MINOR RESEARCH PROJECT

ON

Nutrients' Dynamics in Mangrove Eco-Systems of Tropical Cochin Estuary

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ANGAMALY

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CHAPTER I

Introduction

Mangrove plants require a number of physiological adaptations to overcome the problems of anoxia high salinity and frequent tidal induction. Each species has its own solutions to these problems; this may be the primary reason why, on some shorelines, mangrove tree spices show distinct zonation. Small environmental variations within a mangal may lead to greatly differing methods for coping with the environment. Therefore, the mix of species is partly determined by the tolerances of individual species to physical conditions, such as tidal inundation and salinity, but may also be influenced by other factors, such as predation of plant seedlings by crabs.

Mangroves are trees or plants which grow in the area between the land and water**.** Mangroves are coastal tropical formations found along the boarder of the sea and lagoons, reaching up to the edges of the river to the point where the water is saline, growing in swampy soils covered by sea water during high tides (Aubreville, 1964). The mangrove biome, or mangal, is a distinct saline woodland or shrubland habitat characterized by depositional coastal environments, where fine sediments (often with high organic content) collect in areas protected from high-energy wave action. Mangroves dominate three-quarters of tropical coastlines. The saline conditions tolerated by various mangrove species range from brackish water, through pure seawater (30 to 40 ppt), to water concentrated by evaporation to over twice the salinity of ocean seawater (up to 90 ppt)

The intertidal existence to which these trees are adapted represents the major limitation to the number of species able to thrive in their habitat. High tide brings in salt water, and when the tide recedes, solar evaporation of the seawater in the soil leads to further increases in salinity. The return of tide can flush out these soils, bringing them back to salinity levels comparable to that of seawater. At low tide, organisms are also exposed to increases in temperature and desiccation, and are then cooled and flooded by the tide. Thus, for a plant to survive in this environment, it must tolerate broad ranges of salinity, temperature, and moisture, as well as a number of other key environmental factors.

Once established, mangrove roots provide an oyster habitat and slow water flow, thereby enhancing sediment deposition in areas where it is already occurring. The fine, anoxic sediments under mangroves act as sinks for a variety of heavy metals which colloidal particles in the sediments scavenged from the water. Mangrove removal disturbs these underlying sediments, often creating problems of trace metal contamination of seawater and biota.

There are approximately 80 different species of mangrove trees. All of these trees grow in soils which are low in oxygen. Tidal movements vary in these areas, however it results in fine sediments gathering together along the roots. The Mangrove Community includes all the different mangrove plants, algae, bacteria, fungi, fish, birds, and assortment of animals. The Mangrove Ecosystem consists of the mangrove community, along with the non-living parts of the environment such as the tidal movements, soil, mud, and water. Mangrove Ecology is the study of the mangrove community and how it interacts with its non-living environment.

The plants, as a group, provide excellent storm protection. During hurricanes, they act as a breakwater for storm surge and reduce the impact of the surge on land. Also, the mangrove community is a nursery for fish, birds and many other creatures such as the spiny lobsters and crabs. Some of the common mangrove fish found includes barracuda, needle nose, grey snappers and bone fish.

Mangrove plants are not a single genetic entity because the plant types represented in the tidal zone are not all closely related. So, while they sometimes look the same, and have similar function, this tells us more about the environment they live in, rather than their family relationships. The plants growing in the tidal zone also require serious adaptations for their continued survival in this habitat. However, this does not preclude other plants from occasionally being found within the tidal zone. Some are grouped as ‘associates’ where they only occasionally occur in intertidal sediments and most of the time they are found elsewhere. Others do regularly also share the tidal niche, like salt marsh plants, but these are smaller in size. A number of others, the epiphytes and plant parasites, perch in the branches and stems of mangroves. All these plants shape and define mangrove habitat.

HOW WE PROTECT MANGROVES

The richest mangrove communities occur in tropical and sub-tropical areas, i.e., between the 30°N and 30°S latitudes where the water temperature is greater than 24ºC in the warmest month, where the annual rainfall exceeds 1250mm and mountain ranges greater than 700m high are found close to the coast. Snedaker (1984) has highlighted and emphasized that these world mangrove ecosystems are the most alarming ecosystem, which need urgent protection measures and strict natural conservation stragies.

Mangrove swamps protect coastal areas from erosion, storm surge , and tsunamis. The mangroves massive root systems are efficient at dissipating wave energy. Likewise, they slow down tidal water enough so its sediment is deposited as the tide comes in, leaving all except fine particles when the tide ebbs. In this way, mangroves build their own environments. Because of the uniqueness of mangrove ecosystems and the protection against erosion they provide, they are often the object of conservation programs, including national biodiversity action plans.

However, mangrove swamps' protective value is sometimes overstated. Wave energy is typically low in areas where mangroves grow, so their effect on erosion can only be measured over long periods. Their capacity to limit high-energy wave erosion is limited to events such as storm surges and tsunamis. Erosion often occurs on the outer sides of bends in river channels that wind through mangroves, while new stands of mangroves are appearing on the inner sides where sediment is accruing.

Importance of Mangroves

a. Buffer Zone between the land and sea.
b. Protect the land from erosion.
c. Play an invaluable role as nature's shield against cyclones, ecological disasters and as protector of shorelines.
d. Breeding and nursery grounds for a variety of marine animals.
e. Harbour a variety of life forms like invertebrates, fish, amphibians, reptiles, birds and even mammals like tigers.
f. Good source of timber, fuel and fodder.

g. Main source of income generation for shoreline communities like fisher folk.
h. Save the marine diversity, which is fast diminishing.
i. Purify the water by absorbing impurities and harmful heavy metals and help us to breathe a clean air by absorbing pollutants in the air.
j. Potential source for recreation and tourism.
k. Mangroves, admittedly, are not only important but crucial for the coastal areas. Since estuarine areas are highly populated areas, the slightest ecological imbalance will take a heavy toll. They play a vital role in stabilizing these areas. No engineering and technological solutions can be sought for stabilizing these areas. Even if we negate all benefits of mangroves as forests, their value as "protector of shore-line" is enough to convince us for conserving them.
l. Mangroves are buffers between the land and the sea. Coastlines throughout the world are facing serious problems of coastal erosion and threat of rising sea levels due to global warming have increased the threats by several folds. To control such assault of the sea on land the nature has provided what is called as Mangroves, a tropical littoral ecosystem which is more dynamic than the sea itself.
m. Mangroves not only help in preventing soil erosion but also act as a catalyst in reclaiming land from seas. This is a very unique phenomenon, since there is a general tendency of water to engulf land.
n. Mangrove forests and estuaries are the breeding and nursery grounds for a number of marine organisms including the commercially important shrimp, crab and fish species. Hence, loss of mangroves not only affects us indirectly but there are direct economic repercussions through loss of fishing industry.
o. Mangrove trees are also used for house building, furniture, transmission as well as telephone poles and certain household items. When these activities are managed appropriately it is possible to derive timber products from mangrove forests without significant environmental degradation, and while maintaining their value as a nursery and a source of food for commercial capture fisheries.

p. In many coastal areas including Gulf of Kutch, mangroves are a substitute for fodder. Thus mangroves reduce pressures from the scarce pasturelands.

q. Tannin is extracted from the bark of some mangrove species like Rhizophora mucronata, Bruguiera gymnorrhiza and Ceriops tagal. Indian mangrove trees have 35% tannin in their bark, which is higher compared to other countries. Extracts from mangrove bark are used by Indian fishermen to dye their fishing net and enhance its durability.

r. Avicennia spp., Phoenix paludosa and Sonneratia caseolaris are used for human consumption and as cattle feed. Nypa fruticans is tapped for an alcoholic drink. Leaves of Nypa palm are used for thatching of roofs, Suaeda and Acrostichum leaves are used as green vegetable.

s. Above all, Mangroves are now looked after by scientists as saviors in the today's scenario of global warming. We all know that most of the coastal areas throughout the world are going to be affected by sea level rise due to global warming. The effects of which are already visible. Therefore, when most of the coastal areas will be flooded, mangroves can possibly provide a gene bank for cultivating salt tolerant species of crops which could be our future resource.

Productivity is a concept used to describe the ecological value or function of a vegetation community. Notably, productivity can be estimated by gaining measurements of the amount of living material (ie. leaves, branches, stems and roots) that is produced by a mangrove community over a specified time. Mangrove productivity is important because it has direct impact on the health and function of the marine food chain. Like other plants, mangroves convert energy from the sun into organic matter through the process of photosynthesis. When the leaves and branches of a mangrove fall to the ground they provide a wide variety of aquatic animals such as molluscs, crabs and worms with a primary source of food. These primary level consumers in turn support an array of secondary consumers, including small fish and juvenile predators such as barramundi which, when mature, become third level consumers. In general, high levels of organic matter, or high productivity, means that a larger number and more diverse array of animals can be supported within a particular ecosystem.

MANGROVES IN INDIA

The total area of mangroves in India is about 6,740 sq. km, which is about 7% of the world's total area of mangroves. Of the total mangroves 80% are present along the east coast, mostly forming the Sunderbans, Bhitarkanika and the Andaman & Nicobar mangroves. The Gangetic Sunderbans is about 4,000 sq. km whereas Andaman & Nicobar is about 700 sq km. Besides, large rivers like Mahanadi, Krishna, Cauveri, Godavari also harbour major mangroves in their estuarine regions.The remaining 20% mangroves are scattered on the west coast from Kutch to Kerala. The reason for such a restricted mangrove cover is the peculiar coastal structure and the nature of estuaries formed by the relatively small and non-perennial rivers except Narmada.

MANGROVES IN KERALA

Mangroves are wetland ecosystems formed by the assemblage of specialized plants and animals adapted to semi saline swamps along coasts. Mangrove forests of Kerala are highly localized, but the species diversity of these mangroves and its associates are comparatively rich. It is confined to the upper reaches of estuaries, lagoons, backwaters and creeks. In Kerala mangroves are distributed in all the districts except Idukki, Pathanamthitta, Palakkad and Wayanad. Maximum extent is reported from Kannur district. The total extent of mangrove forests in the state is estimated to be less than 50km^2 . Mangroves play an important role in the economy of coastal people through various ways. Mangroves provide excellent habitat for migratory birds, serve as breeding ground for many species of fishes and prawns helps in controlling pollution, rutting of husks etc. The important mangrove plants are Acanthus cillicifolius, Acrostichum aurem, Aegiceras corniculatum, Avicennia officinalis, A, rina, Azima tetracantha, Bruguiera gymnorrhiza, B. cylindrica, B sexangula, Excoecaria agallocha, E indica, Kandelia candel, Rhizophora apiculate, R mucronata, Sonneratia caseolaris, Calophyllum etc. Some of these species that disappeared from the Kerala coast are Azima tetracantha an Ceriops tagal, Heritiera littoralis and Flagellaria indica. Calamus rotang and Syzygium travancoricum are some of the rare and endangered species found in the mangroves.

The major threats to the mangrove forests are land reclamation for urbanization, intensive aquaculture felling of mangrove trees for fuel and fodder, unsustainable land use, ambiguity in ownership etc. Mangroves provide many ecological, environmental and socioeconomic benefits to mankind. However, biodiversity rich mangrove ecosystems are fast declining world over. Presently, in Kerala, the extent of undisturbed mangroves is reduced to just 150 hectares mostly distributed in Ernakulum, Kannur and Kozhikode Districts, but potential area comes to around 1670 hectares. The vegetation has diminished in its extent drastically and has acquired a threatened status in Kerala. More than 80 per cent of the mangrove lands in Kerala (potential and existing) are under private ownership; the land left with government agencies is very meager. The mangroves in the State are threatened with unprecedented destruction, which includes commercial exploitation of raw materials, land reclamation for agriculture, aquaculture and housing. There have been significant changes in the traditional and present uses of resources within the mangrove system, which have implications on its depletion. The respondent perception on the benefits derived from mangroves highlighted forestry products and seafood as the most important direct benefits. This is indicative of the fact that respondents give more weightage to the direct economic benefits of the ecosystem. On social and environmental problems associated with mangroves' health problems, low agricultural productivity and water pollution were highlighted. The traditional mangrove ecosystem was by and large, self contained following subsistence production, but now it is closely related to the market. The changing land use has drastically affected the mangrove ecosystem. The high returns from high tech aquaculture especially shrimp farming has led to rather quick transformation of the mangrove lands. Many people sold out their mangrove lands to big investors not realizing its environmental and social values. Decline in area under mangrove ecosystem continues in an unconcealed manner due to increase of population, industrialization and implementation of developmental activities. Mangrove afforestation initiative is yet to make a successful leap in the State. Socially, afforestation programme would be benefiting people living in coastal areas in terms of protection, environmental services and support for livelihood. In Kerala, mangrove forests that once occupied about 700 km2, have now dwindled to 17 km2. As in many other parts of the world, the vegetation has diminished in its extent drastically and has acquired a 'threatened' status in Kerala. Most of the mangroves areas (89%) in Kerala are owned by private owners of whom some live within the system. In addition to owners, some people who live outside the system also depend on the mangroves for their livelihood. Both the owners as well as dependents derive a number of direct benefits such as firewood, charcoal, fish, shellfish, and indirect functional benefits such as the watershed benefits, ecosystem services and the evolutionary processes of the mangrove ecosystem. The threats to the mangrove ecosystems could be broadly grouped into both natural as well as anthropogenic. The mangroves in the State are threatened with unprecedented destruction, which includes commercial exploitation of raw materials, land reclamation for agriculture, aquaculture etc

There have been significant changes in the use of resources within the mangrove system, which have much implication on its depletion. For instance, the traditional mangrove dwellers/dependents who often combined the use of land, sea, and inter-tidal resources, were basically involved in primary subsistence activities (agriculture and fishing). Now this trend has changed and a significant number of them are associated with commercial activities. The traditional mangrove ecosystem was, by and large, self-contained following subsistence production, but now it is closely related to market. In the context of commercialization, both the ecological and socioeconomic systems of mangrove are both greatly affected by processes and events beyond its geographical borders. The coastal stretches, the natural home of mangroves, are also the places where there is an exuberance of population (Singh, 2006) that has resulted in high pressure on land. Land reclamation for various developmental activities is the general scenario. The changing land use has worsened the situation. The high returns from the high-tech aquaculture, especially shrimp farming has led to rather quick transformation of the mangrove lands to artificial water bodies. Many people sold out the mangrove lands to high-level investors, though many farmers also took advantage of the situation. The socioeconomic system and mangrove ecosystem are closely interlinked although both the systems are not coterminous. For instance, the harvest rates are far higher than regeneration rates, commercialization of fishing often leads to over fishing, clear felling without replanting, among others. However, there is hardly any study, which gives details of the socioeconomic system of the mangroves and its linkage with its ecological system in Kerala. Besides, the mangroves carry out a variety of functions that generate economic, ecological, scientific and cultural benefits not only for the present generation but also for the future generations.

CHEMICAL ASPECTS OF MANGROVE ECOSYSTEM

Spatial and seasonal variability of sedimentary salinity, pH, redox potential and solid phase sulphide concentration were investigated in a range of mangrove communities. Studies reveals that seasonal depth distributions of these parameters and organic content were compared within Avicennia, Rhizophoraand mixed mangrove stands at different stages of plant development. Mangrove communities and variable surface water inputs strongly impact sediment and ground water properties. In the upper sediment, changes in salinity are mainly controlled by seasonal conditions, transpiration and proximity of fresh water influx, whereas the constant basal salinity results from an accumulation of salt that has migrated as a result of density driven convection processes. There are no clear differences between the depth distributions of salinity obtained beneath Avicennia germinant and Rhizophora mangle stands, implying that plant zonations are not primarily controlled by soil salinity in this environment. Nevertheless, mangle grows in places subjected to the greatest variability in freshwater influxes, suggesting that Rhizophora might require or withstand occasional inundation by freshwater. Beneath Rhizophora stands, sediment properties reflect anaerobic and sulphidic conditions close to the sediment surface. In contrast, beneath Avicenniastands, sediment geochemistry mostly depends on the stages in forest development,on contents in sedimentary organic matter and on seasonal changes. In the early stage of Avicennia settlement, the sediment at the level of radial, pneumatophore-bearing cable roots, displays permanent suboxic conditions

During dry conditions, the desiccation of the upper sediment adds its oxidation effects to those of root activity. As a result, suboxic processes dominate in the upper, 20-cm-thick layer; organic matter decomposition and sulphur oxidation strongly acidify the sediment. Below 20 cm, the sediment is anaerobic and sulphidic. Hence, sulphide concentrations depend on the edaphic conditions controlling decay processes and appear to be a consequence rather than a cause of the observed zonation of vegetal species. The small size of germinant propagules might have a significant influence on the extensive development of this plant community . This study demonstrates that the different properties of pore-water were intimately linked and that the explanation of the evolution of this forest reflects a combination of multiple parameters. Moreover, it appeared that the organic content played a key role along with the species composition and the seasonal variations.

The physico-chemical characteristics are said to play a significant role in the distribution of organisms such as reproduction, feeding etc. Various physico-chemical and biological processes in the mangals make it a habitat for vast array of organisms, leading to rich biodiversity but seasonal variation and anthropogenic pressures bring about a lot of changes in physical-chemical characteristics, which affect the biotic elements of the mangals system. The most important variables which influence the mangrove are temperature, salinity, tides, rainfall and wind. Survival and development of regeneration and recruitment classes depend on salinity and solar radiation . Temperature and salinity determine the species composition, distribution and zonation.

Nutrients are considered as one of the most important parameters in the marine environment. The distribution of nutrients is mainly based on the season's tidal conditions and river flow. Silicate is different from nitrogen and phosphate in some ways and in the strictest sense it is not considered as a nutrient but its usefulness in the formation of skeleton of diatoms and radiolarians is very high. The concentration of reactive silicate was found to be much higher than other nutrients.

Mangrove forests are one of the most dominant vegetation communities in the Everglades National Park(ENP) with an extension of 144,447 ha (Welch et. al.,1999). Although this is the largest mangrove area in the continental USA, there are large information gaps regarding factors regulating productivity and spatial distribution of these coastal wetlands. Current landscape level restoration efforts in south Florida will shift surface regional water flows that may impact the temporal and spatial distributions of mangrove forests in the coastal transi-tion zone. It is not clear if changes in hydroperiod, salinity, and potential nutrient inputs (e.g., nitrogen and phosphorus) will significantly modify critical biogeochemical processes that control productivity patterns, not only within mangrove forests, but also in adjacent estuarine and coastal waters. Although mangrove research in south Florida has histo-rically provided significant conceptual models to explain how mangrove forest structure responds to different hydrological and edaphic conditions there are large information gaps on functional aspects related to nutrient cycling. For instance, few studies have underscored criticalecological processes such as denitrification, nitrogen fixation (Pelegri et. al.,1997; Pelegri & Twilley, 1998), phosphorus sedimentary processes (Chen & Twilley, 1999), and mangrove-water column nutrientexchange (Childers et al., 1999; Davis et. al., 2003) despite their role in maintaining primary productivity rates and regulating the coupling between mangrove forests and estuarine waters. Furthermore, the functional role of mangrove forests in south Florida as potential sources, sinks, or transfor-mers of nutrients is still not clear.

Changing fresh water inflow to the system may affect its ecological structure and function via several mechanisms. Research studies reveals that how changing fresh water inflow affects the cycling of nutrients within the mangrove dominated ecotone between and also affects the net transport of nutrients. Understanding nutrient dynamics in this ecotone is important because this region contains a large pool of nutrients and its importance as a source or sink of nutrients may change with changing fresh water flow. Furthermore, salinity in this ecotone has a wide range and high variability; effects of changing salinity on nutrient biogeochemical cycles should be evident in this region.

Concentrations of dissolved and total organic carbon (DOC and TOC) should highest during the wet season. The findings suggest that the fringe mangrove zone is of considerable importance in regulating nutrient dynamics.

Mangroves provide a unique ecological environment for diverse microbial communities. They are particularly important in controlling the chemical environment of the ecosystem. Mangrove ecosystem being a rapidly changing ecosystem, is under stress due to various anthropogenic activities.

MANGROVE ECOLOGY AND HUMAN DIMENSIONS

The mangrove forest is a complex ecosystem because it represents an inter phase between two contrasting types of communities: terrestrial as represented by lowland forests; and marine, as represented by distinctive ecosystem, notably seagrass meadows and coral reefs. It is characteristically swampy being regularly flushed by brackish water. The tidal inflow also brings in lot of debris and soil particles and the soil being saturated with water is very loose and therefore movement through the mangrove forest is not very easy. Mangroves are composed of salt tolerant plants - the halophytes. Halophytes can successfully regenerate and establish in the saline environment. While many of them have specialized rhizomorphs with stilt roots that ensure anchorage in the highly unstable soil, some of them have specialized breathing roots – the pneumatophores thatprotrude above the ground and augment the breathing ability in the anoxic soil. A few others have specialized secretary glands that excrete the salt contained in the absorbed water. Many of these plants also produce seedlings directly on the mother trees, a phenomenon referred to as vivipary. Mangrove vegetations show characteristic zonation with highly salt-tolerant and tide- tolerant species with stilt roots towards the tidal front and less tolerant species with pneumatophores distributed further landward.

Mangroves are plants adapted to muddy, shifting, saline conditions. The characteristic mangrove species found along the west coast, Rhizophora mucronata, Avicenniaofficianlis, marina, and Excoecaria agallocha are sufficiently large trees. Aegiceras corniculatam, Kandelia candel and Cerbera manghasare trees of medium stature, and Acanthus ilicifolius, isa gregarious spinescent shrub. Clerodendrum inerme
is a climbing or straggling mangrove associated shrub. There are places, where the swamp fern, Acrostichum aureum, grows gregariously. A species of grass belonging to the genus Aeluropus lagopoides is a pioneer on sandy beds and some species of Cyperusand Elaeocharisare also pioneers in muddy, more or less stagnant open swamps. The mangrove areas are biodiversity rich areas.

Among insects, the abundance of butterfly species can be attributed to the large diversity and abundance of flowering trees. It is true that a large body of the documented literature expresses the view that mangroves serve as ‘nature’s nursery’for a variety of marine fishes and other animals of food value to man. Many saline fishes and shrimp species are believed to migrate to the mangroves, where they swarm their fingerlings and young ones. It is generally argued that the mangroves are safer sites for the young ones;the rugged geomorphology of the mangrove ground surface due to the intricately ramifying prop roots and the thousands of erect standing breathing roots provide a difficult to move around three dimensional space, if not a difficult-to-access zone, for larger predators of the fishes and other fauna. Here, unlike in the case of fishes, the mudflats and wetlands are actually the feeding grounds both for the young and adult birds, and the mangrove trees are safe roosting sites directly overhead their food sources. However, recent study on avian fauna in the wetlands of Kerala (CED, 2006) revealed that, the migrant birds arrival to our wetlands have worn-out both in species and number, presumably because of the high rates of destruction of the mangrove habitats. Many kinds of microorganisms are found growing associated with the roots, prop roots and the breathing roots of mangroves. These organisms are supposed to have much reciprocal utility to the host as well. In addition, the mesophyll of many mangrove leaves contains endophytic fungi. Fungal endophytes associated with mangroves are diverse, yet the fundamental aspects of their interaction with the hosts are unknown; some endophytes have a high metabolic versatility and produce novel secondary metabolites of industrial importance. Mangroves, because of their numerous prop roots, knee and other respiratory roots form a skeletal biological meshwork underneath the ground, much like a shallow geotextile. This root-textile is a porous meshwork facilitating accumulation of debris. It does not easily yield to the tidal waves associated with natural disasters mentioned above, as it does not let the soil loosen. In other words, the mangrove stands tranquilize the tidal waves and are therefore rightly the ‘coast guards’or ‘watch dogs’of the shoreline geography and geomorphology. The lessons that we learn from the last few decades of coastline protection activities is that, construction of sea walls and bay building are not as effective as the mangroves in calming down the invading sea. All the more, when the global warming reaches its peak, for economic and other reasons also, it is not even practical to build such rock fortifications all around the shore(s). Unlike artificial barriers, a bio-shield like the mangrove is quite effective; the beauty of the mangrove is that it would be self-regenerating and resource limitation would not arise, as the sea-land interface is a nutrient rich environment. Most mangroves are also highly regenerative, without any innate reproductive constraints; all what we need to provide is an undisturbed land flush with saline water.

Mangrove trees offer significant and unique habitat to birds, mammals, and fish populations through a complex marine food chain, creation of breeding habitat, and establishment of restrictive areas that offer protection for maturing offspring. Mangrove plants produce about one kilogram of litter (mainly leaves, twigs, bark, fruit and flowers) per square meter per year. Crabs consume some of this but most must be broken down before the nutrients become available to other animals. That is where the bacteria, along with fungi, come in. Dividing sometimes every few minutes, they feastoon the litter, increasing its food value by reducing unusable carbohydrates and increasing the amount of protein - up to four times on a leaf which has been in seawater for a few months. Fish and prawns then eat partly decomposed leaf particles, loaded with colonies of protein-rich microorganisms. They in turn produce waste that, along with the smallest mangrove debris, is munched up by mollusks and small crustaceans. Even dissolved substances are used by plankton or, if they land on the mud surface, are browsed by animals such as crabs and mud whelks. This process is not confined to the mangroves. While some litter is recycled on the spot, this system is one of the few to export much of the organic matter it produces. Every time the tide retreats, it carries a cargo of food out to sea. Here bacterial densities are almost as high as those in the mangrove mud and they do much the same job, breaking down the litter to be consumed by bottom-living fauna, prawns and fish. An estimated 75 per cent of commercially caught fish and prawns depend directly on mangroves at some time in their lives or feed on food chains leading back there. Since those species making up the remainder of the catch probably also owe much to nutrients exported from the mangroves, these coastal forests can be seen as one of our major assets.

CHAPTER II

STATION LOCATIONS

In the present investigation three locations in mangrove system at Kadamakudy has selected. Wetlands in Kochi is one of the ‘Green States’ of India and is well known for its wetlands. There are about 217 wetland areas in Kerala and it accounts for as much as one fifth of the land area of the state. The district of Ernakulam tops with 20.26% of the total state’s wetland extent followed by Alappuzha (15.8), Trishur (12.99) and least by Wayanad (0.8). Vembanad Wetland is spread over the districts of Alappuzha, Kottayam, Ernakulam and Thrissur of Kerala. It is the longest water body in the country and largest in the state. The wetland has an area of 1521.5 km^2 and volume of 0.55 km3, fed by 10 rivers flowing into it, adding up to a total drainage area of 15,770 sq km. It is a complex aquatic system of 96 km. long coastal backwaters, lagoons, marshes, mangroves and reclaimed lands, with intricate networks of natural channels and man-made canals. Wetlands occupy the transitional zone between the aquatic and terrestrial environment sharing the characteristics of both of them, and are unique in their own way. Scientists often refer to wetlands as the ‘kidneys’ of the earth. Wetlands support a wide array of flora and fauna and deliver many ecological, climatic and social functions.

Pokklai Fields in Kochi Kerala state has a coastline of 560km. This coastal belt has a unique system of rice cultivation in the saline soils known as pokkali cultivation. The Pokkali field is a unique ecosystem prevailing in the coastal saline tract of central Kerala with rich biodiversity and amazing capacity to generate organic paddy and shrimp alternatively. For protecting our wetlands the traditional practice of cultivating pokkali along with prawn farming can play a major role. Pokkali the oldest variety of rice in Kerala - South India, which has a tradition of at least 3000 years, is highly environment-friendly and also sustainable. Thus, through popularising the organic pokkali-prawn rotational farming practice we can protect our valuable wetland resources as well as can maintain the ecological balance for a better tomorrow.

Construction of Vallarpadam Container Terminal Road and the Rail way Link hinder the natural flow of tidal waves into the pokkali fields. The traditional way of prawn farming in pokkali fields are purely on the basis of tidal waves. The juvenile prawn seedlings, which swim in from the sea and the backwaters are guided to the fields through trap sluices and the sluice gates prevent them from going out. Thus they are allowed to grow in the field. Without Pokkali cultivation, the entire cultivated area would have been flooded and wasted; acidity and toxicity would be high and there would also be less oxygen and more hydrogen sulphide in the land. These wetlands provided livelihood to the residents in the area in the forms of agricultural produce, fish, fuel, fiber, fodder, and a host of other day-to-day necessities. The presence of wetlands helped in providing drinking water besides reducing the impact of beach erosion. It also played a key role in biodiversity conservation. As a consequence to the above mentioned reasons the dream of food security for our state will not be realised with the destruction of pokkali fields in the name of development.

CHAPTER III

Nutrient dynamics in Mangrove Ecosystems

In mangroves, recycling processes include reabsorption or retranslocation of nutrients prior to leaf fall and the immobilization of nutrients in leaf litter during decomposition (Brinson, 1977). There may also be mechanisms of nutrient regeneration associated with animal communities that colonize aerial root systems of mangroves, yet these mechanisms have received little investigation. The patterns in nutrient recycling may influence the productivity of mangrove communities, as well as the exchange of nutrients at the boundary of mangroves. Depending on the nature of nutrient recycling within the forest, mangroves may serve as either a nutrient source or sink to adjacent coastal waters. Sediments suspended in the water column are deposited in mangroves during flooding and this material enriches mangrove soils. The extensive root system of mangroves enhances this trapping process and retards the forces of erosion along the shoreline (Scoffin, 1970). Although this function has been overstated to the extent of calling mangroves "walking trees", roots do contribute to sedimentation in estuaries .

Being circumtropical in distribution, coastal ecosystems such as mangroves are found along transient zones of intertidal regions of the world. The geomorphic location of mangrove ecosystem forms an intermittent platform for efficient nutrient regeneration mechanisms. One such mechanism is geological weathering of minerals from the catchment enhancing their nutrient levels from rivers. Mangrove creeks are responsible for tidal exchange of dissolved and particulate matter between the forest and adjacent coastal waters . These ecosystems play a dual role in acting as sinks of sediments and nutrients, but also as sources of organic matter of low nutrient quality. They are also considered to be the most productive wetlands; the total productivity from mangroves (leaf litter, wood and root production combined) has been estimated as roughly 149 mol C m –2 yr–1 and with such a high productivity, they export detritus to the adjacent oligotrophic marine food webs, supporting valuable estuarine and coastal fisheries. Furthermore, high productivity of mangrove forests, their geomorphological position at stronger tidal regime with regular freshwater riverine input, and non litter retaining feature of mangrove vegetation support the 'outwelling' of nutrients in the mangrove ecosystem . Organic matter degradation carried out by microorganisms results in the recycling of essential nutrients in the sediments, owing to rapid immobilization of nutrients during decomposition in mangrove forest sediments and other sediments as well. The present study the investigations focused on nutrients like Nitrite, Nitrate, Phosphate and Silicate.

1.Nitrite and 2.Nitrate

Anammox (anaerobic ammonium oxidation) is the anaerobic conversion of NO_2 and NH_4^+ to N_2. A consequence of this hypothesis is that the activity and presumably the abundance of these bacteria are strongly linked to the activity of other bacterial groups, since nitrite is produced as an intermediate in both nitrification and denitrification. The abundance of free NO_2 in the sediment is, therefore, a result of the complex balance between diffusive transport, aerobic NH_4 and NO_2 oxidation, and anaerobic NO_3 and NO_2 reduction. The availability of NO_2 , as well as the identification of the principal source for net NO_2 production in sediments, is still not well studied, due to the scarcity of techniques that allow measurements of NO_2 with sufficiently high spatial resolution. Stable-isotope (15N) experiments in sediments have established that NO2 and not NO_3 is the oxidized substrate for the anammox process (8, 27, 38, 39), although recent research suggests that some cultivated anammox bacteria can reduce NO_3 to NO_2 with propionate as the electron donor (15). Furthermore, marine anammox bacteria, in contrast to their competitors, the denitrifiers, appear to require a continuous supply of NOx (NO_2 plus NO_3) to maintain an active enzyme apparatus (26). Given that NH_4 is rarely limiting in sediments (see, e.g., reference 28), the availability of NO_2 most likely controls the abundance of active anammox bacteria.

3.. Phosphate

Input from various anthropogenic activities (such as agricultural run-off, aquaculture run-off and municipal wastewater) into mangrove fringed creeks may increase the rate of decomposition of organic matter by increasing the nutrient conditions suitable for bacterial growth. This in turn leads to an increase in the phosphorus (P) load to the sediments. Hence, Redfield ratio (C : N : P) serves as a crucial tool to identify the phosphorus load/biogeochemistry in a system. In many tropical estuarine and coastal systems, primary production appears to be limited by phosphorus.

The absence of gaseous phases makes the phosphorus cycle relatively simple in nature, although the relationship between microbial activities and changes in phosphorus geochemistry can be highly complex and difficult to measure. The major pools of P include aboveground and belowground biomass and soil, the input involves atmospheric (dry and wet deposition), mangrove (canopy nutrient transfer and litter fall), mineralization from soil and anthropogenic sources (sewage, agriculture, aquaculture, etc.). The removal of P (output) involves mangrove plant assimilation, microbial uptake, uptake by macro-feeder, tidal exchange and soil immobilization.

Concentrations of dissolved (dissolved inorganic phosphorus, DIP) and particulate (dissolved organic phosphorus, DOP) phosphorus in mangrove sediments are usually changed. Seasonal changes in plant uptake and microbial growth, temperature, rainfall, oxygen availability and sediment type have a profound effect on concentration over time and intertidal position . Dissolved inorganic phosphorus (soluble reactive phosphate) exists mainly as a nutrient salt (HPO2 4 –) at the pH of sea water. Soluble reactive phosphate is readily assimilated by bacteria, algae and higher plants, including mangroves. However, most of dissolved P in aquatic systems consists of various organic phosphates (primarily phosphate esters originating from living cells), which have limited availability due to their resistance to enzymatic hydrolysis .

CHAPTER IV

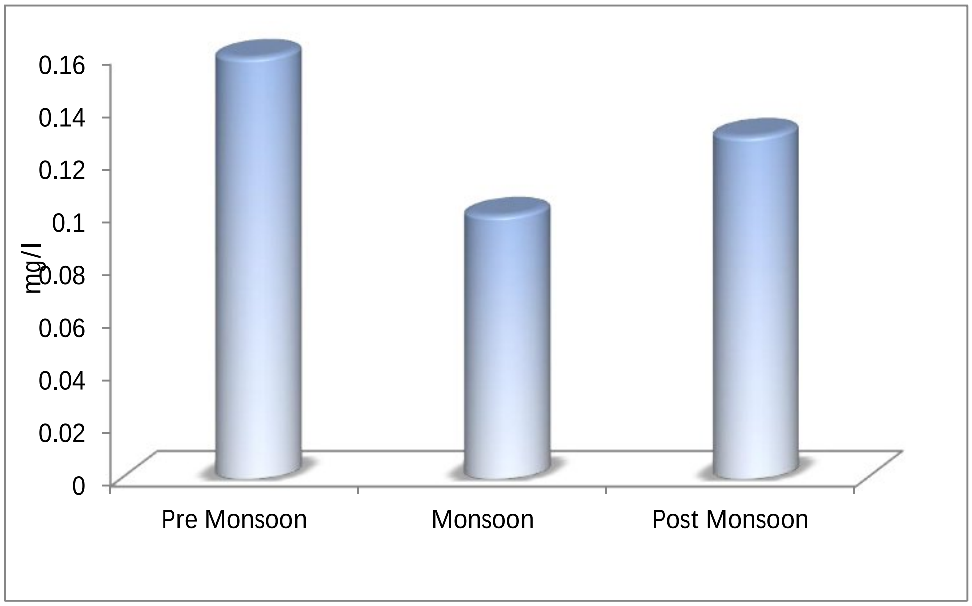
ANALYTICAL TECHNIQUES , RESULTS AND CONCLUSION

Monthly samplings were done at three different locations in Kadamakudy from November 2014 to November 2015. The same procedure is repeated from November 2015 to August 2016. The results obtained are almost same. The water samples for different nutrient analysis were collected in different polythene bottles directly from the water sampler. Surface sediment samples were collected at low tides with clean polythene scoop. All samples were kept in plastic bags and carried in iceboxes to the laboratory. These sediment samples were homogenized and kept deep frozen until analysis. Dissolved Phosphate, Nitrate, Nitrite, and Silicate in water samples were analysed colorimetrically according to the methods described in Grasshoff *et al.* (1983a).

RESULTS OF THE STUDY

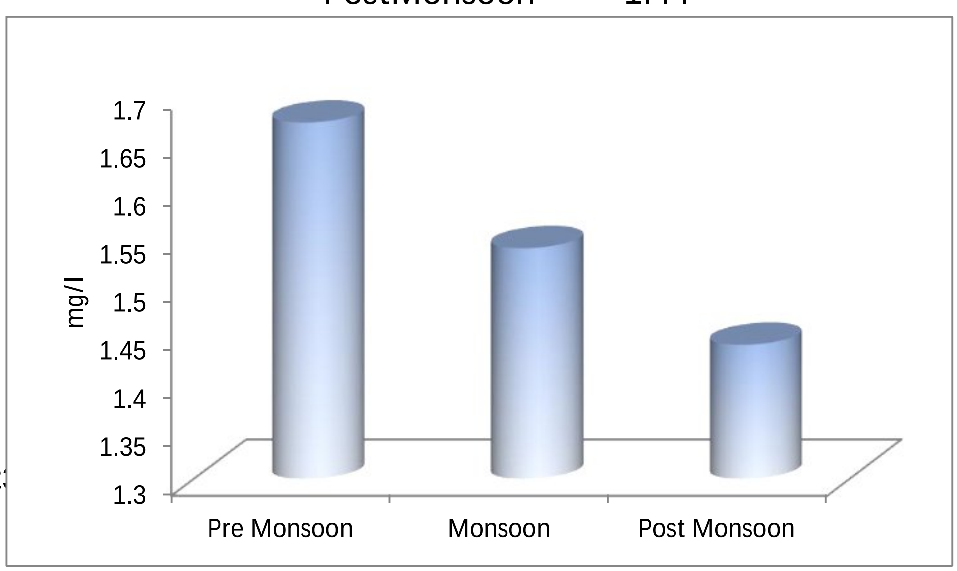
Seasonal Variation of Nitrite

	Season	Nitrite(mg/l)
Station 1	Pre Monsoon	0.16
	Monsoon	0.1
	Post Monsoon	0.13



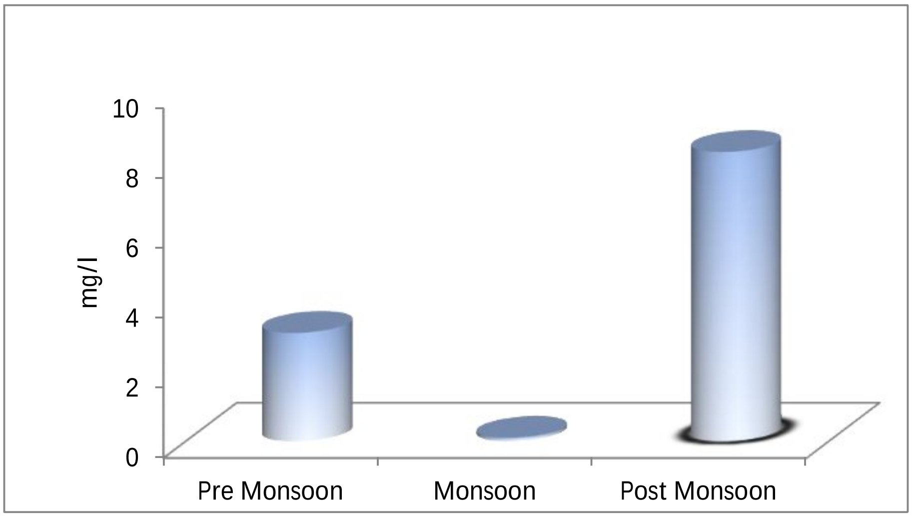
Seasonal Variation of Nitrate

	Season	Nitrate(mg/l)
Station 1	PreMonsoon	1.67
	Monsoon	1.54
	PostMonsoon	1.44



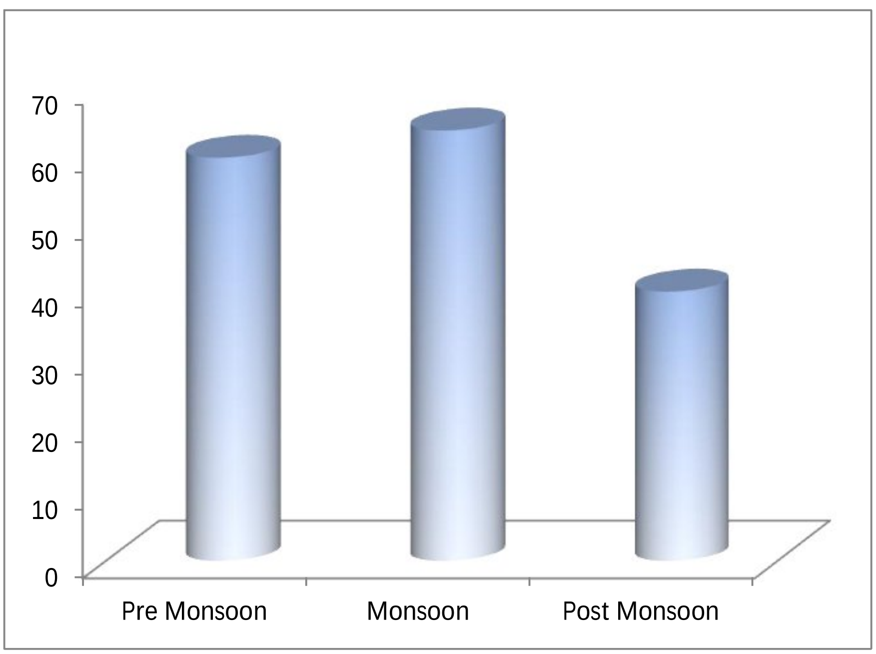
Seasonal Variation of Phosphate

	Season	Phosphate (mg/l)
Station 1	Pre Monsoon	3.11
	Monsoon	0.1
	Post Monsoon	8.28

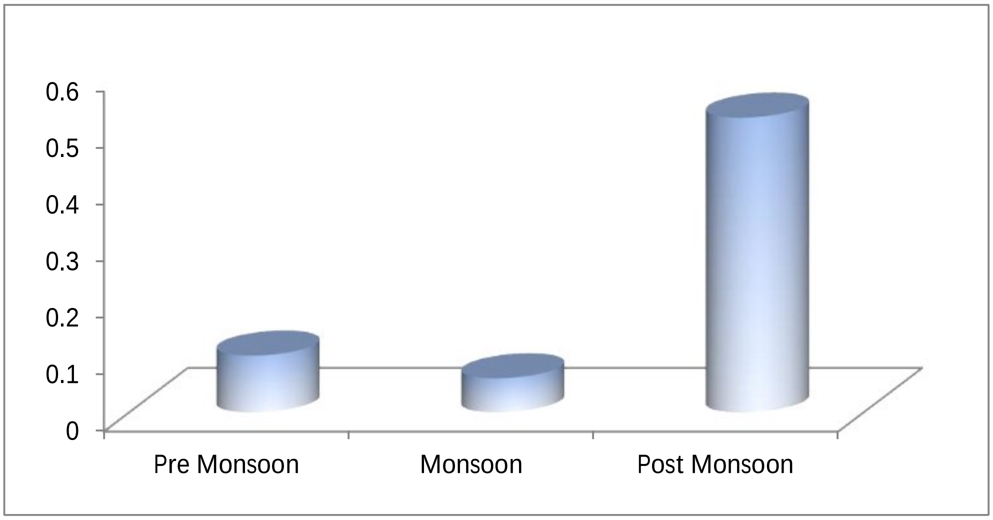


Seasonal Variation of Silicate

	Season	Silicate (mg/l)
Station 1	Pre Monsoon	59.65
	Monsoon	63.67
	Post Monsoon	39.85

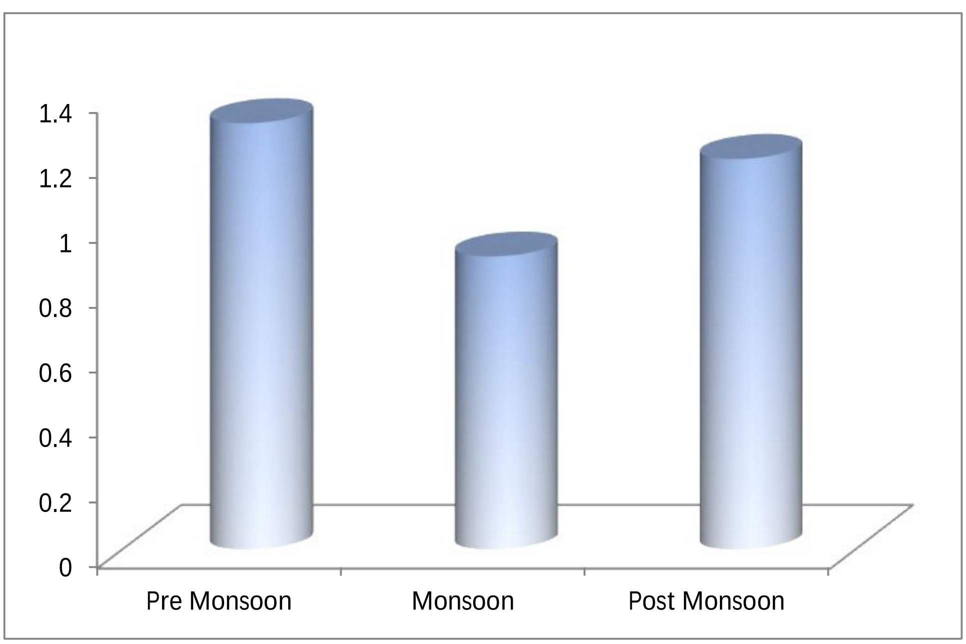


Station 2	Pre Monsoon	0.1
	Monsoon	0.06
	Post Monsoon	0.56



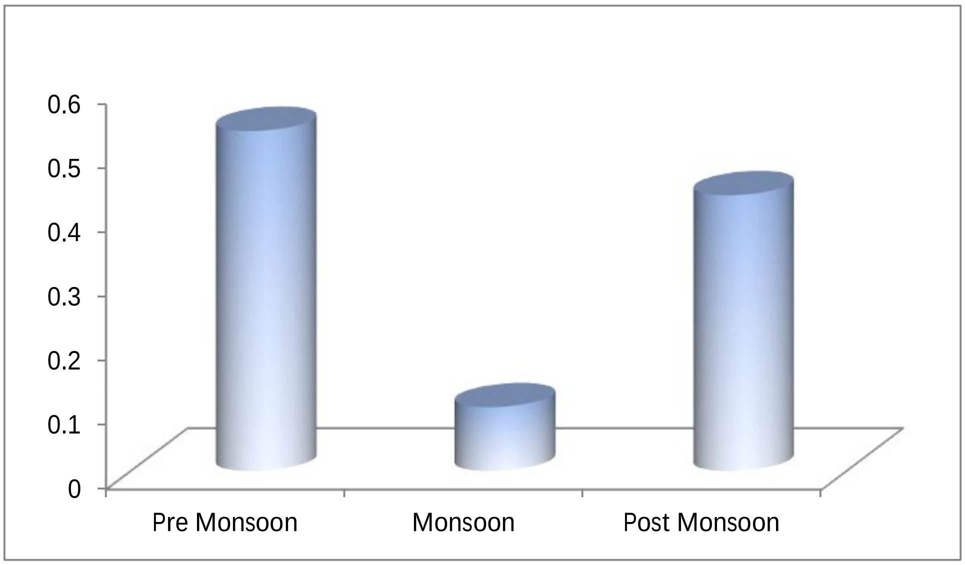
Seasonal Variation of Nitrate

	Season	Nitrate (mg/l)
Station 2	Pre Monsoon	1.31
	Monsoon	0.9
	Post Monsoon	1.2



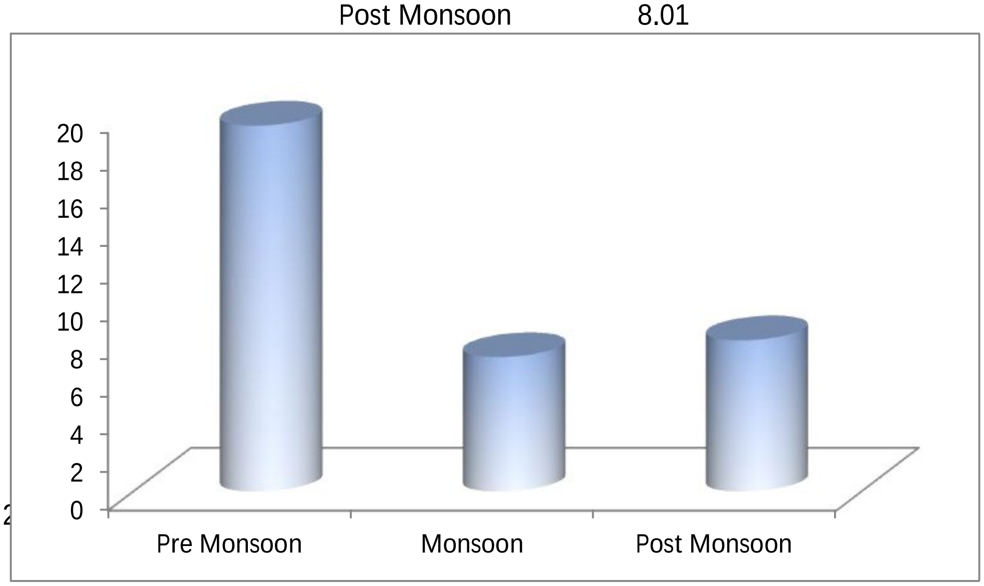
Seasonal Variation of Phosphate

	Season	Phosphate (mg/l)
Station 2	Pre Monsoon	0.53
	Monsoon	0.1
	Post Monsoon	0.43



Seasonal Variation of Silicate

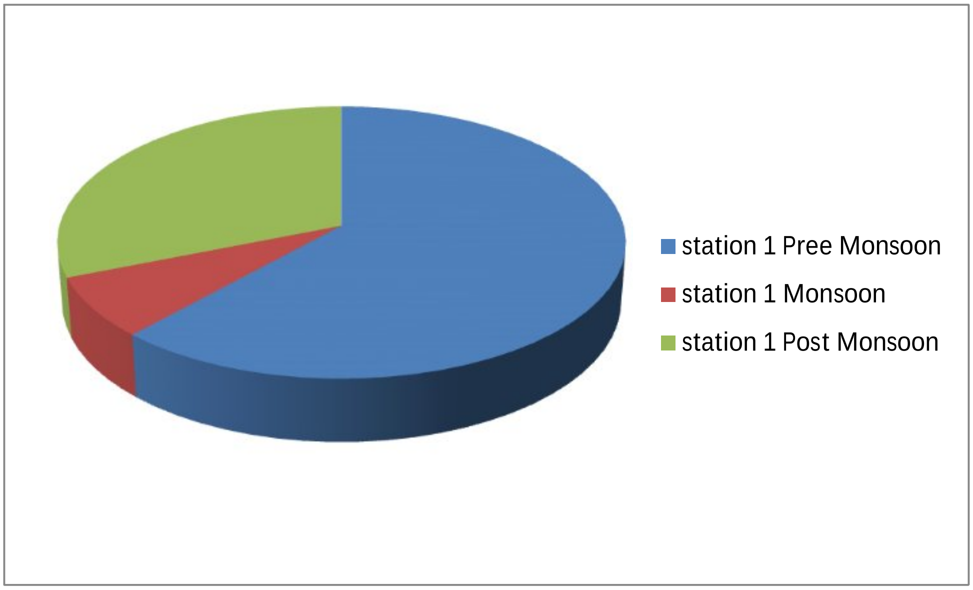
	Season	Silicate (mg/l)
Station 2	Pre Monsoon	19.4
	Monsoon	7.12
	Post Monsoon	8.01



Nutrients in Sediment Samples

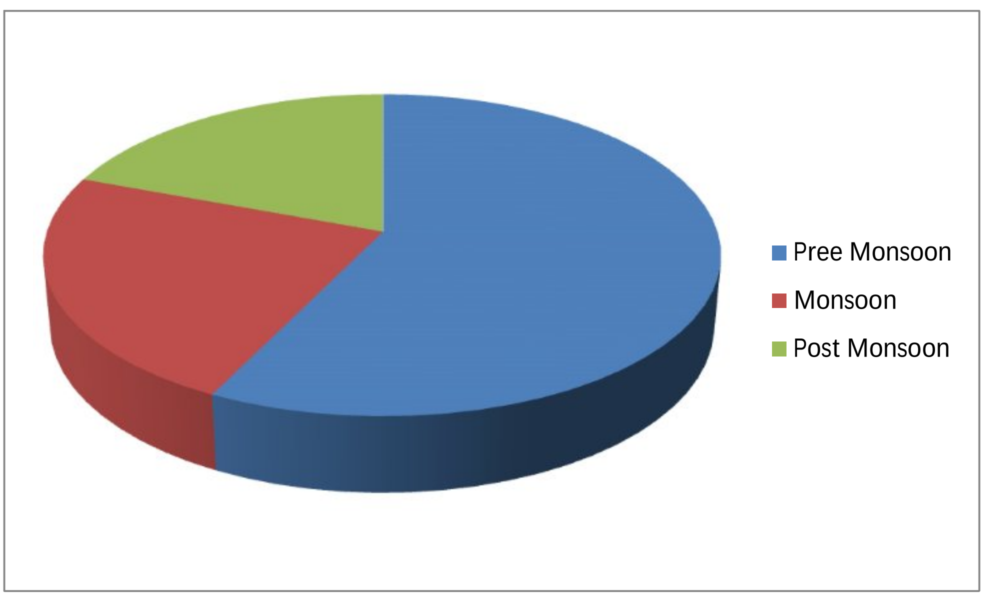
Nitrite mg/kg

Station	Pree Monsoon	1.815
	Monsoon	0.212
	Post Monsoon	0.912

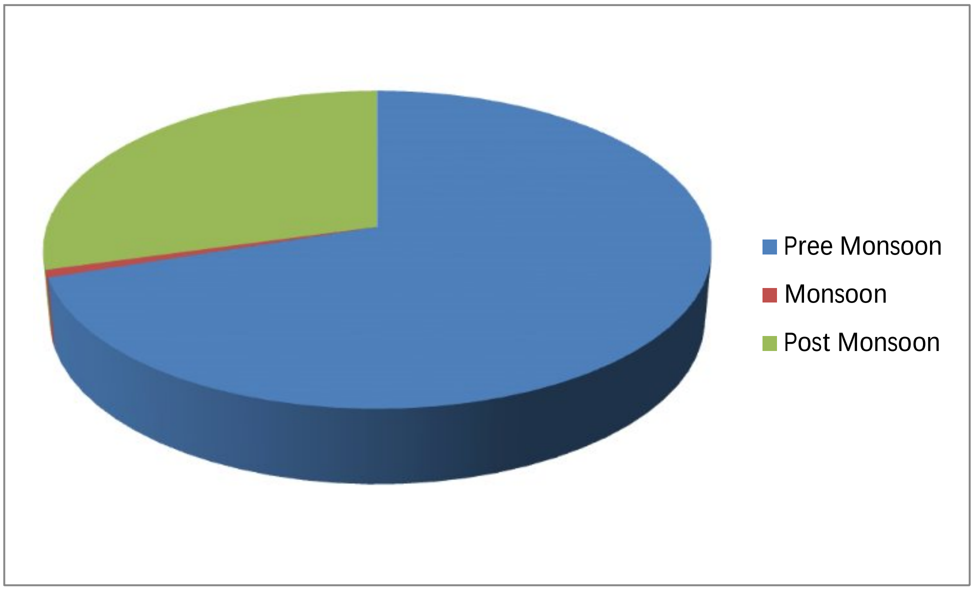


Nitrate mg/kg

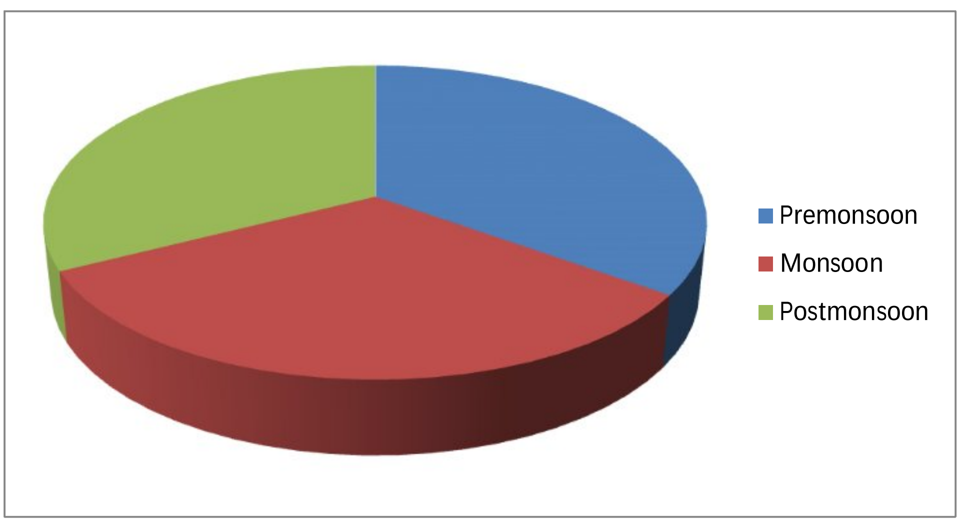
station 1	Pree Monsoon	2.967
	Monsoon	1.212
	Post Monsoon	1.001



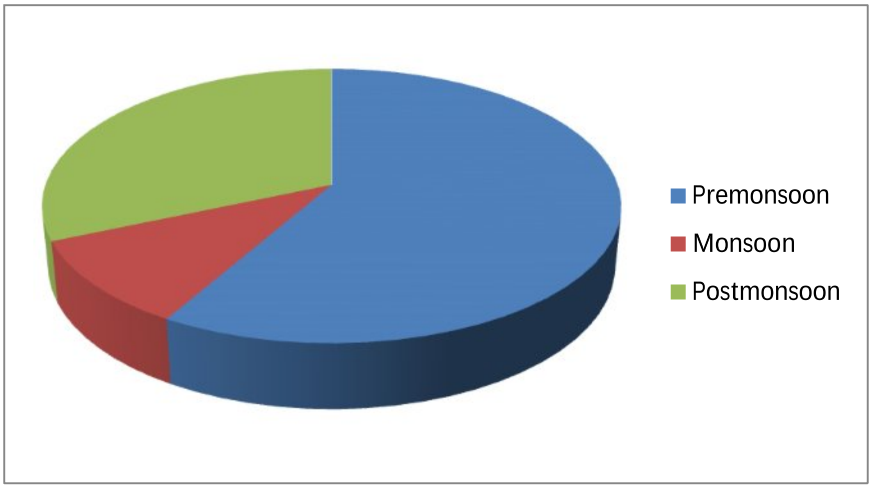
	Phosphate mg/kg	
station 1	Pree Monsoon	2.025
	Monsoon	0.022
	Post Monsoon	0.847



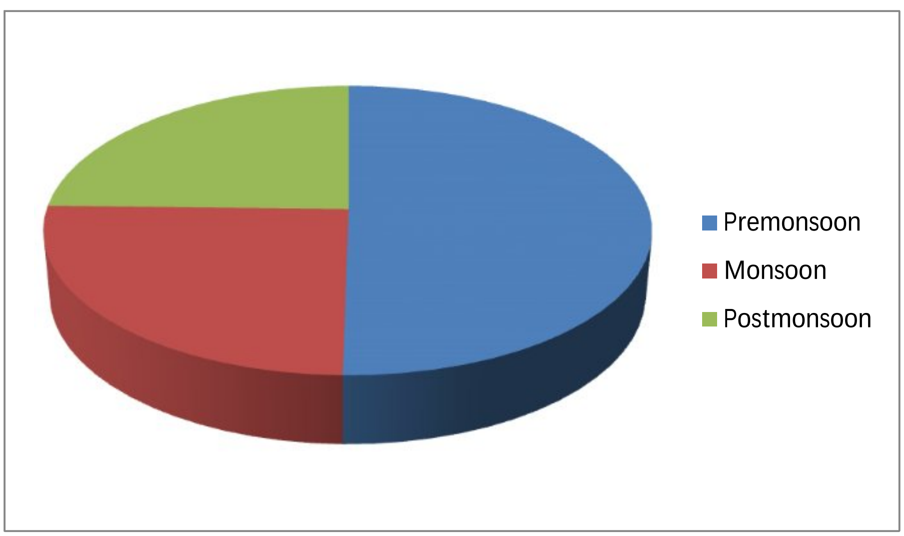
	Silicate mg/kg	
Station 1	Premonsoon	2.141
	Monsoon	2.002
	Postmonsoon	1.992



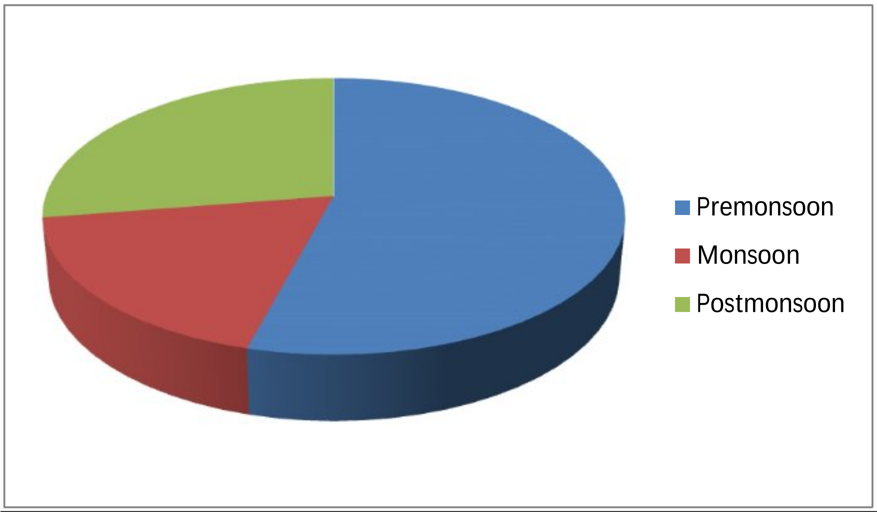
	Nitrite mg/kg	
Station 2	Premonsoon	1.782
	Monsoon	0.312
	Postmonsoon	0.962



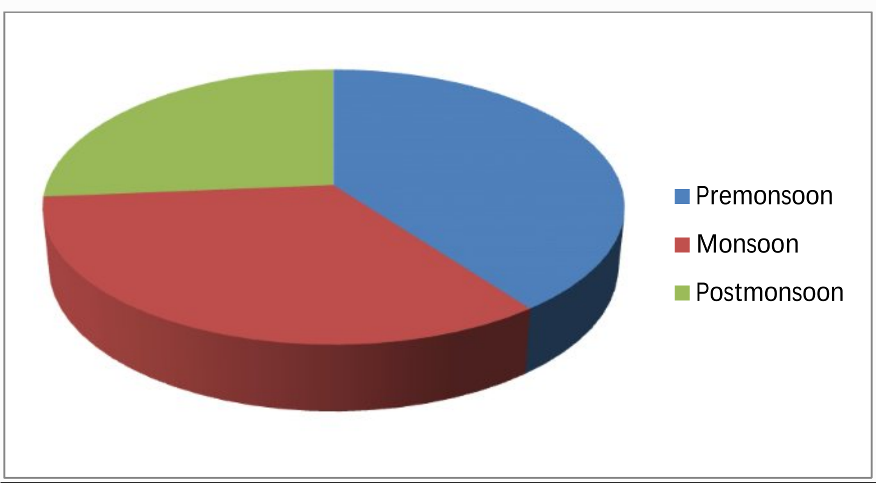
	Nitrate mg/kg	
Station 2	Premonsoon	2.015
	Monsoon	1.007
	Postmonsoon	0.987



	Phosphate mg/kg	
Station 2	Premonsoon	1.546
	Monsoon	0.524
	Postmonsoon	0.785



	Silicate mg/kg	
Station 2	Premonsoon	2.001
	Monsoon	1.698
	Postmonsoon	1.324



CONCLUSION

The study revealed that nutrient concentrations were influenced by seasonal changes. Mean nutrient levels during pre-monsoon, monsoon and post-monsoon seasons, respectively, were in the following ranges in water samples at stations 1 and 2: nitrite (0.16–0.10, 0.1–0.06 and 0.13–0.56 mg/L); nitrate (1.67–1.31, 1.54–0.9 and 1.44–1.2 mg/L); posphate (3.11–0.53, 0.1–0.1 and 8.28–0.43 mg/L) and silicate (59.65–19.4, 63.67–7.12 and 39.85–8.01 mg/L). Increased levels of silicates were recorded during pre-monsoon and monsoon periods. All seasons showed higher silicate content whereas few elevated concentrations were observed during monsoon and post-monsoon at station 2. Sediment samples contained mean nutrient levels in the following ranges: nitrite (1.815–1.782, 0.212-0.312 and 0.912–0.962 mg/kg); nitrate (2.967–2.015, 1.212-1.007 and 1.001-0.987 mg/kg); posphate (2.025-1.546, 2.002-0.524 and 0.847–0.785 mg/kg) and silicate (2.141-2.001, 2.002-1.698 and 1.992-1.324 mg/kg).

Results of the study shows that soil nutrients are vary seasonally in response to wet and dry periods of climate. Most of the pollutants are accumulated in the top layer of the soil tray. The waste water inputs and salinity would have more significant role on seasonal variation of nutrients in mangrove ecosystem. Mangrove plants intake nutrients from the tidal sea water, river courses and the eco systems. The patterns in nutrient recycling may influence the productivity of mangrove communities, as well as the exchange of nutrients at the boundary of mangroves. Depending on the nature of nutrient recycling within the forest, mangroves may serve as either a nutrient source or sink to adjacent coastal waters. Sediments suspended in the water column are deposited in mangroves during flooding and this material enriches mangrove soils. The extensive root system of mangroves enhances this trapping process and retards the forces of erosion along the shoreline . Although this function has been overstated to the extent of calling mangroves “walking trees”, roots do contribute to sedimentation in estuaries .

These both ecosystems are with much anthropogenic input. The increasing prawn culture and ‘pokkali cultivation’affects the nutrient dynamics in concerned systems. The silicate values were comparatively higher than other nutrients (NO_3^-, NO_2^- and PO_4^{3-}). This may be due to heavy influx of fresh water derived from land drainage carrying silicates leached out from rocks and also from bottom sediments exchanging with overlying water due to the turbulent nature of water in the mangrove environment.

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