BIODIVERSITY OF MACROFAUNA IN RELATION TO THE TEMPORAL VARIATION IN THE PHYSIO-CHEMICAL PARAMETERS OF KUMBALAM MANGROVE ECOSYSTEMS.

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CERTIFICATE

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Sagar..

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LIST OF ABBREVIATIONS

SL NO	ABBREVIATION	EXPANSION
1	pH	Potential Hydrogen
2	DO	Dissolved Oxygen
3	%	Percentage
4	°c	Degree Celsius
5	FAO	Food and agricultural organization
6	Chl	Chlorophyll
7	µmol	Micromolar
8	ppt	Parts per thousand
9	m	meter
10	mg	Milligram
11	M	Molar
12	nm	Nanometre
13	µm	micrometre
14	kg	kilogram
16	km^2	Kilometre square

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ABSTRACT

Considering the significance of acquiring knowledge of regionally specific population structure for a better understanding of the existing mangrove with respect to species distribution pattern and conservation actions, a reconnaissance survey of the mangrove areas in the Kumbalam Mangroves was undertaken during the post-monsoons season (dec-jan). Physio-chemical characteristics showed considerable fluctuations from station to station, especially in salinity and DO. The species of *Acanthus ilicifolius L.* dominated the mangrove vegetation. The majority of the resident fauna includes characteristic mangrove invertebrates like snails (Telescopium), bivalves (*Enigmonia & Modiolus*), crustaceans (Sesarma, *Parasesarma* & Scylla), lichens, littorine snails, nerite snails, barnacles, and the mangrove bivalve (Enigmonia), were seen on the trunks and roots of mangrove swamps. 22 species, belonging to 8 orders of birds were observed throughout the study with *Sternula albifrons* found in the highest frequency. Fishes (*Ambassis, Etroplus, Secutor, Mugil, Stolephorus, Aplocheilus* & *Lutjanus*) which can withstand significant salinity variations were found in mangrove habitats. According to the findings of the study, lower temperatures and the stability of environmental characteristics like salinity improve the abundance and diversity of macrofauna. During the post monsoon season, concentrations of larvae and juveniles of prawns and fishes were seen in higher concentrations.

INTRODUCTION

Wetlands are places that transition from terrestrial to aquatic ecosystems and typically have a water table at or near the surface or are submerged in shallow water (Mitsch and Gosselink, 1986). Wetlands are among the most productive ecosystems on earth and are essential for controlling erosion, flooding, recharging aquifers, and absorbing nutrients. A large variety of animals, including birds, mammals, fish, frogs, insects, and plants, also call wetlands home (Buckton, 2007). Hence, wetlands aid in preserving the diversity of vegetation and animals. India has 58.2 million hectares of wetland space (Prasad et al., 2002). 310 of the 1340 bird species identified in India are known to be wetland-reliant (Ali and Ripley, 1987; Manakandan and Pittie, 2001). (Kumar et al., 2005). Wetlands in India and all around the world are facing tremendous anthropogenic pressures (Prasad et al., 2002), which have greatly impacted the structure of the bird community (Kler, 2002; Verma et al., 2004; Reginald et al., 2007). As a result of their beauty, abundance, visibility, and social behaviour, as well as their usefulness for amusement and commerce, water birds have long captured the interest of the general public and scientists. Water birds have recently attracted attention as wetland quality indicators, indicators of the efficacy of restoration efforts, and markers of local biodiversity.

Tropical and subtropical regions all across the world have mangrove ecosystems. Mangroves are stress-tolerant organisms that live in coastal intertidal zones around the world (along rivers, estuaries, and shorelines) (Twilley & Day, 2013). The tropical estuary system is rich in biodiversity, especially in the mangrove forests that line the intertidal zone (Mooney et al. 1995). The mangrove vegetation is made up of species with distinctly marked characteristics classed under "real mangroves," and it exhibits numerous structural and physiological differences. There are also "semi-mangrove" plants, which are those with less pronounced features (Tansley & Fritch, 1905). There is yet another class of plants which thrive adjacent to mangrove areas but flourish on land that is not completely submerged by brackish water, even during high tides, but can withstand some brackish water stagnation for a brief period. These species can be categorised as "mangrove-associated" (Basha, 1992). Just 2.66% of the world's mangroves, or 4,827 square kilometres, are found in India. India's west coast state of Kerala has a coastline of 590 km, and its mangrove acreage is currently estimated to be roughly 17 square km, with 36% of that area either destroyed or declining (Ram & Shaji, 2013).

Mangrove areas are ecologically important coastal environments and act as a buffer zone between the marine and terrestrial ecosystems, characterized by the high variation of physicochemical, morphological, and physio-chemical conditions (Carter 1988; Ysebaert et al. 2002). Mangrove ecosystems have a considerable number of organic compounds and hence are known as biologically rich ecosystems with a variety of living organisms attracting other life forms for various purposes. Mangroves are regarded as one of the most specialised biological assemblages of halophytic plants, operating as a transitional zone between land and ocean. They are made up of taxonomically diverse plants and trees that are found throughout tropical and subtropical climes in habitats including shorelines, estuaries, tidal creeks, backwaters, lagoons, marshes, mudflats, and even upstream locations where the water has been saline (Pillai et al., 2018). Many different species of plants and animals can survive on the substratum that mangroves' aerial roots provide, which helps to stabilise the habitat. A variety of species depend on the mangrove trees and their canopy for habitat above the water. Birds, insects, mammals, and reptiles are some of the groups of organisms that depend on this foliage provided by mangroves. Epibionts including tunicates, sponges, algae, and bivalves have overtaken the mangrove roots beneath the surface of the water. The mangroves' soft substratum serves as a home for a variety of infaunal and epifaunal species, while the spaces between their roots serve as a haven and a source of food for movable fauna like prawns, crabs, and fish. Detritus, which helps support the mangrove food web in part, is created from mangrove waste. The mangrove food web also has a strong foundation in plankton, epiphytic algae, and microphytobenthos. During some or all stages of an animal's life cycle, mangroves make an ideal habitat due to the high supply of food and shelter and low predation pressure. As a result, mangroves may serve as nursery habitats for crab, prawn, and fish species that are commercially significant and support offshore fish populations and fisheries (Nagelkerken., et al., 2008). Numerous marine creatures need mangrove vegetation, and freshwater organisms rely on them as a food source and a place to raise their young. In mangrove settings, 90% of marine fish complete various phases of their life cycles. Mangroves offer a variety of benefits to birds. These serve as nesting locations for owls, storks, herons, and raptors. In the winter, after feeding in the tidal mud flats, Palaearctic waders use them as roosting locations (Jayson et al., 2001).

A considerable amount of bird species around the world relies on mangrove habitat as their home. Hundreds of bird species migrate to the mangrove forest for feeding, roosting, nesting, and breeding (Florida Fish and Wildlife Commission, 2003). This habitat is perfect for penetrating seaside birds like plovers and sandpipers because of the shallow waters and exposed mudflats of the mangroves. Long-legged wading birds utilize these as well as the deeper waters along mangrove-lined waterways. Herons, egrets, bitterns, spoonbills, and ibises are among the wading birds that visit mangroves in search of food. Certain bird species depend on the mangrove ecosystem for roosting, food, breeding, and other necessities. They also play a crucial role in maintaining the mangrove ecosystem through a variety of activities, primarily those of pollinators, seed dispersers, and pollution regulators. They also provide food for other animal predators and contribute to nutrient-recycling processes. Not only are birds important for a mangrove, but the mangrove is also important for birds. They are completely reliant on their habitat for supplying rich food resources. The habitat type, size of the area, plant community structure and landscape pattern can have a great effect on the bird community structure (Wijesekara 1999). However, few animals have been reported to feed on mangrove trees directly, whereas other parts of the mangrove, like dead leaves, stems and roots are progressively broken down into detritus because microbes are not active to decompose them. This detritus is consumed by a variety of invertebrate species (Day et al. 1975). The benthic animals are responsible for secondary productivity, and they are very good pollution indicators. The major production of birds and macrobenthos is what determines the fertility and health of the mangrove ecosystem. Higher faunal diversity in the mangrove ecosystem may be a result of the abundance of food supplies and the diversity of plants, which offer a wide range of animal's suitable habitats for breeding and foraging (Rajpar & Zakaria, 2014). There have been records of 70 bird species, 10 mammals, 12 reptiles, 12 fish, and 3 amphibians from the Puduvypu mangroves in Cochin, Kerala (Kathiresan et al., 2015). About 41 species of birds belonging to 25 families have been recorded in the mangalavanam bird sanctuary of cochin mangroves. (Jayson, E.A., 2001). 39 species of fish were found in the panangad-kumbalam backwaters of Vembanadu Lake, belonging to 27 families, 11 orders, and 31 genera. (Mogalekar, et al., 2015). There are 12 real mangrove crab species in the Puthuvype region, which are divided into 4 families (Portunidae, Grapsidae, Sesarmidae and Ocypodidae) (Apreshgi et al.,2019). The Mangalavanam neighbourhood of Cochin was where records of the Indian Flying Fox (Pteropus giganieus), Painted Bat (Kerivoula picta), Three-striped Palm Squirrel (Funambulus palmarum), House Rat (Rattus rattus), and Bandicoot-rat (Bandfcota sp.) were made, which are the major mammals of the region (Jayson, 2001).

Ironically, despite having such diverse animal groups, mangrove areas are nevertheless losing ground as a result of human activity at an alarming rate every day. Different mangrove-dependent animals, including birds, mammals, reptiles, and amphibians are seriously threatened by habitat degradation, i.e., extinct and critically endangered species (Rajpar & Zakaria, 2014). A comprehensive study on the distribution of macrofaunal diversity was lacking in the Kumbalam mangroves due to the limited number of studies. Therefore, in the present investigation, an attempt has been made to discuss the diversity of macrofauna in the Kumbalam mangroves in association with the analysis of water quality parameters as a corroboration. This work is an attempt to correlate productivity, such as the physical and chemical properties of water, and macrofauna abundance in the Kumbalam mangroves. Hence this study can be considered a novel study.

AIM OF THE STUDY

The present investigation aims to correlate productivity, such as the physical and chemical properties of water, and macrofauna abundance in the Kumbalam mangroves to comprehend the location-specific species for a better knowledge of the existing mangrove biodiversity distribution pattern and conservation actions.

OBJECTIVE OF THE STUDY

- To study the macrofaunal diversity associated with the mangroves of Kumbalam village.
- To estimate the water quality parameters and nutrient content of water samples collected from study stations.
- To corroborate the physio-chemical parameters with the diversity of macrofauna associated with the mangrove of Kumbalam.

RELEVANCE OF THE WORK

Mangrove-associated fauna significantly influences the structure of the mangrove forest and the environment. While considering the ecological and economic functions, mangroves experience an annual loss between 0.16 and 0.39% worldwide as a result of accelerated coastal development. However, compared to the woods they live in, mangrove faunal assemblages have received far less research and documentation. Current studies show that the estuary's hydrology influences the population structure of many mangrove species and also revealed that the widely distributed mangrove species around the world have minimal genetic diversity. Hence, knowledge of regionally specific population structure is needed for a better understanding of the existing mangrove species distribution pattern and conservation actions. For effective management, modern mangrove conservation centres on early detection and pre-emptive rehabilitation. And the criteria for achieving this are knowledge of the location and species of the particular mangrove stands of a region. Since a limited number of works were carried out in Kumbalam mangroves, a thorough analysis of the distribution of macrofaunal diversity in this region was scarce. Thus, to explore the richness of macrofauna in the Kumbalam mangroves in conjunction with the analysis of physio-chemical parameters as a corroboration, an attempt has been undertaken in the current investigation.

REVIEW OF LITERATURE

MANGROVE ECOSYSTEM

Mangrove ecosystems are coastal marshes with woody vegetation that can be found in brackish and intertidal waters (Sreelekshmi et al., 2021). The most productive ecosystems on earth are mangrove forests, which are found in tropical areas where land meets the water. Mangrove forests are sometimes known as "tidal forests," "coastal woodlands," or "oceanic rain forests." These mangrove forests provide a habitat for numerous types of aquatic and terrestrial animals that are genetically diverse. The fauna of mangroves are used to survive in a variety of salinity, tidal amplitudes, winds, temperatures, and even in muddy and anaerobic soil conditions (Kathiresan et al., 2015).

Numerous marine creatures need mangrove vegetation, and freshwater organisms rely on them as a food source and a place to raise their young. The study of Snedaker (1978) in mangrove settings revealed that 90% of marine fishes complete various phases of their life cycles in mangrove forests. According to Jayson (2001), mangroves offer a variety of benefits to birds such as nesting locations for owls, storks, herons, and raptors. In the winter, after feeding in the tidal mud flats, Palaearctic waders use them as roosting locations

The estimated global area of mangroves, a unique species of forest, is 15.2 million hectares over 123 countries and territories. In deltas, estuaries, and wetland coastlines, mangroves exhibit greater faunal richness and abundance (FAO, 2007).

The previous studies of Kathiresan et al., (2015) revealed that in India, mangroves cover a total of 4663 km^2, with 59 per cent of that area located along the Bay of Bengal coast in the east, 28 per cent along the Arabian Sea coast, and 13 per cent in the Andaman and Nicobar Islands. India's mangrove forest habitats support large faunal groups that include 3091 species.

It was reported by Kathiresan et al., (2015) that Sundarbans, located between Bangladesh and India, are the biggest mangrove forest, covering roughly 10,000 km^2. The Bengal tiger, sea turtle, fisher cat, estuary crocodile, Gangetic dolphin, and river terrapin are just a few of the globally vulnerable species that call the Sundarbans, the only tiger mangrove kingdom in the world, home.

MANGROVE FLORA

From the works of Satheeshkumar (2011), mangroves can be defined as plants that can withstand salt efficiently and are found in tropical and subtropical intertidal regions of the world. These plants only thrive in restricted areas called mangrove habitats. These environments serve as the breeding, feeding, and nascent grounds for a variety of estuarine and marine animals, including finfish and shellfish. Only 2.66% of the world's mangroves, or 4,827 square kilometres, are found in India based on the research works of Kathiresan (1999). India has a total of 69 mangrove species that are divided into 42 genera and 22 families. Twenty mangrove species are classified as rare, endemic, and restricted.

One of the crucial ecosystems on India's west coast is the Kerala mangrove and Sreelekshmi et al., (2021) distinguished 18 different species of mangroves in Kerala, with *Avicennia officinalis* and *Rhizophora mucronata* dominating the region while *Ceriops tagal, Avicennia alba*, and *Sonneratia alba* being uncommon. Thirteen different species of mangroves were found in the Kerala region of Ernakulam.

The studies of Rajagopalan et al., (1986) revealed that in the backwaters of Cochin, species of *Acanthus, Excoecaria, Clerodendrum, Aegiceras, Avicemia*, and *Rhizophora* make up the majority of the mangrove flora. The majority of the local fauna consists of characteristic mangrove species like *Uca species* in the upper littoral zone, *Nautica species* and hermit crabs in the middle littoral zone, *Cerethidium species* and *Terebralia species* on the mudflats, and gastropods like *Littorina species* on the trunks and leaves of mangroves.

MANGROVE FAUNA

Abundance in the mangrove faunal communities, both permanent and passing or transient wildlife can be found as birds, mammals, reptiles, and insects making up the majority of visiting terrestrial wildlife. This can be proposed from the work of Ramakrishna (2008) where a few molluscs and echinoderms, fish and crustacean species make up the majority of the aquatic visitor fauna. Visitors from nearby habitats like woods, coral reefs, estuaries, streams, and bays invade mangroves. Benthic fauna in intertidal habitats, which are divided into two major types called infauna and epifauna, make up the majority of the resident fauna of mangroves. Polychaetes, brachyuran crabs, wood-boring creatures, mud-burrowing bivalves, and gobiid fish are the main types of infauna species that burrow and penetrate the substratum.

Common gastropods and several sessile bivalves, including oysters, *Modiolus species*, and barnacle crustaceans, are included in the epifauna. Birds like the black-capped kingfisher (*Halcyon pileata*), brown-winged kingfisher (*Halcyon amauroptera*), and mangrove whistler *(Pachycephala grisola*), as well as insects like Polyura schreiber, are among the local terrestrial fauna (*Lepidoptera: Nymphalidae*).

India's mangrove forest habitats are home to 3091 different species of animals. This may be the world's largest record of biodiversity for mangrove environments (Kathiresan, 2000). Numerous studies, for instance (Gopikumar et al.,2008; Khaleel,2008; Bhosale,2008; Remadevi et al.,2008; Latheef et al.,2008; Rajavel & Natarajan, 2008; Santhakumaran,2008) have revealed that there are more species of invertebrates than there are of vertebrates. The number of faunal species so far identified was largest in the mangroves on the east coast (2061), then on the Andaman and Nicobar Islands (922 species), and the west coast (727 species).

There have been records of 70 bird species, 10 mammals, 12 reptiles, 12 fish, and 3 amphibians from the Puduvypu mangroves in Cochin, Kerala (Gopikumar et al., 2008). There are a total of 11 species in the mangroves of Beypore, which are divided into 9 genera and 9 families, while there are 13 species in the mangroves of Kottakadavu, which are divided into 13 genera and 10 families. This diversity of oribatid mites is found in the mangroves of the Calicut district of Kerala state (Julie et al., 2008). Mangroves' essential faunal component, is mosquitoes. In mangrove swamps, crab holes, and tree holes, mosquitoes can spawn. 62 species of mosquitoes from 19 genera and 21 subgenera have been identified in Indian mangroves thus far. In regions with mangroves, the mosquito population has expanded due to tourism (Rajavel & Natarajan, 2008). The ecological importance of crabs to mangrove productivity cannot be overstated. India has 35 species in total, divided into 25 genera and 10 families. Kerala has the most diversity of crab species, with 27 different varieties (Roy and Nandi, 2008). Mangrove system's diverse habitats, including their core forests, litter-forest floors, mudflats, nearby coral reef and sea grass ecosystems, and nearby water bodies including rivers, bays, intertidal creeks, channels, and backwaters, contribute to their great faunal variety. While oysters, snails, barnacles, crabs, and other invertebrates can be found on the aerial roots, lower trunks of trees and forest floor, the calm waterways of the forests make excellent nurseries and breeding grounds for fish and shellfish. Terrestrial animals including birds, reptiles, insects, and mammals can also be found in forests (Kathiresan et al., 2015).

A highly contemplative work on mangrove macrofauna by Rajagopalan et al., (1986) recorded exceedingly conclusive data such as the dead roots and trunks of mangrove trees to be harmed by wood-boring organisms, such as *Sphaeroma species* among crabs, teredinids, and bivalves. During specific seasons, a high concentration of prawn and fish larvae and juveniles, along with a dense growth of filamentous algae, are seen in mangrove creeks and tidal pools. *Terebralia* that lived in the muddy out pocket of Pambaimoola, a backwater system about 5 km south of Cochin were observed. *Nerita* and *Littorina* were seen on hard surfaces at the top edge of the marsh, and *Crassostrea* and barnacles in the lower area. Both *Marphysia* egg cases and burrowing polychaetes were seen as widespread. On rare occasions, *Terebralia* was seen to be associated with Modiolus species. The leaves of *Acanthus* were used to collect a few nudibranchs. Crabs from the families *Portunidae, Ocypodidae*, and *Grapsidae* are frequently found above the intertidal zone. In the swampy ponds, juveniles of the prawn species, *Aplocheilus, Terapon,* and *Ambassis* were frequently found. During the summer, a lot of hydromedusae, including *Eirene species*, were found in the backwaters of Cochin. Tube-dwelling polychaetes were seen in the sandy flats. On the dead mangrove trunks, *Modiolus* and mussel young were found. On rare occasions, wood-boring bivalves and crustaceans had been spotted on mangrove stumps and breathing roots. The most common time for *Ceretheditm* to occur was between March and May. There were plenty of young *Terapon*, *Ambassis*, and prawns in the tidal pools within the mangrove flora. Boring bivalves were frequently observed in the mangroves' decaying roots. In the exposed muddy places during specific months, anemones and gastropod *Ilobium species* audit egg masses. In the waterways in the mangrove region, juvenile *Penaeus indicus, Metapenaeus dobsoni,* and *M. monoceros* were frequently noted. Only a few *Terebralia* species may be found in Chenthuruthy, Thrissur region and they are dispersed. Crabs such as the *Uca, Scylla serrata, Sesarma*, and *Metapograpsus* were observed above the intertidal zone in various months. Different seasons allowed for the discovery of young *Aplocheilus, Ambassis, Etroplus, gobiids, Tetradon*, and *Batrachus* in the creeks and ponds.

In recent years, there has been considerable interest in the Mangalavanam forest of Cochin and Jayson (2001) recorded the Indian Flying Fox (*Pteropus giganieus*), Painted Bat (*Kerivoula picta*), Three-striped Palm Squirrel (*Funambulus palmarum*), House Rat (*Rattus rattus*), and Bandicoot-rat (*Bandfcota species*) in the region. The Mangalavanam mangroves have documented 41 different bird taxa. These birds belonged to 25 families. Little Cormorant and Black-crowned Night Heron were the most prevalent bird species at Mangalavanam.

Passeriformes were documented maximum in number followed by Ciconiiformes and Pelecaniformes. Only two species, the Eurasian Golden Oriole and the Large Pied Wagtail have been identified as local movers in the region. Other species, except the Little Cormorant and Black-crowned Night Heron, were scarce.

The benthic habitat is an essential component of the food chain for edible resources and determines the ecosystem's overall health. Polychaetes, echiuroids, sipunculids, molluscs, crabs, echinoderms, specific benthic plants, sponges and corals, protozoa, and coelenterates are among these non-edible species. Due to Cochin Port Trust's dredging, a decrease in the benthic fauna was noted by Thomson (2002).

Kurup (1982) compiled a comprehensive inventory of the fish and shellfish species present in the Cochin backwaters. In the backwaters, he claimed, at least 150 species were present in the early 1980s. The disquisition put forward by Thomson (2002) revealed that 43 species, including *Punctius sarana, Mystus gulio, Tachysurus subrostratus, Hyporhamphus xanthpterus, Labeo dussumieri, Amblypharyngodon mola, Oxyurichthys tentacularis, Oxyurichthys microlepis, Oxyurichthys nijsseni, Glossogobius biocellatus, Glossogobius giuris, Puntius filamentosus, Punctius amphibius, Hyporhaphus limbatus, Strongylura strongylura, Xenentedon cancilla, Megalops cyprinoides, Anguilla bicolor bicolor, Daysciaena albida, Scatophagus argus, Sarotherodon mossambicus, Etroplus suratensis, Etroplus maculatus, Valamugil cunnesius, Liza macrolepis, Liza parsia, Stenogobius malabaricus, Brachiurus orientalis, Cynoglossus puncticeps, Platicephalus indicus, Ambassis dayi, Wallago attu, Ambasis gymnocephalus, Terapon jarbua, Sillago vincenti, Lutjanus argentimaculatus, Gerres filamentosus, Sillago sihama, Caranx sexfasciatus, Gerres setifer, Dendrophysa ruselli* and *Chelonodon patoca* were available all year long. The number of migratory species was 74, and the number of vagrant species was 17.

The study undertaken by Apreshgi & Kurian (2019) to assess the Brachyuran crabs of the Puthuvype mangrove belt of Cochin backwaters revealed that there are 12 real mangrove crab species in the Puthuvype region, which are divided into 4 families (*Portunidae, Grapsidae, Sesarmidae and Ocypodidae*). *Ocypodidae* has two species, followed by *Graspidae* with three, *Portunidae* with four, and *Sesarmidae* with three. *Pseudosesarma glabrum* and *Metopograpsus latifrons* recorded the lowest abundance, while *Parasesarma plicatum* and *Astruca annulipes* had the highest abundance. The 12 species of mangrove crabs found in Puthvype *include Scylla olivacea, Scylla tranquebarica, Scylla serrata, Thalamita crenata, Metopograpsus latifrons,* *Metopograspus messor, Metopograspus thukuhar, Neosarmatium malabaricum, Parasesarma plicatum, Pseudosesarma gla*.

The exploration of Vembanad Lake by Mogalekar et al., (2015) revealed that numerous decapod crustaceans use it as a breeding and rearing area. Indian estuarine habitats are home to a variety of well-known decapod crustaceans. One of the main resources of Indian estuaries is the crustacean fishery, which includes commercially valuable shrimp, prawns, and crabs. Up to 705 species of brachyuran crab and 437 species of shrimp and prawn have been identified in India.

The faunistic study in Mangalavanam, a mangrove forest in cochin, by Sebastian et al., (2005) led to the identification of 51 species of spiders from 16 families and 40 genera. This amounts to 27% of all spider families that have been reported in India so far. *Araneidae* was the most abundant family, accounting for 12 species from 8 genera. The leading species at the species level was *Pisaura gitae*. Seven feeding guilds, including orb weavers, stalkers, ground hunters, foliage runners, sheet web builders, scattered line weavers, and ambushers, were identified using guild structure examination. The two main feeding guilds, orb weavers and stalkers, made up 33% and 29% of the entire collection, respectively.

The Ashtamudi Estuary on the southwest coast of India was surveyed for its molluscan fauna by Ravinesh et al., (2021) and the results revealed the presence of 119 species divided into three classes (*Polyplacophora, Gastropoda*, and *Bivalvia*), 57 families, and 96 genera. The *Gastropoda* (69 species), followed by the *Bivalvia* (49 species), and the *Polyplacophora* (1 species), dominated the species diversity.

KUMBALAM MANGROVE FOREST

Arun and Shaji (2013) mapped the seaside region of Kumbalam at 90 54' 41.96" to the north and 760 18' 32.36" to the east of the Ernakulum district. They chronicled mangrove flora of Kumbalam island consists of seven true mangrove species (*Acanthus ilicifolius L, Avicennia officinalis L, Bruguiera gymnorrhiza Lamk, Kandelia candel L, Rhizophora mucronata Lamk, Sonneratia caseolaris L, Excoecaria agallocha L*), two semi-mangrove species (*Acrostichum aureum L, Derris trifoliata L*) and eight species of Mangrove associates (*Bacopa monnieri L, Cayratia carnosa L, Cerbera odollam G, Thespesia populnea L, Mariscus javanicus H, Fimbristylis ferruginea L, Hibiscus tiliaceus L, Morinda citrifolia L*).

Only the Kumbalam and Kumbalagi Panchayaths of Cochin Mangroves have records of extremely rare species like *Bruguieras sexangular* (Warrier, 2010).

(Mogalekar et al., 2015).

Mogalekar et al., (2015) observed 20 species of decapod crustaceans belonging to 5 groups and 10 genera in the Panangad-Kumbalam Backwater of Vembanad Lake. They were recognised as being about 7 species of Penaeid shrimp, 5 species of Palaemonid prawn, 5 species of Portunid crab, 2 species of Sesarmid crab, and 1 species of Ocypodi crab. The most common species among crabs are *Macrobrachium idella* among freshwater prawns and *Metapenaeus affinis* among marine shrimps.

As the result of a highly pivotal inquisition put forward by Mogalekar et al., (2015) 39 species of fish were found in the panangad-kumbalam backwaters of Vembanadu Lake, belonging to 27 families, 11 orders, and 31 genera. Vembanadu Lake is home to 150 species of fish from 100 genera and 56 families. According to a study of family composition, the representation of the *Cichlidae* and *Mugilidae* was higher than that of other families.

MANGROVE DEGRADATION

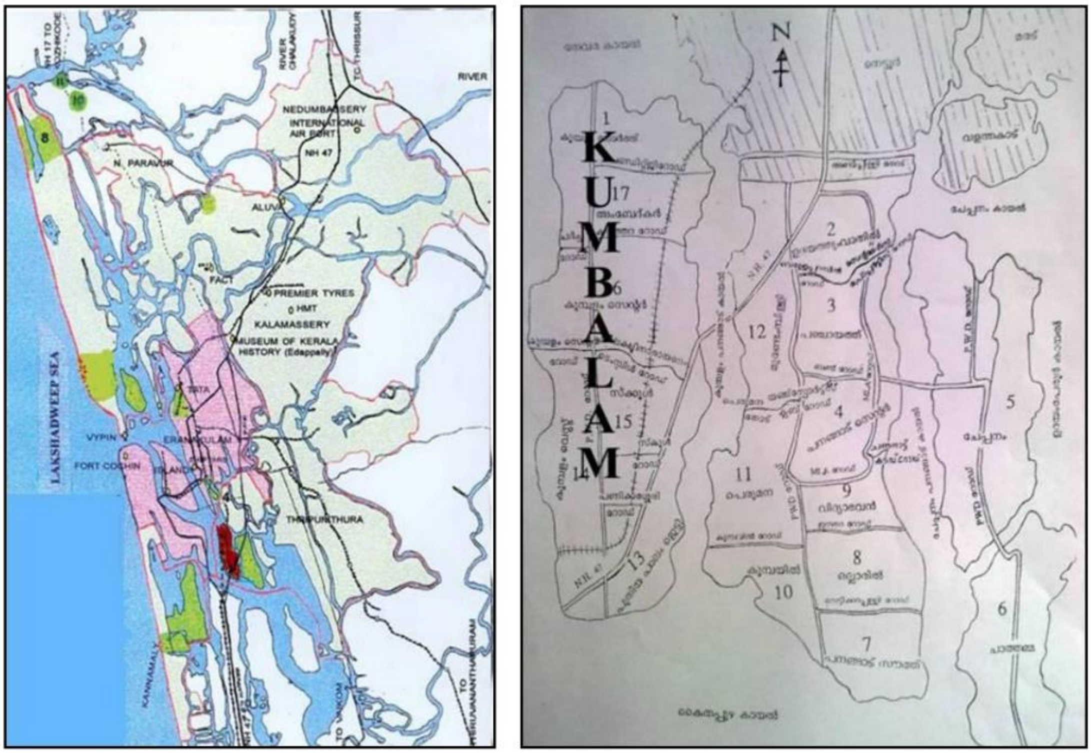
Satheeshkumar (2011) estimated the total mangrove area in Kerala, on India's west coast to be roughly 17 square kilometres, of which 36% are either entirely damaged or are degrading. Globally, mangrove habitats are still being lost at a pace of 0.66 per cent yearly (FAO, 2007). Around 90 per cent of the mangrove forest cover is found in developing countries. Mangrove fragmentation poses a serious threat to the long-term survival of the mangroves. Within a century, it's feasible that mangrove ecosystem services will no longer exist (Duke et al., 2007). Around the world, the loss of mangrove habitat has increased the extinction risk for 40 per cent of mangrove-associated animal species and 16 per cent of mangrove plant species (Polidoro et al., 2010).

A third of the mangrove area has been reported to be lost over the previous 20 years owing to land reclamation, conversion to agricultural fields, deforestation, aquaculture, urbanisation, or coastal development by the extensive investigations of (Rajpar & Zakaria, 2014). In addition, (Lewis 2016) asserts that the depletion of freshwater, nutrient enrichment from sewage discharge, and sea level rise also pose threats to mangrove species, particularly those that are low saline tolerant.

Significant inherent dangers to wildlife species, especially bird species, have resulted from habitat loss and degradation; in fact, 40.0% of the bird population in mangrove regions has reduced. Additionally, all species of turtles, 43% of crocodiles, 20% of fish, 37% of mammals, 21% of birds, and 43% of amphibians that depend on mangroves, mudflats, and estuary environments are extremely threatened to extinction on a worldwide scale. Coastal erosion, habitat loss, excessive exploitation, climate change, organic pollution, toxic contamination and overfishing are the main causes driving the population decline of mangrove fauna (Rajpar & Zakaria, 2014).

MATERIALS AND METHOD

STUDY AREA



(a) (b)

Fig 1: showing the (a) map of Ernakulam district (b) map of Kumbalam island

The study area, Kumbalam is a coastal village, 90 54’ 41.96” North and 760 18’ 32.36” East, in the Ernakulam district of Kerala. Kumbalam, Panangad, Cheppanam, and Chathamma are the little islands that makeup Kumbalam Village, including Madavana and Udayathumvathal. Kumbalam situates on the southwestern side not far from the border of the Corporation of Cochin. They are located in the cochin backwaters connected to the Vembanad estuaries.

Table 1: showing the coordinates of the study area and time of sampling

SL NO	STATION	DATE	TIME	LAT	LONG
1	Station 1	13/12/22	12.51 pm	9.916915˚N	76.309102˚E
2	Station2	15/12/22	7.15 am	9.919967˚N	76.305150˚E
3	Station 3	17/12/22	7.34 am	9.924671˚N	76.30954˚E
4	Station 4	17/12/22	7.53 am	9.930818˚N	76.314338˚E
5	Station 5	17/12/22	8.11 am	9.930336˚N	76.301869˚E
6	Station 6	05/01/23	3.45 pm	9.9114˚N	76.3154˚E

PHYSIO-CHEMICAL PARAMETERS

For the present investigation, water samples were collected from 5 different locations in the investigation area to analyse the water quality parameters.

Water Quality parameters: Temperature, Dissolved oxygen, salinity, pH, nitrite, nitrate, phosphate and silicate.

1. TEMPERATURE

The water samples collected from the sampling station were measured using a calibrated 10-150℃ mercury thermometer (Jennson Deluxe) with 0.1℃ accuracy.

2. pH

The pH is the scale that determines how acidic or basic a solution is. The water samples from the sampling station are recorded using a calibrated pH meter (Oakton pH 550 – benchtop pH meter) with 0.1 accuracies.

3. SALINITY

Salinity is calculated as the weight in grams of solids that can be recovered from 1 kg of saltwater after all the carbonate has been converted to oxide, all the bromine and iodine has been replaced by chloride, all the organic matter has been oxidised, and the residue has been dried at 480°C to a constant weight. The salinity of the water sample collected is measured by using a digital refractometer (Atago Mera Pal Pocket Digital Refractometer) with a Brix range of 0.0-53.0.

4. DISSOLVED OXYGEN

The amount of dioxygen gas (O_2) in micromoles per kilogram of water sample (mol kg-1) is the unit used to measure the amount of dissolved oxygen in a water sample. Dissolved Oxygen (DO) in the water samples is calculated by the method formulated by (Winkler,1888).

calculation

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

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

N = Normality of thiosulphate solution

E =Equivalent weight of Oxygen = 8

1000 = To express per litre

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

5. CHLOROPHYLL

All photosynthetic organisms include the common and plentiful pigment chlorophyll a. It is used widely for estimating phytoplankton biomass. The chlorophyll concentration of the water sample is estimated using Strickland and Parsons (1972). A known volume of the seawater is filtered through a cellulose nitrate membrane (HIMEDIA) having a pore size of 0.45µm. the pigments are extracted from the filter in 90% acetone and kept overnight at 4°C and their concentration is estimated using a UV spectrophotometer

(Genesys 180 UV-vis spectrophotometer) at multiwavelength of 630nm,647nm,664nm and 750nm.

calculation

$$\textbf{(Ca) Chlorophyll a} = 11.85\ E664 - 1.54\ E647 - 0.08\ E630$$

E = absorbance at different wavelengths (corrected by the 750 nm reading)

Ca = amounts of chlorophyll (in µg/mL if a 1 cm light path cuvette)

$$\text{mg chlorophyll}/\ m^3 = \frac{C \times v}{V \times 10}$$

v = volume of acetone in mL

V = volume of the seawater in litres

6. NUTRIENTS

The major nutrients in the water sample are nitrate, nitrite, phosphate and silicate. The determination of its concentration gives an overall report of the productivity of the water sample. Hence, nutrient concentration is also determined.

a. Nitrate

Nitrate concentrations are determined using a modified version of Morris and Riley's (1963) method developed by Strickland and Parsons (1972). The nitrate in the water sample is reduced, almost quantitatively to nitrite, by passing through a column containing coppered cadmium filings. The nitrite produced reacts with sulfanilamide in an acid solution. The resulting diazonium compound is coupled with N-(1-Naphthyl)-ethylenediamine dihydrochloride to form a coloured azo dye. The absorbance of the dye is measured using a UV vis-spectrophotometer (Genesys 180 UV-vis spectrophotometer) at 540 nm.

Calculation

The calculation for Factor value (F):

$$\mathbf{F = \frac{A(st) - A(b)}{Conc.\ of\ standard\ solution}}$$

A (st) = Mean absorbance of standards.

A (b) = Mean absorbance of blanks.

Calculate the concentration of Nitrate present in the sample

Nitrate µmol/L = F x A(s) – A(b)

A(s) = Mean absorbance of samples.

A(b) = Mean absorbance of blanks.

b. Nitrite

The determination of nitrite is based on the method of Strickland and Parsons (1972). In an acidic solution, nitrite and sulfanilamide combine to form a diazonium molecule. A colourful azo dye is created by coupling this with N-(1-Naphthyl)-ethylenediamine dihydrochloride. The absorbance of the dye is measured using a UV vis-spectrophotometer (Genesys 180 UV-vis spectrophotometer) at 540 nm.

Calculation

The calculation for Factor value (F):

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

A (st) = Mean absorbance of standards.

A (b) = Mean absorbance of blanks.

Calculate the concentration of Nitrite present in the sample

Nitrite µmol/L = F x A(s) – A(b)

A(s) = Mean absorbance of samples.

A(b) = Mean absorbance of blanks

c. Phosphate

The determination of reactive phosphorus in seawater is based on the method proposed by Strickland and Parsons (1972). The water sample is allowed to react with a composite reagent containing ammonium molybdate, ascorbic acid and potassium antimonyl-tartrate. The resulting complex is reduced to give a blue-coloured solution. The absorbance of the coloured solution is measured using a UV vis-spectrophotometer (Genesys 180 UV-vis spectrophotometer) at 880 nm.

Calculation

The calculation for Factor value (F):

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

A (st) = Mean absorbance of standards.

A (b) = Mean absorbance of blanks.

Calculate the concentration of phosphate present in the sample

Phosphate µmol/L = F x A(s) – A(b)

A(s) = Mean absorbance of samples.

A(b) = Mean absorbance of blanks.

7. SAMPLING

a) Avian sampling

The study sites were surveyed and the bird population was estimated by direct counting method. A 10 X 50 Olympus binocular and Cannon 1100 D Zoom camera were used to make the observations.

b) Fish sampling

The fish samples were collected from the respective study sites using a nylon 350-micron scoop net.

c) Mammals and reptile sampling

For estimating the mammalian and reptilian population direct counting method was used. The study sites were systematically recorded for indicators of the organism like scat, burrows, scales, hairs etc.

d) Invertebrates sampling

The corresponding invertebrate such as crustaceans were collected from water samples using a nylon 350micron scoop net. Gastropods and bivalves were collected from their substratum using forceps.

8. PRESERVATION OF MACROFAUNAL SAMPLES

Aquatic macrofaunal samples that were recorded and isolated from the sampling stations are preserved in a 4% formaldehyde solution. Other avian and terrestrial macrofaunal samples were recorded as photographic evidence.

9. HERBARIUM PREPARATION

In addition to bringing sample species to prepare the herbarium, photographs were also taken at the location. A herbarium was created, and it was later used to identify the many species of mangroves.

10. STATISTICS

Preliminary data interpretation in Excel

One of the most used tools for data analysis in Microsoft Excel. They are without a doubt the most sought-after analytical tool available since they include built-in pivot tables. You can simply import, browse, clean, analyses, and visualise your data using this all-in-one data management tool.

RESULT

The current study attempted to identify faunal variations in Kumbalam mangroves and substantiate them with changes in physio-chemical conditions. The following stations were selected for the study: (given in Table 2).

Table 2: showing the description of study stations.

STATION	DESCRIPTION
Station 1	It is surrounded by native settlements and has little freshwater inflow into the mangrove, it is extremely contaminated, primarily from domestic waste.
Station 2	It constitutes a dense mangrove forest where diverse fishing activities and routine water transportation are steered.
Stations 3	It depicts the offshore open region corresponding with Station 2, where waves are significant
Station 4	It portrays a lush, abundant, and diversified mangrove habitat with the freshwater influx from the adjacent river.

PHYSIO-CHEMICAL PARAMETERS

The current study investigated several physio-chemical parameters to develop an unambiguous image of the study site's ecology and to project the specific relations that exist between the physio-chemical condition and the faunal population existing in the mangrove ecosystem. Distinct variations in the physio-chemical conditions and the abundance of zooplankton were seen. The physio-chemical results are as follows: (given in Table 3).

Table 3: shows the physio-chemical parameters recorded from the study sites.

SL NO	STATION	TEMP ˚C	pH	SALINITY (ppt)	CHL (mg/L)	DO (mg/L)	NUTRIENTS		
							PHOSP (μmol/L)	NITRATE (μmol/L)	NITRITE (μmol/L)
1	Station 1	28.6	6.7	0.3	30.0784	0.955	29.82	6.79	1.655
2	Station 2	20	7.05	1.2	4.4074	5.277	18.613	8.347	2.4505
3	Station 3.1	23	7.11	2.0	4.4319	5.803	10.857	4.818	1.393
4	Station 3.2	22	7.41	1.6	4.53118	5.111	12.268	1.962	1.793
5	Station 3.3	22.5	7.60	1.6	4.51844	6.134	12.1481	4.376	1.577
6	Station 4	24	7.71	2.4	4.78	5.9	8.347	3.027	0.078

Temperature: The temperature of the water did not fluctuate appreciably over the research period or between the study stations. The average temperature obtained from the study stations was found to be 22.3˚ C. The highest temperature observed was 28.6℃ and the lowest temperature observed was 20℃. Temperature showed a significant positive correlation with pH (r = 0.674169), salinity (r = 0.946233), DO (r = 0.64181) and chlorophyll (r = 0.725555), and a significant negative correlation with nitrite (r= -0.79347), phosphate (r = -0.75007) and nitrate (r = -0.7223).

Salinity: The salinity value of the study station falls within a range of 2.24 ppt to 19.95 ppt and the average value is 11.35167ppt. The research stations were determined to be mesohaline (5-18ppt) except for station I, which was oligohaline (0.5-5 ppt). Salinity showed a significant positive correlation with pH (r = 0.812271), temperature (r = 0.946233) and DO (r = 0.868252) a and significant negative correlation with chlorophyll (r = -0.82046), nitrite (r = -0.59791), phosphate (r = -0.87004) and nitrate (r = -0.63).

pH: Whereas in the case of pH concentration, not many fluctuations have been observed between the stations. The pH values ranging from 6.7 to 7.71 have been noted from the study stations and the average pH is 7.263333. pH showed a significant positive correlation with temperature (r = 0.674169), salinity (r = 0.812271) and DO (0.781094) and a significant negative correlation with chlorophyll (r = -0.71941), nitrite (r = -0.82515), phosphate (r = -0.840540) and nitrate (r = -0.72095).

Chlorophyll: The chlorophyll content in the sample stations varied diversely across the stations and they ranged from 4.4319 mg/L to 30.0784 mg/L. the average chlorophyll obtained from the study stations is 8.79122mg/L. pH showed a significant positive correlation with temperature (r = 0.725555), nitrite (r= 0.304702), phosphate (r= 0.975287) and nitrate (r= 0.387796) and significant negative correlation with pH (r = -0.71941), salinity (r = -0.82046) and DO (r= -0.97922).

Dissolved Oxygen: The concentration of dissolved oxygen varied greatly amongst the study stations. The concentration of dissolved oxygen across the study station ranged from 0.955 mg/L to 6.134 mg/L and the average DO was found to be 4.863333 mg/L. DO show a significant positive correlation with pH (r = 0.781094), temperature (r = 0.64181) and Salinity (r= 0.8682) and a significant negative correlation with chlorophyll (r = -0.97922), nitrite (r= -0.38475), phosphate (r= -0.98541) and nitrate (r= -0.40644).

Nitrite: The nitrite recorded in the sample solution showed the highest value at 2.4505μmol/L and the lowest value at 0.409 μmol/L. The average value of nitrite recorded was 1.068417 μmol/L. Nitrite showed a significant positive correlation with chlorophyll (r = 0.304702), phosphate (r= 0.494335) and nitrate (r= 0.919566) and a significant negative correlation with pH (r = -0.82515), temperature (r = -0.79347), DO (r= -0.38475), Salinity (r= -0.59791).

Phosphate: The concentration of phosphate across the study station ranged from 8.347 μmol/L to 29.82 μmol/L and their average value was estimated to be 12.95733μmol/L. Phosphate showed a significant positive correlation with chlorophyll (r = 0.975287), nitrite (r= 0.494335) and nitrate (r= 0.494335) and a significant negative correlation with pH (r = -0.84054), temperature (r = -0.75007), DO (r= -0.38475) and Salinity (r= -0.87004).

Nitrate: The nitrate recorded in the sample solution showed the highest value at 8.347μmol/L and the lowest value at 1.962 μmol/L. the average nitrate value obtained from the study stations is 4.886667μmol/L. Nitrate showed a significant positive correlation with chlorophyll (r = 0.387796), phosphate (r= 0.531635) and nitrite (r= 0.919566) and significant negative correlation pH (r = -0.72095), temperature (r = -0.7223), DO (r= -0.40644) and salinity (r= -0.63).

Table 4: showing the correlation between physio-chemical parameters.

CORRELATIONS								
	Temp	pH	Salinity	DO	Chl	nitrate	phosphate	nitrite
Temp	1	0.674169	0.946233	0.64181	0.725555	-0.7223	-0.75007	-0.79347
pH		1	0.812271	0.781094	-0.71941	-0.72095	-0.84054	-0.82515
Salinity			1	0.8682523	-0.82046	-0.629995	-0.870042	-0.597905
DO				1	-0.97922	-0.406437	-0.985412	-0.384748
Chl					1	0.3877961	0.9752873	0.3047019
Nitrate						1	0.531635	0.919566
phosphate							1	0.494335
nitrite								1

MACROFLORA

The diversity of mangrove fauna in the study stations was estimated and seven true mangrove species belonging to four families were recorded from the different study stations. *Acanthus ilicifolius L.* was the most recorded species, observed in all study stations. Whereas *Sonneratia caseolaris L., Exoecaria agallocha L.* and *Bruguiera gymnorhiza* were only observed in station 6. The mangrove species *Avicennia officinalis L.* was observed only in station 1.

Table 5: showing the true mangroves observed from the study sites

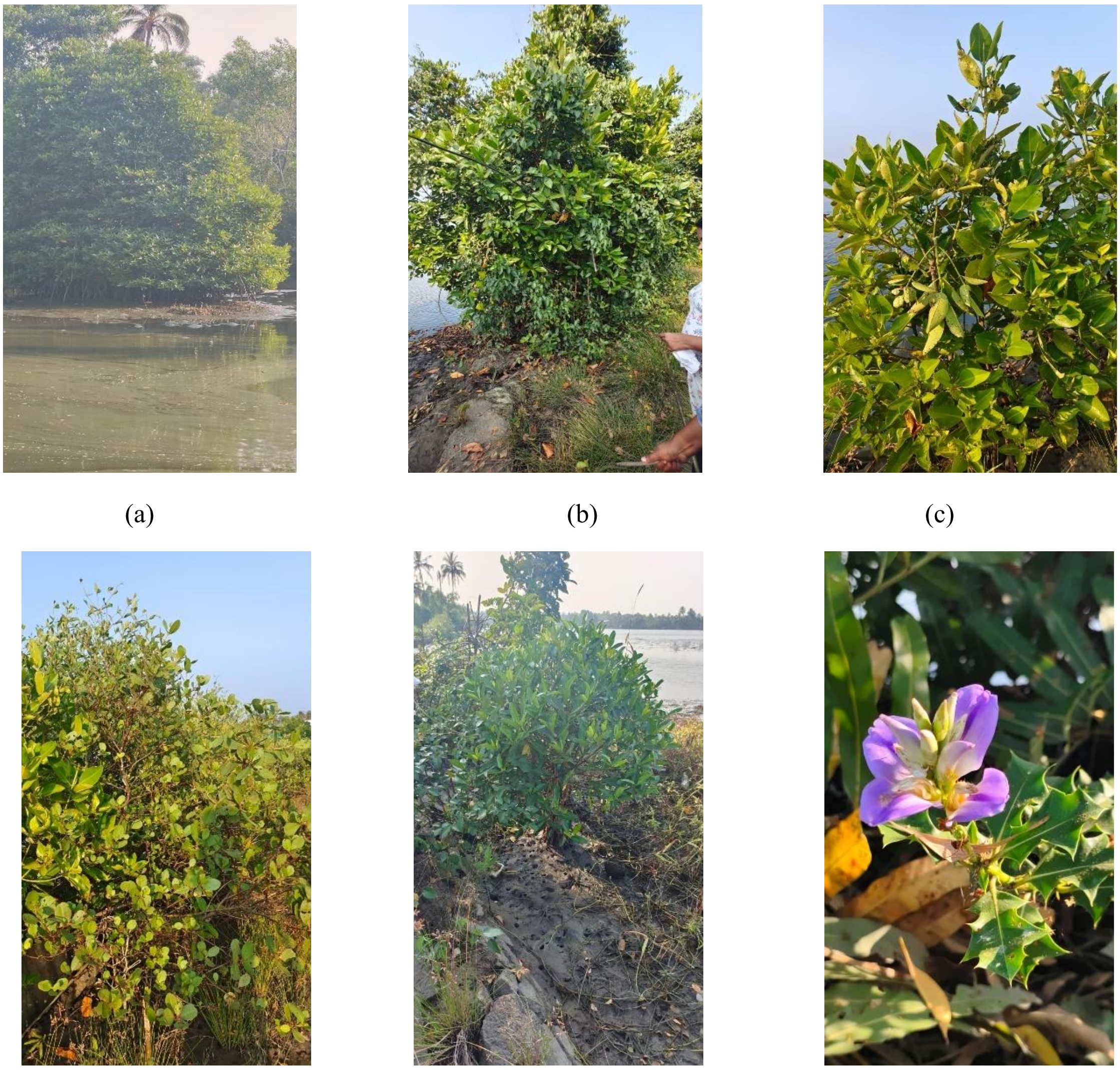
NO.	GENERA	FAMILY	SITE
1	*Acanthus ilicifolius L.*	*Acanthaceae*	1,2,3.1,3.2,3.3,4
2	*Avicennia officinalis L.*	*Avicenniaceae*	1
3	*Rhizophora mucronate*	*Rhizophoraceae*	2,3.1,3.2,3.3,4
4	*Sonneratia caseolaris L.*	*Rhizophoraceae*	4
5	*Exoecaria agallocha L.*	*Euphorbiaceae*	4
6	*Bruguiera gymnorhiza*	*Rhizophoraceae*	4

Table 6: showing the semi-mangroves observed from the study sites

NO.	SEMI MANGROVES	FAMILY	SITE
1	*Acrostichum aureum L.*	*Acrostichaceae*	1,2,3.1,3.2,3.3,4
2	*Derris trifoliata L.*	*Papilionaceae*	1,4

Table 7: showing the mangrove associates observed from the study sites

NO.	ASSOCIATE SPECIES	FAMILY	SITE
1	*Cayratia carnosa L.*	*Vitaceae*	1,4
2	*Salvinia molesta*	*Salviniaceae*	2,3.1,3.2,3.3
3	*Cerbera odollam G.*	*Apocynaceae*	1,4
4	*Fimbristylis ferruginea L.*	*Cyperaceae*	1,4
5	*Mariscus javanicus H.*	*Cyperaceae*	1,4
6	*Thespesia populnea*	*Malvaceae*	1
7	*Hibiscus tiliaceus L.*	*Malvaceae*	1



(a) (b) (c)

(d) (f) (g)

Fig 2; showing mangrove species recorded from the study stations: (a) *Rhizophora mucronate* (b)*Avicennia officinalis L.* (c) *Bruguiera gymnorhiza* (d) *Sonneratia caseolaris* (e) *Exoecaria agallocha* (f) *Acanthus ilicifolius L.*

MACROFAUNA

Avian fauna: 20 species of avian fauna belonging to 9 orders from 213 specimens observed were identified from the study stations. *Sternula albifrons* were observed in the highest number from different study stations.

Table 8: showing the avian fauna observed from station 1

SL N0.	COMMON NAME	SCIENTIFIC NAME	MALAYALAM NAME	ORDER	NO. OBSERVED
1	Brahminy Kite	*Haliastur indus*	കൃഷ്ണപ്പരുന്ത്	*Falconiformes*	5
2	Black kite	*Milvus migrans*	ചക്കിപ്പരുന്ത്	*Falconiformes*	1
3	Great egret	*Ardea alba*	പെരുമുണ്ടി	*Ciconiiformes*	2
4	Greater coucal	*Centeropus sinensis*	ചെമ്പോത്ത്	*Cuculiformes*	1
5	Indian swiftlet	*Aerodramus unicolour*	ചിത്രകൂടൻ ശരപ്പക്ഷി	*Apodiformes*	1

Table 9: showing the avian fauna observed from station 2

SL N0.	COMMON NAME	SCIENTIFIC NAME	MALAYALAM NAME	ORDER	AVERAGE NO. OBSERVED
1	Yellow billed egret	*Ardea intermedia*	ചെറുമുണ്ടി	*Ciconiiformes*	1
2	Little Tern	*Sternula albifrons*	ചെറിയ ആള	*Charadriiformes*	16+
3	Brahminy Kite	*Haliastur indus*	കൃഷ്ണപ്പരുന്ത്	*Falconiformes*	3
4	little egret	*Egretta grazetta*	ചിന്നമുണ്ടി	*Ciconiiformes*	1
5	Common crow	*Corvus splendons*	രാമൻ കാക്ക	*Passeriformes*	6
6	Jungle crow	*Corvus culminatus*	ബലിക്കാക്ക	*Passeriformes*	1
7	Indian pond heron	*Ardeola grayii*	കുളക്കൊക്ക്	*Pelecaniformes*	13+
8	Indian cormorant	*Phalocrocarax fusicollis*	കിന്നരി നീർക്കാക്ക	*Suliformes*	2

Table 10: showing the avian fauna observed from stations 3

SL N0.	COMMON NAME	SCIENTIFIC NAME	MALAYALAM NAME	ORDER	NO. OBSERVED
1	Great egret	*Ardea alba*	പെരുമുണ്ടി	*Ciconiiformes*	3
2	Brahminy kite	*Haliastur indus*	കൃഷ്ണപ്പരുന്ത്	*Falconiformes*	10
3	Black kite	*Milvus migrans*	ചക്കിപ്പരുന്ത്	*Falconiformes*	5
4	Little Tern	*Sternula albifrons*	ചെറിയ ആള	*Charadriiformes*	25+
5	Indian pond Heron	*Ardeola grayii*	കുളക്കൊക്ക്	*Pelecaniformes*	7
6	Indian cormorant	*Phalocrocarax fusicollis*	കിന്നരി നീർക്കാക്ക	*Suliformes*	3
7	Little egret	*Egretta grazetta*	ചിന്നമുണ്ടി	*Ciconiiformes*	2
8	Yellow billed egret	*Ardea intermedia*	ചെറുമുണ്ടി	*Ciconiiformes*	1
9	Alpine swift	*Tachymarptis melba*	വെള്ളവയറൻ ശരപ്പക്ഷി	*Apodiformes*	9

Table 11: showing the avian fauna observed from station 4

SL NO.	COMMON NAME	SCIENTIFIC NAME	MALAYALAM NAME	ORDER	NO. OBSERVED
1	Little egret	*Egretta grazettain*	ചിന്നമുണ്ടി	*Ciconiiformes*	6
2	Alpine swift	*Tachymarptis melba*	വെള്ളവയറൻ ശരപ്പക്ഷി	*Apodiformes*	4
3	Brahminy kite	*Haliastur indus*	കൃഷ്ണപ്പരുന്ത്	*Falconiformes*	12
4	Black kite	*Milvus migrans*	ചക്കിപ്പരുന്ത്	*Falconiformes*	5
5	Black headed ibis	*Threskiornis melanocephalus*	കഷണ്ടിക്കൊക്ക്	*Pelecaniformes*	3
6	Small kingfisher	*Alcedo atthis*	ചെറിയ മീൻകൊത്തി	*Coraciiformes*	1
7	Red wattled lapwing	*Vanellus indicus*	ചെങ്കണ്ണി തിത്തിരി	*Charadriiformes*	15+
8	Red rumped swallow	*Cecropis daurica*	വരയൻ കത്രിക	*Passeriformes*	1
9	Common sand piper	*Actitis hypoleucos*	നീർക്കാട	*Charadriiformes*	2
10	Little cormorant	*Microcarbo niger*	കിന്നരി നീർക്കാക്ക	*Suliformes*	3
11	White throated kingfisher	*Halcyon smyrnensis*	മീൻകൊത്തിച്ചാത്തൻ	*Coraciiformes*	1
12	Yellow billed babbler	*Argya affinis*	പൂത്താങ്കീരി	*Passeriformes*	1
13	Great egret	*Ardea alba*	പെരുമുണ്ടി	*Ciconiiformes*	3
14	Indian pond Heron	*Ardeola grayii*	കുളക്കൊക്ക്	*Pelecaniformes*	11+
15	Little Tern	*Sternula albifrons*	ചെറിയ ആള	*Charadriiformes*	27+

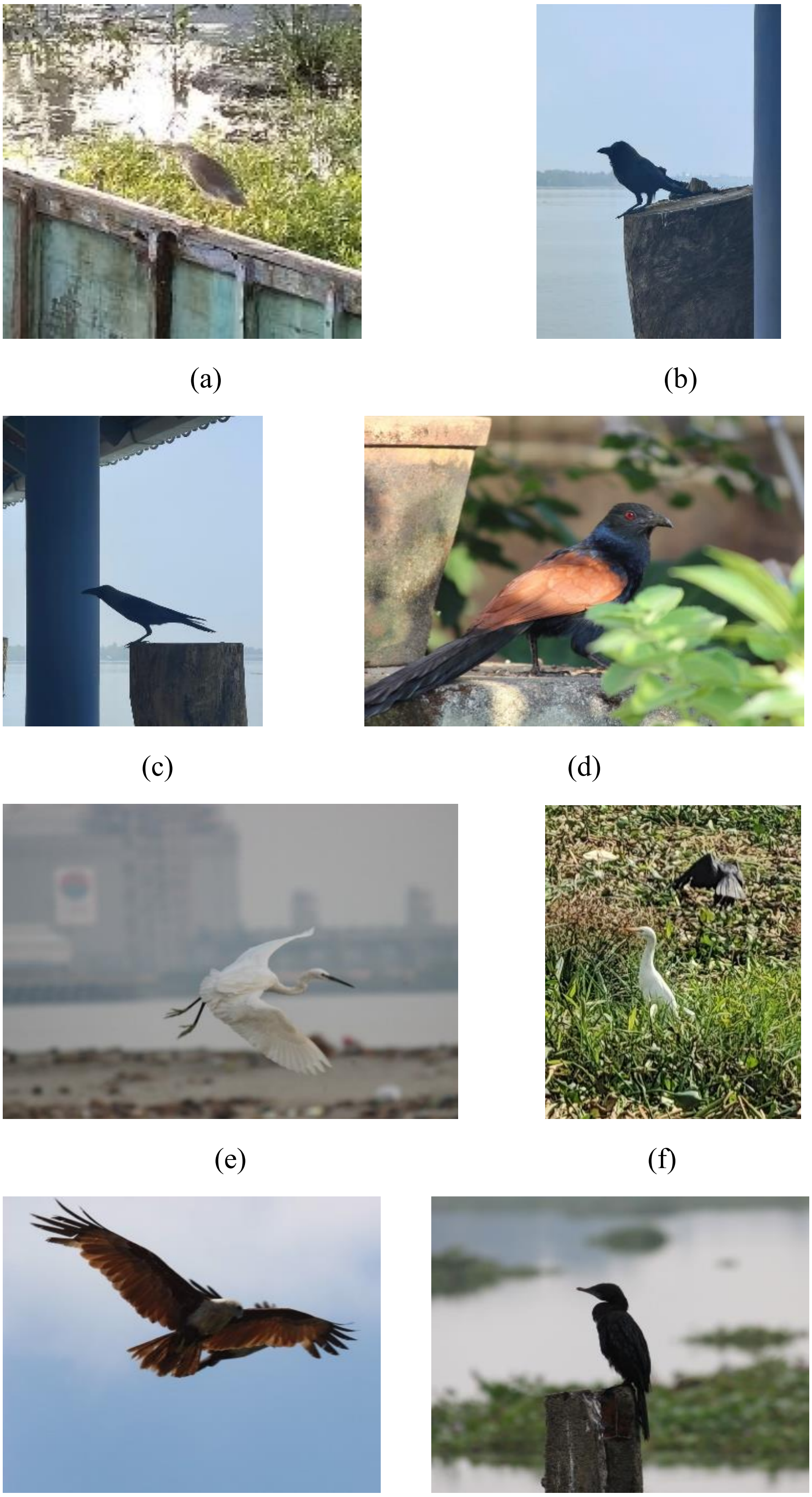
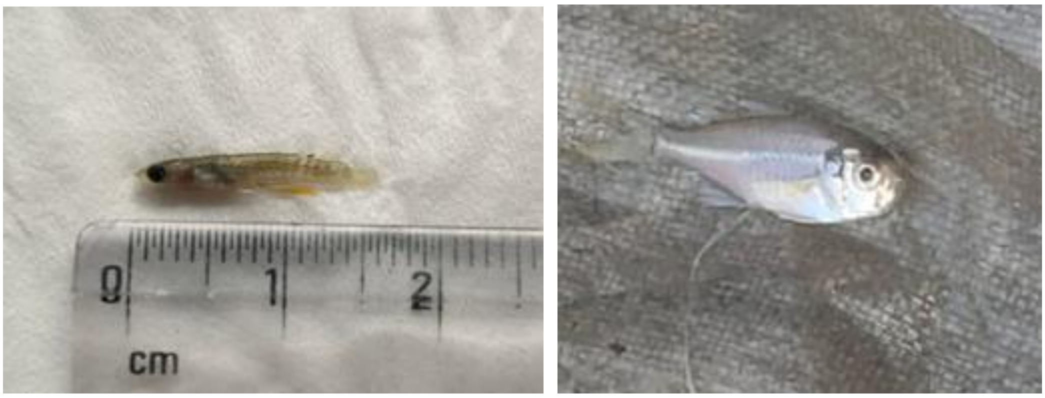


Fig 3; showing avian fauna observed from study stations: (a) *Ardeola grayii* (b) *Corvus culminates* (c) *Corvus splendons* (d) *Centeropus sinensis* (e) *Egretta grazetta* (f) *Ardea intermedia* (g) *Haliastur indus* (h) *Microcarbo niger*

Table 12: showing the fishes observed from study sites

SL NO.	COMMON NAME	SCIENTIFIC NAME	Malayalam name	NO. OBSERVED
1	Mangrove red snapper	*Lutjanus argentimaculatus*	കണ്ടൽ ചെമ്പല്ലി	3
2	Striped Panchax	*Aplocheilus lineatus*	മാനത്തുകണ്ണി	113
3	Commerson's anchovy	*Stolephorus commersoni*	നെത്തോലി	12
4	Flathead grey mullet	*Mugil cephalus*	തിരുത	8
5	barred ponyfish	*Secutor insidiator*	പതിമൂക്കൻ മുള്ളൻകാര	4
6	Orange chromide	*Etroplus maculates*	പള്ളത്തി	3
7	Commerson's Glassy Perchlet	*Ambassis commersoni*	കൊമേഴ്സൺ ഗ്ലാസ്മത്സ്യം	14



(a) (b)

Fig 4; showing fishes obtained from the study stations: (a) *Aplocheilus lineatus* (b) *Ambassis commersoni*

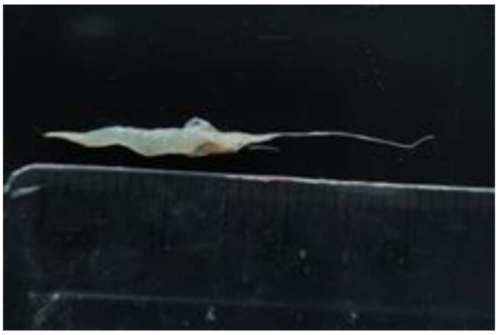
Fish: 7 species of fish from 157 specimens observed were identified from the study stations. *Aplocheilus lineatus* was observed in the highest number from different study stations. A high concentration of fish larvae was seen in the water bodies of the study stations.

Arthropods: The arthropods from the study sites varied from mosquitos to crabs. *Culex tritaeniorhynchus* was observed in the highest numbers among the insects. 3 species of crabs were observed from the study stations. 4 specimens of shrimp juveniles were observed but identification of the samples was not conceivable.

Table 13: showing the arthropods observed from the study site

Sl NO	COMMON NAME	SCIENTIFIC NAME	NO. OBSERVED
1	Culex mosquito	*Culex tritaeniorhynchus*	55
2	Mud crab	*Scylla serrata*	4
3	Mudflat crab	*Parasesarma plicatum*	2
4	Marsh crab	*Sesarma quadratum*	48

(a)



(b)

(c)

(d)

(e)

(f)

Fig 5; showing fishes obtained from the study stations: (a)-(d) unidentified species of shrimp (e) *Sesarma quadratum* (f) *Parasesarma plicatum*

Molluscs: 6 species of molluscs were recorded from the study sites. *Enigmonia aenigmatica* was recorded in the highest number attached to the different substratum like tree trunks, rocks etc.

Table 14: showing the molluscs observed from the study site

SL NO.	COMMON NAME	SCIENTIFIC NAME	NO. OBSERVED
1	Periwinkle	*Littoraria bengalensis*	5
2	Nerite snail	*Neritina canalis*	7
3	Red-mouthed nerite snail	*Neripteron violaceum*	7
4	Mangrove jingle shells	*Enigmonia aenigmatica*	38
5	Telescope snail	*Telescopium telescopium*	17
6	Bivalve	*Modiolus sp.*	2

(a)

(b)

(c)

(d)

(e)

(f)

Fig 6; showing molluscs obtained from the study stations: (a) *Neritina canalis* (b) *Telescopium telescopium* (c) *Modiolus sp.* (d) *Enigmonia aenigmatica* (e) *Neripteron violaceum* (f) *Littoraria bengalensis*

Mammals and Reptiles: one reptile species, *Ptyas mucosa,* and four mammal species were recorded from the study stations. The presence of *Enhydra lutris* was noted from its scat observed from the study stations.

Table 15: showing the mammals and reptiles observed from the study site

SL NO.	COMMON NAME	SCIENTIFIC NAME	Malayalam name
1	Rat snake	*Ptyas mucosa*	ഇന്ത്യൻ ചേര
2	Sea otter	*Enhydra lutris*	നീർനായ
3	Indian grey mongoose	*Urva edwardsii*	കീരി
4	Three-striped Palm Squirrel	*Funambulus palmarum*	അണ്ണാറക്കണ്ണൻ
5	House Rat	*Rattus rattus*	കറുത്ത എലി

CORRELATION BETWEEN MACROFAUNA AND PHYSIO-CHEMICAL PARAMETERS

Avian fauna, fishes and macroinvertebrates abundance showed a positive correlation with pH, temperature, salinity and DO and a negative correlation with chlorophyll, nitrite, phosphate and nitrate. The corresponding values of correlation between the macrofauna and physio-chemical parameters is as following: (given in table below)

Table 16: showing the correlation between macrofauna and physio-chemical parameters.

CORRELATION			
	Avian fauna	**fishes**	**Macroinvertebrates**
Temp	0.924915	0.674169	0.415385
pH	0.909394	0.832645	0.478228
Salinity	0.977747	0.925212	0.512918
DO	0.853392	0.917843	0.246684
Chl	-0.80589	-0.90689	-0.2009
Nitrate	-0.70499	-0.46474	-0.17372
phosphate	-0.88045	-0.91555	-0.23046
nitrite	-0.71002	-0.45912	-0.32028

An extortionate positive correlation (r = 0.936352138) was seen between the abundance of avian and fish fauna. Significant value of positive correlation (r = 0.560513843) can be observed between the abundance of avian fauna and macroinvertebrates. Also, the abundance of fishes and macroinvertebrates also showed significant positive correlation (r = 0.585881866).

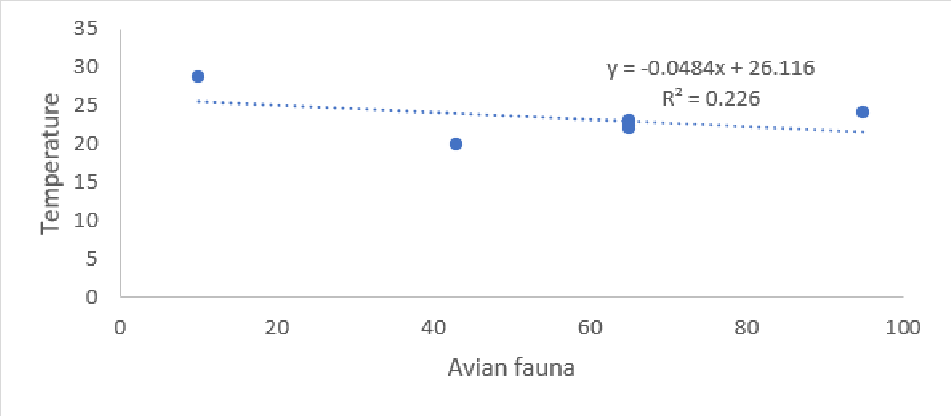


Fig 7; showing the correlation between temperature and avian fauna.

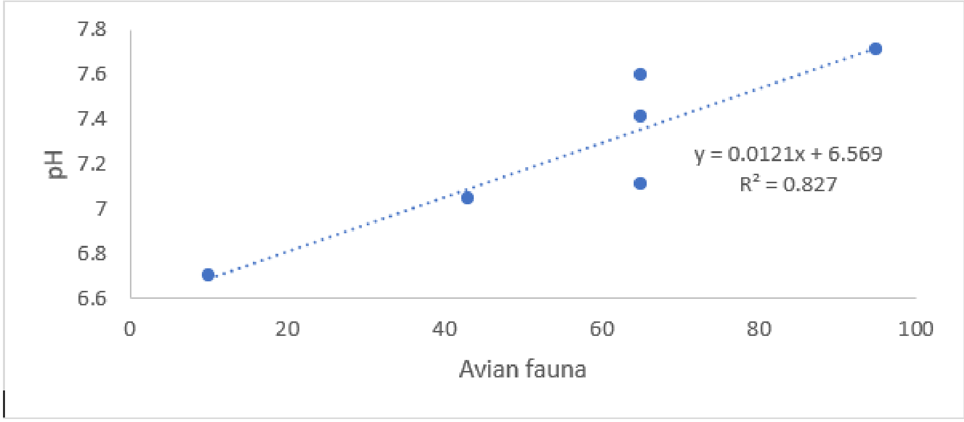


Fig 8; showing the correlation between pH and avian fauna.

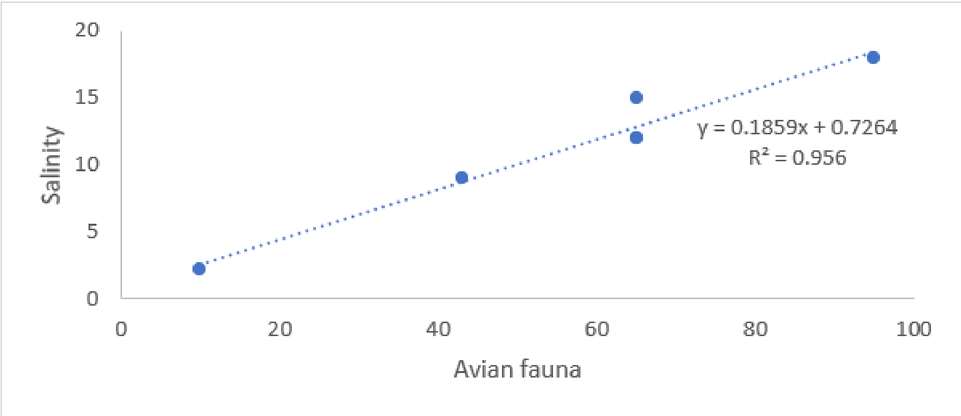


Fig 9; showing the correlation between salinity and avian fauna.

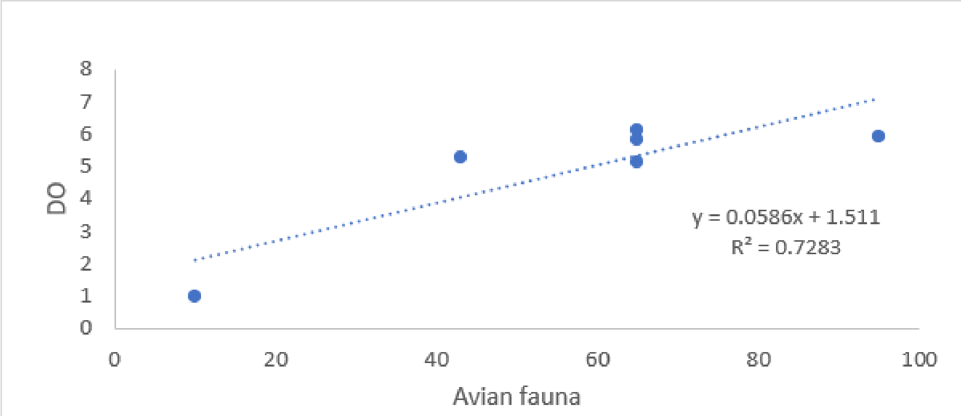


Fig 10; showing the correlation between DO and avian fauna.

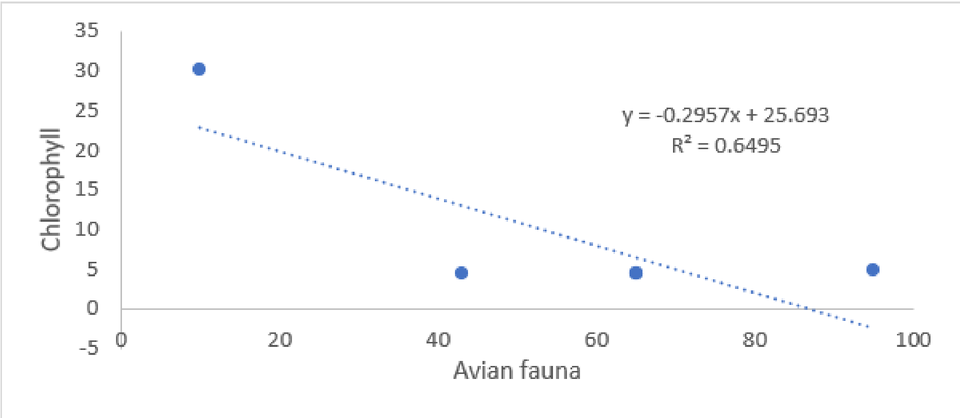


Fig 11; showing the correlation between chlorophyll and avian fauna.

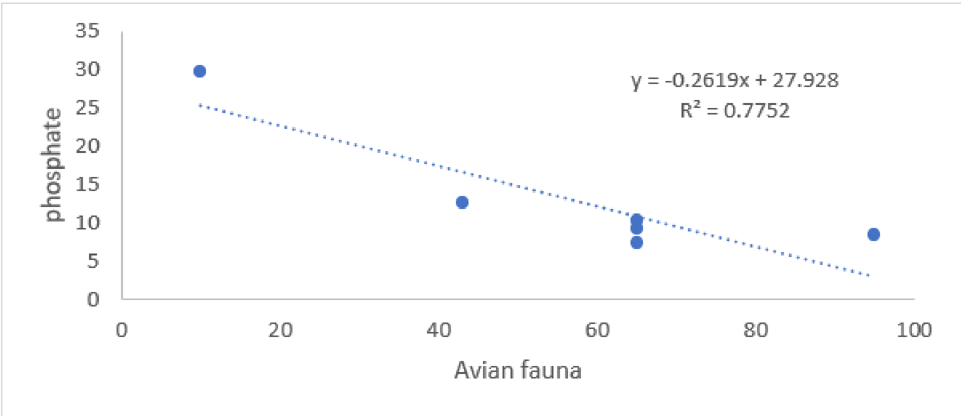


Fig 12; showing the correlation between phosphate and avian fauna.

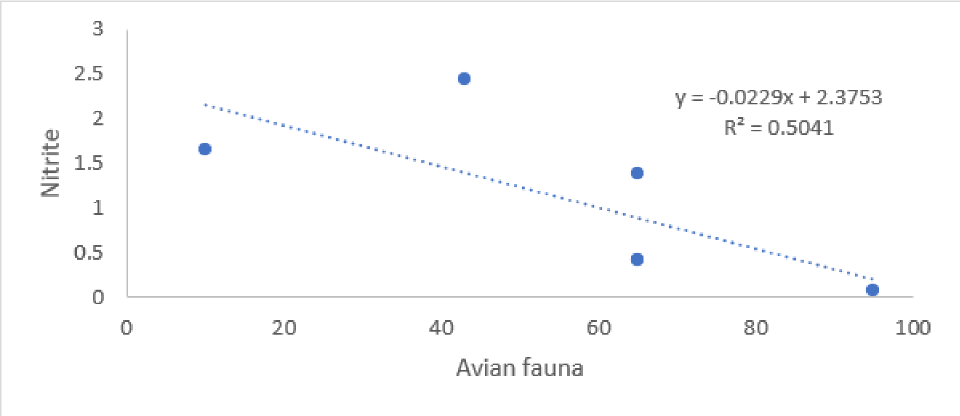


Fig 13; showing the correlation between nitrite and avian fauna.

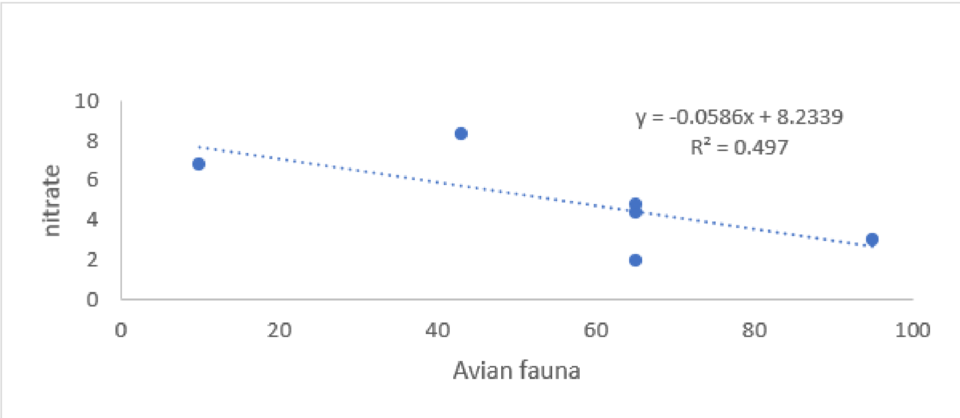


Fig 14; showing the correlation between nitrate and avian fauna.

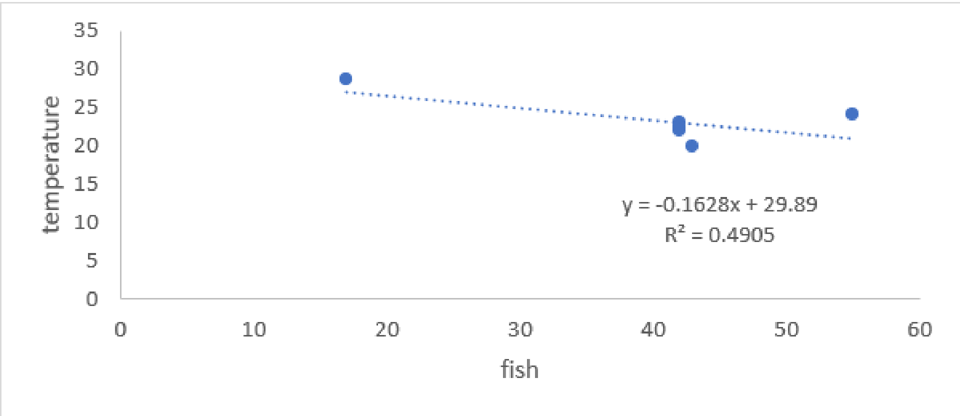


Fig 15; showing the correlation between temperature and fish.

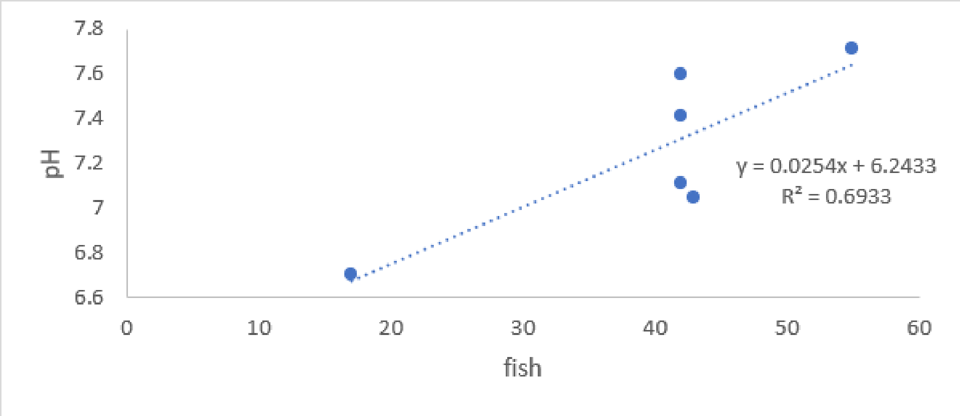


Fig 16; showing the correlation between pH and fish.

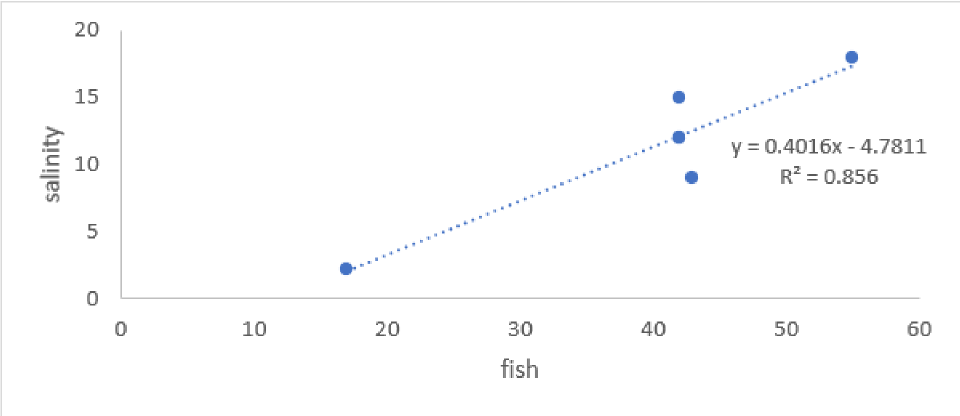


Fig 17; showing the correlation between salinity and fish.

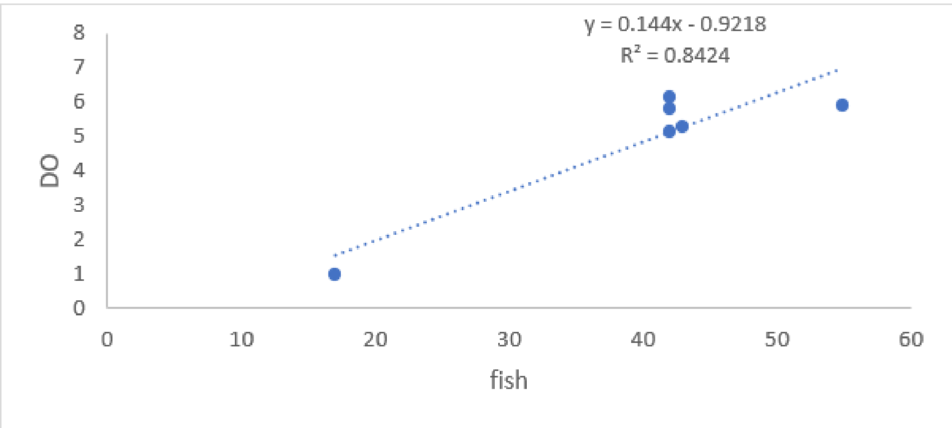


Fig 18; showing the correlation between DO and fish.

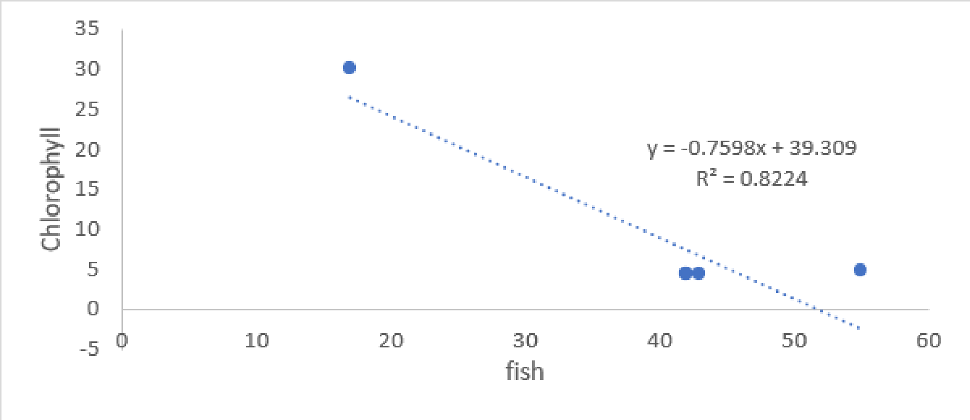


Fig 19; showing the correlation between chlorophyll and fish.

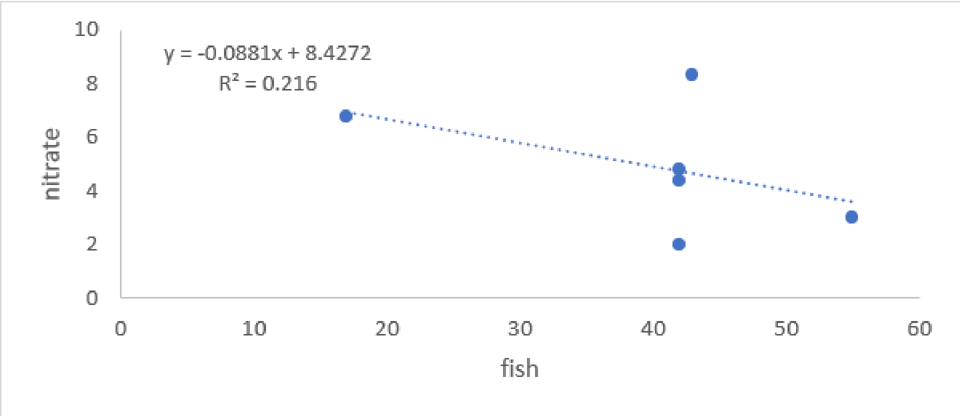


Fig 20; showing the correlation between nitrate and fish.

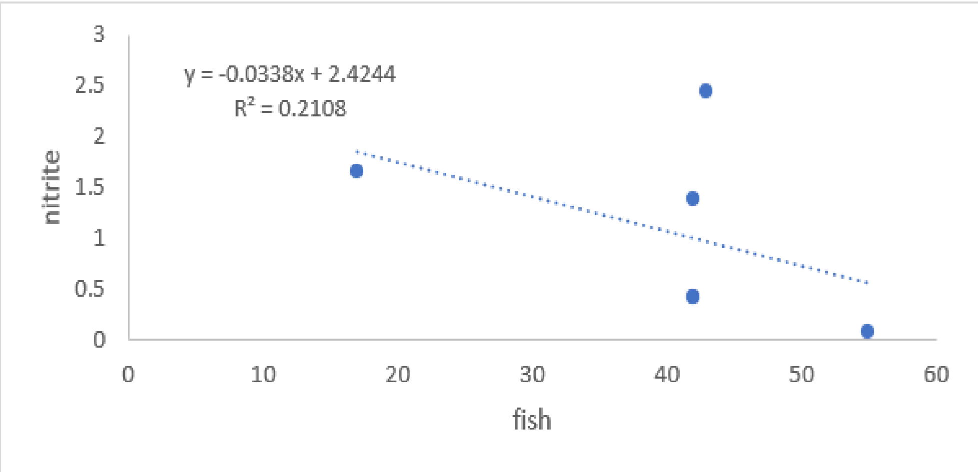


Fig 21; showing the correlation between nitrite and fish.

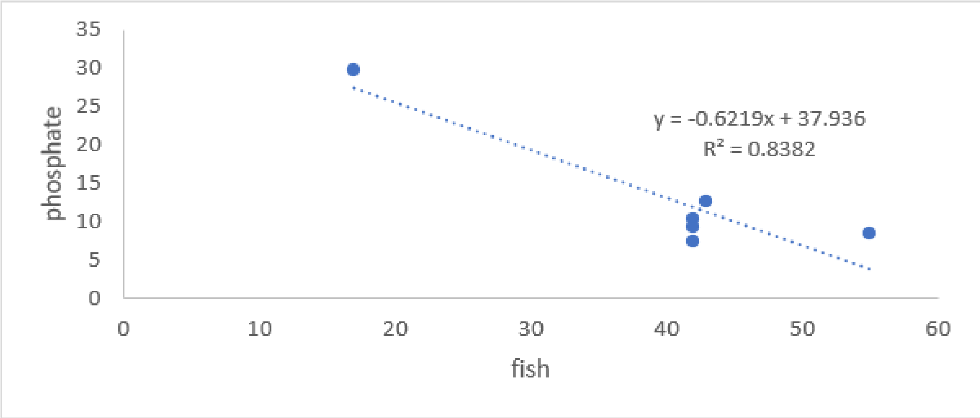


Fig 22; showing the correlation between phosphate and fish.

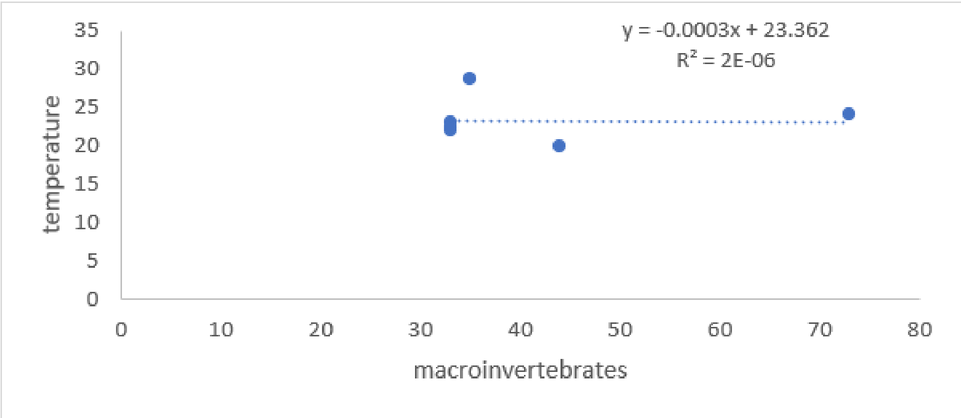


Fig 23; showing the correlation between temperature and macroinvertebrates.

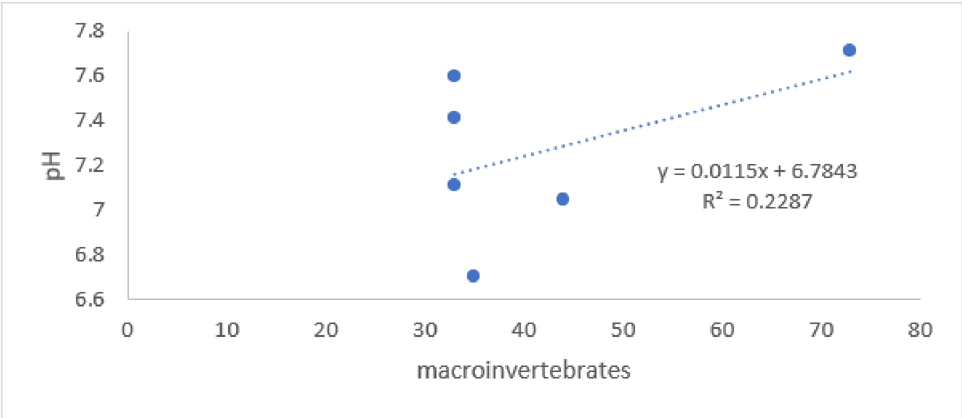


Fig 24; showing the correlation between pH and macroinvertebrates.

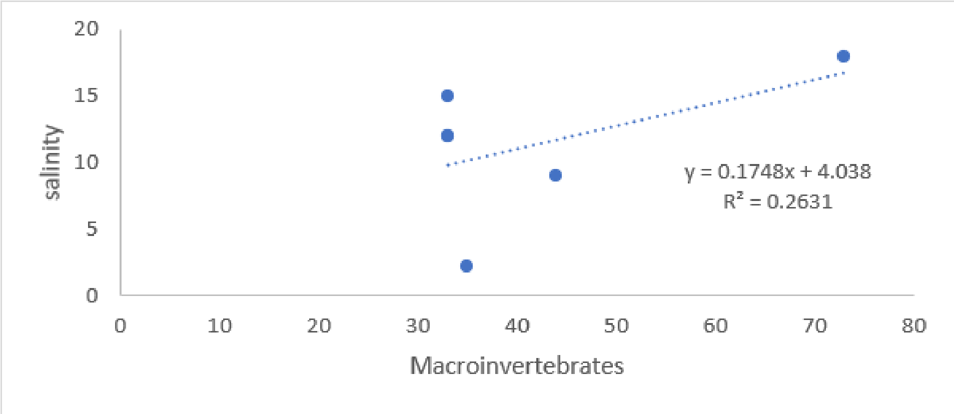


Fig 25; showing the correlation between salinity and macroinvertebrates.

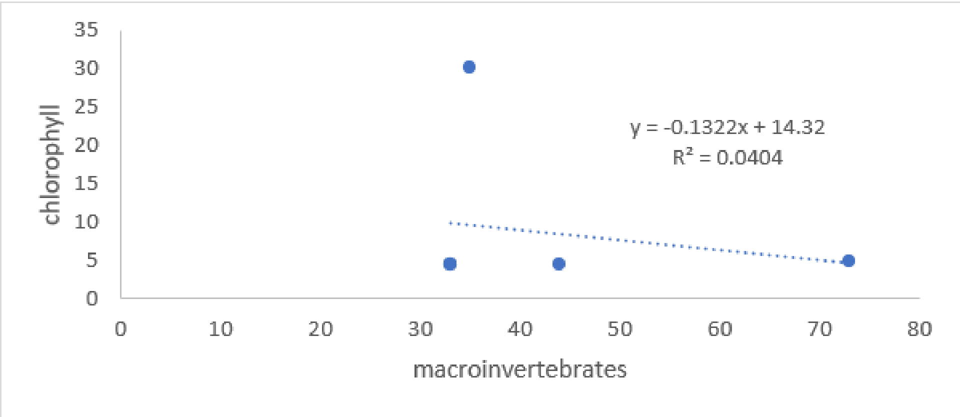


Fig 26; showing the correlation between chlorophyll and macroinvertebrates.

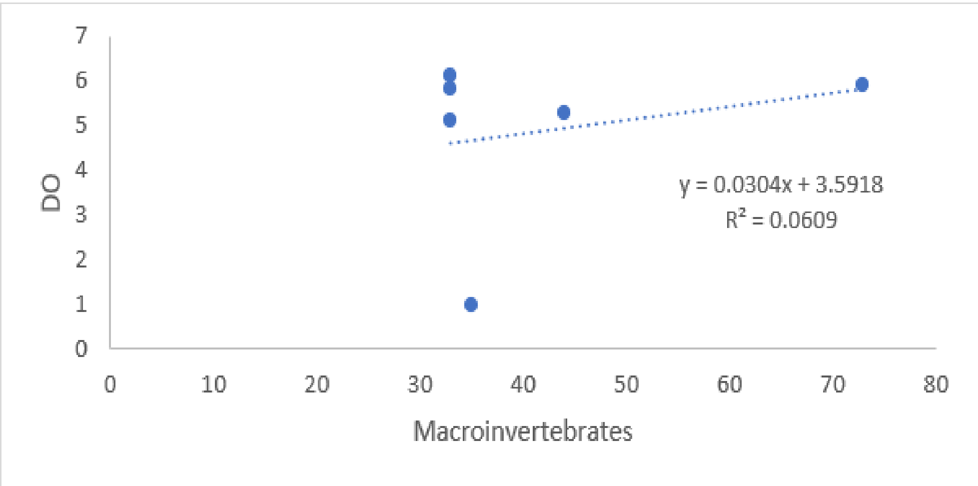


Fig 27; showing the correlation between DO and macroinvertebrates.

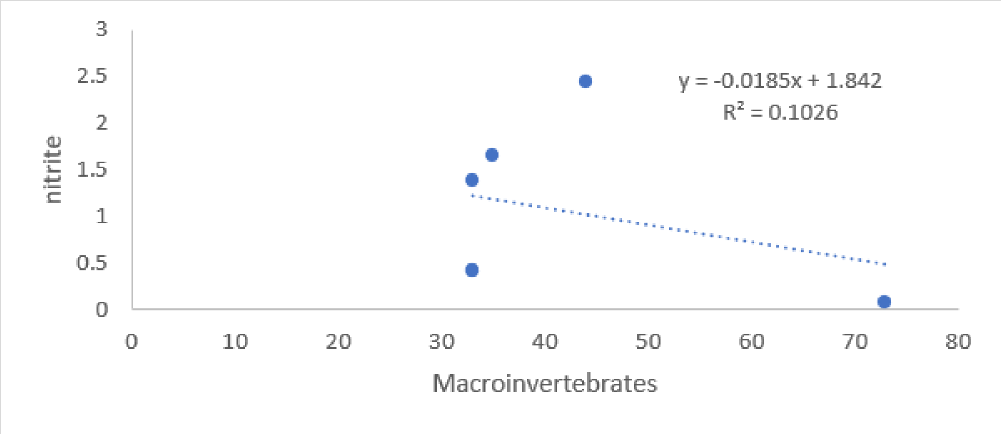


Fig 28; showing the correlation between nitrite and macroinvertebrates.

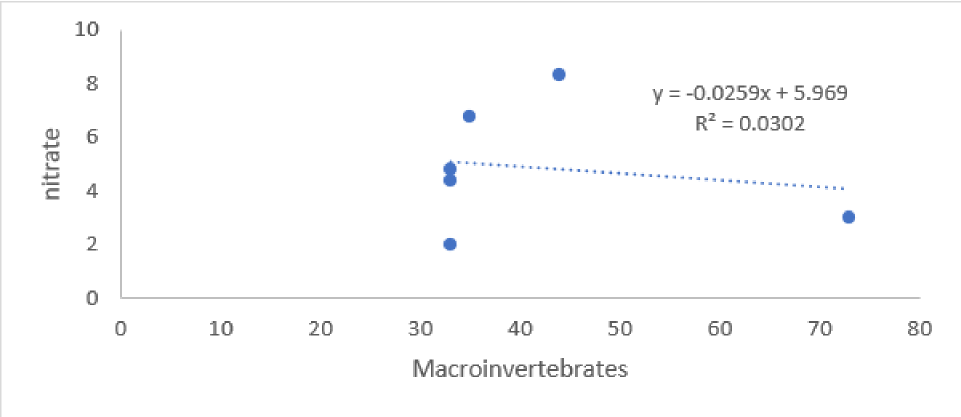


Fig 29; showing the correlation between nitrate and macroinvertebrates.

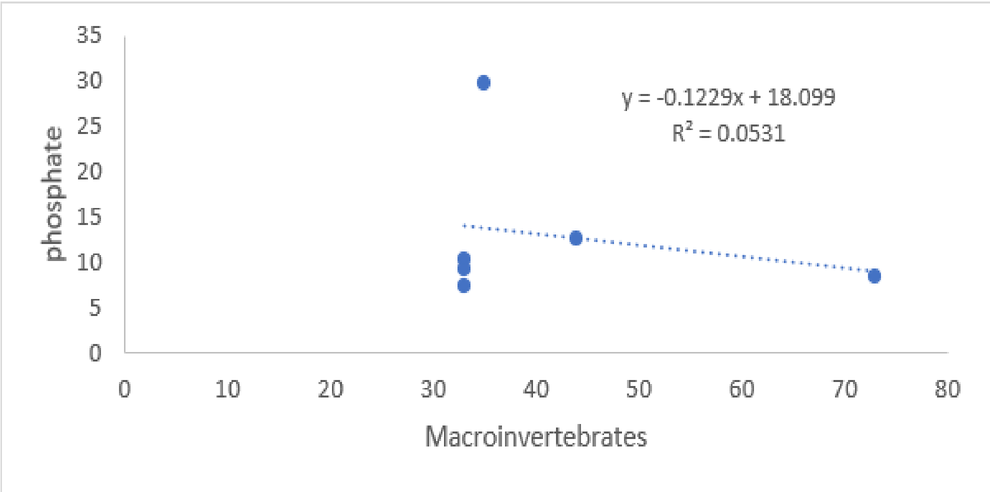


Fig 30; showing the correlation between phosphate and macroinvertebrates.

DISCUSSION

Mangrove-associated fauna significantly influences the structure of the mangrove forest and the environment. Knowledge of regionally specific population structure is needed for a better understanding of the existing mangrove species distribution pattern and conservation actions. The macrofauna as well as the macroflora discovered in this research were all known to science, and no new species or records were found in the region. The research might be viewed as a baseline study for the area's macrofauna.

The average temperature of the water samples collected from the sampling sites was 23.22, ranging from 20 to 28.6. which is contradictory to the findings of Rajagopalan c and Mogalekar et al., (2015). The average pH of the water sample was 7.263333 which is similar to the study of Mogalekar et al., (2015). The salinity in the study area showed wide fluctuation and ranged between 0.3 brix and 2.0 brix during the study. The average salinity during the study was found to be 11.35167ppt.

The average dissolved oxygen value estimated during the study period was 4.863333 mg/L. this was in accordance with the findings of Rajagopalan (1985). The phosphate value ranged between 8.347µmol/L to 29.82µmol/L during the study period with an average of 12.95733µmol/L µg/l. The phosphate value of the present findings disagrees with the observations made by Mogalekar et al., (2015). Nitrite values ranged from 2.4505µmol/L to 0.409 µmol/L with an average of 1.068417 µmol/L. Rajagopalan (1985) reported a nitrate range of 0.35µg/l to 0.85µg/l which is lower to the values observed in the present study of 1.962 µmol/L to 8.347µmol/L The average chlorophyll content during the study period was 8.79122mg/L. The highest value observed was 30.07 mg/L and the lowest was 4.31 mg/L.

Acanthus ilicifolius was found to have the highest frequency, density, and abundance. In comparison to West Bengal's Sundarbans, Kerala has comparatively small patches of mangrove forest. The Kumbalam village contains around 46% of the true mangrove species Ram & Shaji (2013). The results also demonstrated that macroinvertebrates were influenced by the temperature; when the temperature was low, the density of macroinvertebrates was found to be high. The current study's findings include significant correlations between physicochemical parameters, avian density, and macroinvertebrates. This indicates an organism's ability to live, adapt, migrate, and die under favourable and unfavourable environmental conditions Rohit et al., (2016). Tyokumbur et al. (2002) reported a comparable impact of water characteristics in influencing aquatic biodiversity.

Overall, the analysis indicated spatial and temporal variation in the occurrence, distribution and density, composition of macroinvertebrates and bird abundance concerning water quality in a mangrove ecosystem. Saravankumar et al. (2007) found that lower temperatures and the stability of environmental parameters such as salinity improve the abundance and diversity of macrofauna in the Kachchh mangrove forest. According to Ravera (1999) and Ikombi et al., (2005), macrobenthic invertebrates are more reliable bio-indicators of changing aquatic conditions than chemical and microbiological data, which only provide short-term fluctuations. Odiete (1999) stated that the most prevalent biological strategy for monitoring and assessing aquatic ecosystems is the use of birds and macroinvertebrates.

22 species, belonging to 8 orders of birds were observed throughout the study. The number of birds observed during this survey is much low compared to the results obtained by Azeez et al. (2006) and Jason (2001) in the mangalavanam mangrove forest. 21 species of wetland birds contributed to the majority of the bird population during 2006 in mangalavanam, but only 13 species formed the wetland bird fauna during the present survey in kumbalam. *Sternula albifrons* were found to in the highest frequency. The variations in the number of birds observed could be partly due to the time of the survey and also the location. Nevertheless, the reduction in the number of species should be viewed seriously and investigated scientifically and required mitigatory measures need to be implemented.

Analogous to that of Morton (1978) it was noted that a variety of animals, such as snails (*Telescopium*), bivalves (*Enigmonia & Modiolus*), crustaceans (*Sesarma, Parasesarma & Scylla*) and fish (*Ambassis, Etroplus, Secutor, Mugil, Stolephorus, Aplocheilus & Lutjanus*) are often found in mangrove habitats, which can withstand significant salinity variations.

The back of the mangroves is colonised by *Gelonia* or by pulmonate *snails Ellobium, Melampus*, and Cassidula because the mangrove soils and mud are acidic and low in calcium salts, according to Rajagopal et al. (1986). A variety of shoreline life, including lichens, littorine snails, barnacles, and the mangrove bivalve *Enigmonia*, were seen on the trunks and roots of mangrove swamps. The intertidal zonation principle might be seen in these assemblages, which create a hard shore niche in a soft shore environment.

The Kumbalam mangrove ecosystem is under severe threat due to the developmental and industrialization process, there by the existence of mangrove species, both flora and fauna are also under serious threat and warrant immediate conservation.

CONCLUSION

Macrofauna density is an important factor in determining water quality. Water temperature and salinity, in addition to minerals and nutrients, influence macrofauna density. The abundance of macrofauna can be used to monitor and analyse coastal change. 22 species of birds, 7 species of fish, 10 species of macroinvertebrates, 1 reptile species and 4 species of mammals were recorded throughout the study. An extortionate positive correlation was seen between the abundance of avian and fish fauna and among salinity and DO which indicate biodiversity in the area improves with the environmental conditions. The report demonstrates how long-term monitoring of coastal wetlands via this kind of study can improve the quick assessment and management of coastal wetlands and their biodiversity. The Kumbalam mangrove ecosystem is under severe threat due to the developmental and industrialization process, there by the existence of mangrove species, both flora and fauna are also under serious threat and warrant immediate conservation. Due to the limitations in the conduction of investigation and scientific sampling as well as due to the trivial time duration, there are plenty of downsides to obtaining an accurate result. A further advanced investigation with enhanced instruments and experimental setup can be used for understanding the correlation between macrofauna and hydrological parameters of the Kumbalam mangroves. Prolonged research and extensive work on such research areas will provide in-depth evidence on mangrove diversity. The current survey can be regarded as a novel study because there have never been endeavours to comprehend the macrofauna in Kumbalam, which includes both invertebrates and vertebrates. The current survey was the first of its kind to be done in the Kumbalam mangroves, and it concentrated on the corroboration of physicochemical parameters, bird density, and macroinvertebrate density.

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