oct 2017- Sep 2019

Family	Number of Species	Number of Genus	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)
Brachionidae	10	3	2.161	0.873	0.356
Asplanchnidae	3	1	1.068	0.647	0.258
Lecanidae	9	1	2.064	0.862	0.463
Conochilidae	2	1	0.692	0.499	0.176
Trichocercidae	4	1	1.216	0.670	0.295
Synchaetidae	3	2	0.883	0.530	0.254

Table 3.12. The Diversity Indices of Rotifer Family in the Pre-monsoon Season Oct 2017- Sep 2018

Family	Number of Species	Number of Genus	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)
Brachionidae	10	3	2.161	0.873	0.356
Asplanchnidae	3	1	1.068	0.647	0.258
Lecanidae	9	1	2.065	0.863	0.456
Conochilidae	2	1	0.692	0.499	0.173
Trichocercidae	4	1	1.231	0.683	0.293
Synchaetidae	3	2	0.883	0.532	0.252

Table 3.13. The Diversity Indices of Rotifer Family in the Pre-monsoon Season Oct 2018- Sep 2019

3.4.2.1.2. Monsoon Season

The diversity of Rotifers during the monsoon season was very less compared to the other two seasons. A total of 19 Rotifer species, including nine genera, six families and two orders were identified. The Ploimida was the largest order comprising 17 species, eight genera and 5 families. Flosculariacea was a small order representing only one family, Conochilidae during this season. Family Brachionidae was the largest family of 9 species in four genera, with fewer species in other families. The families Mytilinidae, Filinidae, Testudinellidae, and Trochosphaeridae were not found in the study area during the monsoon season. Diversity indices of the Rotifer family and genera during the monsoon season is given in Tables 3.14 & 3.15.

Family Brachionidae was the most diverse family (H = 2.123, 1-D = 0.872), and the family Conochilidae was the least diverse (H = 0.439, 1-D = 0.268). There are six families, Brachionidae, Asplanchnidae, Lecanidae, Conochilidae, Trichocercidae and Synchaetidae present during the monsoon season, family Synchaetidae had only one species, so it was impossible to calculate diversity index of such family. *Brachionus* was the largest genus containing 4 species, followed by *Trichocerca* (3 species). The most diverse genus was *Brachionus* (H = 1.340, 1-D = 0.725), the least diverse genus was *Polyathra*. The species evenness is more in the genus *Brachionus* and less in the genus *Conochilus*. *B. angularis, B. dichotomous, B. patulus, A. priodonta, L. cornuta, L. aculeate, L. furcata, L. luna, L. lateralis, L. inopinata, L. pyriformis, Lecane sp1, Lecane sp2., Mytilina sp., T. kostei, T. longiseta, Synchaeta sp., Polyarthra sp, F. opoliensis, T. patina* and *H. brehmi* were completely absent during this season.

There was an annual variation in the Rotifer diversity, and the variation in the first sampling years was different from the second. The number of species, genera, families and order was the same, but the diversity index varied due to changes in abundance (Table 3.16). The Rotifer diversity was more in the first monsoon than in the second. The Rotifer family diversity index for the two sampling years is given in Tables 3.17 and 3.18. There was no significant difference in the diversity indices of the Rotifer family except for Conochilidae between the two sampling years. The diversity and evenness of this family were higher in the first sampling years than in the second.

Family	Number of Species	Number of Genus	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)
Brachionidae	9	4	2.123	0.872	0.351
Asplanchnidae	2	1	0.685	0.491	0.191
Lecanidae	2	1	0.636	0.444	0.2
Conochilidae	2	1	0.439	0.268	0.078
Trichocercidae	3	1	0.477	0.245	0.095
Synchaetidae	1	1	NIL	NIL	NIL

Table 3.14. The Diversity Indices of the Rotifer Family of Thrissur Kole Wetland during the Monsoon Season

Genera	Number of Species	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)
Anuraeopsis	2	0.636	0.444	0.133
Brachionus	4	1.340	0.725	0.256
Keratella	2	0.669	0.476	0.148
Asplanchna	2	0.685	0.491	0.191
Lecane	2	0.636	0.444	0.2
Conochilus	2	0.439	0.268	0.078
Trichocerca	3	0.477	0.236	0.095
Polyarthra	1	NIL	NIL	NIL

Table 3.15. Diversity Indices of Rotifer Genera of Thrissur Kole Wetland during the Monsoon Season

Period	Number of Species	Number of Genera	Number of Families	Number of Orders	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)
MON 1	19	9	6	2	2.565	0.894	0.420
MON 2	19	9	6	2	2.472	0.875	0.401

Table 3.16. Annual Variation in the Diversity Index of Rotifers in the Monsoon Season

Family	Number of Species	Number of Genus	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)
Brachionidae	9	4	2.123	0.872	0.397
Asplanchnidae	2	1	0.682	0.489	0.238
Lecanidae	2	1	0.636	0.444	0.256
Conochilidae	2	1	0.471	0.295	0.098
Trichocercidae	3	1	0.477	0.236	0.110
Synchaetidae	1	1	NIL	NIL	NIL

Table 3.17. Diversity of Rotifer Family of Thrissur Kole Wetland during the Monsoon Season Oct 2017- Sep 2018

Family	Number of Species	Number of Genus	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)
Brachionidae	9	4	2.123	0.872	0.397
Asplanchnidae	2	1	0.686	0.493	0.238
Lecanidae	2	1	0.636	0.444	0.256
Conochilidae	2	1	0.411	0.246	0.082
Trichocercidae	3	1	0.477	0.236	0.110
Synchaetidae	1	1	NIL	NIL	NIL

Table 3.18. Diversity of Rotifer Family of Thrissur Kole Wetland during the Monsoon Season Oct 2018- Sep 2019

3.4.2.1.3. Post-monsoon Season

Compared to the other two seasons, the Thrissur Kole wetland had a moderate Rotifer diversity (H = 2.997, 1-D = 0.937) and a high evenness (0.449) during the post-monsoon season. 27 species belonging to 11 genera, nine families and two orders were found in this season. The diversity indices of the Rotifer family in the post-monsoon period are shown in Table 3.19. The largest family, Lecanidae, contains ten species, followed by Brachionidae (6 species). A single species represented family

Conochilidae, Synchaetidae, Mytilinidae, Testudinellidae and Trochosphaeridae, and there was no species in the Family Filinidae in this season.

Lecanidae was a more diverse family in the post-monsoon season (H = 2.227, 1-D = 0.886). Species evenness was more in this family (0.439). Family Trichocercidae showed less diversity and evenness. The diversity indices of families comprising only one species could not be quantified. Diversity indices of Rotifer genera in the post-monsoon season are given in Table 3.20. *Lecane* (H = 2.227, 1-D = 0.898) was the largest and most diverse genus, consisting of 10 species, with only one species in the genus *Keratella, Conochilus, Polyarthra, Mytilina, Testudinella*, and *Horaella*. The species *Platyias, Filinia* and *Synchaeta* could not be found in this season. *B. angularis, B. dichotomous, B. forficula, B. patulus, P. quadricornis, K. tropica, L. monostyla, C. hippocrepis, T. cylindrica, T. rattus, Synchaeta sp., Polyarthra sp* and *F. opoliensis* were completely absent in the post-monsoon season.

Family	Number of Species	Number of Genera	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)
Brachionidae	6	3	1.639	0.777	0.289
Asplanchnidae	3	1	1.039	0.999	0.375
Lecanidae	10	1	2.227	0.886	0.439
Conochilidae	1	1	NIL	NIL	NIL
Trichocercidae	3	1	0.999	0.628	0.243
Synchaetidae	1	1	NIL	NIL	NIL

Table 3.19. The Diversity Indices of Rotifer Family of Thrissur Kole Wetland during the Post-monsoon Season

The diversity of the Rotifer family between the post-monsoon seasons of the two sampling years showed a slight variation (Table 3.21 & 3.22). With the exception of the Trichocercidae family, the diversity indices of all families in the post-monsoon seasons of the two sampling years were significantly similar, diversity of Trichocercidae family was higher in the post-monsoon season of the first year (H = 1.006, 1-D = 0.612) than in the second (H = 0.990, 1-D = 0.604).

Genera	Number of Species	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)
Anuraeopsis	2	0.608	0.417	0.121
Brachionus	3	1.052	0.634	0.237
Keratella	1	NIL	NIL	NIL
Asplanchna	3	1.039	0.999	0.375
Lecane	10	2.227	0.898	0.439
Conochilus	1	NIL	NIL	NIL
Trichocerca	3	0.999	0.628	0.243
Polyarthra	1	NIL	NIL	NIL

Table 3.20. The Diversity Indices of Rotifer Genera of Thrissur Kole Wetland during the Post-monsoon Season

Family	Number of Species	Number of Genus	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)
Brachionidae	6	3	1.639	0.777	0.329
Asplanchnidae	3	1	1.039	0.625	0.5
Lecanidae	10	1	2.226	0.886	0.508
Conochilidae	1	1	NIL	NIL	NIL
Trichocercidae	3	1	1.006	0.612	0.294
Synchaetidae	1	1	NIL	NIL	NIL

Table 3.21. Diversity of Rotifer Family during the Post-monsoon Season Oct 2017-Jan 2018

Family	Number of Species	Number of Genus	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)
Brachionidae	6	3	1.639	0.777	0.329
Asplanchnidae	3	1	1.039	0.625	0.5
Lecanidae	10	1	2.227	0.886	0.51
Conochilidae	1	1	NIL	NIL	NIL
Trichocercidae	3	1	0.990	0.604	0.291
Synchaetidae	1	1	NIL	NIL	NIL

Table 3.22. The Diversity of the Rotifer Family during the Post-monsoon Season Oct 2018-Jan 2019

3.4.2.2. Abundance of Rotifer

Rotifera Abundance showed monthly and seasonal variation. The monthly abundance of Rotifers in the Thrissur Kole wetland is given in Figure 3.11. The highest abundance was found in February and the lowest in September. The relative abundance of 40 collected species of Rotifers is shown in Figure 3.12. A higher number of Rotifers were found at low water level, during the pre-monsoon season (Figure 3.13). The relative abundance of the Rotifer family is given in Table 3.23 and Figure 3.14, and the Rotifer genera in Figure 3.15. Brachionidae was the most abundant family, accounting for 47% of the total Rotifera found. Family Lecanidae, Conochilidae and Trichocercidae were 11%, 14% and 10% respectively. Mytilinidae was the less abundant family because this family has only one species. All the collected Rotifer species showed a difference in abundance, monthly variations in Rotifer species abundance of Thrissur Kole wetland is shown in Figure 3.20 to 3.24.

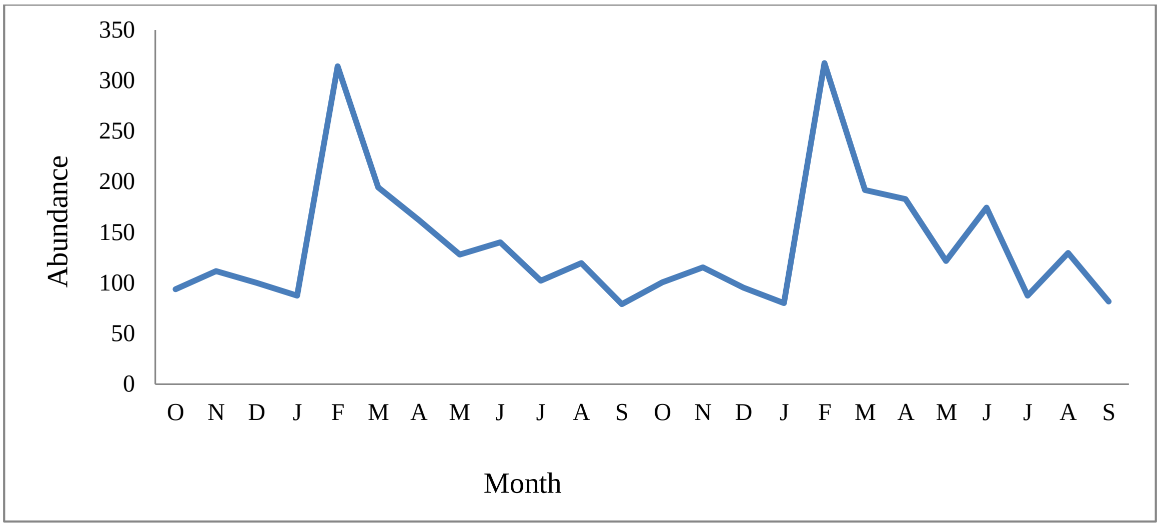


Figure 3.11. Monthly Variation in Rotifer Abundance

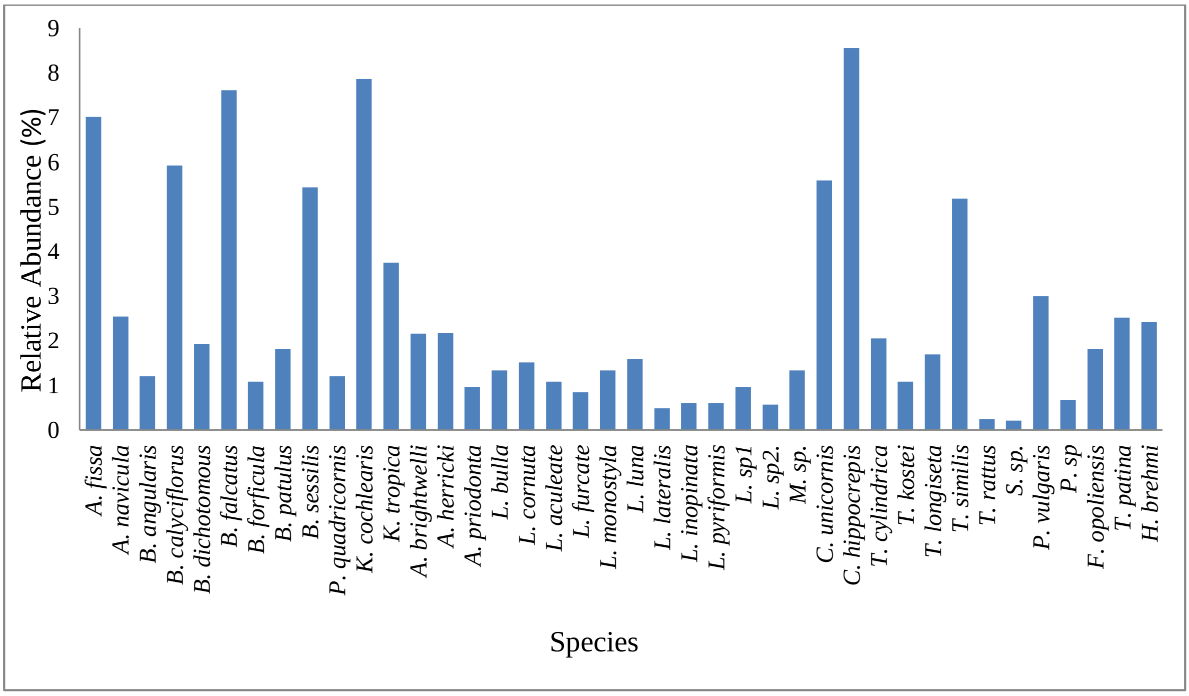


Figure 3.12. Relative Abundance of Rotifer Species of Thrissur Kole Wetland

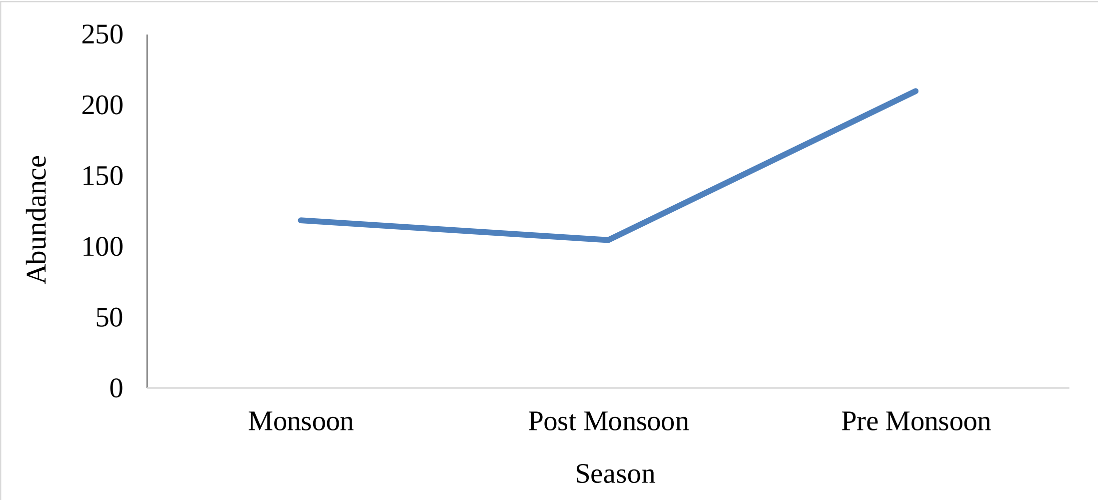


Figure 3.13. Seasonal Variation in the Rotifer Abundance

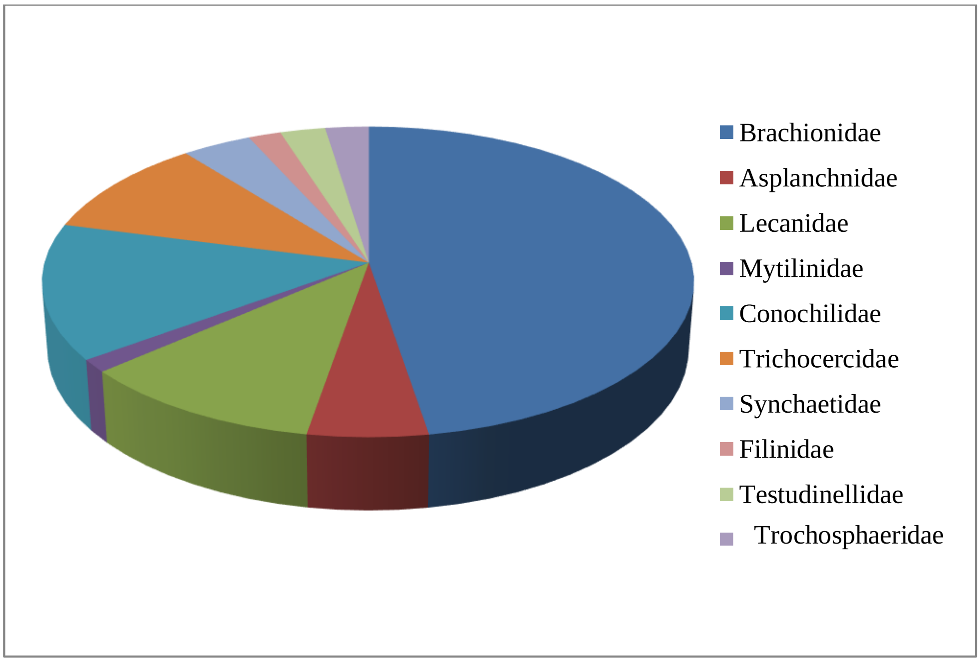


Figure 3.14. Pie Diagram Showing the Dominance of Rotifer Family of Thrissur Kole Wetland

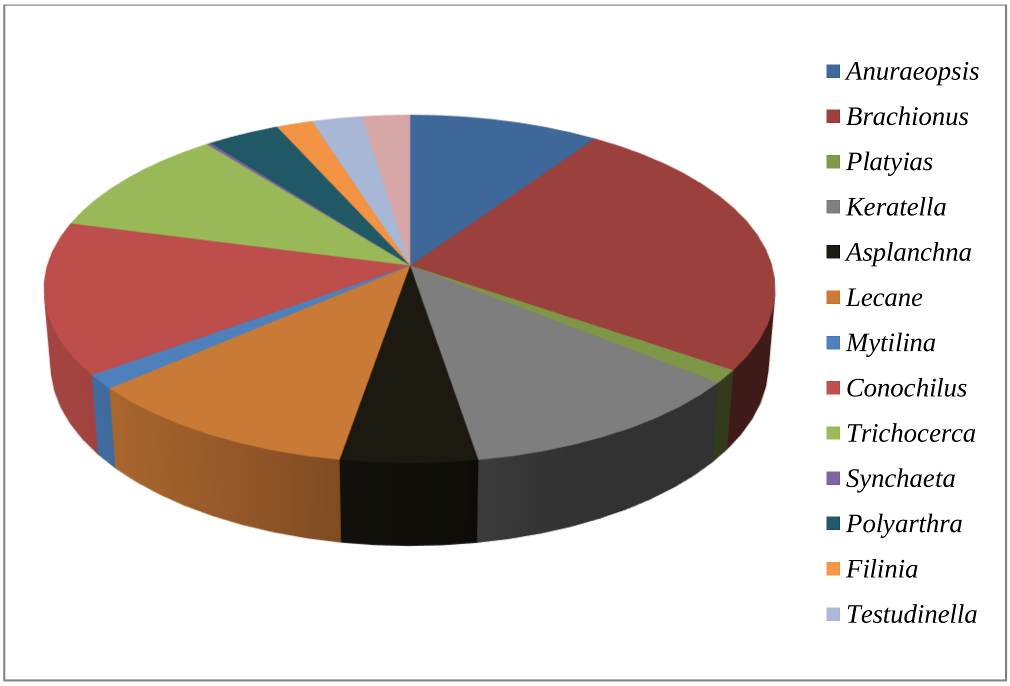


Figure 3.15. Pie Diagram Showing the Dominance of Rotifer Genera of Thrissur Kole Wetland

Family	Whole Study Period	PRM	MON	POM
Brachionidae	47	53	46	37
Asplanchnidae	5	8	4	2
Lecanidae	11	11	3	20
Mytilinidae	1	1	0	3
Conochilidae	14	7	30	11
Trichocercidae	10	8	17	8
Synchaetidae	4	4	1	7
Filinidae	2	4	0	0
Testudinellidae	3	2	0	7

Trochosphaeridae	2	2	0	6

Table 3.23. Seasonal Variation in the Relative Abundance of Rotifer Family of Thrissur Kole Wetland

Species	Relative Abundance	Species Rank
Conochilus hippocrepis	9	1
Keratella cochlearis	8	2
Brachionus falcatus	8	3
Anuraeopsis fissa	7	4
Brachionus calyciflorus	6	5
Conochilus unicornis	6	6
Brachionus sessilis	5	7
Trichocerca similis	5	8
Keratella tropica	4	9
Polyarthra vulgaris	3	10
Anuraeopsis navicula	3	11
Testudinella patina	3	12
Horaella brehmi	2	13
Asplanchna herricki	2	14
Asplanchna brightwelli	2	15
Trichocerca cylindrica	2	16
Brachionus dichotomous	2	17
Brachionus patulus	2	18
Filinia opoliensis	2	19
Trichocerca longiseta	2	20
Lecane luna	2	21
Lecane cornuta	2	22
Lecane bulla	1	23
Lecane monostyla	1	24
Mytilina sp.	1	25
Brachionus angularis	1	26
Platyias quadricornis	1	27
Brachionus forficula	1	28
Lecane aculeate	1	29
Trichocerca kostei	1	30
Asplanchna priodonta	1	31
Lecane sp1	1	32
Lecane furcata	0.8	33
Polyarthra sp.	0.7	34
Lecane inopinata	0.6	35
Lecane pyriformis	0.6	36
Lecane sp2.	0.6	37
Lecane lateralis	0.5	38
Trichocerca rattus	0.2	39
Synchaeta sp.	0.2	40

Table 3.24. Rank Abundance Distribution of Rotifera of Thrissur Kole Wetland Oct 2017- Sep 2019

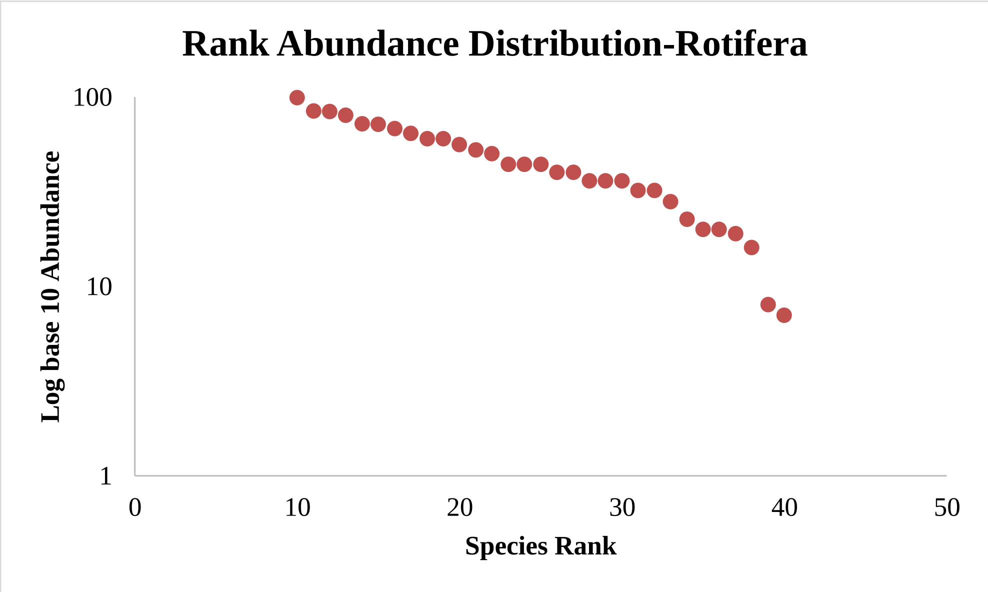


Figure 3.16. The Rank Abundance Distribution Curve of Rotifera of Thrissur Kole Wetland Oct 2017- Sep 2019

The abundance of Rotifers in the pre-monsoon season was high, with 49% of the total collected Rotifers during this season. *C. Hippocrepis* was the most abundant species followed by *K. cochlearis* and *B. falcatus. T. rattus* and *Synchaeta sp.* were the least common species. The Rotifera Rank Abundance Distribution of Thrissur Kole Wetland is given in the Table 3.24. and the Rank Abundance Distribution Curve in Figure 3.16.

3.4.2.2.1. Pre-monsoon

The abundance of Rotifers was very high in this season. Brachionidae was the largest family, accounting for 53% of all pre-monsoon Rotifers. Mytilinidae was the smallest family, with only one species. The relative abundance of the Rotifer in the pre-monsoon season is given in Table 3.25., and the Rank Abundance Curve in Figure 3.17. *B. falcatus* and *K. cochlearis* were the most abundant species followed by *B. calyciflorus* and *B. sessilis. L. inopinata* was found to be a less abundant species during this season. The five species of Rotifera; *Anuraeopsis navicula, Brachionus forficula, Lecane sp2., Lecane lateralis,* and *Trichocerca rattus* detected from the study area during the study period were not detected during the pre-monsoon season.

Month	Relative Abundance	Species Rank
Brachionus falcatus	10	1
Keratella cochlearis	9	2
Brachionus calyciflorus	7	3
Brachionus sessilis	7	4
Keratella tropica	5	5
Brachionus dichotomous	4	6
Brachionus patulus	4	7
Filinia opoliensis	4	8
Trichocerca cylindrica	3	9
Conochilus unicornis	3	10
Asplanchna brightwelli	3	11
Conochilus hippocrepis	3	12
Anuraeopsis fissa	3	13
Asplanchna herricki	3	14
Brachionus angularis	2	15
Polyarthra vulgaris	2	16
Horaella brehmi	2	17
Lecane luna	2	18
Lecane bulla	2	19
Trichocerca longiseta	2	20
Testudinella patina	2	21
Trichocerca similis	2	22
Asplanchna priodonta	2	23
Lecane monostyla	2	24
Polyarthra sp.	1	25
Lecane cornuta	1	26
Platyias quadricornis	1	27
Lecane aculeate	1	28
Mytilina sp.	1	29
Lecane furcata	1	30
Lecane sp1	1	31
Lecane pyriformis	0.5	32
Trichocerca kostei	0.5	33
Synchaeta sp.	0.4	34
Lecane inopinata	0.2	35
Anuraeopsis navicula	0.0	36
Brachionus forficula	0.0	37
Lecane lateralis	0.0	38
Lecane sp2.	0.0	39
Trichocerca rattus	0.0	40

Table 3.25. The Relative Abundance of the Rotifer of Thrissur Kole Wetland during the Pre-monsoon Season

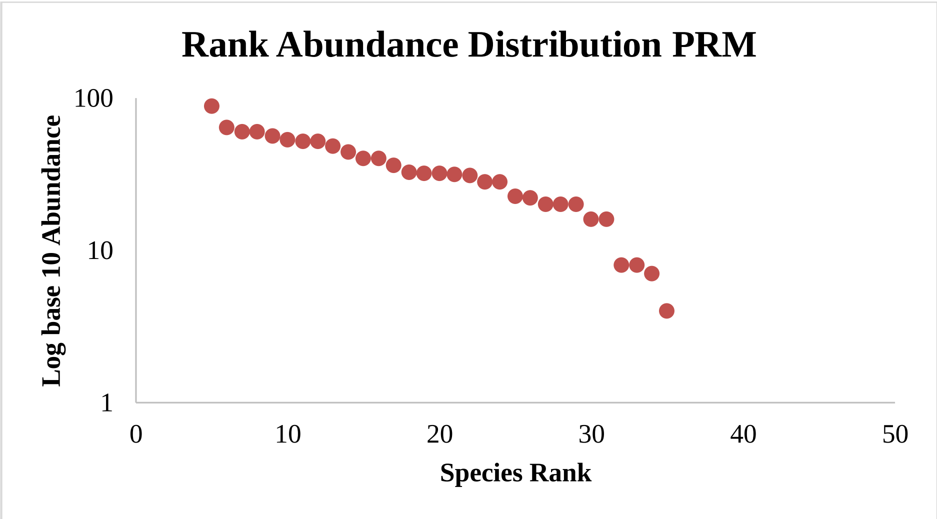


Figure 3.17. The Rank Abundance Distribution Curve of Rotifers of Thrissur Kole Wetland during the Pre-monsoon Season

3.4.2.2.2. Monsoon Season

The abundance of Rotifera during the monsoon season was 28%, which was higher than post-monsoon abundance. Brachionidae was the largest family, accounting for 46% of the total, followed by Family Conochilidae (30%), which was much lower in other seasons. Synchaetidae was the less abundant family, whereas Mytilinidae, Filinidae, Testudinellidae and Trochosphaeridae were absent during this season. The Rank Abundance Distribution of Rotifers during the monsoon season is given in Table 3.26., and Fig 3.18. *C. hippocrepis* was the most abundant species, accounting for 25% of the total, followed by *T. similis*. *T. cylindrica*, *L. bulla* and *T. rattus*. *P. vulgaris* were found as the least abundant species.

Month	Relative Abundance	Species Rank -Mon
Conochilus hippocrepis	25	1
Trichocerca similis	14	2
Anuraeopsis fissa	9	3
Brachionus falcatus	8	4
Keratella cochlearis	6	5
Brachionus sessilis	5	6
Conochilus unicornis	5	7
Anuraeopsis navicula	4	8
Brachionus calyciflorus	4	9
Brachionus forficula	4	10
Keratella tropica	4	11
Platyias quadricornis	2	12
Asplanchna herricki	2	13
Lecane monostyla	2	14
Asplanchna brightwelli	2	15
Trichocerca cylindrica	1	16
Lecane bulla	1	17
Trichocerca rattus	1	18
Polyarthra vulgaris	1	19
Brachionus angularis	0	20
Brachionus dichotomous	0	21
Brachionus patulus	0	22
Asplanchna priodonta	0	23
Lecane cornuta	0	24
Lecane aculeate	0	25
Lecane furcata	0	26
Lecane luna	0	27
Lecane lateralis	0	28
Lecane inopinata	0	29
Lecane pyriformis	0	30
Lecane sp1.	0	31
Lecane sp2.	0	32
Mytilina sp.	0	33
Trichocerca kostei	0	34
Trichocerca longiseta	0	35
Synchaeta sp.	0	36
Polyarthra sp.	0	37
Filinia opoliensis	0	38
Testudinella patina	0	39
Horaella brehmi	0	40

Table 3.26. The Rank Abundance Distribution of Rotifers of Thrissur Kole Wetland during the Monsoon Season

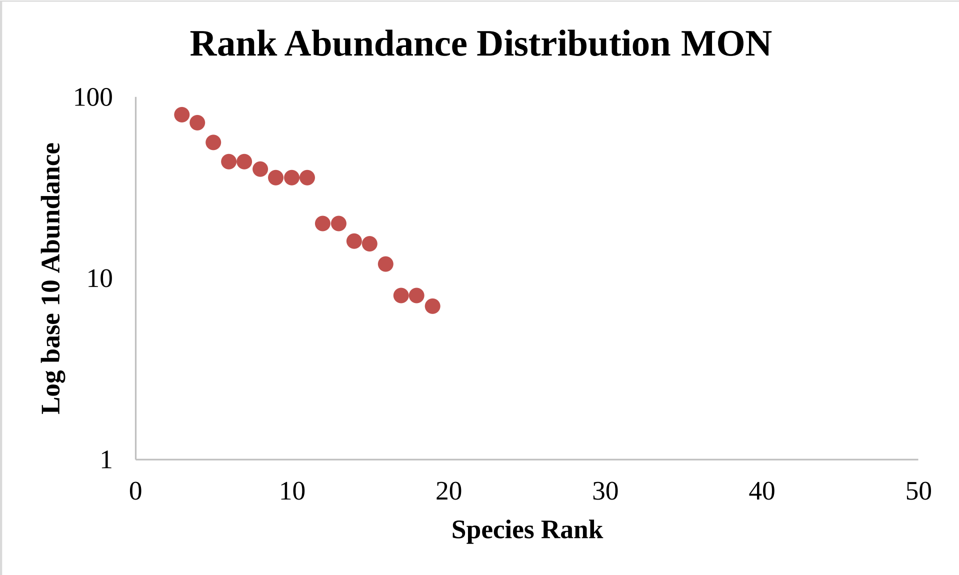


Figure 3.18. The Rank Abundance Distribution Curve of Rotifers of Thrissur Kole Wetland during the Monsoon Season

3.4.2.2.3. Post-monsoon Season

The Rotifera abundance was very low in the post-monsoon season as compared to other seasons. Brachionidae was a dominant family, 37% of the total belonging to this family. Family Lecanidae also showed high abundance, accounting for 20% of the total. Family Asplanchnidae was the least abundant family, and there were no species in the Mytilinidae family. The Rank Abundance Distribution of the Rotifera during the post-monsoon season is given in Table 3.27. The Rank abundance curve in Figure 3.19. *A. fissa* was the most abundant species followed by *C. unicornis. T. similis*, *A. herricki*, *A. brightwelli*, *A. priodonta*, and *L. bulla* were less abundant.

Month	Relative Abundance	Species Rank

Anuraeopsis fissa	13	1
Conochilus unicornis	11	2
Keratella cochlearis	7	3
Polyarthra vulgaris	7	4
Testudinella patina	7	5
Anuraeopsis navicula	6	6
Horaella brehmi	6	7
Brachionus calyciflorus	5	8
Lecane cornuta	4	9
Trichocerca kostei	4	10
Brachionus falcatus	3	11
Mytilina sp.	3	12
Trichocerca longiseta	3	13
Brachionus sessilis	3	14
Lecane luna	3	15
Lecane sp2.	2	16
Lecane aculeate	2	17
Lecane lateralis	2	18
Lecane inopinata	2	19
Lecane sp1.	2	20
Lecane furcata	2	21
Lecane pyriformis	2	22
Trichocerca similis	1	23
Asplanchna herricki	1	24
Asplanchna brightwelli	1	25
Asplanchna priodonta	1	26
Lecane bulla	1	27
Brachionus angularis	0	28
Brachionus dichotomous	0	29
Brachionus forficula	0	30
Brachionus patulus	0	31
Platyias quadricornis	0	32
Keratella tropica	0	33
Lecane monostyla	0	34
Conochilus hippocrepis	0	35
Trichocerca cylindrica	0	36
Trichocerca rattus	0	37
Synchaeta sp.	0	38
Polyarthra sp.	0	39
Filinia opoliensis	0	40

Table 3.27. The Rank Abundance Distribution of Rotiera of Thrissur Kole Wetland during Post-monsoon Season

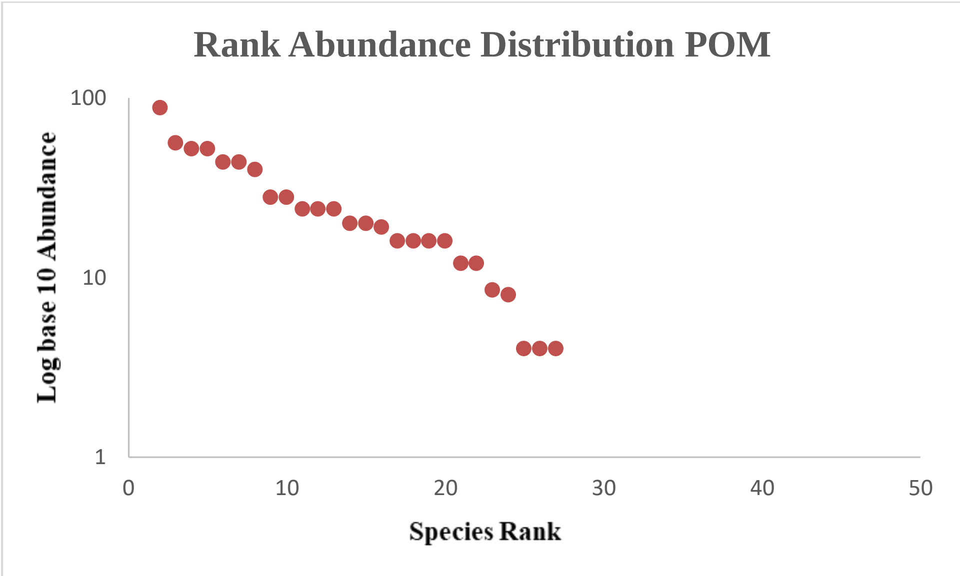


Figure 3.19. The Rank Abundance Distribution Curve of Rotifer of Thrissur Kole Wetland during the Post-monsoon Season

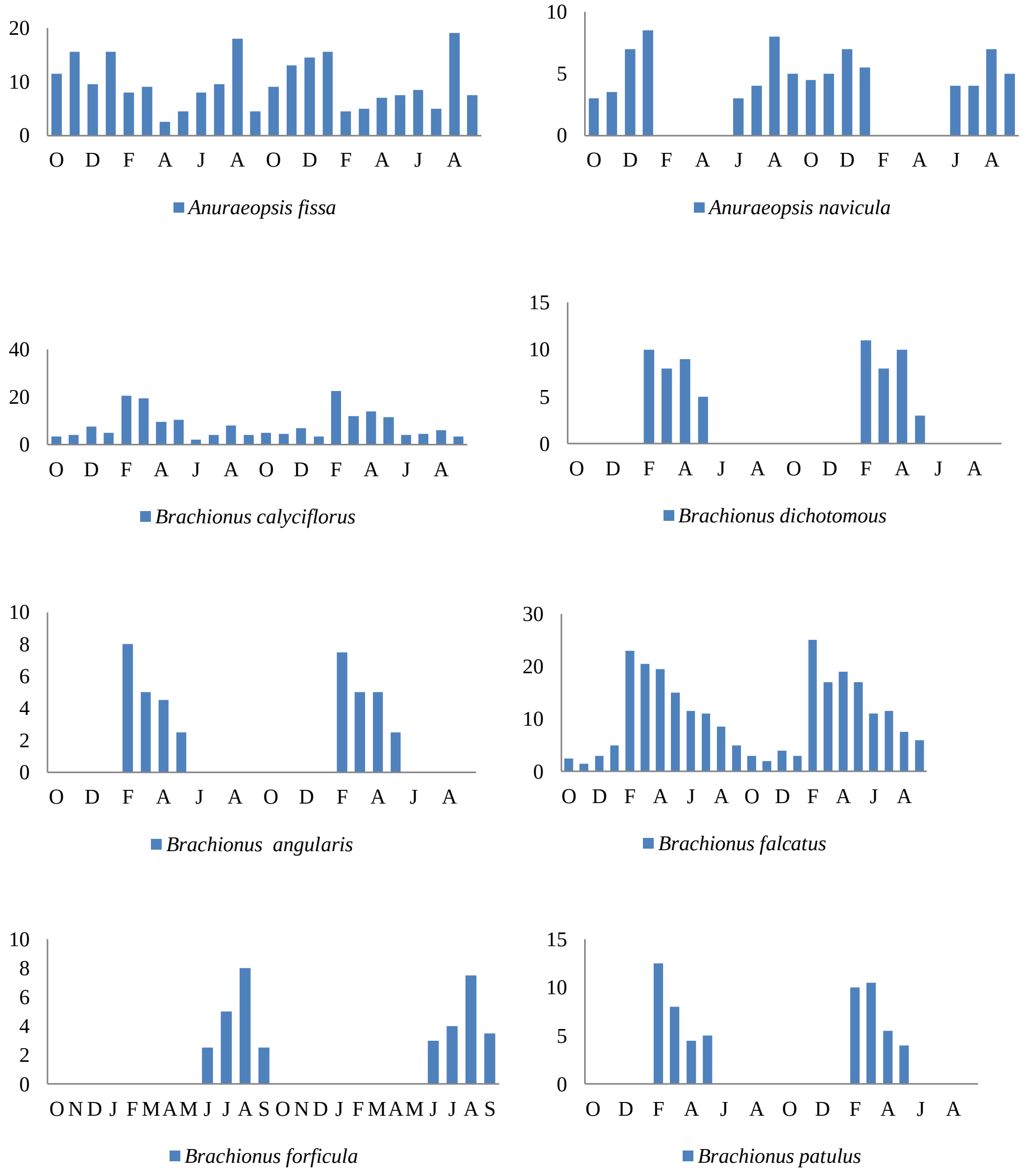


Figure 3.20. Monthly Variations in Rotifer Species Abundance of Thrissur Kole Wetland Oct 2017- Sep 2019 (SP:1 to SP:8)

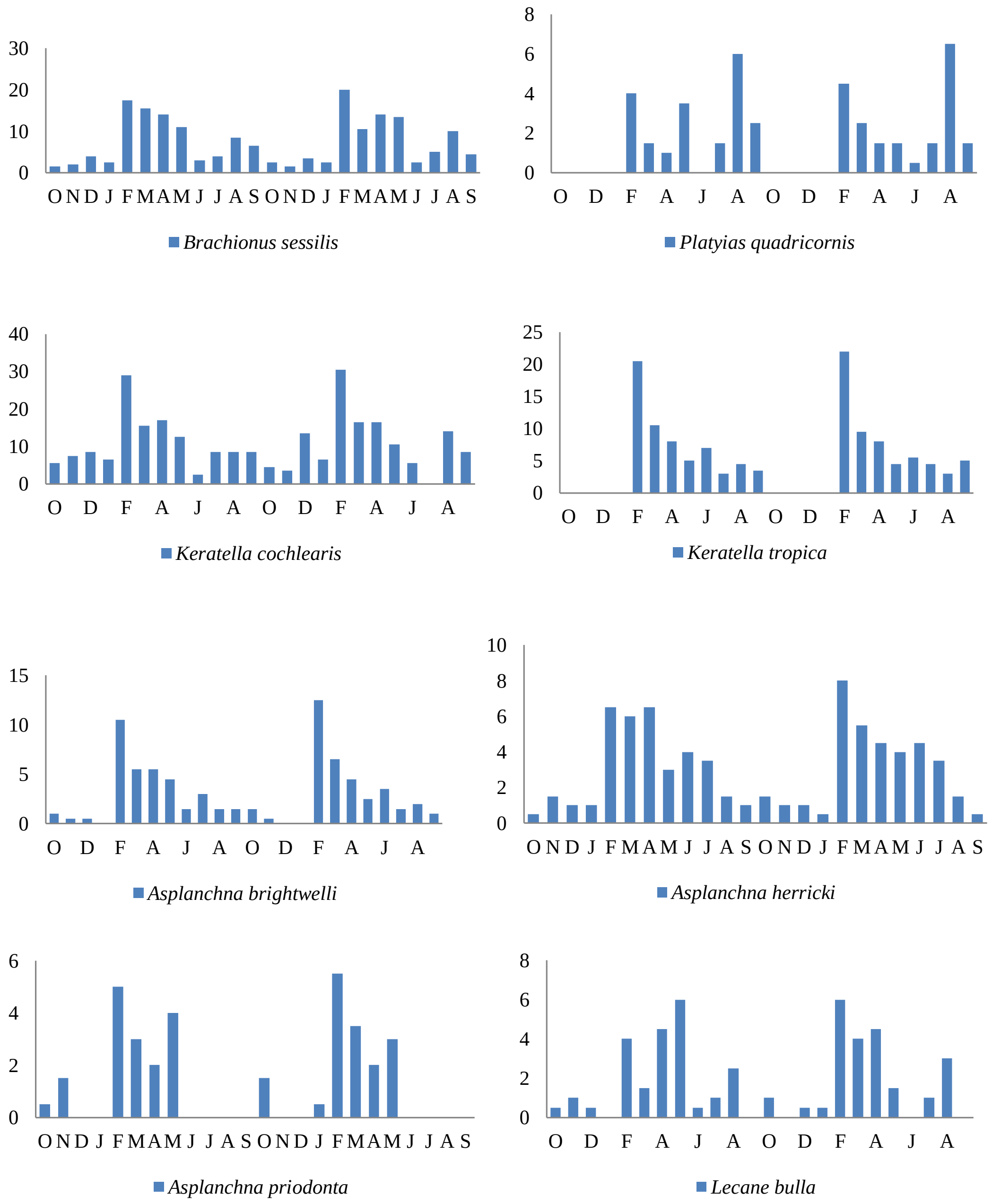


Figure 3.21. Monthly Variations in Rotifer Species Abundance of Thrissur Kole Wetland Oct 2017- Sep 2019 (SP:9 to SP:16) Cont.

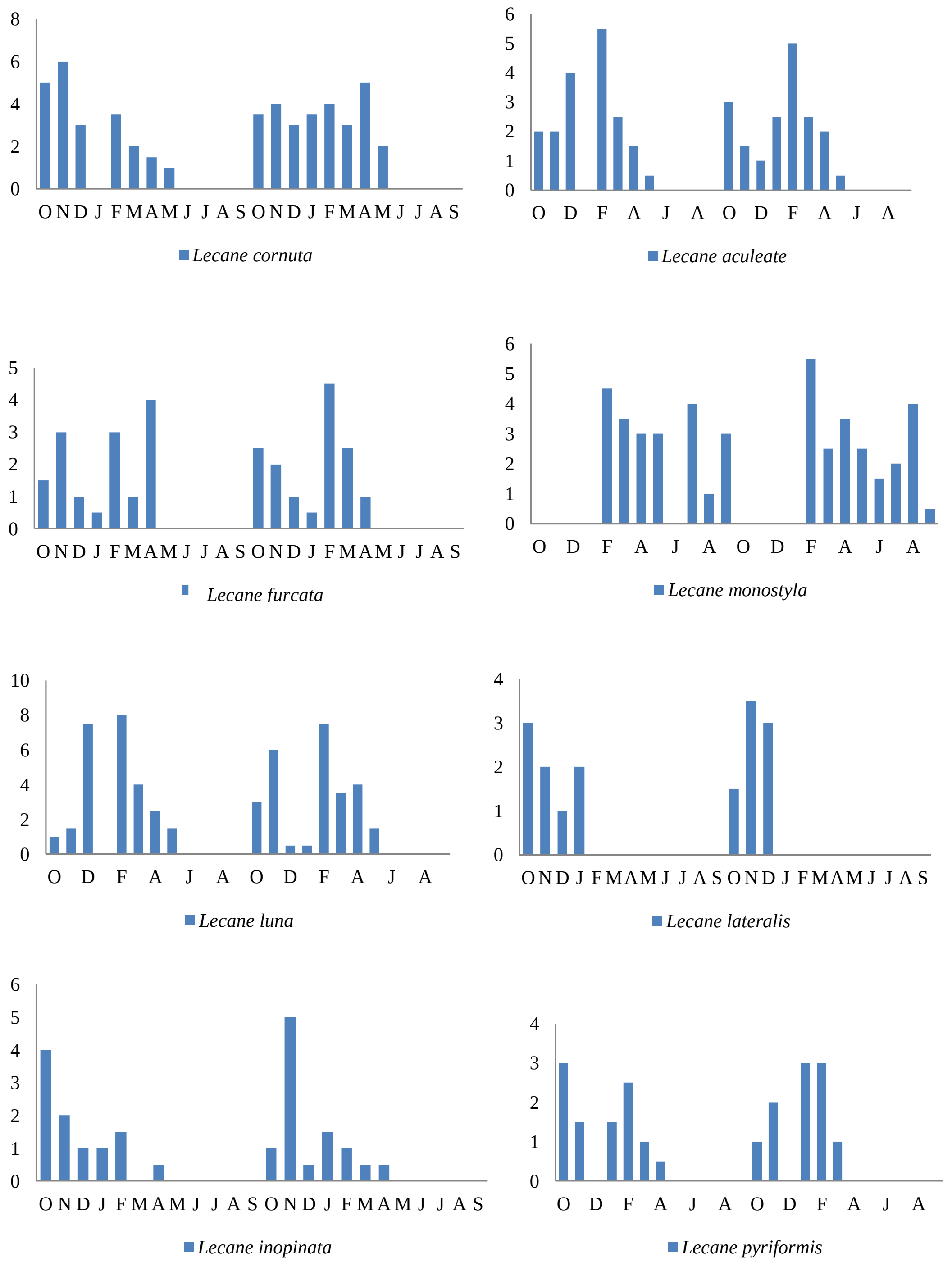


Figure 3.22. Monthly Variations in Rotifer Species Abundance of Thrissur Kole Wetland Oct 2017- Sep 2019 (SP:17 to SP:24) Cont.

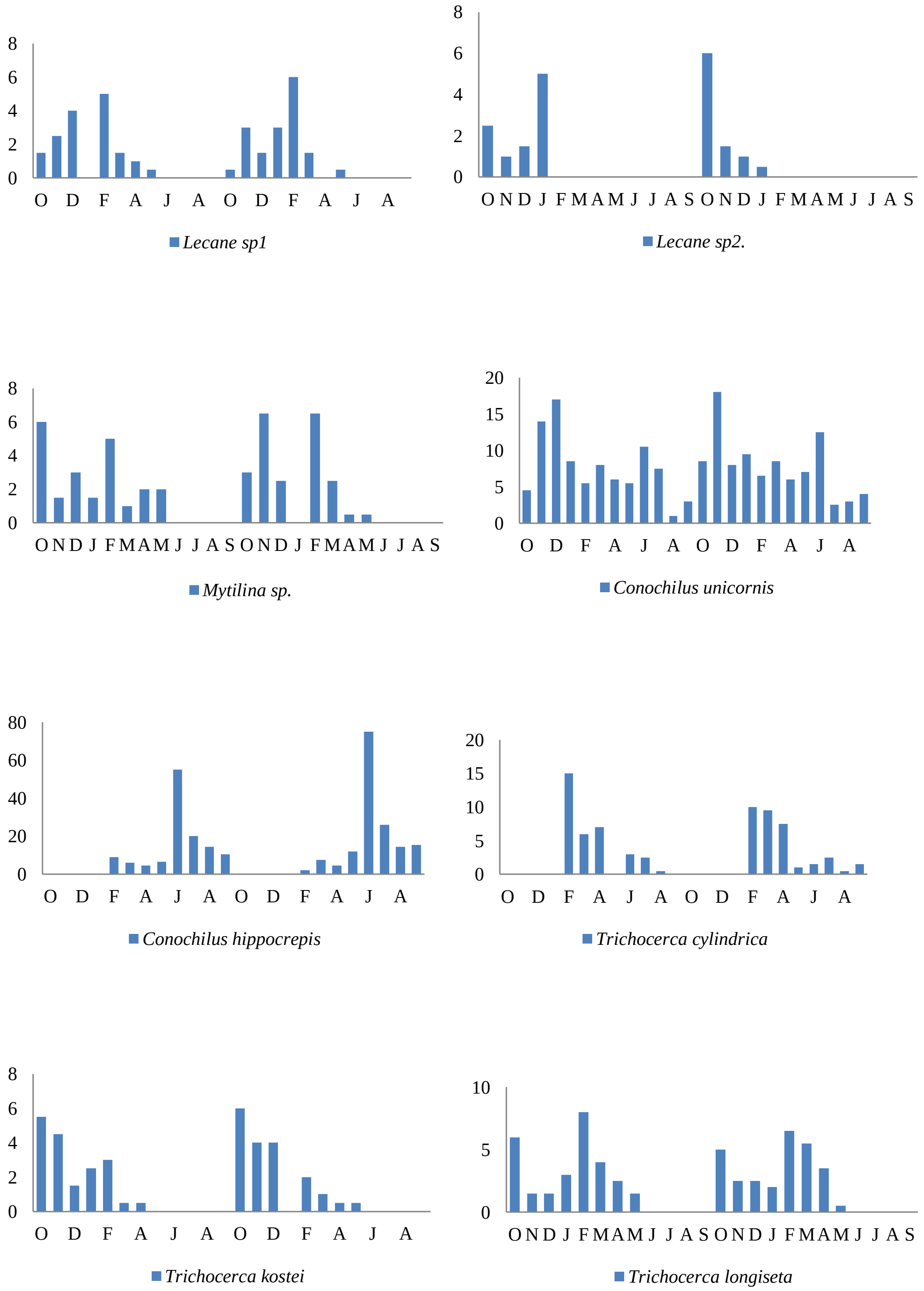


Figure 3.23. Monthly Variations in Rotifer Species Abundance of Thrissur Kole Wetland Oct 2017- Sep 2019 (SP:25 to SP:32) Cont.

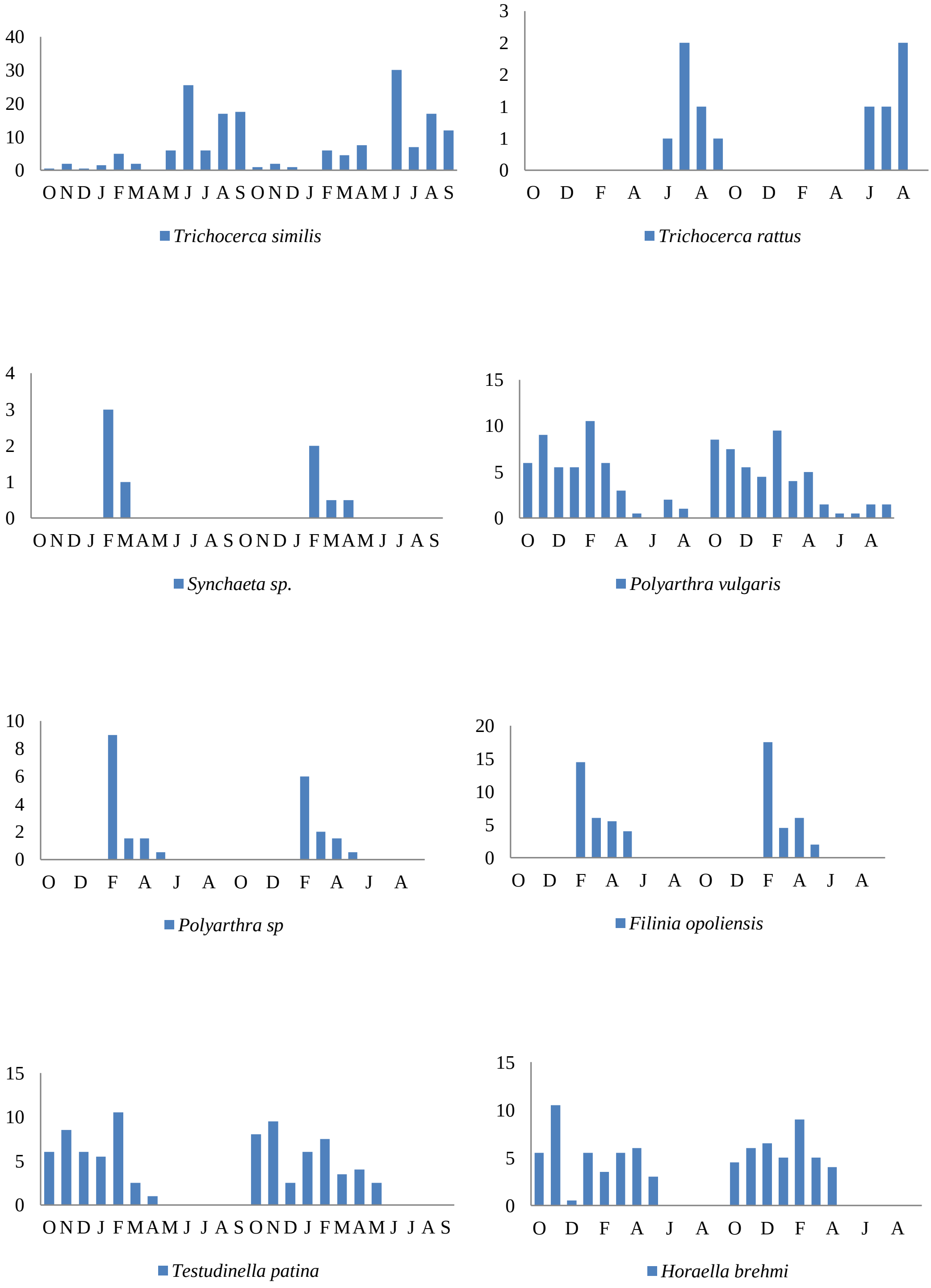


Figure 3.24. Monthly Variations in Rotifer Species Abundance of Thrissur Kole Wetland Oct 2017- Sep 2019 (SP:33 to SP:40) Cont.

3.4.2.3. Relationship with Environmental Parameters

3.4.2.3.1. Regression Analysis

Regression analysis is performed to discover the parameters that directly affect the Rotifer species abundance and to exclude indirectly related parameters from the equation. The Rotifer abundance showed normal distribution, normal p-p plot is shown in Figure 3.25. The total hardness and sulphate were the most influencing variables (statistically significant) on Rotifer abundance (Table 3.28). Rotifer abundance showed a strong positive relationship with sulphate and a negative correlation with total hardness. That means the sulphate and total hardness were the two variables that are directly influencing the Rotifera abundance. This does not mean that only the above parameters affect the abundance of Rotifera; sulphate and total hardness are indirectly affected by many other parameters, as mentioned in the previous chapter.

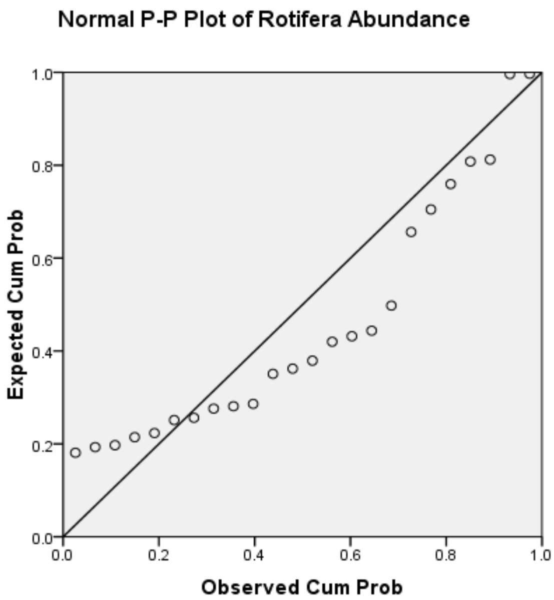


Figure 3.25. Normal P-P Plot of Rotifer Abundance

Model	Unstandardized Coefficients	Std. Error	Standardized Coefficients (Beta)	t	Sig.
(Constant)	79.251	47.376		1.673	0.109
Total hardness	-0.967	0.699	-0.240	-1.383	0.181
Sulphate	11.960	3.810	0.546	3.139	0.005

Table 3.28. Regression Model for Rotifera Abundance

Stepwise Regression Equation: $\mathbf{Y_2 = 79.251-0.967X_4+11.959X_5}$

Wherein,

Y_2= Rotifera Abundance

X_4= Total Hardness

X_5= Sulphate

3.4.2.3.2. Canonical Correspondence Analysis

Canonical Correspondence Analysis (CCA) is a good and appropriate statistical method for understanding species environmental interactions. CCA was used to integrate individual Rotifer species abundance data with the physical and chemical parameters of water, and the resulting biplot is presented in Figure 3.27. The permutation test was significant for all canonical axes ($p < 0.05$), indicating that the physical and chemical parameters of the water were linearly related to the abundance of Rotifers. Within the Canonical Correspondence Analysis eigenvector analysis, most of the inertia is carried by the first axis. The eigenvalue for CCA axis 1 (0.372) and axis 2 (0.253) explained a 74.1% species variation, of which Axis 1 represents 44.1% of the total variable (Table 3.29), the scree plot of the CCA analysis is illustrated in Figure 3.26. This means that the two-dimensional Canonical Correspondence Analysis map will be enough to analyze the relationships between the month, the species and the variables.

Axis 1 was positively associated with DO, nitrate and iron, and negatively with pH, electrical conductivity, Chloride, BOD, COD, and TASA. Axis 2 was positively associated with total hardness and DO, and negatively with sulphate and water temperature. Axis 1 thus indicates water quality (higher DO and lower BOD), and Axis 2 indicates trophic gradient. Axis 1 was strongly positively related to *B. forficula, T. similis* and *T. rattus* and negatively to *L. lateralis, L. inopinata, L. pyriformis, Lecane sp2., T. kostei* and *T. patina*. Axis 2 was strongly positively related to *A. navicula, L. lateralis, T. kostei* and *Lecane sp2* and negatively with *B. angularis, B. dichotomous, B. patulus, F. opoliensis, Polyarthra sp* and *Synchaeta sp.*

The CCA also showed the spatial order of the sampling months based on the environmental variables. The pre-monsoon months were located in the lower-left quadrant, opposite the monsoon months (upper-right quadrant), and the post-monsoon months in the upper left quadrant. This explains the clear difference between the seasons. Pre-monsoon season showed strong negative association with axis 2 (higher total hardness and DO, and lower sulphate), monsoon season showed strong positive association with axis 2 (higher iron and DO, and low BOD) and post-monsoon season showed strong negative association with axis 1 and strong positive association with axis 2 (higher iron and DO, and lower temperature, nitrate and BOD).

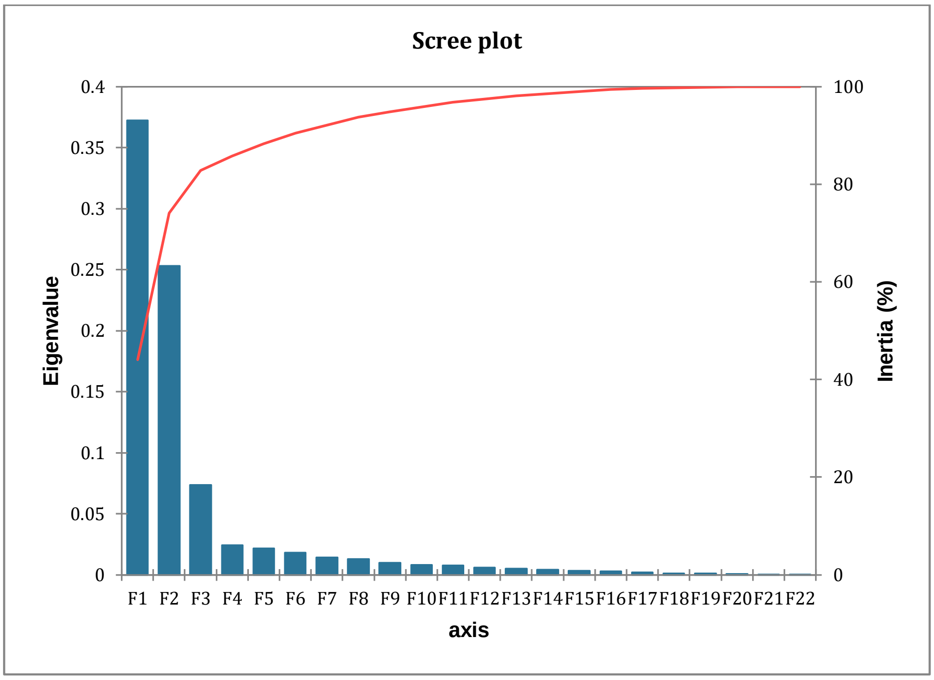


Figure 3.26. The Scree Plot Represents the Eigenvalues for Each Component

	Eigen Value	Constrained Inertia (%)	Cumulative %	Total Inertia	Cumulative % (%)
F1	0.372	44.091	44.091	43.547	43.547
F2	0.253	30.004	74.095	29.634	73.181
F3	0.074	8.721	82.816	8.613	81.795
F4	0.025	2.904	85.720	2.868	84.663
F5	0.022	2.565	88.285	2.534	87.196
F6	0.018	2.135	90.420	2.108	89.305
F7	0.014	1.714	92.134	1.693	90.998
F8	0.013	1.558	93.692	1.539	92.537
F9	0.010	1.175	94.867	1.160	93.697
F10	0.008	0.993	95.860	0.981	94.678
F11	0.008	0.900	96.760	0.889	95.567
F12	0.006	0.732	97.492	0.723	96.290
F13	0.005	0.594	98.086	0.586	96.876
F14	0.004	0.506	98.592	0.500	97.376
F15	0.003	0.411	99.003	0.406	97.782
F16	0.003	0.358	99.361	0.353	98.136
F17	0.002	0.234	99.595	0.231	98.366
F18	0.001	0.134	99.728	0.132	98.498
F19	0.001	0.119	99.847	0.118	98.616
F20	0.001	0.076	99.923	0.075	98.690
F21	0.000	0.048	99.971	0.048	98.738
F22	0.000	0.029	100.000	0.029	98.767

Table 3.29. Eigenvalues and Percentages of Inertia (CCA)

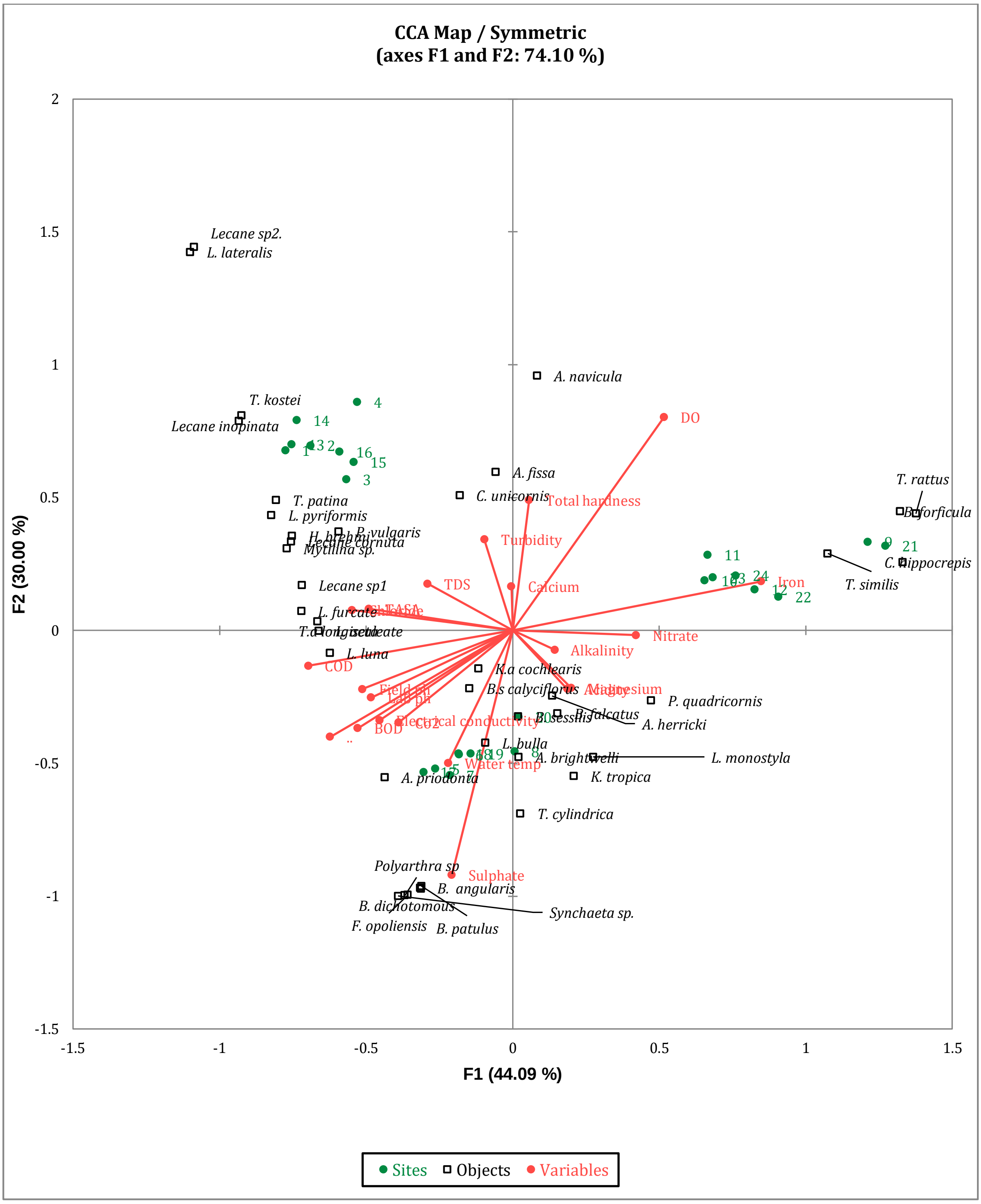


Figure 3.27. Ordination Diagram (CCA) of Descriptive Variables and Rotifer Community

3.4.2.4. Taxonomic Information of Rotifers in Thrissur Kole Wetlands

Phylum Rotifera

Rotifers (Wheel Animalcule) are short-lived multicellular microscopic, mostly aquatic organisms. The body of Rotifer is spherical, bag-like, flattened or wormlike, and consists of head, trunk and foot. The head bears a two-segmented wheel-like organ called the corona, which is either a ciliated or a funnel-shaped structure at the anterior end, and a specialized pharynx called mastax with jaws (trophi).

Key to Classes

1. a. Rotifers with paired ovary : **2**

   b. Rotifers with single ovary : **Monogononta**

2. a. Marine; Corona without two trochal discs, reduced, fully developed males ....**Seisonidea**

   b. Freshwater; corona with two trochal discs, rarely reduced in some species, males unknown ....**Bdelloidea**

Class Monogononta Plate, 1889

Sessile or swimming forms, with a single germovitellarium; males usually reduced, with one testis; mastax not ramate; lateral antennae present; foot present (with two toes or without toes) or absent.

Key to Orders of Monogononta

1. a. Free swimming; foot absent or present, when present with toes .... **Ploimida**

   b. Adults rarely free swimming, foot absent or present, when present without toes **2**

2. a. Trophi malleoramate ....**Flosculariacea**

   b. Trophi uncinate ....**Collothecacea**

Order Ploimida (Hudson & Gosse, 1886)

Of the 17 families in this order (Walter Koste & Shiel, 1987), only six were found from the study area during the study period.

Family: Brachionidae (Wesenberg-Lund, 1899)

Mostly stout; lorica heavy and dorso-ventrally flattened, often carrying several spines or projections and ringed foot; Trophi malleate; funnel-like oral opening in the buccal field having a simple circumapical band of cilia; Foot present (when present with 2 toes) or absent.

In the present study, the family Brachionidae is represented by four genera: *Brachionus, Platyias, Keratella* and *Anuraeopsis*.

Genus: *Brachionus* Pallas, 1776

Lorica broad and covers the trunk completely, usually separated into a dorsal and a ventral plate (some species also have a basal plate) more or less compressed dorso-ventrally. Anterior dorsal margin with different spines, generally six or four; mental margin usually rigid, elevated, with a medium sinus. In some species, posterior-lateral spines have developed, postero-median spines are also found in a few species. Foot opening at the lorica's posterior, between bases of posterior spines, rarely with a surrounding sheath. Long, wrinkled, retractile foot with two toes.

The present study identified seven species belonging to the genus *Brachionus*. They are *B. angularis, B. forficula, B. Calyciflorus, B. falcatus, B. dichotomus, B. sessilis* and *B. patulus*.

Brachionus angularis Gosse, 1851

Lorica hard, lightly stippled, divided into dorsal and ventral plates; Dorsal plate with ridges, moderately compressed; antirodorsal margin with two median spines containing a V-shaped notch; lateral and intermediate spines are usually absent, and some have intermediate spines; posterior spines absent.

Brachionus forficula Wierzejski, 1891

Lorica hard, stippled, subdivided into dorsal and ventral plates, moderately compressed; four occipital spines; laterals longer than medians; intermediate spines absent; occipital spines rounded at tips, rarely pointed; stippled posterior spines, bend inwards with a knee like bulging.

Brachionus Calyciflorus Pallas, 1766

Flexible, oval-shaped lorica, not separated into dorsal and ventral plates; slightly compressed body (dorsoventrally), Anterior dorsal margin with four broad base spines of different lengths, medians longer than laterals; mental margin flexible, elevated, with unflanked V-shaped notch; posterior spines present or absent; posterolateral spines generally absent; lorica slightly stippled or smooth.

Brachionus falcatus Zacharias, 1898,

Lorica hard, slightly stippled, dorsoventrally compressed and consists of dorsal and ventral plates; six spines in the anterodorsal margin; intermediate spines larger than laterals and medians, bend ventrally towards or laterally outwards head; mental edge solid and curved without spine and elevation closer to the centre; posterior spines broadly separated basally, lengthy, their width much extra than anterior spines, parallel or loop outwards, converge, then twist in the direction of their apices; unflanked foot opening.

Brachionus dichotomus Shephard, 1911

Deep fitting of lateral antenna, above the upper border of ventral foot opening, underlying that is the swollen lateral process of the lorica, and the dorsal, a small dome above the foot opening. Short anteromedian spines, anterolateral spines absent, anterosubmedian spines rudimentary

Brachionus sessilis Varga, 1951

Lorica soft, ovoid; anterior dorsal margin with six sharp, broad, triangular spines; most prominent inner spines; least developed, wave-like shape median spines, slightly curving towards the ventral plate; curved anterior ventral margin, a pair of lobules under dorsal sinus; retractile foot.

Brachionus patulus O. F. Mullar, 1786

Rectangular Lorica, ten conspicuous spines on anterior margin (four on ventral side, four on dorsal side and two on lateral sides); dorsal medians long, curved to the ventral side; three segmented foot; foot opening surrounded by two unequal spines.

Genus: *Keratella* Bory de St. Vincent, 1822

Lorica with dorsal and ventral plates, convex dorsal plate, different patterns for different species; ventral plate slightly concave or flat; Lorica is usually covered with a thin aerolated network; anterodorsal margin with six spines (sometimes four); round and rigid mental margin with median notch.

Keratella cochlearis Gosse, l951

Single or medium-sized caudal spine; lorica with a median longitudinal line on the dorsal side, facets are arranged symmetrically on either side.

Keratella tropica Apstein, 1907

Polygonal markings on the surface of lorica; anterior six spines, median long and curved, equal length for laterals and sub medians; posteromedian remnant below postmeridian plaque; two unequal posterior spines.

Genus: *Anuraeopsis* Lauterbom, 1900

Lorica thin, flexible, rounded or pointed, no foot opening, arched dorsal plate, flat ventral plate; lateral sulcus is formed by connecting the lateral edges of these plates; a notch without a spine in the anterodorsal margin; smooth mental margin, a slight depression in the middle.

Anuraeopsis fissa, Gosse, l851

Lorica more or less cylindrical, posteriorly pointed; straight pectoral margin truncated caudal extremity; occipital margin V-shaped; a pair of knob-like projections at the anterolateral angle.

Anuraeopsis navicula Rousselet, 1911

Navicular shape; lorica elongated, granulated, finely serrated anterior border.

Family: Asplanchnidae Harring & Myers,1926

Saclike conical or pear-shaped body; thin and delicate cuticle; trophi incudate; corona reduced to a circumapical band.

Genus *Asplanchna* Gosse, 1850

Asplanchna brightwelli, Gosse, 1850

Thin, sacciform, transparent body; incudate trophi with rami having horn-like process at outer margins of the base and inner spine at the middle; horse-shoe shape vitellarium.

Asplanchna herricki De Geurne, 1888

Large, flexible, sacciform transparent body with a large cavity; no specialised intestine; trophi own several tiny teeth like serrations with fairly sized midramal teeth on each ramus.

Asplanchna priodonta Gosse, 1850

Large, flexible, sacciform, transparent body; anterior opening only; broad corona with fine ciliary filaments; body cavity large; foot absent.

Family: Mytilinidae Bartos, 1959

Stout and laterally compressed body; lorica cylindrical, fused dorsal and ventral plate; foot with indistinct segments.

Family: Lecanidae Bartos, 1959

Dorso-ventrally flattened, lorica shield-shaped, more or less rigid; dissimilar dorsal and ventral plates connected by a soft sulcus; foot protrudes through an opening in the ventral plate carrying one or two long toes.

Genus: *Lecane* Nitzsch, 1827

Oval to shield-shaped lorica; consists of dorsal and ventral plates; foot projects through the ventral plate, bearing two toes, separated, rarely joined at the base.

Lecane cornuta Muller, 1786

Nearly circular lorica; dorsal lorica margin without median spines; anterior margin more or less greatly sinuate; toe with two claws or a fused claw.

Lecane bulla Gosse, 1851

Egg-shaped lorica, anterior dorsal margin with V-shaped sinus, ventral margin with deep rounded sinus; Second foot segment almost triangular; long and single toe enlarged in the middle and ends in acute claws.

***Lecane aculeata* Jakubski, 1912**

Long and rigid lorica; The dorsal plate is narrow at the anterior and posterior regions and wide at the centre; two acutely pointed anterolateral spines in the anterior margin; The ventral plate is elongated with horizontal and longitudinal folds; Foot segment plate protruding outside, with two long toes, and unconnected claws.

Lecane furcata Murray, 1913

Lorica rigid and more or less rounded; dorsal plate narrow at anterior region, wider at centre than the ventral plate. Ventral plate with horizontal and longitudinal folds; simple pseudo segment; single toe with a fissure at its tip.

Lecane monostyla Daday, 1897

Lorica rigid and ovoid; dorsal plate wider than the ventral plate; dorsal plate with notable flexible lateral extension; straight and random anterior margins to dorsal plate and ventral plate; long ventral plate with horizontal and longitudinal folds.

Lecane luna Müller, 1776

Stiff, more or less rounded lorica; narrow dorsal plate than ventral plate; dorsal plate circular, ventral plate long and smooth; anterior margin of both dorsal and ventral plates are concave with anterolateral spines; simple foot pseudo segment; short, needle-like, parallel toes with pseudo claws and accessory claws.

Lecane lateralis Sharma, 1978

Lorica ovate, dorsoventrally compressed; Anterior dorsal margin curved inwards, anterior ventral margin undulating with a median sinus; dorsal plate approximately circular, not marked on surface, maximum width in the middle; ventral plate with obvious external angles, marked by horizontal folds on its posterior part, small lateral extensions at its ventrolateral angles; toes long with long rigid claws.

Lecane inopinata Harring & Myers, 1926

Lorica soft and oval shaped; dorsal plate is narrow at the anterior and wider medially than the ventral plate; dorsal plate and ventral margins are coincident; ventral plate is more or less same size as the dorsal with transverse and longitudinal folding; simple pseudo segment without any projections; slender toes with claws, 1/3 of their length joined together.

Lecane pyriformis Daday, 1905

Lorica is commonly oval-shaped; ventral plate thinner than the dorsal; ventral plate is long and contain longitudinal and transverse foldings; anterior margins are coincident, most of their length straight and strongly curved to the edges of the lorica; simple pseudo segment without any projections; single toe without claws.

Family: Trichocerchidae Remane, 1933

Loricate; asymmetrical trunk, toes and trophi; short foot with bristle like toes; asymmetrically placed lateral antennae.

Genus: *Trichocerca* Lamarck, 1801

Lorica single, cylindrical with teeth and longitudinal ridges; body asymmetrical, cylindrical, more or less curved; spine like toes of unequal length; with some small spinules at the bottom; mastax virgate; trophi asymmetrical.

Trichocerca cylindrica Imhof, 1891

Long, cylindrical body; median dorsal lorica has a ventrally curved spine at the anterior margin; short and striped keel; The foot with two toes, long left toes and short, spine-like right one.

Trichocerca kostei Segers, 1993

Body elongated and curved with flexible lorica; dorsal keel nearly two-third of the body, foot short, unequal and curved, right toe longer than the left; asymmetrical mastax; fulcrum long and broad at the end.

Trichocerca longiseta Schrank, 1802

Unconstructed, spindle-shaped body with two anterior mucrons, no overhang; single crook is present in left manubrium; right toe reduced less than 1/3 length of left toe; six substyles at the base of the toes.

Trichocerca similis Wierzejski, 1893

Elongated, slender body; equal spines in anterior margin; dorsal keel begins from the base of the anterior spines; two-segmented foot with two toes.

Trichocerca rattus Müller, 1776

Wide striated keel at the anterior end reaching up to half the length of the body; long toe extends up to the total body length.

Family: Synchaetidae Remane, 1933

Soft cuticle; trophi vigrate with paired, complex hypo pharyngeal muscles; soft, pyriform, conical, bell, cup shaped, sac like body; foot present or absent, when present short and tapering.

Genus*: Polyarthra* Ehrenberg, 1834

Thin, transparent, rectangular body; paddles from neck, length equal to body length; blade-shaped lateral appendages; 2 antennas in the anterior occipital region; eyespot present.

Polyarthra vulgaris Carlin, 1943

Illoricate; cylindrical body; six spear-shaped appendages on each side of the anterior region long as the body with lateral teeth; lateral antennae at the posterior end of the body; two dorsolateral and two ventrolateral bundles of paddles located at the shoulder region, each consisting of three paddles; paddles overlap slightly, arranged one above the other.

Genus: *Synchaeta* Ehrenberg, 1832

Conical shaped, illoricate body; four long, prominent sensory bristles on the corona; trophy virgate; small toes.

Order: Flosculariacea Ramane, 1933

Family: Trochosphaeridae Harring, 1913

Body spherical, encircled at the equator by a single row of cilia, two eyespots; digestive tract curved.

Genus: Horaella *Donner, 1949*

Body spherical; lorica and appendages absent; Corona has borne apically on a short neck.

Horaella brehmi Donner, 1949

Oval shaped, transparent body with a short neck bearing a circular corona; posterior end tapering and elevated around the cloacal aperture; trophi malleoramate; two wing-like projections anterior end of a fulcrum; foot and toe absent.

Family: Conochilidae Remane, 1933

Soft, conical or vase-shaped body; antennae single, splitted or intermediate, tapering non-segmented foot.

Genus*: Conochilus* Ehrenberg, 1834

Free swimming colonial forms with 10 - 200 individuals in a colony; corona round with small cilia; antenna above the corona; feet of individuals always attached at the posterior end in the mucilagenous sheath.

Conochilus unicornis Rousselet, 1892

Colonies of only a few individuals; only one antenna on corona; ventral antennae completely or partly fused; relatively short feet.

Conochilus hippocrepis Schrank, 1803

Colonies of about 100 animals; 2 unequal antennae on corona, left antennae are half the length of the right; the stomach is divided into two unequal chambers by an asymmetrically placed paramedian partition.

Family: Filinidae Bory de St. Vincent, 1824

Body delicate; saclike, three or four appendages with long spines or thick spines.

Genus: Filinia Bory de St. Vincent, 1824

Illoricate bears two lateral skipping bristles of different lengths and a caudal bristle; trophi malleoramate.

Filinia opoliensis Zacharias1898

Long, cylindrical body; two long broad anterior setae; posterior setae with a small additional seta; One of the two posterior spines is as long as the anterior spine; smaller spine is very short, up to one-sixth of the long posterior spine.

Family: Testudinellidae Harring, 1913

Transparent body, lorica thin, dorsoventrally flattened; small, spherical with undulating margin; foot present or absent.

Genus: *Testudinella* Bory de St. Vincent, 1822

Nearly circular lorica; dorsal and ventral plates completely fused, dorso-ventrally flattened; foot long, annulated, retractile and terminating in a tuft of cilia; mastax malleoramate.

Testudinella patina Hermann, 1783

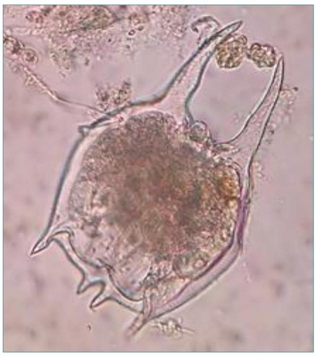
Transparent, circular and dorsoventrally flattened body; anterior end of lorica with a prominent anteromedian lobe; foot-opening approximately one-third from the posterior end and circular; foot annulated, retractile and terminating in a ciliated cap.

Figure 3.28. Images of Rotifer Species Identified during the Study Period (SP:1 to SP:9)

B. falcatus

B. calyciflorus

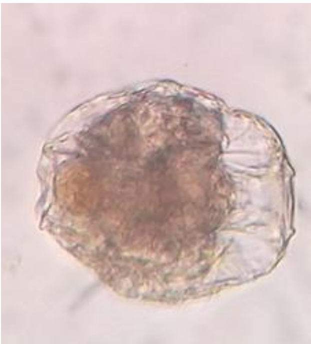
B. dichotomous



B. forficula

B. patulus

B. sessilis

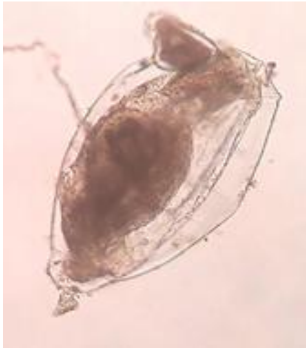


B. angularis

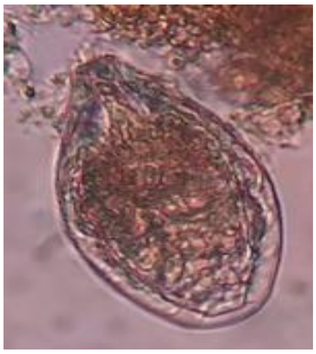
P. quadricornis

K. tropica

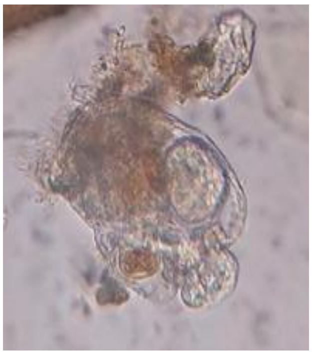
K. cochlearis



A. fissa

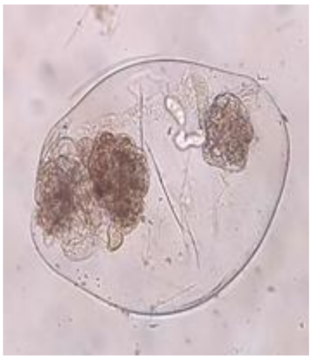


A. navicula

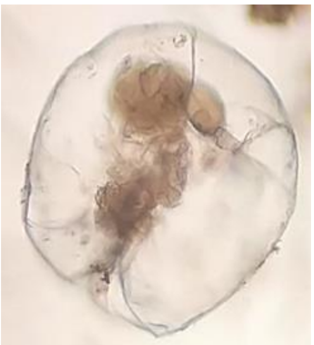


C. unicornis

C. hippocrepis



A. brightwelli



A. Herricki

A. priodonta

F. opoliensis

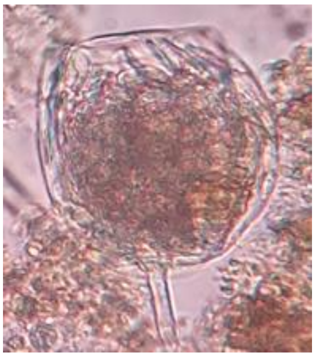
Figure 3.29. Images of Rotifer Species Identified during the Study Period (SP:10 to SP:18) Cont.

H. brehmi

T. patina

L. aculeata

L. bulla



L. furcata

L. luna

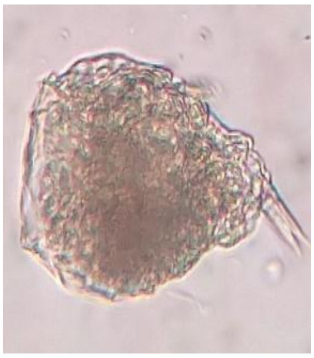
L. inopinata

. lateralis

L. monostyla

Figure 3.30. Images of Rotifer Species Identified during the Study Period (SP:19 to SP:27) Cont.

L. cornuta

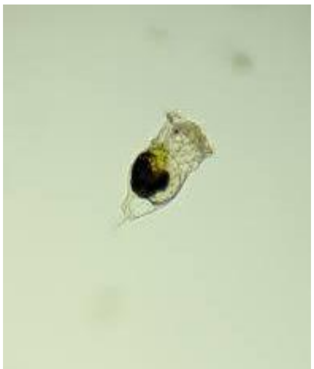


L. sp1.

L. sp2.

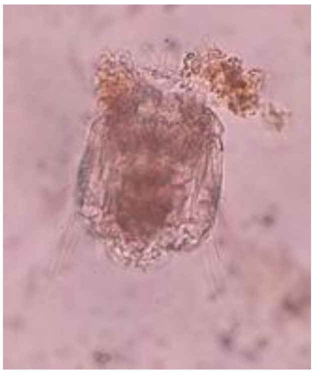
L. unguitata

Mytilina sp.



Synchaeta sp.

P. vulgaris



Polyarthra sp.

T. kostei

Figure 3.31. Images of Rotifer Species Identified during the Study Period (SP:28 to SP:36) Cont.

T. cylindrica

T. longiseta

T. rattus

T. similis

Figure 3.32. Images of Rotifer Species Identified during the Study Period (SP:37 to SP:40) Cont.

3.4.2.5. Evolutionary Relationship

In order to analyze the evolutionary relationship of the Monogononta Rotifers, this study executed the applicability of phylogenetic analysis of 25 species of Rotifers representing 11 genera (*Anuraeopsis, Asplanchna, Brachionus, Conochilus, Filinia, Keratella, Lecane, Platyias, Polyarthra, Testudinella, Trichocerca*) and eight families [Conochilidae, Filinidae, Testudinellidae (from Flosculariacea) and Asplanchnidae, Brachionidae, Lecanidae, Synchaetidae, Trichocercidae (from Ploimida)].

The results obtained from the Molecular Phylogenetic Analysis by the Maximum Likelihood Method revealed that species under the same genera exhibited a prominent range of similarity. In contrast, the species from the different genera are known to illustrate an extensive range of genetic changes. For instance, as depicted in Figure 3.33., the *Asplanchna priodonta* and *Asplanchna brightwelli* showed an extensive range of similarities in genetic characteristics with a branch length 0.12715663, 0.06909123 for the former and later one respectively. While there exists a greater range of genetic change between the *Asplanchna priodonta* and *Filinia opoliensis*.

The same pattern has been found between the *Lecane bulla* and *Lecane luna* with a branch length of 0.16030040 and 0.11910261 for the former and later one respectively. However, the *Lecane* spp. are found to exhibit semblance towards *Brachionus* sp. as well as with *Conochilus* sp with a branch length of 0.09601670. The *Brachionus sessilis* and *Brachionus falcatus* possessed genetic resemblance with a total branch length of 0.03808986. The *Brachionus calyciflorus, Brachionus forficula, and Brachionus angularis* showed similarities, but there is a slight genetic change with the Brachionus described above spp. It indicates the evolutionary significance of this investigation. That means the genetic changes that have happened within the same genus may be considered as the initial processes that are essential for the evolution of organisms.

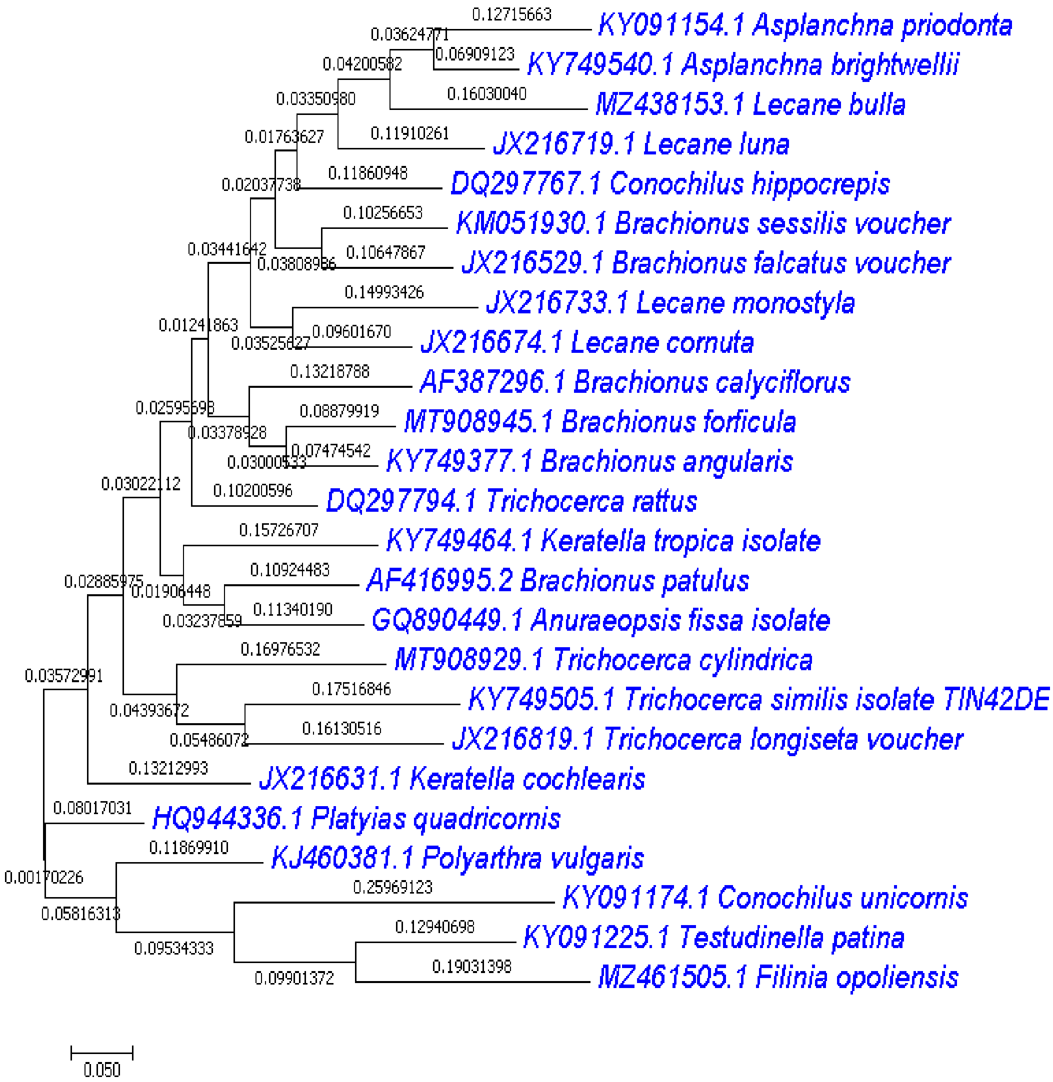


Figure 3.33. Molecular Phylogenetic Analysis by Maximum Likelihood Method

The genetic changes within the same genus like *Brachionus* may happen due to the various environmental factors, including the alterations in the environmental circumstances as discussed in the former sections of this investigation. The *Trichocerca rattus*, *Platyias quadricornis*, *Polyarthra vulgaris* and *Keratella tropica* don’t possess an extensive range of similarities with any other species that are analyzed in this study at the molecular level. Nevertheless, the *Keratella tropica* showed a great range of genetic differences towards the *Keratella cochlearis*, indicating the possibility of emerging new *Keratella* species through the gradual evolutionary process.

One of the major facts is that the *Brachionus patulus*, exhibited a high degree of genetic change with other *Brachionus* spp. analyzed in this investigation. Moreover, the species described above has also formed a link with *Anuraeopsis fissa*. Likewise, a strong genetic change between *Conochilus hippocrepis* and *Conochilus unicornis* indicates the chance of developing the base for evolutionary processes. As mentioned in the former sections, the same pattern has been followed by the *Trichocerca cylindrica*, *Trichocerca similis,* and *Trichocerca longiseta* with a total branch length of 0.04393672. From the results, it was evident that all the analyzed species possessed changes in genetic characteristics even within the same genus and this indicates the chances of evolution.

3.4.3. Cladocera

3.4.3.1. Diversity of Cladocera

A total of 21 species of Cladocera were identified from Thrissur Kole Wetland from Oct 2017 to Sep 2019. The Cladoceran community of the study site belonged to six families; Sididae, Daphnidae, Moinidae, Bosminidae, Macrothricidae and Chydoridae. The Cladoceran species composition of Thrissur Kole wetland varies from month to month and season to season. The seasonal distribution of Cladocera species of Thrissur Kole wetland is shown in Table 3.30.

D. excisum and *B. deitersi*, *D. sarsi* and *P. szalayi* were the most common species seen every month. All Cladoceran, except *S. serrulatus*, were found in all seasons, and the absence of *S. serrulatus* was observed during the pre-monsoon season. Analyzed data on the Cladoceran species richness are shown in detail in Table 4.31. The number of genera and families was the same in all seasons, only in abundance. According to Shannon, the diversity showed a clear seasonal variation, with the highest Cladoceran diversity being in the post-monsoon season (2.708) and the lowest in the pre-monsoon season (1.9732). On an annual basis, the highest diversity was in the post-monsoon period of the second sampling years (2.873), while the lowest diversity was in the pre-monsoon period of the first sampling years (1.962). The difference between the seasons is more pronounced in the Simpson's index, which is more sensitive to differences in the abundance of commonly found species. For example, the Simpson diversity of Cladocera of Thrissur Kole wetland was 0.857, the Simpson diversity was similar and higher in post-monsoon (0.999) and monsoon season (0.998) and lowest in the pre-monsoon season (0.790).

Family	Species	PRM	MON	POM
Sididae	*Diaphanosoma excisum* Sars, 1885	+	+	+
	Diaphanosoma sarsi Richard, 1895	+	+	+
	Pseudosida szalayi Daday, 1898)	+	+	+
	Latonopsis australis Sars, 1888	-	-	+
Daphnidae	*Ceriodaphnia cornuta* Sars, 1885	+	+	-
	Simocephalus serrulatus (Koch, 1841)	-	-	+
	Simocephalus acutirostratus (King, 1853)	-	-	+
Moinidae	*Moina micrura* Kurz, 1874	+	+	-
Bosminidae	*Bosminopsis deitersi* Richard, 1895	+	+	+
Macrothricidae	*Macrothrix goeldii* Richard, 1897	-	+	+
	Macrothrix triserialis (Brady, 1886)	-	+	+
	Ilycryptus spinifer Herrick, 1882	-	+	+
Chydoridae	*Alonella sp.*	+	-	-
	Chydorus sphaericus (O.F. Mliller, 1776)	-	-	+
	Chydorus barroisi Richard, 1894	-	-	+
	Alona rectangula Sars, 1862a	-	+	-
	Alona monacantha Sars, 1901	-	-	+
	Biapertura affinis (Leydig, 1860)	+	-	-
	Oxyurella singalensis (Daday, 1898)	-	-	+
	Kurzia longirostris (Daday, 1898)	+	-	-
	Euryalona orientalis (Daday, 1898)	-	+	+

Table 3.30. The Seasonal Distribution of Cladocera Species of Thrissur Kole Wetland

Period	Number of Species	Number of Genera	Number of Families	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)
Whole Study Period	21	16	6	2.424	0.857	0.3121
PRM	20	16	6	1.9732	0.790	0.2780
MON	20	16	6	2.267	0.998	0.3505
POM	21	16	6	2.708	0.999	0.4354
PRM1	20	16	6	1.9616	0.786	0.3055
PRM2	20	16	6	1.9834	0.794	0.3104
MON1	20	16	6	2.007	0.838	0.3460
MON2	20	16	6	2.1455	0.842	0.3731
POM1	21	16	6	2.5571	0.913	0.4616
POM2	21	16	6	2.873	0.915	0.5208

Table 3.31. The Seasonal Variation in the Diversity Indices of Order Cladocera of Thrissur Kole Wetland, Oct 2017- Sep 2019

When the diversity of Cladocera in two sampling years were specifically compared, the highest diversity was in the post-monsoon season of the first (0.913) and second (0.915) sampling years, and the lowest diversity was in the pre-monsoon period of the first sampling years (0.786). Like Shannon and Simpson's diversity, evenness was also higher in the post-monsoon season (0.4354) and lowered in the pre-monsoon season (0.2780). This also showed annual variation, high evenness recorded in the post-monsoon season of the second sampling year (0.5208) and low during the pre-monsoon season of the first year.

Of the six families identified from the study area, family Bosminidae and Moinidae contain only one species, so diversity index calculations were impossible for the families mentioned above. The diversity index of the Cladocera family that contains more than one species is shown in Table 3.32. The largest family was Chydoridae, which contained five species, four species in Sididae four species, three species each were found in the family Daphnidae and Macrothricidae. The highest diversity and evenness was shown by the family Chydoridae (H= 2.1688, D= 0.8825, E= 0.3743) followed by Macrothricidae (H= 1.0136, D=0.6063, E= 0.1891). The family Sididae (H= 0.9777, D= 0.5224, E= 0.1460) and Daphnidae (H= 0.9877, D= 0.5927, E= 0.1849) showed significantly similar diversity and evenness.

Diversity indices of Cladocera genera contain more than one species as shown in Table 3.33. All species listed below contain two species, high diversity and evenness was found in the genus *Chydorus* (H = 0.693, D = 0.499, E = 0.1655), followed by *Alona* (H = 0.487, D). E = 0.1678).

Family	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)
Sididae	0.9777	0.5224	0.1460
Daphnidae	0.9877	0.5927	0.1849
Macrothricidae	1.0136	0.6063	0.1891
Chydoridae	2.1688	0.8825	0.3743

Table 3.32. Diversity Indices of Cladocera Family of Thrissur Kole Wetland during Oct 2017-Sep 2019

Genera	Number of Species	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)
Diaphanosoma	2	0.52	0.339	0.0801
Chydorus	2	0.693	0.499	0.1655
Macrothrix	2	0.602	0.408	0.1184
Alona	2	0.677	0.484	0.1678
Simocephalus	2	0.65	0.457	0.1423

Table 3.33 Diversity Indices of Cladocera Genera of Thrissur Kole Wetland Oct 2017-Sep 2019

3.4.3.1.1. Pre-monsoon Season

A total of 20 species, including 16 species and 6 families, were identified during the pre-monsoon season. *C. sphearicus* was a less abundant species in the pre-monsoon season of both sampling years. The diversity indices of the Cladocera family during the pre-monsoon season are shown in Table 3.34. The family Chydoridae showed high diversity and evenness (H = 1.8499, D = 0.8047, E = 0.3799), and Daphnidae showed less (H = 0.1977, D = 0.0945, E = 0.0439).

The Cladoceran genera diversity during the pre-monsoon season was shown in Table 3.35. There were two species each in the genus *Diaphanosoma*, *Chydorus*, *Macrothrix*, and *Alona*, and only one for the other 16 genera. According to the Shannon Index, the genus *Diaphanosoma* was less diverse than the other three genera, while the genus *Macrothrix* and *Alona* were more diverse than the others. The diversity, according to the Simpson index, was similar to that of the Shannon. According to the Evenness index, the species evenness was high and similar in genus *Alona* and *Chydorus*, and genus *Diaphanosoma* showed less during the pre-monsoon season.

Family	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)
Sididae	0.7522	0.4206	0.1229
Daphnidae	0.1977	0.0945	0.0439
Macrothricidae	1.0912	0.6617	0.3520
Chydoridae	1.8499	0.8047	0.3799

Table 3.34. Diversity Indices of Cladocera Family of Thrissur Kole Wetland during Pre-monsoon Season

Genera	Number of Species	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)
Diaphanosoma	2	0.538	0.353	0.0887
Chydorus	2	0.649	0.413	0.2979
Macrothrix	2	0.685	0.491	0.2509
Alona	2	0.693	0.491	0.2967

Table 3.35. Diversity of Cladocera Genera of Thrissur Kole Wetland during Pre-monsoon Season Oct 2017- Sep 2019

The diversity and abundance of Cladocera vary over time. The diversity of the Cladocera family in the pre-monsoon season of two sampling years is given in Table 3.36. The family diversity and evenness of Macrothricidae and Chydoridae were slightly higher in the first year and the family Daphnidae and Sididae in the second year.

Family	Shannon Index (H)		Simpson's Index (D)		Evenness Index (E)	
	PRM1	PRM2	PRM1	PRM2	PRM1	PRM2
Sididae	0.7356	0.7677	0.4134	0.4276	0.1359	0.1413
Daphnidae	0.2189	0.1731	0.1075	0.0796	0.057	0.0458
Macrothricidae	1.0963	1.0802	0.6649	0.6515	0.4363	0.4725
Chydoridae	1.8605	1.8359	0.8075	0.8012	0.447	0.4382

Table 3.36. The Diversity of the Cladocera Family during the Pre-monsoon Season of the Two Sampling Years

3.4.3.1.2. Monsoon Season

During the monsoon season of the two sampling years between October 2017 and September 2019, 22 species of Cladocera in 16 genera and 6 families were identified. There was more diversity during the monsoon than in the pre-monsoon season. The diversity index of the Cladocera family during the monsoon season is shown in Table 3.37. Family Chydoridae showed more diversity and evenness, while Daphnidae showed less.

The diversity of Cladocera genera during monsoon is shown in Table 3.38. Of the 16 genus identified, 11 genus are represented by single species and five are represented by 2 species each. The genus *Macrothrix* was more diverse and the genus *Chydorus* showed more evenness than the others. *Diaphanosoma* lags behind others in diversity and evenness. The difference in the Cladocera family diversity during the monsoon season in two sampling years is shown Table 3.39. The diversity and evenness of all four families was higher in the second year than in the first year.

Family	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)
Sididae	0.8711	0.493	0.1567
Daphnidae	0.7577	0.440	0.224
Macrothricidae	1.097	0.6659	0.2702
Chydoridae	1.964	0.8286	0.618

Table 3.37. The Diversity Indices of the Cladocera Family during Monsoon Season

Genera	Number of Species	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)
Diaphanosoma	2	0.344	0.193	0.0653
Chydorus	2	0.624	0.432	0.2709
Macrothrix	2	0.691	0.498	0.1899
Simocephalus	2	0.545	0.3599	0.2546
Alona	2	0.617	0.425	0.2163

Table 3.38. Diversity Indices of Cladocera Genera during Monsoon Season

Family	Shannon Index (H)		Simpson's Index (D)		Evenness Index (E)	
	MON1	**MON2**	**MON1**	**MON2**	**MON1**	**MON2**
Sididae	0.607	0.646	0.488	0.498	0.1242	0.1335
Daphnidae	0.58	0.833	0.391	0.476	0.214	0.312
Macrothricidae	0.73	1.0901	0.666	0.661	0.217	0.324
Chydoridae	1.909	1.9664	0.816	0.8245	0.509	0.5465

Table 3.39. The Diversity Indices of the Cladocera Family during the Monsoon Season of the Two Sampling Years

3.4.3.1.3. Post-monsoon Season

The diversity of Cladocera was much higher in the post-monsoon season than in other seasons, with 21 species of Cladocera in 16 genera and six families. The diversity indices of the Cladocera family in the post-monsoon season are shown in Table 3.40. Family Chydoridae showed more diversity and evenness, followed by Sididae, family Daphnidae showed less. The diversity indices of Cladocera genera during the post-monsoon season are shown in Table 3.41. There were two species in each of the five genera: *Diaphanosoma*, *Chydorus*, *Macrothrix*, *Simocephalus*, and *Alona*, and each of the others had only one species. The genus *Chydorus* showed more diversity and evenness, while the genus *Macrothrix* showed less.

As shown in Table 3.42., the diversity and evenness of Cladocera showed an annual variation. Although all the families except Sididae showed more diversity and evenness in the second year than in the first, Sididae showed more diversity in the first year.

Family	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)
Sididae	1.373	0.744	0.2994
Daphnidae	0.796	0.47	0.1774
Macrothricidae	0.882	0.512	0.1803
Chydoridae	1.977	0.839	0.4183

Table 3.40. Diversity Indices of Cladocera Family of Thrissur Kole Wetland during Post-monsoon Season

Genera	Number of Species	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)
Diaphanosoma	2	0.693	0.499	0.1729
Chydorus	2	0.713	0.579	0.1895
Macrothrix	2	0.482	0.303	0.1031
Simocephalus	2	0.589	0.399	0.1333
Alona	2	0.503	0.321	0.1496

Table 3.41. Diversity Indices of Cladocera Genera of Thrissur Kole Wetland during Post-monsoon Season Oct 2017- Sep 2019

Family	Shannon Index (H)		Simpson's Index (D)		Evenness Index (E)	
	PRM1	PRM2	MON1	MON2	POM1	POM2

Sididae	1.378	1.072	0.746	0.6497	0.350	0.3015
Daphnidae	0.749	1.174	0.437	0.6455	0.199	0.2899
Macrothricidae	0.859	0.9024	0.495	0.5270	0.204	0.2152
Chydoridae	1.641	1.981	0.838	0.841	0.407	0.4954

Table 3.42. The Diversity Indices of the Cladocera Family during the Post-monsoon Season of the Two Sampling Years

3.4.3.2. Abundance of Cladocera

The Cladocera abundance of Thrissur Kole Wetland showed monthly variations. The average monthly abundance of Cladocera was 98 org / L, with a coefficient of 42% in the range 52- 175. The highest number was recorded in March 2018 and the lowest in June 2019. About 51% of the collected Cladocera was obtained during the pre-monsoon season, 27% and 21% during the monsoon and post-monsoon seasons respectively. There was only a slight difference between the seasons of the two sampling years. Cladocera was most prevalent during the pre-monsoon season of the first sampling years and one per cent less in the pre-monsoon season of the second sampling years. Compared to the other two seasons, the number of Cladocera in the post-monsoon season was very low.

The monthly variation of the number of Cladocera of Thrissur Kole wetland is given in the Figure 3.33. *B. dietersi* and *D. excisum* were the most abundant species found throughout the study period, having relative abundance of 27% and 22%, respectively of the total. The remaining species constituted below 10 % each of the total abundance. *A. rectangula* was the least abundant species, accounting for only one per cent of the total. The rank abundance distribution of Cladocera of Thrissur Kole Wetland during Oct 2017-Sep 2019 is given in Table 3.43. The Rank Abundance Curve is given in Figure 3.35.

All the families of Cladocera contain more than one species except Moinidae and Bosminidae. Sididae was the most dominant family of the six families recorded, accounting for 34% of the total Cladocera collected, followed by Bosminidae (27%). Moinidae, Daphnidae and Macrothricidae were the least abundant family with less than 10% abundance. The abundance of the Cladocera family of Thrissur Kole

Wetland is shown in Figure 3.34. The abundance of Cladocera showed significant variations in different seasons (Figure 3.36).

Species	**Richness (%)**	**Species Rank**
B. deitersi	27	1
D. excisum	22	2
M. micrura	7	3
D. sarsi	6	4
M. triserialis	5	5
C. cornuta	5	6
P. szalayi	4	7
S. serrulatus	3	8
I. spinifer	2	9
K. longirostris	2	10
M. goeldii	2	11
O. singalensis	2	12
E. orientalis	1.8	13
L. australis	1.4	14
S. acutirostratus	1.4	15
C. sphaericus	1.4	16
A. monacantha	1.4	17
B. affinis	1.4	18
C. barroisi	1.4	19
Alonella sp.	1.1	20
A. rectangula	1.0	21

Table 3.43. Rank Abundance Distribution of Cladocera of Thrissur Kole Wetland Oct 2017-Sep 2019

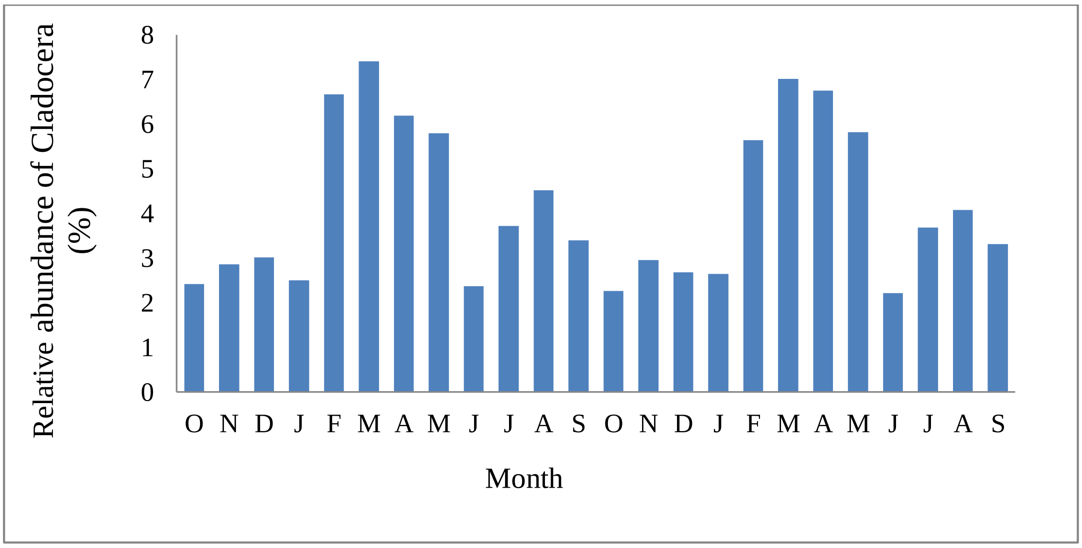


Figure 3.34. The Monthly Variation in the Abundance of Cladocera in Thrissur Kole Wetland, Oct 2017 to Sep 2019

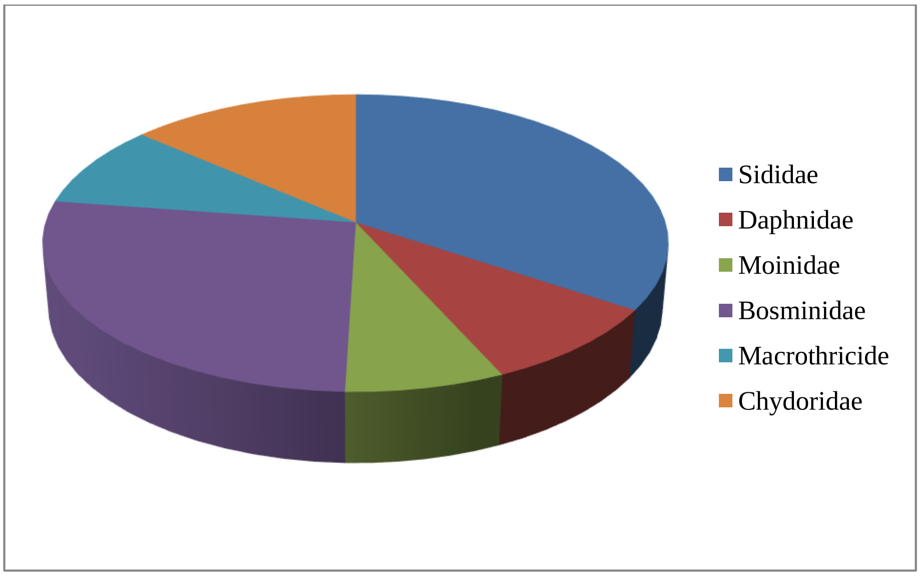


Figure 3.35. Pie Diagram Showing the Abundance of Cladocera Family of Thrissur Kole Wetland, Oct 2017- Sep 2019

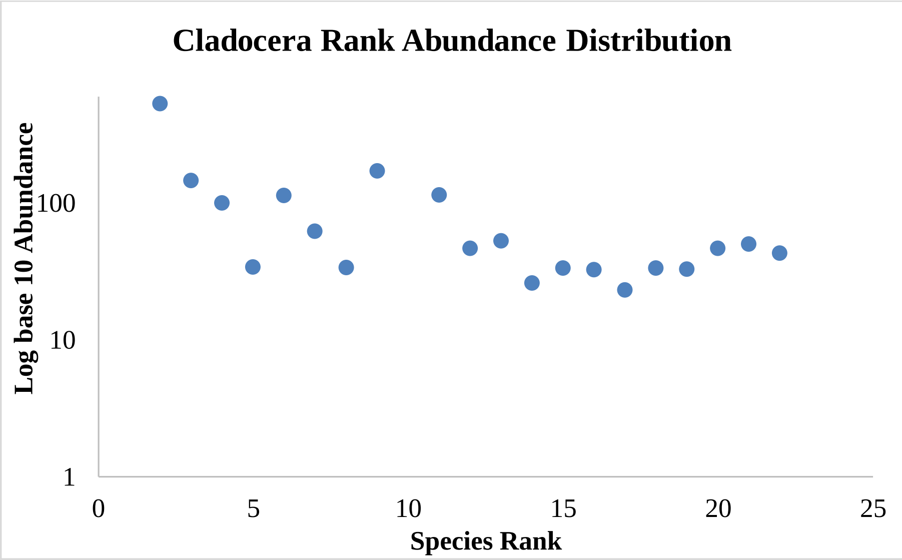


Figure 3.36. Rank Abundance Curve of Cladocera of Thrissur Kole Wetland Oct 2017- Sep 2019

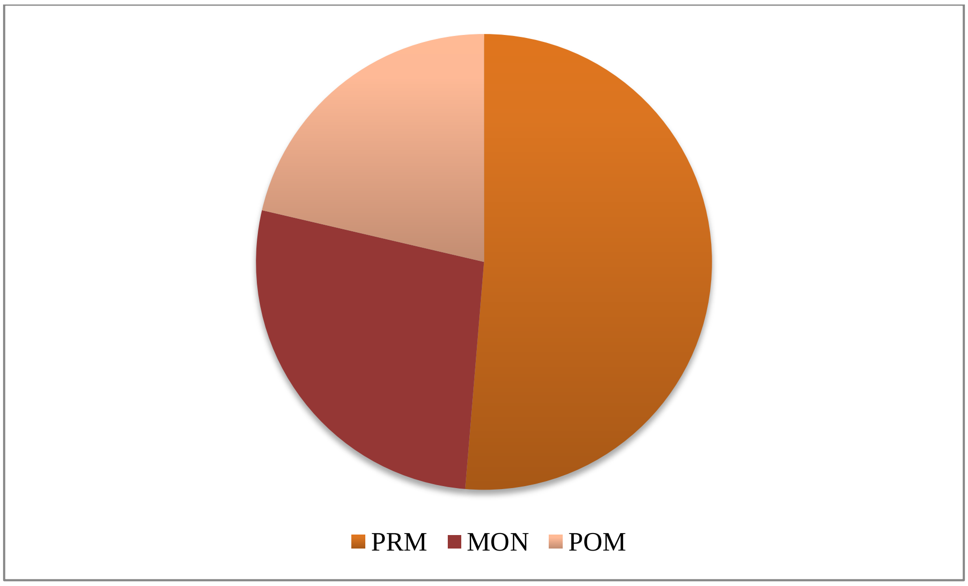


Figure 3.37. Pie-chart showing the Seasonal Variation in the Abundance of Cladocera of Thrissur Kole Wetland

3.4.3.2.1. Pre-monsoon Season

The number of Cladocera collected during the pre-monsoon season was very high, with *B. deitersi* (33%) and *D. excisum* (27%) accounting for about 60% of the total pre-monsoon abundance. *C. sphearicus* was very rare during this season, with an abundance of only 0.3%. In addition, the relative abundance of 9 other species of Cladocera was less than 1% during this season.

The relative abundance between the pre-monsoon seasons of both sampling years was significantly similar. Rank Abundance Distribution of Cladocera of Thrissur Kole wetland during pre-monsoon season is given in Table 3.44., and Rank Abundance Distribution Curve in Figure 3.37. All the families of Cladocera contain more than one species, except Moinidae and Bosminidae. Sididae was the most dominant family of the six families recorded, accounting for 38% of the total pre-monsoon Cladocera, followed by Bosminidae (33.5%). Moinidae, Daphnidae and Macrothricidae were the least abundant family with less than 10% abundance. The most diverse family Chydoridae had nine species, but the abundance was very less than others.

3.4.3.2.2. Monsoon Season

The abundance of Cladocera during the monsoon season was very low compared to the pre-monsoon season and relatively high as compared to the post-monsoon season. *B. dietersi* and *D. excisum* were the two most abundant species, making 70% of the total Cladocera found in the monsoon season. The Rank Abundance of Cladocera in the monsoon season is given in Table 3.45., and Figure 3.38. *S. serrulatus* was the least abundant species accounting for only 0.4% of the total. The relative abundance of the five species, *K. longirostris, B. affinis, C. barroisi, L. australis* and *S. serrulatus* were below 1% of the total.

All the families of Cladocera contain more than one species during this season, except Moinidae and Bosminidae. Of the six families recorded, Sididae was the most dominant family accounting for 40% of the total monsoon Cladocera, followed by Bosminidae (25%), the remaining four families represented by only below 10%.

3.4.3.2.3. Post-monsoon Season

Post-monsoon Cladoceran abundance was significantly lower than other seasons (21%). *M. triserialis* (21%) was the most abundant species accounting for 21% of the total, followed by *B. dietersi* (16%), *S. serrulatus* (14%). *O. singalensis* was the least abundant species accounting for only 1% of the total. On an annual basis, there was no significant difference in the abundance of Cladocera between the post-monsoon seasons of the two sampling years. The Rank Abundance of Cladocera in the post-monsoon season is given in Table 3.46. and Figure 3.39.

All the families of Cladocera contain more than one species except Moinidae and Bosminidae. Of the six families recorded, Macrothricidae was the most dominant family accounting for 26.4% of the total post-monsoon Cladocera, followed by Chydoridae (22%). Moinidae, Bosminidae and Sididae were the less abundant family during this season as compared to other seasons.

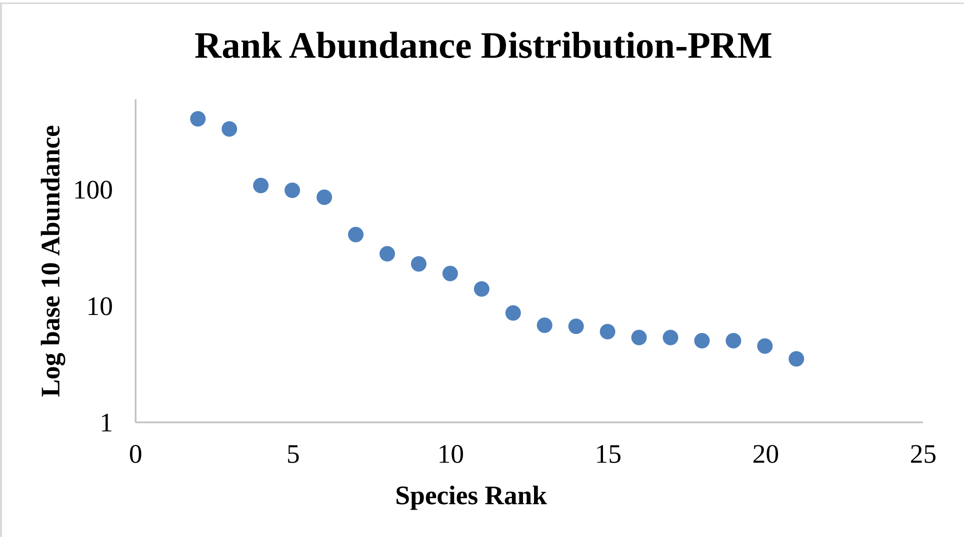


Figure 3.38. The Rank Abundance Curve of Cladocera of Thrissur Kole Wetland during Pre-monsoon Season Oct 2017- Sep 2019

Species	Relative Abundance (%)	Species Rank
B. deitersi	33	1
D. excisum	27	2

Species	Relative Abundance (%)	Species Rank
M. micrura	9	3
D. sarsi	8	4
C. cornuta	7	5
K. longirostris	3	6
O. singalensis	2.3	7
B. affinis	1.9	8
P. szalayi	1.6	9
Alonella sp.	1.2	10
M. triserialis	0.7	11
I. spinifer	0.6	12
M. goeldii	0.6	13
L. australis	0.5	14
C. barroisi	0.4	15
A. rectangula	0.4	16
A. monacantha	0.4	17
E. orientalis	0.4	18
S. acutirostratus	0.4	19
C. sphaericus	0.3	20
S. serrulatus	0	21

Table 3.44. The Rank Abundance Distribution of Cladocera of Thrissur Kole Wetland during Pre-monsoon Season Oct 2017- Sep 2019

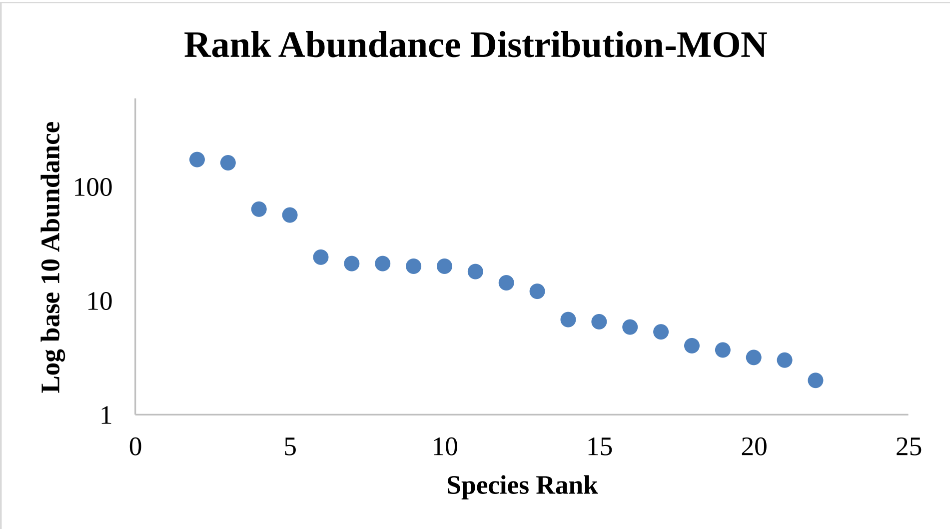


Figure 3.39. Rank Abundance Distribution Curve of Cladocera of Thrissur Kole Wetland during the Monsoon Season

Species	Relative Abundance %	Species Rank
D. excisum	36	1

Species	Relative Abundance %	Species Rank
B. deitersi	34	2
P. szalayi	13	3
M. micrura	12	4
E. orientalis	5	5
D. sarsi	4	6
C. cornuta	4	7
M. goeldii	4	8
I. spinifer	4	9
M. triserialis	3.8	10
O. singalensis	3.0	11
A. rectangula	2.5	12
C. sphaericus	1.4	13
S. acutirostratus	1.4	14
Alonella sp.	1.2	15
A. monacantha	1.1	16
K. longirostris	0.8	17
B. affinis	0.8	18
C. barroisi	0.7	19
L. australis	0.6	20
S. serrulatus	0.4	21

Table 3.45. The Rank Abundance of Cladocera of Thrissur Kole Wetland during the Monsoon Season Oct 2017- Sep 2019

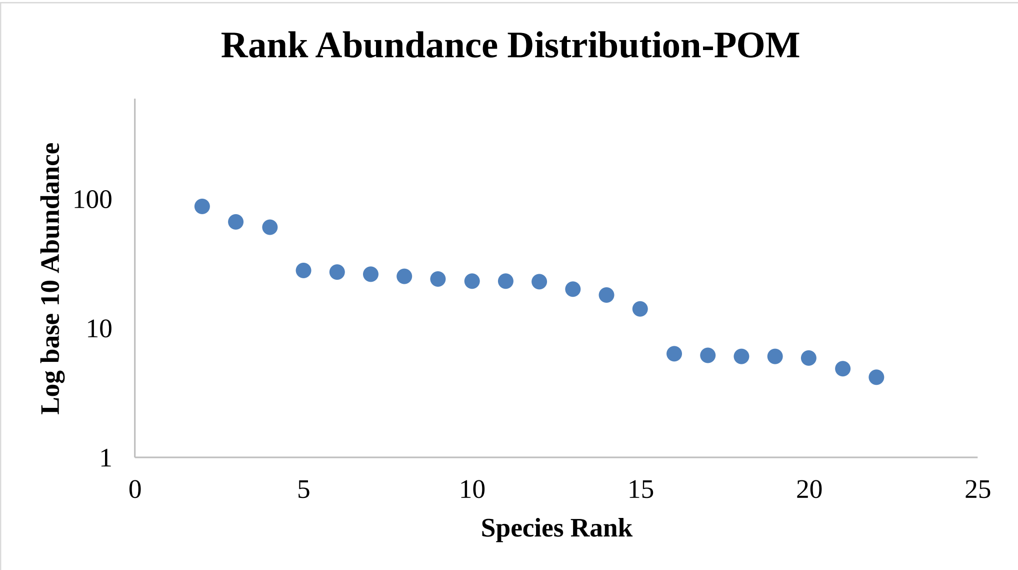


Figure 3.40. Rank Abundance Distribution Curve of Cladocera in the Post-monsoon Season Oct 2017- Sep 2019

Species	Relative Abundance (%)	Species Rank
M. triserialis	21	1
B. deitersi	16	2
S. serrulatus	14	3
D. excisum	7	4
D. sarsi	6	5
I. spinifer	6	6
L. australis	6	7
C. barroisi	6	8
C. sphaericus	6	9
A. monacantha	6	10
S. acutirostratus	5	11
M. goeldii	5	12
P. szalayi	4	13
E. orientalis	3	14
M. micrura	1.5	15
Alonella sp.	1.5	16
C. cornuta	1.4	17
B. affinis	1.4	18
A. rectangula	1.4	19
K. longirostris	1.2	20
O. singalensis	1.0	21

Table 3.46. Rank Abundance Distribution of Cladocera in the Post-monsoon Season Oct 2017- Sep 2019

3.4.3.3. Relationship with Environmental Parameters

3.4.3.3.1. Regression Analysis

Regression analysis was performed to discover the parameters that directly affect the Cladocera abundance and exclude indirectly related parameters from the equation. The Cladocera abundance showed normal distribution, the normal p-p plot is shown in Figure 3.40. The air temperature, total hardness and magnesium were the most influencing factors (statistically significant) (Table 3.47). Cladocera abundance showed a strong positive relationship with air temperature and magnesium and a negative correlation with total hardness.

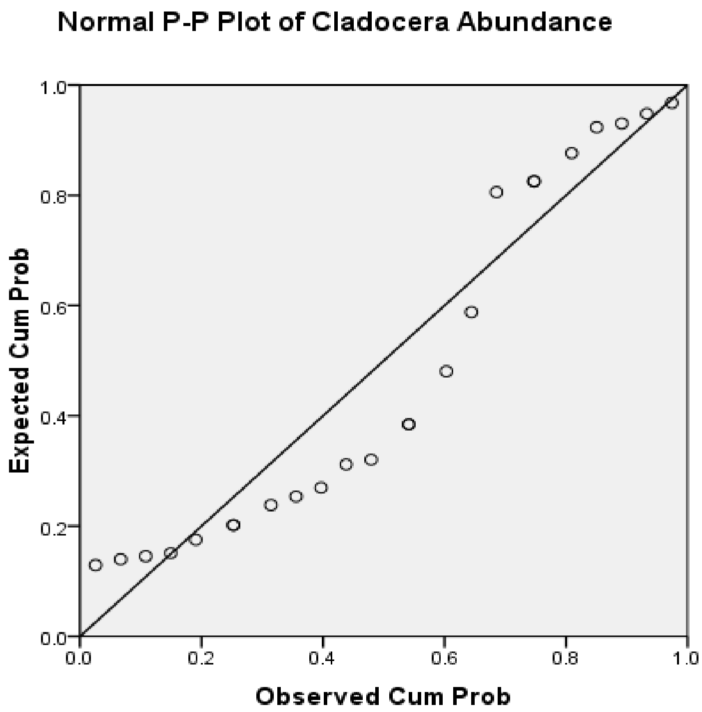


Figure 3.41. Normal p-p Plot of Cladocera Abundance

Model	Unstandardized Coefficients	Std. Error	Standardized Coefficients (Beta)	t	Sig.
(Constant)	-148.8004	58.567		-2.540	0.01946
Air temperature	8.8751	2.1891	0.5795	4.0542	0.00061
Total hardness	-0.8599	0.329	-0.3479	-2.6107	0.01673
Magnesium	8.3930	5.169	0.2305	1.6236	0.0120

Table 3.47. Regression Model for Cladocera Abundance

Thus the model is

$$\mathbf{Y_1 = -148.8+8.875X_1-0.8599X_2+8.393X_3}$$

Wherein,

Y1= Cladocera Abundance

X1= Air Temperature

X2= Total Hardness

X3= Magnesium

3.4.3.3.2. Canonical Correspondence Analysis

Canonical Correspondence Analysis (CCA) was used to integrate Cladocera abundance data with the physical and chemical parameters of the water, and the resulting biplot is presented in Figure 3.42. The permutation test was significant for all canonical axes ($p < 0.05$), indicating that the physical and chemical parameters of the water were linearly related to the number of Cladocera. Within the Canonical Correspondence Analysis eigenvector analysis, most of the inertia is carried by the first axis. The eigenvalue for CCA axis 1 (0.464) and axis 2 (0.098) explained a 85.3% species variation, of which Axis 1 represents 70.4% of the total variable (Table 3.48), the scree plot of the CCA analysis is illustrated in Figure 3.41. This means that the two-dimensional Canonical Correspondence Analysis map will be enough to analyze the relationships between the sampling months, the species and the variables.

Axis 1 was positively associated with water temperature, alkalinity, magnesium, nitrate and sulphate, and negatively associated with turbidity, total hardness and dissolved oxygen. Axis 2 was positively associated with iron, and negatively associated with electrical conductivity and BOD. *C. cornuta, M. micrura*, and *O. singalensis* were with strong positive association with axis 1, and *L. australis, S. serrulatus, S. acutirostratus, M. triserialis, M. goeldii, I. spinifer, C. sphaericus, C. barroisi* and *A. monacantha* showed strong negative association with axis 1. *P. szalayi, A. rectangula* and *E. orientalis* showed strong positive association with axis 2 and *B. affinis* and *K. longirostris* showed a strong negative association with axis 2. Axis 1 thus indicates trophic conditions, higher nitrate and lower dissolved oxygen made axis one a trophic gradient, and excess nitrates indicate excessive growth of plants and algae, creating unstable oxygen levels. Low oxygen levels are a result of high temperatures.

The CCA also showed the spatial order of the sampling months based on the environmental variables. The pre-monsoon months were located in the lower right quadrant, and monsoon months in the upper-right quadrant, opposite to the post-monsoon months (lower left quadrant). This explains the clear difference between the seasons. Pre-monsoon season showed a strong positive association with axis 1 (higher temperature, nitrate and lower DO), monsoon season showed a strong positive association with axis 2 (higher iron and DO, and low BOD) and the post-monsoon season exhibited a strong negative association with axis 1 (low temperature, nitrate and high DO).

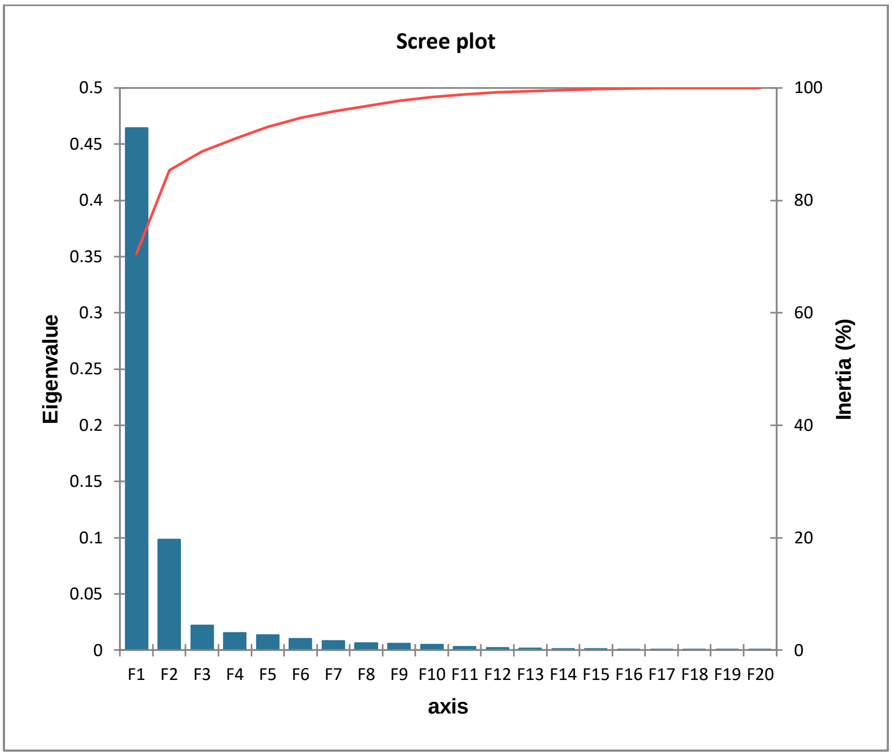


Figure 3.42. Scree Plots Represents the Eigenvalues for Each Component

	Eigen Value	Constrained Inertia (%)	Cumulative %	Total Inertia	Cumulative % (%)
F1	0.464	70.422	70.422	69.800	69.800
F2	0.098	14.913	85.335	14.781	84.581
F3	0.022	3.344	88.679	3.314	87.895
F4	0.015	2.330	91.008	2.309	90.204
F5	0.014	2.071	93.079	2.053	92.256
F6	0.010	1.541	94.620	1.527	93.784
F7	0.008	1.227	95.847	1.216	95.000
F8	0.006	0.941	96.788	0.933	95.932
F9	0.006	0.877	97.665	0.869	96.801
F10	0.005	0.730	98.395	0.723	97.525
F11	0.003	0.458	98.853	0.454	97.979
F12	0.002	0.352	99.205	0.349	98.328
F13	0.002	0.237	99.441	0.234	98.562
F14	0.001	0.195	99.637	0.194	98.756
F15	0.001	0.156	99.792	0.154	98.910
F16	0.001	0.095	99.887	0.094	99.004
F17	0.000	0.049	99.936	0.048	99.052
F18	0.000	0.033	99.968	0.032	99.085
F19	0.000	0.023	99.991	0.023	99.107
F20	0.000	0.009	100.000	0.009	99.116

Table 3.48. Eigenvalues and Percentages of Inertia (CCA)

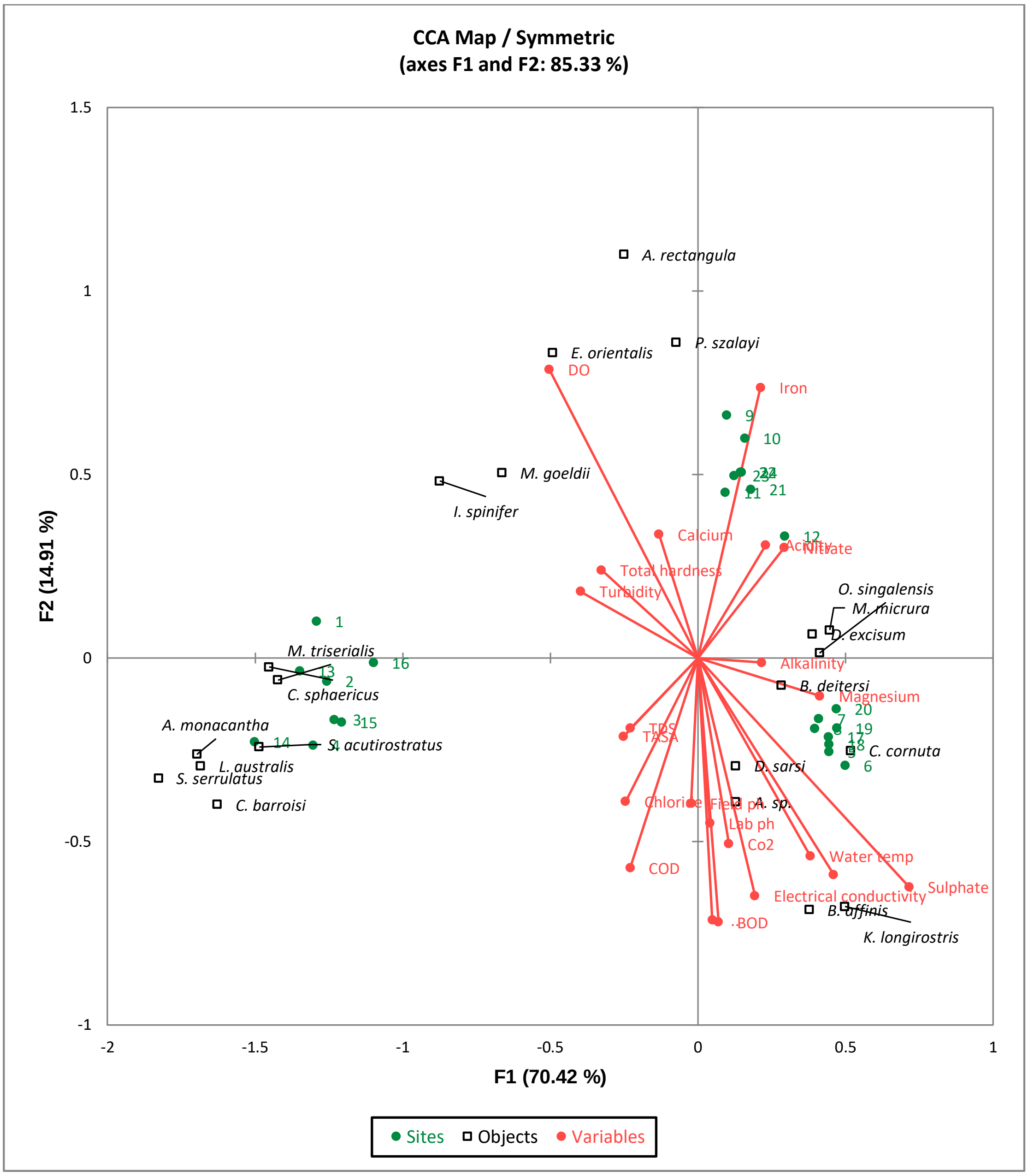


Figure 3.43. Ordination Diagram (CCA) of Descriptive Variables and Cladocera Community

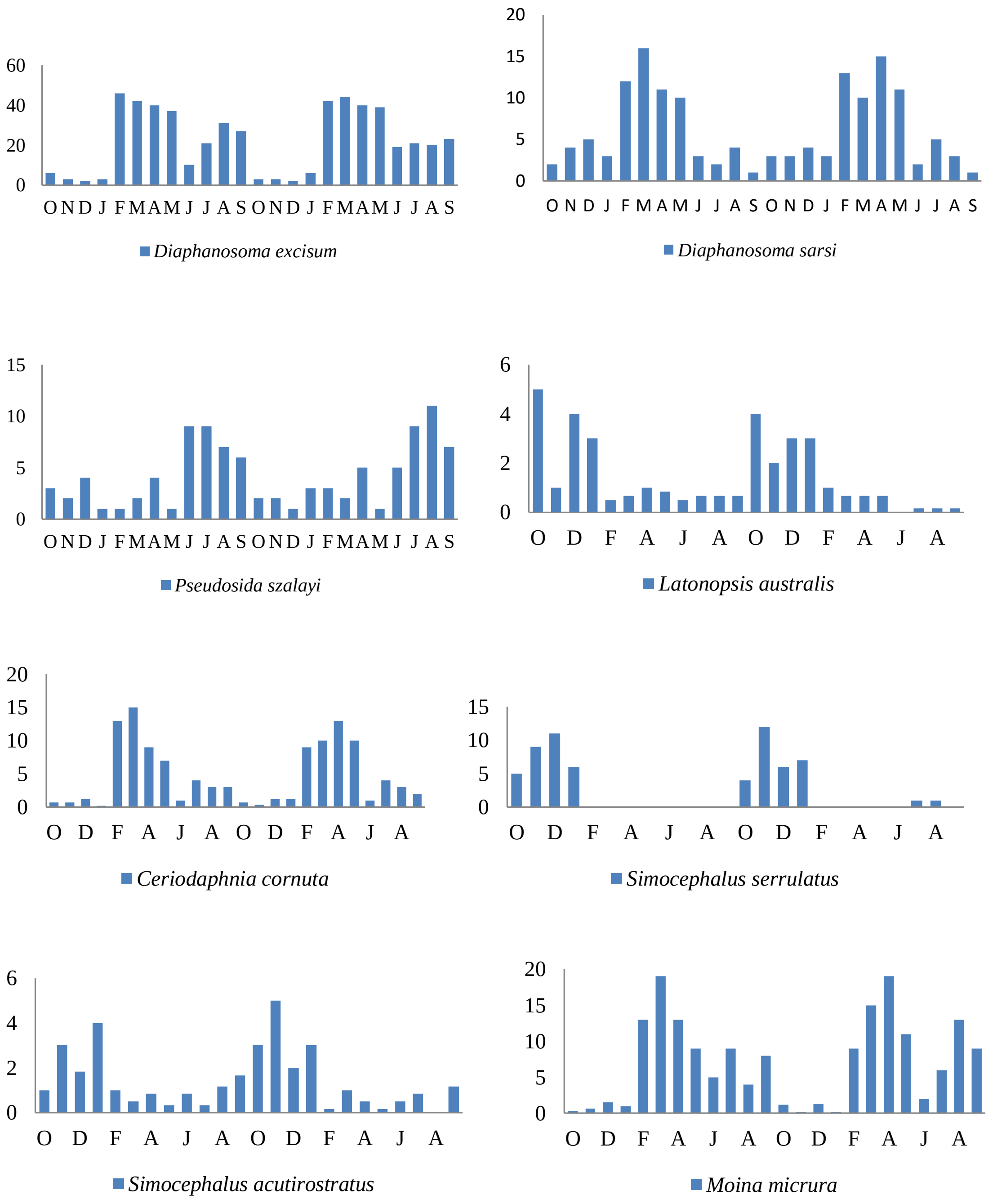


Figure: 3.44. Monthly variation in the Cladocera species of Thrissur Kole wetland, Oct 2017- Sep 2019 (SP:1 to SP:8)

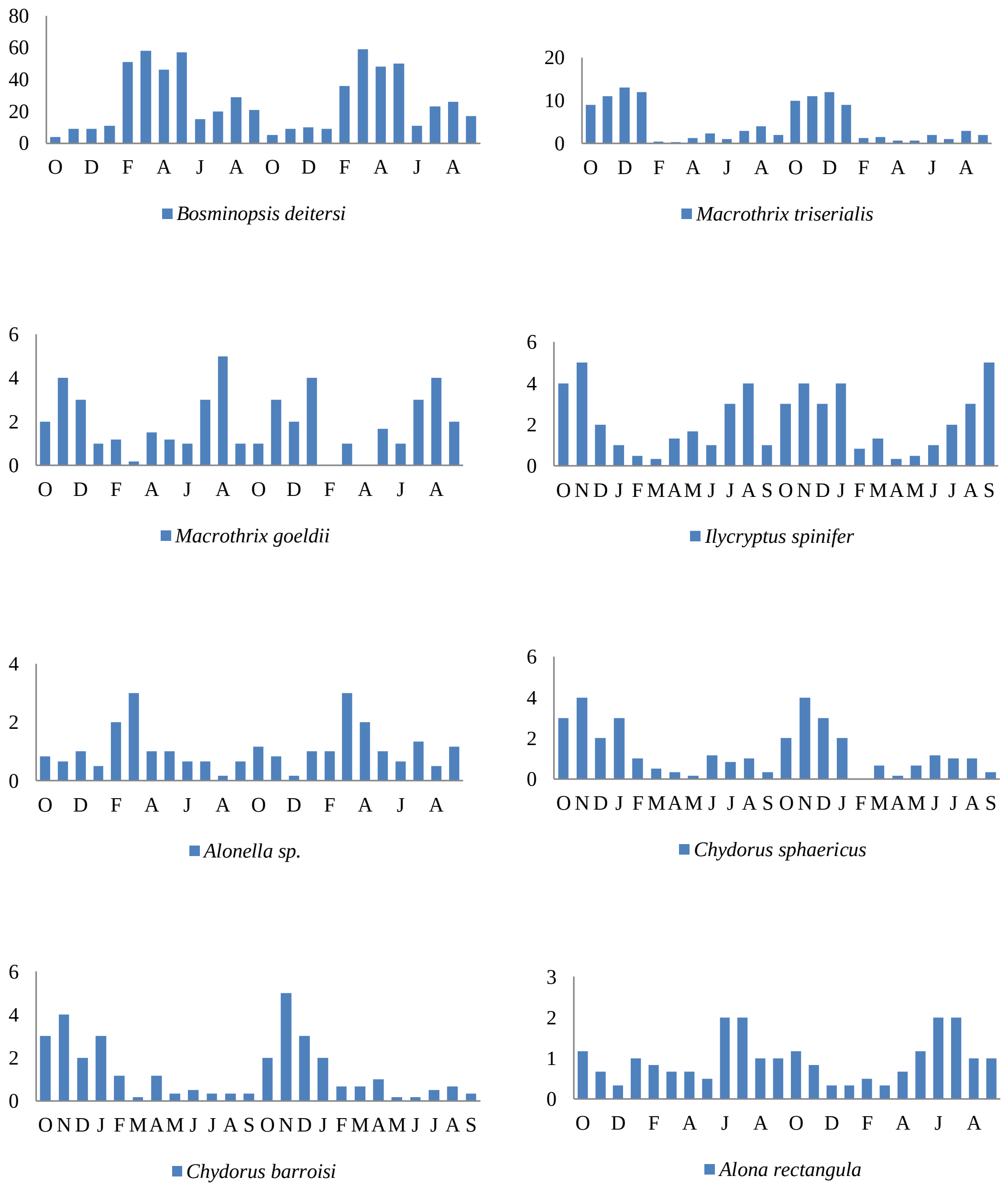


Figure: 3.45. Monthly variation in the Cladocera species of Thrissur Kole wetland, Oct 2017- Sep 2019 (SP:9 to SP:16) Cont.

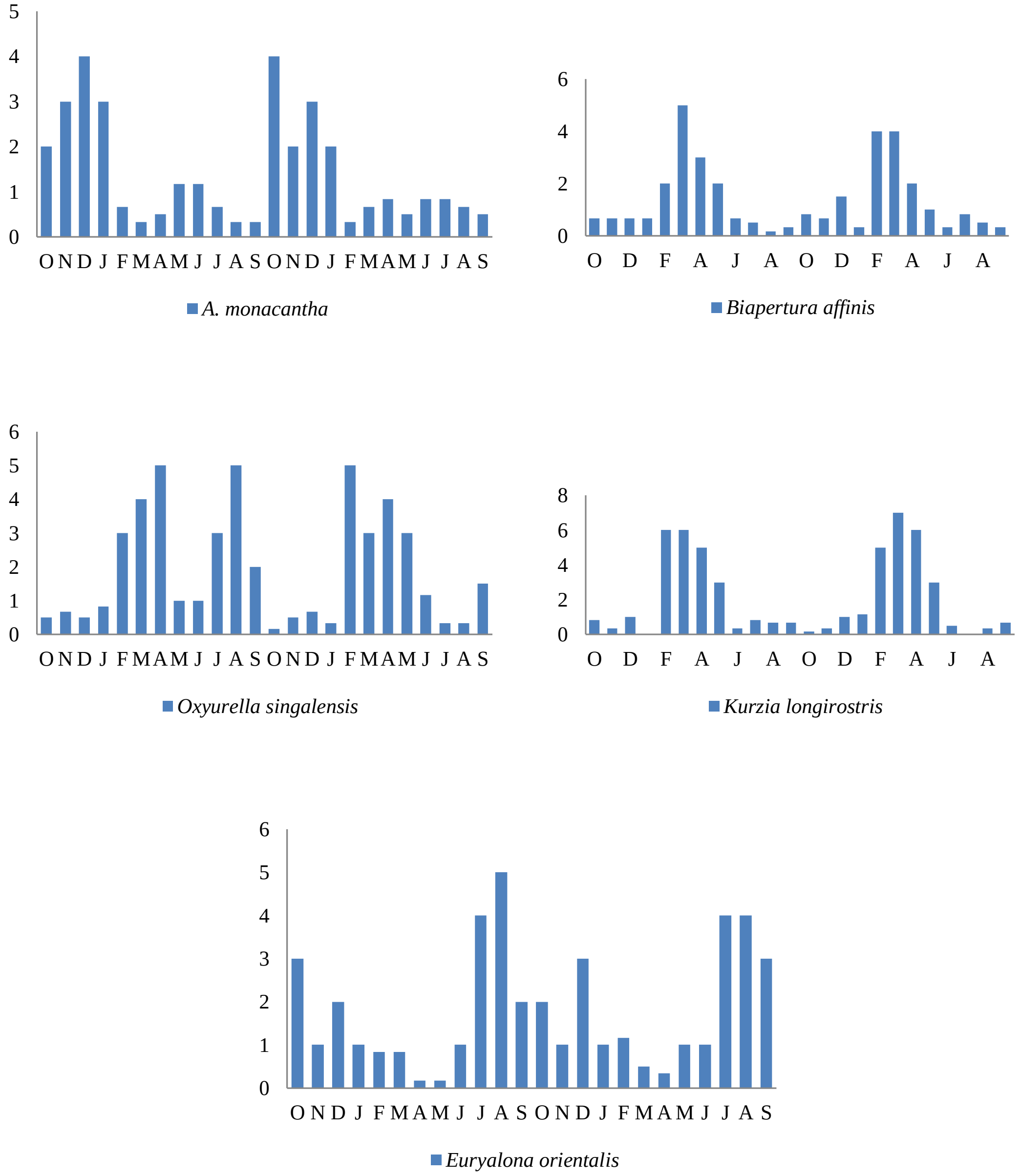


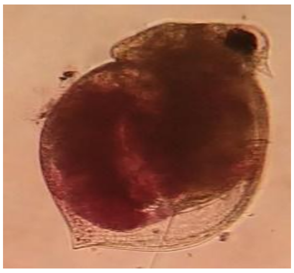
Figure: 3.46. Monthly variation in the Cladocera species of Thrissur Kole wetland, Oct 2017- Sep 2019 (SP:17 to SP:21) Cont.

Diaphanosoma excisum

Diaphanosoma sarsi

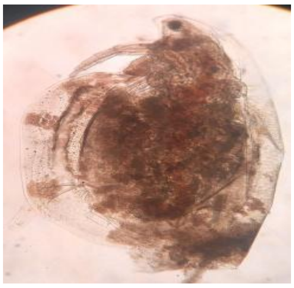
Pseudosida szalayi

Latonopsis australis



Ceriodaphnia cornuta

Simocephalus serrulatus

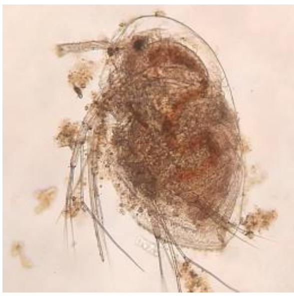


Simocephalus acutirostratus

Moina micrura

Bosminopsis deitersi

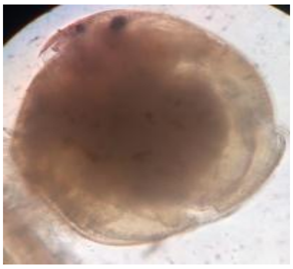
Macrothrix triserialis



Macrothrix goeldii

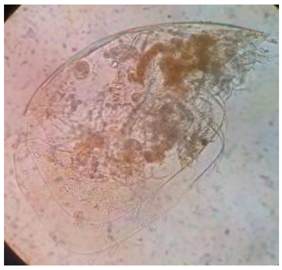
Ilyocryptus spinifer

Figure 3.47. Images of Cladocera Species Identified during the Study Period (SP:1 to SP:12)



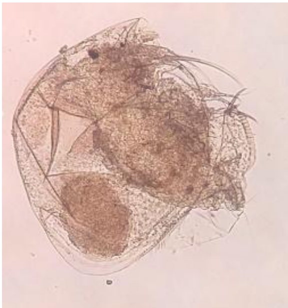
Chydorus sphaericus

Chydorus barroisi



Alona rectangula

A. monamcantha



Biapertura affinis

Oxyurella singalensis

Kurzia longirostris

Euryalona orientalis

Figure 3.48. Images of Cladocera Species Identified during the Study Period (SP:13 to SP:20) Cont.

3.4.4. Copepoda

3.4.4.1. Diversity

Compared to Rotifera and Cladocera, the diversity of Copepoda in the Thrissur Kole wetland was very less. From October 2017 to September 2019, 10 species belonging to eight genera, two families and two orders were identified. Order Calanoida contains three species and Cyclopoida 7 species, with each order representing only one family, Diaptomidae and Cyclopidae respectively. The seasonal occurrence of the Copepoda of the Thrissur Kole wetland is shown in Table 3.49. The diversity of Copepoda of Thrissur Kole wetland varies from season to season (Table 3.50). Of the ten species identified, five species were found in all seasons. *E. serrulatus* and *E. rubescens* were found in two seasons, with the similar seasonal distribution. *Neodiaptomus sp.* and *T. crassus* found only in the monsoon season, and *M. rubellus* in the post-monsoon season.

The Copepoda diversity and evenness were higher in the post-monsoon season (H= 2.0647, D= 0.8509, E= 0.4749), followed by the monsoon (H= 1.5603, D= 0.7216, E= 0.2765) and lowest in the pre-monsoon season (H = 1.2699, D = 0.6025, E = 0.2125). Cyclopoida were the most diverse order (H=1.77683, D= 0.8046) than the order Calanoida (H= 0.80743, D= 0.5187). Species evenness was also greater in Cyclopoida (E = 0.3482) than in Calanoida (E = 0.1265). Of the ten species identified, only two genera contained more than one species, and the other had only one species, so diversity index calculations were possible only in these two genera *mesocyclops* and *microcyclops*. The diversity indices of these two genera are given in Table 3.51. Species diversity and similarity were found more in *mesocyclops* than in *microcyclops*.

3.4.4.1.1. Pre-monsoon Season

During the pre-monsoon season, seven species (two species of Calanoida and five species of Cyclopoida) belonging to 6 genera and two families were identified. All genera except the genus *mesocyclops* of Cyclopoida contain only one species so that it was impossible for other species to calculate the diversity index. The genus

Mesocyclops was the most diverse genus (H = 0.6876, D = 0.4944, E = 0.2335). The number of species was similar in the pre-monsoon period of the two sampling years, the difference in the diversity index value was due to the difference in abundance. The annual variation in the Copepoda diversity of the pre-monsoon season is shown in Table 3.52. The species diversity and evenness was greater in the second year than in the first, and the Cyclopoida was more diverse than the Calanoida.

3.4.4.1.2. Monsoon Season

Seven species belonging to 6 genera and two families were identified during the monsoon season. *Neodiaptomus sp.* and *T. crassus* were found only during this season. The genus Mesocyclops showed more diversity and evenness (H = 0.503, D = 0.334, E = 0.1359), and other genera contained only one species. There was no difference in the number of species between the monsoon seasons of the two sampling years, but the difference was in the diversity index because of the difference in the abundance of the species. Table 3.53., shows the variation in the diversity indices between the monsoon seasons of the two sampling years. The diversity and evenness were higher in the first year than in the second. Order Calanoida was more diverse than Cyclopoida.

3.4.4.1.3. Post-monsoon Season

During the post-monsoon season, eight species belonging to six genera and two families were identified. It includes two species of Calanoida and six species of Cyclopoida. The diversity and evenness of the species in the Cyclopoida order was greater than that of the Calanoida. All species, except *microcyclops* and *mesocyclops*, contain only one species. *Microcyclops rubellus* was found only in the post-monsoon season. The diversity indices of the Copepod genera containing more than one species are shown in Table 3.54. The *Mesocyclops* showed more species diversity and evenness (H = 0.6813, D = 0.4882, E = 0.2656) than *microcyclops* (H = 0.5127, D = 0.3106, E = 0.1878). The difference in Copepoda diversity in the post-monsoon of the two sampling years is given in Table 3.55. The number of species was similar in the post-monsoon seasons of the two sampling years, but there was a slight difference in the diversity index due to the difference in abundance. The post-monsoon season of the first sampling years was more diverse and even than the second.

Order	Family	Species	PRM	MON	POM
Calanoida	**Diaptomidae**	*Heliodiaptomus cinctus* Gurney, 1907.	+	+	+
		Allodiaptomus mirabilipes Kiefer, 1936.	+	+	+
		Neodiaptomus sp.	-	+	-
Cyclopoida	**Cyclopidae**	*Eucyclops serrulatus* Fischer, 1851.	+	-	+
		Mesocyclops leuckarti Claus, 1857.	+	+	+
		Mesocyclops ogunnus Onabamiro, 1957.	+	+	+
		Microcyclops varicans Reid, 1992.	+	+	+
		Microcyclops rubellus Lilljeborg, 1901.	-	-	+
		Ectocyclops rubescens Brady, 1904.	+	-	+
		Thermocyclops crassus Fischer, 1853.	-	+	-

Table 3.49. Seasonal Distribution of Copepoda of Thrissur Kole Wetland, Oct 2017- Sep 2019

Period	Group	Number of Species	Number of Genera	Number of Families	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)
Whole Study Period	**Total**	10	8	2	1.5433	0.6965	0.2329
	Calanoid	3	3	1	0.80743	0.5187	0.1265
	Cyclopoid	7	5	1	1.77683	0.8046	0.3482
PRM	**Total**	7	6	2	1.2699	0.6025	0.2125
	Calanoid	2	2	1	0.6695	0.4503	0.1153
	Cyclopoid	5	4	1	1.75881	0.811837	0.4276
MON	**Total**	7	6	2	1.5603	0.7216	0.2765
	Calanoid	3	3	1	0.90116	0.7375	0.1671
	Cyclopoid	4	3	1	0.6592	0.9841	0.1593
POM	**Total**	8	6	2	2.0647	0.8509	0.4749
	Calanoid	2	2	1	0.90381	0.572234	0.25093
	Cyclopoid	6	4	1	1.78922	0.819349	0.48313

Table 3.50. Seasonal Variation in the Diversity Indices of Copepoda of Thrissur Kole Wetland

Genera	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)
Microcyclops	0.4711	0.2907	0.1236
Mesocyclops	0.6163	0.4306	0.14389

Table 3.51. Diversity Indices of Copepoda Genera of Thrissur Kole Wetland Oct 2017- Sep 2019

Group	Shannon Index (H)		Simpson's Index (D)		Evenness Index (E)	
	PRM1	PRM2	PRM1	PRM2	PRM1	PRM2
Total	1.24506	1.29394	0.594217	0.611124	0.2344	0.2463
Calanoida	0.66856	0.67049	0.449443	0.451328	0.129784	0.1321
Cyclopoida	1.74056	1.76576	0.809801	0.81075	0.51231	0.5129

Table 3.52. The Annual Variation in the Copepoda Diversity during Pre-monsoon Season

Group	Shannon Index (H)		Simpson's Index (D)		Evenness Index (E)	
	MON1	MON2	MON1	MON2	MON1	MON2
Total	1.5873	1.53	0.7285	0.7145	0.3200	0.31
Calanoida	0.9119	0.903	0.5718	0.5644	0.1942	0.1921
Cyclopoida	1.492	1.416	0.693	0.668	0.4266	0.4176

Table 3.53. The Annual Variation in the Copepoda Diversity during Monsoon Season

Genera	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)
Microcyclops	0.5128	0.3106	0.1878
Mesocyclops	0.6813	0.4882	0.2656

Table 3.54. Diversity of Copepoda Genera of Thrissur Kole Wetland during Post-monsoon Season

Group	Shannon Index (H)		Simpson's Index (D)		Evenness Index (E)	
	POM1	POM2	POM1	POM2	POM1	POM2
Total	2.0502	2.0725	0.8462	0.8545	0.5589	0.5694
Calanoida	0.9194	0.883	0.5887	0.5513	0.3091	0.3111
Cyclopoida	1.779	1.7923	0.8216	0.8158	0.5982	0.5887

Table 3.55. The Annual Variation in the Copepoda Diversity during Post-monsoon Season

3.4.4.2. Abundance

The relative abundance of Copepoda in different seasons is shown in Table 3.56. The Calanoid Copepod (78%) was more abundant than the Cyclopoid. Copepod abundance was highest in the pre-monsoon season (52%), followed by the monsoon (37%) and the lowest in the post-monsoon season (10%). Rank Abundance Distribution of Copepoda of Thrissur Kole wetland is shown in the Table 3.57., and Rank Abundance Curve in Figure 3.48. Calanoid was the dominant group accounting for 76% of the total with *H. cinctus* being the most dominant species (45%), followed by *A. mirabilipes* (31%). *T. crassus* and *M. rubellus* were the less abundant species.

	Copepod (%)	Calanoid Copepod (%)	Cyclopoid Copepod (%)
PRM	52	56	37
MON	38	37	38
POM	10	6	25
PRM1	27	29	18
PRM2	25	27	19
MON1	19	19	20
MON2	19	19	18
POM1	5	3	12
POM2	5	3	13

Table 3.56. Seasonal Variation in the Abundance of Copepoda of Thrissur Kole Wetland

Species	Relative Abundance	Species Rank
Heliodiaptomus cinctus	45	1
Allodiaptomus mirabilipes	31	2
Mesocyclops ogunnus	7	3
Microcyclops varicans	5	4
Mesocyclops leuckarti	3	5
Neodiaptomus sp.	3	6
Eucyclops serrulatus	3	7
Ectocyclops rubescens	2	8
Thermocyclops crassus	1	9
Microcyclops rubellus	1	10

Table 3.57. Rank Abundance Distribution of Copepoda of Thrissur Kole Wetland during Oct 2017- Sep 2019

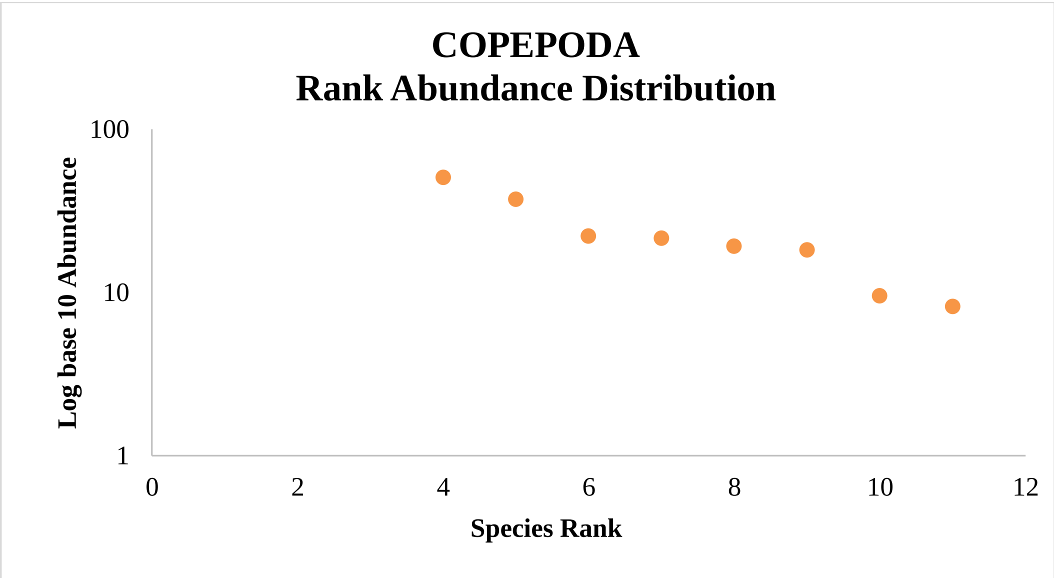


Figure 3.49. Rank Abundance Distribution Curve of Copepoda of Thrissur Kole Wetland during Oct 2017- Sep 2019

3.4.4.2.1. Pre-monsoon Season

Copepod abundance was highest in the pre-monsoon period (52%), accounting for 84% Calanoida and 16% Cyclopoida. The Rank Abundance Distribution of

Copepod during the pre-monsoon season is shown in the Table 3.58., and Rank Abundance Curve in Figure 3.49. Again, *H. cinctus* was the most abundant species, *M. leuckarti* was less. There was only a slight difference in pre-monsoon Copepod abundance between sampling years, with 2% more abundance in the first year than in the second year.

Species	Relative Abundance	Species Rank
Heliodiaptomus cinctus	57	1
Allodiaptomus mirabilipes	28	2
Microcyclops varicans	4	3
Eucyclops serrulatus	3	4
Ectocyclops rubescens	3	5
Mesocyclops ogunnus	3	6
Mesocyclops leuckarti	2	7
Microcyclops rubellus	0	8
Neodiaptomus sp.	0	9
Thermocyclops crassus	0	10

Table 3.58. The Rank Abundance Distribution of the Copepod during the Pre-monsoon Season

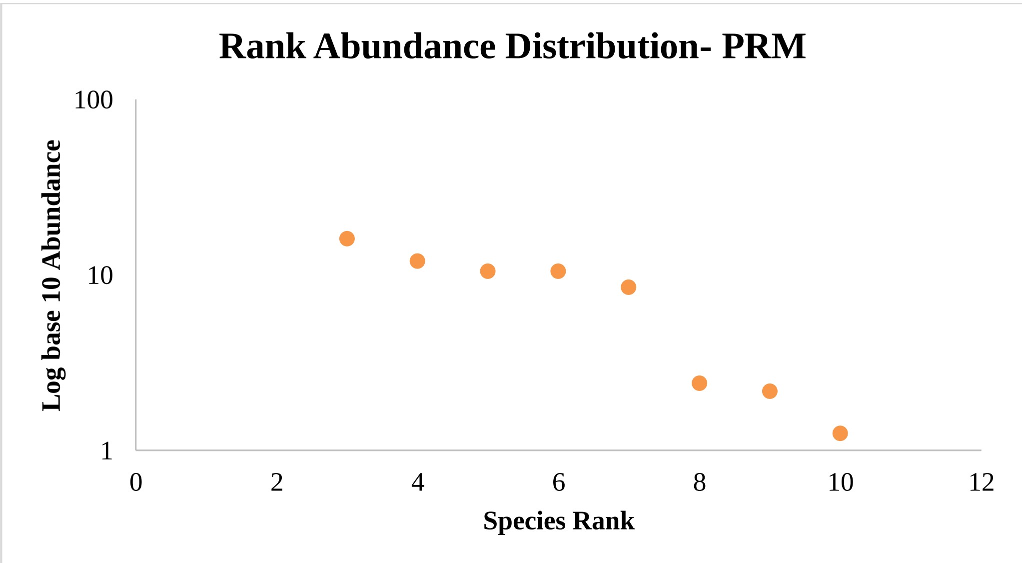


Figure 3.50. The Rank Abundance Distribution Curve of the Copepod during the Pre-monsoon Season

3.4.4.2.2. Monsoon Season

The Copepoda abundance during the monsoon season constituted 37% of the total, accounting for 78% Calanoida and 22% Cyclopoida. The Rank Abundance Distribution of Copepoda during the monsoon season is given in Table 3.59. and Rank Abundance Curve in Figure 3.50. *A. mirabilipes* and *H. cinctus* were the most abundant species, and *T. crassus* less abundant.

Species	Relative Abundance	Species Rank
Allodiaptomus mirabilipes	37	1
Heliodiaptomus cinctus	35	2
Mesocyclops ogunnus	12	3
Neodiaptomus sp.	6	4
Microcyclops varicans	3	5
Mesocyclops leuckarti	3	6
Thermocyclops crassus	2	7
Microcyclops rubellus	0	8
Ectocyclops rubescens	0	9
Eucyclops serrulatus	0	10

Table 3.59. Rank Abundance Distribution of Copepoda of Thrissur Kole Wetland during Monsoon Season

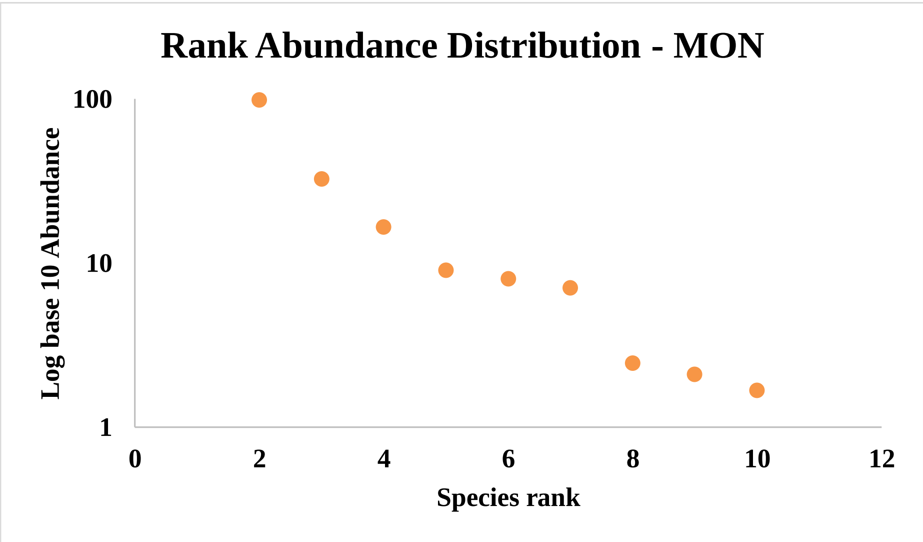


Figure 3.51. Rank Abundance Distribution Curve of Copepoda of Thrissur Kole Wetland during Monsoon Season

3.4.4.2.3. Post-monsoon Season

The post-monsoon abundance was 10%, of which the relatively abundant Calanoida and Cyclopoida constituted 47% and 53% respectively. The difference in the abundance of Cyclopoida compared to other seasons was small, and the abundance of Cyclopoids was greater than that of Calanoid. Rank Abundance Distribution of Copepoda species in the post-monsoon period is shown in Table 3.60. and the Rank Abundance Curve in Figure 3.51. *A. mirabilipes* and *H. cinctus* were the most common species, 23% and 21% respectively. The abundance of *M. varicans* (15%) was very low. There was no annual difference in the total Copepod abundance between the post-monsoon seasons. The abundance of Calanoid and Cyclopoid was similar in the first year, and in the second year the Cyclopoid was 10% higher than that of the Calanoid.

Species	Relative Abundance	Species Rank
Allodiaptomus mirabilipes	23	1
Heliodiaptomus cinctus	21	2
Microcyclops varicans	15	3
Mesocyclops ogunnus	10	4
Eucyclops serrulatus	8	5
Ectocyclops rubescens	8	6
Mesocyclops leuckarti	8	7
Microcyclops rubellus	4	8
Neodiaptomus sp.	0	9
Thermocyclops crassus	0	10

Table 3.60. Rank Abundance Distribution of Copepoda during the Post-monsoon Season

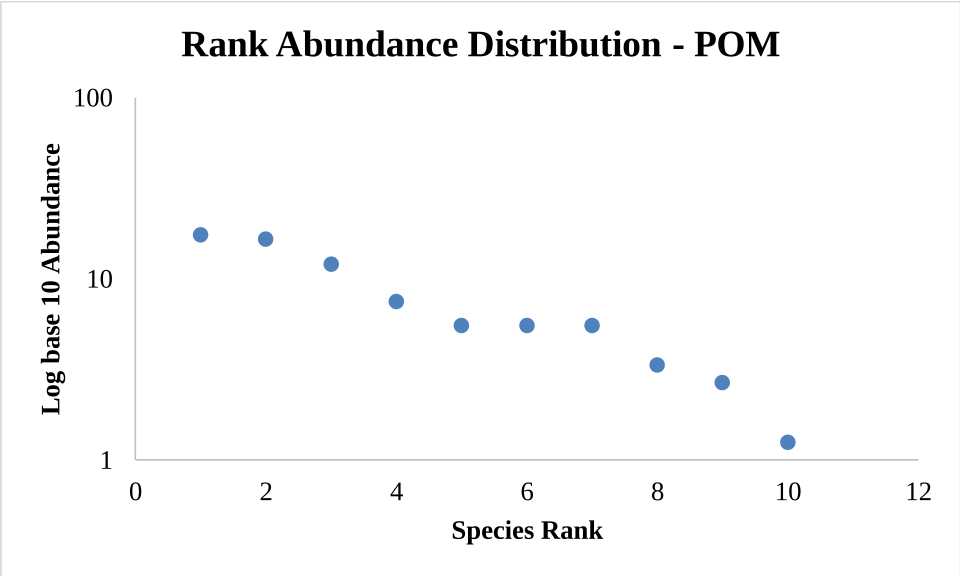


Figure 3.52. Rank Abundance Distribution Curve of Copepoda during the Post-monsoon Season

3.4.4.3. Relationship with Environmental Parameters

3.4.4.3.1. Regression Analysis

Regression Analysis was performed to discover the parameters that directly affected the Copepod species abundance and to exclude indirectly related parameters from the equation. The Copepod abundance showed normal distribution, normal p-p plot is shown in Figure 3.52. The total hardness and air temperature were the most influencing variables (statistically significant) on Copepod abundance (Table 3.61). Copepoda abundance showed a strong positive relationship with air temperature and a negative correlation with total hardness. That means the air temperature and total hardness were the two variables that directly influenced the Copepoda abundance.

Model	Unstandardized Coefficients	Std. Error	Standardized Coefficients (Beta)	t	Sig.
(Constant)	-36.534	32.206		-1.134	0.269
Air Temperature	3.021	1.123	0.463	2.691	0.014
Total Hardness	-0.382	0.181	-0.363	-2.107	0.047

Table 3.61. Regression Model for Copepod Abundance

Stepwise Regression Equation:

$$\mathbf{Y_3 = -36.534+3.02*X_6-0.38X_7}$$

Wherein,

Y3= Copepoda Abundance

X6= Air Temperature

X7= Total Hardness

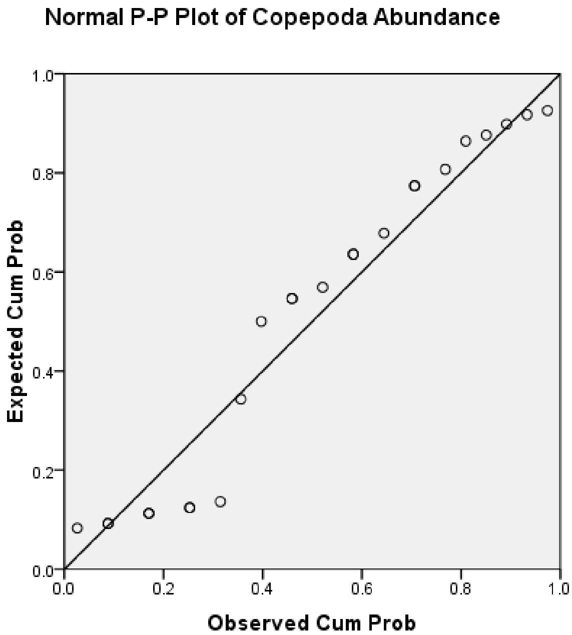


Figure 3.53. Normal p-p Plot of Copepod Abundance

3.4.4.3.2. Canonical Correspondence Analysis

Canonical Correspondence Analysis (CCA) was used to integrate Copepod abundance data with water's physical and chemical parameters, and the resulting biplot is presented in Figure 3.54. The Monte-Carlo permutation test was not significant for all canonical axes ($p > 0.05$), indicating the nonlinear relationship of Copepoda with its environmental variables. Within the Canonical Correspondence Analysis eigenvector analysis, most of the inertia is carried by the first axis. The eigenvalue for CCA axis 1 (0.148) and axis 2 (0.109) explained a 77.7% species variation, of which Axis 1 represents 44.7% of the total variable (Table 3.62), the scree plot of the CCA analysis is illustrated in Figure 3.53 This means that the two-dimensional Canonical Correspondence Analysis map was enough to analyze the relationship between the month, the species and the variables.

Axis 1 was positively associated with iron and negatively associated with BOD and COD. Axis 2 was positively associated with DO and negatively associated with water temperature and BOD. *Neodiaptomus sp. and T. crassus* exhibited strong positive association with axis 1, and *E. serrulatus*, *E. rubescens*, *M. varicans and M. rubellus* displayed strong negative association. *M. leuckarti*, *M. ogunnus* and *T. crassus* showed strong positive association with axis 2 and *H. cinctus* was negatively associated.

The CCA also showed the spatial order of the sampling months based on the environmental variables. The pre-monsoon months were located in the lower-left quadrant opposite to the monsoon months (upper-right quadrant), and post-monsoon months in the (upper left quadrant.) This explains the clear difference between the seasons. Pre-monsoon season showed strong negative association with axis 2 (higher temperature and BOD, lower DO), monsoon season showed strong positive association with axis 1 (higher iron and lower BOD and COD) and the post-monsoon season showed strong negative association with axis 1 and strong positive association with axis 2 (higher DO and COD, lower iron and temperature).

	Eigenvalue	**Constrained Inertia (%)**	**Cumulative %**	**Total Inertia**	**Cumulative % (%)**
F1	0.148	44.649	44.649	44.114	44.114
F2	0.109	33.001	77.650	32.605	76.720
F3	0.034	10.266	87.917	10.143	86.863
F4	0.022	6.779	94.696	6.698	93.561
F5	0.006	1.731	96.427	1.710	95.271
F6	0.005	1.383	97.810	1.366	96.637
F7	0.004	1.136	98.945	1.122	97.760
F8	0.003	0.836	99.782	0.826	98.586
F9	0.001	0.218	100.000	0.216	98.801

Table 3.62. Eigenvalues and Percentages of Inertia (CCA)

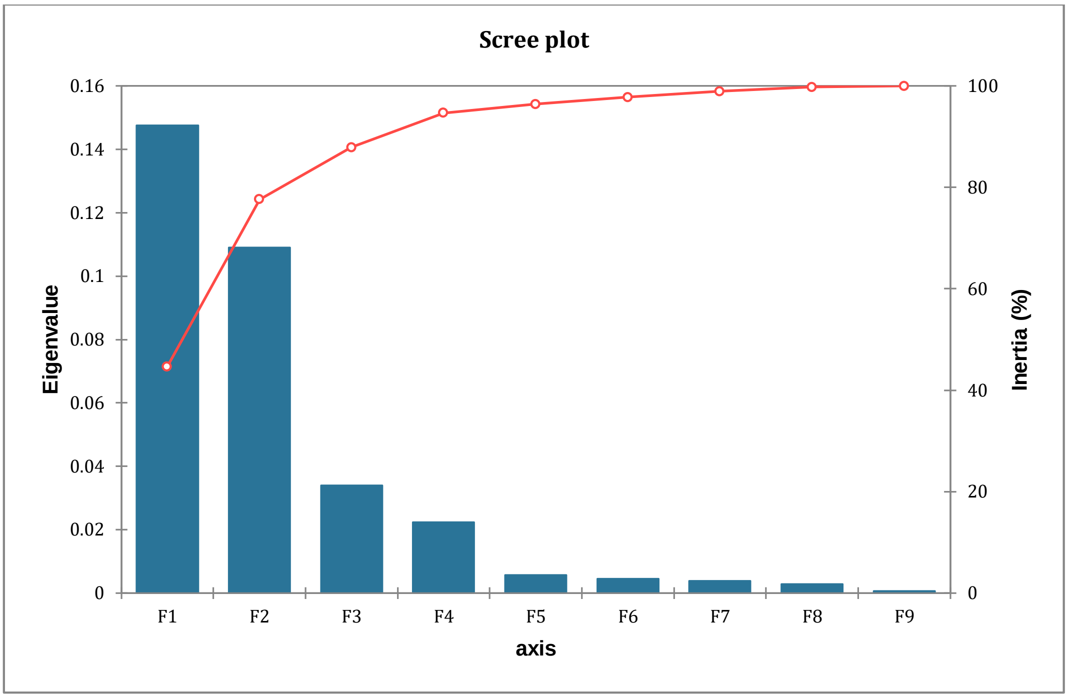


Figure 3.54. The Scree Plot Represents the Eigenvalues for Each Component

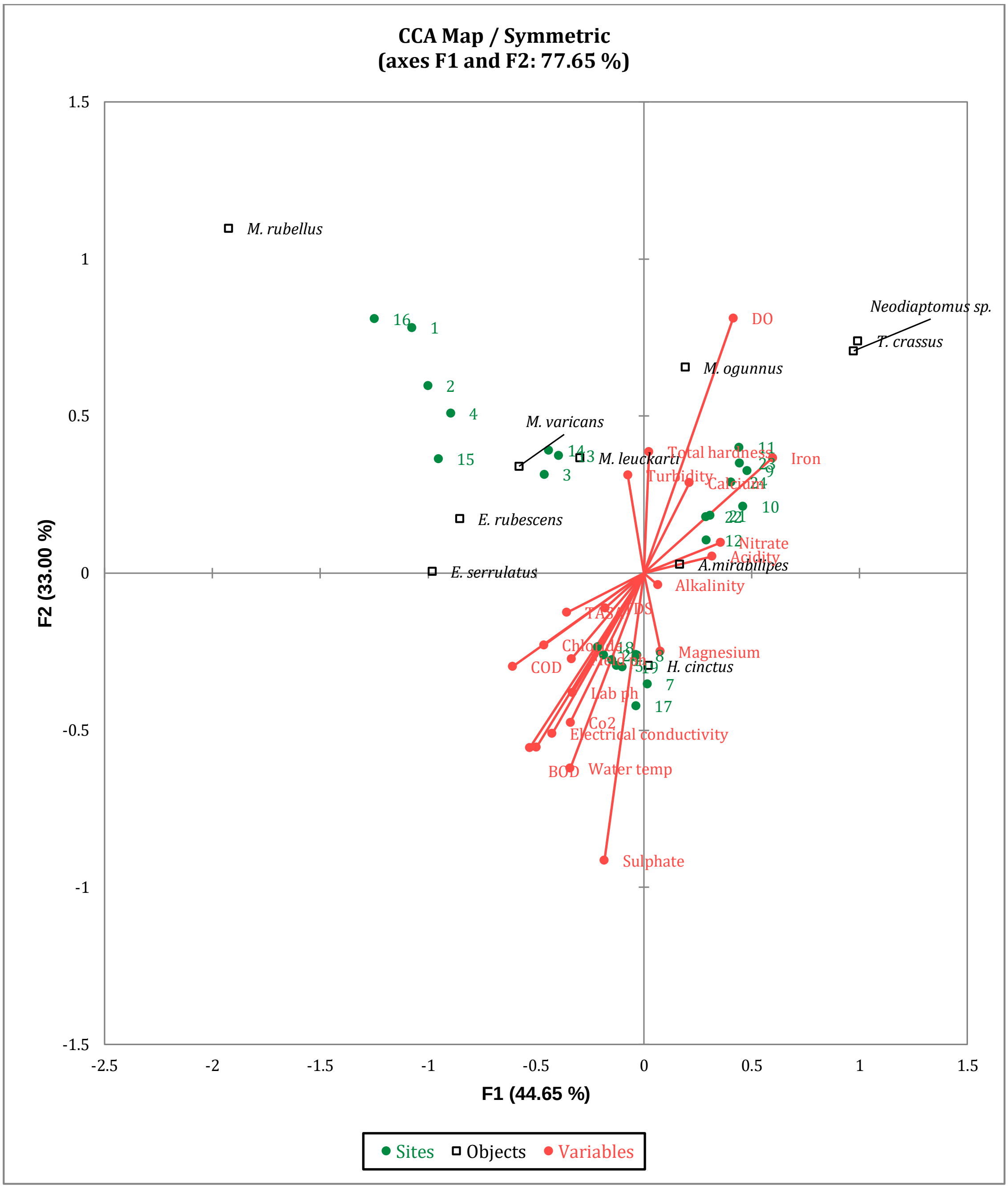


Figure 3.55. Ordination Diagram (CCA) of Descriptive Variables and Copepod Community

H. cinctus (male)

H. cinctus (female)

A. mirabilipes (male)

A. mirabilipe (female)

Neodiaptomus sp.

M. varicans

E. serrulatus

E. rubescens

M. rubellus

M. leuckarti

M. ogunnus

T. crassus

Figure 3.56. Images of Copepod Species Identified during the Study Period

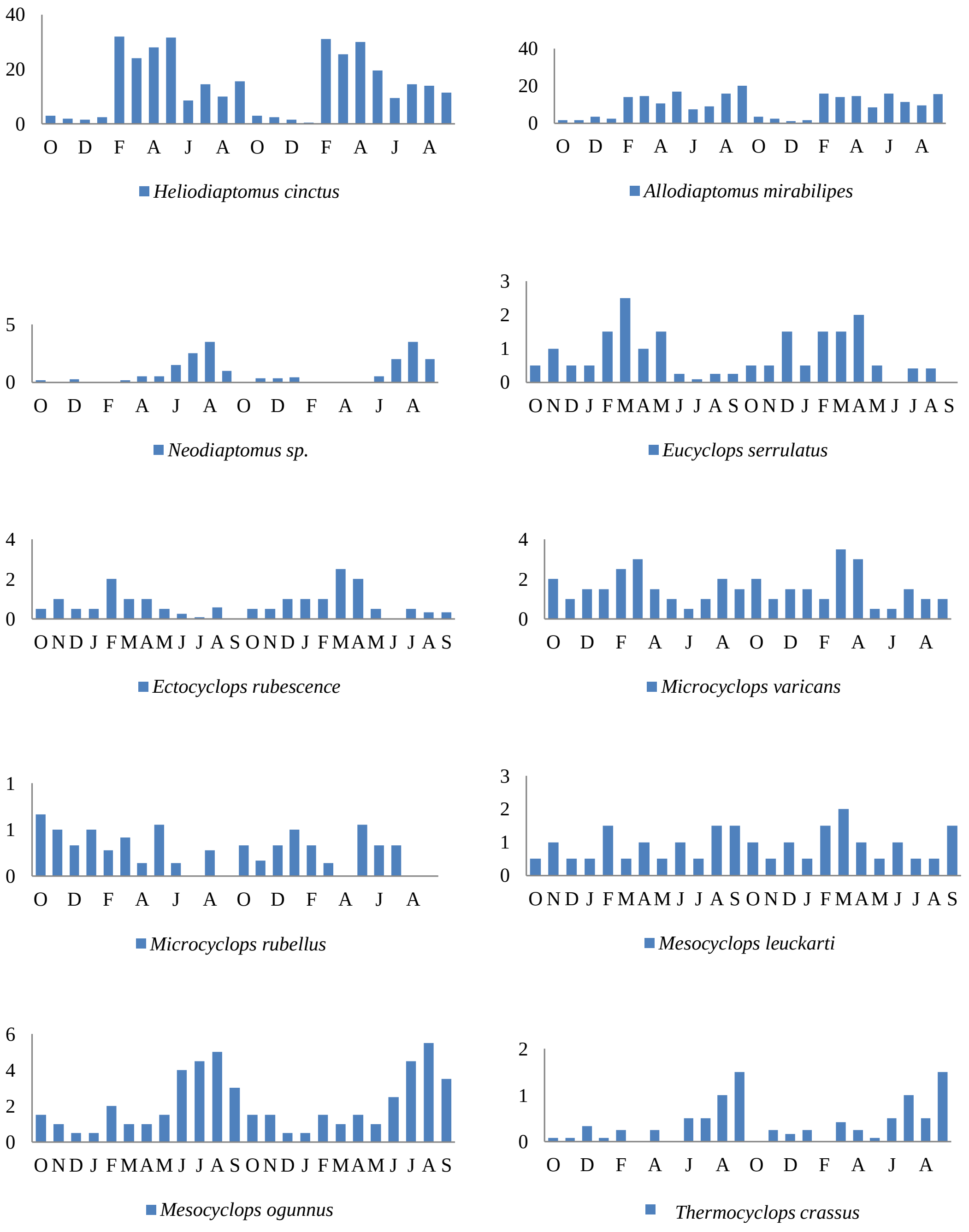


Figure 3.57. Monthly Variations in Copepod Species Abundance of Thrissur Kole Wetland Oct 2017- Sep 2019

3.4.5. Ostracoda

3.4.5.1. Diversity

Ostracoda was not a diverse group compared to Rotifera and Cladocera in the Thrissur Kole wetland, but they were more diverse than the Copepoda. Systematic list and the seasonal occurrence of Ostracoda of Thrissur Kole wetland is shown in Table 3.63. Six species belonging to six genera and two families were identified. Of these, five species belong to the family Cyprididae and one species to the family Ilyocyprididae.

3.4.5.1.1. Seasonal Variation

The Ostracoda diversity showed seasonal variations, with no Ostracoda in the pre-monsoon season. Four and five species of Ostracoda were identified during the monsoon and post-monsoon seasons respectively. Of the two families in the Ostracoda, the family Ilyocyprididae was found only during the monsoon season. Two Ostracoda species, *C. cingalensis* and *S. sewelli* were found only in the post-monsoon season. Seasonal variation in the diversity indices is shown in Table 3.64. During the monsoon season (H = 1.5006, D = 0.7528, E = 0.0801) diversity and evenness were high, followed by post-monsoon (H = 1.3133, D = 0.6607, E = 0.0209). Annual variation in Ostracoda diversity and evenness was shown in Table 4.35. There was a slight annual difference in the Ostracoda diversity. Diversity and evenness were higher in the first monsoon season than in the second. Similarly, the second post-monsoon season was more diverse than the first.

Family	Species	PRM	MON	POM
Cyprididae	*Cyprinotus cingalensis* Brady, 1886	-	-	+
	Stenocypris sewelli Klie, 1927	-	-	+
	Strandesia flavescens Klie, 1932	-	+	+
	Cypreta fontinalis Hartman, 1964	-	+	+
	Eucypris sp.	-	+	+
Ilyocyprididae	*Indiacypris dispar* Hartman, 1964	-	+	-

Table 3.63. Seasonal Occurrence of Ostracoda of Thrissur Kole Wetland Oct 2017- Sep 2019

Period	Number of Species	Number of Genera	Number of Families	Shannon Index (H)	Simpson's Index (D)	Evenness Index (E)
Whole Study Period	6	6	2	1.713	0.808	0.056
PRM	0	0	0	-	-	-
MON	4	4	2	1.5006	0.7528	0.0801
POM	5	5	1	1.3133	0.6607	0.0209

Table 3.64. The Diversity Indices of Ostracoda of Thrissur Kole Wetland

Period	Shannon Index (H)	Simpson's Diversity (D)	Evenness (E) Index
MON1	1.5122	0.7558	0.0965
MON2	1.4878	0.7492	0.093
POM1	1.2880	0.6557	0.0211
POM2	1.334	0.665	0.0278

Table 3.65. Annual Variation in the Diversity Indices of Ostracoda during Different Seasons

3.4.5.2. Abundance

The abundance of Ostracoda in the study area was very low compared to other Zooplankton groups. The Rank Abundance Distribution of Ostracoda was shown in Table 3.66 and the Rank Abundance Curve in Figure 3.57. *S. sewelli* and *S. flavescence* were the most abundant species, accounting for 26% and 23% of the total respectively. *C. cingalensis* was the least abundant species accounting for only 8% of the total.

3.4.5.2.1. Seasonal Variations

Ostracoda showed more abundance in the post-monsoon season (51%) and monsoon (49%), with no Ostracoda in the pre-monsoon season. The Rank Abundance Distribution of Ostracoda during monsoon season is shown in Table 3.67. The Rank Abundance Curve in Figure 3.58. *C. fontinalis* and *I. dispar* were the most dominant species during the monsoon season, constituted 33% and 31%, respectively. The Ostracoda Rank Abundance Distribution in the post-monsoon season is given in Table 3.68. The Rank Abundance Distribution Curve in Figure 3.59. *S. sewelli* was the most dominant species, making up about half of the post-monsoon Ostracoda. Ostracoda abundance was found to be similar in the post-monsoon seasons of the two sampling years.

Species	Relative Abundance	Species Rank
Stenocypris sewelli	26	1
Strandesia flavescence	23	2
Cypreta fontinalis	18	3
Indiacypris dispar	16	4
Eucypris sp.	10	5
Cyprinotus cingalensis	8	6

Table 3.66. The Rank Abundance Distribution of Ostracoda of Thrissur Kole Wetland Oct 2017- Sep 2019

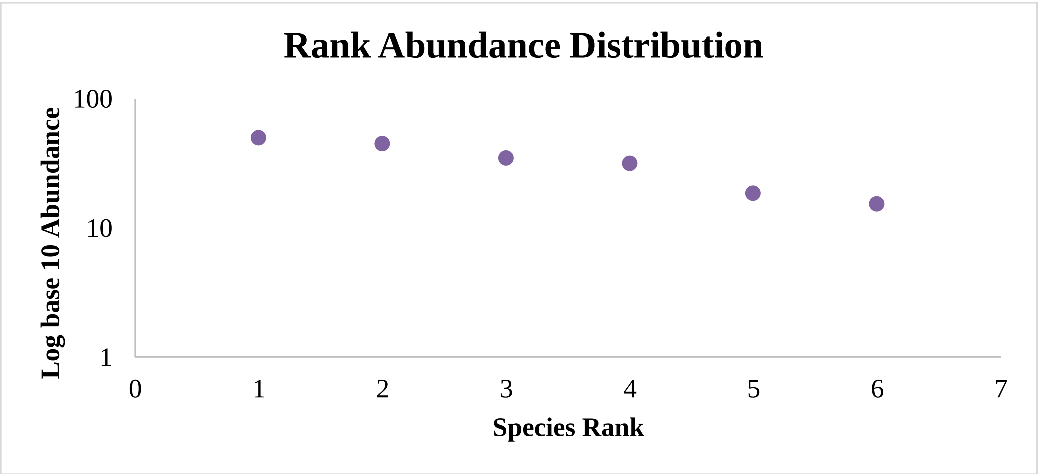


Figure 3.58. The Rank Abundance Distribution Curve of Ostracoda of Thrissur Kole Wetland Oct 2017- Sep 2019

Species	Relative Abundance	Species Rank
Cypreta fontinalis	33	1
Indiacypris dispar	31	2
Strandesia flavescence	21	3
Eucypris sp.	15	4
Stenocypris sewelli	0	5
Cyprinotus cingalensis	0	6

Table 3.67. The Rank Abundance Distribution of Ostracoda during the Monsoon Season

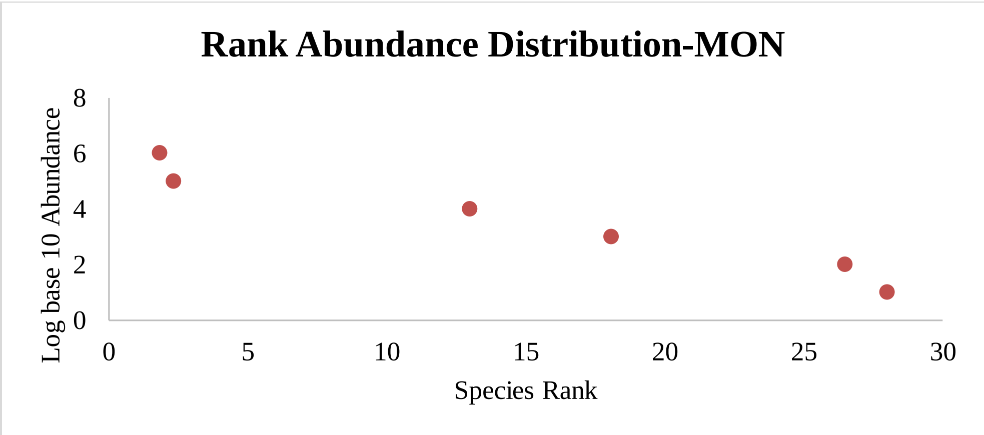


Figure 3.59. The Rank Abundance Distribution Curve of Ostracoda during the Monsoon Season

Species	Relative Abundance	Species Rank
Stenocypris sewelli	51	1
Strandesia flavescence	28	2
Cyprinotus cingalensis	13	3
Cypreta fontinalis	4	4
Eucypris sp.	3	5
Indiacypris dispar	0	6

Table 3.68. The Rank Abundance Distribution of Ostracoda during the Post-monsoon Season

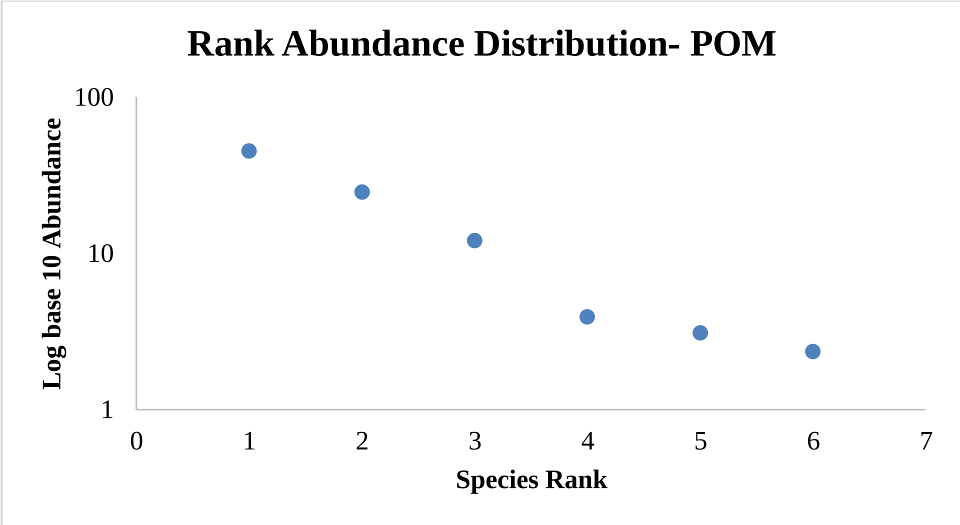


Figure 3.60. The Rank Abundance Distribution curve of Ostracoda during the Post-monsoon Season

Cyprinotus cingalensis

Stenocypris sewelli

Strandesia flavescence

Cypreta fontinalis

Eucypris sp.

Indiacypris dispar

Figure 3.61. Images of Rotifer Species Identified during the Study Period

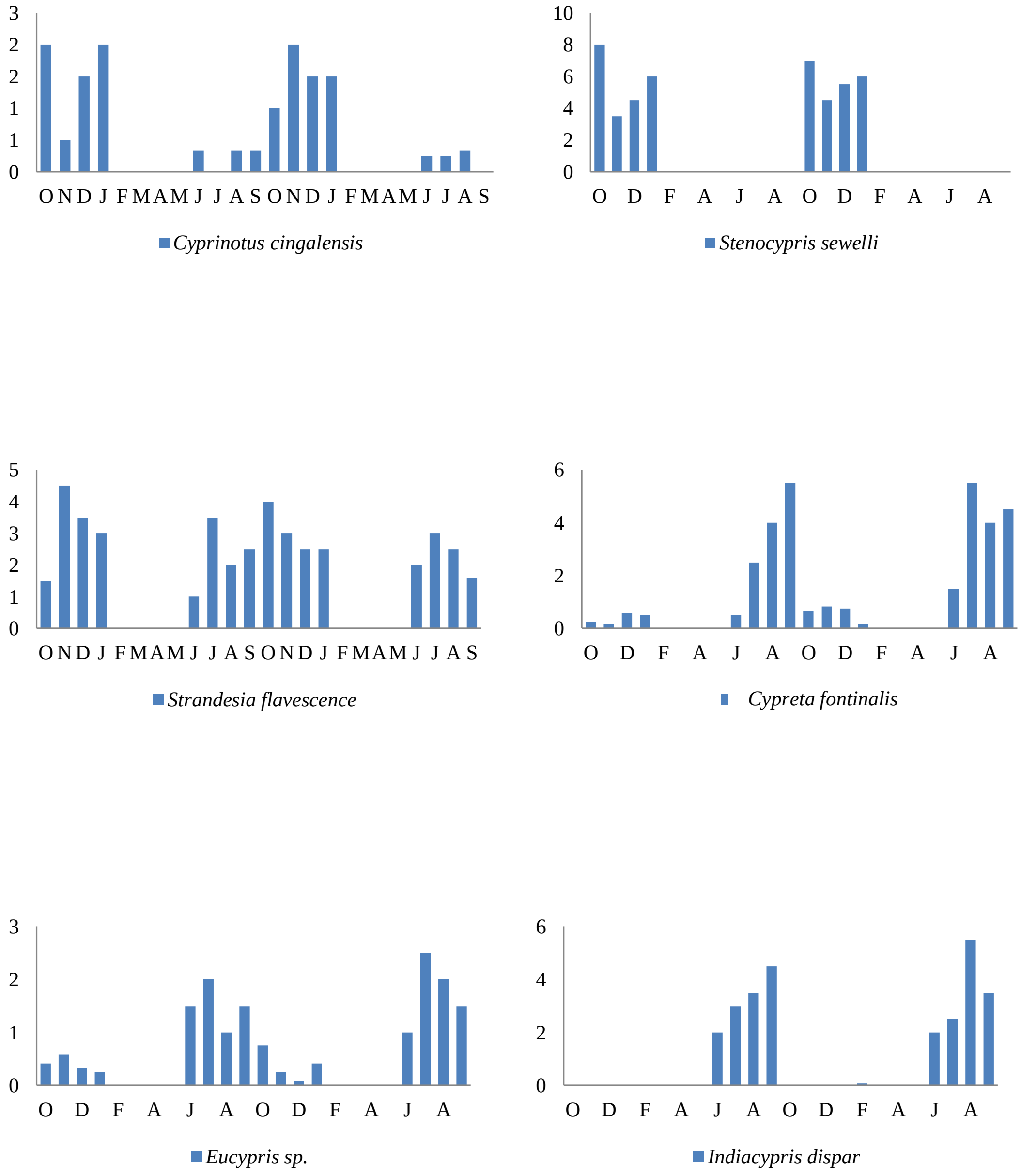


Figure 3.62. Monthly Variations in Ostracoda Species Abundance of Thrissur Kole Wetland Oct 2017- Sep 2019

3.4.5.3. Relationship with Environmental Parameters

Canonical Correspondence Analysis (CCA) is a good and appropriate statistical method for understanding species environmental interactions. The number of Ostracods in this study was very small/zero for many species, so CCA cannot be performed. Regression Model for Ostracoda Abundance was performed. Regression analysis was performed to exclude the variables from the equation that were slightly related to the Ostracoda abundance ($p > 0.05$). The water temperature and BOD were the most influencing variables (statistically significant) on Ostracoda species abundance (Table 3.69). All the β coefficients were negative- which tells that an increase in the value of water temperature or BOD leads to a decrease in Ostracoda abundance. The Ostracoda abundance showed normal distribution, the normal p-p plot of Ostracoda abundance is shown in Figure 3.62.

Model	Unstandardized Coefficients	Std. Error	Standardized Coefficients (Beta)	t	Sig.	VIF
(Constant)	62.874	14.761		4.259	0.000	
Water Temperature	-1.861	0.567	-0.525	-3.284	0.004	1.04875
BOD	-3.820	1.693	-0.361	-2.256	0.035	1.04875

Table 3.69. Model Parameter Values

Stepwise Regression Equation: Y4 = 62.874-1.86X8-3.82X9

Wherein,

Y4- Ostracoda Abundance

X8- Water Temperature

X9- BOD

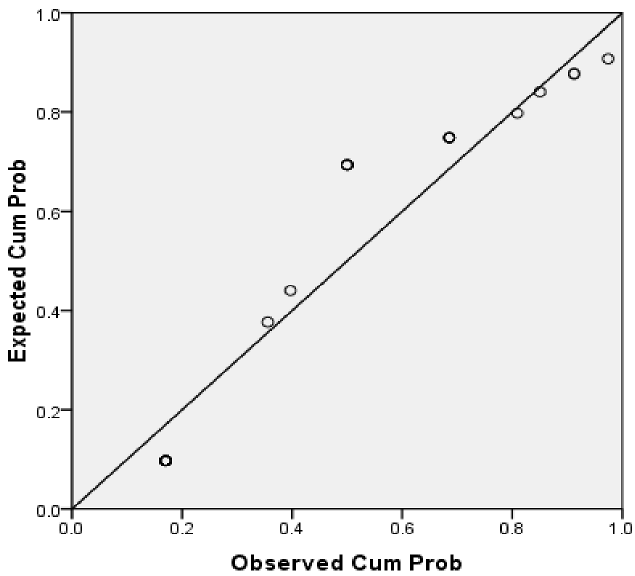


Figure 3.63. Normal p-p Plot of Ostracoda Abundance

3.5. Discussion

Rotifera was the dominant group of Zooplankton of Thrissur Kole wetland, and this was usual in the majority of the freshwater ecosystem. Many authors (U Ahmad et al., 2011; Collado, Fernando, & Sephton, 1984; R. T. Pawar, 2016; K. Sharma et al., 2013) recognized Rotifera as the dominant group in the freshwater ecosystem; this is due to the parthenogenetic reproduction, high fecundity and less specialised diet (Sampaio, Rocha, Matsumura-Tundisi, & Tundisi, 2002).

The most important factors affecting the Rotifer species composition under natural conditions are the temporal variation of the water cycle and the type of environment. Rapid changes in the abundance, community structure and diversity of Rotifera indicates nutrient fluctuations, which were influenced by many factors. Nutrient loading reduces the species richness and increases the abundance of Rotifera (Yun, Liu, Cui, & Chen, 2019)

The results of the Rotifer diversity in Thrissur Kol Wetland revealed that the Rotifer in the study area showed a great deal of diversity and all belonged to the class Monogononta. The dominant families were Brachionidae and Lecanidae, with *Lecane* being the most diverse genus, followed by *Brachionus*. The current study also reveals that the Rotifer diversity was higher during the pre-monsoon season and lower during the monsoon season. A similar result was reported by F. Tóth et al. (2020), Sunita and Singh (2017), Durairaju and SIivakami (2020). They found higher diversity in the pre-monsoon period and Brachionidae as the most dominant family.

Viayeh and Špoljar (2012) Karuthapandi, Rao, and Innocent (2015), Serafim-Júnior, Perbiche-Neves, and Lansac-Tôha (2019), Shah, Pandit, and Shah (2017), Nandini, Sarma, and Gulati (2017), Mamaril (2001), Fernando (1980) identified Brachionidae and Lecanidae as the most diverse family, especially the genus *Brachionus* and *Lecane*. Brachionidae and Lecanidae have a strong ability to adapt to diverse and adverse environmental conditions (G. George, 2011).

Chittapun, Pholpunthin, and Segers (2007), Karuthapandi et al. (2012) identified *Lecane* as the most diverse genus. Kuczynska-Kippen and Ejsmont-Karabin (2020) also recognized this and reported the absolute dominance of Monogononta Rotifers as found in the present study. Contreras, Sarma, Merino-Ibarra, and Nandini (2009) found high diversity in the post-monsoon season and low diversity in the pre-monsoon. This result is contrary to the present study. Dastgeer et al. (2020), Riddhi et al. (2011), Tijare and Thosar (2008), Mukhopadhyay, Chattopadhyay, Goswami, and Chatterjee (2007) identified Brachionidae as the most diversified family; this agreed with the current investigation. Sampaio et al. (2002) recorded Rotifera as the most abundant group of Zooplankton in the freshwater ecosystem and found *Lecane* as the most diversified genus, and *K. cochlearis* as one of the dominant species. This result agreed with the current investigation.

The results indicate that the abundance of Rotifera showed a monthly and seasonal variation. This study revealed that the Rotifer abundance was very high in the pre-monsoon season in the Thrissur Kole wetland. Previous workers, Contreras et al. (2009), Ekhande, Patil, Patil, and Padate (2013), B. Sharma and Pachuau (2013), Shah et al. (2017), N. Manickam et al. (2015), Dhanasekaran et al. (2017), Durairaju and SIivakami (2020) found the maximum abundance during the pre-monsoon and the minimum during the monsoon season. These findings are consistent with the current investigation. Similar to the current findings, Castro, Antunes, Pereira, Soares, and Goncalves (2005) found high diversity and abundance in the pre-monsoon season.

Sarang and Manoj (2021) found high Rotifera abundance during the monsoon and post-monsoon seasons due to the organic load of the water. T. A. Kumar and Nadim (2012) argue that a higher abundance of Rotifers than other Zooplankton in water indicates eutrophication. The abundance of Rotifers in the present study was very high compared to other groups. Sitre (2012), S. Sharma et al. (2010) reported more abundance during the pre-monsoon months and *Brachionus* as the most dominant genus; this study agrees with the current investigation. High pre-monsoon abundance is associated with stable water elements and low water levels. Pre-monsoon high temperatures increase the rate of decay, which enriches the water nutrients and increases the availability of food so that the Rotifera abundance is higher during the pre-monsoon season. During the monsoon season, the density decreases due to heavy flooding and water dilution.

Choi et al. (2014) found high Rotifer diversity and abundance in the pre-monsoon period due to the growth of submerged macrophytes as a result of summer concentrated rainfall. In the present study, rainfall may be one reason for the high diversity and abundance in the pre-monsoon period. *C. hippocrepis, K. cochlearis* and *B. falcatus* were the most prevalent species during the whole study period. *B. falcatus* and *K. cochlearis* were most dominant in the pre-monsoon season. *C. hippocrepis* and *A. fissa* were in the monsoon and post-monsoon seasons respectively. Yin, Ji, Zhang, Chong, and Chen (2018) identified high Rotifer abundance in the pre-monsoon season, and *K. cochlearis* is one of the dominant species, and this result is similar to the current findings. *K. cochlearis* has been reported in many studies as a dominant Rotifer species (Gutiérrez, Sarma, & Nandini, 2017; WEN, XU, LIN, & HAN, 2017).

Rotifera like indicator species in the study is beneficial for measuring the biological response to environmental changes, especially for studies that provide early warning of environmental reactions. It is generally thought that the presence of Rotifera is associated with trophic status. The high abundance of the genus *Brachionus* indicates pollution (Perbiche-Neves, Fileto, Laço-Portinho, Troguer, &

Serafim-Júnior, 2013; R. Sarkar et al., 2020). The presence of *Brachionus calyciflorus*, *B. angularis, Anuraeopsis fissa*, and *Trichocerca cylindrica* is indicative of eutrophication (N. A. Bhat, Raina, R., & Wanganeo, A. , 2013; Guo, Zhao, & Yin, 2010; Kim, Kim, Joo, & Choi, 2020; Mäemets, 1983; Mola, 2011; Neetu, Prabhakar, Kedia, & Sinha, 2020; PahariI, 2002; Pal, 2015; Radwan, 1983; Sampaio et al., 2002; Shei, 2012), *Keratella cochlearis, conochilus hippocrepis, asplanchna herricki, F. longiseta* and *Plationus patulus* are oligotrophic species (Hillbricht-Ilkowska, 1983; Mäemets, 1983). The dominance of *Poyarthra* is often found in waters with high trophic status (Guo et al., 2010). In the present study, Rotifera species, which are indicators of eutrophic and mesotrophic waters, have been identified from the study area, indicating that the presence of indicator species on the water is not an absolute biological indicator of quality and that trophic status can only be inferred if the abundance is very high.

Environmental factors play an important role in determining Rotifer composition (Kobayashi, Shiel, Gibbs, & Dixon, 1998). CCA describes the cumulative effect of physical and chemical parameters on Rotifer species composition (B. K. Sharma & Sharma, 2014). The results of our ordination indicated that these environmental gradients could significantly explain the 74% variation in species composition. The present study revealed that Dissolved oxygen, COD, sulphate, turbidity, TDS, total hardness, iron and alkalinity were the major factors for species composition. In addition, different species prefer different concentrations of variables, Arora and Mehra (2009) also recorded the distribution of different Rotifer species in preference with different concentrations of variables.

Water temperature is always considered to be the main parameter affecting Rotifer composition and seasonal continuity. Many previous studies (Akbulut, Akbulut, & Park, 2008; I. C. Duggan, Green, Thompson, & Shiel, 1998; Geraldes & Boavida, 2007; Halabowski, Bielańska-Grajner, & Lewin, 2019; Kobayashi et al., 1998; kulSharma & Noroh, 2020; B. Sharma & Pachuau, 2013; B. K. Sharma, Noroh, N., & Sharma, S., 2017; K. Sharma et al., 2013; Špoljar, Habdija, Primc-Habdija, & Sipos, 2005; C. Wang, Wang, Deng, & Zhou, 2016; Yin et al., 2018) have shown the influence of temperature on Rotifer species composition. Kuczynska-Kippen and Ejsmont-Karabin (2020) also recognized that salinity and electrical conductivity positively affected the Rotifer abundance, adversely affecting the Rotifer diversity.

K. cochlearis and *B. calyciflorus* were strongly associated with low dissolved oxygen and high temperature, low dissolved oxygen was characteristic of eutrophication, and correlation with low dissolved oxygen confirmed that *K. cochlearis* and *B. calyciflorus* are biological indicators. The association of *B. calyciflorus* with higher temperature noticed by Branco, Rocha, Pinto, Gômara, and Filippo (2002) and association of *K. cochlearis* with low oxygen condition noticed by Yoshida, Urabe, and Elser (2003), supports the author's point of view. One axis of CCA was positively related to dissolved oxygen and negatively related to temperature. I. Duggan, Green, and Shiel (2001) found similar relationships as mentioned earlier and Bera, Dutta, Patra, and Sar (2014) recorded the influence of DO on total Rotifer abundance. B. Sharma (2017) reported the negative influence of water temperature, nitrate, and dissolved oxygen on Rotifer abundance; this supports the author's findings that many species show this kind of correlation.

The differences in morphological and genomic characteristics of species, from simple to large-scale variation, can be sketched to investigate the various factors behind the process of evolution. Molecular evolutionary analysis offers several strategies that allow us to infer the evolutionary history of specific organisms, gene functions, and the relative contributing factors that are recognized as the driving force of gene evolution (Purugganan, 1998). Studies concerning the aforesaid aspect in Rotifers are relatively considered as scanty. As for a reason, the author analyzed the level of genetic variation between the selected species belonging to the Class Monogononta (Order: Flosculariacea and Ploimida).

The Rotifers have often been noticed as the slowly evolving group that has inadequate capacity to respond against the changing ecological conditions. Hence studies based on the aforesaid aspects in context with the alteration of genetic characteristics as a result of various factors, including changes in the environmental conditions (Peijnenburg & Goetze, 2013) need much more significance in the current scenario. Previous literature also verified the fact that there may be a chance of developing evolutionary responses to the changes in the environmental conditions (van Dam, 2012).

The phylogenetic analysis of this investigation has clearly depicted the fact that all the analyzed species possessed changes in genetic characteristics even within the same genus. In agreement with the authors' point of view, a previous study by Peijnenburg and Goetze (2013) summarized that Zooplankton may be capable of rapid evolutionary responses to altering environmental conditions. Studies concerning the evolutionary potential of Rotifers are scanty in the current scenario; however, some of the authors have presumed that Zooplankton is only able to possess limited evolutionary responses towards the alterations in the environmental conditions (Helaouët & Beaugrand, 2009; Reygondeau & Beaugrand, 2011; Stegert, Ji, & Davis, 2010). This has justified the phylogenetic analysis of selected organisms belonging to the order Flosculariacea and Ploimida.

As described in the former sections, the changes that happen in the genetic characteristics of analyzed organisms may be considered evolutionary responses since the various factors including the changes in the environmental conditions, have already been reported in extensive literature as the major reason behind the evolutionary processes. A study by Cristescu, Constantin, Bock, Caceres, and Crease (2012) and Orsini, Spanier, and De Meester (2012) verified the aforementioned evidence. The results from this investigation give insight into the suggestion that the genetic changes that happened between the same genus and the different genus may be considered as the driving force behind the evolution of organisms belonging to the order Flosculariacea and Ploimida. Another study before, as it did in this study have used the DNA barcoding to explore the phylogeny and cryptic speciation with special emphasis on *Asplanchna priodonta*, *Asplanchna brightwelli*, *Lecane* sp., *Keratella* sp., *Trichocerca* sp., and *Brachionus* sp. (Zhang, Xu, Sun, Dumont, & Han, 2021). One of the major significance of using the COI sequence of organisms belonging to Rotifera is due to the “extensive phylogenetic resolution, high mutation rate followed by abundant reference sequence” (Geller, Meyer, Parker, & Hawk, 2013).

The phylogenetic analysis performed by Walsh, Wallace, and Shiel (2005) supports the authors' point of view in terms of the genetic changes that happen between the *Asplanchna* spp. They also reported the alterations in the genetic makeup of *Trichocerca* spp. The current study has reported the genetic changes between the *Trichocerca cylindrica, Trichocerca similis* and *Trichocerca longiseta*. A study by Proios et al. (2014) updated the taxonomic status of *Brachionus sessilis* in context with genetic data. However, none have piloted a study concerning the evolutionary aspects of *Brachionus sessilis* with particular emphasis on the ecological and habitat perspective.

The *Brachionus* spp. are previously known for cryptic species complexes, and experimental crosses between such species have resulted in F1 hybrids as mentioned by Suatoni, Vicario, Rice, Snell, and Caccone (2006). One of the major facts is that very little information is about the degree of hybridization between *Brachionus* cryptic species. The above-discussed perspectives have illustrated the significance of using the "Molecular Phylogenetics" as a valuable tool in analyzing the cryptic diversity of organisms along with their evolutionary perspectives (Fontaneto, 2014).

In this study, the *Brachionus* spp. exhibit extensive genetic changes, illustrating their significance in evolutionary perspectives. Hartfield, Wright, and Agrawal (2016) reported that the *Brachionus* spp. are facultative sexual organisms and the low rates of sex may augment the effect of gene conversion on specific times like coalescent times. Papakostas et al. (2016) also noted that advanced molecular strategies could differentiate the Rotifer cryptic species complex. Furthermore, mitochondrial COI genes can be recognized as more informative in the phylogenetic analyses of diverged lineages because of their faster evolution rate.

According to Cieplinski, Weisse, and Obertegger (2017) and Cornils and Held (2014), the COI nucleotide sequences have been successfully used to distinguish and identify the species *Lecane* spp. and *Keratella* spp. In addition, a study by Kordbacheh, Wallace, and Walsh (2018) revealed that the Rotifer *Brachionus plicatilis* exhibited ≤13.3 % variation within clades and ≥11.9 % variation between clades while the *Polyarthra* spp. have been shown to exhibit ≤4.4 % variation within species ≥5–24% variation between species. Leasi, Tang, De Smet, and Fontaneto (2013) reported the probable percentage of genetic variation of *Testudinella clypeata* (0.16–4.5 within clades and 16.7–27.7 between clades).

In agreement with the findings of this study, Cieplinski et al. (2017) reported the extensive range of genetic variation in *Lecane* spp. From the above-discussed inferences, it was clearly evident that there exists a prominent range of genetic variation between and within the genus, and this has illustrated as the base for the evolution of organisms belonging to the Phylum Rotifera.

The study revealed that Cladocera was the most potent crustacean Zooplankton and the second most abundant Zooplankton group in the freshwater ecosystem after Rotifera. Many authors (U Ahmad et al., 2011; Elías-Gutiérrez, Suárez-Morales, & Sarma, 2001; Fernando, 1980) confirm the current finding, Cladocera as the second most abundant group. Perbiche-Neves et al. (2019) identified Cladocera as the major group of crustacean Zooplankton, and found a minimum of 15 species per sample. The Cladocera of Thrissur Kole wetland belongs to six families Sididae, Daphnidae, Bosminidae, Moinidae, Macrothricidae and Chydoridae. Similar family presence was reported by V. Sharma, Verma, B. K., Sharma, R., Sharma, M. S., & Gaur, K. S. (2012) from south Rajasthan. There was a noticeable diversity of Cladocera, and it also showed seasonal variation. Cladocera diversity was more in the post-monsoon season and less in the pre-monsoon season. Family Chydoridae was the most diversified family, similar results were obtained by Neves, Rocha, Roche, and Pinto (2003), Sampaio et al. (2002), kulSharma and Noroh (2020). *C. cornuta*, was a ubiquitous and *Simocephalus* was a very rare tropical species (Mamaril, 2001). *Ceriodaphnia, Diaphanosoma, Moina, Chydorus* are limnetic and *Alona. Macrothrix, Simocephalus* and *Ilyocryptus* are littoral species.

Cladocera abundance in the Kole wetland showed seasonal or temporal variation. Many authors (Indur et al., 2016; R. Jose & Sanalkumar, 2012; Koli & Muley, 2012; Narasimha Manickam, 2018; R. T. Pawar, 2016; Sitre, 2012) recorded seasonal variation in Cladocera species composition. The result revealed that the abundance of Cladocera of Thrissur Kole wetland was higher in the pre-monsoon season and lowered in the post-monsoon season. The higher abundance during the pre-monsoon season may be due to nutrient load and more food availability. N. Manickam et al. (2015), Dhanasekaran et al. (2017), agrees with the current finding. R. T. Pawar (2016) also noticed a similar seasonal abundance as reported in the current study. Similar to the reports of Shah and Pandit (2013), Güntzel, Panarelli, da Silva, and Roche (2010), R. N. D. Etilé. (2020), R. Jose and Sanalkumar (2012) this study also identified Chydoridae as a diverse family, hence the other findings being consistent with the current investigation. High pre-monsoon abundance is associated with stable water elements and low water levels. Pre-monsoon high temperatures increase the rate of decay, which enriches the water nutrients and increases food availability so that the Cladocera abundance is higher during this season. During the monsoon season, the density decreases due to heavy flooding and the dilution of water.

More than one species of the same genus is uncommon in a limnetic community, according to Pennak (1957). According to the Niche phenomenon, when two specimens of the same genus coexist for some time, one is usually 20 or more times more abundant than the other. Current data do not support this viewpoint. Genus *Diaphanosoma* shows a large difference in the abundance of two species *D. excisum* and *D. sarsi* during pre-monsoon and monsoon season, but the difference is less than ten times, this refutes the above argument. *B. deitersi* were the most abundant species followed by *D. excisum.* Similar to the current finding, Neves et al. (2003) found *B. deitersi* as a dominant species, and Sa-Ardrit and Beamish (2005), Etile et al. (2020) and Majagi and Vijaykumar (2009) found *D. excisum* as one of the dominant species.

Environmental factors play an important role in determining Cladocera species composition. Water temperature, pH, nutrients, turbidity, dissolved oxygen, and species interactions influence Cladocera community composition (Gieskes, 1971; A. Korhola, 1999; A. S. Sharma, Gupta, & Singh, 2017). Similarly, our analysis showed that the abundance of Cladocera was related to environmental factors and varied according to the seasons (Branco et al., 2002). CCA described the cumulative effect of physical and chemical parameters on Cladocera species composition. The results of our ordination indicated that these environmental gradients could significantly explain the 85.3% variation.

Our results revealed that water temperature, alkalinity, magnesium, nitrate, sulphate, turbidity, total hardness, dissolved oxygen, iron, electrical conductivity, and BOD were responsible for the Cladocera species composition. The first axis of the CCA shows a gradient of decreasing turbidity, total hardness and dissolved oxygen to increasing water temperature, alkalinity, magnesium, nitrate and sulphate. Higher nitrate and lower dissolved oxygen make axis 1 a trophic gradient; excess nitrates indicate excessive growth of plants and algae, creating unstable oxygen levels. High temperature also reduces the oxygen level in water. The second axis of the CCA shows a gradient of decreasing electrical conductivity and BOD to increasing iron concentration. Whiteside (1970) reported negative effects of pH, alkalinity and conductivity on Cladocera species composition. K. Sharma et al. (2013) found temperature, calcium and magnesium as influencing factors for Cladocera abundance. Novichkova and Azovsky (2017) reported positive influence of water temperature on Cladocera abundance.

The most abundant Cladocera, *B. ditersi* and *D. excisum* are at almost the centre of the ordination diagram, indicating that the abundance of these taxes is not strongly correlated with the changes in the physical and chemical variables analyzed. Therefore, it may be suggested that this species is well adapted to Kole wetland water. In the present study, the Kole wetland water has more nutrients in the pre-monsoon season than the other seasons. *C. cornuta, M. micrura,* and *O. singalensis* prefer high nutrient water and *L. australis, S. serrulatus, S. acutirostratus, M. triserialis, M. goeldii, I. spinifer, C. sphaericus, C. barroisi* and *A. monacantha* prefer nutrient poor water. *P. szalayi, A. rectangula* and *E. orientalis* prefer water with high iron and lower electrical conductivity and BOD, and *B. affinis* and *K. longirostris* prefer the opposite.

Water temperature is an important factor influencing the Cladocera abundance, Kiss, Ágoston-Szabó, Dinka, Schöll, and Berczik (2014) found an inverse relationship with the temperature. Cladocera responds rapidly to changes in trophic levels. Whiteside (1970) found that low diversity of *Chydorid* and the absence of

Chydorus sphaericus and *Alona rectangula* indicate water contamination/eutrophication. The diversity of Chydorus was low in the present study, but the species mentioned above were present in a very low abundance. *A. rectangula* preferred water with high iron and low BOD and electrical conductivity, and *C. sphaericus* preferred nutrient poor water. The condition mentioned above is found in good/unpolluted water, supporting the author's findings. Certain pollution tolerant Cladocera genera, *Diaphanosoma*, *Ceriodaphnia* and *Moina* have been recorded from some eutrophic water around the world (Singh, Ahluwalia, Sharma, Jindal, & Thakur, 2013). In the present study, the genera *Moina* and *Ceriodaphnia* prefer the nutrient-rich state of water; this confirms the above study.

Copepoda was the second most abundant crustacean Zooplankton in the present study. Many authors (Uzma Ahmad, Parveen, Mola, Kabir, & Ganai, 2012; Collado et al., 1984; B. Sharma & Pachuau, 2013; Walseng, Yan, & Schartau, 2003) recorded Copepod as second most abundant group. However, the Cyclopoid Copepod was more diverse and even than the Calanoid. A number of Cyclopoid species was more than double the number of Calanoida. The taxonomic richness of the Cyclopoida was greater than that of the Calanoida, and similar findings were made by Morales-Ramírez, Suarez-Morales, Corrales-Ugalde, and Garrote (2014), Gutiérrez-Aguirre and Suárez-Morales (2001).

All the Calanoids identified from the study area belonged to the family Diaptomidae. Boxshall (2008) identified Diaptomidae as a major family of Calanoida found in inland waters of Europe, Asia, North America, Africa, and northern lowland South America. Sampaio et al. (2002), Joshi (2011), Karuthapandi et al. (2012) Ansari and Khan (2014), Morales-Ramírez et al. (2014), Majumder et al. (2015) recorded Diaptomidae as the only family of a freshwater Calanoid Copepod; this result agrees with the current investigation. The diversity of Copepod showed seasonal variation. Many studies (Ghosh & Biswas, 2015; Jalilzadeh, Yamakanamardi, & Altaff, 2007; Panwar & Malik, 2016; B. Sharma, 2011) reported similar results; it supports the author's findings on the chronological impact on the Copepoda community. The Copepod diversity was found to be more during the post-monsoon season followed by monsoon and least during the pre-monsoon season. Riddhi et al. (2011) recorded Diaptomidae as the only Calanoid family in freshwater and higher Copepod diversity during the post-monsoon season, similar to the current investigation.

The Calanoid Copepod was more abundant than the Cyclopoid, even when the number of species was very less. Copepod abundance of the study area showed seasonal or temporal variation. Koli and Muley (2012), R. Jose and Sanalkumar (2012), Sitre (2012), Indur et al. (2016), R. T. Pawar (2016) and Narasimha Manickam (2018) also noticed the seasonal variation in the abundance of Copepods; this agrees with the current investigation. The abundance was more during the pre-monsoon season and less during the post-monsoon season.

S. Sharma et al. (2010), D. K. Sharma and Singh (2012), Bera et al. (2014), Stire (2014), B. Sharma and Pachuau (2013), Sehgal, Phadke, Chakraborty, and Reddy (2013), Watkar and Barbate (2013), Manickam et al. (2015), Panwar and Malik (2016) and Rao (2017) reported high abundance during the pre-monsoon season, similar to the current investigation. R. T. Pawar (2016) found similar seasonal variation as in the current study; high abundance during the pre-monsoon season and low during the post-monsoon season. High pre-monsoon abundance was associated with stable water elements and low water levels. Pre-monsoon high temperatures increase the rate of decay, which enriches the water nutrients and increases the availability of food so that the Copepoda abundance was higher during the pre-monsoon season. During the monsoon and post-monsoon season, the density decreased due to heavy flooding.

Higher Copepod abundance indicates higher phytoplankton density. The dominance of Calanoid Copepod indicates the water's oligotrophic condition (Baqai & Ishrat, 1973). The dominance of *Mesocyclops* and *Thermocyclops* are the indicators of eutrophication, both genera were present in the current study but the number was very less. Certain pollution tolerant Copepods, *Cyclops, Diaptomus*, *mesocyclops* and *Eucyclops* have been recorded in eutrophic/oligotrophic water around the world (U Ahmad et al., 2011; Singh et al., 2013).

Environmental factors play an important role in determining Copepod species composition. Our analysis showed that the abundance of Copepods was related to environmental factors and varied according to the seasons. CCA describes the cumulative effect of physical and chemical parameters on Copepod species composition. The results of our analysis indicate that these environmental gradients can significantly explain the 77.7% variation.

Our results revealed that iron, BOD, COD, DO, and water temperature was responsible for the Copepoda species composition. The first axis of the CCA showed a gradient of decreasing BOD and COD to increasing iron. The second axis of the CCA showed a gradient of decreasing air temperature, water temperature and BOD to increasing DO. Indication of dissolved oxygen on one side and temperature and BOD on the other side made axis 2 as a trophic gradient. DO varies with temperature; oxygen decreases rapidly as the BOD rises. Fefilova, Dubovskaya, Kononova, and Khokhlova (2013) found pH and temperature as the most influencing factor on Copepoda. Koli and Muley (2012) recorded higher Copepod abundance during the warmer months in correlation with the temperature. Thakur, Jindal, Singh, and Ahluwalia (2013) reported the influence of pH, temperature, dissolved oxygen, chloride and nitrate as the influencing factors on Copepod abundance. These are consistent with the current investigation. kulSharma and Noroh (2020) found the influence of pH, calcium and TDS; the current study cannot find a strong influence of these variables on Copepoda.

The most abundant Copepod *A. mirabilipes* showed no relation with changes in the physical and chemical variables analyzed. It may be suggested that this species is well adapted to Kole wetland water. In the present study, the temperature and BOD were higher and DO was lower during the pre-monsoon season, which means the presence of more oxygen requiring wastes during this season. Here, *E. serrulatus, E. rubescens, M. varicans, M. rubellus* prefer post-monsoon condition, *H. cinctus* prefer pre-monsoon condition, *Neodiaptomus sp., M. ogunnus, T. crassus* prefer monsoon condition. Novichkova and Azovsky (2017) reported significant positive correlation of Copepod with water temperature; this agrees with the current investigation.

Ostracoda was the least abundant group of Zooplankton in Thrissur Kole wetland. Many authors (N. A. Bhat, Wanganeo, & Raina, 2014; P. Kumar, Wanganeo, Wanganeo, & Sonaullah, 2011; Narasimha Manickam (2018); R. T. Pawar, 2016), reported similar findings. This agrees with the current investigation. Extensive use of fertilizers and pesticides has led to a decline in Ostracoda richness (Ruiz et al., 2013) and this is one reason for the declining Ostracoda richness in the current study. The abundance of Ostracoda showed clear seasonal variation; this was noted in many previous studies (Bera et al., 2014; JI, Das, Mukherji, & Kumar, 2011; Riddhi et al., 2011). The diversity and evenness were high during the monsoon season, followed by post-monsoon.

The dominant family was Cyprididae, accounting for about half of the world's Ostracoda diversity (K. Martens, Schön, I., Meisch, C., & Horne, D. J., 2007). All species except one are found in the present study belong to the Cyprididae family. The two genera found in the present study, Cyprinotus and Stenocypris, were also found in a short-term study by Rajagopal, Thangamani, Sevarkodiyone, Sekar, and Archunan (2010). Only one species in the family Ilyocyprididae, *Indiacypris dispar*, was previously described in Kerala from the Chalakudy river (S. George & Martens, 2004).

Ostracoda abundance was significantly similar in both post-monsoon season and monsoon season, with the complete absence of Ostracoda in the pre-monsoon season. Ansari and Khan (2014) reported the absence of Ostracoda in March. On the other hand, Stire (2014), Joshi (2011) recorded higher abundance during the post-monsoon season; this agrees with the present investigation.

Environmental variables that directly affect phytoplankton may affect the Ostracoda community structure in wetlands (Beaver, Miller-Lemke, & Acton, 1998; Rossetti, Bartoli, & Martens, 2004). Regression analysis was performed to exclude the slightly related parameters to the Ostracoda abundance from the equation. The water temperature and BOD were the most influencing variables on Ostracoda species abundance. The other variables did not show a strong correlation, indirectly affecting the abundance by changing the water temperature and BOD. There was a strong correlation between air temperature and water temperature, and if the air temperature changes, it changes the temperature of the water, which affects the Ostracoda abundance. As mentioned in the previous chapter, there was a strong correlation for water temperature with sulphate, turbidity, electrical conductivity, alkalinity, magnesium, CO2, and dissolved oxygen.

Ostracoda prefers different temperatures; some adapt to lower temperatures (K. Martens & Tudorancea, 1991) and higher temperatures (Rieradevall & Roca, 1995). Different species show specific reactions to various environmental factors (Külköylüoğlu, 2013; Külköylüoğlu, Yavuzatmaca, Sarı, & Akdemir, 2016). Bera et al. (2014), Coviaga, Cusminsky, and Pérez (2018), Altınsaçlı (2014) recorded strong correlation of Ostracoda abundance with water temperature similar to the present investigation. Karuthapandi et al. (2012) recorded the influence of TDS and alkalinity on Ostracoda abundance, and in the present study, neither of these two variables got directly affected. Ostracoda prefers different concentrations of dissolved oxygen like temperature; some species are very sensitive to oxygen depletion, while some species tolerate oxygen deficiency for at least a short time (Ruiz et al., 2013).

Nagorskaya and Keyser (2005) found that Ostracoda abundance positively correlated with water temperature and dissolved oxygen. This contradicts the current study, where temperature adversely affects abundance but is consistent with dissolved oxygen because BOD has a strong negative relationship. Uçak, Külköylüoğlu, Akdemir, and Başak (2014) recorded strong correlations between temperature and dissolved oxygen with the Ostracoda species composition, and found high tolerance to temperature and dissolved oxygen in four species. Like other Zooplankton, Ostracoda acts as a pollution indicator, a large population of a sensitive species indicates good water quality (Külköylüoğlu, 2004; Schneider et al., 2016). There was no record on Ostracoda in a previous study on Zooplankton diversity as part of the major environmental threats to the Muriyad Kole wetlands, a part of the Thrissur Kole Wetlands, and their impact on flora and fauna conducted by John Thomas (2003).

John Thomas (2003) documented the diversity of Zooplankton, based on some random collections, as part of a study of the major environmental threats to the

Muriyad Kole wetlands, a part of the Thrissur Kole Wetlands, and their impact on flora and fauna. They reported 20 species of Rotifera, 34 species of Cladocera and eight species of Copepoda 14 years before this study. *B. dichotomous, B. angularis, B. forficula, B. sessilis, A. navicula, A. fissa, C. hippocrepis, C. unicornis, A. brightwelli, A. priodonta, A. herricki, H. brehmi, L. luna, L. furcata, L. monostyla, L.sp1, L. sp2, L. cornuta, L. unguitata, Synchaeta sp, Mytilina sp, T. cylindrica, , T. longiseta, T. kosteiT. Rattus, T. similis, P. vulgaris* and *Polyarthra sp.* are the Rotifers reported for the first time in this area. Nine previously reported species (*Brachionus qudridentatus, Brachionus caudatus, Macrochetus collinsi, Euchalanis dilatata, Lecane ludwigii, L. quadridentata, L. papuana, L. ungulate* and *Lepadella patella*) were not identified in this study. *B. caudatus* seems to prefer eutrophic water, physical and chemical properties of water influence its population regulation more seriously than other Rotifers (PahariI, 2002). Life span and fecundity of the *B. caudatus* depends on the temperature (Athibai, 2008). The number of offspring was more during the high temperature as compared to the lower temperature.

Only 21 Cladocera species have been identified in the present study, including the species not found in the previous study. The 20 species recorded in the previous study were not found, *D. excisum, C. cornuta, S. acutirostratus, M. goeldii, C. barroisi, A. rectangula* and *B. affinis* were new species found in the present study. Of these, *D. excisum* was one of the most dominant Cladoceran species found throughout the study. The elimination of 14 species may be a reason for ecological changes due to natural and manmade activities.

10 Copepod species have been identified in the present study that includes five species not found in the previous study. The three species recorded in the previous study (*Mesocyclops splendidus, Thermocyclops decipiens,* and *Tropodiaptomus informis*) were not found. *Neodiaptomus sp., Eucyclops serrulatus, Mesocyclops leuckarti, Microcyclops rubellus* and *Thermocyclops crassus* are new species. The elimination of three species may be a reason for ecological changes due to natural and manmade activities.

According to Brown et al. (2020), the abundance of organisms in a sample is associated with sample effort, and more abundance is obtained from a more precise sample in a more stable environment. Otherwise, errors will occur and some species may go unnoticed. The present study also predicts the same.

3.6. Summary and Conclusion

The diversity and abundance of all four Zooplankton groups show significant seasonal variations. The study clearly indicates that the species richness and abundance of Rotifera was more during the pre-monsoon season. Shannon-Weaver index and Simpson's index values clearly indicate more diversity during the pre-monsoon and less diversity during the monsoon season, and evenness value significantly similar in pre-monsoon and post-monsoon season. The number of Cladocera was more during the pre-monsoon season. Shannon-Weaver index and Simpson's index value indicated higher Cladocera diversity during the post-monsoon season and less during the pre-monsoon season. Evenness value of Cladocera was higher in the post-monsoon season and lower in the pre-monsoon season.

The abundance of Copepoda was more during the pre-monsoon season. Shannon-Weaver index and Simpson's index value indicate more diversity during the post-monsoon season and less diversity during the pre-monsoon season. Evenness index was higher in the post-monsoon season and lower and significantly similar in monsoon and pre-monsoon seasons. Ostracoda was much smaller in number than other Zooplankton. This is the first attempt to find the diversity of Ostracoda in the Thrissur Kole wetland. Six species of Ostracoda were identified, which differed in seasons. The abundance was significantly similar during the monsoon and post-monsoon seasons and was completely absent in the pre-monsoon season.

The CCA explained the high cumulative variation of Zooplankton assemblies with axes 1 and 2 according to the seasons. The study revealed that different species prefer different values of environmental variables. Dissolved oxygen, iron, sulphate, water temperature and total hardness are the main parameters influencing the Rotifer species abundance. Dissolved oxygen is the important parameter that positively controls the abundance of Rotifera. Temperature, DO, BOD, COD, iron, sulphate, electrical conductivity and nitrate were the main parameters that directly influenced the Cladocera species abundance. Temperature, DO, BOD, COD, iron, sulphate and electrical conductivity were the main parameters that directly influenced the Copepod species abundance. Multiple regression analysis was performed to detect the influence of environmental variables on Ostracoda abundance. BOD and water temperature were the main factors that directly affected the abundance of Ostracoda. Other parameters indirectly influenced these, as some parameters were found to correlate these two variables strongly.

The *Brachionus* is the second most abundant genera of Rotifera, which indicates pollution. There are some eutrophic and oligotrophic indicator species of Rotifera in the study area. *Brachionus calyciflorus*, *Brachionus angularis, Anuraeopsis fissa*, and *Trichocerca cylindrica* are eutrophic indicators. *Keratella cochlearis, Conochilus hippocrepis, Asplanchna herricki*, *Filinia longiseta* and *Plationus patulus* are oligotrophic indicators. Chydoridae was the most diversified family in Cladocera, and *D. excisum* and *B. dietersi* were the most dominant species. In Copepoda, Calanoidae was the dominant order whereas Cyclopoidae was the most diversified order, and *H. cinctus* and *A. mirabilipes* were the most dominant species. The most common Ostracoda species are *S. sewelli* and *S. flavescence*, which account for about half of the Ostracoda abundance of the Thrissur Kole wetland.

In conclusion, the diversity and richness of Zooplankton is influenced by various physical, chemical and biological factors such as temperature, dissolved oxygen, BOD, turbidity, conductivity, nutrient density, food chain and soil and water chemistry. The fourteen species of Cladocera, nine species of Rotifera and three species of Copepoda previously found were not yet found, which may be due to changes in physical, chemical, and biological parameters. Studies on biotic components such as phytoplankton, species interaction, and food availability are also needed to determine the cause of the change in Zooplankton species composition. Therefore, studies including biotic interaction have again been recommended to confirm changes in the species composition of the Zooplankton. Monitoring the changes closely and bringing them to the public's attention may help alleviate the problems caused by human intervention.

REFERENCES

Abdulwahab, S., & Rabee, A. M. (2015). Ecological factors affecting the distribution of the Zooplankton community in the Tigris River at Baghdad region, Iraq. *The Egyptian Journal of Aquatic Research, 41*(2), 187-196.

Acharya, G., & Barbier, E. B. (2000). Valuing groundwater recharge through agricultural production in the Hadejia-Nguru wetlands in northern Nigeria. *Agricultural Economics, 22*(3), 247-259.

Adhikari, S., Goswami, A. R., & Mukhopadhyay, S. K. (2017). Diversity of Zooplankton in municipal wastewater-contaminated urban pond ecosystems of the lower Gangetic plains. *Turkish Journal of Zoology, 41*(3), 464-475.

Ahangar, I., Saksena, D., & Mir, M. (2012). Seasonal Variation in Zooplankton Community Structure of Anchar lake, Kashmir. *Universal Journal of Environmental Research & Technology, 2*(4).

Ahmad, U., Parveen, S., Khan, A., Kabir, H., Mola, H., & Ganai, A. (2011). Zooplankton population in relation to physico-chemical factors of a sewage fed pond of Aligarh (UP), India. *Biology and Medicine, 3*(2), 336-341.

Ahmad, U., Parveen, S., Mola, H. R. A., Kabir, H. A., & Ganai, A. H. (2012). Zooplankton population in relation to physico-chemical parameters of Lal Diggi pond in Aligarh, India. *Journal of environmental biology, 33*(6), 1015.

Akbulut, N., Akbulut, A., & Park, Y.-S. (2008). Relationship between Zooplankton (Rotifera) distribution and physico-chemical variables in Uluabat Lake (Turkey). *Fresenius Environ. Bull, 17*(8), 947-955.

Akdemir, D., & Kulkoyluoglu, O. (2011). Freshwater Ostracoda (Crustacea) of Diyarbakır Province, including a new report for Turkey. *Turkish Journal of Zoology, 35*(5), 671-675.

Almeida, R., Formigo, N. E., Sousa-Pinto, I., & Antunes, S. C. (2020). Contribution of Zooplankton as a biological element in the assessment of reservoir water quality. *Limnetica, 39*(1), 245-261.

Alongi, D. M. (2008). Mangrove forests: resilience, protection from tsunamis, and responses to global climate change. *Estuarine, coastal and shelf science, 76*(1), 1-13.

Altaff, K. (2004). A manual of Zooplankton. *University Grants Commission, New Delhi*, 1-155.

Altınsaçlı, S. (2014). Species diversity and distribution of Ostracoda (Crustacea) in mesosaline Lake Bafa (Aegean region, Turkey). *Journal of Entomology and Zoology Studies, 2*(2), 16-32.

Amaral, L. M., de Almeida Castilho, M. C., Henry, R., & Ferragut, C. (2020). Epipelon, phytoplankton and Zooplankton responses to the experimental oligotrophication in a eutrophic shallow reservoir. *Environmental Pollution*,.

Amsha Devi, V., Baskaran, S., & Suresh Kumar, R. (2013). Physico-chemical parameters and Zooplankton diversity of a temple pond in Virudhunagar, Tamil Nadu. *International Journal of Science, Environment and Technology, 2*(2), 250-257.

An, X. P., Du, Z. H., Zhang, J. H., Li, Y. P., & Qi, J. W. (2012). Structure of the Zooplankton community in Hulun Lake, China. *Procedia Environmental Sciences, 13*, 1099-1109.

Andersen, T., & Hessen, D. O. (1991). Carbon, nitrogen, and phosphorus content of freshwater Zooplankton. *Limnology and Oceanography, 36*(4), 807-814.

Ansari, S., & Khan, A. A. (2014). Diversity and distribution of Zooplankton in a freshwater body of Aligarh region. *Indian Journal of Scientific Research and Technology, 2*(1), 73-82.

Antonopoulos, V. Z., & Gianniou, S. K. (2003). Simulation of water temperature and dissolved oxygen distribution in Lake Vegoritis, Greece. *Ecological Modelling, 160*(1-2), 39-53.

APHA. (1992). *Standard Methods for the Examination of Water and Wastewater* (17 ed.). Washington, DC: American Public Health Association.

Arora, J., & Mehra, N. (2009). Seasonal dynamics of Zooplankton in a shallow eutrophic, man-made hyposaline lake in Delhi (India): role of environmental factors. *Hydrobiologia, 626*(1), 27-40.

Athibai, S., & Sanoamuang, L. O. (2008). Effect of Temperature on Fecundity, Life Span and Morphology of Long-and Short-Spined Clones of Brachionus caudatus f. apsteini (Rotifera). *International Review of Hydrobiology, 93*(6), 690-699.

Avery, A. A. (1999). Infantile methemoglobinemia: reexamining the role of drinking water nitrates. *Environmental health perspectives, 107*(7), 583-586.

Avolio, M. L., Carroll, I. T., Collins, S. L., Houseman, G. R., Hallett, L. M., Isbell, F., Wilcox, K. R. (2019). A comprehensive approach to analyzing community dynamics using rank abundance curves. *Ecosphere, 10*(10), e02881.

Ayoade, A., Agarwal, N., & Chandola-Saklani, A. (2009). Changes in physicochemical features and plankton of two regulated high altitude rivers Garhwal Himalaya, India. *European Journal of Scientific Research, 27*(1), 77-92.

Azevêdo, D. J. S., Barbosa, J. E. L., Gomes, W. I. A., Porto, D. E., Marques, J. C., & Molozzi, J. (2015). Diversity measures in macroinvertebrate and Zooplankton communities related to the trophic status of subtropical reservoirs: Contradictory or complementary responses? *Ecological Indicators, 50*, 135-149.

Balai, V. K., Sharma, L., & Ujjania, N. (2014). Diversity and seasonal variations of Zooplankton in Jaisamand lake, Udaipur, India. *Indian Journal of Animal Research, 48*(5), 432-437.

Banerjee, S., Nur, R., & Barat, S. (2014). Study on the Zooplankton production in ponds under different fish farming system in West Bengal. *Journal of Krishi Vigyan, 3*(1), 79-83.

Baqai, I., & Ishrat, R. (1973). Seasonal fluctuation of freshwater Copepods of Keenjhar Lake, Sindh and its correlation with physico-chemical factors. *Pak J Zool, 5*, 165-168.

Battish, S. (1992). *Freshwater Zooplankton of India*: Oxford & IBH Publishing Company.

Bazzuri, M. E., Gabellone, N. A., & Solari, L. C. (2020). Zooplankton-population dynamics in the Salado-River basin (Buenos Aires, Argentina) in relation to hydraulic works and resulting wetland function. *Aquatic Sciences, 82*(3), 1-18.

Beaver, J. R., Miller-Lemke, A. M., & Acton, J. K. (1998). Midsummer Zooplankton assemblages in four types of wetlands in the Upper Midwest, USA. *Hydrobiologia, 380*(1), 209-220.

Benyahya, L., Caissie, D., St-Hilaire, A., Ouarda, T. B., & Bobée, B. (2007). A review of statistical water temperature models. *Canadian Water Resources Journal, 32*(3), 179-192.

Bera, A., Dutta, T., Patra, B., & Sar, U. (2014). Correlation study on Zooplankton availability and physico-chemical parameters of Kangsabati Reservoir, West Bengal, India. *Int. Res. J. Environ. Sci, 3*(12), 28-32.

Bhanja, D., Ghosh, J., Basu, A., Kundu, G., Ghosh, P., & Roy, S. (2014). Dynamics of plankton community in two adjacent unmanaged ponds of West Bengal, India. *Biosc Dis, 5*, 241-247.

Bhat, N. A., Raina, R., & Wanganeo, A. (2013). Occurrence and spatial distribution of Brachionus species: a bioindicator of eutrophication in Bhoj wetland, Bhopal. *Angewandten Biologie Forschung, 1*(3), 21.

Bhat, N. A., Wanganeo, A., & Raina, R. (2014). The composition and diversity of net Zooplankton species in a tropical water body (Bhoj Wetland) of Bhopal, India. *International Journal of Biodiversity and Conservation, 6*(5), 373-381.

Bhatia, S. K., & Nair, S. (2020). Assessment of water quality index for Shivnath river in Durg, Chhattisgarh State, India.

Bhavan, P. S., Udayasuriyan, R., Vadivalagan, C., Kalpana, R., & Umamaheswari, S. (2016). Diversity of Zooplankton in four perennial lakes of Coimbatore (India) and molecular characterization of Asplanchna intermedia, Moina micrura, Mesocyclops edax and Cypris protubera through mt-COI gene. *J Entomol Zool Stud, 4*(2), 183-197.

Birky Jr, C. W., & Gilbert, J. J. (1971). Parthenogenesis in rotifers: the control of sexual and asexual reproduction. *American Zoologist*, *11*(2), 245-266.

Biswas, M. (2015). Seasonal abundance of Zooplankton in relation to physicochemical features in Rabindra Sarobar, Kolkata. *International Research Journal of Interdisciplinary and Multidisciplinary Studies*, *1*, 56-62.

Bogdan, K. G., & Gilbert, J. J. (1984). Body size and food size in freshwater Zooplankton. *Proceedings of the National Academy of Sciences*, *81*(20), 6427-6431.

Boon, P. I., Bunn, S. E., Green, J. D., & Shiel, R. J. (1994). Consumption of cyanobacteria by freshwater Zooplankton: Implications for the success of'top-down'control of cyanobacterial blooms in Australia. *Marine and Freshwater Research, 45*(5), 875-887.

Bora, M., & Goswami, D. C. (2017). Water quality assessment in terms of water quality index (WQI): case study of the Kolong River, Assam, India. *Applied Water Science, 7*(6), 3125-3135.

Boxshall, G. A., & Defaye, D. (2008). Global diversity of copepods (Crustacea: Copepoda) in freshwater. *Freshwater animal diversity assessment*, 195-207.

Boyd, C. E., Tucker, C. S., & Somridhivej, B. (2016). Alkalinity and hardness: critical but elusive concepts in aquaculture. *Journal of the World Aquaculture Society, 47*(1), 6-41.

Boyles, W. (1997). Chemical oxygen demand. *Technical information series, Booklet,(9), 24*.

Branco, C. W., Rocha, M. I. A., Pinto, G. F., Gômara, G. A., & Filippo, R. D. (2002). Limnological features of Funil Reservoir (RJ, Brazil) and indicator properties of rotifers and cladocerans of the Zooplankton community. *Lakes & Reservoirs: Research & Management, 7*(2), 87-92.

Brandl, Z. (2005). Freshwater copepods and rotifers: predators and their prey. *Hydrobiologia*, *546*(1), 475-489.

Brendonck, L., & De Meester, L. (2003). Egg banks in freshwater Zooplankton: evolutionary and ecological archives in the sediment. *Hydrobiologia*, *491*(1-3), 65-84.

Brooks, J. L., & Dodson, S. I. (1965). Predation, body size, and composition of plankton. *Science*, *150*(3692), 28-35.

Brown, P. D., Schröder, T., Ríos-Arana, J. V., Rico-Martinez, R., Silva-Briano, M., Wallace, R. L., & Walsh, E. J. (2020). Patterns of Rotifer Diversity in the Chihuahuan Desert. *Diversity*, *12*(10), 393.

Castro, B. B., Antunes, S. C., Pereira, R., Soares, A. M., & Goncalves, F. (2005). Rotifer community structure in three shallow lakes: seasonal fluctuations and explanatory factors. *Hydrobiologia*, *543*(1), 221-232.

Chambers, L. G., Steinmuller, H. E., & Breithaupt, J. L. (2019). Toward a mechanistic understanding of "peat collapse" and its potential contribution to coastal wetland loss. *Ecology*, *100*(7), e02720.

Chari, T. J., Mahender, J., Kumar, A. S., & Rajashekhar, A. (2013). Zooplankton Diversity, Abundance and Seasonal Variation of Nagulakunta Water Tank, Vinjapally, Karimnagar Dist, Telangana State, India.

Chen, G. (2020). Analysis on the changes of Zooplankton in the restoration of urban lake water. *In IOP Conference Series: Earth and Environmental Science*, *525*(1), 012010.

Chennakrishnan, C., Stephen, A., Manju, T., & Raveen, R. (2008). Water Quality status of three vulnerable freshwater Lakes of Suburban Chennai, India. *Ind. J. Environ. Ecoplan*, *15*(3), 591-596.

Chittapun, S., Pholpunthin, P., & Segers, H. (2007). Diversity of rotifer fauna from five coastal peat swamps on Phuket Island, Southern Thailand. *ScienceAsia, 33*, 383-387.

Choi, J. Y., Jeong, K. S., Kim, S. K., La, G. H., Chang, K. H., & , & Joo, G. J. (2014). Role of macrophytes as microhabitats for Zooplankton community in lentic freshwater ecosystems of South Korea. *Ecological informatics,, 24*, 177-185.

Cieplinski, A., Weisse, T., & Obertegger, U. (2017). High diversity in Keratella cochlearis (Rotifera, Monogononta): morphological and genetic evidence. *Hydrobiologia, 796*(1), 145-159.

Cleetus, R. I., Asha, C. V., Suson, P. S., & Nandan, S. B. (2016). MesoZooplankton abundance and community structure in vembanad-kol wetland ecosystem, kerala, India. *Indian journal of Gio-Marine Sciences, 45*(4), 533-545.

Cohen, G. M., & Shurin, J. B. (2003). Scale-dependence and mechanisms of dispersal in freshwater Zooplankton. *Oikos, 103*(603-617).

Collado, C., Fernando, C., & Sephton, D. (1984). The freshwater Zooplankton of Central America and the Caribbean *Tropical Zooplankton* (pp. 105-119): Springer.

Colter, A., & Mahler, R. L. (2006). *Iron in drinking water*: University of Idaho Moscow.

Contreras, J. J., Sarma, S., Merino-Ibarra, M., & Nandini, S. (2009). Seasonal changes in the rotifer (Rotifera) diversity from a tropical high altitude reservoir (Valle de Bravo, Mexico). *Journal of Environmental Biology, 30*(2), 191-195.

Corgosinho, P. H. C., Hołyńska, M., Marrone, F., de Oliveira Geraldes-Primeiro, L. J., dos Santos-Silva, E. N., Perbiche-Neves, G., & López, C. (2019). An annotated checklist of freshwater Copepoda (Crustacea, Hexanauplia) from continental Ecuador and the Galapagos Archipelago. *ZooKeys, 871*, 55.

Cornils, A., & Held, C. (2014). Evidence of cryptic and pseudocryptic speciation in the Paracalanus parvus species complex (Crustacea, Copepoda, Calanoida). *Frontiers in zoology, 11*(1), 1-17.

Coviaga, C., Cusminsky, G., & Pérez, P. (2018). Ecology of freshwater ostracods from Northern Patagonia and their potential application in paleo-environmental reconstructions. *Hydrobiologia, 816*(1), 3-20.

Cristescu, M. E., Constantin, A., Bock, D. G., Caceres, C. E., & Crease, T. J. (2012). Speciation with gene flow and the genetics of habitat transitions. *Molecular ecology, 21*(6), 1411-1422.

Da Silva Brito, Tábatha, M., Diniz, L. P., Pozzobom, U. M., Landeiro, V. L., & Sousa, F. D. R. (2020). *Cladocera (Crustacea: Branchiopoda) from the state of Mato Grosso, Brazil-Biodiversity of Cladocera (Crustacea: Branchiopoda) from the state of Mato Grosso, Brazil: new records and species richness in hydrographic regions.* Paper presented at the Annales de Limnologie-International Journal of Limnology.

Da Silva, N. J., Lansac-Tôha, F. M., Lansac-Tôha, F. A., Sales, P. C. L., & , & Rocha, J. D. R. S. (2020). Beta diversity patterns in Zooplankton assemblages from a semiarid river ecosystem. *International Review of Hydrobiology*.

Dalal, A., & Gupta, S. (2013). Plankton diversity of two temple ponds of Silchar, Assam, North east India. *International Journal of Science and Nature, 4*(1), 79-83.

Das, B. K., & Kar, D. (2016). Diversity of Zooplankton in River Siang of Arunachal Pradesh, India.

Dastgeer, G., Hussain, M., Aftab, K., Tufail, M., Malik, M., Umar, M., & Sajid, M. (2020). Seasonal distribution of rotifer diversity in selected fish ponds and Marala Headworks Sialkot, Pakistan. *J Animal and Plant Sci, 30*(5), 1298-1308.

Datta, T. (2011). Zooplankton diversity and physicochemical conditions of two wetlands of Jalpaiguri district, India. *International Journal of Applied Biology and Pharmaceutical Technology, 2*(3), 576-583.

De Meester, L. (1996). Local genetic differentiation and adaptation in freshwater Zooplankton populations: patterns and processes. *Ecoscience, 3*(4), 385-399.

De Stasio Jr, B. T. (1990). The role of dormancy and emergence patterns in the dynamics of a freshwater Zooplankton community. *Limnology and Oceanography, 35*(5), 1079.

Decker, M. B., Breitburg, D. L., & Purcell, J. E. (2004). Effects of low dissolved oxygen on Zooplankton predation by the ctenophore Mnemiopsis leidyi. *Marine Ecology Progress Series, 280*, 163-172.

Dede, A., & Deshmukh, A. (2015). Study on Zooplankton composition and seasonal variation in Bhima river near Ramwadi village, Solapur district (Maharashtra), India. *Int. J. Curr. Microbiol. App. Sci, 4*(3), 297-306.

Desrosiers, C., Leflaive, J., Eulin, A., & Ten-Hage, L. (2013). Bioindicators in marine waters: benthic diatoms as a tool to assess water quality from eutrophic to oligotrophic coastal ecosystems. *Ecological indicators, 32*, 25-34.

Dhanasekaran, M., Bhavan, P. S., Manickam, N., & Kalpana, R. (2017). Physico-chemical characteristics and Zooplankton diversity in a perennial lake at Dharmapuri (Tamil Nadu, India). *Journal of Entomology and Zoology Studies, 5*(1), 285-292.

Diel, P., Kiene, M., Martin-Creuzburg, D., & Laforsch, C. (2020). Knowing the Enemy: Inducible Defences in Freshwater Zooplankton. *Knowing the Enemy: Inducible Defences in Freshwater Zooplankton, 12*(4), 147.

Divya, K. R., Zhao, S., Chen, Y., Cheng, F., Zhang, L., Qin, J., . . . Xie, S. (2020). A comparison of Zooplankton assemblages in Nansi Lake and Hongze Lake, potential influences of the East Route of the South-to-North Water Transfer Project, China. *Journal of Oceanology and Limnology*, 1-14.

DJ, M. K. H. (2009). Ostracoda. *Encyclopedia of inland waters, 2*, 405-414.

Dodson, S., & Frey, D. (1991). Cladocera and other branchiopoda. p. 723–726.

Duarte, C. M., & Agustí, S. (1998). The CO2 balance of unproductive aquatic ecosystems. *Science, 281*(5374), 234-236.

Duggan, I., Green, J., & Shiel, R. (2001). Distribution of rotifers in North Island, New Zealand, and their potential use as bioindicators of lake trophic state *Rotifera IX* (pp. 155-164): Springer.

Duggan, I. C., Green, J. D., Thompson, K., & Shiel, R. J. (1998). Rotifers in relation to littoral ecotone structure in Lake Rotomanuka, North Island, New Zealand *Rotifera VIII: A Comparative Approach* (pp. 179-197): Springer.

Durairaju, R., & SIivakami, R. (2020). A Seasonal Assessment of Zooplankton Diversity in relation to Pisciculture in a Fresh Water System at Kumbakonam, Tamil Nadu, India. *Journal of Natural Remedies, 21*(6).

Dutta, A., Kar, S., Das, P., Das, U., Das, S., & Kar, D. (2017). Studies on physico-chemical aspects and Zooplankton diversity of a freshwater wetland in Cachar, Assam. *International Journal of Science, Environment and Technology, 6*(3).

Efe, S., Ogban, F., Horsfall, M. J., & Akporhonor, E. (2005). Seasonal variations of physico-chemical characteristics in water resources quality in western Niger Delta region, Nigeria. *Journal of Applied Sciences and Environmental Management, 9*(1), 191-195.

Ekhande, A., Patil, J., Patil, R., & Padate, G. (2013). Water quality monitoring-study of seasonal variation of rotifer and their correlation with physicochemical parameters of Yashwant Lake, Toranmal (MS) India. *Archives of Applied Science Research, 5*(1), 177-181.

El-Feky, M. M., E Alprol, A., MM Heneash, A., A Abo-Taleb, H., & Y Omer, M. (2019). Evaluation of water quality and plankton for Mahmoudia Canal in

Northern West of Egypt. *Egyptian Journal of Aquatic Biology and Fisheries, 22*(5 (Special Issue)), 461-474.

Elías-Gutiérrez, M., Suárez-Morales, E., & Sarma, S. (2001). Diversity of freshwater Zooplankton in the neotropics: the case of Mexico. *Internationale Vereinigung für theoretische und angewandte Limnologie: Verhandlungen, 27*(7), 4027-4031.

Eliku, T., & Leta, S. (2018). Spatial and seasonal variation in physicochemical parameters and heavy metals in Awash River, Ethiopia. *Applied Water Science, 8*(6), 1-13.

Eskinazi-Sant'Anna, E. M., Santos, G. D. S., Alves, N. J. D. S., Brito, L. A. F., & Leite, M. G. P. (2020). The relative importance of regional and local factors in shaping Zooplankton diversity in high-altitude tropical shallow lakes. *Journal of Freshwater Ecology*, 203-221.

Espinosa-Rodríguez, C. A., Sarma, S. S. S., & Nandini, S. . (2020). Zooplankton community changes in relation to different macrophyte species: Effects of Egeria densa removal. *Ecohydrology & Hydrobiology*.

Etile, R. N. d., Bédia, T. A., Blahoua, G. K., Bi, G. G., Bi, P. E., Kouamelan, P. E., & N'Douba, V. (2020). Checklist and Distribution of Freshwater Cladocera (Crustacea: Branchiopoda) in Cote d'Ivoire (West Africa). *Zoological Studies, 59*.

Fathibi, K. S., A.V, & Aneesh, E.M. (2020). Species composition and abundance of rotifers (Rotifera: Eurotatoria) in Thrissur Kole wetland, Kerala, India. *Egyptian Journal of Aquatic Biology and Fisheries, 24*(6), 439-451.

Fefilova, E., Dubovskaya, O., Kononova, O., & Khokhlova, L. (2013). A comparative survey of the freshwater copepods of two different regions of the Central Palaearctic: European and Siberian. *Journal of Natural History, 47*(5-12), 805-819.

Fernando, C. (1980). The freshwater Zooplankton of Sri Lanka, with a discussion of tropical freshwater Zooplankton composition. *Internationale Revue der gesamten Hydrobiologie und Hydrographie, 65*(1), 85-125.

Florencio, M., Fernández-Zamudio, R., Lozano, M., & Díaz-Paniagua, C. (2020). Interannual variation in filling season affects Zooplankton diversity in Mediterranean temporary ponds. *Hydrobiologia, 847*(5), 1195-1205.

Fontaneto, D. (2014). Molecular phylogenies as a tool to understand diversity in rotifers. *International Review of Hydrobiology, 99*(1-2), 178-187.

Forró, L., Korovchinsky, N. M., Kotov, A. A., & Petrusek, A. (2007). Global diversity of cladocerans (Cladocera; Crustacea) in freshwater. *Hydrobiologia*, 177-184.

Freiry, R. F., Gouvea, A., Becker, J., Lansac-Tôha, F. A., Lansac-Tôha, F. M., Pires, M. M., & Maltchik, L. (2020). Community structure and concordance patterns among Zooplankton life stages in subtropical temporary ponds. *Aquatic Ecology, 54*(1), 257-270.

Früh, L., Kampen, H., Schaub, G. A., & Werner, D. (2019). Predation on the invasive mosquito Aedes japonicus (Diptera: Culicidae) by native copepod species in Germany. *Journal of Vector Ecology, 44*(2), 241-247.

Fryer, G. (1957). *The feeding mechanism of some freshwater cyclopoid copepods.* Paper presented at the Proceedings of the Zoological Society of London.

Gadekar, G. (2014). Seasonal Variations in Zooplankton Diversity of Railway Pond, Gondia, District Gondia (MS). *International Journal of Life Sciences*, 169-171.

Geller, J., Meyer, C., Parker, M., & Hawk, H. (2013). Redesign of PCR primers for mitochondrial cytochrome c oxidase subunit I for marine invertebrates and application in all-taxa biotic surveys. *Molecular ecology resources, 13*(5), 851-861.

George, G. (2011). Brachionid rotifer diversity in Andaman waters.

George, S., & Martens, K. (2003). On a new species of the genus Newnhamia King, 1855 (Crustacea, Ostracoda) raised from Chalakkudy River sand,(Kerala, India), with notes on the taxonomy and distribution of the Notodromadidae. *Hydrobiologia, 497*(1-3), 25-37.

George, S., & Martens, K. (2002). *On a new species of Potamocypris (Crustacea, Ostracoda) from Chalakkudy River, Kerala (India), with a checklist of the Potamocypris-species of the world*: Magnolia Press.

George, S., & Martens, K. (2004). On the taxonomic position of Indiacypridinae (Crustacea, Ostracoda), with the description of a new species of Indiacypris Hartmann, 1964 from Chalakkudy River (Kerala, India). *Journal of Natural History, 38*(5), 537-548.

Gerakis, A., & Kalburtji, K. (1998). Agricultural activities affecting the functions and values of Ramsar wetland sites of Greece. *Agriculture, ecosystems & environment, 70*(2-3), 119-128.

Geraldes, A. M., & Boavida, M.-J. (2007). Zooplankton assemblages in two reservoirs: one subjected to accentuated water level fluctuations, the other with more stable water levels. *Aquatic Ecology, 41*(2), 273-284.

Ghosh, D., & Biswas, J. K. (2015). Zooplankton Diversity Indices: Assessment of an Ox-Bow Lake Ecosystem for Sustainable Management in West Bengal. *International Journal of Advanced Biotechnology and Research, 6*(1), 37-43.

Gieskes, W. (1971). Ecology of the Cladocera of the North Atlantic and the North Sea, 1960–1967. *Netherlands Journal of Sea Research, 5*(3), 342-376.

Gleick, P. H. (1993). Water in crisis. *Pacific Institute for Studies in Dev., Environment & Security. Stockholm Env. Institute, Oxford Univ. Press. 473p, 9*, 1051-0761.

Gonçalves, A. M. M., Azeiteiro, U. M., Pardal, M. A., & De Troch, M. (2012). Fatty acid profiling reveals seasonal and spatial shifts in Zooplankton diet in a temperate estuary. *Estuarine, coastal and shelf science, 109*, 70-80.

Goździejewska, A. M., Skrzypczak, A. R., Koszałka, J., & Bowszys, M. (2020). Effects of recreational fishing on Zooplankton communities of drainage system reservoirs at an open-pit mine. *Fisheries Management and Ecology, 27*(3), 279-291.

Grosell, M., Gerdes, R. M., & Brix, K. V. (2006). Chronic toxicity of lead to three freshwater invertebrates—Brachionus calyciflorus, Chironomus tentans, and Lymnaea stagnalis. *Environmental Toxicology and Chemistry: An International Journal, 25*(1), 97-104.

Guevara, G., Lozano, P., Reinoso, G., & Villa, F. (2009). Horizontal and seasonal patterns of tropical Zooplankton from the eutrophic Prado Reservoir (Colombia). *Limnologica, 39*(2), 128-139.

Güntzel, A. M., Panarelli, E. A., da Silva, W. M., & Roche, K. F. (2010). Influence of connectivity on Cladocera diversity in oxbow lakes in the Taquari River floodplain(MS, Brazil). *Acta Limnologica Brasiliensia, 22*(1), 93-101.

Guo, K., Zhao, W., & Yin, S. (2010). Relationship between eutrophication status of the water body and rotifer community structure in Guanting Reservoir, Beijing. *J Lake Sci, 2*, 256-264.

Gutiérrez-Aguirre, M., & Suárez-Morales, E. (2001). Diversity and distribution of freshwater copepods (Crustacea) in southeastern Mexico. *Biodiversity & Conservation, 10*(5), 659-672.

Gutiérrez, S. G., Sarma, S., & Nandini, S. (2017). Seasonal variations of rotifers from a high altitude urban shallow water body, La Cantera Oriente (Mexico City, Mexico). *Chinese Journal of Oceanology and Limnology, 35*(6), 1387-1397.

Gyllström, M., & Hansson, L. A. . (2004). Dormancy in freshwater Zooplankton: induction, termination and the importance of benthic-pelagic coupling. *Aquatic Sciences, 66*(3), 274-295.

Hairston Jr, N. G., Van Brunt, R. A., Kearns, C. M., & Engstrom, D. R. (1995). Age and survivorship of diapausing eggs in a sediment egg bank. *Ecology, 76*(6), 1706-1711.

Hairston, N. G., & Cáceres, C. E. (1996). Distribution of crustacean diapause: micro- and macroevolutionary pattern and process. *Hydrobiologia, 320*(1-3), 27-44.

Halabowski, D., Bielańska-Grajner, I., & Lewin, I. (2019). Effect of underground salty mine water on the rotifer communities in the Bolina River (Upper Silesia, Southern Poland). *Knowledge & Management of Aquatic Ecosystems*(420), 31.

Hanazato, T. P. e. o. f. z. a. e. p. E. p., 112(1), 1-10. (2001). Pesticide effects on freshwater Zooplankton: an ecological perspective. *Environmental pollution, 112*(1), 1-10.

Harkal, A. D., & Mokashe, S. S. (2015). An Assessment of periphytic fauna of Kagzipura Lake, District Aurangabad, Maharashtra, India. *Journal of Basic Sciences, 1*, 34-38.

Hartfield, M., Wright, S. I., & Agrawal, A. F. (2016). Coalescent times and patterns of genetic diversity in species with facultative sex: effects of gene conversion, population structure, and heterogeneity. *Genetics, 202*(1), 297-312.

Havel, J. E., & Shurin, J. B. (2004). Mechanisms, effects, and scales of dispersal in freshwater Zooplankton. *Limnology and Oceanography, 49*(4(part2)), 1229-1238.

Hays, G. C. (2003). A review of the adaptive significance and ecosystem consequences of Zooplankton diel vertical migrations. *Migrations and dispersal of marine organisms*, 163-170.

Heinle, D. R. (1969). Temperature and Zooplankton. *Chesapeake Science, 10*(3-4), 186-209.

Helaouët, P., & Beaugrand, G. (2009). Physiology, ecological niches and species distribution. *Ecosystems, 12*(8), 1235-1245.

Hillbricht-Ilkowska, A. (1983). Morphological variation of Keratella cochlearis (Gosse) in Lake Biwa, Japan *Biology of Rotifers* (pp. 297-305): Springer.

Hudson, C. T., & Gosse, P. H. (1886). *The Rotifera or wheel-animalcules* (Vol. 1): Longmans, Green.

Iloba, K. I., & Arebun, B. (2020). Comparative Study on Water Variables and plankton diversity of earthen Fish Ponds along River Ethiope. *IOSR Journal of Environmental Science, Toxicology and Food Technology, 14*(6), 1-8.

Indur, B., Reddy, R., & Vijaykumar, K. (2016). Seasonal Variation in Primary Productivity of Freshwater Reservoirs of Yadigir District, Karnataka, India. *International Journal of Environment, Agriculture and Biotechnology, 1*(2).

Islam, M. S., Azadi, M. A., Nasiruddin, M., & Islam, M. S. (2020). Zooplankton abundance, diversity and its relationship with physicochemical parameters of three ponds in Chittagong University campus, Bangladesh. *International Journal of Fisheries and Aquatic Studies, 8*(3), 626-632.

Jaiswal, D., Ahirrao, K., & Shejule, K. (2014). Study of Zooplankton population in a freshwater, Rangavali Dam, Navapur, Dist-Nandurbar (MS) India.

Jalilzadeh, A. K., Yamakanamardi, S. M., & Altaff, K. (2007). *Abundance of Zooplankton in three contrasting lakes of Mysore city, Karnataka state, India.* Paper presented at the Proceedings of Taal2007: The 12th World Lake Conference.

Janssen, C. R., Rodrigo, M. D. F., & Persoone, G. (1993). *Ecotoxicological studies with the freshwater rotifer Brachionus calyciflorus*, Dordrecht.

Jeppesen, E., Nõges, P., Davidson, T. A., Haberman, J., Nõges, T., Blank, K., . . . Laugaste, R. (2011). Zooplankton as indicators in lakes: a scientific-based plea for including Zooplankton in the ecological quality assessment of lakes according to the European Water Framework Directive (WFD). *Hydrobiologia, 676*(1), 279.

Jewson, D., & Taylor, J. (1978). The influence of turbidity on net phytoplankton photosynthesis in some Irish lakes. *Freshwater Biology, 8*(6), 573-584.

JI, N. K., Das, M., Mukherji, R., & Kumar, R. N. (2011). Assessment of Zooplankton diversity of a tropical wetland system. *Int. J. of Pharm. & Life Sci.(IJPLS), 2*(8), 983-990.

Johnkutty, I., & Venugopal, V. (1993). Kole lands of Kerala. *Kerala Agricultural University, Vellanikkara, Thrissur, Kerala.*, 68 p.

Johnston, C. A. (1991). Sediment and nutrient retention by freshwater wetlands: effects on surface water quality. *Critical Reviews in Environmental Science and Technology, 21*(5-6), 491-565.

Jomet, S. K., & Yamakanamardi, S. M. (2013). Assessment of Water Quality Index of Cauvery and Kapila rivers and at their confluence. *International Journal of Lakes and rivers, 6*(1), 59-67.

Jose, D., & Senthilkumaar, P. (2015). Physicochemical Parameters and Zooplankton Diversity in Anicadu Chira, Kerala, India. *International Research Journal of Biological Sciences 4*(11), 55-60.

Jose, R., & Sanalkumar, M. (2012). Seasonal variations in the Zooplankton diversity of River Achencovil. *International Journal of Scientific and Research Publications, 2*(11), 1-5.

Joshi, P. S. (2011). Studies on Zooplanktons of Rajura lake of Buldhana district, Maharashtra India. *Science Research Reporter, 1*(3), 132-137.

Junk, W. J., Piedade, M. T. F., Lourival, R., Wittmann, F., Kandus, P., Lacerda, L. D., . . . Maltchik, L. (2014). Brazilian wetlands: their definition, delineation, and classification for research, sustainable management, and protection. *Aquatic Conservation: marine and freshwater ecosystems, 24*(1), 5-22.

Kadam, S. S. (2016). Macrophytes From Bhogaon Reservoir in Parbhani District, Maharashtra.

Kamboj, V., & Kamboj, N. (2020). Spatial and temporal variation of Zooplankton assemblage in the mining-impacted stretch of Ganga River, Uttarakhand, India. *Environmental Science and Pollution Research*, 1-12.

Kar, S., Das, P., Das, U., Bimola, M., Kar, D., & Aditya, G. (2018). Correspondence of Zooplankton assemblage and water quality in wetlands of Cachar, Assam, India: Implications for environmental management. *Limnological Review, 18*(1), 9-19.

Kar, S., & Kar, D. (2016a). Zooplankton diversity of a freshwater perennial pond in Silchar city of Assam, India. *American International Journal of Research in Formal, Applied and Natural Sciences, 14*(1), 10-14.

Kar, S., & Kar, D. (2016b). Zooplankton diversity of a freshwater wetland of Assam. *International Journal of Advanced Biotechnology and Research, 7*(2), 614-620.

Karpowicz, M., Ejsmont-Karabin, J., Kozłowska, J., Feniova, I., & Dzialowski, A. R. (2020). Zooplankton Community Responses to Oxygen Stress. *Water, 12*(3), 706.

Karuthapandi, M., Rao, D., & Innocent, B. X. (2015). Rotifer diversity of Osmansagar Reservoir, Hyderabad, Telangana, India. *Records of the Zoological Survey of India, 115*(1), 39-49.

Karuthapandi, M., Xavier Innocent, B., & Siddiqi, S. (2012). Zooplankton in a temporary freshwater pond habitat, in Attapur, Hyderabad Andhra Pradesh, India. *International Journal of Advanced Life Sciences (IJALS), 1*, 22-31.

Kelly, W., Panno, S., & Hackley, K. (2012). The Sources, Distribution, and Trends of Chloride in Waters of Illinois. *Bulletin (Illinois State Water Survey) no. 74*.

Kim, S.-K., Kim, J.-C., Joo, G.-J., & Choi, J.-Y. (2020). Response of the rotifer community to human-induced changes in the trophic state of a reservoir. *Oceanological and Hydrobiological Studies, 49*(4), 329-344.

Kiss, A., Ágoston-Szabó, E., Dinka, M., Schöll, K., & Berczik, Á. (2014). Microcrustacean (Cladocera, Copepoda, Ostracoda) diversity in three side arms in the Gemenc Floodplain (Danube River, Hungary) in different hydrological situations. *Acta Zool Bulg (Suppl.), 7*, 135-141.

Klemetsen, A., Aase, B. M., & Amundsen, P. A. . (2020). Diversity, abundance, and life histories of littoral chydorids (Cladocera: Chydoridae) in a subarctic European lake. *The Journal of Crustacean Biology, 40*(5), 534-543.

Kobayashi, T., Shiel, R., Gibbs, P., & Dixon, P. (1998). Freshwater Zooplankton in the Hawkesbury-Nepean River: comparison of community structure with other rivers. *Hydrobiologia, 377*(1), 133-145.

Koli, K., & Muley, D. (2012). Study of Zooplankton diversity and seasonal variation with special reference to physicochemical parameters in Tulshi Reservoir of Kolhapur District (MS), India. *E-International Scientific Research Journal, 4*(1), 38-46.

Kordbacheh, A., Wallace, R. L., & Walsh, E. J. (2018). Evidence supporting cryptic species within two sessile microinvertebrates, Limnias melicerta and L. ceratophylli (Rotifera, Gnesiotrocha). *PloS one, 13*(10), e0205203.

Korhola, A. (1999). Distribution patterns of Cladocera in subarctic Fennoscandian lakes and their potential in environmental reconstruction. *Ecography, 22*(4), 357-373.

Korhola, A., & Rautio, M. (2001). Cladocera and other branchiopod crustaceans. In Tracking environmental change using lake sediments. *Springer, Dordrecht*, 5-41.

Koste, W. (1980). Brachionus plicatilis, ein Salzwasser-radertier. *Mikrokosmos, 69*, 148-155.

Koste, W., & Shiel, R. J. (1987). *Tasmanian Rotifera: affinities with the Australian fauna*. Paper presented at the Rotifer Symposium IV.

Kožíšek, F. (2003). Health significance of drinking water calcium and magnesium. *National Institute of Public Health, 29*, 9285.9286-9203.

Kuczyńska-Kippen, N. (2020b). Biodiversity of Zooplankton in Polish Small Water Bodies. *In Polish River Basins and Lakes–Part II*, 55-76.

Kuczyńska-Kippen, N. (2020a). Response of Zooplankton Indices to Anthropogenic Pressure in the Catchment of Field Ponds. *Water, 12*(3), 758.

Kuczynska-Kippen, N., & Ejsmont-Karabin, J. (2020). Rotifera of various aquatic environments of Costa Rica in reference to Central American rotifer fauna. *Turkish Journal of Zoology, 44*(3), 238-247.

Kuczyńska-Kippen, N., Špoljar, M., Zhang, C., & Pronin, M. (2020). Zooplankton functional traits as a tool to assess latitudinal variation in the northern-southern temperate European regions during spring and autumn seasons. *Ecological Indicators, 117*, 106629.

Külköylüoğlu, O. (2003). Ecology of freshwater Ostracoda (Crustacea) from lakes and reservoirs in Bolu, Turkey. *Journal of Freshwater Ecology, 18*(3), 343-347.

Külköylüoğlu, O. (2004). On the usage of ostracods (Crustacea) as bioindicator species in different aquatic habitats in the Bolu region, Turkey. *Ecological Indicators, 4*(2), 139-147.

Külköylüoğlu, O. (2013). Diversity, distribution and ecology of nonmarine Ostracoda (Crustacea) in Turkey: application of pseudorichness and cosmoecious species concepts. *Recent Research Development in Ecology, 4*, 1-18.

Külköylüoğlu, O., & Sarı, N. (2012). Ecological characteristics of the freshwater Ostracoda in Bolu Region (Turkey). *Hydrobiologia, 688*(1), 37-46.

Külköylüoĝlu, O., & Vinyard, G. L. (2000). Distribution and ecology of freshwater Ostracoda (Crustacea) collected from springs of Nevada, Idaho, and Oregon: a preliminary study. *Western North American Naturalist*, 291-303.

Külköylüoğlu, O., Yavuzatmaca, M., Akdemir, D., & Sari, N. (2012). Distribution and local species diversity of freshwater Ostracoda in relation to habitat in the Kahramanmaraş Province of Turkey. *International Review of Hydrobiology, 97*(4), 247-261.

Külköylüoğlu, O., Yavuzatmaca, M., Sarı, N., & Akdemir, D. (2016). Elevational distribution and species diversity of freshwater Ostracoda (Crustacea) in Çankırı region (Turkey). *Journal of Freshwater Ecology, 31*(2), 219-230.

kulSharma, B. K., & Noroh, N. (2020). Zooplankton diversity of three floodplain lakes of the Dibru-Saikhowa Biosphere reserve, upper Assam, northeast India. *International Journal of Aquatic Biology, 8*(1), 18-34.

kumar Dutta, T., & Patra, B. C. (2013). Biodiversity and seasonal abundance of Zooplankton and its relation to physico–chemical parameters of Jamunabundh, Bishnupur, India. *International Journal of Scientific and Research Publications, 76*.

Kumar, H. K., Kiran, B., & Narayana, J. (2015). Diversity of Zooplankton in sewage fed tank of Bhadravathi Taluk, Karnataka

Kumar, P., Wanganeo, A., Sonaullah, F., & Wanganeo, R. (2012). Limnological study on two high altitude Himalayan Ponds, Badrinath, Uttarakhand. *International Journal of Ecosystem, 2*(5), 103-111.

Kumar, P., Wanganeo, A., Wanganeo, R., & Sonaullah, F. (2011). Seasonal variations in Zooplankton diversity of railway pond, Sasaram, Bihar. *International Journal of Environmental Sciences, 2*(2), 1007-1016.

Kumar, P. A., Balakrishna, D., & Jangir, O. (2020). Abundance of Zooplankton and Physico Chemical Properties of Kamareddy Town Lake, Telangana. *Uttar Pradesh Journal of Zoology*, 15-20.

Kumar, S., Stecher, G., & Tamura, K. (2016). MEGA7: molecular evolutionary genetics analysis version 7.0 for bigger datasets. *Molecular biology and evolution, 33*(7), 1870-1874.

Kumar, S. D., & Rakhi, U. (2018). A study of seasonal variations in Zooplankton diversity of Pagara dam of Morena district, Madhya Pradesh, India. *Int. J. of Life Sciences, 6*(2), 409-414.

Kumar, T. A., & Nadim, C. (2012). Rotifer Diversity in a Semiurban Shallow Perrenial Water Body: A Case Study of Jalaser Tank Mandalgarh, India. *Int. Res. J. Environment Sci, 1*(1), 42-45.

Ladipo, M., Ajibola, V., & Oniye, S. (2011). Seasonal variations in physicochemical properties of water in some selected locations of the Lagos Lagoon. *Science World Journal, 6*(4), 5-11.

Langan, S., Donald, L., Donaghy, M., Hay, D., & Soulsby, C. (2001). Variation in river water temperature in a Scottish highland stream over a 30 year period. *Science of the Total Environment, 265*(1-3), 199-212.

Latif, U., & Dickert, F. L. (2015). Chemical oxygen demand *Environmental Analysis by Electrochemical Sensors and Biosensors* (pp. 719-728): Springer.

Leasi, F., Tang, C. Q., De Smet, W. H., & Fontaneto, D. (2013). Linneanus Zoological.

LeRoy, P. (1995). Troubled waters: population and water scarcity. *Colo. J. Int'l Envtl. L. & Pol'y, 6*, 299.

Lessard, J. L., & Hayes, D. B. . (2003). Effects of elevated water temperature on fish and macroinvertebrate communities below small dams. *River research and applications, 19*(7), 721-732.

Li, Y., Zhao, H., Hu, L., & Leppänen, J. J. (2020). Cladoceran communities in soda lakes of the Badain Jaran desert, NW China. *Journal of Arid Environments, 177*, 104133.

Litvinchuk, L. F. (2018). Zooplankton of mountain and lowland water bodies of northwestern India. *Proceeding of the Zoological institute of Russian Academy of Sciences, 322*(1), 66-83.

Liu, P., Xu, S. L., Liao, J., Dumont, H. J., & Han, B. P. . (2020). Development of microsatellite markers for Diaphanosoma dubium (Crustacea, Cladocera) and application to seasonal population dynamics. *Aquatic Ecology*, 1-18.

Liu, P., Xu, S., Lin, J., Li, H., Lin, Q., & Han, B. P. (2020). Urbanization increases biotic homogenization of Zooplankton communities in tropical reservoirs. *Ecological Indicators, 110*(105899).

Livingstone, D. M., & Lotter, A. F. (1998). The relationship between air and water temperatures in lakes of the Swiss Plateau: a case study with pal\sgmaelig; olimnological implications. *Journal of Paleolimnology, 19*(2), 181-198.

Lloyd, D. S., Koenings, J. P., & Laperriere, J. D. (1987). Effects of turbidity in fresh waters of Alaska. *North American Journal of Fisheries Management, 7*(1), 18-33.

Lopez, M. L. D., & Papa, R. D. S. (2020). Diversity and distribution of copepods (Class: Maxillopoda, Subclass: Copepoda) in groundwater habitats across South-East Asia. *Marine and Freshwater Research, 71*(3), 374-383.

Lower, S. K. (1999). Carbonate equilibria in natural waters. *Simon Fraser University, 544*.

Lund, J. W. G. (1972). Eutrophication. *Proceedings of the Royal Society of London. Series B. Biological Sciences, 180*(1061), 371-382.

Mäemets, A. (1983). Rotifers as indicators of lake types in Estonia. *Hydrobiologia, 104*(1), 357-361.

Mahesh, T., Balakrishna, D., Surender Reddy, K., & Ravinder Reddy, T. (2015). A Study of Zooplankton diversity and their seasonal variation in Kandlapally lake, Jagtial, Telangana. *Int, J of Sci & Enging, 1*(2), 20.

Majagi, S., & Vijaykumar, K. (2009). Ecology and abundance of Zooplankton in Karanja reservoir. *Environmental monitoring and assessment, 152*(1), 451-458.

Majumder, S., Dhua, R. P., Kar, S., Mishra, T., Mahapatra, S. S., Shit, S., & Patra, A. (2015). Zooplankton diversity influenced by hydro biological parameters in some ponds of south eastern part of Bankura town of WB, India. *International Journal of Advanced Research, 3*, 354-368.

Makino, W., Machida, R. J., Okitsu, J., & Usio, N. (2020). Underestimated species diversity and hidden habitat preference in Moina (Crustacea, Cladocera) revealed by integrative taxonomy. *Hydrobiologia, 847*(3), 857-878.

Mamaril, A. C. (2001). *Zooplankton diversity in Philippine lakes.* Paper presented at the Conservation and Ecological Management of Philippine Lakes in Relation to Fisheries and Aquaculture: Proceedings of the National Seminar-Workshop held on October 21-23, 1997, INNOTECH, Commonwealth Ave., Diliman, Quezon City, Philippines.

Manickam, Bhavan, P. S., Santhanam, P., Muralisankar, T., Srinivasan, V., Vijayadevan, K., & , & Bhuvaneswari, R. (2015). Biodiversity of freshwater Zooplankton and physico-chemical parameters of Barur Lake, Krishnagiri District, Tamil Nadu, India. *Malaya Journal Bioscience, 2*, 1-12.

Manickam, N., Bhavan, P., Santhanam, P., Muralisankar, T., Srinivasan, V., Radhakrishnan, S., Ali, A. (2014). Seasonal variations of Zooplankton diversity in a perennial reservoir at Thoppaiyar, Dharmapuri District, South India. *Austin. J. Aquacul. Mar. Biol, 1*, 1-7.

Manickam, N., Bhavan, P. S., Santhanam, P., Bhuvaneswari, R., Muralisankar, T., Srinivasan, V., Karthik, M. (2018). Impact of seasonal changes in Zooplankton biodiversity in Ukkadam Lake, Coimbatore, Tamil Nadu, India, and potential future implications of climate change. *The Journal of Basic and Applied Zoology, 79*(1), 1-10.

Manickam, N., Bhavan, P. S., Santhanam, P., Muralisankar, T., Srinivasan, V., Vijayadevan, K., & Bhuvaneswari, R. (2015). Biodiversity of freshwater Zooplankton and physico-chemical parameters of Barur Lake, Krishnagiri District, Tamil Nadu, India. *Malaya Journal Bioscience, 2*, 1-12.

Manikandan, R., Selvakumar, S., & Ezhili, S. K. a. N. (2016). Zooplankton Diversity and Seasonal Variation of Three Lakes in Coimbatore, Tamil Nadu, India. *Journal of Academia and Industrial Research (JAIR), 5*(3), 40.

Manjare, S., Vhanalakar, S., & Muley, D. (2010). Water quality assessment of Vadgaon tank of Kolhapur (Maharastra), with special reference to Zooplankton. *International Journal of Advanced Biotechnology and Research, 1*(2), 91-95.

Manju, S., & Sagar, N. (2017). Renewable energy integrated desalination: A sustainable solution to overcome future fresh-water scarcity in India. *Renewable and Sustainable Energy Reviews, 73*, 594-609.

Mantovano, T., Diniz, L. P., da Conceição, E. d. O., Rosa, J., Bonecker, C. C., Bailly, D., Lansac-Tôha, F. A. (2021). Ecological niche models predict the potential distribution of the exotic rotifer Kellicottia bostoniensis (Rousselet, 1908) across the globe. *Hydrobiologia, 848*(2), 299-309.

Martens, K., Schön, I., Meisch, C., & Horne, D. J. (2007). Global diversity of ostracods (Ostracoda, Crustacea) in freshwater. *In Freshwater Animal Diversity Assessment*, 185-193.

Martens, K., & Tudorancea, C. (1991). Seasonally and spatial distribution of the ostracods of Lake Zwai, Ethiopia (Crustacea: Ostracoda). *Freshwater Biology, 25*(2), 233-241.

Mayorga, E., Aufdenkampe, A. K., Masiello, C. A., Krusche, A. V., Hedges, J. I., Quay, P. D., Brown, T. A. (2005). Young organic matter as a source of carbon dioxide outgassing from Amazonian rivers. *Nature, 436*(7050), 538-541.

Michael, R. G., & Sharma, B. K. (1988). *Indian Cladocera (Crustacea. Branchiopoda. Cladocera)*: Zoological Survey of India.

Mohamed, I., Othman, F., Ibrahim, A. I., Alaa-Eldin, M. E., & Yunus, R. M. (2015). Assessment of water quality parameters using multivariate analysis for Klang River basin, Malaysia. *Environmental monitoring and assessment, 187*(1), 4182.

Mohseni, O., & Stefan, H. (1999). Stream temperature/air temperature relationship: a physical interpretation. *Journal of hydrology, 218*(3-4), 128-141.

Mojumder, I., Kibria, M., & Bhuyan, M. (2020). A baseline taxonomic study of Zooplankton in the lower Halda River, Bangladesh. *Glob J Zool, 5*(1), 001-008.

Mola, H. (2011). Seasonal and spatial distribution of Brachionus (Pallas, 1966; Eurotatoria: Monogononanta: Brachionidae), a bioindicator of eutrophication in lake El-Manzalah, Egypt. *Egypt. Biol. Medi, 3*(2), 60-69.

Morales-Ramírez, Á., Suarez-Morales, E., Corrales-Ugalde, M., & Garrote, O. E. (2014). Diversity of the free-living marine and freshwater Copepoda (Crustacea) in Costa Rica: a review. *ZooKeys* (457), 15.

Morrill, J. C., Bales, R. C., & Conklin, M. H. (2005). Estimating stream temperature from air temperature: implications for future water quality. *Journal of Environmental Engineering, 131*(1), 139-146.

Mruthyunjaya, N., Venkateshwarlu, M., Kiran, B., & Somashekar, D. (2016). Diversity of Phytoplankton in Ayyanakere Lake, Chikmagalur District, Karnataka.

Mukhopadhyay, S. K., Chattopadhyay, B., Goswami, A. R., & Chatterjee, A. (2007). Spatial variations in Zooplankton diversity in waters contaminated with composite effluents. *Journal of Limnology, 66*(2), 97.

Nagorskaya, L., & Keyser, D. (2005). Habitat diversity and ostracod distribution patterns in Belarus. *Hydrobiologia*, *538*(1), 167-178.

Nandini, S., Sarma, S., & Gulati, R. (2017). A seasonal study reveals the occurrence of exotic rotifers, the River Antigua, Veracruz, close to the Gulf of Mexico. *River Research and Applications*, *33*(6), 970-982.

Narasimha Manickam, B., P. S., Santhanam, P., Bhuvaneswari, R., Muralisankar, T., Srinivasan, V., & Karthik, M. (2018). Impact of seasonal changes in Zooplankton biodiversity in Ukkadam Lake, Coimbatore, Tamil Nadu, India, and potential future implications of climate change. *The Journal of Basic and Applied Zoology*, *79*(1), 15.

Nath, B., Borah, D. K., & Deka, C. (2020). A study of plankton diversity in Kumri Beel, Goalpara, Assam, India. *Int. J. of Life Sciences, 8*(1), 145-148.

Nayak, B., Acharya, B., Panda, U., Nayak, B., & Acharya, S. (2004). Variation of water quality in Chilika lake, Orissa.

Neetu, A. K., Prabhakar, R., Kedia, D. K., & Sinha, R. K. (2020). Rotifers Abundance, Species Composition and Temporal Distribution in a Sewage Fed Fish Pond at Pahari, Patna. *Environment and Ecology*, *38*(2), 140-151.

Negi, R., & Mamgain, S. (2013). Zooplankton diversity of Tons river of Utarakhand State India. *Int. J. Zoology and Research, 3*(2), 1-8.

Neves, I., Rocha, O., Roche, K., & Pinto, A. (2003). Zooplankton community structure of two marginal lakes of the river Cuiabá (Mato Grosso, Brazil) with analysis of Rotifera and Cladocera diversity. *Brazilian Journal of Biology, 63*(2), 329-343.

Nimbalkar, R., Kamtikar, V., Shinde, S., & Wadikar, M. (2013). Studies On Zooplankton Diversity In Relation To Water Quality Of Ambe Ghosale Lake Of Thane City,(Ms) India. *Bioscience Discovery, 4*(1), 124-127.

Niyoyitungiye, L., Giri, A., Mishra, B., & Kar, D. (2020). The impact of abiotic environmental factors on the occurrence, assemblages and diversity of freshwater Zooplanktons in lake tanganyika, burundian littoral. *International Journal of Entomology Research, 5*(5), 2455-4758.

Novichkova, A. A., & Azovsky, A. I. (2017). Factors affecting regional diversity and distribution of freshwater microcrustaceans (Cladocera, Copepoda) at high latitudes. *Polar Biology, 40*(1), 185-198.

Oberholster, P., Botha, A.-M., & Cloete, T. (2008). Biological and chemical evaluation of sewage water pollution in the Rietvlei nature reserve wetland area, South Africa. *Environmental Pollution, 156*(1), 184-192.

Obuid-Allah, A., S Moustafa, A., HM Hussien, E., M Gaber, A., & A Mohammad, W. (2020). Distribution of Zooplankton Community in the River Nile at Esna Barrages, Egypt in relation to some ecological factors. *Egyptian Journal of Aquatic Biology and Fisheries, 24*(1), 131-143.

Orsini, L., Spanier, K. I., & De Meester, L. (2012). Genomic signature of natural and anthropogenic stress in wild populations of the waterflea Daphnia magna: validation in space, time and experimental evolution. *Molecular ecology, 21*(9), 2160-2175.

Örstan, A., & Plewka, M. (2017). An introduction to bdelloid rotifers and their study.

Oswald, W. J., & Gotaas, H. B. (1957). Photosynthesis in sewage treatment. *Trans. Am. Soc. Civ. Eng, 122*(1), 73-105.

Pace, M. L., & Orcutt Jr, J. D. . (1981). The relative importance of protozoans, rotifers, and crustaceans in a freshwater Zooplankton community. *Limnology and Oceanography, 26*(5), 822-830.

Padhye, S. M. (2020). Seasonal variation in functional composition and diversity of cladoceran Zooplankton of a lotic eutrophic habitat from India. *In Annales de Limnologie-International Journal of Limnology, 56*, 11.

PahariI, P., Dutta, T., & Bhattacharya, T. (2002). Brachionus as Bioindicator of VVater Quality. Proc. zool. Soc. Calcutta. *55, 2*(9-13).

Pal, S., Patra, A. K., & Chakraborty, K. (2015). Prospect of Brachionus calyciflorus, a holoplankton, for its potential bio-indicator property. *Inter. J. Rec. Scie. Res. Res*, *6*, 7603-7608.

Pandey, M., Shukla, A., Mishra, S., & Rai, S. (2015). Distribution and Diversity of Zooplankton in River Narmada Madhya Pradesh. *International Journal of Current Research, 7*(12), 23471-23474.

Pandey, P., Sahu, P. K., Jha, Y. N., & Shrivastava, A. K. (2014). Diversity in Macrobenthic & Algal Fauna of Limha Pond, Ghutku Bilaspur India. *Open Journal of Marine Science, 2014*.

Panwar, S., & Malik, D. (2016). Zooplankton diversity, species richness and their distribution pattern in Bhimtal Lake of Kumaun region,(Uttarakhand). *Hydrology Current Research, 7*(1), 219.

Papakostas, S., Michaloudi, E., Proios, K., Brehm, M., Verhage, L., Rota, J., Fontaneto, D. (2016). Integrative taxonomy recognizes evolutionary units despite widespread mitonuclear discordance: evidence from a rotifer cryptic species complex. *Systematic Biology, 65*(3), 508-524.

Patterson, L. N., Harris, B. D., & Covi, J. A. (2020). Lack of dormancy to protect diversity: Decrease in diversity of active Zooplankton community observed in lake with depauperate egg bank. *Science of The Total Environment*.

Pawar, R. T. (2016). Zooplankton diversity and seasonal variation of Majalgaon reservoir, Maharashtra state, India. *International journal of environmental sciences, 6*(5), 859-866.

Pawar, S. M. (2014). Zooplankton Diversity and Density in Some Freshwater Bodies around Satara (MS) India. *Journal of Environments, 1*(2), 64-67.

Peijnenburg, K. T., & Goetze, E. (2013). High evolutionary potential of marine Zooplankton. *Ecology and Evolution*, *3*(8), 2765-2781.

Pennak, R. W. (1957). Species Composition of Limnetic Zooplankton Communities 1. *Limnology and Oceanography, 2*(3), 222-232.

Perbiche-Neves, G., Fileto, C., Laço-Portinho, J., Troguer, A., & Serafim-Júnior, M. (2013). Relations among planktonic rotifers, cyclopoid copepods, and water quality in two Brazilian reservoirs. *Latin American Journal of Aquatic Research, 41*(1), 138-149.

Perbiche-Neves, G., Saito, V. S., Simões, N. R., Debastiani-Júnior, J. R., de Oliveira Naliato, D. A., & Nogueira, M. G. (2019). Distinct responses of Copepoda and Cladocera diversity to climatic, environmental, and geographic filters in the La Plata River basin. *Hydrobiologia, 826*(1), 113-127.

Pereira, L. S., Cordery, I., & Iacovides, I. (2009). *Coping with water scarcity: Addressing the challenges*: Springer Science & Business Media.

Pérez-Legaspi, I. A., & Rico-Martínez, R. (2001). Acute toxicity tests on three species of the genus Lecane (Rotifera: Monogononta). *Hydrobiologia*, *446*(1), 375-381.

Perumal, N. V., Rajkumar, M., Perumal, P., & Rajasekar, K. T. (2009). Seasonal variations of plankton diversity in the Kaduviyar estuary, Nagapattinam, southeast coast of India. *J. Environ. Biol, 30*(6), 1035-1046.

Postel, S. L. (2000). Entering an era of water scarcity: the challenges ahead. *Ecological applications, 10*(4), 941-948.

Prabhakar, R., Kumari, A., & Neetu, R. K. S. (2019). Impact of Sand Mining on Zooplankton of River Ganga in and Around Patna, Bihar, India. *Environment and Ecology, 37*(4A), 1301-1308.

Pradeep, V., Deepika, C., Urvi, G., & Hitesh, S. (2012). Water quality analysis of an organically polluted lake by investigating different physical and chemical parameters. *Int. J. Res. Chem. Environ, 2*(1), 105-111.

Preston, B. L., Snell, T. W., Robertson, T. L., & Dingmann, B. J. (2000). Use of freshwater rotifer Brachionus calyciflorus in screening assay for potential endocrine disruptors. *Environmental Toxicology and Chemistry: An International Journal, 19*(12), 2923-2928.

Proios, K., Michaloudi, E., Papakostas, S., Kappas, I., Vasileiadou, K., & Abatzopoulos, T. J. (2014). Updating the description and taxonomic status of Brachionus sessilis Varga, 1951 (Rotifera: Brachionidae) based on detailed morphological analysis and molecular data. *Zootaxa, 3873*(4), 345-370.

Purugganan, M. D. (1998). The molecular evolution of development. *BioEssays, 20*(9), 700-711.

Qin, H., Cao, X., Cui, L., Lv, Q., & Chen, T. (2020). The Influence of Human Interference on Zooplankton and Fungal Diversity in Poyang Lake Watershed in China. *Diversity, 12*(8), 296.

R. N. D. Etilé., B., T. A., Blahoua, G. K., Bi, G. G., Bi, P. E., Kouamelan, P. E., & N'Douba, V. (2020). Checklist and Distribution of Freshwater Cladocera (Crustacea: Branchiopoda) in Cote d'Ivoire (West Africa). *Zoological Studies, 59*.

Radwan, S., & Paleolog, A. (1983). Notes on the rotifers of coal mine water in Eastern Poland. In Biology of Rotifers (pp. 307-309). Springer, Dordrecht. (1983). Notes on the rotifers of coal mine water in Eastern Poland. *Biology of Rotifers, Springer*, 307-309.

Rahman, M. A., & Huda, M. (2012). Study of the seasonal variations in physicochemical and biological aspects of the Padma River at Paturia Ghat, Manikganj. *Jahangirnagar University Environmental Bulletin, 1*, 55-66.

Rai, S. (2016). Arjun Shukla et al. published work on the fauna of River Narmada, Jabalpur region: A review.

Rajagopal, T., Thangamani, A., Sevarkodiyone, S., Sekar, M., & Archunan, G. (2010). Zooplankton diversity and physico-chemical conditions in three perennial ponds of Virudhunagar district, Tamilnadu. *Journal of Environmental Biology, 31*(3), 265-272.

Ramzan, M., Zafarullah, M., Ahmad, I., Ali, Q., & Malik, A. (2020). Study on Zooplankton diversity during spring season in Chashma Lake, Pakistan. *Biological and Clinical Sciences Research Journal, 2020*(1), e009-e009.

Rao, K. R. (2017). Zooplankton diversity and seasonal variations in Thandava reservoir, Visakhapatnam, India. *International Journal of Aquaculture and Fishery Sciences, 5*(1), 90-97.

Rautio, M., & Tartarotti, B. (2010). UV radiation and freshwater Zooplankton: damage, protection and recovery. *Freshwater reviews: a journal of the Freshwater Biological Association, 3*(2), 105.

Reddy, K., & Gale, P. (1994). Wetland processes and water quality: a symposium overview. *Journal of environmental quality, 23*(5), 875-877.

Reddy, Y. R. (1994). *Copepoda; Calanoida; Diaptomidae*: SPB Acadamic Publishing.

Reid, J. W., & Williamson, C. E. (2010). Copepoda *Ecology and classification of North American freshwater invertebrates* (pp. 829-899): Elsevier.

Reju J., T. J. W. P. (2019). Seasonal variations of Zooplanktons in the selected ponds of Venganoor Grama Panchayath, southern Western Ghats. *Plant Archives, 19*(1), 1534-1540.

Resh, V. H., & Unzicker, J. D. (1975). Water quality monitoring and aquatic organisms: the importance of species identification. *Journal (Water Pollution Control Federation)*, 9-19.

Reygondeau, G., & Beaugrand, G. (2011). Future climate-driven shifts in distribution of Calanus finmarchicus. *Global Change Biology, 17*(2), 756-766.

Ricci, C., Melone, G., & Sotgia, C. (1993). *Old and new data on Seisonidea (Rotifera).* Paper presented at the Rotifer Symposium VI.

Riddhi, S., Vipul, S., Sudan, S. M., Kumar, V. B., Rachana, M., & Singh, G. K. (2011). Studies on Limnological Characteristic, Planktonic Diversity and Fishes (Species) in Lake Pichhola, Udaipur, Rajasthan (India). *Universal Journal of Environmental Research & Technology, 1*(3).

Rieradevall, M., & Roca, J. (1995). Distribution and population dynamics of ostracodes (Crustacea, Ostracoda) in a karstic lake: Lake Banyoles (Catalonia, Spain). *Hydrobiologia, 310*(3), 189-196.

Roshan, F. J., & Sreejai, R. (2020). Zooplankton diversity of Kottakayal–a wetland in south Kerala that is under the threat of sand and clay mining. *Uttar Pradesh Journal of Zoology*, 52-58.

Rossetti, G., Bartoli, M., & Martens, K. (2004). *Limnological characteristics and recent ostracods (Crustacea, Ostracoda) of freshwater wetlands in the Parco Oglio Sud (Northern Italy).* Paper presented at the Annales de Limnologie-International Journal of Limnology.

Rubio-Arias, H., Contreras-Caraveo, M., Quintana, R. M., Saucedo-Teran, R. A., & Pinales-Munguia, A. (2012). An overall water quality index (WQI) for a man-made aquatic reservoir in Mexico. *International journal of environmental research and public health, 9*(5), 1687-1698.

Ruiz, F., Abad, M., Bodergat, A., Carbonel, P., Rodríguez-Lázaro, J., González-Regalado, M., . . . Prenda, J. (2013). Freshwater ostracods as environmental tracers. *International Journal of Environmental Science and Technology, 10*(5), 1115-1128.

Sa-Ardrit, P., & Beamish, F. W. H. (2005). Cladocera diversity, abundance and habitat in a Western Thailand Stream. *Aquatic Ecology, 39*(3), 353-365.

Sahu, P., & Sikdar, P. (2008). Hydrochemical framework of the aquifer in and around East Kolkata Wetlands, West Bengal, India. *Environmental Geology*, *55*(4), 823-835.

Saksena, D. (1987). Rotifers as indicators of water quality. *Acta hydrochimica et hydrobiologica*, *15*(5), 481-485.

Sampaio, E., Rocha, O., Matsumura-Tundisi, T., & Tundisi, J. (2002). Composition and abundance of Zooplankton in the limnetic zone of seven reservoirs of the Paranapanema River, Brazil. *Brazilian Journal of Biology*, *62*(3), 525-545.

Sankhala, D. R., & Nama, P. (2020). Microscopic Crustaceans Diversity in Eutrophic Ratholai Pond at Pipar City, Jodhpur, Rajasthan (India). *International Journal of Advance Study and Research Work*, *3*(3).

Sarang, T., & Manoj, K. (2021). Assessment of water quality of Tapi river with reference to rotifera community.

Sarkar, R., Ghosh, A. R., & Mondal, N. K. (2020). Comparative study on physicochemical status and diversity of macrophytes and Zooplanktons of two urban ponds of Chandannagar, WB, India. *Applied Water Science*, *10*(2), 1-8.

Sarkar, R., Ghosh, A. R., & Mondal, N. K. (2020). Comparative study on physicochemical status and diversity of macrophytes and Zooplanktons of two urban ponds of Chandannagar, WB, India. *Applied Water Science*, *10*(2), 63.

Savci, S. (2012). Investigation of effect of chemical fertilizers on environment. *Apcbee Procedia*, *1*, 287-292.

Schmidt, J., Andrade, P. D. B. D., & Padial, A. A. (2020). Zooplankton trajectory before, during and after a hydropower dam construction. *Acta Limnologica Brasiliensia*, *32*.

Schneider, A., Wetterich, S., Schirrmeister, L., Herzschuh, U., Meyer, H., & Pestryakova, L. A. (2016). Freshwater ostracods (Crustacea) and environmental variability of polygon ponds in the tundra of the Indigirka Lowland, north-east Siberia. *Polar Research, 35*(1), 25225.

Segers, H. (2007). Annotated checklist of the rotifers (Phylum Rotifera), with notes on nomenclature, taxonomy and distribution. *Zootaxa, 1564*(1), 1-104

Sehar, S., Naeem, S., Perveen, I., Ali, N., & Ahmed, S. (2015). A comparative study of macrophytes influence on wastewater treatment through subsurface flow hybrid constructed wetland. *Ecological Engineering, 81*, 62-69.

Sehgal, K., Phadke, G., Chakraborty, S., & Reddy, S. V. K. (2013). Studies on zooplakton diversity of Dimbhe reservoir, Maharashtra, India. *Advances in Applied Science Research, 4*(1), 417-420.

Sendek, A., & Aynalem, Y. (2020). Abundance, diversity of Zooplankton and weed bed macro invertebrates in the fogera floodplain, Ethiopia. *International Journal of Fisheries and Aquatic Studies, 8*(4), 247-256.

Sentis, A., Hemptinne, J. L., & Brodeur, J. (2012). Using functional response modeling to investigate the effect of temperature on predator feeding rate and energetic efficiency. *Oecologia, 169*(4), 1117-1125.

Serafim-Júnior, M., Perbiche-Neves, G., & Lansac-Tôha, F. A. (2019). An assessment of the factors determining rotifer assemblage in river-lake systems: the effects of seasonality and habitat. *Zoologia (Curitiba), 36*.

Setubal, R. B., de Oliveira Sodré, E., Martins, T., & Bozelli, R. L. (2020). Effects of functional diversity and salinization on Zooplankton productivity: an experimental approach. *Hydrobiologia, 847*(13), 2845-2862.

Shah, J. A., & Pandit, A. K. (2013). Diversity and Abundance of Cladoceran Zooplankton in Wular Lake, Kashmir Himalaya. *Research Journal of Environmental and Earth Sciences, 5*(7), 410-417.

Shah, J. A., Pandit, A. K., & Shah, G. M. (2017). Rotifer community in relation to limnological characteristics of Wular lake in Kashmir Himalaya. *Ceylon Journal of Science*, *46*(2), 49-57.

Sharma, A. S., Gupta, S., & Singh, N. R. (2017). Zooplankton community of Keibul Lamjao National Park (KLNP) Manipur, India in relation to the physico-chemical variables of the water. *Chinese journal of oceanology and limnology*, *35*(3), 469-480.

Sharma, B. (2011). Zooplankton diversity of two floodplain lakes (pats) of Manipur, northeast India. *Opuscula Zoologica Budapest*, *42*(2), 185-197.

Sharma, B. (2017). Biodiversity of the rotifers (Rotifera: Eurotatoria) of Nagaland, northeast India: Composition and ecosystem diversity.

Sharma, B., & Pachuau, L. (2013). Zooplankton diversity of a sub-tropical reservoir of Mizoram, Northeast India. *Opuscula Zoologica Budapest*, *44*(1), 47-60.

Sharma, B. K. (1998). Faunal Diversity in India: Rotifera. *Faunal diversity of India. ENVIS Centre, Zoological Survey of India, Calcutta*, 57-70.

Sharma, B. K. (1998). Faunal Diversity in India: Rotifera. Faunal diversity of India. *ENVIS Centre, Zoological Survey of India, Calcutta*, 57-70.

Sharma, B. K., & Noroh, N. (2020). Zooplankton diversity of three floodplain lakes of the Dibru-Saikhowa Biosphere reserve, upper Assam, northeast India. *International Journal of Aquatic Biology*, *8*(1), 18-34.

Sharma, B. K., & Sharma, S. (2018). The Indian species of Testudinella (Rotifera: Flosculariacea: Testudinellidae) and their distribution. *International Journal of Aquatic Biology*, *6*(1), 15-20.

Sharma, B. K., Noroh, N., & Sharma, S. (2017). Rotifers (Rotifera: Eurotatoria) from floodplain lakes of the Dibru Saikhowa Biosphere Reserve, upper Assam, northeast India: ecosystem diversity and biogeography. *International Journal of Aquatic Biology*, *5*(2), 79-94.

Sharma, B. K., & Sharma, S. (2014). Northeast India: an important region with a rich biodiversity of Rotifera. *International Review of Hydrobiology, 99*(1-2), 20-37.

Sharma, D. K., & Singh, R. (2012). Seasonal variation in Zooplankton diversity in Tighra reservoir, Gwalior (Madhya Pradesh). *Indian Journal of Scientific Research, 3*(2), 155.

Sharma, K., Devi, A., Arti, S., & Neha, A. (2013). Zooplankton diversity and physico-chemical conditions of a temple Pond in Birpur (J&K, India). *International Research Journal of Environment Sciences, 2*(5), 25-30.

Sharma, S., Siddique, A., Singh, K., Chouhan, M., Vyas, A., Solnki, C., Sengupta, T. (2010). Population dynamics and seasonal abundance of Zooplankton community in Narmada River (India). *Researcher, 2*(9), 1-9.

Sharma, V., Verma, B. K., Sharma, R., Sharma, M. S., & Gaur, K. S. (2012). A report on the freshwater Cladocera (Crustacea: Branchiopoda) of south Rajasthan (India). *International journal of Environmental sciences, 3*(1), 275-296.

Sheeba S, R. N. (2005). Qualitative and Quantitative study of Zooplankton in Ithikkara River, Kerala. *Poll Res., 24*(1), 119-122.

Shei, M. R. P., Rodrigues, R. V., & Sampaio, L. A. N. D. (2012). Use of commercial live feeds enrichment during first feeding period of the barber goby Elacatinus figaro.

Shiel, R. (1995). A Guide to Identification of Rotifers, Cladocerans and Copepods from Australian Inland Waters. Cooperative Research Centre for Freshwater Ecology Identification Guide 3. *Murray Darling Freshwater Research Centre: Albury*.

Shruthi, R., & Ramakrishna, S. (2020). Heterogeneity of Zooplanktons in Boranakanive reservoir of Tumakuru District, Karnataka, India. *Eco. Env. & Cons.*, S204-S209.

Shurin, J. B., Winder, M., Adrian, R., Keller, W., Matthews, B., Paterson, A. M., ... & Yan, N. D. (2020). Environmental stability and lake Zooplankton diversity–contrasting effects of chemical and thermal variability. *Ecology Letters, 13*(4), 453-463.

Singh, K. (2020). Study of Physicochemical Parameters in Reference to Zooplankton Diversity in River Water near to Industrial AREA OF PALI, Rajasthan. *Plant Archives, 20*(1), 649-652.

Singh, S., & Sharma, R. C. (2020). Zooplankton diversity and potential indicator species for assessment water quality of high altitude wetland, Dodi Tal of Garhwal Himalaya, India. *Academia Arena, 12*(5), 1-16.

Singh, U. B., Ahluwalia, A., Sharma, C., Jindal, R., & Thakur, R. (2013). Planktonic indicators: A promising tool for monitoring water quality (early-warning signals). *Ecology, Environment and Conservation, 19*(3), 793-800.

Sinha, B. (2018). Status of studies on Zooplankton fauna of Arunachal Pradesh, India. *Journal of Threatened Taxa, 10*(11), 12552-12560.

Sitre, S. R. (2012). Studies on the Seasonal Variation of Freshwater Zooplankton in A Perennial Urban Lake of Nagpur City (MS) India. *Lokavishkar International E-Journal, 1*(3), 10.

Smirnov, N. N. (2017). *Physiology of the Cladocera*: Academic Press.

Smith, D. G. (2001). *Pennak's freshwater invertebrates of the United States: Porifera to Crustacea*: John Wiley & Sons.

Sommer, U., Hansen, T., Blum, O., Holzner, N., Vadstein, O., & Stibor, H. (2005). Copepod and microZooplankton grazing in mesocosms fertilised with different Si: N ratios: no overlap between food spectra and Si: N influence on Zooplankton trophic level. *Oecologia, 142*(2), 274-283.

Špoljar, M., Habdija, I., Primc-Habdija, B., & Sipos, L. (2005). Impact of environmental variables and food availability on rotifer assemblage in the karstic barrage Lake Visovac (Krka River, Croatia). *International Review of Hydrobiology: A Journal Covering all Aspects of Limnology and Marine Biology*, *90*(5-6), 555-579.

Srivastava, B., & Reddy, P. B. . (2020). Environmental interactions of Zooplankton in the Chambal River at Nagda (MP, India). *Trends in Life Scienes*, *9*(1), 10-18.

Stegert, C., Ji, R., & Davis, C. S. (2010). Influence of projected ocean warming on population growth potential in two North Atlantic copepod species. *Progress in Oceanography, 87*(1-4), 264-276.

Stire, S. (2014). Zooplankton fauna of a freshwater pond in bhadrawati town of Chandrapur District in Maharashtra State (India). *Online International Interdisciplinary Research Journal, 4*(Special Issue (March)), 219-226.

Suatoni, E., Vicario, S., Rice, S., Snell, T., & Caccone, A. (2006). An analysis of species boundaries and biogeographic patterns in a cryptic species complex: the rotifer—Brachionus plicatilis. *Molecular phylogenetics and evolution, 41*(1), 86-98.

Sunita, S., & Singh, D. (2017). Studies on seasonal bio-diversity of rotifers in a fresh water pond of Birganj (Nepal). *Environment and Ecology, 35*(4D), 3476-3478.

Tamura, K. (1992). Estimation of the number of nucleotide substitutions when there are strong transition-transversion and G+ C-content biases. *Mol Biol Evol, 9*(4), 678-687.

Thakur, R., Jindal, R., Singh, U. B., & Ahluwalia, A. (2013). Plankton diversity and water quality assessment of three freshwater lakes of Mandi (Himachal Pradesh, India) with special reference to planktonic indicators. *Environmental monitoring and assessment, 185*(10), 8355-8373.

Tho, N. M., & Ha, T. K. (1984). A theoretical study of the formation of carbonic acid from the hydration of carbon dioxide: a case of active solvent catalysis. *Journal of the American Chemical Society, 106*(3), 599-602.

Thomas, J. K., Sreekumar, S., & Chriyan, J. . (2003). Muriyad wetlands: Ecological changes and human consequences *Project report submitted to Kerala Research Programme on Local Develop ment (Thiruvananthapuram: Centre for Developmental Studies)*.

Thurston, R. V., Russo, R. C., & Vinogradov, G. A. (1981). Ammonia toxicity to fishes. Effect of pH on the toxicity of the unionized ammonia species. *Environmental science & technology, 15*(7), 837-840.

Tiang-Nga, S., Sinev, A. Y., & Sanoamuang, L.-O. (2020). High diversity of Cladocera (Crustacea: Branchiopoda) in a Ramsar site Lake Kud-Thing, Northeast Thailand. *Zootaxa, 4780*(2), 275-290.

Tijare, R., & Thosar, M. (2008). *Rotifer diversity in three lakes of Gadchiroli, a Tribal District of Maharashtra (India).* Paper presented at the Proceedings of Taal2007: The 12th World Lake Conference.

Totawar, D. V. (2020). Zooplankton diversity in a Godavari River near Nanded City. *Indian Journal of Applied Research, 9*(12).

Tóth, F., Zsuga, K., Kerepeczki, É., Berzi-Nagy, L., Körmöczi, L., & Lövei, G. L. (2020). Seasonal differences in taxonomic diversity of rotifer communities in a hungarian lowland oxbow lake exposed to aquaculture effluent. *Water, 12*(5), 1300.

Tóth, F., Zsuga, K., Kerepeczki, É., Berzi-Nagy, L., Jakabné Sándor, Z., & Körmöczi, L. (2020). The Effect of Feed Composition on the Structure of Zooplankton Communities in Fishponds. *Water, 12*(5), 1338.

Trivedy, R. (1989). *Pollution management in industries*: Environmental publications.

Trivedy, R., & Goel, P. (1984). *Chemical and biological methods for water pollution studies*: Environmental publications.

Tucker, C. S., & D'Abramo, L. R. (2008). *Managing high pH in freshwater ponds*: Southern Regional Aquaculture Center Stoneville.

Uçak, S., Külköylüoğlu, O., Akdemir, D., & Başak, E. (2014). Distribution, diversity and ecological characteristics of freshwater Ostracoda (Crustacea) in shallow aquatic bodies of the Ankara region, Turkey. *Wetlands, 34*(2), 309-324.

Uitto, A., & Hällfors, S. (1997). Grazing by mesoZooplankton and metazoan microplankton on nanophytoplankton in a mesocosm experiment in the northern Baltic. *Journal of plankton research, 19*(6), 655-673.

Vajravelu, M., Martin, Y., Ayyappan, S., & Mayakrishnan, M. (2018). Seasonal influence of physico-chemical parameters on phytoplankton diversity, community structure and abundance at Parangipettai coastal waters, Bay of Bengal, South East Coast of India. *Oceanologia, 60*(2), 114-127.

Valleau, R. E., Paterson, A. M., & Smol, J. P. (2020). Effects of road-salt application on Cladocera assemblages in shallow Precambrian Shield lakes in south-central Ontario, Canada. *Freshwater Science, 39*(4), 824-836.

van Dam, J. A. (2012). Scanning the fossil record: stratophenomics and the generation of primary evolutionary-ecological data. *Evolutionary Ecology, 26*(3), 449-463.

Verhoeven, J. T., & Setter, T. L. (2010). Agricultural use of wetlands: opportunities and limitations. *Annals of botany, 105*(1), 155-163.

Verma, A. K., & Prakash, S. (2020). Limnological studies of Semara Taal, a wetland of district Siddharthnagar, Uttar Pradesh, India. *Journal of Fisheries and Life sciences, 5*(1), 15-19.

Verma, P., Chandawat, D., & Solanki, H. (2011). Seasonal variation in physico-chemical and phytoplankton analysis of Kankaria Lake. *Life sciences leaflets, 19*, 842-854.

Viayeh, R. M., & Špoljar, M. (2012). Structure of rotifer assemblages in shallow waterbodies of semi-arid northwest Iran differing in salinity and vegetation cover. *Hydrobiologia, 686*(1), 73-89.

Victor, R. (2004). Crustacea: ostracoda. *yule, C. M & sen, YH (Eds). Fresh water Invertebrates of the Malaysian Region. Academy of sciences Malaysion*, 225-252.

Victor, R., & Fernando, C. (1979). The freshwater ostracods (Crustacea: Ostracoda) of India. *Records of the zoological survey of India, 74*(2), 147-242.

Viet, N. D., Bac, N. A., & Huong, H. T. T. (2016). *Dissolved oxygen as an indicator for eutrophication in freshwater lakes.* Paper presented at the Proceedings of international conference on environmental engineering and Management for Sustainable Development.

Wallace, R. L., Snell, T. W., & Smith, H. A. (2015). *Phylum rotifera. In Thorp and Covich's freshwater invertebrates*: Academic Press.

Walseng, B., Yan, N. D., & Schartau, A. K. (2003). Littoral microcrustacean (Cladocera and Copepoda) indicators of acidification in Canadian Shield lakes. *AMBIO: A Journal of the Human Environment, 32*(3), 208-213.

Walsh, E. J., Wallace, R. L., & Shiel, R. J. (2005). Toward a better understanding of the phylogeny of the Asplanchnidae (Rotifera) *Rotifera X* (pp. 71-80): Springer.

Wang, C., Wang, L., Deng, D., & Zhou, Z. (2016). Temporal and spatial variations in rotifer correlations with environmental factors in Shengjin Lake, China. *Environmental Science and Pollution Research, 23*(8), 8076-8084.

Wang, W.-N., Wang, A.-L., Chen, L., Liu, Y., & Sun, R.-Y. (2002). Effects of pH on survival, phosphorus concentration, Adenylate Energy Charge and Na+–K+ ATPase activities of Penaeus chinensis Osbeck Juveniles. *Aquatic toxicology, 60*(1-2), 75-83.

Watkar, A. (2020). Ecological study of rotifers from Kolar River, Saoner, Dist. Nagpur (MS), India. *Asian Journal of Science and Technology, 11*(05), 10975-10977.

Watkar, A., & Barbate, M. (2013). Studies on Zooplankton Diversity of River Kolar, Saoner, Dist. Nagpur, Maharashtra. *Journal of Life Sciences and Technologies, 1*(1), 26-28.

Welch, D. B. M., & Meselson, M. (2000). Evidence for the evolution of bdelloid rotifers without sexual reproduction or genetic exchange. *Science, 288*(5469), 1211-1215.

WEN, Z., XU, J., LIN, Q., & HAN, B. (2017). Rotifer species diversity and community structure in the pelagic zone of the Liuxihe Reservoir. *Acta Ecologica Sinica*, 04.

Wesenberg-Lund, C. (1899). *Danmarks rotifera: I. Grundtrækkene i rotiferernes økologi, morfologi og systematik* (Vol. 1): Bianco Lunos Kgl. Hof-Bogtrykkeri (F. Dreyer).

Whiteside, M. C. (1970). Danish chydorid Cladocera: modern ecology and core studies. *Ecological Monographs, 40*(1), 79-118.

Wiener, C. S. W. (1949). The Mathematical Theory of Communication: Unknown Distance Function. *Urbana, IL: Illinois Press*.

Wilde, K. L., Stauber, J. L., Markich, S. J., Franklin, N. M., & Brown, P. L. . (2006). The effect of pH on the uptake and toxicity of copper and zinc in a tropical freshwater alga (Chlorella sp. *Archives of environmental contamination and toxicology, 51*(2), 174.

Wilson, A. E., Sarnelle, O., & Tillmanns, A. R. (2006). Effects of cyanobacterial toxicity and morphology on the population growth of freshwater Zooplankton: Meta-analyses of laboratory experiments. *Limnology and Oceanography, 51*(4), 1915-1924.

Wurts, W. A., & Durborow, R. M. . (1992). Interactions of pH, carbon dioxide, alkalinity and hardness in fish ponds. *SRAC Publication*, 1-3.

Xiong, W., Huang, X., Chen, Y., Fu, R., Du, X., Chen, X., & Zhan, A. (2020). Zooplankton biodiversity monitoring in polluted freshwater ecosystems: A technical review. *Environmental Science and Ecotechnology, 1*, 100008.

Yang, J., & Zhang, X. (2020). eDNA metabarcoding in Zooplankton improves the ecological status assessment of aquatic ecosystems. *Environment international, 134*, 105230.

Yin, L., Ji, Y., Zhang, Y., Chong, L., & Chen, L. (2018). Rotifer community structure and its response to environmental factors in the Backshore Wetland of Expo Garden, Shanghai. *Aquaculture and fisheries, 3*(2), 90-97.

Yoshida, T., Urabe, J., & Elser, J. J. (2003). Assessment of 'top-down'and 'bottom-up'forces as determinants of rotifer distribution among lakes in Ontario, Canada. *Ecological Research, 18*(6), 639-650.

Yun, L., Liu, L., Cui, S., & Chen, F. (2019). Long-term effects of nutrient changes on rotifer communities in a subtropical lake. *Limnology, 20*(2), 191-201.

Zak, D., Hupfer, M., Cabezas, A., Jurasinski, G., Audet, J., Kleeberg, A., . . . Liu, H. (2020). Sulphate in freshwater ecosystems: A review of sources, biogeochemical cycles, ecotoxicological effects and bioremediation. *Earth-Science Reviews*, 103446.

Zeng, Y., Wei, N., Wang, Q., Iakovenko, N. S., Li, Y., & Yang, Y. (2020). Bdelloid rotifers (Rotifera, Bdelloidea) of China: diversity and new records. *ZooKeys, 941*(1).

Zhang, Y., Xu, S., Sun, C., Dumont, H., & Han, B.-P. (2021). A new set of highly efficient primers for COI amplification in rotifers. *Mitochondrial DNA Part B, 6*(2), 636-640.

Zhang, Y., Zhang, G., Xia, J., & Wang, H. (2005). The research of wastewater treatment mechanism in wetlands. *Environmental Science and Technology, 28*(1), 165-167.

APPENDIX

Research article Published out of this thesis work:

- **Fathibi K**., Sudhikumar, A.V., & Aneesh, E. M. (2020). Species composition and abundance of rotifers (Rotifera: Eurotatoria) in Thrissur Kole wetland, Kerala, India. *Egyptian Journal of Aquatic Biology and Fisheries*, 24(6), 439-451.

- **Fathibi K**., Sudhikumar, A.V., & Aneesh, E. M. (2017). Indian freshwater Zooplankton; a Review. *International Journal of Recent Scientific Research* 8(10), 20999-21015.

Research article presentations:

- **Fathibi K**., Sudhikumar, A.V., & Aneesh, E. M. Faunal diversity of Rotifers (Rotifera: Eurotatoria) of Thrissur Kole Wetlands, Kerala- A ramsar site. National seminar on impacts of climate change on Biodiversity, St. Joseph's College, Irinjalakkuda, February 2020.

- **Fathibi K**., Sudhikumar, A.V., & Aneesh, E. M. Zooplankton diversity of Thrissur Kole Wetlands, Kerala, India. Proceedings of the international seminar on Re-iterating Biodiversity. KKTM Government College, Pullut, October 2019.

- **Fathibi K**., Sudhikumar, A.V., & Aneesh, E. M. Diversity of zooplankton in Indian freshwater ecosystem. National Seminar on Faunal Diversity and Recent trends in Animal Taxonomy, Department of Zoology, Christ College, December 2017.

- Misvar Ali, K., **Fathibi, K**., & Aneesh, E. M. Disturbance regimes and change in habitats act as a cue for biodiversity: a study focuses on Dung Beetles (Coleoptera: Scarabaeidae). Proceedings on the international Conference on Biodiversity & Evaluation: Perspectives and Paradigm shifts. Sree Sankara College, Kalady, December 2015.

PUBLICATIONS