STUDIES ON THE STANDARDIZATION OF GROWTH REQUIREMENTS OF MANGROVES FOR ASSESSING THE PROBABILITY OF SITES FOR AFFORESTATION

Thesis submitted to the
University of Calicut in partial fulfillment of the
requirements for the award of the degree of

DOCTOR OF PHILOSOPHY

IN

BOTANY

by

NEETHU G. PILLAI

DIVISION OF ENVIRONMENTAL SCIENCE
DEPARTMENT OF BOTANY
UNIVERSITY OF CALICUT
KERALA - 673 635, INDIA

OCTOBER 2017

UNIVERSITY OF CALICUT
DEPARTMENT OF BOTANY
Division of Environmental Science
P.O. Calicut University, Tenhipalam
Malappuram District, Kerala – 673 635
Contact: 09447956226
Mail: ccharilal22@gmail.com

Dr. C.C. Harilal
Associate Professor

CERTIFICATE

This is to certify that the thesis entitled "**Studies on the standardization of growth requirements of mangroves for assessing the probability of sites for afforestation**", submitted to the University of Calicut by Mrs. Neethu G. Pillai, in partial fulfillment of the award of the degree of Doctor of Philosophy in Botany is a bonafide record of the research work carried out by her under my guidance and supervision. No part of the present work has formed the basis for the award of any other degree or diploma, previously.

University of Calicut
31st October 2017

Dr. C. C. Harilal
(Supervising Teacher)

UNIVERSITY OF CALICUT

DEPARTMENT OF BOTANY
P.O. Calicut University, Thenhipalam
Malappuram District, Kerala – 673 635
Contact: 09447956226
Mail: ccharilal22@gmail.com

Dr. C.C. Harilal
Associate Professor

CERTIFICATE

This is to certify that the corrections / modifications suggested by both the adjudicators have been incorporated in the thesis entitled "Studies on the standardization of growth requirements of mangroves for assessing the probability of sites for afforestation" submitted by **Mrs. Neethu G. Pillai,** Research Scholar, Department of Botany, University of Calicut. The thesis is hereby submitted to the University of Calicut vide reference no. 196636/RESEARCH-C-ASST-1/2017/Admn. dated 30/04/2018.

Calicut University
12-06-2018

C. C. Harilal
(Supervising Teacher)

DECLARATION

The thesis entitled "**Studies on the standardization of growth requirements of mangroves for assessing the probability of sites for afforestation**", submitted by me in partial fulfillment of the requirements for the award of the degree of Doctor of Philosophy in Botany of the University of Calicut is an original research work carried out by me under the guidance and supervision of Dr. C.C. Harilal, Assistant Professor, Department of Botany, University of Calicut. No part of the work formed the basis for the award of any other degree or diploma of any University.

University of Calicut **Neethu G. Pillai**

31st October 2017

ACKNOWLEDGEMENT

Completion of this doctoral research was accomplished with the support of many. I would like to take this opportunity to thank all the persons who have made it possible for me to commence and complete this task. I remember them for their efforts, cooperation and collaboration that have worked towards the successes of this study.

First of all, I am extremely privileged to place on record my deep sense of gratitude to my supervising guide, Dr. C.C. Harilal, Assistant professor, Department of Botany, University of Calicut, for patiently taking me through this research work. He has been a source of inspiration and support throughout the course of my research work. This feat was possible only because of the valuable guidance and scholarly inputs provided by him. I owe him a lot for providing constant encouragement and invaluable time in all the stages of my research.

I wish to place on record my gratitude to Prof. (Dr). Santhosh Nampy, Head, Department of Botany, Prof. (Dr). John E. Thoppil, Prof. (Dr). K.M Jayaraman, Prof (Dr). M. Sabu (former heads), for providing various facilities during the tenure of my work.

Dr. K.V. Mohanan, Professor, Department of Botany and Director, Interuniversity centre for Plant Biotechnology, University of Calicut is greatly acknowledged for his timely help in the statistical analysis of my research work.

The valuable suggestions from Dr. P. Manimohan, Professor, Department of Botany, University of Calicut as Doctoral Committee member is greatly acknowledged.

I wish to thank all the faculty members of Department of Botany, University of Calicut, for their valuable support.

It is my pleasure to put on record the support and friendliness I have enjoyed from Miss Karthika S. Menon, Mr. Sajith U and Mrs. Shilna E.P.

The timely help rendered by Dr. Hidayathulla R.M., is greatly acknowledged. I owe special thanks to my fellow researchers Mrs. Rathy M.C., Mrs. Snisha S., Dr. Ajayan K.V, Mrs Bindhumol G.P., Mrs Sheeja K.M., Mrs Jasmine P.J. and Mr. Hareesh for their companionship, inspiring advice, continuous encouragement and well-timed support.

I wish to thank all the office staff, Department of Botany, University of Calicut for their help during the course of my work. Special thanks to Dr. Prakasan, Librarian, Department of Botany for extending the Library facilities.

I thank Mr. Ayyappan, staff, Kadalundi – Vallikkunnu community Reserve, Malappuram and the officials of Ayiramthengu Government fish farm, Kollam, for facilitating my field collections.

I am sincerely grateful to Mrs. Soorya, Dr. Aswani, Mrs. Fabeena, and Mrs Ambili for their timely help during my field studies and sample collections.

Words make me fail to express my feelings of gratitude to my beloved Amma, my husband Syam Krishnan, daughter Vedhika, my in- laws and all other members of my family, who stood by me in all the tough times during my research work. It was their prayers, love and innumerable sacrifices that fuelled my journey through these research work. I deeply miss my father, who is not with me to share this joy.

Above all, I owe it all to Almighty God for granting me the wisdom, health and strength to undertake this research task and its completion.

Neethu G. Pillai

Dedicated to
My Beloved Family

CONTENTS

LIST OF TABLES

ABBREVIATIONS

µm	:	Micromolar
µmol/l	:	Micromole per litre
$CaCO_3$	:	Calcium carbonate
cm	:	Centimeter
Cmol/kg	:	Centimole per kilogram
CRZ	:	Coastal Regulatory Zone
DO	:	Dissolved oxygen
EDTA	:	Ethylenediaminetetraacetic acid
g	:	Gram
g/kg	:	Gram per kilogram
ha	:	Hectare
HCl	:	Hydrochloric acid
hrs	:	Hours
KCl	:	Potassium Chloride
Kg/ha	:	Kilo gram per hectare
km	:	Kilometer
km^2	:	Square kilometer
m	:	Meter
Mg/g	:	Milligram per gram
Mg/kg	:	Milligram per kilo gram
Mg/l	:	Milligram per litre
ml	:	Milli litre
mm	:	Millimolar
mms	:	Millimeter per second

mS	:	Milli seimens
nm	:	Nanometer
NTU	:	NephelometricTurbidity Unit
^{o}C	:	Degree Celsius
pm	:	Picomolar
ppt	:	Parts per thousand
psu	:	Practical Salinity Unit

GENERAL INTRODUCTION

Mangroves are considered as one of the most specialized ecological assemblages of halophytic plants acting as a transient zone between land and ocean. They comprise of taxonomically diverse shrubs and trees, distributed along tropical and sub tropical environments having specific habitats such as shores, estuaries, tidal creeks, backwaters, lagoons, marshes, mudflats and even at upstream points where water remains saline (Qasim, l998).

Mangrove trees are highly adapted with aerial roots, viviparous seeds and salt exclusion/excretion mechanisms (Tomlinson, 1986; Hogarth, 2007). This enables them to cope up with periodic immersion and exposure to the tide, fluctuating salinity, and low oxygen concentrations in the water and sediments and sometimes high temperatures (Hogarth, 2007). The peculiar adaptation of the trees with aerial and salt-filtering roots and salt-excreting leaves enable them to occupy the saline wetlands, where other plant life cannot survive.

Both climate and environment are known to play prominent role in the survival of mangroves (Gilman et al., 2008). Among the climatic factors, temperature fluctuations, humidity percentage, total annual rainfall, regular wind flow, radiation and sedimentation along with upstream water supply also play very dominant role in the growth and establishment of mangroves (Kathiresan and Bingham, 2001).

Mangroves prefer a humid climate and fresh water inflow that brings in abundant nutrients and silt. They grow luxuriantly in alluvial soil and are plentiful in broad, sheltered, low lying coastal plains where topographic gradients are small and tidal amplitudes are large. Repeatedly flooded and well drained soils support good mangrove growth and high species diversity (Azariah et al., 1992) and they grow poorly in stagnant water (Gopal and Krishnamoorthy, 1993). Their distribution is strongly affected by temperature (Duke, 1992), moisture (Saenger and Snedaker, 1993) and large scale currents (De Lange and De Lange, 1994). Studies have revealed that the most favorable temperature range for mangrove plants is between 20°C and 35°C (www.niobioinformatics.in). It has also been reported that, annual average temperatures below 5°C and above 35°C are detrimental to the growth of mangroves (Alongi, 2002).

Development of mangrove patches depends on the hydrological, sedimentological and ecological features of the area. Accordingly six mangrove types are recognized worldwide and they include over wash forests, fringe forests, riverine forests, basin forests, scrub and hammock forests (Lugo and Snedaker, 1974). Over wash mangroves occur on low elevation islands and peninsulas which are characterized by inundation on all high tides. Fringe forests dominate sheltered shorelines and are commonly a part of allowing sediments and organic debris. They are also inundated by high tides. Riverine forests develop in embayment downstream of rivers with ample water flow. It is a productive one, occurred by seasonal flooding. Basin mangrove forests are located in the river/tidal drainages, where there is a reduced tidal inundation. Scrub mangrove forests are seen along the flat coastal fringes by forming dwarf mangrove settings. Hammock mangrove forests are similar to the basin type, except that they occur in more elevated sites than the other five. If the mangrove system is having regular flooding and is in rhythm with tidal conditions, riverine forests, which are the most productive one, will establish.

Mangrove forests are unique functional ecosystems having much social, economic and biological importance. They are among one of the most productive ecosystems of the world as they provide important ecosystem supplies and services to human society as well as coastal and marine systems (Bouillon et al., 2003; FAO, 2007). These habitats interact with a wide array of aquatic or terrestrial flora and fauna, enabling their growth and establishment. They serve as habitat for a variety of organisms and are an excellent breeding and nursing grounds for marine and pelagic organisms such as juvenile fish, shellfish, reptiles, crabs etc. (Giri et al., 2011). They also serve as food, medicine, fuel and building materials for local communities (Sasidhar and Rao, 2015).

The proximity of mangrove habitats to the coastline makes them efficient water filters of pollutants and contaminants, thus improving water quality. The production of a more-or-less continuous input of dead leaf material to the surrounding bodies of water provides the basic food input to the detritus food web, which is the basis of secondary production in mangrove-linked estuaries. As a nutrient filter and synthesizer of organic matter, mangroves create a living buffer between land and sea (Tomlinson, 1986; Macintosh and Ashton, 2002).

Together with sea grass meadows and salt marshes, mangroves are recognized as one of the key ‘blue carbon’ habitats. They are the most carbon-rich forests in the tropics, able to sequester 6 to 8 tonnes of carbon dioxide equivalent per hectare per year. This rate is two to four times greater than global rates observed in mature tropical forests (Murray et al., 2011). Most of the carbon stored by mangroves is in the form of below-ground biomass (Alongi, 2014). Covering only 0.1% of the earth’s continental surface, the forests account for 11% of the total input of terrestrial carbon into the ocean (Jennerjahn and Ittekot, 2002) and 10% of the terrestrial dissolved organic carbon (DOC) to the ocean (Dittmar et al., 2006). The ability of mangroves to sequester and store huge amounts of carbon plays an important role in global carbon budgets and in the process of mitigating climate change.

Mangroves are considered to play an important role in controlling coastal hydrodynamics and sediment movements (Boto, 1992; Eong, 1993). As mangroves are bordered by shallow sea water, they are protected from direct wave action. Mangrove cover act as an effective protector against the assault of coastal events and its ferocity than any of the artificial structures. Roots of mangrove trees and plants bind and stabilize the substrate sediment. They prevent shoreline erosion by acting as a buffer zone and catch alluvial materials, thus stabilizing land elevation through sediment accretion that balances sediment loss (Krauss et al., 2003). All such properties reveal their pivotal role in coastal protection, reducing the risk of damage from erosion, natural ecological disasters and calamities such as tsunamis, hurricanes etc. (Guebas et al., 2005; Alongi, 2008).

Mangroves are mainly found between the Tropic of Cancer and the Tropic of Capricorn, covering majority of the tropical and subtropical coastlines, worldwide (Saenger, 2002). Global distribution of mangroves largely lies between latitudes 30ºN and 30ºS (Giri et al., 2011). FAO (2007) estimated that mangroves cover an area of 12 to 20 million hectares. The world's mangroves are distributed mainly in Asia (42%), followed by Africa (21%), North and Central America (15%), Oceania (12%) and South America (10%).Though the world's mangrove forests are spread across 118 countries and territories, one third of them are spread in just 15 countries (FAO, 2007). Distribution status of mangroves in 2010 revealed that they occur in 123 countries and territories globally, constituting a total of 1, 52,000 km^2 (Spalding et al., 2010). 73 mangrove species were also reported, including some hybrid species. The list included both true mangroves and mangrove associates. Another statistical report proposed by Giri et al. (2011) revealed the existence of 1, 37,760 km^2 of mangrove forests in 118 countries and territories.

Recent reports on the distribution of mangroves show that they are found in 105 nations globally (Hamilton and Casey, 2016). Although mangroves have been distributed across different nations, the top 10 mangrove holding nations possess approximately 52% of the global mangrove stock. Indonesia alone holds 26 – 29 % (Hamilton and Casey, 2016). The largest continuous area of mangrove forest is situated in-and-around the Sundarbans National Park in India and the Sundarbans Mangrove Forests in Bangladesh, both recognized by UNESCO as World Heritage Sites (UNESCO, 2016).

The mangrove distribution status in Asia shows that, they are mainly distributed in Bangladesh, Indonesia, Pakistan, Srilanka, Philippines and India. India has been reported for holding the fourth largest mangrove cover in the world (Mandal et al., 1995). Including the island territories, India has a total of 7,516.6 km coastline. Of these, 6,749 km^2 areas were occupied by mangrove forest (Naskar and Mandal, 1999).

There are several reports with the Ministry of Environment and Forest, Government of India, stating the status of mangroves in the country. "Status Report on

Mangroves of India in 1987 and report of the Inter alia Forest Survey of India stated that, within the 7,500 km coastalline, India supports 4, 87,100 ha of mangrove wetlands, in that nearly 56.7% i.e. 2, 75,800 ha is spread along the east coast region and 23.5% (1, 14,700 ha) in the west coast region and the remaining 19.8% (96,600 ha) in Andaman and Nicobar islands (MoEF, 1987). Among the Indian mangroves, the Sundarbans of West Bengal is the largest one. It is followed by the Andaman and Nicobar Islands. The mangroves of the above two localities together accounts for 80% of the total Indian mangroves (MoEF, 1987). The remaining mangroves are scattered in Maharashtra, Gujarat, Orissa, Goa, Andhra Pradesh, Tamil Nadu, Karnataka and Kerala.

According to a status report of the Government of India publication, the total area of the mangroves in India has been reckoned at about 6,740 km^2. This covers about 7% of the world mangroves (Krishnamurthy, 1987) and 8% of the Indian coastline (Untawale, 1987). Of the total area of mangroves, about 60% is along the east coast (Bay of Bengal), 27% is along the west coast (Arabian Sea) and the remaining 13% is in the Andaman and Nicobar Islands. These mangrove habitats (69^o - 89.5^oE longitude and 7^o - 23^oN latitude) comprise three distinct zones: east coast habitats having a coast line of about 2700 km, facing Bay of Bengal, west coast habitats with a coast line of about 3000 km, facing Arabian sea, and Island Territories with about 1816.6 km coastline. The state of West Bengal has the maximum cover (2,097 km^2), followed by Gujarat (1,103 km^2) and the Andaman and Nicobar Islands (604 km^2) (FAO, 2007; FSI, 2009).

However, a recent assessment shows that India has a total mangrove cover of only 4,628 km^2. This accounts for 0.14% of the country's land area, 3% of the global mangrove area, and 8% of Asia's mangroves (FSI, 2013). Reports show that Indian mangroves comprise of 59 species in 41 genera and 29 families. Of these, 34 species coming under 25 genera and 21 families belong to west coast. About 16 mangrove species are reported from Gujarat coast, 20 from Maharashtra, 14 from Goa and 10 species from Karnataka (Singh et al., 2012).

In Kerala, the mangrove cover has been distributed along the upper reaches of estuaries, lagoons, backwaters and creeks (Mohanan, 1997). It has been reported that, the extent of mangroves of Kerala is 2,502 ha out of which, 1,189 ha belongs to the state and 1,313 ha is under private ownership (Vidyasagaran and Madhusoodanan, 2014).

Kannur district occupies maximum extent of mangroves (1,100 ha) followed by Ernakulam (600 ha) and Kasaragod (315 ha) and minimum extent was represented by three districts namely Malappuram (26 ha), Thiruvanthapuram (28 ha) and Thrissur (30 ha) (Vidyasagaran and Madhusoodanan, 2014). The major patches of mangroves are also distributed in places like Veli, Asraamam, Ashtamudi, Keeryad Island, Chetwai, Vypeen Island, Mallikkad, Kumarakom, Pathiramanal, Edakkad, Pappinissery, Kunhimangalam, Chittarai and in several other small patches across the State (Suma, 1995).

A total of 15 pure mangroves species and about 33 semi mangrove species were recorded from different parts of the State (Vidyasagaran and Madhusoodanan, 2014). The important species found are *Aegiceras corniculatum, Avicennia marina, Avicennia officinalis, Bruguiera cylindrica, B. gymnorhiza , B. sexangula , Ceriops tagal, Excoecaria agallocha, E. indica , Kandelia candel, Lumnitzera racemosa, Rhizophora apiculata, R. mucronata, Sonneratia alba and S. caseolaris* (Banerjee, 1989).

The mangrove ecosystem is one of the most productive ecosystems on the globe, despite being one of the most threatened. In spite of the ecological and economical importance, mangroves are being widely destroyed at a mean rate of 1-2 per cent per year (Duke et al., 2007; FAO, 2007) and rate of loss may be as high as 8 per cent per year in some developing countries (Polidoro et al., 2010).

Nature as well as man is responsible for the destruction of mangrove ecosystem (Valiela et al., 2001). Natural processes such as storms, cyclones, hurricanes, tides, sea level changes, drought, floods etc can be detrimental to the existence of mangroves. The mangroves may or may not tolerate the sea level rise depending on the tide level (Mc Kee et al., 2007), species composition, sediment accretion rate etc.

Global warming and eutrophication also plays havoc to the mangrove population. By 2025, due to global warming and green house effect, temperature is expected to increase by 0.5-0.9^{o}C, resulting in sea level rise by 3-12 cm (Watson et al., 2001). This may induce changes in soil chemistry and structure as well as variation in communities of flora and fauna. Bacteria, viruses, fungi, boring insects and crustaceans which feed on mangrove propagules are other natural agents bringing destruction to mangroves. High rates of sedimentation can also prove to be fatal to mangrove habitats by initiating changes in the biogeochemistry of the environment and smothering the pnuematophores (Ellis et al., 2004).

The greatest threat to mangroves is through human activities. Vast tracts of mangroves have been converted to shrimp farms or agricultural fields, in addition to construction for residential and recreational purposes. Clear cutting of mangrove forests for timber contributes to changes in mangrove forests. This can lead to major modifications of soil properties of mangrove forests; disturb the watershed level (Dai et al., 2001) and loss of soil nutrients.

Urbanization often resulted in increased sedimentation in coastal waters, which destroys the flora and fauna of mangrove ecosystem. Since mangroves are usually close to human habitats, they are used as dumping grounds for sewage and other domestic wastes. Land use changes result in increased nutrient and toxic material loading into water bodies which may pose unacceptable ecological risk to coastal ecosystems including mangroves (Bouillon, 2003). Terrestrial run offs containing fertilizers, pesticides, effluents carried by rivers containing trace metals, organic toxicants such as poly nuclear hydrocarbons, polychlorinated biphenyls, oil spills and petroleum hydrocarbons pose great threat to mangroves (Zhang et al., 2014).

Over the last century, there has been extensive loss and degradation of mangrove habitats due to coastal development, pollution, aquaculture and logging for timber and fuel wood. It is estimated that since 1970, 28% of mangrove habitats have been directly displaced by commercial aquaculture (Hamilton, 2013). But the greatest loss has been noticed in the period from 1980 to 1990 (Valiela et al., 2001).

From 2000 to 2012, the global mangrove deforestation rate was between 0.16% and 0.39% annually but as high as 3.58% to 8.08% in Southeast Asia (Hamilton and Casey, 2016). The most recent and comprehensive global assessment of mangrove distribution was conducted by Richards and Friess (2016) and provided a high-resolution global database of mangrove loss.

According to the International Union for Conservation of Nature and Natural resources (IUCN) Red List criteria categories of endangered species, up to 11 mangrove plants species are at high risk of extinction (Polidoro et al., 2010). Estimates show that 11 out of 70 mangrove species (16%) which were assessed will have to be placed on the IUCN Red List. The Atlantic and Pacific coasts of Central America, where as many as 40 percent of mangrove species are considered threatened, are particularly affected (www.iucnredlist.org.). The fauna also have more than 40% of mangrove-endemic vertebrates that are globally threatened (Luther and Greenberg, 2009).

The depletion of mangroves is a cause of serious environmental and economic concern to many developing countries. In the last 50 years, between 30% and 50% of the mangrove forests have disappeared, this loss is continuing and in some places, it is even accelerating. The rate of coastal ecosystems annual loss is 4-times the rate of tropical forest loss (Copertino, 2011). The continuing degradation and depletion of this vital resource will reduce not only terrestrial and aquatic production and wildlife habitats, but more importantly, the environmental stability of coastal forests that provide protection to inland agricultural crops and villages will become seriously impaired.

Of the remaining mangrove stands, it is estimated that 52% are degraded due to shrimp/fish culture, 26% due to forest use, and 11% due to freshwater diversion. As a result, mangroves and the species that depend on them are at an elevated risk of extinction. At the present rate of loss, the world faces a real risk of losing the services provided by mangroves entirely in the next 100 years (Duke, 2007).

Rates of mangrove degradation vary significantly between countries, often due to differences in environmental policies, legislation, and management. For example, although total mangrove loss in many of the Asian and Pacific regions between 1980 and 2005 is estimated as being consistent with the global rate of 20 per cent, East African and Australian regions loss was less than 10 per cent over the same period (Spalding et al., 2010). Mangrove cover in Sri Lanka experienced deforestation rates of only 0.1 per cent between 1975 and 2005 (Giri et al., 2007), while rate of loss in both the Philippines and Honduras have been increasing since the 1990s because of promotion of shrimp farming and aquaculture (Mc Owen et al., 2016).

Indian mangroves have a long history that received attention right from the 17 century itself. Inspite of their immense role in protecting human resource as well as biodiversity, these unique mangrove habitats have been facing tremendous threats due to indiscriminate exploitation for multiple uses like fodder, fuel wood, timber for building material, alcohol, paper, charcoal and medicine (Upadhyay et al., 2002). Reports show that almost all the mangrove areas in India are severely degraded with reduced or negligible vegetation cover (Wilkie et al., 2003). Maximum decline in the mangrove cover has been noticed from the period 1980-2000. This fact was evidenced by a higher decline of 80% in the Pichavaram mangroves of South East Coast of India (Selvam et al., 2010; Sahu et al., 2015). Reports also show that, more than 33% of the Indian mangrove areas have been lost within the last 15 years. Of this, east coast area has lost about 28%, west coast area about 44% and Andaman & Nicobar Islands about 32% (Jagtap et al., 1993; Naskar, 2004).

The uncontrolled exploitation and degradation of mangroves in most of the tropical countries have called for an urgent need of implementing conservation and management strategies. In addition, awareness concerning economic, social, and ecological values of mangroves has led to an increase in the number of initiatives to protect and restore mangrove areas (Valiela et al., 2001; FAO, 2007). Considering their value for the environment and coastal communities, mangrove conservation should become a priority and efforts must be invested to find new and successful methods for conserving mangrove ecosystems (Bosold, 2012).

Mangroves are considered as wastelands by general public. This has been the reason for their wide destruction along different parts of the world. Environmental education and awareness campaigns are necessary for preserving mangrove areas. Involvement of local government or non government educational institutions in terms of conducting awareness programs and comprehension of mangrove ecosystem restoration goals and methods have to be ensured with active participation from all stake holders within the community. For the proper management of mangrove areas, stress should be given for mangrove biodiversity conservation and ecosystem restoration.

Scientists from different parts of the world have recognized and realized that these vulnerable ecosystems are threatened and endangered. Various international organizations like UNESCO, UNDP, IUCN and WWF have shown active interest in the restoration of mangroves (Nasker and Guhabakshi, 1989). Silvicultural techniques like regeneration, restoration and afforestation of mangroves can very well reverse the issues of degradation. Mangrove conservation requires a collaborated research involving natural, social and inter-disciplinary approaches. In order to formulate long term conservation strategies, consideration of factors such as monitoring of growth conditions, socio-economic dependency and biodiversity are indispensable (Kiran and Ramachandra, 1999).

Restoration is defined as the return from a disturbed or totally altered condition to a previously existing natural or altered condition by some human action (Lewis, 1990). Mangrove ecosystems are often cited as being responsive to differences in soil salinity, frequency of tidal inundation, sedimentation, soil chemistry, freshwater influx and groundwater availability. This is said to have led to significant variations noted in mangrove community structure and function, even within small geographic ranges (Ravichandran, 2002). The restoration program should be sensibly designed in such a way that, mass afforestation of the native species and elimination of undesirable species are carried out. Restoration sometimes requires reconstruction of the physical conditions, chemical adjustment of the soil and water, biological manipulation, reintroduction of native flora and fauna, etc. (Zedler, 1996). The use of biotechnological interventions to produce improved mangrove plantlets (e.g., faster growing plants) could improve the success rate of restoration (Lewis and Brown, 2014).

The drastic decline in global mangrove cover and the on-going elimination of mangrove habitats have led both governmental and non-governmental organizations to formulate policies and actions (Giri et al., 2011). Mangrove conservation measures range from traditional approaches, including creation of designated areas protected from clearing and legislation restricting or prohibiting their degradation. In some countries mangroves of states or regions are protected through legislation, limiting or prohibiting mangrove clearing. Legislation of such kind includes Brazil's Federal Forestry Code, which has been interpreted to prohibit the use of any components of mangrove trees or plants (Webber and Good body, 1998).

Mangrove habitats are protected by multiple international conventions and programs. In 2009, the convention on wetlands namely "Ramsar Convention on Wetlands of International importance" has been conducted in which the member countries ensured the maintenance of ecological characteristics along with conservation of mangroves. This movement has resulted in the protection of 278 Ramsar mangrove sites in 68 countries (Webber and Good body, 1998).

Other attempts to protect mangroves on an international context included 'World Heritage sites' designated by UNESCO, protecting around 26 mangrove habitats. Man and the Biosphere Programme sites of UNESCO have also been involved in the protection of mangrove habitats (Spalding et al., 2010). Protection of mangrove habitat across the world has also been achieved by establishing marine protected areas, including national parks and marine reserves. Examples of national parks that protect mangroves include mangroves national park in the Democratic Republic of Congo, Parc Marin de Moheli of Comoros, Kakadu national park of Australia, Bastimientos island national park of Panama, Kiunga biosphere reserve of Kenya, Everglades national park of United States of America, Sirinat national park of Thailand and Subterranean national park of Philippines.

Upon considering the ecosystem service values of mangroves and their decline, various non-governmental organizations are engaged in education about the conservation and restoration of mangroves. These include organizations with projects around the world such as the Mangrove Action Project, Western Indian Ocean (WIO) Mangrove Network, the Mangrove Alliance and Mangrove Watch (Webber and Good body, 1998). In addition to these, there do exist some local and regional agencies for the protection of mangroves (Carter et al., 2015). Some countries such as Cuba and Ecuador have invested significant resources and are testing new approaches to mangrove conservation through engagement of local communities in natural resource governance (Gravez et al., 2013; Lugo et al., 2014).

The emerging movements to conserve mangrove habitats include Payment for Ecosystem Services (PES) and Reducing Emissions from Deforestation and forest Degradation (REDD+). Such approaches may provide novel strategies for mangrove conservation in countries that lack sufficient resources for conservation and management (Locatelli et al., 2014).

In India strategies pertaining to the conservation and reforestation of mangroves have initiated along the Central West coast. This was mainly with the intention of creating awareness among public regarding the significance of mangroves, control of intertidal mud banks, new avenues for forestry and social forestry activities, biomass increase along the estuaries to enhance biological productivity and to improve bird and animal life (Untawale, 1996).

Mangrove forests have been categorized as ecologically sensitive areas by Government of India under the Environment (Protection) Act, 1986. Restriction for development activities and disposal of wastes in these areas have also put forwarded by the CRZ Notification, 1991. Ministry had made a plan-scheme for conservation and management of mangroves and coral reefs in 1986 and constituted a National Committee to advise the Government on relevant policies and programs (Anon, 1997).

The national Committee recommends intensive conservation for 15 mangrove areas in the country (Anon, 1997; Jagtap et al., 2002). Creation of buffer zones that limit the anthropogenic activities around the demarcated corridor of the wetland has been considered as the most important management strategy for mangroves (Castelle et al., 1994). Buffer zone might be consisting of diverse vegetation along the perimeter of water body, preferably an indigenous one serving as trap for sediments, nutrients, metals and other pollutants, reducing human impacts by limiting easy access and acting as a barrier to invasion of weeds and other stress inducing activities (Stockdale, 1991).

Some of the states in India with long coastlines adopted different strategies for the conservation of mangroves. After many years of wide spread destruction and degradation, significant efforts have been made in recent years by the State Government and the International agencies to restore and regenerate the mangrove stock in Gujarat (Singh et al., 2012). The Gujarat Forestry Development Project implemented in 2007 for a period of 8 years have also significantly focused on restoration involving mangrove plantation along the coastal regions such as forest areas of eastern tribal belt of the state, reserved grasslands in Rajkot district, mangroves in Kori Creek, Kutch Coast, Marine National Park in Jamnagar Division (Viswanath et al., 2011). Conservation strategies in Goa state included the implementation of the Act in 1984 as Daman and Diu Preservation of Trees that restricted the cutting of 15 species of mangrove trees (Notification No. 8/ 10/ 83-FOR dated 11.09.1990).

In Kerala, the most vital approach towards the conservation of mangroves relied on awareness among the public. Novel concepts like mangrove resort and conservation through eco-tourism have also been put forwarded towards the protection of mangroves (George and Fernandez, 1994). Pappinissery mangrove theme park is such an ecotourism project on the banks of Valapattanam river, Kannur. For the prevention and deterioration of mangrove environments of Kerala, better co-ordination among various government agencies are also inevitable.

Considering many of the ecosystem services and other aspects along coastal environments, mangrove conservation should become a priority and effort must be invested to find out new and successful methods for their afforestation. Reports show that worldwide, the extent of mangrove forests are alarmingly degrading day by day. Similar trends have been noticed along most of the coastal states in India and Kerala is not an exception. A comprehensive approach in terms of research on various aspects of mangrove eco system of Kerala should be given utmost priority for their effective conservation and restoration. Advanced research with respect to diversity, distribution, growth sustaining attributes (water and sediment) of mangroves may aid in the process of formulating proper afforestation strategies along diverse shoreline environments of Kerala and elsewhere.

In the above context, present study has been attempted to evaluate the current status of diversity and extent of mangroves in Kerala, standardization of their growth sustaining conditions and assessing different sites for their probability of afforestation. For the better understanding of above facts, results of the present study are depicted in three chapters. Chapter 1 is dealing with extent and diversity of mangroves in Kerala; Chapter 2 with standardization studies on growth parameters of selected mangrove species and Chapter 3 with delineation of sites for mangrove afforestation.

CHAPTER 1

EXTENT AND DIVERSITY OF MANGROVES IN KERALA

Introduction

The mangroves are intertidal plant formations of tropics and subtropics, which are adapted to grow in the saline environments. They are unique in their location, structure and function. These are comparatively one of the well-studied ecosystems throughout the world and have been received attention of researchers from different fields of science.

Mangroves belong to diverse group, which may not be closely related in a phylogenetic sense, but may have many special characteristics in common (Chapman, 1975). This evergreen flora comprising of shrubs as well as arborescent species with forestry importance is confined to a few families. They can be classified into four categories; (i) mangroves of moist region (ii) mangroves of sub-humid region (iii) mangroves of semi-arid region and (iv) mangroves of arid region (Anon, 1984; Singh, 2000).

Different authors have classified mangroves and associated vegetation into different categories. According to Basha (1992), the mangrove vegetation possesses many structural and physiological peculiarities and is composed of species with strongly marked characteristics, grouped as 'True mangroves'. *Avicennia, Rhizophora* etc. are grouped under this category. There are also plants with less strongly marked characteristics, which are grouped as 'Semi mangroves' by Transley and Fritch (1905). Examples for semi mangrove species are *Achrostichum*. There is yet another group, which grow in saline soils fringing the mangrove areas, but thrive on the land which does not get inundated with brackish water even during high tides. They can withstand some amount of brackish water stagnation only for a very short period. These can be grouped as 'non- mangroves' or 'mangrove associates', which grow near mangrove locations (Basha, 1992). *Derris trifoliate, Cerebra odollum* are examples of semi mangrove species.

The Indian mangroves are one of the major forests of the South East Asia. In India, the total area of mangroves is estimated to be 6,740 km^2 (MoEF, 1987), which is about 7% of the world's mangrove area. The extent of mangroves along the east coast of India is larger than those along the west coast. West Bengal has the biggest mangrove formation and about 4,200 km^2 area support mangroves (Basha, 1992). The mangrove ecosystem of the Sundarbans (West Bengal) comprises about 65% and the remaining 35% are distributed in the Bay islands (Andaman and Nicobar islands) and coast lines of eight other states (Blasco, 1975).

Indian mangroves are diverse with 125 species, comprising of 39 mangroves and 86 mangrove associates. About 56% of the world's mangrove species occur in India with mangrove associates as 30 tree species, 24 shrubs, 18 herbs, 6 climbers, four grasses and 4 epiphytes. The species diversity is highest in Orissa (101 species) followed by West Bengal (92 species) and Andaman and Nicobar islands (91 species) (Kathiresan, 2010).

Mangroves in Kerala are highly fragmented and confined mostly to the estuaries of major rivers, lagoons, backwaters and creeks along the coastal belt. Mohanan (1997) estimated that, mangroves in Kerala coast are less than 50 km^2, existing in discrete and isolated patches with a total of 32 mangrove species. It has been reported that the extent of mangroves of Kerala is 2502 ha, of which 1189 ha belongs to the State and 1313 ha under private ownership (Vidyasagaran and Madhusoodanan, 2014).

The major patches of mangroves in Kerala are distributed in Veli, Asraamam, Ashtamudi, Keeryad Island, Chetwai, Vypeen Island, Mallikkad, Kumarakom, Pathiramanal, Edakkad, Pappinissery, Kunhimangalam, Chithari and in several other small patches across the State (Suma, 1995). Kannur district reported maximum extent of mangroves (1100 ha) followed by Ernakulam (600 ha) and Kasaragod (315 ha) and minimum extent with three districts namely Malappuram (26 ha), Thiruvananthapuram (28 ha) and Thrissur (30 ha) (Vidyasagaran and Madhusoodanan, 2014). The dominant species are *Acanthus ilicifolius, Avicennia marina, Avicennia officinalis, Bruguiera cylindrica, B. gymnorhiza, B. parviflora, Ceriops tagal, Rhizophora apiculata, R. mucronata* and *Sonneratia caseolaris* (Banerjee, 1989).

In the last two decades, mangrove populations have witnessed annual loss between 0.16 and 0.39% globally due to various anthropogenic activities (Hamilton and Casey, 2016). In many areas of the world, mangrove deforestation is contributing to decline in fisheries, degradation of clean water supplies, erosion and land subsidence. At least 40% of the animal species that are restricted to mangrove habitats and have previously been assessed under IUCN categories and criteria are at elevated risk of extinction due to extensive habitat loss. Similarly decline in species diversity is also reported in many geographical regions owing to various anthropogenic stresses.

It has been reported that Kerala coast once supported about 700 sq.km of mangroves and presently it has been dwindled to a considerable extent. Mangrove ecosystems are receiving increasing attention in Kerala, but still lack updated information on their diversity and extent for deriving strategic plans for conservation / afforestation. The present study has been carried out to assess the extent and diversity of mangrove ecosystems in the heterogeneous environments of Kerala with a view to conserve their existing habitats from further degradation.

Review of Literature

Numerous attempts have been carried out worldwide on the extent and diversity of mangroves. Some of the most important ones on a global, national and regional context are summarized below.

The greatest extent of mangrove species is found in the Indo-Malaysian region (Chapman, 1975) and thus, it can be considered as the cradle of evolution of mangrove vegetation. There are about 60-100 species of mangroves totally present in the world coming under 30 genera and more than 20 different families (Singh et al., 1987). Studies on their status and distribution in Asia reports that they are distributed mainly in Bangladesh, Indonesia, Pakistan, Srilanka, Philippines and India (Naskar and Mandal, 1999).

Earlier reports reveal that globally mangroves cover an area of 12 to 20 million hectares, of which, about one-third is found in Asia (42%), followed by Africa (21%), North and Central America (15%), Oceania (12%) and South America (10%). It has also been reported that 15 countries behold one third of the total global mangroves (FAO, 2007). Later, the total area of mangroves in the year 2000 was estimated to be 1, 37,760 km^2 in 118 countries in the tropical and subtropical regions of the world (Giri et al., 2011).

Spalding et al. (2010) revealed the World Atlas of Mangroves, covering 123 countries, constituting a total area of 1, 52,000 km^2. The lists included both true mangroves and mangrove associates. Distribution status by Hamilton and Casey (2016) showed that mangroves are found in 105 nations globally; of which 10 nations possess approximately 52%. Higher percentage of global mangrove cover was noted in Indonesia (26-29%). The Sundarbans National Park in India and the Sundarbans Mangrove Forests in Bangladesh have been known to possess the world's largest continuous stretch of mangrove forest (UNESCO, 2016).

India has been reported for holding the fourth largest mangrove cover in the world. 60 species of mangroves belonging to 41 genera and 29 families have been reported (Blasco, 1975). Blasco (1977) reported 58 mangrove species in the Indian territories, while Rao (1986) listed 60 species from 41 genera and 29 families. Studies have reported that the country occupies an area of about 7% of the world mangroves (Krishnamurthy, 1987) and 8% of the Indian coastline (Untawale, 1987).

Status report on mangroves of India in 1987 and report of the Inter alia Forest Survey of India stated that, within the 7,500 km coastal line, India supports 4, 87,100 ha of mangrove wetlands, in that nearly 56.7% is spread along the east coast, 23.5% along the west coast and the remaining 19.8% in Andaman and Nicobar islands (MoEF, 1987). The report has also stated that Sundarbans of West Bengal and Andaman and Nicobar Islands together occupy 80% of the total Indian mangroves. Rest of the mangrove flora have been distributed along some of the coastal states such as Maharashtra, Gujarat, Orissa, Goa, Andhra Pradesh, Tamil Nadu, Karnataka and Kerala (MoEF, 1987).

Banerjee et al. (1989) reported 59 species including true mangroves and associates belonging to 41 genera and 29 families. Comprehensive studies reported the existence of 32 true mangrove species in India (Singh et al., 2012; Singh and Garge, 1993). Dagar et al. (1993) and Jagtap et al. (1993) reported 36 and 50 species of true mangroves from India. Later in 1999 it has reported that including the island territories, India has a total of 7,516.6 km coastline. Of these, 6,749 km^2 areas were occupied by mangrove forest (Naskar and Mandal, 1999).

Studies with respect to species distribution revealed varied statistics as some of them included true mangroves whereas others included both true mangroves and mangrove associates. Naskar (2004) has reported 85 species of mangroves / mangrove associates that were common to the Indian coasts. Studies have also reported that, there are 55 species of true mangroves in India and majority are coming under the families Acanthaceae, Avicenniaceae, Meliaceae and Rhizophoraceae (Vidyasagaran and Gopikumar, 2006).

Detailed account on the diversity of Indian mangroves has been given by Mandal and Naskar (2008). The total extent of mangroves has been classified in to 3 groups as ‘Major mangroves,’ Mangrove associates,’ and ‘Back mangal’. From a total of 12 habitats, 82 species of mangroves belonging to 52 genera and 36 families have been reported. Using the total number of families, genera and species, relative mangrove diversity has also been calculated. Among different habitats studied, maximum value for relative mangrove diversity has been reported from Sundarbans and minimum from Lakshadweep Atoll (Mandal and Naskar, 2008).

According to a status report of the Government of India publication, the total area of the mangroves in India was reckoned at about 6,740 km^2. Of the total area of mangroves, about 60% is along the east coast (Bay of Bengal), 27% is along the west coast (Arabian Sea) and the remaining 13% is in the Andaman and Nicobar Islands (FSI, 2009).

An overview on the status of biodiversity and distribution of Indian mangroves revealed that there are 59 species in 41 genera and 29 families. 34 species belonging to 21 families have been noticed as unique species along the west coast and the east coast comprised of 25 species. The most important species distributed along west coast were *Sonneratia caseolaris, Suaeda fruticosa, Urochondra setulose* etc. Distribution status with respect to different states revealed 16 species from Gujarat, 20 species from Maharashtra, 14 species from Goa and 10 species from Karnataka (Singh et al., 2012).

Based on preliminary surveys, an updated checklist of true mangrove species falling along Andaman and Nicobar Islands has been reported (Goutham-Bharathi et al., 2014). Visits to selected locations during the period 2009 to 2013 revealed the occurrence of 25 true mangrove species belonging to 10 families and 14 genera. The study also highlighted the need for periodic evaluation of the extent and status of mangroves towards their better management and conservation (Goutham et al., 2014).

Mangrove forests have been considerably diminishing as most of the areas are taken for various agricultural and developmental purposes. It was reported that during the last century, Indian coastline has lost 40% of its mangrove cover (Brahma and Mukherjee, 2016). In this background, studies have been conducted to assess the extent of mangroves in India with special reference to Lothian Island Wildlife Sanctuary in Sundarbans. Including 16 true mangrove species and 14 mangrove associates a total of 30 species have been reported from the area. The study has pointed out the need for conserving mangrove ecosystems in terms of effective governance structures, better education and awareness building in local communities (Brahma and Mukherjee, 2016).

The preceding literature presented a scattered idea regarding the extent and diversity of mangroves from different districts of Kerala. Bourdillon (1908) reported *Brugueira gymnorhiza* and *Rhizophora* species from Kollam district. Rao and Sastry (1974) and Thomas (1962) reported 5 mangrove species such as *Acanthus ilicifolius, Avicennia officinalis, Bruguiera gymnorhiza, Rhizophora apiculata* and *R. mucronata* under 4 genera and 3 families from Veli backwaters, Trivandrum. The species *Acanthus ilicifolius* has been reported from Kollam district (Blasco, 1975).

The total extent of mangrove cover in Kerala has undergone drastic changes over a period of time. Kerala once had a total mangrove cover of 700 km^2 and has dwindled to 16.71 km^2 (Basha, 1991). According to him, the entire mangrove flora of the state has been distributed among different districts like Trivandrum (23 ha), Kollam (58 ha), Alleppey (90 ha), Kottayam (80 ha), Ernakulam (260ha), Thrissur (21 ha), Malappuram (12 ha), Kozhikkode (293 ha), Kannur (755 ha) and Kasaragod (79 ha).

Later on Kurien, et al., (1994) has reported that the mangrove cover of the state is only 1,095 ha. Studies by Suma (1995) revealed that the major patches of mangroves in Kerala are distributed in places like Veli, Asraamam, Ashtamudi, Keeryad Island, Chetwai, Vypeen Island, Mallikkad, Kumarakom, Pathiramanal, Edakkad, Pappinissery, Kunhimangalam and Chittarai and in several other small patches across the State. Reports by Mohanan (1997) revealed that the total extent of mangroves in Kerala has been distributed along the upper reaches of estuaries, lagoons, backwaters and creeks were coming to a tune of 4200 ha.

Sunil (2000) reported the most important mangroves species of Alleppey district as *Acanthus ilicifolius*, *Aegiceras corniculatum, Avicennia marina, A. officinalis, Bruguiera cylindrica, B. gymnorhiza, Excoecaria agallocha, E. indica, Kandelia* *candel, Lumnitzera racemosa, Rhizophora apiculata, R. mucronata and Sonneratia apetalae,* coming under 9 genera and 7 families.

Detailed descriptions on the mangroves of Kerala have been furnished by Anupama and Sivadasan (2004). The study as a whole reported 15 true mangroves and 49 mangrove associates from the entire Kerala coast. The true mangrove species were coming under 9 genera and 7 families. The study revealed detailed notes on all the true mangrove species along with their updated nomenclature and distribution (Anupama and Sivadasan, 2004).

Radhakrishnan et al. (2006) reported the occurrence of 7 species of mangroves from Kozhikode district such as *Acanthus ilicifolius*, *Aegiceras corniculatum, Avicennia marina, Excoecaria agallocha, Kandelia candel, Rhizophora mucronata* and *Sonneratia caseolaris*.

Thekkumbad island of Kannur district has been studied for the total area covered diversity and population structure of mangroves. Using plot quadrat method, a total of 11 true mangroves and 6 associates have been reported. The most dominant species recorded from the area were *Rhizophora mucronata*, *Bruguiera cylindrica*, *Sonneratia alba* and *Excoecaria agallocha* (Sreeja and Khaleel, 2010).

Compared to other districts, floristic diversity of mangroves in Kannur is very high. Diversity studies from Kannur district revealed 12 species of mangroves under 9 genera, belonging to 7 families. The most important family reported was Rhizophoraceae with four species (Vidyasagaran et al., 2011). Diversity, distribution and abundance of mangroves from Poyya backwaters of Thrissur district reported a total of 9 species; of which 4 were true mangroves and remaining 5 were associates. The true mangrove species reported were *Aegiceras corniculatum, Avicennia officinalis, Acanthus ilicifolius,* and *Excoecaria agallocha*. The mangrove associates reported were *Derris uliginosa, Clerodendron inerme, Sphaeranthus indicus, Achrostichum aureum, Mariscus javanicus* and *Cyperus* species (Saritha and Tessy, 2011). Studies conducted at Kumbalam Island of Ernakulam district revealed the status of mangroves in the area from the year 2010. A total of 17 species including 7 true mangroves, 2 semi mangroves and 8 mangrove associates have been reported from the area (Ram and Shaji, 2013).

It has been reported that the extent of mangroves of Kerala is 2,502 ha, out of which, 1,189 ha belongs to the state and 1,313 ha is under private ownership (Vidyasagaran and Madhusoodanan, 2014). Kannur district occupies maximum extent of mangroves (1,100 ha), followed by Ernakulam (600 ha) and Kasaragod (315 ha) and minimum extent was represented by three districts namely Thrissur (30 ha), Thiruvanthapuram (28 ha) and Malappuram (26 ha). A total of 15 pure mangroves species and about 33 semi mangrove species were recorded from different parts of the state. The important species found were *Aegiceras corniculatum, Avicennia marina, Avicennia officinalis, Bruguiera cylindrica, B. gymnorhiza, B. sexangula, Ceriops tagal, Excoecaria agallocha, E. indica, Kandelia candel, Lumnitzera racemosa, Rhizophora apiculata, R. mucronata, Sonneratia alba and S. caseolaris* (Vidyasagaran and Madhusoodanan, 2014).

Studies at Kadalundi- Vallikkunnu community reserve of Malappuram- Kozhikode districts revealed the occurrence of 7 species of mangroves under 5 families. The most important species recorded from the area was *Avicennia officinalis* followed by *Rhizophora mucronata*, *Excoecaria agallocha* and *Sonneratia alba* (Rahees et al., 2014). A total of 11 species of true mangroves and 6 mangrove associates have been reported from the Ashtamudi estuary of Kollam district (Sumesh et al., 2014).

Survey pertaining to the distribution, abundance and plant diversity of the left over mangroves along the 10 coastal districts of Kerala has been carried out. The results revealed a total of 24 species of mangroves belonging to 15 genera and 9 families (Mini et al., 2014). 8 species have been reported from the family Rhizophoraceae. The other families and number of species reported were Acanthaceae (4 species), Myrsinaceae (1 species), Combretaceae (1 species), Malvaceae (1 species), Pteridaceae (1 species), Euphorbiacea (2 species), Lythraceae (3 species) and Arecaceae (3 species). The study highlights the significance and services of the ecosystem as a whole and suggests the urgent need for protecting them in terms of massive afforestation practices (Mini et al., 2014).

Diversity and phyto-sociological characteristics of mangroves from six locations of Kollam district has been reported. The study revealed 12 species of mangroves belonging to 8 genera and 6 families in which *Rhizophoraceae* and *Avicenniaceae* were the most predominant families. Results of the density and other diversity indices revealed that the most common species recorded was *Avicennia officinalis* followed by *A. marina* (Vijayan et al., 2015).

The diversity and distribution of mangroves from Kannur district for the period of 2015-16 have been reported by Vaiga and Sincy (2016). From Vellikkeel, 7 species of true mangroves, 4 species of semi mangroves and 7 species of mangrove associates have been reported. 10 species of true mangroves, 3 semi mangroves and 7 mangrove associates have also been reported from Ezhome area. The study concluded that most of the mangrove area within the district has been facing tremendous threats from the public.

A review of the literature revealed that studies pertaining to the extent and diversity of mangroves confining to the coast of Kerala is either fragmentary or outdated in nature. Comprehensive database pertaining to their extent and diversity is required for establishing ideal strategies for conservation reliable methods for afforestation. In this perspective, the present study has been outlined to assess the extent and diversity of mangrove ecosystems confining to heterogeneous coastal environments of Kerala.

Materials and Methods

Study area

The state of Kerala (8^{o} 18' and 12^{o} 48' N and longitudes 74^{o} 52' and 77^{o} 22' E) is bounded by Karnataka in the North, Tamil Nadu in the South and East and the Arabian Sea in the West. The width of the State varies between 15 and 120 km. The coastal belt extends up to 580 km in length, with a long stretch of back waters, estuaries and river deltas and a series of lagoons running parallel to the sea. Owing to the Western Ghats along the eastern side (wind ward side) and Arabian Sea along the western side, the topography of the state is highly diversified with highland, midland and coastal plain. Most of the rivers of Kerala originate from the highland area, characterized by the Western Ghats. The midlands, lying between the mountains and the lowlands are made up of undulating hills and valleys that serve as an area for intensive cultivation. The coastal area is made up of numerous shallow lagoons, river deltas, backwaters and shores of the Arabian Sea. Though small in size, the state is affluent in water sources. 44 rivers traverse the land, of which 41 are west-flowing and 3 are east-flowing. Apart from these 44 rivers, their tributaries and countless number of rivulets and streams crisscross the land and make them green and fertile.

The State is situated in the humid tropics, where the main climatic factor is the rainfall. Kerala's rains are mostly the result of seasonal monsoons. The average annual rainfall of the State is 240 cm, of which 65-70% is received during south-west monsoon (June-August), 18-22% during north-east monsoon (October-December) and remaining as pre monsoon showers. Heavy rainfall coupled with tropical climate is responsible for higher humidity of approximately 70 % throughout the year. The mean annual temperature is 27^{o} C. The average minimum temperature ranges from 19^{o}-20^{o}C whereas, average maximum temperature from 27^{0}- 37^{0}C. The varied topographical features, high precipitation and geological conditions have favored the formation of diverse vegetation groups, from high altitude shola forests on the high ranges to the coastal mangrove forests.

Administratively, the state is divided into 14 districts. Of these, districts like Idukki, Pathanamthitta, Palakkad and Wayanad are falling in the highland area and are not having a coastal plain. All other districts have coastlines, having diverse types of vegetation, including mangroves. The present study envisages evaluation of the extent and diversity of mangroves confining to the 10 districts of Kerala, which include Trivandrum, Kollam, Alleppey, Kottayam, Ernakulam, Thrissur, Malappuram, Kozhikode, Kannur and Kasaragod.

Methodology

Extensive literature survey has been carried out to have an idea about their habitats, together with a collection of earlier reports on their extent and diversity in the coastal environments of Kerala. Accordingly field visits were carried out to these mangrove habitats confining to 10 districts of Kerala. Specimens were collected from different locations and their identification was carried out following standard mangrove identification guidebook, ‘Mangroves in India – Identification manual’ by Banerjee et al. (1989) and also with the help of experts. Representative specimens were preserved.

Similarly, the mangrove patches distributed along different districts under study were categorized into homogeneous and heterogeneous types. The assemblage of true mangrove species along with their associates in a particular area were grouped as homogeneous mangrove population, while patches of true mangroves along with mangrove associates and other vegetation were categorized as heterogeneous mangrove population. Coordinates of mangrove habitats were worked out using a GPS and mangrove area with respect to each district has been evaluated using toposheets and Google map imageries. Both homogenous and heterogeneous patches were separately measured to find out the total extent in square kilometers.

Results and Discussion

Consolidation of data pertaining to the current status on the extent and diversity of mangroves is a pre requisite for the selection of any strategy for the conservation of existing or the introduction of newer population. In this direction, the present study has been carried out to assess the extent and diversity of mangrove ecosystems confining to 10 districts of Kerala. District wise extent of mangroves in hectares / square kilo meters and their percentage to the total mangrove cover of the State is depicted in Table 1.1 and 1.2 respectively.

Table 1.1. District wise extent of mangrove patches in Kerala.

Sl. No	Location	Mangrove Extent (ha)			Total extent in (km^2)
		Homogenous	Heterogeneous	Total	
	Trivandrum District				
1.	Akkulam - Veli	7.628444	4.92336	12.551804	0.1255
2.	Poovar	1.201513	1.950117	3.151630	0.0315
3.	Uchakkada	0.017168	-	0.017168	0.0002
4.	Puthiyathura	0.096991	0.700350	0.797341	0.0079
5.	Kottukal	0.099236	-	0.099236	0.0009
6.	Adimalathura	0.259014	-	0.259014	0.0026
7.	Vizhinjam	0.014711	-	0.014711	0.0002
8.	Thiruvallom	5.321500	4.827689	10.149189	0.1015
9.	Edayar -Poonthura	0.424184	-	0.424184	0.4242
Total		**15.062761**	**12.401516**	**27.464277**	**0.2746**
	Kollam District				
10.	Paravur	0.313207	4.219016	4.532223	0.0453
11.	Kalakkode	0.327387	1.182936	1.510323	0.0151
12.	Onninmoodu	0.177036	0.001174	0.178210	0.0018
13.	Bhoothakkulam	0.394560	-	0.394560	0.0039
14.	Ayiramthengu	5.847678	-	5.847678	0.0585
15.	Oachira	0.082951	-	0.082951	0.0008
16.	Shaktikulangara	15.272060	7.339282	22.611342	0.2261
17.	Neendakara	3.447457	-	3.447457	0.0345
18.	Ashtamudi	1.066141	-	1.066141	0.0107
19.	Perumon	0.149522	0.901315	1.050837	0.0105
20.	Thekkumbhagom	-	2.391093	2.391093	0.0239
21.	Chavara	-	0.186698	0.186698	0.0019
22.	Munroe island	1.233865	-	1.233865	0.0123
23.	Asraamam	1.183758	4.645034	6.828792	0.0683
24.	Azheekkal	1.609925	-	1.609925	0.0161
Total		**27.105547**	**20.866548**	**52.972095**	**0.5297**
	Alleppey District				
25.	Azheekkal	0.776385	-	0.776385	0.0078
26.	Valiyazheekkal	3.783586	2.981934	6.765520	0.0677
27.	Kandalloor	1.271858	1.882454	3.154312	0.0315
28.	Perumpally	0.010541	-	0.010541	0.0001
29.	Mullasseril	0.383270	-	0.383270	0.0038
30.	Keerikkad	0.059945	1.498759	1.558704	0.0156
31.	Arattupuzha	0.225867	-	0.225867	0.0023
32.	Puthiyavila	0.039430	0.190175	0.229605	0.0023
33.	Muthukulam	0.582634	2.872550	3.455184	0.0346
34.	Ramapuram	-	0.459792	0.459792	0.0046
35.	Chingoli	0.090292	-	0.090292	0.0009
36.	Nangiarkulangara	-	0.107198	0.107198	0.0011
37.	Karthikappally	0.115249	-	0.115249	0.0012
38.	Harippad	0.120767	-	0.120767	0.0012
39.	Perumpalam	-	2.396408	2.396408	0.0239

40.	Pathiramanal island	2.471841	-	2.471841	0.0247
41.	Thankey	0.866303	1.457920	2.324223	0.0232
42.	Vayalar	1.241332	2.816479	4.057811	0.0406
43.	Valamangalam North	6.147551	6.961954	13.109505	0.1311
44.	Thuravur Thekku	1.545206	1.983196	3.528402	0.0353
45.	Kodamthuruthu	4.299972	2.169306	6.469278	0.0647
46.	Kuthiathode	3.242565	-	3.242565	0.0324
47.	Eramalloor	12.500859	16.128475	28.629334	0.2863
48.	Kaithavalappu	3.140598	6.532150	9.672748	0.0967
49.	Aroor	11.629718	5.681956	17.311674	0.1731
Total		**48.71394**	**55.120706**	**103.834646**	**1.0383**
	Kottayam District				
50.	Kumaranalloor	5.967512	4.987557	10.955069	0.1096
51.	Nattassery	5.425619	3.544014	8.969633	0.0897
52.	Choottuveli	1.678164	-	1.678164	0.0168
53.	Nagampadam	1.782108	3.311871	5.093979	0.0509
54.	Kanjikkuzhi	-	0.920370	0.920370	0.0092
55.	Keezhukunnu	-	0.704752	0.704752	0.0070
56.	Kalathipady	-	3.756028	3.756028	0.0376
57.	Vadavathoor	8.970006	1.316505	10.286511	0.1029
58.	Poovanthuruthu	10.821003	-	10.821003	0.1082
59.	Kaduvakkulam	3.732499	-	3.732499	0.0373
60.	Kollad	5.095399	-	5.095399	0.0510
61.	Panachikkadu	-	3.251433	3.251433	0.0325
62.	Chozhiakkad	2.433232	-	2.433232	0.0243
63.	Kumarakom	10.563218	20.199589	30.762807	0.3076
Total		**56.46876**	**41.992119**	**98.4609**	**0.9846**
	Ernakulam District				
64.	Chellanam	3.006008	2.731752	5.73776	0.0574
65.	Kannamali	0.243164	0.248395	0.491559	0.0049
66.	Kandakkadavu	0.052681	-	0.052681	0.0005
67.	Pazhangad	0.456357	0.662327	1.118684	0.0112
68.	Kumbalangi	0.894757	1.940362	2.835119	0.0284
69.	Cheriakadavu	2.856128	-	2.856128	0.0286
70.	Mundamveli	4.466231	5.172010	9.638241	0.0964
71.	Kattiparambu	0.370742	-	0.370742	0.0037
72.	Karuvelipady	1.412494	1.893061	3.305555	0.0331
73.	Veli- Kochi	5.536089	5.585651	11.12174	0.1112
74.	Mattancherry	-	0.775301	0.775301	0.0078
75.	Kunnumpuram	0.693331	-	0.693331	0.0069
76.	Fort Kochi, Jawahar park	3.025151	-	3.025151	0.0303
77.	Thamaraparambu, Fort Kochi	1.494012	-	1.494012	0.0149
78.	Kumbalam	7.401797	2.007154	9.408951	0.0941
79.	Willington island	7.036808	12.921685	19.958493	0.1996
80.	Panangad	1.042186	0.936355	1.978541	0.0198
81.	Madavana	0.193311	1.198379	1.39169	0.0139
82.	Nettoor	7.798867	9.163901	16.962768	0.1696

83.	Puthuvypin	89.429313	12.995115	102.424428	1.0242
84.	Murikumpadam	5.110346	2.790738	7.901084	0.0790
85.	Valappu	8.95082	5.579373	14.530193	0.1453
86.	Malippuram	-	1.030023	1.030023	0.0103
87.	Elamkunnapuzha	2.946826	2.492637	5.439463	0.0544
88.	Njarackal	1.659706	1.102762	2.762468	0.0276
89.	Nayarambalam	1.699621	2.664618	4.364239	0.0436
90.	Sathar island	1.674117	-	1.674117	0.0167
91.	Munambam	0.586015	0.325813	0.911828	0.0091
92.	Pallipuram	0.586616	0.075048	0.661664	0.0066
93.	Cherai	0.231925	-	0.231925	0.0023
94.	Ayyampilly	0.247196	-	0.247196	0.0025
95.	Vypin	0.484587	-	0.484587	0.0048
96.	Nedungad	0.724406	-	0.724406	0.0072
97.	Valiyakadamakudy	0.188992	0.609413	0.798405	0.0080
98.	Kottuvally	0.545107	0.312438	0.857545	0.0086
99.	Kedamangalam	0.069970	-	0.069970	0.0007
100.	Ernakulam	35.891752	276.693412	312.585164	3.1259
101.	Gothuruth	0.48973	-	0.48973	0.0049
102.	Chathedom	0.222977	-	0.222977	0.0022
103.	Puthenvelikkara	1.09907	-	1.09907	0.0110
104.	Edakkunnu	6.778119	-	6.778119	0.0678
105.	Palissery	13.843178	-	13.843178	0.1384
106.	Pallimalipady	0.695229	5.915043	6.610272	0.0661
107.	Vengoor	22.862794	10.022375	32.885169	0.3289
108.	Mangalavanam	2.439453	-	2.439453	0.0244
Total		**267.437979**	**426.845141**	**615.283120**	**6.1528**
	Thrissur District				
109.	Azhikode	0.164948	-	0.164948	0.0017
110.	Kodungallur	0.181586	-	0.181586	0.0018
111.	Anapuzha	0.47732	0.224865	0.702185	0.0070
112.	Chanda Nagar	0.093403	-	0.093403	0.0009
113.	Kavinagar	0.329166	-	0.329166	0.0033
114.	Mathilakam	0.270521	-	0.270521	0.0027
115.	Perinjanam	0.896566	0.322433	1.218999	0.0122
116.	Vadanappally	0.523641	-	0.523641	0.0052
117.	Manalur	0.764281	-	0.764281	0.0076
118.	Chettuvai	6.510775	2.940348	9.451123	0.0945
119.	Mullassery	-	0.327618	0.327618	0.0033
120.	Ayanikkad	-	0.293864	0.293864	0.0029
121.	Chavakkad	1.428346	0.498284	1.92663	0.0193
122.	Poyya	5.501876	1.120398	6.622274	0.0662
123.	Pallipuram	3.12118	-	3.12118	0.0312
124.	Chenthuruthy	-	1.826916	1.826916	0.0183
125.	Kombathukadavu	7.25925	-	7.25925	0.0726
126.	Chakkamkandam	1.663806	-	1.663806	0.0166
127.	Blangad	0.668339	-	0.668339	0.0067
128.	Thrissur	2.971368	-	2.971368	0.0297
Total		**33.148805**	**7.554726**	**40.703531**	**0.4070**

	Malappuram District				
129.	Ponnani	1.251754	0.437909	1.689663	0.0169
130.	Malappuram	0.967873	0.712248	1.680121	0.0168
131.	Veliancode	1.361774	0.71653	2.078304	0.0208
132.	Malappuram	0.967873	0.712248	1.680121	0.0168
133.	Thavalakulam	-	0.385546	0.385546	0.0039
134.	Beeyam	0.452704	-	0.452704	0.0045
135.	Puthuponnani	0.420663	-	0.420663	0.0042
136.	Tavanur	0.873704	-	0.873704	0.0087
137.	Mangalam	7.017804	0.412155	7.429959	0.0743
138.	Triprangode	1.192038	-	1.192038	0.0119
139.	Purathur	0.51798	1.107084	1.625064	0.0163
140.	Koottayi	2.434402	-	2.434402	0.0243
141.	Tirur	1.130865	0.426823	1.557688	0.0156
142.	Palathingal	1.018511	-	1.018511	0.0102
143.	Anangadi	0.886409	-	0.886409	0.0089
144.	Kadalundi	10.346335	-	10.346335	0.1035
145.	Balathiruthi	2.621499	-	2.621499	0.0262
Total		**32.918591**	**3.800018**	**36.718609**	**0.3672**
	Kozhikode District				
146.	Kadalundi	8.213445	-	8.213445	0.0821
147.	Feroke	4.315825	-	4.315825	0.0432
148.	Chelembra	1.358132	-	1.358132	0.0136
149.	Sarovaram biopark	17.065138	-	17.065138	0.1707
150.	Kuruvattoor	3.628640	-	3.628640	0.0363
151.	Kottooli	4.119521	-	4.119521	0.0412
152.	Malaparamba	0.510675	-	0.510675	0.0051
153.	Velur west	-	1.720911	1.720911	0.0172
154.	Atholi	-	2.778702	2.778702	0.0278
155.	Ulliyeri	10.828369	-	10.828369	0.1083
156.	Mannankavu	3.628527	-	3.628527	0.0363
157.	Arikkulam	-	4.756577	4.756577	0.0476
158.	Maniyur	2.114330	-	2.11433	0.0211
159.	Iringal	0.834364	-	0.834364	0.0083
160.	Azhiyur	7.023100	-	7.023100	0.0702
161.	Payyoli	4.379777	-	4.379777	0.0438
162.	Thekkepuram	1.082589	-	1.082589	0.0108
163.	Payyanakkal	1.283695	-	1.283695	0.0128
164.	Kallai	4.717977	-	4.717977	0.0472
165.	Azhchavattam	0.505164	-	0.505164	0.0051
166.	Thiruvannur	0.530882	-	0.530882	0.0053
167.	Odumbra	1.444049	-	1.444049	0.0144
168.	Nallalam	0.683540	-	0.683540	0.0068
169.	Cheruvennur	8.482533	-	8.482533	0.0848
170.	Kozhikkode	14.553373	7.122649	21.676022	0.2168
171.	Koottayi	0.896581	-	0.896581	0.0090
172.	Mahe,Puducherry	2.150383	-	2.150383	0.0215
Total		**104.350609**	**16.378839**	**120.729448**	**1.2073**
	Kannur District				

173.	Kokkapuram,Chalil	0.135299	-	0.135299	0.0014
174.	Pattiam	0.380572	-	0.380572	0.0038
175.	Eranholi	-	2.310792	2.310792	0.0231
176.	Palayad	15.190857	-	15.190857	0.1519
177.	Pinarayi	6.982656	-	6.982656	0.0698
178.	Melur	3.835016	-	3.835016	0.0384
179.	Kunduchira	4.77715	-	4.77715	0.0478
180.	Chonadam	8.058994	-	8.058994	0.0806
181.	Koduvally	6.678762	-	6.678762	0.0668
182.	Thalassery	15.632793	-	15.632793	0.1563
183.	Dharmadom	15.213152	12.391306	22.604458	0.2260
184.	Muzhuppilangad	24.374663	1.949701	26.324364	0.2632
185.	Edakkad	13.592886	-	13.592886	0.1359
186.	Nadal	10.361687	-	10.361687	0.1036
187.	Azhikode South	10.481565	-	10.481565	0.1048
188.	Kadankode	1.766004	-	1.766004	0.0177
189.	Kattampally	9.887925	-	9.887925	0.0989
190.	Azhikkal	1.121476	-	1.121476	0.0112
191.	Valapattanam	15.31957	-	15.31957	0.1532
192.	Azhikode North	4.190798	-	4.190798	0.0419
193.	Pappinisseri	25.979863	-	25.979863	0.2598
194.	Mattool	3.446462	-	3.446462	0.0345
195.	Madakkara	13.620580	-	13.620580	0.1362
196.	Thekkumbad	8.071152	7.236124	15.307276	0.1531
197.	Cherukunnu	4.851336	5.422163	10.273499	0.1027
198.	Muttil	10.70575	7.019283	17.725033	0.1773
199.	Payil island	3.587666	-	3.587666	0.0359
200.	Ezhome	22.18455	4.784542	26.969092	0.2697
201.	Muthukuda	14.318986	-	14.318986	0.1432
202.	Narikode	1.234545	-	1.234545	0.0123
203.	Payyannur	21.965911	-	21.965911	0.2197
204.	Kavvayi	15.211589	-	15.211589	0.1521
205.	South Thrikkaripur	5.999580	13.119900	19.11948	0.1912
206.	Peringadi	15.214815	-	15.214815	0.1521
207.	Padannakkara	5.179541	-	5.179541	0.0518
208.	Kariyad	1.1805628	-	1.1805628	0.0118
209.	Punnol, New mahe	1.262873	-	1.262873	0.0126
210.	Pallithazhe	1.620177	-	1.620177	0.0162
211.	Keezhathoor	2.426456	-	2.426456	0.0242
212.	Mavilayil	8.336698	2.854263	11.190961	0.1119
213.	Kunhimangalam	28.5467864	-	28.5467864	0.2855
214.	North Thrikkaripur	6.341315	-	6.341315	0.0634
215.	Vellur	9.045433	-	9.045433	0.0905
216.	Kannur	183.401864	86.429671	269.831535	2.6983
Total		**602.927485**	**143.517745**	**746.445230**	**7.4645**
	Kasaragod District				
217.	Madakkal	1.18173	-	1.18173	0.0118
218.	South Thrikkaripur	20.796795	4.865676	25.66247	0.2566
219.	Edayilekkadu	3.520208	-	3.520208	0.0352

220.	Thrikkaripur	0.133095	-	0.133095	0.0013
221.	Padne	0.294753	-	0.294753	0.0029
222.	Kokkal	0.815911	-	0.815911	0.0082
223.	Udumbumthala	0.037283	-	0.037283	0.0004
224.	kaithakkad	2.820422	-	2.820422	0.0282
225.	Kanhangad	0.086232	-	0.086232	0.0009
226.	Chithari	1.082473	-	1.082473	0.0108
227.	Karakkunnu	0.327534	-	0.327534	0.0033
228.	Alakkode	3.378275	-	3.378275	0.0338
229.	Keezhur	3.127838	-	3.127838	0.0313
230.	Kudlu	-	1.262766	1.262766	0.0126
231.	Mogral puthur	7.591862	-	7.591862	0.0759
232.	Kumbla	44.520961	-	44.520961	0.4452
233.	Arikady	8.490294	-	8.490294	0.0849
234.	Shiriya	5.063362	-	5.063362	0.0506
235.	Mangal pady	-	0.954388	0.954388	0.0095
Total		**103.269028**	**7.08283**	**110.351858**	**1.1035**

Table 1.2. Extent of mangroves along different districts of Kerala

Sl. No	District	Current extent (km^2)	Existing percentage (%)
1.	Trivandrum	0.275	1.41
2.	Kollam	0.530	2.71
3.	Alappuzha	1.038	5.32
4.	Kottayam	0.985	5.04
5.	Ernakulam	6.153	31.50
6.	Thrissur	0.407	2.08
7.	Malappuram	0.367	1.88
8.	Kozhikkode	1.207	6.18
9.	Kannur	**7.465**	**38.22**
10.	Kasaragod	1.104	5.65
Total		**19.531**	

Data pertaining to the present status of mangroves in the 10 districts of Kerala revealed that, Trivandrum district occupy 0.275 km^2 (1.41%) of mangrove population, which is inclusive of 0.151 km^2 of homogeneous and 0.124 Km^2 heterogeneous mangrove population. Of the 9 locations studied, Akkulam - Veli region occupied the largest mangrove area (0.126 km^2) whereas, Vizhinjam has been noticed for least mangrove population (0.0002 km^2). Mohanan (1997) reported a total of 15 ha of mangrove population in Trivandrum district, whereas Vidyasagaran and Madhusoodanan (2014) reported the existence of 0. 28km^2. A significant increase in area has been noticed in the district compared to 1997. However, comparing the present data with latest reports (2014), a slight decrease in area has been noticed. The reason for this decline can be attributed to the enhanced land clearance activities at Vizhinjam, in connection with towards the construction of harbor.

Mangrove areas of 0.530 km^2 (2.71%), inclusive of 0.2711 km^2 of mangrove patches and 0.2087 km^2 of mixed patches are reported in Kollam district. Here, the highest mangrove area is reported from the Shakthikulangara region (0.226 km^2) and the lowest area from Oachira (0.008 km^2). Previous reports by Basha (1991) showed 0.58 km^2 of mangrove patch in Kollam district. Thus, comparing earlier reports, a noticeable decline along the coastal plains of the district has been noticed.

In the present study, the extent of mangrove areas in Alleppey district was estimated to be 1.038 km^2 (5.32%) with 0.487 km^2 of homogenous and 0.551 km^2 of heterogeneous mangrove patches. Eramalloor and Perumpally have been noticed as the areas with higher and lower mangrove patches with 0.286 km^2 and 0.0001 km^2, respectively. Basha in 1991 reported a total of 0.90 km^2 in the district. Upon comparing with the earlier reports, considerable increase in the total area of mangroves has been noticed. Similarly, Kottayam district occupied 0.985 km^2 (5.04%) of mangrove areas with 0.565 km^2 of homogeneous and 0.420 km^2 of heterogeneous population. Among the 14 locations studied, Kumarakom has occupied maximum area with 0.308 km^2 and Keezhukunnu with a lowest area of 0.007 km^2. Previous reports revealed that the district of Kottayam occupied only

0.80 km^2 of mangrove forests (Basha, 1991). Thus it can be concluded that upon comparing with previous reports, significant increase had happened to the total area of mangrove patches in Kottayam district.

Ernakulam district has been noticed to occupy 6.153 km^2 (31.50%) of mangrove areas, which are inclusive of 2.67 km^2 of homogeneous and 4.27 km^2 of heterogeneous patches. Puthuvypin occupied the largest stretch (1.02 km^2), while Kandakkadavu reported the smallest (0.0005 km^2). In 2014, Vidyasagaran and Madhusoodanan reported an extent of 6 km^2 from the district. Upon comparing with the earlier reports it can be stated that, the total area of mangrove patches within Ernakulam district has grown further to show an increase of 0.153 km^2. As Ernakulam is a fast developing district of the state, significant attention has been given for the conservation of its mangroves. Increased awareness on the importance of mangrove among people, especially those who live along the coastal region have contributed to the prevention of cutting of mangrove trees for recreational purposes. Also the interventions of some of the non-governmental organization have resulted in the establishment of local bodies to conserve and restore mangrove ecosystems.

In the present survey, a total of 0.407 km^2 (2.08%) mangrove forest has been identified from Thrissur district, including 0.332 km^2 homogeneous and 0.076 km^2 heterogeneous patches. Among different locations studied, Chettuvai reported the largest area (0.095 km^2) and Chanda Nagar reported the smallest patch with 0.001 km^2. Kurien et al. (1994) reported the existence of 0.41 km^2 of mangroves in the district. A total of 0.30 km^2 were reported by Vidyasagaran and Madhusoodanan in 2014. Thus upon comparing with reports of 1994, no significant change has been noticed in the total area of mangroves, whereas a marginal increase has been noticed as compared to the data published in 2014.

A total area of 0.367 km^2 (1.88%) mangrove habitats has been reported from the district of Malappuram. The homogeneous and heterogeneous patches reported were 0.329 km^2 and 0.038 km^2 respectively. Out of 17 locations studied, Kadalundi-Vallikkunnu region is reported for higher extent (0.104 km^2) and Thavalakulam for lower (0.004 km^2). Earlier report by Vidyasagaran and Madhusoodanan (2014) recorded a total of 0.26 km^2 mangrove forest from the district. Thus, compared to previous studies, the present study reported an increase of 0.10 km^2 in the total mangrove cover of the district.

The district of Kozhikode has been noticed for a total of 1.207 km^2 (6.18%) mangrove forests including both homogeneous (1.044 km^2) and heterogeneous (0.164 km^2) patches. Mangrove areas of Sarovaram bio park, Kottooli occupied the largest area (0.171 km^2) and Azhchavattam region occupied the smallest patch within the district. Mohanan in 1997 reported 2.0 km^2 of mangrove areas from the district.

Kannur district showed the existence of a total of 7.465 km^2 (38.22%) mangrove cover, which is inclusive of 6.029 km^2 homogeneous and 1.435 km^2 heterogeneous patch. Among the numerous healthy patches, Kunhimangalam possesses the highest area of 0.286 km^2 and Chalil with least area of 0.001 km^2. Vaiga and Sincy (2016) reported 7.55 km^2 of mangrove forest from the district. Upon comparing the present estimate with the recent report (2016), the total mangrove cover of the district has been dwindled by around 0.1 km^2. The coastal population has grown as a result of increased returns from fishing. Land clearance for the construction of new sea ports, extension of existing sea ports and establishment of industrial units near the coast has also contributed to the depletion of mangrove cover in the district.

Kasaragod district occupies a total area of 1.104 km^2 (5.65%) of mangroves, with both homogeneous (1.033 km^2) and heterogeneous (0.071 km^2) patches. Kumbala has been reported for holding largest area of mangroves (0.445 km^2) and Udumbumthala for a smallest patch with a size of 0.0004 km^2. Mohanan (1997) reported 0.50 km^2 of mangroves in the district. Upon comparing the data with previous reports, it can be stated that the mangrove cover of the district has considerably increased for about 0.604 km^2. This might be due to the intense afforestation activities conducted both at government and non-government level.

The present survey estimates the total extent of mangroves in Kerala to a tune of 19.53 km^2. It has also been highlighted that, out of 10 districts studied, Kannur district occupies maximum mangrove cover with 7.465 km^2, which is coming around 38.22% of the total extent of the State. This is followed by Ernakulam district with 6.153 km^2 (31.50%). Minimum extent was represented by Trivandrum district with 0.275 km^2 (1.41%).

In the present study, attempts have been carried out to compare the results with earlier authentic reports. The most reliable studies on the district wise and total extent of mangroves in Kerala has been carried out by Basha in 1991. He reported that the total mangrove cover of the State is 16.71 Km^2. Upon comparing the present results with these reports (Basha, 1991), significant changes were noticed within 25 years with respect to the district wise and state wise extent of mangroves in Kerala. The observations concerning the extent of mangroves in the present study in comparison with earlier studies (Basha, 1991) is given in Table 1.3.

Table 1.3. Mangrove cover changes in km^2

District	**Current extent (2016)** km^2	**Basha (1991)** km^2	**Changes between 1991 – 2016 (25 years)** km^2
Trivandrum	0.275	0.23	+0.045
Kollam	0.530	0.58	-0.050
Alleppey	1.038	0.90	+0.138
Kottayam	0.985	0.80	+0.185
Ernakulam	6.153	2.60	+3.553
Thrissur	0.407	0.21	+0.197
Malappuram	0.367	0.12	+0.247
Kozhikode	1.207	2.93	-1.723
Kannur	**7.465**	7.55	-0.085
Kasaragod	1.104	0.79	+0.314
Total	**19.531**	**16.71**	**+2.821**

'+' indicates increasing trend and '-' indicates decreasing trend

The results revealed that most of the districts are reported with increase in the total mangrove area. Trivandrum (+0.045 km^2), Alleppey (+0.138 km^2), Kottayam (+0.185 km^2), Ernakulam (+3.553 km^2), Thrissur (0.197 km^2), Malappuram (+0.247 km^2) and Kasaragod (+0.314 km^2) districts have been reported for increase in the total mangrove cover during last 25 years. The districts with decline in total mangrove cover during last 25 years were Kollam (-0.050 km^2), Kozhikode (-1.723 km^2) and Kannur (-0.085 km^2).

Thus, upon comparing the results of the present study with that of Basha (1991), an increasing mangrove cover of about 2.821 km^2 within the last 25 years is noted. This increase might be due to an increase in awareness on the importance of mangroves among public. Also there were contributions from the part of governmental and non-governmental organizations. The incidence of Asian tsunami in 2004 and Hurricane Katrina in 2005 have also contributed towards the enhanced awareness on mangroves as their contribution in preventing coastal erosion and subsequent inundation was significant.

Among all the districts under study, Kollam (-0.050 km^2), Kozhikode (-1.723 km^2) and Kannur (-0.085 km^2) showed a decreasing trend of mangrove cover with respect to the report of Basha (1991). The study reveals that the mangroves in these districts have shrunken considerably to few patches, mainly in Dharmadom, Nadakkavu, Edakkad, Pappinisseri, Valapattanam, Muzhappilangad, Kunhimangalam, Pazhayangadi, Kavvayi, Thalassery and Ezhimala of Kannur district, Kottooli, Koduvally, Kallai and Kadalundi of Kozhikkode district and Asraamam and Shaktikulangara of Kollam district. The year wise declines in the total mangrove cover of these districts are 0.002 km^2/yr, 0.069 km^2/yr and 0.003 km^2/yr respectively. High extent of degradation in the total mangrove cover has been noticed in Kozhikode district. The year wise mangrove declining rate of Kozhikode district is alarming, indicating the fact that the remaining mangrove patches will be degraded within the next 20 years.

Along with the extent, diversity assessment of mangroves confining to Kerala has been worked out and reported. Field studies have been carried out in all the 10 districts for the collection and identification of mangrove species. Each district has been reported with different number of mangroves. The results are depicted in Table 1.4.

Table 1.4. Diversity of true mangrove species in different districts of Kerala

Sl. No	Species	Family	No of species
1. Trivandrum District			
1.	*Aegiceras corniculatum* (L.) Blanco	Myrsinaceae	10 species under 7 genera and 6 families
2.	*Avicennia officinalis* L.	Avicenniaceae	
3.	*Bruguiera cylindrica* (L.) Blume	Rhizophoraceae	
4.	*Bruguiera gymnorhiza* (L.) Savi.		
5.	*Rhizophora apiculata* Blume		
6.	*Rhizophora mucronata* Lam.		
7.	*Excoecaria agallocha* L.	Euphorbiaceae	
8.	*Excoecaria indica* L.		
9.	*Lumnitzera racemosa* Willd.	Combretaceae	
10.	*Sonneratia caseolaris* (L.)Engl.	Sonneratiaceae	
2. Kollam District			
1.	*Aegiceras corniculatum* (L.) Blanco	Myrsinaceae	14 species under 9 genera and 6 families
2.	*Avicennia marina* (Forssk.) Vierh.	Avicenniaceae	
3.	*Avicennia officinalis* L.		
4.	*Bruguiera cylindrica* (L.) Blume	Rhizophoraceae	
5.	*Bruguiera gymnorhiza* (L.) Savi.		
6.	*Bruguiera sexangula* (Lour.) Poir.		
7.	*Ceriops tagal* (Pers.) C. B. Rob.		
8.	*Kandelia candel* (L.) Druce		
9.	*Rhizophora apiculata* Blume		
10.	*Rhizophora mucronata* Lam.		
11.	*Excoecaria agallocha* L.	Euphorbiaceae	
12.	*Excoecaria indica* L.		
13.	*Lumnitzera racemosa* Willd.	Combretaceae	
14.	*Sonneratia caseolaris* (L.)Engl.	Sonneratiaceae	
3. Alleppey District			
1.	*Aegiceras corniculatum* (L.) Blanco	Myrsinaceae	10 species under 7 genera and 5 families
2.	*Avicennia marina* (Forssk.) Vierh.	Avicenniaceae	
3.	*Avicennia officinalis* L.		
4.	*Bruguiera cylindrica* (L.) Blume	Rhizophoraceae	
5.	*Bruguiera gymnorhiza* (L.) Savi.		
6.	*Kandelia candel* (L.) Druce		
7.	*Rhizophora apiculata* Blume		
8.	*Rhizophora mucronata* Lam.		
9.	*Excoecaria agallocha* L.	Euphorbiaceae	
10.	*Sonneratia caseolaris* (L.)Engl.	Sonneratiaceae	
4. Kottayam District			
1.	*Avicennia marina* (Forssk.) Vierh.	Avicenniaceae	7 species under 5 genera and 4
2.	*Avicennia officinalis* L.		
3.	*Bruguiera sexangula* (Lour.) Poir.	Rhizophoraceae	

4.	*Rhizophora apiculata* Blume		families
5.	*Rhizophora mucronata* Lam.		
6.	*Excoecaria agallocha* L.	Euphorbiaceae	
7.	*Sonneratia caseolaris* (L.)Engl.	Sonneratiaceae	
5. Ernakulam District			
1.	*Aegiceras corniculatum* (L.) Blanco	Myrsinaceae	11 species under 7 genera and 5 families
2.	*Avicennia marina* (Forssk.) Vierh.	Avicenniaceae	
3.	*Avicennia officinalis* L.		
4.	*Bruguiera cylindrica* (L.) Blume	Rhizophoraceae	
5.	*Bruguiera gymnorhiza* (L.) Savi.		
6.	*Kandelia candel* (L.) Druce		
7.	*Rhizophora apiculata* Blume		
8.	*Rhizophora mucronata* Lam.		
9.	*Excoecaria agallocha* L.	Euphorbiaceae	
10.	*Sonneratia alba* Sm.	Sonneratiaceae	
11.	*Sonneratia caseolaris* (L.)Engl.		
6. Thrissur District			
1.	*Aegiceras corniculatum* (L.) Blanco	Myrsinaceae	7 species under 6 genera and 4 families
2.	*Avicennia officinalis* L.	Avicenniaceae	
3.	*Bruguiera cylindrica* (L.) Blume	Rhizophoraceae	
4.	*Kandelia candel* (L.) Druce		
5.	*Rhizophora apiculata* Blume		
6.	*Rhizophora mucronata* Lam.		
7.	*Excoecaria agallocha* L.	Euphorbiaceae	
7. Malappuram District			
1.	*Aegiceras corniculatum* (L.) Blanco	Myrsinaceae	10 species under 7 genera and 5 families
2.	*Avicennia marina* (Forssk.) Vierh.	Avicenniaceae	
3.	*Avicennia officinalis* L.		
4.	*Bruguiera cylindrica* (L.) Blume	Rhizophoraceae	
5.	*Bruguiera sexangula* (Lour.) Poir.		
6.	*Kandelia candel* (L.) Druce		
7.	*Rhizophora mucronata* Lam.		
8.	*Excoecaria agallocha* L.	Euphorbiaceae	
9.	*Sonneratia alba* Sm.	Sonneratiaceae	
10.	*Sonneratia caseolaris* (L.)Engl.		
8. Kozhikkode District			
1.	*Aegiceras corniculatum* (L.) Blanco	Myrsinaceae	10 species under 7 genera and 5 families
2.	*Avicennia marina* (Forssk.) Vierh.	Avicenniaceae	
3.	*Avicennia officinalis* L.		
4.	*Bruguiera cylindrica* (L.) Blume	Rhizophoraceae	
5.	*Kandelia candel* (L.) Druce		
6.	*Rhizophora apiculata* Blume		
7.	*Rhizophora mucronata* Lam.		
8.	*Excoecaria agallocha* L.	Euphorbiaceae	
9.	*Sonneratia alba* Sm.	Sonneratiaceae	

10	*Sonneratia caseolaris* (L.)Engl.		
9. Kannur District			
1.	*Aegiceras corniculatum* (L.) Blanco	Myrsinaceae	12 species under 8 genera and 6 families
2.	*Avicennia marina* (Forssk.) Vierh.	Avicenniaceae	
3.	*Avicennia officinalis* L.		
4.	*Bruguiera cylindrica* (L.) Blume	Rhizophoraceae	
5.	*Bruguiera sexangula* (Lour.) Poir.		
6.	*Kandelia candel* (L.) Druce		
7.	*Rhizophora apiculata* Blume		
8.	*Rhizophora mucronata* Lam.		
9.	*Excoecaria agallocha* L.	Euphorbiaceae	
10.	*Lumnitzera racemosa* Willd.	Combretaceae	
11.	*Sonneratia alba* Sm.	Sonneratiaceae	
12.	*Sonneratia caseolaris* (L.)Engl.		
10. Kasaragod District			
1.	*Aegiceras corniculatum* (L.) Blanco	Myrsinaceae	10 species under 7genera and 5 families
2.	*Avicennia marina* (Forssk.) Vierh.	Avicenniaceae	
3.	*Avicennia officinalis* L.		
4.	*Bruguiera cylindrica* (L.) Blume	Rhizophoraceae	
5.	*Kandelia candel* (L.) Druce		
6.	*Rhizophora apiculata* Blume		
7.	*Rhizophora mucronata* Lam.		
8.	*Excoecaria agallocha* L.	Euphorbiaceae	
9.	*Sonneratia alba* Sm.	Sonneratiaceae	
10.	*Sonneratia caseolaris* (L.)Engl.		

Trivandrum district possessed 10 true mangrove species, which include *Aegiceras corniculatum, Avicennia officinalis, Bruguiera cylindrica, B. gymnorhiza, Excoecaria agallocha, E. indica, Lumnitzera racemosa, Rhizophora apiculata, R. mucronata* and *Sonneratia caseolaris.* The number of species was found to be the same as reported by Mini et al. (2014). However, Thomas (1962) and Vidyasagaran and Madhusoodanan (2014) reported 5 and 4 species of mangroves respectively from the district. Upon comparing with earlier reports, the present study reported considerably higher number of mangrove species from the district.

Kollam district has been reported with maximum species diversity of 14 true mangrove species. Species such as *Aegiceras corniculatum, Avicennia marina, A. officinalis, B. sexangula, Excoecaria agallocha, E. indica, Kandelia candel, Lumnitzera racemosa, Rhizophora apiculata, R. mucronata and Sonneratia* *caseolaris* were scattered sporadically in different parts of the district. Vishal and Vidyasagaran (2014) have reported 12 true mangrove species from the district. The present result indicated an increase in the number of species.

Alleppey district is reported with 10 mangrove species such as *Aegiceras corniculatum, Avicennia marina, A. officinalis, Bruguiera cylindrica, B. gymnorhiza, Excoecaria agallocha, Kandelia candel, Rhizophora apiculata, R. mucronata* and *Sonneratia caseolaris.* Sunil (2000), Vidyasagaran and Madhusoodanan (2014) and Mini et al. (2014) have reported 12 true mangrove species from the district. Comparison of the present result with these reports indicated a decline in the number of true mangrove species.

7 true mangrove species such as *Avicennia marina, A. officinalis, B. sexangula, Excoecaria agallocha, Rhizophora apiculata, R. mucronata* and *S. caseolaris* are sparsely distributed along different locations of Kottayam district. Marginal decline in the number of species has been noticed as compared to the reports revealed 8 species by Mini et al. (2014). However, as compared to the reports with 5 species of mangroves by Vidyasagaran and Madhusoodanan (2014), the present study described a higher number.

True mangrove species such as *Aegiceras corniculatum, Avicennia marina, A. officinalis, Bruguiera cylindrica, B. gymnorhiza, Excoecaria agallocha, Kandelia candel, Rhizophora apiculata, R. mucronata, Sonneratia alba* and *S. caseolaris* were the 11 species distributed in the Ernakulam district. Upon comparing with the reports of Mini et al (2014), the present study described a lesser number of true mangrove species from the district. However, the study reported higher number of species as compared to the reports of Kurian (1984), Sunilkumar (1993) and Vidyasagaran and Madhusoodanan (2014).

Thrissur district is characterized by 7 mangrove species such as *Aegiceras corniculatum, Avicennia officinalis, Bruguiera cylindrica, Excoecaria agallocha, Kandelia candel, Rhizophora apiculata* and *R. mucronata.* Considerable decline in the total number of true mangrove species has been noticed as compared to the reports (11 species) of Mini et al. (2014).

Malappuram district has been reported with 10 mangrove species such as *Aegiceras corniculatum, Avicennia marina, A. officinalis, Bruguiera cylindrica, B. sexangula, Excoecaria agallocha, Kandelia candel, Rhizophora mucronata, Sonneratia alba* and *S. caseolaris*. Radhakrishnan et al. (2006), Vidyasagaran et al. (2014) and Mini et al. (2014) reported 2, 8 and 9 species of true mangrove species from the district. As compared to all these reports, the present study reported a higher number of species.

Kozhikkode district was also with 10 true mangrove species such as *Aegiceras corniculatum, Avicennia marina, A. officinalis, Bruguiera cylindrica, Excoecaria agallocha, Kandelia candel, Rhizophora apiculata, R. mucronata, Sonneratia alba* and *S. caseolaris*. Radhakrishnan et al. (2006) reported 7 and Vidyasagaran and Madhusoodanan (2014) reported 9 species of true mangroves from the district. The present result indicated that the species diversity confined to the district has increased.

Kannur has been reported for a maximum of 12 true mangrove species such as *Aegiceras corniculatum, Avicennia marina, A. officinalis, Bruguiera cylindrica, , B. sexangula, Excoecaria agallocha, Kandelia candel, Lumnitzera racemosa, Rhizophora apiculata, R. mucronata, Sonneratia alba* and *S. caseolaris*. Radhakrishnan et al. (2006) and Vidyasagaran et al. (2014) reported 7 and 11 species of true mangrove species from the district. The present result revealed a higher number of species as compared to these reports and is similar to the reports of Mini et al. (2014).

Kasaragod was reported with 10 true mangrove species such as *Aegiceras corniculatum, Avicennia marina, A. officinalis, Bruguiera cylindrica, Excoecaria agallocha, Kandelia candel, Rhizophora apiculata, R. mucronata, Sonneratia alba* and *S. caseolaris*. The study described similar number of species as compared to the reports of Vidyasagaran and Madhusoodanan (2014). However, as compared to the reports by Mini et al. (2014) with 12 species, the species diversity of the district has presently decreased.

Consolidation of the above observation revealed the existence of 15 true mangrove species falling under 9 genera and 6 families in the state of Kerala (Plate 1.1). The details regarding their scientific name, vernacular name (Malayalam), family and recent IUCN status are depicted in Table 1.5.

Table 1.5. True mangrove species of Kerala identified in the present study

Sl. No	Scientific Name	Vernacular Name (Malayalam)	Family	IUCN Category
1.	*Aegiceras corniculatum* (L.) Blanco	Pookandal	Myrsinaceae	LC
2.	*Avicennia marina* (Forssk.) Vierh.	Cheru uppatti	Avicenniaceae	LC
3.	*Avicennia officinalis* L.	Uppatti, Uppootti	Avicenniaceae	LC
4.	*Bruguiera cylindrica* (L.) Blume	Kuttikandal	Rhizophoraceae	LC
5.	*Bruguiera gymnorhiza* (L.) Savi.	Penakandal	Rhizophoraceae	LC
6.	*Bruguiera sexangula* (Lour.) Poir.	Swarnakandal	Rhizophoraceae	LC
7.	*Ceriops tagal* (Pers.) C. B. Rob.	Manjakandal	Rhizophoraceae	LC
8.	*Excoecaria agallocha* L.	Kannampotti, Kammatti	Euphorbiaceae	LC
9.	*Excoecaria indica* L.	Kandal	Euphorbiaceae	DD
10.	*Kandelia candel* (L.) Druce	Ezhuthanikandal, Nallakandal	Rhizophoraceae	LC
11.	*Lumnitzera racemosa* Willd.	Kadakandal	Combretaceae	LC
12.	*Rhizophora apiculata* Blume	Vallikandal, Peekandal	Rhizophoraceae	LC
13.	*Rhizophora mucronata* Lam.	Pranthankandal	Rhizophoraceae	LC
14.	*Sonneratia alba* Sm.	Nakshathrakandal	Sonneratiaceae	LC
15.	*Sonneratia caseolaris* (L.)Engl.	Chakkarakandal	Sonneratiaceae	LC

- IUCN Red list of threatened species version 2017-2 (www.iucnredlist.org)
- LC – Least Concern (A taxon is Least Concern when it has been evaluated against the criteria and does not qualify for critically endangered,

endangered, vulnerable or near threatened. Widespread and abundant taxa are included in this category).

- DD – Data Deficient (Appropriate data on abundance and distribution are lacking).

Inquiries on the true mangrove species of Kerala revealed that, the state is endowed with 15 True mangrove species as a whole. They are *Aegiceras corniculatum, Avicennia marina, A. officinalis, Bruguiera cylindrica, B. gymnorhiza, B. sexangula, Ceriops tagal, Excoecaria agallocha, E. indica, Kandelia candel, Lumnitzera racemosa, Rhizophora apiculata, R. mucronata, Sonneratia alba* and *S. caseolaris* belonging to the families Myrsinaceae, Avicenniaceae, Euphorbiaceae, Rhizophoraceae, Combretaceae and Sonneraceaceae. Among different families reported, Rhizophoraceae possesses the maximum number of species (7) followed by Avicenniaceae (2 species), Euphorbiaceae (2 species), Sonneraceaceae (2 species), Combretaceae (1 species) and Myrsinaceae (1 species). 14 mangrove species reported in this study are coming under Least Concern (LC) Category of IUCN. The species *Excoecaria indica* is coming under the Data deficient category. The study revealed that, even though the existing mangrove areas are highly localized, the species diversity of these mangroves confining to the coast of Kerala is comparatively rich.

Though there is a technical increase in the extent of mangroves, most of the major mangrove growing areas are under drastic pressure. Various reasons have been identified during the present investigation and that can be summarized as follows. Invasion of mangrove areas by human population is one of the main reason, in which most of the mangrove areas has been removed either partially or completely for various purposes. Unscientific developmental activities like construction of concrete walls and other retaining structures around the mangrove areas or filling/ reclamation of these areas hinder the entry of tidal water into the mangrove areas and hamper its expansion. Over exploitation of mangrove resources like cutting of mangroves for fire wood, cattle feed, etc. by the local people, also damaged this fragile ecosystem. Removal of mud from the banks of backwaters by local people for household purposes together with plantation activities has also been noticed as factors leading to threat on mangroves. Waste disposal also affected the mangroves to a large extent. The policies framed by the government to encourage tourism and other recreational activities in the coastal environments have also contributed adversely to the conservation of mangroves and other marine biodiversity. Above all, lack of awareness among the public regarding the importance of mangroves is a major problem associated with mangrove conservation and protection. Ezhimala-Kunhimangalam region is highly affected with fishing related activities, sand mining, coir retting etc. Valapattanam mangroves are pressurized by pollution from wastes like slaughter house, domestic sewage, carcasses of animals, reclamation and coconut husk retting. Encroachment and unscientific construction activities are the main reasons of destruction in Chetwai and Ashtamudi mangroves. Mangalavanam mangroves are stressed by land encroachment, pollution due to dumping of cement bags and other wastes. Cutting of mangrove trees for fuel wood and other construction activities, draining and filling of the areas are threats at Puthuvypin region.

Significant measures have to be adopted for protecting / uplifting the mangrove habitats of Kerala. Special enforcement cell should be placed to take legal actions through the departments concerned for mangrove area protection. Identification of private owned mangrove areas through field surveys and their acquisition by the government has to be carried out for better protection. The developmental activities that are harmful to mangrove population should be subjected to regular examination by a joint committee involving panchayath authorities, local people representatives and scientists. Creation of awareness regarding the importance of mangroves and mangrove habitats need to be given top priority. Since the survival of this eco system is very important for the well-being of all coupled flora and fauna, intensive and extensive conservation and ecosystem reinstatement programmes should be undertaken without delay. Conservation of these worth preserving pieces of nature's gift is highly insistent because tomorrow may be too late.

Summary and Conclusion

Mangroves are one among the most productive and biologically important ecosystem on this planet, providing vital ecosystem goods and services. Besides all these imperative services provided, these fragile ecosystems are under tremendous pressure.

It has been reported that Kerala coast once supported about 700 sq.km of mangroves and presently it has been dwindled to a considerable extent. Mangrove ecosystems are receiving increasing attention in Kerala, but still lack updated information on their diversity and extent for deriving strategic plans for conservation / afforestation. The present study has been carried out to assess the extent and diversity of mangrove ecosystems in the heterogeneous environments of Kerala with a view to conserve their existing habitats from further degradation.

Thorough literature survey and frequent field visits were carried out to elucidate the extent and diversity of mangroves confining to the coastal environments of Kerala. GPS survey has been carried out and the total area under mangrove cover (both homogenous and heterogenous) was estimated in square kilometers using Google map imageries. For the assessment of species diversity, collection of the true mangrove species has also been carried out from all the districts under study. The collected species were identified with the help of standard manuals and experts. All the specimens were preserved for future reference.

The present survey estimated the total extent of mangroves in Kerala as 19.531 km^2. It has also been highlighted that out of 10 districts studied, Kannur district occupied highest mangrove cover with 7.465 km^2 which is coming around 38.22 % of the total extent within the state. This is followed by Ernakulam district with 6.153 km^2 (31.5%). Minimum extent has been reported from Trivandrum district with 0.275 Km^2 (1.41%).

Attempts have been carried out to compare the results with earlier authentic reports. Upon comparing the results of the present study with that of Basha (1991), an increasing mangrove cover of about 2.821 km^2 within the last 25 years is noted. This increase might be due to an increase in awareness on the importance of mangroves among public. Also there were contributions from the part of governmental and non-governmental organizations in the area of mangrove introduction. The incidence of Asian tsunami in 2004 and Hurricane Katrina in 2005 have also contributed towards the enhanced awareness on mangroves as their contribution in preventing coastal erosion and subsequent inundation was significant.

Most of the districts are reported with increase in the total mangrove area. Trivandrum (0.045 km^2), Alleppey (0.138 km^2), Kottayam (0.185 km^2), Ernakulam (3.553 km^2), Thrissur (0.197 km^2), Malappuram (0.247 km^2) and Kasaragod (0.314 km^2) districts have been reported for increase in the total mangrove cover during last 25 years. The districts with decline in total mangrove cover during last 25 years were Kollam (0.050 km^2), Kozhikode (1.723 km^2) and Kannur (0.085 km^2).

Among all the districts under study, Kollam, Kozhikode and Kannur showed a decreasing trend of mangrove cover with respect to the report of Basha (1991). The year wise decline in the total mangrove cover of these districts are 0.002 km^2/yr, 0.069 km^2/yr and 0.003 km^2/yr respectively. High extent of degradation in the total mangrove cover has been noticed in Kozhikode district. The year wise mangrove declining rate of Kozhikode district is alarming, indicating the fact that the remaining mangrove patches will be degraded within the next 20 years.

Attempts were also carried out to study the diversity of true mangrove species in Kerala. Mangrove specimens were collected and identified following standard manuals and with the help of experts. The results revealed that, the state is endowed with 15 True mangrove species as a whole. They are *Aegiceras corniculatum, Avicennia marina, Avicennia officinalis, Bruguiera cylindrica, B. gymnorhiza, B. sexangula, Ceriops tagal, Excoecaria agallocha, E. indica, Kandelia candel, Lumnitzera racemosa, Rhizophora apiculata, R. mucronata, Sonneratia alba* and *S. caseolaris* under the families Myrsinaceae, Avicenniaceae, Euphorbiaceae, Rhizophoraceae, Combretaceae and Sonneraceaceae. Among different families reported, Rhizophoraceae possesses the maximum number of species (7) followed by Avicenniaceae (2 species), Euphorbiaceae (2 species), Sonneraceaceae (2 species), Combretaceae (1 species) and Myrsinaceae (1 species). The study revealed that, even though the existing mangrove areas are highly localized, the species diversity is comparatively rich.

The study concluded that, though there is a technical increase in the extent of mangroves, drastic degradation have been undergoing in many of the urbanized and semi urbanized areas especially in Kozhikode and Kannur districts. The study also suggested that, if this unsystematic destruction proceeds unchecked, the mangrove patches may completely wiped out within few years. Since the survival of this eco system is very important for the well being of all coupled flora and fauna, intensive and extensive conservation and ecosystem reinstatement programmes should be undertaken without delay. Conservation of these worth preserving pieces of nature's gift is highly insistent because tomorrow may be too late.

CHAPTER 2

STANDARDIZATION STUDIES ON THE GROWTH SUSTAINING ATTRIBUTES OF SELECTED MANGROVE SPECIES

Introduction

Mangrove forests play a very important role in coastal ecosystems located at the interface between land and sea along tropical and subtropical regions of the world. Such transition zones are influenced by waves, tides and thereby varying levels of environmental conditions. Many factors that strongly influence the establishment of mangroves in heterogeneous habitats, which include geographical features, wave action, tide action, rainfall, freshwater runoff, erosion/sedimentation rates, aridity, salinity, nutrient inputs, soil/ sediment quality etc. (Kjerfve et al., l999). Waves, tides and rainfall affect water circulation by generating turbulence, longitudinal mixing and trapping of coastal water, influencing the rate of erosion and deposition of sediments on which mangroves grow (Duke et al., 1998).

Morphological and ecophysiological characteristics and adaptations of mangrove trees include aerial roots, viviparous embryos, tidal dispersal of propagules, rapid rates of canopy production, frequent absence of an understorey, absence of growth rings, wood with narrow, densely distributed vessels, highly efficient nutrient retention mechanisms, and the ability to cope with salt and to maintain water and carbon balance. Subtle variations in key environmental factors have resulted in further adaptations not only among species, but also between individuals of the same species living in different conditions. Differences in climate, geomorphology, hydrodynamic disturbances and sedimentation regime have created differential incentives for root characteristics such as strength, retention of oxygen, nutrient acquisition, and resilience to sedimentation.

All mangrove plant species do not have the same ability to tolerate soil salinity, nutrient, wave energy and flooding (anaerobic) conditions that vary within as well as among mangrove areas. Depending on the water and soil nutrient conditions and also the extent to which the area is protected from high energy waves; mangrove species occupy different localities in an inter-tidal area, forming diverse zones of vegetation. Each zone is composed of either one or a few species of mangroves that can tolerate its environmental conditions. Knowledge on mangrove zonation therefore is essential to determine suitable candidate species for planting.

Several studies have been conducted to elucidate the nutrient enrichment of mangrove wetlands. Salinity of water and soil organic matter has been reported to have the most significant influence on the proliferation of mangroves (Clough, l984; Kathiresan and Thangam, 1990). Salinity plays a pivotal role in the species distribution, productivity and growth of mangrove forests (Twilley and Chen, 1998). Changes in salinity are normally controlled by climate, hydrology, rainfall, topography and tidal flooding. Most of the mangroves prefer brackish to saline waters for their growth. Freshwater discharge or terrestrial runoff, on the other hand, greatly favors mangrove colonization; it supplies nutrients and leaches the soil, thus keeping soil salinity within a tolerable range (Thom, 1967).

It has been reported that, establishment of mangrove forests are more abundant along areas wherein a lower salinity persists (Kathiresan et al., 1996). At conditions of higher salinity, mangroves spend more energy to maintain water balance and ion concentration rather than for primary production and growth (Clough, l984). Reports also shows that mangroves can tolerate salinities of higher ranges than any other plants. Different species of mangroves are reported to grow in a wider range of salinity conditions and there have been variations within the same genus. Salinity tolerances of some species of mangroves reported are *Rhizophora mucronata* (30ppm), *R. apiculata* (15 ppm), *Sonneratia alba* (2 -18 ppm) and *S. lanceolata* (2 ppm) (Ball and Pidsley, 1995; Kathiresan et al., 1996).

Mangrove plants may grow in different types of soils; therefore their vegetation, species composition and structure may vary considerably at the global, regional and local scales (Vilarrubia, 2000). The ecosystem showed analogous patterns of variability in the sources of organic carbon in surface sediments. The sedimentary organic matter depends on factors like algal mats, roots, tidal fluctuations, rate of change in decomposition and the maturity of the forest (Middelburg et al., 1997).

Root systems of some species are probably better as anchorage while those of others are better as means to acquire nutrients from the sediment, or oxygen from the air. For instance, stilt or prop roots of *Rhizophora* offer support to tall trees to withstand the forces of strong winds (Field, 1995). Some mangrove species are able to respond to inundation or sedimentation. The stilt roots of *Rhizophora* are capable of elongating up to eight meters (Santisuk 1983). From the observation of Aksornkoae (1975), it was found that the height of aerial roots of *Rhizophora* in a high tidal area was greater than that in a short tidal area. Additionally, pneumatophores of *Avicennia* have limited height of less than 30 cm and develop little secondary thickening. In the case of *Sonneratia,* the pneumatophores are taller because they have a much longer period of development and the highest length ever found was three meters (Tomlinson 1986). Therefore, *Avicennia* trees are not likely to survive under abrupt sediment accretion of more than 30 cm.

The uncontrolled exploitation and degradation of mangroves in most of the tropical countries have called for an urgent need of implementing conservation and management strategies. Mangrove conservation requires a collaborated research involving natural, social and inter-disciplinary approaches. Afforestation of mangroves seems to be a promising solution for the restoration of degraded habitats. Selection of ideal and adaptable species is the most vital prerequisite towards successful afforestation/ restoration of mangroves. Different criteria followed for the selection of an ideal species for afforestation activities are; planting purpose, adaptability, occurrence, availability of mature propagules, size of propagules and zoning pattern of species (Macintosh et al., 2012). The following criteria are also followed for the selection of mangrove species. (i) Regeneration of mangroves (ii) coastal protection against tidal waters, erosion and cyclones (iii) protection of lagoons and estuaries (iv) dyke protection along the sea and aquaculture farms and (v) introduction to new mudflats.

According to Kathiresan (1994, 2011), among the Kerala mangroves, *Aegiceras corniculatum* can be used for regeneration of mangroves and introduction to new mudflats. *Avicennia officinalis* and *Avicennia marina* are known to satisfy all the above criteria. *Bruguiera cylindrica* can be utilized for the purpose of protection of lagoons and estuaries whereas; *Bruguiera gymnorhiza and Ceriops tagal* can be used for dyke protection along the sea and aquaculture farms. *Excoecaria agallocha* can be introduced for regeneration of mangroves and dyke protection along the sea and aquaculture farms. *Kandelia candel* can be included in the afforestation practices of coastal protection against tidal waters, erosion and cyclones and protection of lagoons and estuaries. *Rhizophora apiculata* and *R. mucronata* satisfies all the planting purposes except regeneration of mangroves. *Sonneratia alba* can be used for coastal protection against tidal waters, erosion and cyclones and protection of lagoons and estuaries. *S. caseolaris* can be included in protection of lagoons and estuaries and dyke protection along the sea and aquaculture farms.

It is evident from the literature that, the growth conditions of mangroves differs in heterogeneous habitats. Also the selection of mangroves to specific habitats is dependent on their ecosystem services. Basically, any afforestation or restoration endeavors of mangroves primarily require reliable information on ecology, hydrology and sedimentology that control the successful growth of the targeted mangrove species. Thus, it can be stated that among all such vital attributes, water and sediment quality are known to have supreme influence on the growth of mangroves (Thom, 1967). In light of this, the present investigation was carried out with the objective of evaluating the hydrogeochemical, sedimentological and climatological conditions ideal for the growth and establishment of selected mangrove species in pursuit of their utilization for species specific afforestation practices.

Review of Literature

Among various inputs, water and sediment are known to have supreme influence on the growth and development of mangroves. On regional and global level, many studies have been reported on the growth supporting attributes of mangroves.

Soil characteristics and vegetation of mangrove forest of Sunderban in India has been reported by Frith et al. (1976). The results revealed that the pH of soil was fluctuating within acidic to alkaline range. Studies on the ecology of estuarine mangroves of Goa revealed nutrients, especially inorganic phosphate, exhibiting an inverse correlation with sediment load (Untawale and Parulakar, 1976).

Studies pertaining to the physico-chemical attributes of soil from mangrove ecosystems of Sunderban forest revealed that pH is an important determinant of mangrove proliferation. It has also been reported that the soil pH of the ecosystem was ranging from 7.9 to 8.4 (Matilal, 1986).

Influence of temperature, salinity, sediment nitrogen, phosphorous and potassium on rooting of *Rhizophora mucronata* was studied and reported by Kathiresan et al (1996). The results revealed that, temperature and salinity were maximum during summer and minimum during monsoon months. The sediment nitrogen, phosphorous and potassium were noticed to be higher during pre monsoon and lower during monsoon months.

Monthly assessment of the physico-chemical characteristics of the water in Muthupettai mangrove ecosystem were carried out for a period of 2 years. The ranges of different parameters such as air temperature (27-35°C), surface water temperature (26-33°C), salinity (20-38‰), pH (7.1 to 8.7), dissolved oxygen (3.1 to 6.35 mg L-1), nitrate-NO (15 to 14.17 μM), nitrite-N (0.09 to 3.58 μM), silicate-Si (0.6 to -19.86 μM), phosphate-P (0.07 to 10.3 μM) and particulate organic carbon (1.46 to 85.43 mg/l) were reported (Paramasivam and Kannan, 2005).

Assessment of the physico-chemical and biological characteristics of the mangrove waters, south of Chennai has been carried out and reported. The ranges of various parameters studied were water temperature (22 to 33°C), salinity (2 to 29.5%), dissolved oxygen (3.8 to 8.2 mg/l), pH (7.2 to 9.2), nitrate (9.2 to 27.3 pM) and inorganic phosphate (1.6 to 28.9 pM). The study concluded that seasonal mean values of most of the parameters recorded at both the stations were found to be high during the summer and low during the monsoon season (Ajith Kumar et al., 2006).

Physicochemical attributes of soil along the mangrove habitats of Andaman islands have been reported. The range of various parameters reported was pH (4.1 to 6.7), organic carbon (14.1 to 24.6 mg/g), clay (19 to 27 %) and total nitrogen (2.01 to 2.81 mg/g). The range of various elements such as Potassium (1.12 to 1.35 Cmol/ kg), Calcium (6.7 to 7.9 Cmol/ kg), Magnesium (3.2 to 3.8 Cmol/ kg) and Sodium (8.2 to 12.7 Cmol/ kg) have also been reported (Ghoshal et al., 2009).

Studies have been conducted to evaluate the seasonal variations in physico-chemical characteristics of Pichavaram mangroves, southeast coast of India. Attributes such as temperature, salinity, pH, dissolved oxygen and nutrients like nitrate, nitrite, inorganic phosphate and reactive silicate have been assessed from various sites within the habitat for a period of 2 years. The ranges of all the parameters reported were surface water temperatures (26 to 37^{o}C), salinity (3.0 to 33.0%), dissolved oxygen (2.4 to 5.0 mg/l), nitrates (9.50 to 32.12 mM) and phosphates (0.73 to 2.36 mM). The role of various parameters studied on the proliferation of mangroves has also been discussed (Ashok Prabhu et al., 2008).

Both water and sediment in arid zone mangroves of Kachchh-Gujarat have been subjected to physico-chemical characterization for a period of one year to elucidate their seasonal variations (Saravanakumar et al., 2008). Variation among almost all the attributes studied has been noticed. Surface water temperatures (17 to 37^{0}C), sediment temperatures (18.4 to 37^{0} C), salinity (34.0 to 44 ppm), and the pH in water and sediment ranged between 7.0 and 8.9 and 6.29 and 8.45 respectively. The ranges of other nutrients reported were nitrate (0.23 to 7.26 microM), nitrite (0.04 to 0.87 microM), phosphate (0.13 to 3.12 microM) and reactive silicate (4.23 to 19.02 microM), total organic carbon (0.29% to 2.56%), total inorganic phosphorus (0.12 mg/g to 1.97 mg/g) and total nitrogen (0.02 mg/g to 1.95 mg/g). All the three stations studied were reported for sediment texture, which ranged in terms of % of sand, clay and silt as 0.26 to 19.2; 7.6 to 47 and 47 to 87.4 % respectively. The texture triangle studies have revealed that the nature of soil in all the locations studied were silty loam, silty clay and silty clay loam (Saravanakumar et al., 2008).

Studies were carried out to assess the seasonal variations in physico-chemical attributes of water and sediment samples from Pondicherry mangroves along southeast coast of India (Satheeshkumar and Anisa Khan, 2009). The range of various attributes reported were atmospheric and surface water temperatures (17.9 to 41.7 and 16.66 to 37.91 respectively), annual rainfall and relative humidity (1.1 to 808 mm and 37 to 100% respectively), salinity (6.36 to 36.77ppt), dissolved oxygen (3.45 to 5.49 mg/l), pH (7.11 to 8.52), electrical conductivity (26.65 to 52 ms), sulphide (2.76 to 47.16 mg/l), soil parameters such as sand (63.69 to 87.31%), silt (9.89 to 29.32 %), clay (3.06 to 17.98 %) and organic matter (0.94 to 3.94 %). Positive correlation has been noticed between growth of mangroves and attributes like pH, temperature, salinity, sand, silt, clay and organic matter (Satheeshkumar and Anisa Khan, 2009).

Krishna Mohan et al. (2012) studied the water quality of Bhavanapadu mangrove habitats of north coastal Andhra Pradesh. Samples were collected from three locations in the post monsoon season to elucidate various physico-chemical parameters of water. The result revealed that, there have been considerable variations in the parameters such as pH, EC and TDS and nutrients like NO_3 and PO_4.

Yang et al. (2013) reported the response of mangroves to sedimentary patterns in the mangrove habitats of north Island of New Zealand. Vegetation and sediment characteristics were studied across seasons for a period of one year. Low ranges of pH were reported from all the locations. The ranges of total organic carbon of the sediments were reported to be higher from all the sites. The study also reported that the two parameters determined the growth of mangroves.

Rahman et al. (2013) reported the quality parameter of water within the world’s largest mangrove forest located at Sundarbans, Bangladesh. The ranges of the important water quality attributes reported were dissolved oxygen (6.0 to 7.33 mg/l), TSS (10.8 to 19.7 g/l), TDS (3.5 to 53.3 g/l), chloride (12.5 to 4672 mg/l), sulphate (9.02 to 968.3 mg/l), magnesium (4.86 to 583.2 mg/l), sodium (329 to 8839 mg/l) and potassium (45.15 to 992.0 mg/l). The study as a whole reported that the water quality parameters of the river were acceptable for the growth of mangroves during rainy season. However, moderate to high values of these parameters appeared for winter and summer seasons were not found to influence the growth of mangroves (Rahman et al., 2013).

Diverse mangrove habitats along the southeast coast of India have been subjected to studies pertaining to various physico-chemical parameters. Assessment of temperature, pH, salinity, dissolved oxygen and nutrients, that can influence the growth of mangrove species were worked out. The ranges of some of the important attributes reported were atmospheric temperature 25.0 to 29.9°C, water temperature 26.0 to 30.2°C, salinity 24.0 to 34.0 ppt, water pH 7.4 to 8.2, turbidity 43.0 to 260.0 NTU, TDS 82.0 to 522.0 mg/l, total phosphorus 1.32 to 2.893 µmol/l and total nitrogen 5.123 to 38.916 µmol/l (Srilatha et al., 2013).

Distribution status of nutrients on a seasonal basis has been studied at the Rupsha-Passur tidal river system of the Sundarbans mangrove forest, Bangladesh. Different ranges of parameters such as nitrate, phosphate, sulphate have been reported. Sulphate was coming in the range 7.301 to 126.92 mg/l. Likewise, phosphate (0.314 to 1.347 mg/l) and nitrate (0.083 and 1.233 mg/l) were also fluctuated. The study also reported that semidiurnal tidal activity has resulted in daily fluctuations in nutrient concentrations and other physicochemical properties of water (Rahaman et al., 2014).

Studies have been carried out to evaluate the hydrogeochemical attributes on mangrove forests at Pichavaram, South India. Water samples were collected during pre-monsoon and post-monsoon seasons to evaluate the role of rain and seawater in the hydro-geochemical processes. To define the variations and the genetic origin of chemical parameters of water in mangrove ecosystem, geochemical model, WATEQ4F involving Piper diagram and multivariate statistical methods of data analysis were jointly used. Grouping of waters on the Piper diagram showed a common composition and origin. Further results revealed that pre and post monsoon samples mainly contained Na–Cl and Ca–Cl water type, indicating a significant contribution of cations and anions from terrestrial and marine inputs in the mangrove ecosystem (Kumar et al., 2015).

Studies pertaining to the physico-chemical attributes of water within the east Godavari mangrove ecosystem, Andhra Pradesh have been carried out and reported. Monthly analysis of influential water quality parameters were analyzed for a period of two years. The results revealed the ranges of all parameters studied, such as temperature (26 to 33.8^{0}C), pH (7.15 to 8.5), salinity (0 to 24 ppt), dissolved oxygen (4 to 7.8 mg/l), ammonia (0.05 to 1.2 mg/l), alkalinity (80 to 340 mg/l), nitrite (0.01 to 1mg/l), hardness (110 to 3500 mg/l), calcium (80 to 250 mg/l) and magnesium (180 to 450 mg/l) (Jarugulla and Krishna, 2017).

Restoration of mangroves are greatly depend on physico-chemical properties of sediments and it also mediates the nutrient recycling. Sahoo et al. (2017) studied the physico-chemical parameters of sediment in the mangrove habitats of Odisha, India. Sediment samples were collected from 5 locations and analyzed. The ranges of some of the important sediment characters reported were pH (4.32 to 8.77), salinity (0.39 to 4.63 PSU) and organic carbon (6.7 to 51.86 mg/g).

In Kerala, several studies have been conducted to elucidate the role of various physico chemical attributes of water and sediment on the growth of mangroves. Physico - chemical characteristics of Cochin backwaters and its implications on the growth of mangroves have been reported by Sreedharan and Salih (1974). Seasonal variation in the hydrographic conditions of mangrove areas of Cochin backwaters have been reported by Balakrishnan and Shynamma (1976). Chapman (1977) reported the role of temperature as an important determinant of growth and proliferation of different mangrove species. The extreme high levels of organic carbon, phosphorus and nitrogen from the sediment of Cochin back waters and their positive impact on the establishment of mangroves have been reported (Sankaranarayanan et al., 1979).

Studies have been carried out to evaluate the physico - chemical parameters of mangrove habitats from the backwaters of Thrissur district. Among different sites, all the parameters were noticed to be fluctuating during different seasons. The range of various parameters reported were pH (7.03 to 7.34), temperature (25 to 31^0C) and total hardness (30 to 52 mg/ l). The ranges of salinity during pre monsoon and monsoon seasons were 19.88 to 31.24 ppt and 19.88 to 28.4 ppt respectively (Saritha and Tessy, 2011).

Detailed study on the mangrove ecosystems of Kerala with respect to their water quality parameters has been conducted and reported. Seasonality based collection of water has been carried out from 5 natural habitats of mangroves. The mean values of all the parameters studied with respect to pre monsoon, monsoon and post monsoon seasons were pH (7.20 to 8, 7.81 to 8.05 and 7.1 to 7.4), salinity (29.31 to 35.97 psu, 0.24 to 26.64 psu and 4.26 to 9.25 ppt), alkalinity (121.25 to 167.33 mg/l, 22.31 to 83.42 mg/l and 44.55 to 79.20 mg/l), total nitrogen (10.26 to 102.78 µM, 124.78 to 188.38 µM and 34.55 to 63.69 µM), total phosphorous (1.53 to 6.65 µM, 10.04 to 22.88 µM and 2.96 to 8.61 µM), calcium (148.37 to 453.13 mg/l, 8.02 to 108.27 mg/l and 21.78 to 172.51 mg/l), magnesium (616.65 to 1362.8 mg/l, 8.63 to 621.09 mg/l and 65.44 to 540.23 mg/l), sodium (4000 to 7400 mg/l, 50 to 2600 mg/l and 434 to 2523 mg/l), potassium (160 to 320 mg/l, 3.3 to 130 mg/l and 18 to 105 mg/l) and sulphate (1700 to 4166.67 mg/l, 12 to 966.67 mg/l and 235.24 to 1086.5 mg/l). The study reported that the five locations showed variations with respect to different water quality parameters, which has resulted in changes in mangrove cover and its diversity (Manju et al, 2012).

Physico- chemical characterization of water samples from the Ayiramthengu mangrove habitats of Kollam district has been carried out and reported. The results revealed that pH of soil ranged from slight to strong acidic (5.4 to 6.1), EC from 1.72 to 2.14 mS/m. Slight difference in temperature among the sites has also been noticed. Slightly alkaline, high DO, medium hardness and highly saline water, along with other components of a typical mangrove ecosystem has also been reported (Praseetha and Rajani, 2015).

Growth sustaining conditions of mangrove species along selected shoreline environments of Malappuram district, Kerala has been worked out and reported. Both water and sediment samples were estimated for their physico chemical attributes. Accordingly, tolerance limit of various water and sediment quality attributes towards the growth of mangrove species were estimated (Shilna et al., 2016).

Though studies have been carried out globally and nationally on the physico chemical aspects of marine, estuarine and back water sediment and water samples on the growth of mangroves, there is a paucity of information on the physico chemical characteristics of growth sustaining conditions from the mangrove ecosystems of Kerala. Also there is a dearth of information on the specific growth requirements of selected mangrove species from the coastal environments of Kerala. In this light, an attempt has been carried out to assess the growth requirements of selected mangrove species and to assess the key factors responsible for their growth and establishment in heterogeneous coastal environments of Kerala. Such information is likely to give way for the conservation and management of existing mangrove habitats of Kerala and also to formulate strategies for their introduction in ideal environments falling in the coastal stretch of Kerala.

Materials and Methods

Successful restoration/afforestation practices of mangroves require reliable information on their growth supporting conditions. The present study has been carried out to evaluate various geo environmental and climatological parameters responsible for the growth of selected mangrove species. Evaluation of the physico-chemical characteristics of water and soil / sediment along with climatological attributes associated with specific mangrove species were worked out monthly for a period of one year for deriving conclusions regarding their growth requirements. The details regarding mangrove species, study area, sampling of specimens and methods of analysis are summarized in the following sessions.

Heterogeneous natural habitats confining to the coastal environments of Kerala have been selected for assessing the growth sustaining conditions of 5 true mangrove species; *Avicennia officinalis, Bruguiera cylindrica, Excoecaria agallocha, Rhizophora mucronata* and *Sonneratia alba*. Three sampling sites have been fixed for each mangrove species at varying locations (Figure 2.1). The physico chemical characteristics of sediment and water samples from three heterogeneous locations were monitored monthly for each mangrove species for a period of one year. The details of mangrove species selected and habitats monitored are given in Table 2.1.

Table 2.1. Study sites for selected mangrove species.

Sl. No:	Location	District	Latitude	Longitude
(i) *Avicennia officinalis*				
S1.	Kumbalam	Ernakulam	9°54'15.68"N	76°18'46.59"E
S2.	Kadalundi	Malappuram	11°07'42.49"N	75°49'53.31"E
S3.	Thekkumbad	Kannur	11°58'00.10"N	75°17'49.27"E
(ii) *Bruguiera cylindrica*				
S4	Ayiramthengu	Kollam	9°07'28.93"N	76°28'39.18"E
S5	Kadalundi	Malappuram	11°07'53.40"N	75°49'45.79"E
S6	Thekkumbad	Kannur	11°58'00.12"N	75°17'50.14"E
(iii) *Excoecaria agallocha*				
S7	Ayiramthengu	Kollam	9°07'28.71"N	76°28'38.89"E
S8	Kumbalam	Ernakulam	9°54'15.02"N	76°18'45.49"E
S9	Thekkumbad	Kannur	11°58'00.71"N	75°17'49.79"E
(iv) *Rhizophora mucronata*				
S10	Ayiramthengu	Kollam	9°07'28.74"N	76°28'39.44"E
S11	Kumbalam	Ernakulam	9°54'22.16"N	76°18'42.21"E
S12	Thekkumbad	Kannur	11°58'02.87"N	75°17'45.38"E
(v) *Sonneratia alba*				
S13	Kadalundi 1	Malappuram	11°07'35.14"N	75°49'51.77"E
S14	Kadalundi 2	Malappuram	11°07'35.42"N	75°49'50.72"E
S15	Thekkumbad	Kannur	11°58'04.32"N	75°17'45.38"E

Details of mangrove species selected are as follows:

a) *Avicennia officinalis* L. (Avicenniaceae)

Avicennia officinalis (Plate 2.1) is a fast growing shrub / tree, mostly found in the lower intertidal estuarine zones. It is a shade intolerant species, grows on soft, recently consolidated mud banks; with a maximum pore water salinity tolerance limit that of hypersaline conditions (Tomlinson, 1986).

Habit: Greatly branched, medium sized, evergreen trees to 10 m high, with occasional stilt roots; radial cable roots producing numerous pneumatophores which are whitish brown in color; brownish grey or whitish grey smooth stem barks, pale brown or pale green colored terate and glabrous twigs with conspicuous and swollen nodes.

Leaves: Simple and exstipulate leaves possess pale - green petiole with deep basal groove which are covered with dark or black marginal hairs. Opposite and decussate, 3- 10 x 2.5 – 5 cm, ovate, broadly elliptic - obovate, cuneate at base and obtuse at apex, glabrous above, silvery white tomentose beneath, coriaceous shiny green above; midrib prominent beneath with inconspicuous lateral veins.

Inflorescence: Terminal or axillary compound spikes in which flowers are decussately arranged in dense capitates units, each with 10 – 12 flowers; fragrant, sessile, bisexual and slightly zygomorphic flowers; bracts and bracteoles persistent in the fruit; Brownish green persistent calyx, 5 unequal sepals with slight union at base; Gamopetalous corolla with thick, fleshy yellow petals fused basically to form a tube, glabrous within and dense silvery pubescent outside. Epipetalous stamens, as many as and alternating with corolla lobes, very short filaments fused basically with corolla lobes; basifixed, bilobed, longitudinally dehiscing anthers; superior ovary, imperfectly locular with 4 ovules which are pendulous.

Fruit: Grayish green or yellowish green mango shaped fruit with persistent bract, bracteoles and calyx. Broad, flattened and apex pointed with persistent stylar beak. One seeded; seed shows incipient vivipary. (Mature capsule open by two valves, releasing the propagule on to the ground and the propagule develop into young plant within a few days).

Flowering and Fruiting: April – November.

The present study monitored three natural habitats of *Avicennia officinalis* falling in the coastal stretch of Kerala, such as Kumbalam 1 of Ernakulam district (9°54'15.68"N: 76°18'46.59"E), Kadalundi 1 of Malappuram district (11°07'42.49"N: 75°49'53.31"E) and Thekkumbad 1 of Kannur district (11°58'00.10"N: 75°17'49.27"E).

b) *Bruguiera cylindrica* (L.) Blume (Rhizophoraceae)

Bruguiera cylindrica **(**Plate 2.2**)** is a shade tolerant species (Robertson and Alongi, 1992), found in the downstream and intermediate estuarine zones of mid-intertidal region. The species is widespread and common within its range including some marine and coastal protected areas.

Habit: Greatly branched, medium sized to tall evergreen trees to 6m high, with occasionally buttressed stem base, underground cable roots producing numerous knee roots; greyish, lenticellate, cracked smooth stem barks; bronze or occasionally green colored terate and glabrous twigs with conspicuous nodes and stipular scars.

Leaves: 4 – 13 x 2 – 5.5 cm, simple, stipulate, petiolate, opposite and decussate leaves possess two reddish colored overlapping stipules and reddish colored, terate petiole; elliptic to elliptic oblong or ovate- lanceolate, cuneate at base and acute at apex, reddish green colored above, pale green beneath; prominent midrib beneath with inconspicuous lateral veins.

Inflorescence: Unbranched three flowered axillary cyme, rarely cyme branched to form upto six flowers, with sessile flowers usually; inconspicuous bracts and connate bracteoles form a stubby ring on which the flowers rest; greenish white calyx with basally fused sepals form prominent calyx tubes, which are smooth, glabrous and enclosing the ovary, calyx lobes are fleshy and persistent in fruit. Petals are as many as and alternating with the calyx lobes, free, shortly stalked, white colored, turning brown after anthesis and these longitudinally folded petals enclosing a pair of stamens. Stamens double the number of petals and free, but seen in groups of two. Each group of stamens possesses filaments of unequal length. Anthers are basifixed, long, mucronata and bilobed, dehiscing longitudinally. Ovary is semi inferior with 2 locules, the ovules in each locule is 2 with pendulous placentation.

Fruit: Drupe; Ovoid in shape with reddish green, glabrous, persistent calyx lobes reflects at maturity. One seeded; seed exhibiting vivipary. (Mature viviparous seedlings fall on the ground and develop into a young plant within a few days).

Flowering and Fruiting: December – October.

The present investigation focused on three natural habitats of *Bruguiera cylindrica,* which include Ayiramthengu 1 of Kollam district ($9^0$07'28.93"N: $76^0$28'39.18"E), Kadalundi 2 of Malappuram district (11°07'53.40"N: 75°49'45.79"E) and Thekkumbad 2 of Kannur district (11°58'00.12"N: 75°17'50.14"E).

c) *Excoecaria agallocha* L. (Euphorbiaceae)

Excoecaria agallocha (Plate 2.3) is a small to medium sized back mangrove species and often exploits open areas along with some marine and coastal protected regions. This species is widespread, common and can be decidiuous in cooler/drier areas. Coastal development has created some localized threats and decline in overall population has been reported.

Habit: Small to Medium sized trees with 10 m high, much branched dioecious trees with milky latex, sometimes, branching is from the base, hence shrubby with a bushy appearance; many superficial lateral roots are spreading, intermingling and exposed during low tides, a prominent main root is absent; greyish to pale brown stem barks with smooth lenticels; brownish green or occasionally green, terate and glabrous twigs.

Leaves: alternate, 3 – 13 x 1.5 – 5 cm, spirally arranged, simple, stipulate and petiolate; minute stipules as lateral triangular scales present on each side of the petiole; terate and green petiole with ovate, ovate- elliptic, or ovate – oblong, cuneate or obtuse and with a pair of glands at base, shiny green colored above, turning red before shedding, pale green beneath; prominent midrib beneath with 8 – 14 pairs lateral veins.

Inflorescence: Unisexual, axillary, pale green, initiated as catkin like structures within the leaf bearing portion of the shoot. Male spikes of 3.5 – 12.5 cm long, 2 – 3 together in an axil with a series of spirally arranged bracts; each bract subtending 1 male flower; one bracteole each present on either side of the flower; Male flowers almost sessile, cream colored; 3 tepals, narrow and lanceolate; 3 yellow stamens; anthers are long, basifixed to almost versatile, bilobed, dehiscing longitudinally; Female inflorescence is a raceme, 4 – 8 cm long, usually shorter than the male inflorescence; shortly pedicellate female flowers are with the inflorescence. Bract and bracteoles is present, superior ovary with 3 locules, ovules 1 in each locule, pendulous.

Fruit: capsule of 4 – 6 x 8 – 12 mm, depressed globose, crustaceous, 3 celled.

Flowering and Fruiting: November – February.

The present study was carried out in three heterogeneous natural habitats of *Excoecaria agallocha*, falling in Ayiramthengu 2 of Kollam district (9^{o}07'28.71"N: 76^{o}28'38.89"E), Kumbalam 2 of Ernakulam district (9°54'15.02"N: 76°18'45.49"E) and Thekkumbad 3 of Kannur district (11°58'00.71"N: 75°17'49.79"E).

d) *Rhizophora mucronata* Lam. (Rhizophoraceae)

Rhizophora mucronata **(**Plate 2.4**)** is a widespread common mangrove species (along marine and coastal protected areas) found in the intermediate to upstream estuarine zone in the lower to mid-intertidal region and more to the seaward side. This species tolerates a maximum salinity of 40 ppt and the salinity for optimal growth has been reported as 8-33 ppt (Robertson and Alongi, 1992). This is a fast-growing, hardy species that is easily propagated and is one of the preferred species for restoration programs.

Habit: Greatly branched small evergreen trees to 8 m high, profusely spread branches; trunk and lower branches supported by numerous lenticellate, corky, profusely looping stilt roots and prop roots; Brown and longitudinally fissured stem bark.

Leaves: 10 - 15 x 5 – 9 cm, simple, stipulate, petiolate, opposite and decussate, elliptic to ovate; dark green above and pale green beneath with numerous black dots; interpetiolar, pale green with pinkish tinge on stipules; petiole cuneate at base and mucronate at apex, green above, pale green beneath; prominent midrib beneath with 8 pairs of lateral veins.

Inflorescence: axillary cymes, opposite, decussate, dichotomously or trichotomously branched or unbranched, 2 - 4 flowered, main peduncle upto 3 – 5 cm long. Flowers 2.5 cm long, 1.5 cm across, sessile, bracteate; bract small, connate; bracteoles 2, connate; yellowish white calyx enclosing the base of the pistil; lobes 4, thick, fleshy; petals 4, white lanceolate, densely white hairy along the margin; 8 free stamens, free, sessile, 4 stamens opposite to the petals and 4 to the calyx tubes; semi inferior, 2 loculed ovary, ovules 2 in each locule, pendulous in placentation.

Fruit: 5 –7 cm long, ovoid or conoid, brown pericarp, reflexed calyx lobes, 1 seeded. (Mature viviparous seedlings fall on the ground and develop into a young plant within a few days).

Flowering and Fruiting: Mostly throughout the year.

The present investigation was carried out in three natural habitats of Rhizophora mucronata, which include Ayiramthengu 3 of Kollam district ($9^{0}07'28.74''$N: $76^{0}28'39.44''$E), Kumbalam 3 of Ernakulam district ($9^{o}54'22.16''$N: $76^{o}18'42.21''$E) and Thekkumbad 4 of Kannur district ($11^{o}58'02.87''$N: $75^{o}17'45.38''$E).

e) *Sonneratia alba* Sm. (Sonneratiaceae)

Sonneratia alba **(**Plate 2.5**)** is a widespread and common species found in the low-intertidal zone. It is intolerant of long periods of freshwater, and prefers high salinity. It is a pioneering species that is fast growing, but has low seed-viability. In the low intertidal zone, it can be the dominant species along with *A. marina*, forming a tree line along the seaward margin of its range. It prefers soils of consolidated mud and sand.

Habit: Greatly branched small evergreen trees to 9 m high; radial cable roots are with pneumatophores, 75 x 0.8 cm, straight, stout, conical, outer thin layer flaky, yellowish – brown; cracked brown bark; swollen nodes with 2 lateral pairs of circular glands.

Leaves: 4.5 - 11 x 3 – 9 cm, simple, opposite, broadly elliptic, ovate or sub orbicular; lateral nerves looped near the margin forming intramarginal nerve, estipulate; white or pink petiole, cuneate at base and obtuse at apex.

Flowers: White flowers, to 6.5 – 8 cm, in terminal axillary or leaf opposed clusters of 2 or 3, rarely solitary; calyx green outside, white within ; calyx cup angular, lobs oblong, thick, persistent; petals linear, white with reddish tinge towards apex, membraneous, glabrous; numerous white thread like, free stamens inflexed in bud; reniform anthers; style coiled in bud.

Fruit: a drupe, to 4 cm across, green, flattened above with reflexed calyx and style with a depression around the stylar base. Smooth pericarp; many seeded.

Flowering and Fruiting: Feb-July.

The present investigation focused on three heterogeneous natural habitats of *Sonneratia alba* in Kerala, such as Kadalundi 3 (11°07'35.14"N: 75°49'51.77"E) and Kadalundi 4 of Malappuram district (11°07'35.42"N: 75°49'50.72"E) and Thekkumbad 5 (11°58'04.32"N: 75°17'45.38"E) of Kannur district.

Sample Collection and Analysis

In order to standardize the growth sustaining conditions of selected mangrove species, samples of water and soil / sediment were collected from three heterogeneous natural habitats for each mangrove species. Samples were collected on a monthly basis from all the locations under study, for a period of one year from June 2013 to May 2014. The surface water samples from mangrove habitats were collected in sampling bottles and were brought to laboratory for the analysis of various parameters like pH, turbidity, total solids, total dissolved solids, total suspended solids, salinity, resistivity, conductivity, acidity, alkalinity, total hardness, calcium, magnesium, chloride, sulphate, sodium, total nitrogen, phosphorous and potassium. All the parameters were analyzed following standard procedures (Trivedy et al., 1987 and APHA, 2005) as given below.

a) pH (Electrometric method)

pH of the collected water samples were measured electrometrically using a pH meter (Systronics, MK IV).

b) Turbidity (Nephelometric method)

Turbidity of samples was determined by Nephelometric method using a Digital Nephelometer (Systronics, Model 341). The results are presented in NTU.

c) Total solid (TS) (Gravimetric method)

Total solid content measure the amount of all kinds of solids (suspended, dissolved, volatile, etc.) in water. Total solids can be determined as the residue left after evaporation of the unfiltered sample. For the present study, evaporating dishes of suitable size were taken and weighed. 100 ml of respective unfiltered water samples were taken and evaporated to dryness in an oven. After evaporation, the samples were heated at 103ºC for 1 hour in a hot air oven (Rotek, Model 07253). These were then cooled in a desiccator and weighed. Total solids (mg/l) were estimated, following the equation:

$$\text{Total solid, mg/L} = \frac{(a - b) \times 1000 \times 1000}{v}$$

Where,

a = Final weight of the dish in g.

b = Initial weight of the dish in g.

v = volume of sample evaporated in ml

d) Total Dissolved Solid (TDS) (Gravimetric method)

Total dissolved solids measure various kinds of minerals present in water. It can be determined as the residue left after evaporation of the filtered sample. Evaporating dishes of suitable size were taken and weighed. 100 ml of respective samples were filtered through Whatmann filter paper and evaporated to dryness in an oven. After evaporation, the samples were heated at 103ºC for 1 hour in a hot air oven (Rotek, Model 07253). These were then cooled in a desiccator and weighed. Total dissolved solids (mg/l) were estimated by the following equation:

$$\text{Total dissolved solid, mg/L} = \frac{(a - b) \times 1000 \times 1000}{v}$$

Where,

a = Final weight of the dish in g.

b = Initial weight of the dish in g.

v = volume of sample evaporated in ml

e) Total Suspended Solids (TSS) (Gravimetric method)

TSS indicates the suspended impurities present in water and in most of the cases, they are of organic in nature. TSS is the difference between TS and TDS present in water. Total Suspended Solids (mg/l) were calculated by the following equation:

$$TSS = TS - TDS$$

f) Salinity

Salinity is the measure of all the salts dissolved in water and is usually measured in parts per thousand (ppt). Salinity in the present study was measured using Eutech Cyber Scan Series water sample analyzer (Eutech PCD, 650). The results are represented in ppt.

g) Resistivity

Electrical resistivity was measured using Eutech cyber scan series water sample analyzer (Eutech PCD, 650). The results are presented in ohms (Ω).

h) Electrical Conductivity

Electrical Conductivity (EC) is a measurement of the dissolved materials in an aqueous solution, which relates to the ability of the material to conduct electrical current through it. EC was measured using Eutech cyber scan series water sample analyzer (Eutech PCD, 650). The results are depicted in milli Siemens (mS) per unit area.

i) Acidity (Titrimetric method)

It is measure of the aggregate property of water to react with a strong base at a particular pH. In natural waters, the most important attribute that imparts acidity are carbon dioxide.

Reagents

1. 0.05N Sodium hydroxide
2. Phenolphthalein indicator

Procedure

To 100 ml of water sample in conical flask, added few drops of Phenolphthalein indicator and mixed well. The contents were titrated against 0.05N Sodium hydroxide taken in the burette. The end point was noticed at the appearance of pink color. Acidity was calculated as:

$$\text{Acidity, mg/L} = \frac{(\text{ml x N}) \text{ of NaOH x 1000 x 44}}{\text{ml sample}}$$

j) Total alkalinity (Titrimetric method)

Alkalinity of the water is the capacity to neutralize a strong acid and is characterized by the presence of all hydroxyl ions. The free hydroxyl groups impart alkalinity in natural waters. Such ions are also formed in water due to the hydrolysis of salts such as carbonates and bicarbonates.

Reagents:

1. 0.1N Hydrochloric acid
2. 0.1N Sodium Carbonate
3. Methyl orange indicator

Procedure:

100ml of water sample was taken in conical flask and added 2-3 drops of methyl orange indicator. Mixed well and titrated the contents against 0.1N HCl taken in the burette. The end point was noted as color change from yellow to pink.

$$\text{Total alkalinity as } CaCO_3\text{, mg/L} = \frac{\text{(ml x N) of HCl x 1000 x 50}}{\text{ml sample}}$$

k) Total hardness (Titrimetric method)

Both cations and anions are responsible for hardness of water. The important cations imparting hardness in water are calcium and magnesium. Anions like carbonates, bicarbonates and sulphates are the major anions imparting hardness to water.

Reagents

1. 0.01 M EDTA solution
2. Buffer solution- Mixture of Ammonium chloride, Ammonium hydroxide and disodium EDTA.
3. Eriochrome Black T indicator

Procedure

To 50 ml of water sample in conical flask, added 1 ml of buffer solution. This was followed by 100 mg of Eriochrome Black T indicator and mixed well. Development of a wine red color was noticed. The contents were then titrated against EDTA solution taken in the burette. The end point was noticed as color change from wine red to blue.

$$\text{Total Hardness as } CaCO_3\text{, mg/L} = \frac{\text{ml EDTA used x 1000}}{\text{ml sample}}$$

l) Calcium (Titrimetric method)

Calcium is one of the most abundant elements imparting the hardness to the natural water. At high pH, much of the quantities may get precipitated as $CaCO_3$.

Reagents

1. 0.01M EDTA solution
2. 1N Sodium hydroxide
3. Murexide indicator- Mixture of 0.2 g ammonium purpurate and 100g of NaCl.

Procedure

50 ml of sample was taken in a conical flask; added 2 ml sodium hydroxide solution and approximately 100 mg of Murexide indicator to it. Development of a pink color was observed. Titrated the solution against 0.01 M EDTA, until the color changed to purple.

$$\text{Calcium mg/L} = \frac{\text{ml EDTA used x 400.8}}{\text{ml sample}}$$

m) Magnesium (Titrimetric method)

Magnesium is also one of the important cations imparting hardness to the water, but its concentration remains generally lower.

Reagents

1. 0.01M EDTA solution

2. Buffer solution- Mixture of Ammonium chloride, Ammonium hydroxide and disodium EDTA

3. Eriochrome Black T indicator

4. 1N Sodium hydroxide

5. Murexide indicator- Mixture 0.2 g ammonium purpurate and 100g of NaCl.

Procedure

Magnesium is determined as the difference between Ca + Mg titration and the titration alone for calcium. In the present study, titrated a constant volume of sample for calcium and also for total hardness, found out the volume of EDTA used for both the titrations separately.

$$\text{Magnesium mg/L} = \frac{(y - x) \times 400.8}{\text{ml sample} \times 1.645}$$

Where, x = EDTA used for calcium determination

y = EDTA used for total hardness (Ca + Mg)

n) Chloride (Argentometric method)

Chlorides are present in all natural waters. Sewage discharges into the water bodies will enhance the chloride content.

Reagents

1. 0.02 N Silver nitrate

2. 5% potassium chromate solution

Procedure

To 50 ml of water sample, added 2 ml of 5% potassium chromate solution and mixed well. Titrated the contents against 0.02 N Silver nitrate solution taken in the burette. Appearance of reddish brown color persisting for 30 seconds was noted as the end point.

$$\text{Chloride, mg/L} = \frac{(\text{ml x N}) \text{ of } AgNO_3 \text{ x } 1000 \text{ x } 35.45}{\text{ml sample}}$$

o) Sulphate (Turbidimetric method)

Sulphate is a naturally occurring anion found in almost all kinds of water bodies. It may undergo transformation to sulphur or hydrogen sulphide, depending largely upon the redox potential of the water. It also imparts hardness to water to a certain extent.

Reagents

1. Conditioning reagent- mixed 50 ml of glycerol to the solution prepared by mixing 75 g of NaCl, 30 ml concentrated HCl, 100 ml 95% ethyl or isopropyl alcohol in 300 ml distilled water.

2. Barium chloride

3. Standard sulphate solution- Dissolved 0.1479 g of anhydrous Na_2SO_4 in distilled water to prepare 1 litre of solution and the solution contains 100 mg of sulphate.

Procedure

To 100 ml of clear sample, added 5 ml of conditioning reagent and stirred well. Added about one spatula of $BaCl_2$ crystals and stirred for 1 minute. Optical density was measured with a spectrophotometer at 420 nm, exactly after 4 minutes and found out the sulphate concentration from the standard graph.

p) Sodium (Flame photometric method)

Sodium is an important cation occurring naturally in water and domestic sewage is one of the most important sources of sodium to the fresh waters. Sodium with chlorides and sulphates make the water unpalatable.

Reagents

1. Stock sodium solution (1000mg/L) - dissolved 2.542 g NaCl in distilled water to make 1 litre of solution.

2. Intermediate sodium solution (100mg/L) – Dilute the stock solution to 10 times.

3. Standard sodium solution (10 mg/L) - Dilute the intermediate solution further 10 times.

Procedure

The concentration of sodium present in the sample was estimated by using Flame Photometer (Systronics, 128). The instrument was calibrated with a higher and lower concentration of standard sodium solution. All the samples were analyzed in the instrument and the results are obtained in ppm concentration.

q) Total Nitrogen (Kjeldahl Method)

The nitrogen content of water is one of the measures used to evaluate its purity. Kjeldahl method is the most common, reliable and economical method for nitrogen estimation.

Reagents

1. Catalyst mixture – Mixture of Sodium sulphate and Cupric sulphate in 5 : 1 ratio

2. Concentrated Sulphuric acid

3. 40% NaOH

4. 0.32% Potassium permanganate

5. 4% Boric acid

6. Mixed indicators - Methyl red and Bromo-cresol green (1:2)

7. 0.1 N HCl

Procedure

Nitrogen content of the samples were analyzed using an automated nitrogen estimation system (KELPLUS, ELITE=EX (VA). The principle followed for estimating the nitrogen content of the sample is Kjeldahl method. Analysis was carried out as per the manual of the instrument given below.

a) Digestion

In order to digest the water sample, 2 spatula of catalyst mixture and 10 ml of concentrated sulphuric acid was added to 10 ml of sample and subjected to digestion within the infra digestion unit of the Kelplus nitrogen estimating system. The sample attained a green color, when it was fully digested. The samples were allowed to cool and diluted with distilled water for further analysis.

b) Distillation

The diluted sample was placed in the distillation system for ammonia recovery using ammonia trapping solution (Boric acid and mixed indicator).

c) Titration

After trapping all ammonia present, the resultant solution was titrated against 0.1 N HCl for estimating the total nitrogen content.

Total nitrogen was estimated using the formula;

$$\% \text{ Nitrogen} = \frac{14.01 \text{x (ml titrant – ml blank) x N x } 100}{\text{Sample volume x}1000}$$

r) Total Phosphorous (Stannous chloride method**)**

Phosphorous mostly occurs as phosphates in natural waters. It is necessary for the growth of organisms and can be the nutrient that confines primary productivity to a water body. Phosphorous estimation generally includes two steps; (a) conversion of any form of phosphorous to dissolved orthophosphates and (b) spectrophotometric determination of the orthophosphate. The first step is accomplished through persulphate oxidation technique and the second one through stannous chloride method.

Reagents

1. Sulfuric acid solution- added 300 ml of concentrated sulfuric acid to about 600 ml of distilled water. Cooled and diluted to 1 litre with distilled water.

2. Ammonium molybdate solution - Dissolved 25 g of $(NH_4)6Mo_7O_{24}$. $4H_2O$ in 175 ml of distilled water. Added 280 ml of concentrated sulfuric acid slowly to 400 ml of distilled water. Cooled and added molybdate solution to the acid solution and diluted to 1 liter.

3. Stannous chloride solution: Dissolved 2.5 g of fresh $SnCl_2$-$2H_2O$ in 100 ml of glycerol. Heated in water bath and stirred with a glass rod to hasten dissolution.

4. Potassium persulfate as the analytic reagent.

Procedure

1 ml of sulfuric acid solution and 0.4 g of potassium persulfate was added to 50 ml of sample and boiled gently for 30 minutes until a volume of 10 ml was reached. Diluted the sample to 50 ml with distilled water. 2 ml of ammonium molybdate solution and 3 drops of stannous chloride solution were added to the sample and mixed well. Kept the samples for another 10 – 12 minutes and measured the optical density at 690 nm.

Compared the values with a calibration curve, using distilled water as blank. The concentration of phosphorous from the standard graph was calculated.

s) Potassium (Flame photometric method)

Potassium is also a naturally occurring element in water, but its concentrations remains quite lower than sodium, calcium and magnesium.

Reagents

1. Stock potassium solution (1000mg/L) - dissolved 1.907 g KCl in distilled water to make 1 litre of solution.
2. Intermediate sodium solution (100mg/L) – Diluted the stock solution to 10 times.
3. Standard sodium solution (10 mg/L) - Diluted the intermediate solution further to 10 times.

Procedure

The concentration of potassium present in the sample was estimated using Flame Photometer (Systronics, 128). The instrument was calibrated with a higher and lower concentration of standard potassium stock solutions. All the samples were analyzed in the instrument and the results are reported in ppm concentration.

Similar to water samples, soil / sediment samples from respective habitats were collected using a clean plastic spatula. Each sample was packed in a clean polythene bag, tightly closed and kept in an icebox. The collected samples were brought to laboratory for the analysis of various quality parameters like pH, moisture percentage, organic carbon, total nitrogen, total phosphorous, potassium, sodium and textural percentages of sand, silt and clay. All the parameters were analyzed following standard procedures (Jackson, 1973; Trivedy et al., 1987 and Subramanyam and Sambamurthy, 2002).

a) pH

pH is a good measure of acidity and alkalinity of a soil- water suspension and provides basic information about the chemical nature of soil. In order to determine the pH of soil/ sediment, a suspension was prepared (1:5 ratio) with distilled water and the pH was measured electrometrically using a pH meter (Systronics, MK IV).

b) Moisture percentage

Soil moisture content is determined by drying a known quantity of soil sample in an electric oven at 105^{o}C to 110 ^{o}C and finding out the loss of weight.

Procedure

10 g of sediment sample was taken in a clean, dry and pre weighed non corrodible air tight container and kept it in an electric oven at 105^{o}C for about 8 hours. Removed the container, allowed to cool and weighed it out quickly. Moisture % is then calculated as:

$$\text{Moisture \%} = \frac{(a_1 - a) - (b - a)}{(a_1 - a)}$$

Initial weight of the container	=	a
Weight of the container + sample	=	a_1
Initial weight of the sample	=	$(a_1 - a)$
Final weight of the container with sample	=	b
Final weight of the sample	=	$(b - a)$

c) Organic carbon

Organic carbon is the measure of total carbon in the soil / sediment sample. In the present study, organic carbon was estimated by a semi-quantitative method - Hydrogen Peroxide (H_2O_2) digestion method (Schumacher, 2002). Semi-quantitative methods are based upon the indiscriminant removal of all organic matter followed by gravimetric determination of sample weight loss. The hydrogen peroxide (H_2O_2) digestion method destroys the organic matter in the sample through oxidation.

Reagents

1. 30% Hydrogen peroxide

Procedure

A known volume of hydrogen peroxide (30%) was added to 20 g of sediment sample continually, until the sample frothing ceases. Once the digestion process was completed, the sample was dried at $105^{O}C$, cooled in a desiccator, and weighed. Organic carbon percentage was determined gravimetrically as follows:

$$\text{Organic carbon \%} = \frac{[(a_1 - a) - (c - a)]}{(a_1 - a)} \times 100$$

Initial weight of beaker	=	a
Weight of beaker + sample	=	a_1
Wet weight of sample	=	$(a_1 - a)$
Final weight of beaker + sample	=	c
Dry weight of sample	=	$(c - a)$

d) Total Nitrogen (Kjeldahl method)

Kjeldahl method is the most common, reliable and economical method for nitrogen estimation. It is being carried out as follows:

Reagents

1. Catalyst mixture – Mixture of Sodium sulphate and Cupric sulphate in 5 : 1 ratio
2. Concentrated Sulphuric acid
3. 40% NaOH
4. 0.32% Potassium permanganate

5. 4% Boric acid

6. Mixed indicators - Methyl red and Bromo-cresol green (1:2)

7. 0.1 N HCl

Procedure

Nitrogen content of the samples were analysed using an automated nitrogen estimation system (KELPLUS, ELITE=EX (VA). The principle followed was Kjeldahl method. Analysis was carried out following the manual of the instrument.

The method Kjeldahl includes three phases.

a) Digestion

In order to digest the sediment sample, 2 spatula of catalyst mixture and 10 ml of concentrated sulphuric acid was added to 1.0 g of sample and subjected to digestion within the infra digestion unit of the Kelplus nitrogen estimating system. The sample attained a milky white color, when it gets completely digested. Allowed the samples to cool and diluted for further analysis.

d) Distillation

The diluted sample was placed in the distillation system for ammonia recovery using ammonia trapping solution (Boric acid and mixed indicators).

e) Titration

After trapping all the ammonia, the resultant solution was titrated against 0.1 N HCl for estimating the total nitrogen content.

Total nitrogen was estimated using the formula;

$$\% \text{ Nitrogen} = \frac{14.01 \text{x (ml titrant – ml blank) x N x } 100}{\text{Sample volume x} 1000}$$

e) Total Phosphorous

Phosphorous estimation generally includes two steps; (a) conversion of any form of phosphorous to dissolved orthophosphates and (b) colorimetric determination of the orthophosphate. Here, the first step is accomplished with persulphate oxidation technique and the second is with the stannous chloride method.

Reagents

1. Nitric acid (Concentrated)
2. Perchloric acid
3. Sulphuric acid (5%)
4. Ammonium molybdate solution - dissolved 25 g of (NH4)6Mo7O24. 4H2O in 175 ml of distilled water. Add 280 ml of concentrated sulfuric acid slowly while stirring to 400 ml of distilled water. Cool. Add the molybdate solution to the acid solution and dilute to 1 liter.
5. Stannous chloride solution: dissolved 2.5 g of fresh $SnCl_2$-$2H_2O$ in 100 ml of glycerol. Heated in water bath and stirred with a glass rod to hasten dissolution.

Procedure

Added 2 ml of Nitric acid and 2 ml Perchloric acid to 0.5 g air dried sediment sample. Heated gently upto dryness and allowed it to cool for some time. 21 ml of 5 % sulphuric acid was added to the sample and boiled for 15 minutes. After cooling, filtered the content through Whatman no: 44 filter paper and made up the volume to 250 ml with distilled water.

2 ml of ammonium molybdate solution and 3 drops of stannous chloride solution was added to 50 ml of acid digested sample and mixed well. Kept the samples for another 10 – 12 minutes and measured the optical density at 690 nm.

Compared the values with a calibration curve using distilled water as blank and found out the phosphorous concentration from the standard graph.(Standard graph prepared by following the same procedure for the sample, anhydrous KH_2PO_4 was used to prepare the stock solution).

f) Potassium (Flame photometric method)

Potassium estimation in sediment sample generally includes two procedural steps; acid digestion technique and flame photometric analysis.

Reagents

1. Stock potassium solution (1000mg/L) - dissolved 1.907 g KCl in distilled water to make 1 litre of solution.
2. Intermediate sodium solution (100mg/L) – Diluted the stock solution to 10 times.
3. Standard sodium solution (10 mg/L) - Diluted the intermediate solution further 10 times.
4. Nitric acid
5. Perchloric acid
6. 5% Sulphuric acid

Procedure

The concentration of potassium present in the acid digested sample was estimated using Flame Photometer (Systronics, 128). The instrument was calibrated with a higher and lower concentration of standard stock potassium solution. Analysis was carried out, following the instruction manual and the results are represented in ppm levels.

g) Sodium (Flame photometric method)

Estimation of sodium in sediment sample is generally accomplished with the acid digestion technique and the flame photometric analysis.

Reagents

1. Stock sodium solution (1000mg/L) - dissolved 2.542 g NaCl in distilled water to make 1 litre of solution.
2. Intermediate sodium solution (100mg/L) – Diluted the stock solution to 10 times.
3. Standard sodium solution (10 mg/L) - Diluted the intermediate solution further to 10 times.
4. Nitric acid
5. Perchloric acid
6. Sulphuric acid 5%

Procedure

The concentration of sodium present in the acid digested sample was estimated by Flame Photometer (Systronics, 128). The instrument was calibrated with a higher and lower concentration of standard sodium stock solutions. Samples were analyzed and the results were obtained in ppm concentration.

h) Textural analysis (International Pipette Method)

Relative proportion of the soil particles of various sizes is an important physical parameter which determines texture of the soil. Larger particles help in providing the physical support to the plants, while smaller size particles determine the capacity of soil to hold water and availability of nutrients.

Reagents

1. Hydrogen peroxide (6%)

2. HCl (5N)

Procedure

20 g each of air dried soil / sediment sample was transferred in to a 500 ml beaker. Slowly added 60 ml of Hydrogen peroxide (6%) till the frothing ceased. Added 200 ml of 5N HCl and kept overnight. Filtered the contents through Whatman No. 50 filter paper. Washed the soil residue with water and transferred to a 1000 ml measuring cylinder, volume was made up to 1000 ml mark with water. The contents were shaken thoroughly and kept undisturbed till the settling time is over. After the stipulated time for clay and silt, 20 ml of suspension was pipette out from a depth of 10 cm and transferred to a pre weighed clean porcelain dish. Evaporate and dried the suspension at 105^{o}C in a hot air oven. Cooled the dish in a desiccator and determined the weight of clay and silt separately. After attained the settling time for sand, drained the water as much as possible and transferred the content of sand in to a pre weighed porcelain dish and subjected to dryness. Cooled in a desiccator and weighed.

$$\% \text{ of Clay} = \frac{\text{Weight of clay x 100}}{\text{Weight of sample taken}}$$

$$\% \text{ Sand} = \frac{\text{Weight of sand x 100}}{\text{Weight of sample taken}}$$

$$\% \text{ Silt} = 100 - (\% \text{ Clay} + \% \text{ Sand})$$

The estimated percentages of sand, silt and clay were used to determine the textural class of the soil.

Data on various climatological attributes like atmospheric maximum temperature; atmospheric minimum temperature, Total Rainfall (MMS) and Relative Humidity (%) with respect to all the sites and period of study were procured from India

Meteorological Department, Government of India. The results of all analyses were depicted in the following sections.

Statistical analysis

Statistical analysis in the case of relevant data was carried out using two way ANOVA without replications using Microsoft Excel Software and Significance level of 5% was taken as the level of significance.

Results and Discussion

Many ecological factors strongly influence the growth and development of mangroves (Kjerfve et al., l999). Among them, water and sediment quality are known to have supreme influence (Thom, 1967). The growth requirements of mangroves are also species specific. The present investigation focus on an evaluation of the hydrogeochemical, sedimentological and climatological factors influencing the growth and establishment of five mangrove species (*Avicennia officinalis, Bruguiera cylindrica, Excoecaria agallocha, Rhizophora mucronata* and *Sonneratia alba*) growing along their natural habitats in the coastal environments of Kerala.

The mean values of all water quality parameters together with their standard deviation from habitats containing *Avicennia officinalis, Bruguiera cylindrica, Excoecaria agallocha, Rhizophora mucronata* and *Sonneratia alba* are depicted in Tables 2.2 - 2.6, respectively.

Table 2.2. Physico- chemical characteristics of water samples from habitats of *Avicennia officinalis.*

PRE MONSOON				MONSOON					POST MONSOON					
Mar	Apr	May	**Seasonal Mean± SD**	Jun	Jul	Aug	Sep	**Seasonal Mean± SD**	Oct	Nov	Dec	Jan	**Seasonal Mean± SD**	**Annual Mean± SD**
Water pH														
6.55	6.71	7.03	**6.88 ± 0.307**	6.56	7.29	6.38	6.57	**6.7 ± 0.403**	6.79	6.89	6.91	7.79	**7.095 ± 0.466**	**6.8917 ± 0.397**
8.16	7.899	7.67	**7.91 ± 0.200**	6.99	7.07	7.64	7.02	**7.18 ± 0.308**	7.49	7.62	7.97	7.9	**7.745 ± 0.228**	**7.6116 ± 0.397**
7.61	xx	xx	**7.805 ± 0.276**	xx	6.98	5.73	3.86	**5.523± 1.570**	6.8	7.41	7.71	7.48	**7.35 ± 0.388**	**6.8422 ± 1.302**
7.44 ± 0.818	**7.305 ± 0.841**	**7.35 ± 0.453**		**6.775 ± 0.304**	**7.113 ± 0.160**	**6.583 ± 0.971**	**5.817 ± 1.709**		**7.027 ± 0.401**	**7.307± 0.376**	**7.53 ± 0.552**	**7.723 ± 0.218**		
Turbidity (NTU)														
2.8	2.1	10.6	**4.2 ± 4.311**	24.9	12.7	16.4	16.3	**17.575± 5.178**	3.4	5.3	5	5.6	**4.825± 0.981**	**8.8667 ± 7.354**
15.8	29.9	5.1	**16.25 ± 10.248**	19.1	11.9	4.9	58	**23.475 ± 23.736**	26.3	5.8	10.5	7.4	**12.5± 9.405**	**17.4083 ± 15.134**
2.4	xx	xx	**2.95 ± 0.778**	xx	22.4	12.9	0.7	**12 ± 10.878**	5.1	16.1	10.9	3.8	**8.975± 5.665**	**8.6444 ± 7.354**
7± 7.624	**16 ± 19.658**	**7.85 ± 3.889**		**22 ± 4.101**	**15.67 ± 5.845**	**11.4± 5.895**	**25 ± 29.624**		**11.6± 12.759**	**9.067 ± 6.096**	**8.8 ± 3.297**	**5.6 ± 1.8**		
T.S (mg/l)														
25800	25200	5400	**19750 ± 9666.954**	1000	1000	800	200	**750 ± 378.594**	4800	2800	16800	22400	**11700 ± 9439.633**	**10733.333 ± 10769.092**
41800	42200	43200	**42400 ± 588.7846**	1800	1200	8600	3600	**3800 ± 3358.571**	7400	14800	39600	40200	**25500 ± 16901.676**	**23900 ± 18798.356**
42200	xx	xx	**42300 ± 141.421**	xx	600	200	1600	**800 ± 721.110**	25800	44400	44000	27800	**35500 ± 10080.344**	**25444.444 ± 19686.995**
36600 ± 9355.213	**33700 ± 12020.815**	**24300 ± 26728.636**		**1400 ± 565.685**	**933.33 ± 305.505**	**3200 ± 4686.150**	**1800 ± 1708.801**		**12666.67 ± 11447.853**	**20666.67 ± 21411.523**	**33466.67 ± 14600.457**	**30133.33 ± 9126.518**		
T.D.S (ppt)														
23.0	24.4	5.2	**18.4 ± 8.910**	1.0	0.2	0.2	0.2	**0.4 ± 0.4**	4.6	2.2	16.2	20.6	**10.9 ± 8.899**	**9.9± 10.136**
41.4	39.6	39.8	**40.65 ± 1.112**	1.2	0.6	8.4	3.0	**3.3 ± 3.550**	7.2	14.2	39.0	38.8	**24.8 ± 16.530**	**22.916 7 ± 18.272**
42.0	xx	xx	**41.6± 0.566**	xx	0.4	0.2	0.8	**0.467 ± 0.306**	24.6	43.4	2.8	27.6	**24.6 ± 16.710**	**20.3333 ± 19.364**
35.467 ± 10.801	**32 ± 10.748**	**22.5 ± 24.466**		**1.1 ± 0.141**	**0.4 ± 0.2**	**2.93± 4.734**	**1.333 ± 1.474**		**12.133 ± 10.874**	**19.933 ± 21.190**	**19.333 ± 18.302**	**29 ± 9.180**		
T.S.S (mg/l)														
2800	800	200	**1350 ± 1123.981**	0	800	600	0	**350 ± 412.311**	200	600	600	1800	**800 ± 692.820**	**833.3333 ± 839.1915**
400	2600	3400	**1750±**	600	600	0	600	**450 ±**	200	600	600	1400	**700 ±**	**966.6667 ±**

			1482.116					300					503.322	1019.2094
200	xx	xx	700 ± 707.107	xx	200	0	800	333.33 ± 416.333	1200	1000	41200	200	10900 ± 20204.620	5111.1111 ± 13541.459
1133.33 ± 1446.836	1700± 1272.792	1800 ± 2262.742		300 ± 424.264	533.33 ± 305.501	200 ± 346.410	466.67 ± 416.333		533.33 ± 577.350	733.33 ± 230.940	14133.33 ± 23440.421	1133.33 ± 832.666		
Salinity (ppt)														
20.65	19.97	4.807	15.852 ± 7.450	0.699	0.762	0.195	0.334	0.498 ± 0.276	4.233	2.213	14.27	18.2	9.729 ± 7.726	8.6928 ± 8.654
35.42	35.39	34.73	34.8 ± 0.824	1.234	0.831	6.807	2.623	2.874 ± 2.732	6.582	12.8	32.18	33.87	21.358 ± 13.726	19.6773 ± 15.507
34.98	xx	xx	34.755 ± 0.318	xx	0.216	0.05	0.996	0.421 ± 0.505	11.31	33.69	38.05	23.18	26.5575 ± 11.928	19.6669 ± 16.523
30.35 ± 8.403	27.68 ± 10.904	19.769 ± 21.159		0.9665 ± 0.378	0.603 ± 0.337	2.3507 ± 3.86	1.318 ± 1.178		7.375 ± 3.605	16.234 ± 16.017	28.167 ± 12.388	25.083 ± 8.007		
Resistivity (Ω)														
30.91	31.75	117.4	53.733 ± 42.479	723.8	671.6	2520	1461	1344.1 ± 862.832	131.1	243.5	42.75	34.54	112.97 ± 97.381	503.6017 ± 769.471
19.03	19.03	19.22	19.263± 0.35	420.6	608.4	84.98	208	330.495 ± 231.396	86.7	47.52	20.52	19.7	43.61 ± 31.501	131.1225 ± 191.476
19.28	xx	xx	19.31 ± 0.042	xx	2244	10790	4968	6000.67 ± 4365.585	53.18	19.68	17.71	27.74	29.5775 ± 16.322	2017.6589 ± 3699.783
23.073 ± 6.788	25.39 ± 8.994	68.31 ± 69.424		572.2 ± 214.395	1174.67 ± 926.609	4464.99 ± 5611.293	2212.33 ± 2467.342		90.327 ± 39.086	103.57 ± 121.983	26.993 ± 13.718	27.327 ± 7.4286		
Conductivity (mS)														
31.62	30.78	8.339	24.693 ± 11.010	1.348	1.456	0.389	0.669	0.9655 ± 0.519	7.455	4.024	22.83	28.3	15.652 ± 11.746	13.77 ± 13.231
51.41	51.37	50.8	50.7825 ± 0.868	2.325	1.61	11.48	4.698	5.02825 ± 4.499	11.27	20.6	47.66	49.66	32.2975 ± 19.291	29.369 ±22.193
50.71	xx	xx	50.585 ± 0.177	xx	0.435	0.091	0.196	0.2407 ± 0.176	18.38	49.74	55.23	35.26	39.6525 ± 16.494	28.9447 ± 24.195
44.58 ± 11.229	41.075 ± 14.559	29.57 ± 30.025		1.8365 ± 0.691	1.167 ± 0.639	3.987 ± 6.491	1.854 ± 2.474		12.368 ± 5.545	24.788 ± 23.144	41.907 ± 16.949	37.74 ± 10.894		
Acidity (Mg/l)														
88	26.4	13.2	36.85 ± 34.523	22	8.8	6.6	11	12.1± 6.840	17.6	8.8	22	26.4	18.7 ± 7.5144	22.55 ± 21.741
30.8	30.8	44	35.2 ± 6.223	8.8	8.8	26.4	22	16.5 ± 9.071	66	1.32	17.6	44	32.23 ± 28.5681	27.9767 ± 18.1392
39.6	xx	xx	44 ± 6.223	xx	13.2	48.4	26.4	29.33 ± 17.782	26.4	52.8	22	44	36.3 ± 14.537	35.6889 ± 13.9911
52.8 ± 30.80	28.6 ± 3.111	28.6 ± 21.779		15.4 ± 9.334	10.267 ± 2.540	27.133 ± 20.910	19.8 ± 7.932		36.667 ± 25.782	20.973 ± 27.815	20.533 ± 2.540	38.133 ±10.161		
Alkalinity (Mg/l)														
210	200	120	170 ± 42.426	130	50	110	90	95 ± 34.157	175	100	120	130	131.25 ± 31.721	132.0833± 45.898
200	160	150	170 ± 21.603	70	120	160	340	172.5 ± 117.580	170	100	150	140	140 ± 29.439	160.8333 ± 66.121
230	xx	xx	215 ± 21.213	xx	150	120	70	113.333 ± 40.415	150	170	160	230	177.5 ± 35.940	164.4444 ± 51.505
213.33 ±	180 ±	135 ±		100 ±	106.67 ±	130 ±	166.7 ±		165 ±	123.33 ±	143.33 ±	166.67 ±		

15.275	**28.284**	**21.213**		**42.426**	**51.316**	**26.458**	**150.444**		**13.229**	**40.415**	**20.817**	**55.076**		
Hardness (Mg/l)														
4300	4540	1100	**3425 ± 1583.951**	740	136	38	58	**243 ± 334.02**	150	92	2740	3780	**1690.5 ± 1861.523**	**1786.167 ± 1872.344**
6980	7620	7280	**7190 ± 333.267**	340	145	300	304	**272.25 ± 86.719**	280	440	4500	6820	**3010 ± 3203.852**	**3490.75 ± 3414.501**
7060	xx	xx	**7060 ± 0**	xx	46	26	54	**42 ± 14.422**	406	910	6900	5000	**3304 ± 3158.970**	**3051.333 ± 3344.774**
6113.3 ± 1570.902	**6080 ± 2177.889**	**4190 ± 4369.920**		**540± 282.843**	**109 ± 54.745**	**121.333 ± 154.846**	**138.7 ± 143.197**		**278.67 ± 128.005**	**480.67 ± 410.514**	**4713.3 ± 2088.189**	**5200 ± 1529.837**		
Calcium (Mg/l)														
352.44	320.4	144.18	**276.345 ± 91.912**	120.15	12.42	6.4	9.62	**37.148 ± 55.390**	59.32	27.25	184.23	288.36	**139.79 ±119.984**	**151.094± 132.436**
440.56	448.56	552.69	**482.605 ± 51.234**	56.07	12.82	24.85	36.87	**32.653 ± 18.443**	80.16	152.3	392.49	448.56	**268.38 ± 179.601**	**261.217 ± 215.509**
528.66	xx	xx	**492.615 ± 50.975**	xx	13.63	8.82	10.42	**10.957 ± 2.450**	152.3	344.69	464.58	801	**440.64 ± 272.506**	**308.963± 280.318**
440.553 ± 88.11	**384.48 ± 90.623**	**348.44 ±288.860**		**88.11 ±45.311**	**12.957 ± 0.617**	**13.357 ± 10.027**	**18.97 ± 15.507**		**97.26 ± 48.791**	**174.75 ± 159.906**	**347.1 ± 145.582**	**512.64 ± 262.259**		
Magnesium (Mg/l)														
832.65	910.56	180.16	**665.875 ± 331.219**	107.12	25.58	5.4	8.28	**36.595 ± 47.854**	0.49	5.84	555.1	745	**326.608 ± 381.447**	**343.026 ± 377.323**
1426.7	1582.5	1436.4	**1455.9 ± 88.183**	48.69	27.53	57.99	51.61	**46.455 ± 13.201**	19.48	14.61	857	1387.8	**569.723 ± 673.967**	**690.693 ± 703.719**
1397.5	xx	xx	**1419.4 ± 30.971**	xx	2.92	0.97	6.82	**3.57 ± 2.979**	6.33	12.17	1397.5	730.4	**536.6 ± 667.063**	**555.101 ± 684.092**
1218.95 ± 334.864	**1246.53 ± 475.133**	**808.28 ± 888.296**		**77.905 ± 41.316**	**18.677 ± 13.681**	**21.453 ± 31.719**	**22.237 ± 25.449**		**8.767 ± 9.727**	**10.873 ± 4.527**	**936.53 ± 426.795**	**954.4 ± 375.406**		
Chloride (Mg/l)														
16330	21300	6390	**14377.5 ± 6226.853**	4402	710	525.4	440.2	**1519.4 ± 1925.03**	2896.8	2982	11857	14697	**8108.2 ± 6080.088**	**8001.7 ± 7192.611**
22720	23856	40186	**27441.5 ± 8510.034**	3834	724.2	4544	1959.6	**2765.45 ± 1743.668**	4260	10295	18460	29252	**15566.75± 10821.135**	**15257.9 ± 12778.04**
26980	xx	xx	**25134 ± 2610.638**	xx	255.6	326.6	298.2	**293.467 ± 35.736**	13490	27335	25347	16543	**20678.75± 6705.241**	**14873.711 ± 11857.436**
22010 ± 5360.382	**22578± 1807.365**	**23288 ± 23897.38**		**4118 ± 401.637**	**563.27 ± 266.542**	**1798.67 ± 2379.605**	**899.3 ± 920.959**		**6882.27 ± 5762.915**	**13537.33 ± 12496.067**	**18554.67 ± 6745.498**	**20164 ± 7924.376**		
Sulphate (Mg/l)														
115	105	35	**76.5 ± 39.442**	6	4	2	2.5	**3.625 ± 1.797**	27.5	15	42	43.5	**32 ± 13.435**	**37.375 ± 38.154**
105	126	63	**88.75 ± 32.066**	12	7.5	32	23	**18.625 ± 11.041**	34	53	51	47	**46.25 ± 8.539**	**51.208 ± 35.229**
120	xx	xx	**90.25± 42.073**	xx	4	2.75	5.5	**4.083 ± 1.377**	53	53	57	48	**52.75 ± 3.686**	**44.861 ± 37.370**
113.33 ± 7.638	**115.5± 14.849**	**49 ± 19.799**		**9 ± 4.24**	**5.167 ± 2.021**	**12.25 ± 17.108**	**10.33 ± 11.072**		**38.167 ± 13.251**	**40.333 ± 21.939**	**50 ± 7.549**	**46.167 ± 2.363**		

Sodium (ppt)														
14	12.8	0.65	**9.713 ± 6.134**	4.6	0.475	0.21	0.02	**1.326± 2.191**	3.115	1.4	6.4	13.05	**5.991 ± 5.1428**	**5.677 ± 5.624**
23.55	24.3	20.4	**24.45 ± 3.797**	4.05	0.595	3.885	1.83	**2.59 ± 1.67**	4.835	8.37	20.55	25.3	**14.764 ± 9.729**	**13.935 ± 10.852**
24.65	xx	xx	**27.15 ± 3.536**	xx	0.265	0.15	0.15	**0.188 ± 0.066**	6.825	54.6	27.8	16.55	**26.444 ± 20.635**	**17.849 ± 18.351**
20.733 ± 5.857	**18.55 ± 8.132**	**10.525 ± 13.965**		**4.325 ± 0.389**	**0.445±0.167**	**1.415 ± 2.139**	**0.667 ± 1.010**		**4.925 ± 1.857**	**21.457 ± 28.914**	**18.25 ± 10.884**	**18.3 ± 6.310**		
Nitrogen (mg/l)														
42	28	42	**45.5± 17.616**	42	39	38	50	**42.25 ± 5.439**	70	160	80	49	**89.75 ± 48.582**	**59.167 ± 35.334**
42	42	35	**40.25± 3.5**	42	28	34	20	**31± 9.310**	70	196	91	35	**98 ± 69.297**	**56.417 ± 47.910**
49	xx	xx	**52.5 ± 4.950**	xx	35	140	45	**73.333 ± 57.951**	80	98	56	56	**72.5± 20.421**	**68.333 ± 32.860**
44.333 ± 14	**35 ± 4.042**	**38.5± 9.900**		**42 ± 0**	**34 ± 5.568**	**70.667 ± 60.078**	**38.33 ± 16.073**		**73.333 ± 5.774**	**151.33 ± 49.572**	**75.667 ± 17.898**	**46.667 ±10.69**		
Phosphorous (mg/l)														
12	12	23.5	**12.5 ± 8.59**	13	60	70	8	**37.8 ± 31.79**	9.5	24.5	0.5	29	**15.9 ± 13.21**	**22.043 ± 21.91**
3	4.5	17.5	**35.0 ± 53.73**	0.5	4	25	12.5	**10.5 ± 10.9**	4.0	6	70	3	**20.8 ± 32.86**	**22.08 ± 34.99**
100	xx	xx	**106.3 ± 8.84**	xx	40	42.5	1.0	**27.8 ± 23.27**	0.5	1.5	14	16	**8.0 ± 8.13**	**36.44 ± 42.67**
38.3 ± 53.59	**8.25± 5.30**	**20.5± 4.24**		**6.75± 8.84**	**34.7 ± 28.38**	**45.8± 22.68**	**7.2 ± 5.8**		**4.7 ± 4.54**	**10.7 ± 4.54**	**28.2 ± 36.85**	**16.0 ± 13.0**		
Potassium (mg/l)														
6400	700	150.0	**1832.5 ± 1683.380**	1800	10	210	35	**513.75 ± 862.104**	20	25	95	1400	**385 ± 677.532**	**910.417 ± 1828.762**
20550	0	400.0	**5297.5 ± 5549.816**	1650	0	3885	120	**1413.75 ± 1810.651**	1830	35	185	8370	**2605± 3928.407**	**3105.417 ± 6015.647**
27800	450	100.0	**7412.5 ± 7624.979**	xx	25	150	30	**68.333 ± 70.770**	150	30	285	5460	**1481.25 ±2654.55**	**3252.727± 8296.386**
18250 ± 10883.82	**383.33 ± 354.730**	**216.67 ± 160.728**		**1725 ± 106.066**	**11.667 ± 12.583**	**1415 ± 2139.29**	**61.67 ± 50.58**		**666.67 ± 1009.57**	**30 ± 5**	**188.33 ± 95.044**	**5076.67 ± 3500.78**		

Table 2.3. Physico- chemical characteristics of water samples from habitats of *Bruguiera cylindrica.*

PRE MONSOON			MONSOON					POST MONSOON					
Apr	May	Seasonal Mean ± SD	Jun	Jul	Aug	Sep	Seasonal Mean ± SD	Oct	Nov	Dec	Jan	Seasonal Mean ± SD	Annual Mean ± SD
Water pH													
7.72	7.06	7.665 ± 0.419	7.47	6.96	6.91	7.04	7.095 ± 0.256	7.57	7.64	7.66	7.73	7.65 ± 0.066	7.47 ± 0.379
7.75	7.81	7.953 ± 0.215	7.13	7.15	8.23	7.07	7.395 ± 0.558	7.61	7.98	8	8.01	7.9 ± 0.194	7.7492 ± 0.420
xx	xx	7.505 ± 0.332	xx	6.81	6.23	6.23	6.423 ± 0.335	6.59	7.04	7.62	8.6	7.463 ± 0.868	7.1256 ± 0.776
7.735 ± 0.021	7.435 ± 0.53		7.3 ± 0.240	6.973 ± 0.170	7.123 ± 1.017	6.78 ± 0.477		7.257 ± 0.578	7.553 ± 0.476	7.76 ± 0.209	8.113 ± 0.444		
Turbidity (NTU)													
3.4	7	6.975 ± 5.258	4	7.7	2.1	5.1	4.725 ± 2.339	5.5	12.1	15.4	4	9.25 ± 5.403	6.983 ± 4.551
26.1	22.8	17.4 ± 8.983	25.7	23.7	1.7	35.6	21.675 ± 14.297	18.2	14.3	44.4	14.7	22.9 ± 14.44	20.658 ± 11.861
xx	xx	2.75 ± 1.626	xx	3.6	4.6	4.6Ta	4.267 ± 0.577	12.3	3.4	4.5	3.6	5.95 ± 4.260	4.678 ± 3.004
14.75 ± 16.051	14.9 ± 11.172		14.85 ± 15.344	11.667 ± 10.621	2.8 ± 1.572	15.1 ± 17.755		12 ± 6.355	9.933 ± 5.764	21.433 ± 20.623	7.433 ± 6.296		
T.S (mg/l)													
33400	23200	34200 ± 7984.999	12800	1000	4000	6200	6000 ± 5009.325	20400	21400	36000	39400	29300 ± 9806.8	23166.67 ± 14682.29
42600	42600	45400 ± 4156.922	2200	3800	11600	2400	5000 ± 4457.204	12400	18800	38400	40000	27400 ± 13889.08	25933.33 ± 18991.35
xx	xx	45800 ± 3676.955	xx	2200	400	1000	1200 ± 916.515	2000	40000	51200	50600	35950 ± 23210.56	26555.56 ± 24119.03
38000 ± 6505.382	32900 ± 13717.87		7500 ± 7495.332	2333.33 ± 1404.754	5333.33 ± 5717.808	3200 ± 2690.725		11600 ± 9226.05	26733.33 ± 11562.58	41866.67 ± 8171.495	43333.33 ± 6300.265		
T.D.S (ppt)													
31.2	22.6	32.85 ± 7.743	12.4	1.0	3.2	6.0	5.65 ± 4.943	19.4	19.6	34.6	38.6	28.05 ± 10.007	22.183 ± 14.27
39.4	24.0	37.85 ± 9.497	2.0	2.0	10.6	2.0	4.15 ± 4.3	12.2	18.8	38.4	38.4	26.95 ± 13.493	22.983 ± 17.157

xx	xx	45.7 ± 3.818	xx	2.0	2.0	1.0	1.667 ± 0.577	1.6	40.0	47.0	49.6	34.55 ± 22.338	26.067 ± 23.337
35.3 ± 5.798	23.3 ± 0.99		7.2 ± 7.354	1.667 ± 0.578	5.267 ± 4.658	3 ± 2.646		11.067 ± 8.954	26.133 ± 12.016	40 ± 6.353	42.2 ± ±6.409		
T.S.S (mg/l)													
2200	600	1350 ± 869.866	400	0	800	200	350 ± 341.565	1000	1800	1400	800	1250 ± 443.471	983.333 ± 715.838
3200	18600	7550 ± 7680.929	200	1800	1000	400	850 ± 718.7953	200	0	0	1600	450 ± 772.442	2950 ± 5288.15
xx	xx	100 ± 141.421	xx	2000	200	0	733.33 ± 1101.514	400	0	4200	1000	1400 ± 1911.369	888.889 ± 1403.96
2700 ± 707.107	9600 ± 12727.92		300 ± 141.421	1266.67 ± 1101.514	666.67 ± 416.333	200 ± 200		533.33 ± 416.333	600 ± 1039.23	1866.67 ± 2138.535	1133.33 ± 416.333		
Salinity (ppt)													
28.39	18.5	28.028 ± 6.656	10.73	1.043	4.412	4.422	5.152 ± 4.045	16.99	17.92	25.92	30.72	22.888 ± 6.583	18.689 ± 11.538
51.72	51.07	51.095 ± 0.782	1.596	6.582	14.91	3.382	6.618 ± 5.901	17.55	25.9	47.31	49.99	35.188 ± 15.952	30.967 ± 21.177
xx	xx	37.35 ± 0.198	xx	0.098	0.394	0.394	0.295 ± 0.171	1.139	32.81	38.69	41.32	28.49 ± 18.578	21.061 ± 19.623
40.055 ± 16.497	34.785 ± 23.031		6.163±6.459	2.574±3.503	6.572±7.495	2.733±2.091		11.893±9.318	25.543±7.451	37.307±10.762	40.677±9.651		
Resistivity (Ω)													
23.07	33.88	24.4 ± 6.452	55.74	490.8	127.5	127.6	200.41 ± 196.531	36.25	34.88	24.84	21.47	29.36 ± 7.317	84.723 ± 133.658
18.9	19.11	19.128 ± 0.296	328.8	148.3	65.65	289	207.938 ± 122.449	55.78	37.75	20.64	19.54	33.428 ± 17.075	86.831 ± 110.481
xx	xx	17.995 ± 0.092	xx	5030	1256	1258	2514.67 ± 2178.343	456	20.16	17.35	16.48	127.498 ± 219.007	898.887 ± 1635.489
20.985 ± 2.949	26.495 ± 10.444		192.27 ± 193.083	1889.7 ± 2724.966	483.05 ± 670.108	558.2 ± 611.392		182.677 ± 236.9063	30.93 ± 9.437	20.943 ± 3.754	19.163 ± 2.516		
Conductivity (mS)													
42.39	28.84	41.833± 9.066	17.53	1.995	7.676	7.666	8.717 ± 6.456	26.96	28.04	39.24	45.52	34.94 ± 8.976	28.496 ± 16.67
51.72	51.07	51.095 ± 0.782	2.971	6.582	14.91	3.382	6.961± 5.54	17.55	25.9	47.31	49.99	35.188 ± 15.952	31.081 ± 21.007
xx	xx	54.3 ± 0.198	xx	0.194	0.779	0.777	0.583 ± 0.337	2.143	48.49	56.38	59.33	41.586 ± 26.69	30.744 ± 28.387
47.055 ± 6.597	39.955 ± 15.719		10.251 ± 10.295	2.924 ± 3.294	7.788 ± 7.066	3.942 ± 3.478		15.551 ± 12.529	34.143 ± 12.471	47.643 ± 8.575	51.613 ± 7.047		
Acidity (Mg/l)													

35.2	39.6	33± 5.680	22	8.8	22	28.6	20.35± 8.305	48.4	24.2	35.2	30.8	34.65± 10.221	29.333 ± 10.031
26.4	39.6	30.8± 6.221	13.2	28.6	35.2	17.6	23.65± 10.062	48.4	1.76	26.4	48.4	31.24± 22.222	28.563 ± 13.64
xx	xx	57.2± 6.223	xx	17.6	44	30.8	30.8± 13.2	44	57.2	35.2	22	39.6± 14.813	40.578 ± 15.365
30.8 ± 6.223	39.6±0		17.6±6.223	18.333±9.920	33.733±11.073	25.67±7.07		46.933±2.54	27.72±27.887	32.267±5.081	33.733±13.442		
Alkalinity (Mg/l)													
190	160	175 ± 31.091	130	150	205	130	153.75± 35.444	160	130	160	160	152.5 ± 15	160.417 ± 27.998
160	160	160 ± 8.165	80	225	150	120	143.75± 61.288	270	110	140	210	182.5 ± 71.822	162.083 ± 52.2
xx	xx	170 ± 0	xx	90	200	1060	450± 531.131	180	200	180	180	185 ± 10	270 ± 298.035
175 ± 21.213	160 ± 0		105 ± 35.355	155 ± 67.639	185 ± 30.414	436.67 ± 539.846		203.33 ± 58.595	146.67 ± 47.258	160 ± 20	183.33 ± 25.166		
Hardness (Mg/l)													
6100	3920	5875 ± 1369.708	2760	128	364	374	906.5 ± 1240.885	740	680	4880	5960	3065 ± 2754.941	3282.17 ± 2741.46
7260	7380	7110 ± 247.386	460	330	240	236	316.5 ± 105.051	340	800	62	6720	1980.5 ± 3174.289	3135.67 ± 3447.724
xx	xx	6830 ± 1173.797	xx	30	68	62	53.333 ± 20.429	170	800	5200	8180	3587.5 ± 3792.127	3130 ± 3555.53
6680 ± 820.244	5650 ± 2446.589		1610 ± 1626.346	162.67 ± 152.975	224 ± 148.647	224 ± 156.346		416.67 ± 292.632	760 ± 69.282	3380.67 ± 2878.5	6953.3 ± 1128.243		
Calcium (Mg/l)													
400.5	352.4	412.505 ± 46.494	304.38	23.25	138.68	40.08	126.598 ± 128.994	192.38	200.4	376.47	544.68	328.483 ± 167.305	289.195 ± 168.718
480.6	768.9	544.665 ± 150.251	40.05	34.07	36.84	27.25	34.553 ± 5.447	120.24	208.42	392.49	432.54	288.423 ± 148.645	289.213 ± 243.933
xx	xx	508.635 ± 5.664	xx	6.01	18.44	24.05	16.167 ± 9.232	28.86	300.6	496.62	1121.4	486.87 ± 464.469	334.806 ± 371.638
440.55 ± 56.639	560.65 ± 294.51		172.215 ± 186.91	21.11 ± 14.152	64.653 ± 64.766	30.46 ± 8.483		113.827 ± 81.948	236.47 ± 55.68	421.86 ± 65.238	699.54 ± 369.619		
Magnesium (Mg/l)													
1241.7	740.1	1179.6± 306.564	486.93	17.05	4.38	66.71	143.768± 230.351	63.3	43.82	959.25	1119.9	546.568± 573.097	623.312 ± 572.688
1475.4	1329.3	1399.92± 60.234	87.65	59.69	36.06	40.9	56.075± 23.388	9.74	68.17	1270.9	1373.1	680.478± 742.324	712.159 ± 693.053
xx	xx	1353.7± 289.207	xx	3.65	5.4	0.49	3.18± 2.489	23.86	12.17	964.12	1309.8	577.488± 661.275	558.543± 669.587
1358.55±165.251	1034.7±416.627		287.29±282.334	26.797±29.264	15.28±18.003	36.03±33.377		32.3±27.76	41.387±28.079	1064.757±178.54	1267.6±131.77		

Chloride (Mg/l)													
19028	13348	19081.25± 4079.206	10082	994	3976	3067.2	4529.8± 3906.179	9230	12141	11005	20377	13188.25± 4939.945	12266.43± 7370.04
25560	24282	24234.67± 1349.623	3266	2279.1	5396	1618.8	3139.975± 1649.304	5722.6	10508	19880	23217	14831.9± 8113.131	13144.68 ± 9949.87
xx	xx	24566	xx	269.8	426	681.6	459.133± 207.89	1917	22436	24140	20235	17182± 10301.45	11833.93± 11850.96
22294±4618.821	18815±7731.506		6674±4819.64	1180.967±1017.614	3266±2559.941	1789.2±1201.894		5623.2±3657.513	15028.33±6466.979	18341.67±6701.262	21276.33±1682.166		
Sulphate (Mg/l)													
126	62	77.75± 32.17	38.5	8.5	25	22.5	23.625± 12.291	45.5	43	60	60	52.125± 9.15	51.167 ± 29.655
128	63	90± 33.357	15	30	36	19	25± 9.695	42	57	51	47	49.25± 6.344	54.75 ±33.537
xx	xx	89.25± 40.659	xx	2	10	6.5	6.1667± 4.01	30	49	60	61	50± 14.399	44.111 ± 36.82
127±1.414	62.5±0.707		26.75±±16.617	13.5±14.654	23.667±13.051	16±8.411		39.167±8.129	49.667±7.024	57±5.196	56±7.81		
Sodium (ppt)													
20.9	11.7	20.613± 6.422	4.7	0.71	2.715	3.14	2.816± 1.643	10.92	11.02	21.4	22.4	16.435± 6.324	13.288 ± 9.267
24.65	23.55	25.138± 1.465	4	2.555	5.035	1.34	3.2325±1.621	6.425	10.47	21.8	34.1	18.199± 12.439	15.523 ± 11.604
xx	xx	28.85± 1.344	xx	0.05	0.13	0.145	0.108± 0.051	0.875	31.1	26.55	30.05	22.143± 14.312	16.289 ± 15.225
22.775±2.652	17.625±8.379		4.35±0.495	1.105±1.298	2.627±2.454	1.542±1.508		6.073±5.032	17.53±11.755	23.25±2.865	28.85±5.942		
Nitrogen (mg/l)													
42	49	47.25± 6.702	35	27	41	25	32± 7.394	80	210	80	49	104.75± 71.672	61.333 ± 49.986
42	42	42±0	35	15	32	24	26.5± 8.963	80	110	63	56	77.25± 24.047	48.583 ± 25.914
39	xx	41± 7.211	xx	17	34	42	30.75± 12.767	91	140	49	80	90± 37.78	55.091 ± 35.43
41±1.732	45.5±4.95		33.333±0	19.667±6.429	35.667±4.726	30.333±10.116		83.667±6.351	153. 33±51.316	64±15.524	61.667±16.258		

Phosphorous (mg/l)														
1.5	0.3	21.5	5.85± 10.45	3.0	170	50	9.0	58.0± 77.53	5.0	12.0	25	19.5	15.38± 8.73	26.4 ± 47.44
102.5	55	19.5	73.0± 44.05	58.0	60	65	5.5	47.13± 27.91	5.0	9.5	0.1	10	6.15± 4.62	42.09 ± 39.67
105	xx	xx	108.75± 5.3	xx	15	32.5	24.0	23.83± 8.75	14.0	7.5	0.09	6.5	7.0± 5.69	35.23 ± 42.8
69.7±59.05	27.65±38.68	20.5±1.41		30.5±38.89	81.7±79.74	49.17±16.27	12.8±9.83		8.0±5.2	9.7±2.26	8.4±14.38	12.0±6.73		
Potassium (mg/l)														
250	0	700	300± 291.548	1300	0	70	85	363.75± 625.265	460	380	100	150	272.5± 174.619	312.083± 373.786
300	200	100	237.5± 110.868	1800	75	185	15	518.75± 857.063	295	350	300	850	448.75± 268.65	401.667 ± 488.836
300	xx	xx	425± 176.777	xx	20	10	15	15± 5	10	100	350	550	252.5± 245	211.667 ± 230.516
283.33±28.868	100±141.421	400±424.264		1550±353.553	31.67±38.837	88.33±88.929	38.33±40.415		255±227.651	276.667±153.731	250±132.288	516.667±351.189		

Table 2.4. Physico- chemical characteristics of water samples from habitats of *Excoecaria agallocha.*

	PRE MONSOON			MONSOON					POST MONSOON					
	Apr	May	Seasonal Mean± SD	Jun	Jul	Aug	Sep	Seasonal Mean± SD	Oct	Nov	Dec	Jan	Seasonal Mean± SD	Annual Mean± SD
						Water pH								
	7.73	6.81	7.59± 0.529	7.34	6.9	6.73	6.99	6.99± 0.257	7.57	7.46	7.55	7.77	7.588± 0.131	7.389± 0.431
	6.98	6.97	6.945± 0.155	7.07	7.22	6.4	5.99	6.67± 0.577	6.7	6.83	7.22	7.71	7.115± 0.454	6.91 ± 0.436
	xx	xx	7.28± 0.269	xx	6.81	5.32	5.06	5.73± 0.944	6.6	7.03	8.31	7.13	7.268± 0.732	6.758 ± 1.014
	7.355±0.53	6.89±0.113		7.205±0.191	6.977±0.216	6.15±0.738	6.013±0.965		6.957±0.534	7.107±0.322	7.693±0.559	7.537±0.354		
						Turbidity (NTU)								
	2.6	9.1	5.125± 3.186	5.3	2.9	2.1	4.4	3.675± 1.443	8.1	9.7	36.7	4.1	14.65± 14.888	7.817 ± 9.468
	5.9	7	4.625± 2.334	26.9	9	4.1	13.8	13.45± 9.802	3.7	7	9.9	21.6	10.55± 7.79	9.542 ± 7.678
	xx	xx	3± 1.131	xx	7.1	2.5	1.5	3.7± 2.987	13	9.6	2.9	8.5	8.5± 4.196	5.678 ± 4.029
	4.25±2.334	8.05±1.485		16.1±15.27	6.333±3.121	2.9±1.058	6.567±6.423		8.267±4.652	8.767±1.531	16.5±17.84	11.4±9.103		
						T.S (mg/l)								
	36000	26200	35850± 6859.3	10200	3600	1800	4600	5050± 3623.534	20200	23000	37000	38200	29600± 9320.944	23500 ± 15260.53
	21800	8200	19450± 7569.016	1800	800	1000	1000	1150± 443.471	5000	3000	13200	21600	10700± 8501.765	10433.33 ± 9814.214
	xx	xx	44700± 1555.635	xx	400	200	400	333.33± 115.470	1800	40400	44600	28000	28700± 19268.28	22800 ± 21589.81
5.77	28900±10040.92	17200±12727.92		6000±5939.697	1600±1743.56	1000±800	2000±2271.563		9000±9830.565	22133.33±18715.06	31600±16381.7	29266.67±8372.176		
						T.D.S (ppt)								
	34.6	25.0	34.8± 6.995	10.2	3.4	1.8	4.0	4.85± 3.686	19.8	21.8	34.8	37.4	28.45± 8.934	22.7 ± 14.831
	20.8	7.8	18.2±6.965	1.0	0.6	1.0	0.8	0.85± 0.192	5.0	2.8	13.0	21.4	10.55± 8.458	9.867 ± 9.367
	xx	xx	41.4± 5.94	xx	0.2	0.2	0.4	0.267± 0.116	1.4	39.4	38.6	27.8	26.8± 17.74	21.2 ± 20.111
1	27.7±9.758	16.4±12.162		5.6±6.505	1.4±1.744	1±0.8	1.733±1.973		8.733±9.752	21.33±18.305	28.8±13.815	28.867±8.053		

T.S.S (mg/l)														
	1400	1200	1050± 574.456	0	200	0	600	200± 282.843	400	1200	2200	800	1150± 772.442	800 ± 687.552
	1000	400	1250± 680.686	800	200	0	200	300± 346.41	0	200	200	200	150± 100	566.667 ± 648.542
	xx	xx	3300± 4384.062	xx	200	0	0	66.667± 115.47	400	1000	6000	200	1900± 2754.39	1600 ±2626.785
5	1200±282.843	800±565.686		400±565.686	200±0	0±0	266.67±305.505		266.667±230.94	800±529.15	2800±2946.184	400±346.41		
Salinity (ppt)														
	29.7	20.08	28.97± 6.135	8.285	3.268	3.164	3.142	4.465± 2.547	17.66	19.17	26.86	31.38	23.768± 6.48	19.067 ± 12.03
	18.12	6.713	15.9133± 6.195	1.050	0.744	0.87	0.494	0.79± 0.234	4.137	2.277	11.51	17.61	8.884± 7.053	8.529 ± 8.106
	xx	xx	37.135± 0.106	xx	0.1289	0.131	0.045	0.102± 0.049	0.538	32.74	35.04	24.05	23.092± 15.763	18.55 ± 17.818
	23.91±8.188	13.397±9.452		4.6675±5.116	1.38±1.664	1.389±1.581	1.227±1.674		7.445±9.028	18.062±15.262	24.47±11.946	24.347±6.89		
Resistivity (Ω)														
	22.12	31.4	23.39± 5.432	70.6	168.4	173.1	173.9	146.5± 50.658	35.4	32.64	24.1	21.14	28.32± 6.786	66.07 ±65.219
	34.59	85.67	46.255± 26.314	489.1	683.5	587.7	1014	693.575± 227.884	135	234.7	52.06	35.57	114.333± 91.281	284.721 ± 329.615
	xx	xx	18.045± 0.021	xx	3809	3750	12270	6609.67± 4902.08	930.2	20.13	19.05	26.72	249.025± 454.129	2317.91 ± 4056.43
	28.355±8.818	58.535±38.375		279.85±295.924	1553.633±1970.112	1503.6±1956.453	4485.97±6754.245		366.867±490.396	95.823±120.433	31.737±17.781	27.81±7.277		
Conductivity (mS)														
	44.2	31.19	43.263± 8.341	13.85	5.8	5.65	5.62	7.73± 4.081	27.61	29.91	40.55	46.26	36.083± 8.821	29.025 ± 17.363
	28.27	11.42	25.03± 9.159	1.998	1.431	1.663	0.964	1.514± 0.434	7.241	4.17	18.82	27.5	14.433± 10.757	13.659 ± 12.464
	xx	xx	54.175± 0.092	xx	0.257	0.261	0.079	0.199± 0.104	1.051	48.58	51.42	36.59	34.41± 23.15	27.399 ± 26.119
5	36.235±11.264	21.305±13.98		7.924±8.381	2.496±2.921	2.525±2.796	2.221±2.977		11.967±13.896	27.553±22.299	36.93±16.599	36.783±9.382		
Acidity (Mg/l)														
	30.8	48.4	37.95± 9.736	26.4	35.2	35.2	17.6	28.6± 8.425	44	30.8	48.4	26.4	37.4± 10.474	34.65 ± 9.755
	39.6	30.8	34.1± 9.756	22	11	30.8	28.6	23.1± 8.891	22	17.6	22	35.2	24.2± 7.621	27.133 ± 9.49
	xx	xx	50.6± 9.334	xx	17.6	30.8	17.6	22± 7.621	48.4	63.8	8.8	66	46.75± 26.484	39.356 ± 21.456
	35.2±6.222	39.6±12.445		24.2±3.111	21.267±12.51	32.267±2.54	21.267±6.351		38.133±14.144	37.4±23.797	26.4±20.163	42.533±20.79		

Alkalinity (Mg/l)														
	150	190	180± 21.603	120	130	215	190	163.75± 46.075	210	130	200	150	172.5± 38.6221	172.083 ± 34.076
	180	170	157.5± 20.616	100	60	160	70	97.5± 45	85	90	130	140	111.25± 27.8014	122.083 ± 39.969
	xx	xx	195± 21.213	xx	100	100	130	110± 17.321	160	165	150	160	158.75± 6.2915	150.556 ± 35.920
94	165±21.213	180±14.142		110±14.142	96.667±35.119	158.33±57.518	130±60		151.67±62.915	128.33±37.528	160±36.06	150±10		
Hardness (Mg/l)														
	6000	4400	5960± 1124.752	2200	282	316	278	769± 954.152	700	640	4940	6160	3110± 2861.258	3279.667 ± 2782.29
	3860	1400	3460± 1411.099	700	115	154	66	258.75± 296.361	180	68	2300	3420	1492± 1645.111	1736.917 ± 1789.164
	xx	xx	7560± 141.421	xx	36	94	22	50.667± 38.175	102	850	6600	5300	3213± 3219.184	3124.89 ± 3514.90
594	4930±1513.209	2900±2121.32		1450±1060.66	144.33±125.596	188±114.839	122±136.88		327.33±325.087	519.33±404.724	4613.33±2168.533	4960±1401.285		
Calcium (Mg/l)														
	392.49	320.4	410.513± 69.33	256.32	49	51.3	54.51	102.783± 102.383	213.23	236.47	352.44	424.53	306.667± 99.407	273.321 ± 157.128
	264.33	120.2	232.303± 79.271	120.15	10.42	19.2	10.42	40.048± 53.562	46.49	25.65	176.22	232.29	120.163± 100.125	130.838 ± 109.603
	xx	xx	580.725± 141.598	xx	7.214	7.21	6.41	6.945± 0.463	6.81	320.64	416.52	472.59	304.14± 207.912	266.538± 263.387
9	328.41±90.623	220.3±141.563		188.235±96.287	22.211±23.255	25.903±22.797	23.78±26.688		88.843±109.534	194.25±151.959	315.06±124.435	376.47±127.155		
Magnesium (Mg/l)														
	1222.2	876.47	1201.428± 233.037	379.81	39.47	45.77	34.57	124.905± 169.999	40.9	12.17	988.47	1241.7	570.81± 637.029	632.381 ± 588.34
	779.09	267.81	701.18± 296.27	97.39	21.68	25.8	9.74	38.653± 39.746	15.58	0.97	452.85	691.44	290.21± 339.862	343.348 ± 370.431
	xx	xx	1487.57± 51.647	xx	4.39	18.5	1.46	8.1167± 9.111	20.69	12.17	1353.67	1003.08	597.403± 685.957	598.789 ± 710.721
41	1000.645±313.326	572.14±430.388		238.6±199.701	21.847±17.541	30.023±14.117	15.257±17.231		25.723±13.389	8.437±6.466	931.66±453.089	978.74±275.936		

Chloride (Mg/l)														
	19312	16614	20412.5± 3037.55	8520	2130	2485	2797.4	3983.1± 3036.864	8804	12780	17395	20732	14927.75± 5224.614	13107.78 ± 7959.909
	13490	6816	12283± 3772.143	4686	617.7	908.8	397.6	1652.525± 2033.125	3280.2	2485	9372	21158	9073.8± 8623.512	7669.775 ± 6849.184
	xx	xx	25702± 602.455	xx	227.2	568	343.4	379.533± 173.25	1349	25205	23075	16330	16489.75± 10779.44	13166.84 ± 12237.16
25	16401±4116.776	11715±6928.232		6603±2711.047	991.633±1005.003	1320.6±1022.696	1179.467±1401.433		4477.733±3869.085	13490±11376.63	16614±6884.804	19406.67±2672.972		
Sulphate (Mg/l)														
	128	62.5	78.375± 33.089	36	20.5	20	23	24.875± 7.532	47	46	63	60	54± 8.756	52.417± 29.271
	63	41	69± 33.892	9	4.25	5	4.5	5.688± 2.23	26.5	16	38.5	43.5	31.125± 12.352	35.27± 33.082
	xx	xx	87± 36.77	xx	3	7	0.5	3.5± 3.279	23.5	50.5	57	60	47.75± 16.646	41.722 ± 36.799
[illegible]	95.5±45.962	51.75±15.203		22.5±19.092	9.25±9.763	10.67±8.145	9.333±12.004		32.33±12.79	37.5±18.755	52.833±12.77	54.5±9.526		
Sodium (ppt)														
	21.65	13.95	22.538± 6.317	2.75	2.38	1.98	2.33	2.36± 0.315	11.72	12.27	19.9	28.15	18.01± 7.722	14.303 ± 10.426
	15.65	3.7	15.45± 9.853	3.25	0.36	0.45	0.285	1.086± 1.444	3.055	2.01	6.6	23.55	8.804± 10.025	8.447 ± 9.594
	xx	xx	26.9± 1.414	xx	0.075	0.95	0.095	0.373± 0.5	0.34	29.8	23.4	18.65	18.048± 12.658	14.123± 13.409
	18.65±4.243	8.825±7.248		3±0.354	0.938±1.257	1.127±0.78	0.903±1.239		5.038±5.944	14.693±14.053	16.633±8.864	23.45±4.751		

Nitrogen (mg/l)														
49.0	28.0	35.0	38.5± 9.037	42.0	35.0	220.0	39.0	84± 90.712	91.0	130.0	70.0	56.0	86.75± 32.222	69.75 ± 55.531
42.0	42.0	49.0	44.75± 3.403	35.0	22.0	175.0	39.0	67.75± 71.867	80.0	140.0	56.0	49.0	81.25± 41.355	64.583 ± 46.108
35.0	xx	xx	42± 9.9	xx	22.0	98.0	39.0	53± 39.887	98.0	110.0	70.0	49.0	81.75± 27.524	63.333 ± 31.898
42±7	35±9.9	42±9.9		38.5±4.95	26.33±7.506	164.333±61.696	39±0		89.667±9.074	126.67±15.275	65.333±8.083	51.333±4.042		
Phosphorous (mg/l)														
80	60	25	41.3± 35.6	0.7	4.0	12.5	9.0	6.55± 5.23	4.0	11.5	4.0	8.0	6.875± 3.61	18.24 ± 25.43
1	6	23	16.3± 15.73	4.0	85	47.5	15.0	37.875± 36.44	1.5	15.0	0.6	9.0	6.525± 6.79	20.2 ± 25.09
40	xx	xx	75.0± 49.5	xx	80	60.0	6.5	48.833± 38.00	1.5	75.5	5.5	4.0	21.625± 35.96	42.56 ± 40.61
40.33±39.5	33.0±38.18	24.0±1.41		2.35±2.34	56.33±45.4	40 ±24.62	10.17±4.37		2.33±1.44	34.0±35.98	3.37±2.51	7.0±2.65		
Potassium (mg/l)														
400.0	100.0	450.0	325± 155.456	1550.0	60.0	40.0	55.0	426.25± 749.215	470.0	520.0	150.0	500.0	410± 174.547	387.083 ± 412.478
200.0	50.0	900.0	387.5± 370.53	1700.0	5.0	5.0	15.0	431.25± 845.847	85.0	30.0	500.0	300.0	228.75± 215.111	349.167± 503.433
250.0	xx	xx	375± 176.777	xx	15.0	20.0	25.0	20± 5	20.0	100.0	150.0	0	67.5± 69.941	120 ± 164.716
83.333±104.08	75±35.355	675±318.198		1625±106.066	26.667±29.297	21.667±17.559	31.667±20.817		191.667±243.225	216.667±265.016	266.667±202.073	266.667±251.661		

Table 2.5. Physico- chemical characteristics of water samples from habitats of *Rhizophora mucronata.*

PRE MONSOON			MONSOON					POST MONSOON					
Apr	May	Seasonal Mean± SD	Jun	Jul	Aug	Sep	Seasonal Mean± SD	Oct	Nov	Dec	Jan	Seasonal Mean± SD	Annual Mean± SD
					Water pH								
7.74	6.88	7.595± 0.481	7.43	7.01	6.4	7.08	6.98± 0.428	7.33	7.3	7.91	7.76	7.575± 0.306	7.383 ± 0.477
7.11	7.07	7.108± 0.052	6.95	7.18	6.48	6.26	6.717± 0.421	6.83	6.91	7.13	7.76	7.157± 0.421	6.994 ± 0.374
7.31	xx	7.74± 0.375	7.64	7.1	3.97	3.9	5.652± 1.995	7.34	7.93	7.89	7.8	7.74± 0.272	6.98± 1.534
7.387±0.322	6.975±0.134		7.34±0.353	7.097±0.085	5.617±1.426	5.747±1.651		7.166±0.291	7.38±0.514	7.643±0.444	7.773±0.023		
					Turbidity (NTU)								
3.2	9.4	5.875± 3.699	4	12.4	7.1	7.3	7.7± 3.478	11.6	25.6	9.4	15.3	15.475± 7.175	9.683 ± 6.322
5.6	11.5	5.35± 4.453	21.2	5.3	12.6	10.7	12.45± 6.602	6.6	5.5	3.1	2.6	4.45± 1.912	7.417 ± 5.679
35.3	xx	18.733± 14.492	60.3	12.7	0.6	10.5	21.025± 26.707	10.5	30.9	25.3	27.7	23.6± 9.029	21.3364 ± 16.869
14.7±17.88	10.45±1.484		28.5±28.851	10.133±4.188	6.767±6.006	9.5±1.907		9.567±2.624	20.667±13.399	12.6±11.44	15.2±12.55		
					T.S (mg/l)								
38600	25600	36000± 6964.673	10000	1800	3600	2400	4450± 3774.917	20800	22200	37000	40600	30150± 10111.87	23533.33 ± 15807.09
25800	6200	21250± 10055.02	600	400	400	600	500± 115.47	13200	2200	17000	25200	14400± 9551.265	12050 ± 11565.19
39200	xx	39933.33 ± 702.376	22200	2600	400	800	6500± 10510.31	16200	56000	41600	38600	38100± 16457.22	27109.09 ± 19545.92
34533.33±7569.236	15900±13717.87		10933.33±10830.2	1600±1113.553	1466.667±1847.521	1266.667±986.576		16733.33±3827.967	26800±27193.38	31866.67±13078.74	34800±8373.769		
					T.D.S (ppt)								
36.0	25.6	34.9± 6.378	9.6	1.2	2.6	1.2	3.65± 4.021	19.8	20.6	37.0	39.2	29.15± 10.378	22.567± 15.68
23.6	6.0	20.2± 9.514	0.6	0.2	0.4	0.4	0.4± 0.163	9.8	2.0	17.0	25.2	13.5± 9.917	11.367 ± 11.193
39.2	xx	39.267± 0.702	22.2	2.2	0.4	0.6	6.35± 10.597	15.8	45.8	37.6	38.6	34.45± 12.958	25.546± 17.882
32.933±8.239	15.8±13.859		10.8±10.85	1.2±1	1.133±1.270	0.733±0.416		15.133±5.033	22.8±21.982	30.533±11.724	34.333±7.915		

T.S.S (mg/l)														
	2600	0	1100± 1113.553	400	600	1000	1200	800± 365.148	1000	1600	0	1400	1000± 711.805	966.667 ± 727.803
	2200	200	1050± 1112.055	0	200	0	200	100± 115.470	3400	200	0	0	900± 1669.331	683.33± 1136.048
	0	xx	666.666± 7 1154.701	0	400	0	200	150± 191.485	400	10200	4000	0	3650± 4722.641	1563.636 ± 3122.586
4	1600±1400	100±141.421		133.333±230.94	400±200	333.333±577.35	533.333±577.35		1600±1587.451	4000±5414.795	1333.333±2309.401	466.667±808.29		
Salinity (ppt)														
	29.77	19.67	28.875± 6.33	8.339	1.965	3.129	3.116	4.137± 2.853	17.57	19.13	27.22	31.15	23.765± 6.489	18.927± 12.194
	20.93	5.241	17.37± 8.094	0.467	0.598	0.327	0.247	0.409± 0.155	8.537	1.85	15.05	21.28	11.679± 8.367	9.819 ± 9.547
	35.62	xx	34.83± 0.703	18.8	1.592	0.708	0.743	5.46± 8.902	12.72	30.01	32.72	33	27.112± 9.689	21.343± 14.86
	28.773±7.395	12.455±10.202		9.202±9.196	1.385±0.706	1.388±1.519	1.3687±1.533		12.942±4.520	16.996±14.2	24.996±9.042	28.477±6.31		
Resistivity (Ω)														
	22.09	31.98	23.52± 5.725	70.17	273.3	174.4	175.7	173.392 ± 82.951	35.47	32.56	23.73	21.17	28.232± 6.862	75.048 ± 84.722
	30.32	107.7	49.125± 39.053	1062	833.2	1506	1977	1344.55 ± 505.757	68.94	284.3	40.76	29.93	105.983± 120.01	499.885 ± 681.066
	18.83	xx	19.203± 0.323	33.47	327.8	714	685.3	440.142 ± 323.06	47.12	21.92	20.17	20.14	27.337± 13.214	175.23± 274.747
	23.747±5.921	69.84±53.542		388.547±583.516	478.1±308.73	798.133±669.774	946±928.517		50.51±16.99	112.9267±148.509	28.22±11.004	23.7467±5.379		
Conductivity (mS)														
	44.28	30.55	43.137± 8.665	13.93	3.576	5.595	5.566	7.166± 4.606	27.54	29.99	41.1	46.12	36.187± 8.869	28.83± 17.677
	32.25	9.077	27.051± 11.996	1.998	1.176	0.648	0.495	1.079± 0.678	14.22	3.438	23.99	32.67	18.579± 12.597	15.57 ± 14.499
	51.76	xx	50.88± 0.762	29.27	2.984	1.369	1.426	8.7622± 13.692	20.71	44.6	48.49	48.6	40.6± 13.389	31.826± 21.508
	42.763±9.843	19.813±15.183		15.066±13.671	2.578±1.250	2.537±2.672	2.495±2.699		20.823±6.66	26.009±20.867	37.86±12.567	42.463±8.571		
Acidity (mg/l)														
	39.6	61.6	42.9± 13.138	17.6	13.2	48.4	17.6	24.2± 16.266	57.2	26.4	30.8	35.2	37.4± 13.680	34.833± 15.409
	39.6	13.2	29.7± 16.993	13.2	13.2	8.8	13.2	12.1± 2.2	26.4	17.6	30.8	39.6	28.6± 9.159	23.467 ± 13.177
	44	xx	35.2± 11.641	26.4	11	26.4	35.2	24.75± 10.061	48.4	39.6	30.8	44	40.7± 7.514	33.4 ± 11.253

	41.066±2.54	37.4±34.224		19.067±6.721	12.467±1.270	27.867±19.84	22±11.641		44±15.864	27.8667±11.0731	30.8±0	39.6±4.4		
Alkalinity (mg/l)														
	140	170	155± 12.909	140	250	220	160	192.5± 51.234	200	180	140	150	167.5± 27.537	171.667 ± 35.118
	140	150	140± 8.165	140	80	80	60	90± 34.641	95	80	100	150	106.25± 30.379	112.083 ± 32.714
	280	xx	190± 78.102	110	120	40	100	92.5± 35.939	110	180	170	160	155± 31.091	141.818± 60.302
	186.67±80.829	160±14.142		130±17.32	150±88.881	113.333±94.516	106.667±50.332		135±56.789	146.667±57.735	136.667±35.118	153.333±5.773		
Hardness (mg/l)														
	5980	4140	5950± 1278.071	2100	228	276	296	725± 917.110	720	680	4980	6200	3145± 2866.886	3273.333 ± 2808.766
	4200	1140	3595± 1664.242	440	100	60	34	158.5± 189.619	260	56	2900	4000	1804± 1954.744	1852.5 ± 1988.906
	7200	xx	7360± 260	3800	270	80	82	1058± 1830.17	390	700	6140	6720	3487.5± 3408.297	3660.182 ± 3366.064
1	5793.333±1508.686	2640±2121.32		2113.333±1680.04	199.33±88.551	138.667±119.353	137.33±139.489		456.667±237.135	478.667±366.176	4673.333±1641.625	5640±1443.884		
Calcium (mg/l)														
	408.51	312.4	406.51± 69.939	264.33	35.27	56.11	46.5	100.553 ± 109.516	210.02	228.46	360.45	424.53	305.865± 103.664	270.975± 158.807
	288.36	96.12	250.313± 103.692	92.12	11.22	9.6	7.21	30.037± 41.421	100.2	19.24	216.27	272.34	152.012± 113.901	144.120± 125.676
	472.59	xx	480.6± 21.192	304.38	23.65	12.83	12.02	88.22± 144.204	144.29	260.52	416.52	472.59	323.48± 149.402	280.781± 201.405
	389.82±93.526	204.26±152.933		220.276±112.779	23.38±12.027	26.18±25.970	21.91±21.43		151.503±55.264	169.407±131.032	331.08±103.305	389.82±104.54		
Magnesium (mg/l)														
	1207.6	818.0	1201.475 ± 270.104	350.59	34.11	33.11	43.82	115.408 ± 156.862	47.72	26.78	993.34	1251.4	579.81± 635.348	632.23± 593.851
	847.26	219.1	723.088± 344.516	51.13	17.54	8.8	3.89	20.34± 21.288	2.43	1.95	574.58	808.3	346.815± 409.218	363.414± 410.008
	1465.7	xx	1499.767 ± 72.020	740.13	51.41	11.7	12.66	203.975 ± 357.915	7.3	12.17	1241.7	1348.8	652.493± 743.481	720.47± 704.304
9	1173.52±310.625	518.55±423.486		380.617±345.48	34.353±16.936	17.87±13.277	20.123±20.985		19.15±24.861	13.633±12.479	936.54±337.167	1136.167±288.087		
Chloride (mg/l)														
	18460	18602	20767.5± 2990.72	8946	2002.2	2343	2612.8	3976± 3322.739	9940	12638	19241	22010	15957.25 ± 5616.746	13566.92 ± 8272.571

	14200	5964	13276.5± 5003.213	3976	639	553.8	411.8	1395.15 ± 1723.117	5112	2130	11857	17395	9123.5± 6853.002	7931.717 ± 6847.36
	25205	xx	25063± 122.975	14626	1093.4	766.8	837.8	4331± 6864.766	9088	19738	23430	23785	19010.25 ± 6863.262	15323.09 ± 10511.9
3	19288.33±5549.064	12283±8936.416		9182.667±5328.943	1244.867±694.107	1221.2±977.327	1287.467±1167.369		8046.667±2576.951	11502±8858.797	18176±5859.544	21063.33±3298.509		
Sulphate (mg/l)														
	129	62	78.75± 33.5	36	13	17.5	22	22.125± 9.953	47	44	60	60	52.75± 8.460	51.208± 30.608
	120	41	82.75± 41.08	5	2	2.5	2	2.875± 1.436	39.5	13.5	42	46	35.25± 14.745	40.291 ± 41.157
	60.5	xx	78.667± 31.465	54	14	11	10	22.25± 21.234	43	50.5	57	60.5	52.75± 7.708	48.727 ± 30.115
	103.167±37.223	51.5±14.849		31.667±24.785	9.667±6.658	10.333±7.522	11.333±10.066		43.167±3.752	36±19.754	53±9.643	55.5±8.231		
Sodium (ppt)														
	22.05	11.95	21.075± 6.520	1.6	1.18	2.08	2.4	1.815± 0.536	10.82	12.85	19.4	25.65	17.18± 6.729	13.356 ± 9.972
	16.55	0.8	13.05± 8.319	4.5	0.265	0.015	0.08	1.215± 2.192	5.46	1.69	11.75	16.65	8.887± 6.633	7.717 ± 7.642
	23.15	xx	24.916± 1.704	11.15	1.215	0.36	0.48	3.301± 5.246	8.97	22	21.65	28.05	20.167± 8.022	15.33 ± 11.088
	20.583±3.536	6.375±7.884		5.75±4.896	0.886±0.538	0.818±1.106	0.987±1.24		8.417±2.722	12.18±10.171	17.6±5.189	23.45±6.01		
Nitrogen (mg/l)														
	35	42	38.5± 4.041	35	22	130	35	55.5± 50.043	56	140	42	63	75.25± 44.040	56.417 ± 38.242
	42	63	49± 9.899	42	19	130	41	58± 49.159	70	80	80	49	69.75± 14.614	58.917 ± 28.684
	49	xx	46.667± 4.041	42	22	220	25	77.25± 95.573	120	168	63	28	94.75± 61.824	75.272± 65.490
	42±7	52.5±14.849		39.667±4.041	21±1.732	160±51.961	33.667±8.082		82±33.645	129.333±44.959	61.667±19.035	46.667±17.616		
Phosphorous (mg/l)														
	75	24	65.38± 39.1	62.5	7.0	30	4.0	25.88± 27.04	5	16	19.5	12.0	13.125± 6.22	34.79± 34.156
	26.5	20	68.5± 52.41	0.7	110	35	9.0	38.68± 49.74	1.0	9	2.5	23	8.875± 10.04	38.68± 45.8
	60.0	xx	91.67± 27.88	10.5	3.0	87.5	4	26.25± 40.97	3.5	18.5	15.0	9.0	11.5± 6.62	38.73 ± 43.26
	53.83±24.83	22.0±2.83		24.57±33.22	40±60.66	50.83±31.85	5.67±2.89		3.17±2.021	14.5±4.92	12.33±8.81	14.67±7.37		

Potassium (mg/l)													
150.0	650.0	312.5± 268.871	1550.0	25.0	45.0	85.0	426.25± 749.581	440.0	570.0	50.0	500.0	390± 232.808	376.25 ± 436.109
100.0	1100.0	362.5± 492.231	1800.0	0	20.0	25.0	461.25± 892.565	220.0	40.0	250.0	0	127.5± 125.797	317.083± 555.920
150.0	xx	300± 180.277	1200.0	35.0	0	0	308.75± 594.395	320.0	500.0	50.0	500.0	342.5± 212.661	318.636 ± 355.57
133.333±28.867	875±318.198		1516.667±301.385	20±18.027	21.667±22.546	36.667±43.684		326.667±110.151	370±287.923	116.667±115.47	333.333±288.675		

Table 2.6. Physico- chemical characteristics of water samples from habitats of *Sonneratia alba.*

PRE MONSOON			MONSOON					POST MONSOON					
Apr	May	Seasonal Mean± SD	Jun	Jul	Aug	Sep	Seasonal Mean± SD	Oct	Nov	Dec	Jan	Seasonal Mean± SD	Annual Mean± SD
Water pH													
8.04	7.85	7.935	7.51	6.97	8.3	8.32	7.775	8.46	8.57	8.01	7.97	8.252	7.987 ± 0.458
8.07	8.31	8.23	7.67	7.01	6.93	8.45	7.515	7.73	8.54	8.03	8.17	8.117	7.954± 0.526
7.35	6.98	7.66	xx	7.06	6.06	6.02	6.38	6.39	6.89	7.12	6.97	6.842	7.013± 0.710
7.82±0.407	7.713±0.675		7.59±0.113	7.013±0.045	7.096±1.12	7.596±1.367		7.527±1.049	8±0.961	7.72±0.519	7.703±0.642		
Turbidity (NTU)													
29.6	11.6	16.1	8.4	12.2	4.2	37.6	15.6	41.1	6.4	6.6	6.3	15.1	15.6± 12.94
32.8	4.5	14.025	5	12.6	14.4	53.9	21.475	14	6.7	4.6	4	7.325	14.275± 15.004
2.2	20.3	7.35	xx	11.4	2.9	3.4	5.9	21.2	28.4	29.9	7.6	21.775	12.2 ± 10.776
21.533±16.819	12.133±7.913		6.7±2.404	12.067±0.611	7.167±6.297	31.633±25.773		25.433±14.037	13.833±12.616	13.7±14.065	5.967±1.823		

T.S (mg/l)														
	42200	43200	42800	7000	400	9000	9200	6400	13600	19800	40000	41400	28700	25966.67± 17437.86
	41600	41800	42900	9200	600	400	18200	7100	8200	19200	39800	43800	27750	25916.67± 18254.46
	42800	49400	43950	xx	1400	800	1600	1266.67	27400	24200	43600	42400	34400	28836.36± 19133.18
22	42200±600	44800±4044.75		8100±1555.635	800±529.15	3400±4853.864	9666.667±8309.834		16400±9901.515	21066.67±2730.079	41133.33±2138.535	42533.33±1205.543		
T.D.S (ppt)														
	42.0	42.2	42.1	6.4	0.2	7.2	8.4	5.55	13.6	18.6	39.8	40.8	28.2	25.283± 17.5
	40.4	41.6	41.65	8.4	0.4	0.4	16.6	6.45	8.2	19.0	39.8	41.0	27	25.033± 17.765
	38.0	49.0	41.8	xx	1.2	0.8	1.4	1.133	26.2	22.2	43.0	42.4	33.45	27.673± 18.628
2	40.133±2.013	44.267±4.11		7.4±1.414	0.6±0.529	2.8±3.815	8.8±7.607		16±9.236	19.933±1.973	40.867±1.847	41.4±0.871		
T.S.S (mg/l)														
	200	1000	700	600	200	1800	800	850	0	1200	200	600	500	683.33± 611.753
	1200	200	1250	800	200	0	1600	650	0	200	0	2800	750	883.33± 1032.062
	4800	400	2150	xx	200	0	200	133.333	1200	2000	600	0	950	1163.636± 1430.575
66	2066.667±2419.366	533.33±416.333		700±141.421	200±0	600±1039.23	866.67±702.376		400±692.82	1133.333±901.85	266.6667±305.505	1133.333±1474.223		
Salinity (ppt)														
	35.11	34.71	34.865	5.425	0.299	0.448	8.32	3.623	12.07	16.9	32.26	34.28	23.877	20.789± 14.844
	35	34.5	35.09	7.156	0.419	8.074	11.68	6.832	7.107	16.49	32.97	35.15	22.929	21.617± 14.194
	35.68	38.5	35.807	xx	0.847	0.813	0.792	0.817	22	33.64	33.71	35.15	31.125	24.562 ± 15.788
2	35.263±0.365	35.903±2.251		6.290±1.224	0.521±0.288	3.112±4.301	6.93±5.575		13.725±7.583	22.343±9.785	32.98±0.725	34.86±0.502		

Resistivity (Ω)													
19.02	19.15	19.165	104.3	1634	1113	69.97	730.317	50.02	36.49	20.47	19.51	31.622	260.368± 532.327
19.07	19.28	19.042	80.67	1174	72.83	51.14	344.66	81.46	37.52	20.08	19.09	39.537	134.413± 328.379
18.71	17.49	18.702	xx	599.3	629.6	635.5	621.466	29.02	19.77	19.59	18.98	21.84	184.233± 280.969
18.933±0.195	18.64±0.998		92.485±16.708	1135.767±518.408	605.143±520.516	252.203±332.078		53.5±26.392	31.26±9.964	20.046±0.441	19.193±0.279		
Conductivity (mS)													
51.39	50.97	50.972	9.374	0.599	0.878	13.94	6.197	19.5	26.81	47.76	50.03	36.025	31.065± 21.278
51.25	50.71	51.307	12.11	0.833	13.44	19.1	11.372	12.02	26.12	48.7	51.13	34.492	32.39± 20.105
52.24	55.87	52.3575	xx	1.634	1.553	1.538	1.575	33.65	49.38	49.86	51.55	46.11	36.235± 22.938
51.626±0.535	52.516±2.907		10.742±1.934	1.022±0.542	5.290±7.065	11.526±9.026		21.723±10.985	34.103±13.234	48.773±1.052	50.9033±0.784		
Acidity (Mg/l)													
48.4	35.2	45.1	8.8	11	30.8	13.2	15.95	22	3.52	26.4	57.2	27.28	29.443± 19.701
52.8	26.4	31.9	15.4	6.6	8.8	17.6	12.1	39.6	3.08	22	48.4	28.27	24.09 ± 16.1
52.8	70.4	50.6	xx	15.4	30.8	30.8	25.667	61.6	74.8	35.2	66	59.4	47 ± 20.121
51.333±2.54	44±23.282		12.1±4.667	11±4.4	23.467±12.701	20.533±9.159		41.067±19.84	27.133±41.281	27.867±6.721	57.2±8.8		
Alkalinity (Mg/l)													
160	170	182.5	70	85	180	140	118.75	280	120	180	270	212.5	171.25± 67.289
270	190	200	80	160	80	160	120	250	100	180	250	195	171.667± 63.794
200	220	220	xx	60	140	120	106.667	140	180	210	170	175	172.727± 54.2385
210±55.6776	193.333±25.166		75±7.071	101.667±52.041	133.333±50.332	140±20		223.333±73.71	133.333±41.633	190±17.32	230±52.915		
Hardness (Mg/l)													
7220	8760	7440	1140	69	200	440	462.25	370	880	4580	6720	3137.5	3679.917± 3436.343
7040	6840	6925	1560	96	67	520	560.75	280	880	6200	6800	3540	3675.25± 3275.315
7720	8000	7475	xx	146	32	130	102.667	484	900	6200	6800	3596	4053.818± 3594.697
7326.667±352.325	7866.667±966.919		1350±296.984	103.6667±39.068	99.667±88.636	363.333±205.993		378±102.235	886.666±11.547	5660±935.307	6773.333±46.188		

Calcium (Mg/l)														
	456.57	496.6	490.6075	80.1	13.63	40.08	106.6	60.102	134.67	216.43	488.61	448.56	322.0675	290.926±207.41
	448.56	456.6	480.6075	144.18	16.03	12.42	134.7	76.832	84.17	200.4	424.53	424.53	283.4075	280.282 ± 198.113
	464.58	528.7	480.61	xx	15.23	10.42	9.62	11.756	160.32	320.64	448.56	432.54	340.515	301.797±210.601
	456.57±8.01	493.967±36.122		112.14±45.311	14.963±1.222	20.973±16.577	83.64±65.624		126.386±38.744	245.823±65.287	453.9±32.372	435.21±12.235		
Magnesium (Mg/l)														
	1480.3	1830.9	1513.15	228.86	8.53	24.36	42.36	76.028	8.28	82.78	818.04	1363.4	568.125	719.1±718.942
	1441.3	1387.8	1393.85	292.16	13.64	8.77	44.79	89.84	17.04	92.52	1251.4	1397.5	689.615	724.435 ± 680.402
	1597.1	1626.4	1527.75	xx	26.31	1.46	25.81	17.86	20.45	24.35	1236.8	1392.6	668.55	803.525±757.403
	1506.233±81.072	1615.033±221.768		260.51±44.759	16.16±9.154	11.53±11.696	37.653±10.328		15.257±6.277	66.55±36.869	1102.08±246.094	1384.5±18.436		
Chloride (Mg/l)														
	23998	30672	25347	5964	383.4	5964	4118	4107.35	6958	10650	19880	41322	19702.5	16385.62±12576.02
	23430	25560	24672.5	6674	461.5	404.7	4828	3092.05	4316.8	10863	20022	39263	18616.2	15460.25±12495.2
	26270	27406	25489	xx	681.6	795.2	809.4	762.06	15265	21158	22720	22720	20465.75	16918.7±104848.48
21	24566±1502.787	27879.33±2588.662		6319±502.045	508.833±154.632	2387.967±3103.084	3251.8±2144.764		8846.6±5713.22	14223.67±6006.253	20874±1600.259	34435±10197.59		
Sulphate (Mg/l)														
	127	63	89.125	31.5	2	36	41	27.625	43.5	57	48	46	48.625	55.125±32.993
	126	63	89.5	38.5	3	2.5	44	22	36	57	51	47	47.75	53.083±35.934
	60.5	63	75.625	xx	9	8.5	5.5	7.667	57	53.5	60	60.5	57.75	50.59±32.673
	104.5±38.108	63±0		35±4.949	4.667±3.785	15.667±17.862	30.167±21.414		45.5±10.641	55.833±2.020	53±6.245	51.1667±8.0984		
Sodium (ppt)														
	25.55	29.65	27	0.01	0.075	0.002	0.61	0.174	8.12	11.67	22.55	28.05	17.597	14.923±12.617
	23.9	26.15	25.375	0.45	0.135	4.735	8.17	3.372	5.33	11.32	23.8	24.55	16.25	14.999±10.855
	26.8	26.9	26.225	xx	0.475	0.465	0.67	0.536	12.77	46.8	24.3	28.65	28.13	19.912±14.695
	25.417±1.454	27.567±1.842		0.23±0.3111	0.228±0.215	1.73±2.609	3.15±4.347		8.74±3.758	23.263±20.384	23.55±0.901	27.083±2.214		

Nitrogen (mg/l)														
	63.0	56.0	47.25	28.0	38.0	140.0	490.0	174	80.0	110.0	70.0	42.0	75.5	98.917± 127.6825
	56.0	35.0	42	42.0	14.0	120.0	34.0	52.5	98.0	98.0	42.0	56.0	73.5	56± 32.1106
	42.0	42.0	40.25	xx	22.0	110.0	39.0	57	63.0	70.0	110.0	42.0	71.25	56.091± 29.5752
	53.667±10.692	44.333±10.692		35±9.899	24.667±12.22	123.333±15.275	187.667±261.840		80.333±17.502	92.667±20.526	74±34.176	46.667±8.082		
Phosphorous (mg/l)														
	62.5	17	49.5	62.5	50	35	3	37.625	11	3	3.5	31	12.125	33.08± 30.37
	5.5	15	57.68	77.5	40	25	1.5	36	4	65	13.5	20	25.625	39.77± 38.87
	25	25.5	63.88	xx	15	30	20	21.667	3	7.5	10	15	8.875	32.36± 35.77
	31±28.97	19.17±5.58		70±10.61	35±18.03	30.0±50.0	8.17±10.28		6±4.36	25.17±34.57	9±5.07	22±8.19		
Potassium (mg/l)														
	100.0	100.0	237.5	1600.0	10.0	20.0	220.0	462.5	290.0	520.0	150.0	450.0	352.5	350.83± 427.88
	0	400.0	250	1650.0	15.0	170.0	260.0	523.75	120.0	440.0	200.0	300.0	265	346.25± 434.694
	150.0	450.0	337.5	xx	10.0	0	0	3.333	560.0	500.0	300.0	500.0	465	292.727± 223.297
5	83.333±76.376	316.667±189.296		1625±35.355	11.667±2.886	63.333±92.915	160±140		323.333±221.885	486.667±41.633	216.667±76.376	416.667±104.083		

As far as the pH of water confining to the habitat of *Avicennia officinalis* is concerned, higher annual average was noticed at Kadalundi 1 of Malappuram district (7.612 ± 0.397), followed by Kumbalam 1 of Ernakulam district (6.892 ± 0.397) and Thekkumbad 1 of Kannur district (6.842 ±1.302). With respect to *Bruguiera cylindrica*, highest pH was recorded at Kadalundi 2 of Malappuram district (7.749 ± 0.420) followed by Ayiramthengu 1 of Kollam district (7.470 ± 0.379) and Thekkumbad 2 of Kannur district (7.126 ± 0.776). Among the study sites of *Excoecaria agallocha*, higher pH was recorded at Ayiramthengu 2 (7.389 ± 0.431), followed by Kumbalam 2 (6.91 ± 0.436) and lower at Thekkumbad 3(6.758 ± 1.014). Results on the annual mean pH of *Rhizophora mucronata* habitats revealed higher pH at Ayiramthengu 3(7.383 ± 0.477) followed by Kumbalam 3(6.994 ± 0.374) and Thekkumbad 4(6.981 ±_1.534). With respect to *Sonneratia alba*, higher pH was noticed at Kadalundi 3 (7.988 ± 0.459) followed by Kadalundi 4 (7.954 ± 0.527) and Thekkumbad 5 (7.014 ± 0.710).

Results of the annual mean turbidity of water along the habitat of *Avicennia officinalis* showed a highest value of 17.408 ± 15134 NTU at Kadalundi 1, 8.867 ± 7.354 NTU at Kumbalam1 and 8.644 ± 7.354 NTU at Thekkumbad 1. Highest annual average of turbidity with respect to *Bruguiera cylindrica* was noticed at Kadalundi 2 (20.658±11.861 NTU) followed by Ayiramthengu 1(6.983 ±4.551 NTU) and Thekkumbad 2(4.678 ±3.004 NTU). As far as the turbidity of water confining to the habitat of *Excoecaria agallocha* is concerned, higher annual average was noticed at Kumbalam 2 (9.542 ± 7.678 NTU) followed by Ayiramthengu 2, (7.817 ± 9.468 NTU) and Thekkumbad 3 (5.678 ± 4.029 NTU). Among the habitats of *Rhizophora mucronata*, Thekkumbad 4 was reported for highest annual mean turbidity of 21.336 ± 16.869 NTU followed by Ayiramthengu 3(9.683 ± 6.323 NTU) and Kumbalam 3(7.417 ±_5.680 NTU).). With respect to *Sonneratia alba*, highest turbidity was noted at Kadalundi 3 (15.6 ± 12.94 NTU) followed by Kadalundi 4 (14.275 ± 15.004 NTU) and Thekkumbad 5 (12.2 ±10.776 NTU).

Results of total solids (TS) of water confining to the habitat of *Avicennia officinalis* revealed higher annual average at Thekkumbad 1 (25444.4 ± 19686.9 mg/l) followed by Kadalundi 1 (23900 ± 18798.4 mg/l) and Kumbalam 1 (10733.3 ± 10769.1 mg/l). With respect to *Bruguiera cylindrica*, highest TS was noted at Thekkumbad 2 (26555.6 ± 24119.03 mg/l) followed by Kadalundi 2 (25933.3 ± 18991.35 mg/l) and Ayiramthengu 1 (23166.7 ± 14682.29 mg/l). Among the study sites of *Excoecaria agallocha,* Ayiramthengu 2 was noticed for highest value of TS (23500 ± 15260.5 mg/l) followed by Thekkumbad 3 (22800 ± 21589.8 mg/l) and Kumbalam 2 (10433.3 ± 9814.2 mg/l). Data on the annual mean TS with respect to *Rhizophora mucronata* revealed higher values at Thekkumbad 4 (27109.1 ± 19545.9 mg/l) followed by Ayiramthengu 3 (23533.3 ± 15807.1 mg/l) and Kumbalam 3 (12050.0 ± 11565.2 mg/l). Studies on the habitats of *Sonneratia alba* showed higher value of TS at Thekkumbad 5 (28836.4 ± 19133.2 mg/l) followed by Kadalundi 3 (25966.7 ± 17437.9 mg/l) and Kadalundi 4 (25916.7 ± 18254.5 mg/l).

As far as the total dissolved solids (TDS) of water confining to the habitat of *Avicennia officinalis* is concerned, higher annual average was noticed at Kadalundi 1 of Malappuram district (22.917 ± 18.272 ppt) followed by Thekkumbad 1 of Kannur district (20.333 ±_19.364 ppt) and Kumbalam 1 of Ernakulam district (9.9 ± 10.136 ppt). In the case of *Bruguiera cylindrica,* highest TDS was noted at Thekkumbad 2 (26.067 ± 23.34 ppt) followed by Kadalundi 2 (22.983 ± 17.157 ppt) and Ayiramthengu 1 (22.183 ± 14.27 ppt). As far as the TDS of water confining to the habitat of *Excoecaria agallocha* is concerned, higher annual average was noticed at Ayiramthengu 2 (22.7 ± 14.83 ppt) followed by Thekkumbad 3 (21.2 ± 20.11 ppt) and Kumbalam 2 (9.867 ± 9.367 ppt). Among the habitats of *Rhizophora mucronata*, Thekkumbad 4 was recorded with higher annual mean of TDS (25.546 ± 17.882 ppt) followed by Ayiramthengu 3 (22.567 ± 15.687 ppt) and Kumbalam 3 (11.367 ± 11.193 ppt). With respect to *Sonneratia alba*, highest TDS was noted at Thekkumbad 5 of Kannur district (27.673 ± 18.628 ppt) followed by Kadalundi 4 (25.283 ± 17..500 ppt) and Kadalundi 3 of Malappuram district (25.033 ± 17.765 ppt).

Total suspended solids (TSS) of water confining to the habitats of *Avicennia officinalis* showed a higher annual average value at Thekkumbad 1 (5111.11 ± 13541.46 mg/l) followed by Kadalundi 1 (966.67 ± 1019.21 mg/l) and Kumbalam 1 (833.33 ± 839.192 mg/l). With respect to *Bruguiera cylindrica*, highest TSS was noted at Kadalundi 2 (2950 ± 5288.15 mg/l) followed by Ayiramthengu1 (983.33 ± 715.84 mg/l) and Thekkumbad 2 (888.89 ± 1403.96 mg/l). Among the study sites of *Excoecaria agallocha*, Thekkumbad 3 was noticed for higher TSS (1600 ± 2626.79 mg/l) followed by Ayiramthengu 2 (800 ± 687.55 mg/l) and Kumbalam 2 (566.67 ± 648.54 mg/l). TSS with respect to *Rhizophora mucronata* showed a higher annual mean (1563.64 ± 3122.59 mg/l) at Thekkumbad 4 followed by Ayiramthengu 3 (966.67 ± 727.80 mg/l) and Kumbalam 3 (683.33 ± 1136.05 mg/l). The study areas of *Sonneratia alba* showed a higher TSS at Thekkumbad 5(1163.64 ± 1430.58 mg/l) followed by Kadalundi 4 (883.33 ± 1032.06 mg/l) and Kadalundi 3 (683.33 ± 611.75 mg/l).

As far as the acidity of water confining to the habitat of *Avicennia officinalis* is concerned, higher annual average was noticed at Thekkumbad 1 (35.689 ± 13.99 mg/l) followed by Kadalundi 1 (27.977 ± 18.139 mg/l) and Kumbalam 1 (22.55 ± 21.74 mg/l). With respect to *Bruguiera cylindrica*, highest acidity was noted at Thekkumbad 2 (40.578 ± 15.365 mg/l) followed by Ayiramthengu 1 (29.333 ± 10.03 mg/l) and Kadalundi 2 (28.563 ± 13.64 mg/l). Among the study sites of *Excoecaria agallocha*, higher acidity was noticed at Thekkumbad 3 (39.356 ± 21.456 mg/l) followed by Ayiramthengu 2 (34.65 ± 9.755 mg/l) and Kumbalam 2 (27.133 ± 9.49 mg/l). With respect to *Rhizophora mucronata*, annual mean acidity was higher at Ayiramthengu 3 (34.833 ± 15.41 mg/l) followed by Thekkumbad 4 (33.4 ± 11.25 mg/l) and Kumbalam 3 (23.467 ± 13.18 mg/l). The study areas of *Sonneratia alba* showed a higher acidity at Thekkumbad 5 (47 ± 20.122 mg/l) followed by Kadalundi 3 (29.443 ± 19.702 mg/l) and Kadalundi 4 (24.09 ± 16.100 mg/l).

Results of the annual average alkalinity confining to the habitats of *Avicennia officinalis* revealed a higher value at Thekkumbad 1 of (164.444 ± 51.505 mg/l) followed by Kadalundi 1 (160.833 ± 66.121 mg/l) and Kumbalam 1 (132.083 ± 45.898 mg/l). In the case of *Bruguiera cylindrica*, highest mean alkalinity was noted at Thekkumbad 2 (270.0 ± 298.035 mg/l) followed by Kadalundi 2 (162.083 ± 52.2 mg/l) and Ayiramthengu 1 (160.417 ± 27.998 mg/l). As far as the alkalinity of water confining to the habitat of *Excoecaria agallocha* is concerned, higher annual average was noticed at Ayiramthengu 2 (172.083 ± 34.076 mg/l) followed by Thekkumbad 3 of (150.556 ± 35.920 mg/l) and Kumbalam 2 (122.083 ± 39.969 mg/l). Among the habitats of *Rhizophora mucronata*, Ayiramthengu 3 (171.667 ± 35.119 mg/l) was noticed for higher value followed by Thekkumbad 4 (141.818 ± 60.302 mg/l) and Kumbalam 3 (112.083 ± 32.715 mg/l). With respect to *Sonneratia alba*, highest alkalinity was noted at Thekkumbad 5 (172.727 ± 54.239 mg/l) followed by Kadalundi 4 (171.667 ± 63.794 mg/l) and Kadalundi 3 (171.667 ± 63.794 mg/l).

Hardness of water confining to the habitat of *Avicennia officinalis* showed higher annual average values at Kadalundi 1 (3490.75± 3414.5 mg/l) followed by Thekkumbad 1 (3051.33 ± 3344.77 mg/l) and Kumbalam 1 (1786.17 ± 1872.34 mg/l). With respect to *Bruguiera cylindrica*, highest hardness was noted at Ayiramthengu 1 (3282.17 ± 2741.46 mg/l) followed by Kadalundi 2 (3135.67± 3447.72 mg/l) and Thekkumbad 2 (31300 ± 3555.53 mg/l). In the case of *Excoecaria agallocha*, hardness showed a higher value at Ayiramthengu 2 (3279.67 ± 2782.29 mg/l) followed by Thekkumbad 3 (3124.89 ± 3514.9 mg/l) and Kumbalam 2 (1736.92 ± 1789.16 mg/l). Among the habitats of *Rhizophora mucronata*, the annual mean hardness was higher at Thekkumbad 4 (3660.18 ± 3366.06 mg/l) followed by Ayiramthengu 3 (3273.33 ± 2808.77 mg/l) and Kumbalam 3 (1852.5 ± 1988.9 mg/l). The study areas of *Sonneratia alba* showed a higher hardness at Thekkumbad 5 (4053.82 ± 3594.7 mg/l) followed by Kadalundi 3 (3679.92 ± 3436.34 mg/l) and Kadalundi 4 (3675.25 ± 3275.32 mg/l).

Annual average value of calcium confining to the habitats of *Avicennia officinalis* was higher at Thekkumbad 1 (308.96 ± 280.96 mg/l) followed by Kadalundi 1 (261.22 ± 215.51 mg/l) and Kumbalam 1 (151.09 ± 132.44 mg/l). With respect to *Bruguiera cylindrica*, highest calcium was noted at Thekkumbad 2 (334.806 ± 371.638 mg/l) followed by Kadalundi 2 (289.213 ± 243.933 mg/l) and Ayiramthengu 1(289.195 ± 243.933 mg/l). In the case of *Excoecaria agallocha*, higher annual average of calcium was noticed at Ayiramthengu 2 (273.321 ± 157.128 mg/l) followed by Thekkumbad 3 (266.538 ± 263.387 mg/l) and Kumbalam 2 (130.838 ± 109.603 mg/l). Higher annual mean value of calcium with respect to the habitats of *Rhizophora mucronata* was reported at Thekkumbad 4 (280.78 ± 201.41 mg/l) followed by Ayiramthengu 3 (270.976 ± 158.808 mg/l) and Kumbalam 3 (144.12 ± 125.68 mg/l). With respect to *Sonneratia alba*, highest calcium was noted at Thekkumbad 5 (301.797 ± 210.601 mg/l) followed by Kadalundi 3 (290.926 ± 207.41 mg/l) and Kadalundi 4 (280.28 ± 198.11 mg/l).

As far as the magnesium of water confining to the habitat of *Avicennia officinalis* is concerned, higher annual average was noticed at Kadalundi 1 (690.693 ± 703.72 mg/l) followed by Thekkumbad 1 (555.101 ± 684.09 mg/l) and Kumbalam 1 (343.026 ± 377.323 mg/l). With respect to *Bruguiera cylindrica*, highest magnesium content was noted at Kadalundi 2 (712.159 ± 693.05 mg/l) followed by Ayiramthengu 1 (623.312 ± 572.688 mg/l) and Thekkumbad 2 (558.543 ± 669.587 mg/l). Among the habitats of *Excoecaria agallocha*, Ayiramthengu 2 showed higher magnesium (632.381 ± 588.34 mg/l) followed Kumbalam 2 (598.789 ± 710.721 mg/l) and Thekkumbad 3 (343.348 ± 370.431 mg/l). In the case of *Rhizophora mucronata*, the annual mean content of magnesium was higher at Thekkumbad 4 (720.47 ± 704.30 mg/l) followed by Ayiramthengu 3 (632.231 ± 593.85 mg/l) and Kumbalam 3 (363.41 ± 410.01 mg/l). The study areas of *Sonneratia alba* showed a higher magnesium at Thekkumbad 5 (803.526 ± 757.404 mg/l) followed by Kadalundi 4 (724.435 ± 680.40 mg/l) and Kadalundi 3 (719.101 ± 718.94 mg/l).

In the present investigation, the annual average value of chloride confining to the habitat of *Avicennia officinalis* was higher at Kadalundi 1 (15257.9 ± 12778.04 mg/l) followed by Thekkumbad 1 (14873.71 ± 11857.44 mg/l) and Kumbalam 1(8001.7 ± 7192.61 mg/l). Highest annual average value of chloride with respect to *Bruguiera cylindrica* was noted at Kadalundi 2 (13144.68 ± 9949.87 mg/l) followed by Ayiramthengu 1 (12266.43 ± 7370.04 mg/l) and Thekkumbad 2 (11833.93 ± 11850.96 mg/l). As far as the chloride of water confining to the habitat of *Excoecaria agallocha* is concerned, annual average was higher at Thekkumbad 3 of Kannur district (13166.84 ± 12237.16 mg/l) followed by Ayiramthengu 2 (13107.78 ± 7959.91 mg/l) and Kumbalam 2 (7669.78 ± 6849.18 mg/l). With respect to *Rhizophora mucronata* the annual mean chloride was higher at Thekkumbad 4 (15323.09 ± 10511.9 mg/l) followed by Ayiramthengu 3 (13566.92 ± 8272.57 mg/l) and Kumbalam 3 (7931.71 ± 6847.36 mg/l). In the case of *Sonneratia alba*, highest chloride was noted at Thekkumbad 5 (16918.7 ± 10848.48 mg/l) followed by Kadalundi 3 (16385.617 ± 12576.02 mg/l) and Kadalundi 4 (15460.25 ± 12495.2 mg/l).

Among different habitats of *Avicennia officinalis,* higher annual average values of sulphate was noticed at Kadalundi 1 (51.208 ± 35.229 mg/l) followed by Thekkumbad 1 (44.861 ± 37.370 mg/l) and Kumbalam 1 (37.375 ± 38.154 mg/l). With respect to *Bruguiera cylindrica*, highest sulphate was noted at Kadalundi 2 (54.75 ± 33.537 mg/l) followed by Ayiramthengu 1 (51.167 ± 29.655 mg/l) and Thekkumbad 2 (44.111 ± 36.82 mg/l). In the case of *Excoecaria agallocha*, higher sulphate was noticed at Ayiramthengu 2 (52.417 ± 29.271 mg/l) followed by Thekkumbad 3 (41.722 ± 36.799 mg/l) and Kumbalam 2 (35.271 ± 33.082 mg/l). In the case of *Rhizophora mucronata*, the annual mean sulphate was higher at Ayiramthengu 3 (51.208 ± 30.61 mg/l) followed by Thekkumbad 4 (48.727 ± 30.12 mg/l) and Kumbalam 3 (40.292 ± 41.158 mg/l). The study sites of *Sonneratia alba* showed a higher sulphate at Kadalundi 3 (55.125 ± 32.99 mg/l) followed by Kadalundi 4 (53.083 ± 35.94 mg/l) and Thekkumbad 5 (50.591 ± 32.673 mg/l).

Annual average values of sodium confining to the habitat of *Avicennia officinalis* was higher at Thekkumbad 1 (17.849 ± 18.35 ppt) followed by Kadalundi 1 (13.935 ± 10.852 ppt) and Kumbalam 1 (5.677 ± 5.624 ppt). With respect to *Bruguiera cylindrica*, the annual average value of sodium was highest at Thekkumbad 2 (16.289 ± 15.225 ppt) followed by Kadalundi 2 (15.523 ± 11.604 ppt) and Ayiramthengu 1 (13.288 ± 9.267 ppt). Higher annual average values of sodium with respect to *Excoecaria agallocha* was noticed at Ayiramthengu 2 (14.303 ± 10.426 ppt) followed by Thekkumbad 3 (14.123 ± 13.409 ppt) and Kumbalam 2 (8.447 ± 9.594 ppt). The habitats of *Rhizophora mucronata* has been noticed with higher annual mean sodium of 15.33 ± 11.088 ppt at Thekkumbad 4 followed by Ayiramthengu 3 (13.357 ± 9.97 ppt) and Kumbalam 3 (7.718 ± 7.642 ppt). With respect to *Sonneratia alba*, highest sodium was noted at Thekkumbad 5 (19.912 ± 14.7 ppt) followed by Kadalundi 4 (14.999 ± 10.86 ppt) and Kadalundi 3 (14.924 ± 12.62 ppt).

As far as the nitrogen content of water confining to the habitat of *Avicennia officinalis* is concerned, higher annual average was noticed at Thekkumbad 1 (68.333 ± 32.86 mg/l) followed by Kumbalam 1 (59.167 ± 35.334 mg/l) and Kadalundi 1(56.417 ± 47.91 mg/l). With respect to *Bruguiera cylindrica*, highest nitrogen content was noted at Ayiramthengu 1 (61.333 ± 49.99 mg/l) followed by Thekkumbad 2 (55.091 ± 35.43 mg/l) and Kadalundi 2 (48.583 ± 25.91 mg/l). In the case of *Excoecaria agallocha*, higher nitrogen was reported at Ayiramthengu 2 (69.75 ± 55.531 mg/l) followed by Kumbalam 2 (64.583 ± 46.108 mg/l) and Thekkumbad 3 (63.333± 31.9 mg/l). Among different habitats of *Rhizophora mucronata* studied, annual mean nitrogen was higher at Thekkumbad 4 (75.273 ± 65.49 mg/l) followed by Kumbalam 3 (58.92 ± 28.69 mg/l) and Ayiramthengu 3 (56.417 ± 38.242 mg/l). The study sites of *Sonneratia alba* showed a higher value of nitrogen at Kadalundi 3 (98.917 ± 127.683 mg/l) followed by Thekkumbad 5 (56.091 ± 29.58 mg/l) and Kadalundi 4 (56.0 ± 32.11 mg/l).

Phosphorous content of water confining to the habitat of *Avicennia officinalis* showed higher annual average values at Thekkumbad 1 (36.4 ± 42.7 mg/l) followed by Kadalundi 1 (22.08 ± 35 mg/l) and Kumbalam 1 (22.04 ± 21.9 mg/l). With respect to *Bruguiera cylindrica*, highest phosphorous was noted at Kadalundi 2 (42.1 ± 39.7 mg/l) followed by Thekkumbad 2 (35.2 ± 42.8 mg/l) and Ayiramthengu 1 (26.4 ± 47.4 mg/l). Among the study sites of *Excoecaria agallocha*, higher phosphorous was recorded at Thekkumbad 3 with 42.6 ± 40.6 mg/l followed by Kumbalam 2 (20.2 ± 25.1 mg/l) and Ayiramthengu 2 (18.2 ± 25.4 mg/l). In the case of Rhizophora *mucronata,* Thekkumbad 4 was noticed for higher annual mean phosphorous (38.73 ± 43.26 mg/l) followed by Kumbalam 3 (38.68 ± 45.8 mg/l) and Ayiramthengu 3 (34.8 ± 34.0 mg/l). With respect to *Sonneratia alba*, higher phosphorous was recorded at Kadalundi 4 (39.8 ± 38.9 mg/l) followed by Kadalundi 3 (33.1 ± 30.4 mg/l) and Thekkumbad 5 (32.4 ± 35.8 mg/l).

Annual mean values of potassium confining to the habitats of *Avicennia officinalis* was higher at Thekkumbad 1 (3252.73 ± 8296.39 mg/l) followed by Kadalundi 1 (3105.42 ± 6015.65 mg/l) and Kumbalam 1 (910.42 ± 1828.76 mg/l). Among the sites with respect to *Bruguiera cylindrica*, the annual average value of potassium was noted to be higher at Kadalundi 2 (401.67 ± 488.8 mg/l) followed by Ayiramthengu 1 (312.083 ± 373.79 mg/l) and Thekkumbad 2 (211.67 ± 230.52 mg/l). As far as the potassium concentration of water confining to the habitat of *Excoecaria agallocha* is concerned, higher annual average was noticed at Ayiramthengu 2 (387.08 ± 412.48 mg/l) followed by Kumbalam 2 (349.17 ± 503.43 mg/l) and Thekkumbad 3 (120.0 ± 164.7 mg/l). The habitat of *Rhizophora mucronata* is with an annual mean level of potassium of 376.25 ± 436.11 mg/l at Ayiramthengu 3 followed by Thekkumbad 4 (318.64 ± 355.57 mg/l) and Kumbalam 3 (317.08 ± 555.92 mg/l). With respect to *Sonneratia alba*, highest potassium level was noted at Kadalundi 3 (350.83 ± 427.88 mg/l), followed by Kadalundi 4 (346.25 ± 434.69 mg/l) and Thekkumbad 5 (292.73 ± 223.3 mg/l).

Salinity of water confining to the habitats of *Avicennia officinalis* showed higher annual average at Kadalundi 1 (19.678 ± 15.507 ppt) followed by Thekkumbad 1 (19.667 ± 16.523ppt) and Kumbalam 1 (8.693 ± 8.654 ppt). With respect to *Bruguiera cylindrica*, highest salinity was noted at Kadalundi 2 (30.967 ± 21.061 ppt) followed by Thekkumbad 2 (21.061 ± 19.623 ppt) and Ayiramthengu 1 (18.689 ± 11.538 ppt). In the case of study areas of *Excoecaria agallocha*, Ayiramthengu 2 was recorded for higher salinity (19.067 ±_12.03 ppt) followed by Thekkumbad 3 (18.55 ± 17.818 ppt) and lower salinity of 8.529 ± 8.106 ppt at Kumbalam 2. In the habitats of *Rhizophora mucronata*, higher mean salinity of 21.344 ± 14.86 ppt was noted at Thekkumbad 4 followed by Ayiramthengu 3 (18.927 ± 12.19 ppt) and Kumbalam 3 (9.82 ± 9.55 ppt). With respect to the study sites of *Sonneratia alba*, higher salinity was recorded at Thekkumbad 5 (24.562 ± 15.788 ppt) followed by Kadalundi 4 (21.617 ± 14.19 ppt) and Kadalundi 3 (20.789 ± 14.85 ppt).

As far as the resistivity of water confining to the habitat of *Avicennia officinalis* is concerned, higher annual average was noticed at Thekkumbad 1 (2017.66 ± 3699.78 Ω) followed by Kumbalam 1 (503.602 ± 769.47 Ω) and Kadalundi 1 (131.123 ± 191.48 Ω). With respect to *Bruguiera cylindrica*, highest resistivity was noted at Thekkumbad 2 (898.886 ± 1635.49 Ω) followed by Kadalundi 2 (86.831 ± 110.48 Ω) and Ayiramthengu 1 (84.723 ± 133.658 Ω). Higher values of resistivity with respect to *Excoecaria agallocha* was noticed at Thekkumbad 3 (2317.91 ± 4056.43 Ω) followed by Kumbalam 2 (284.721 ± 329.615 Ω) and Ayiramthengu 2 (66.07 ± 65.22 Ω). Among the habitats of *Rhizophora mucronata*, annual mean resistivity was higher at Kumbalam 3 (499.886 ± 681.07 Ω) followed by Thekkumbad 4 (175.23 ± 274.75 Ω) and Ayiramthengu 3 (75.048 ± 84.72 Ω). The study sites of *Sonneratia alba* showed a higher resistivity at Kadalundi 3 (260.368 ± 532.33 Ω) followed by Thekkumbad 5 (184.237 ± 280.97 Ω) and Kadalundi 4 (134.413 ± 328.38 Ω).

Annual average values of conductivity of water confining to the habitat of *Avicennia officinalis* was higher at Kadalundi 1 (29.369 ± 22.193 mS) followed by Thekkumbad 1 (28.945 ± 24.195 mS) and Kumbalam 1 (13.77 ± 13.23 mS). With respect to *Bruguiera cylindrica*, highest conductivity was noted at Kadalundi 2 (31.081 ± 21.007 mS) followed by Thekkumbad 2 (30.744 ± 28.39 mS) and Ayiramthengu 1 (28.496 ± 16.67 mS). In the case of *Excoecaria agallocha*, higher conductivity was recorded at Ayiramthengu 2 with 29.025 ± 17.36 mS followed by Thekkumbad 3 (27.40 ± 26.12 mS) and lower at Kumbalam 2 (13.659 ± 12.464 mS). Among different habitats of *Rhizophora mucronata*, the annual mean conductivity was higher at Thekkumbad 4 (31.826 ± 21.51 mS) followed by Ayiramthengu 3 (28.831 ± 17.68 mS) and Kumbalam 3 (15.570 ± 14.5 mS). With respect to the species *Sonneratia alba*, higher conductivity was recorded at Thekkumbad 5 (36.236 ± 22.938 mS) followed by Kadalundi 4 (32.390 ± 20.105 mS) and Kadalundi 3 (31.065 ± 21.279 mS).

Similar to water samples, soil / sediment samples were collected on a monthly basis for a period of one year from the respective mangrove habitats confining to the coast of Kerala and were subjected to the analysis of pH, moisture percentage, organic carbon, total nitrogen, total phosphorous, potassium, sodium and textural percentage of sand, silt and clay by standard instruments and procedures (Subramanyam and Sambamurthy, 2002; Trivedy et al., 1987 and Jackson, 1973).

The results of sediment quality parameters together with their standard deviation are depicted in Tables 2.7 – 2.11.

Table 2.7. Physico- chemical characteristics of sediment samples from habitats of *Avicennia officinalis*.

PRE MONSOON				MONSOON					POST MONSOON					
Mar	Apr	May	Seasonal Mean± SD	Jun	Jul	Aug	Sep	Seasonal Mean± SD	Oct	Nov	Dec	Jan	Seasonal Mean± SD	Annual Mean± SD
Sediment pH														
6.62	7.25	7.33	7.33 ± 0.318	5.01	7.54	7.27	6.76	6.645 ± 1.137	4.25	6.04	6.2	6.56	5.762± 1.031	6.487 ± 0.993
8.32	7.42	7.37	7.37 ± 0.499	7.55	6.9	7.69	7.1	7.31 ± 0.371	8.06	7.82	7.8	8.33	8.002± 0.248	7.712± 0.465
7.23	7.34	7.51	7.51 ± 0.117	7.07	6.73	5.97	4.08	5.962± 1.336	6.39	6.13	6.57	7.16	6.562± 0.437	6.632 ± 0.952
7.39 ± 0.861	7.34 ± 0.085	7.40 ± 0.094		6.54 ± 1.349	7.1 ± 0.427	6.98 ± 0.896	5.98 ± 1.654		6.2 ± 1.909	6.66 ± 1.002	6.86 ± 0.837	7.35 ± 0.9		
Moisture (%)														
12.06	10.5	16.27	13.05 ± 2.445	13.43	14.05	4.97	20.15	13.15 ± 6.239	20.05	13.58	10.96	9.28	13.47 ± 4.731	13.220 ± 4.288
8.89	8.67	14.49	9.96 ± 3.057	10.45	10.14	9.19	13.44	10.805± 1.836	9.45	7.28	5.83	7.26	7.46 ± 1.493	9.406± 2.506
11.06	12.43	9.04	9.9 ± 2.348	10.27	14.76	18.94	19.69	15.915 ± 4.343	12.29	10.88	6.48	13.465	10.78 ± 3.054	12.197 ± 4.108
10.67 ± 1.620	10.53 ± 1.880	13.27± 3.767		11.38 ± 1.774	12.98 ± 2.487	11.03 ± 7.165	17.76± 3.748		13.93± 5.487	10.58± 3.160	7.76 ± 2.793	10.01± 3.164		
Sand %														
85.7	52.2	80.3	77.225 ± 17.215	63.5	62.1	93.5	83.9	75.75 ± 15.469	88.7	66.9	79.5	94.4	82.375 ± 12.004	78.45 ± 13.935
97.6	81.6	84	85.75 ± 8.085	89.3	71.3	51.4	77.1	72.275 ± 15.809	94.8	91.5	91.8	95.2	93.325 ± 1.944	83.783 ± 13.027
90	94	95.9	93.025 ± 2.5198	99	75	74.5	61.8	77.575 ± 15.534	88.7	92.2	93.4	90.8	91.275 ± 2.018	87.291 ± 10.987
91.1 ± 6.025	75.933 ± 21.468	86.73 ± 8.151		83.93 ± 18.348	69.47 ± 6.642	73.13 ± 21.083	74.27 ± 11.319		90.73 ± 3.521	83.53 ± 14.409	88.23 ± 7.605	93.467 ± 2.343		
Silt %														
0.1	0.1	0.1	0.125 ± 0.05	0.3	0.3	0.4	0.7	0.425 ± 0.189	0.2	0.7	2.5	0.1	0.875 ± 1.1147	0.475 ± 0.673
0.5	0.2	0.3	0.275 ± 0.170	0.1	0.5	1.2	1.2	0.75 ± 0.544	0.3	0.2	0.2	0.1	0.2 ± 0.0816	0.408 ± 0.394
0.4	0.3	0.4	0.3 ± 0.141	0.2	0.1	0.6	0.7	0.4 ± 0.294	0.1	0.1	0.1	0.1	0.1 ± 0	0.266 ± 0.214
0.33 ± 0.208	0.2 ± 0.1	0.267 ± 0.152		0.2 ± 0.1	0.3 ± 0.2	0.733 ± 0.416	0.867 ± 0.288		0.2 ± 0.1	0.33 ± 0.321	0.933 ± 1.357	0.1 ± 1.69967E-17		

Clay %														
14.2	47.7	19.6	22.65 ± 17.241	36.2	37.6	6.1	15.4	23.825 ± 15.578	11.1	32.4	18	5.5	16.75 ± 12.514	21.075 ± 13.947
1.9	18.2	15.7	13.975 ± 8.249	10.6	28.2	47.4	21.7	26.975 ± 15.434	4.9	8.3	8	4.7	6.475 ± 13.999	15.808 ± 12.759
9.6	5.7	3.7	6.675 ± 2.543	0.8	24.9	24.9	37.5	22.025 ± 15.346	11.2	7.7	6.5	9.1	8.625 ± 11.607	12.441 ± 10.857
8.567 ± 6.214	23.867 ± 21.565	13 ± 8.286		15.867 ± 18.278	30.23 ± 6.589	26.13 ± 20.677	24.87 ± 11.385		9.067 ± 3.608	16.133 ± 14.09	10.833 ± 6.251	6.433 ± 2.343		
Organic carbon (g/kg)														
57	8	29	38.75	96	21	24	71	53±36.688	12.5	6	1.5	30	12.5 ± 12.5	34.75±29.776
9.5	1	16	8.125	23	16	9	1	12.25 ± ± 9.43	22	43	24	36.6	31.4 ± 10.08	17.258±13.227
29	11.3	18	19.45	17	5	53	47	30.5 ± 23.173	1	17	2	60	20 ± 27.65	23.317±19.943
31.833± 23.876	6.767±5.26	21±7		45.333±43.981	14±8.185	28.667±22.368	39.67±35.572		11.833±10.516	22±19	9.167±12.848	42.2±15.764		
Total Nitrogen (mg/kg)														
4580	3260	4200	4290 ± 783.581	5500	6180	18840	7900	9605 ± 6238.961	3500	3500	3450	1300	2937.5 ±1091.9210	5610.833 ± 4488.08
5100	5950	5600	5625 ± 379.692	4950	5380	3300	6850	5120 ± 1460.798	4350	2980	4100	4480	3977.5 ± 683.4410	4907.5 ± 1125.531
1330	9800	1120	3395 ± 4271.147	1400	1400	2380	2800	1995 ± 708.119	1050	1190	1400	2030	1417.5±432.9261	2269.167 ± 2432.109
3670 ± 2043.11	6336.7 ± 3287.101	3640 ± 2291.899		3950 ± 2225.421	4320 ± 2560.234	8173.3 ± 9249.05	5850± 2693.047		2966.667±1713.427	2556.7 ± 1211.789	2983.3 ± 1409.196	2603.3 ± 1665.723		
Total Phosphorous (mg/kg)														
28	18.2	28	23.3 ± 5.46	32.9	9.8	11.2	24.5	19.6 ± 11.07	18.2	14.7	18.9	9.8	15.4 ± 4.16	19.43 ± 7.59
7.7	8.4	14	9.6 ± 2.94	8.4	15.4	7.7	14.7	11.6 ± 4.06	7	7	10.5	7	7.9 ± 1.75	9.68±3.18
22.4	18	19	19.4 ± 2.09	18	22.5	32.8	38.5	28 ± 9.37	13.2	27	20	28	22 ± 6.89	23.12 ±7.22
19.4± 10.48	14.9± 5.60	20.3±7.09		19.8 ± 12.35	15.9 ± 6.36	17.2 ± 13.59	25.9±11.96		12.8± 5.61	16.2± 10.09	16.6± 5.2	14.9± 11.40		
Potassium (Mg/kg)														
113	163	9	86.25 ± 66.45	130	39.8	37.5	24.9	58.05 ± 48.411	3.4	26.1	46	14	22.375± 18.277	55.558 ± 51.780
42	91	240	108 ± 90.314	87.5	47.1	35.5	61.8	57.975 ± 22.433	29.1	70	80	73	63.025 ± 23.001	76.333 ± 55.296
69	89	62	63.5 ± 22.752	62.5	12	26.8	20.1	30.35 ± 22.271	66	64	113	107	87.5 ± 26.108	60.45 ± 35.577
74.67 ± 35.8376	114.33 ± 42.158	103.7 ± 121.0055		93.33 ± 34.126	32.967 ± 18.5209	33.267 ± 5.6889	35.6 ± 22.8164		32.83 ± 31.4665	53.367 ± 23.8034	79.67 ± 33.5012	64.67 ± 47.0567		

Sodium (ppt)														
0.436	0.867	0.178	0.452 ± 0.296	0.445	0.106	0.561	0.057	0.292 ± 0.248	0.08	0.076	0.528	0.443	0.282 ± 0.237	0.342 ± 0.250
0.401	0.797	0.528	0.539 ± 0.180	0.415	0.127	0.289	0.120	0.238 ± 0.141	0.132	0.491	0.742	0.682	0.512 ± 0.274	0.429 ± 0.234
0.662	1.884	0.752	1.008 ± 0.585	0.077	0.042	0.120	0.293	0.133 ± 0.111	0.108	0.697	5.46	1.834	2.025 ± 2.399	1.055 ± 1.522
0.499 ± 0.141	1.183 ± 0.608	0.486 ± 0.289		0.313 ± 0.204	0.092 ± 0.044	0.323 ± 0.222	0.157 ± 0.122		0.107 ± 0.025	0.421 ± 0.316	2.243 ± 2.787	0.986 ± 0.743		

Table 2.8. Physico- chemical characteristics of sediment samples from habitats of *Bruguiera cylindrica*

PRE MONSOON			MONSOON					POST MONSOON					
Apr	May	Seasonal Mean± SD	Jun	Jul	Aug	Sep	Seasonal Mean± SD	Oct	Nov	Dec	Jan	Seasonal Mean± SD	Annual Mean± SD
Sediment pH													
5.7	7.07	6.453± 0.959	6.71	5.92	6.9	7.09	6.655± 0.514	7.13	7.22	7.71	7.69	7.438± 0.305	6.848± 0.738
7.74	7.77	7.74± 0.049	8.21	6.72	6.65	7.1	7.17± 0.721	7.51	7.59	7.92	7.61	7.658± 0.180	7.522 ± 0.469
6.68	6.65	7.08± 0.479	6.9	6.65	5.7	5.9	6.288± 0.577	6.58	7.19	7.88	7.07	7.18± 0.536	6.849 ± 0.637
6.707±1.02	7.163±0.565		7.273±0.816	6.43±0.443	6.417±0.633	6.7±0.69		7.07±0.467	7.333±0.222	7.837±0.111	7.457±0.337		
Moisture %													
6.67	3.81	6.462± 2.597	9.997	6.45	3.48	8.897	7.206± 2.892	8.9	8.56	7.79	5.48	7.682± 1.54	7.117 ± 2.245
8.42	8.48	9.342± 1.338	12.33	15.43	11.67	10.72	12.537± 2.038	8.28	6.71	6.29	9.4	7.67± 1.436	9.85 ± 2.575
10.36	14.13	10.342± 2.685	12.89	11.81	16.38	14.57	13.912± 1.998	12.94	10.38	8.41	9.6	10.332± 1.917	11.529 ± 2.675
8.48±1.845	8.807±5.1677		11.739±1.534	11.23±4.518	10.51±6.527	11.4±2.896		10.04±2.530	8.55±1.835	7.497±1.090	8.16±2.323		

Sand %													
68.4	92.8	79.4± 14.861	63.5	84.3	95.4	94.4	84.4± 14.807	90.3	95.7	98.7	93	94.425± 3.603	86.075 ± 12.89
85.8	81.5	82.75± 2.538	89.3	58.7	76.9	83.1	77± 13.208	89	87.4	91.3	77.6	86.325± 6.032	82.025 ± 8.681
87.4	74.7	85.8± 8.485	99	86.2	88.9	92.7	91.7± 5.549	90.6	94.7	69.7	77.1	83.025± 11.638	86.841 ± 8.902
80.53±10.538	83±9.1428		83.93±18.348	76.4±15.358	87.067±9.385	90.07±6.092		89.97±0.850	92.6±4.531	86.567±15.068	82.567±9.03		
Silt %													
0.1	0.1	0.175± 0.15	0.3	0.1	1.8	1.0	0.8± 0.770	0.5	0.3	0.1	0.1	0.25± 0.191	0.408 ± 0.512
0.3	0.1	0.15± 0.1	0.1	0.1	1.5	0.5	0.55± 0.66	0.7	0.3	0.1	0.1	0.3± 0.282	0.333 ± 0.416
0.3	0.4	0.3± 0.141	0.2	0.4	1.1	0.8	0.625± 0.403	0.4	0.2	0.8	0.1	0.375± 0.3096	0.433 ± 0.3114
0.233±0.115	0.2±0.173		0.2±0.1	0.2±0.1732	1.467±0.351	0.767±0.251		0.53±0.152	0.267±0.057	0.33±0.404	0.1±1.7E-17		
Clay %													
31.5	7.1	20.425± 14.763	36.2	15.6	2.8	4.6	14.8± 15.348	9.2	4	1.2	6.9	5.325± 3.477	13.516 ± 13.013
13.9	18.4	17.1± 2.619	10.6	41.2	21.6	16.4	22.45± 13.283	10.3	12.3	8.6	22.3	13.375± 6.139	17.641 ± 8.684
12.3	24.9	13.9± 8.48	0.8	13.4	10	6.5	7.675± 5.379	9	5.1	29.5	22.8	16.6± 11.472	12.725 ± 8.867
19.233± 10.653	16.8± 9.007		15.867± 18.278	23.4± 15.454	11.467± 9.485	9.167± 6.335		9.5± 0.7	7.133± 4.508	13.1± 14.676	17.33± 9.039		
Organic carbon (g/kg)													
1.1	5.5	14.15	11	2	5	13	7.75	52	9.4	34	79	43.6	21.833± 24.135
10.4	1	31.1	3	33	32	8	19	12	22	1	8	10.75	20.283±20.09
22.3	155	48.2	8	4	22	35	17.25	30	6	16	6	14.5	26.65±26.65
11.267±10.63	53.833±87.64		7.333±4.04	13±17.35	19.667±13.65	18.667±14.36		31.333±20.03	12.467±8.43	17±16.52	31±41.58		

Total Nitrogen (mg/kg)														
	700	630	1032.5 ± 759.050	630	1190	630	700	787.5± 270.354	630	630	700	560	630± 57.154	816.667 ± 455.937
	1400	1820	1470± 370.405	1890	2380	1750	1470	1872.5 ± 380.733	1400	1260	980	1540	1295± 239.095	1545.83 ± 395.37
	1470	2870	1522.5 ± 941.536	2590	1260	1540	980	1592.5 ± 703.201	1400	1260	770	2100	1382.5 ± 549.325	1499.166 ± 683.553
2	1190±425.793	1773.3±1120.729		1703.3±993.243	1610.0±667.757	1306.7± 595.343	1050±389.7435		1143.3±444.559	1050±363.73	816.67±145.716	1400±779.487		
Total Phosphorous (mg/kg)														
	11	14.5	12.2± 2.047	7.5	13	12	14.5	11.8± 3.01	16.8	12	1.2	12	10.5± 6.6	11.48 ± 4.01
	58	77	71.5± 10.49	61.5	61.8	74.5	44.5	60.6± 12.31	39.5	46.8	20	61.8	42.0± 17.37	58.02 ± 17.7
	25	38.5	24.6± 10.234	43	21	33.8	15.5	28.3± 12.43	14.5	19.2	9.2	37.5	20.1± 12.3	24.34 ± 11.1
	31.3±24.13	43.3±31.53		37.3±27.44	31.9±26.17	40.1±31.72	24.8±17.04		23.6±13.82	26±18.37	10.1±9.44	37.1±24.90		
Potassium (Mg/kg)														
	69	21	47.25± 20.694	107.5	9.9	15.5	13.2	36.525 ± 47.372	14.1	32.5	80	119	61.4± 47.385	48.391 ± 38.137
	230	78	101.75 ± 87.248	70	35.8	56	16.1	44.475 ± 23.556	18.6	60.5	84	135	74.525 ± 48.55	73.583 ± 58.882
	194	212	118.25 ± 98.1372	92.5	21.4	12.7	10.7	34.325 ± 39.0605	8.5	89	94	29	55.125 ± 42.876	69.233 ± 70.238
	164.33±84.5	103.7±98.052		90±18.874	22.367±12.977	28.067±24.231	13.33±2.702		13.73±5.059	60.667±28.250	86±7.211	94.33±57.143		
Sodium (ppt)														
	0.626	0.752	0.48± 0.265	0.535	0.026	0.09	0.047	0.175± 0.241	0.091	0.279	0.862	0.26	0.373± 0.336	0.342 ± 0.288
	1.674	0.102	0.683± 0.684	0.33	0.126	0.306	0.074	0.209± 0.128	0.069	0.466	0.832	0.942	0.577± 0.394	0.489 ± 0.468
	2.81	0.433	1.046± 1.178	0.47	0.089	0.039	0.046	0.161± 0.207	0.032	0.852	1.077	1.335	0.824± 0.563	0.677 ± 0.794
	1.703±1.092	0.429±0.325		0.445±0.104	0.081±0.05	0.145±0.141	0.056±0.016		0.064±0.029	0.532±0.292	0.924±0.133	0.846±0.543		

Table 2.9. Physico- chemical characteristics of sediment samples from habitats of *Excoecaria agallocha.*

PRE MONSOON			MONSOON					POST MONSOON					
Apr	May	Seasonal Mean± SD	Jun	Jul	Aug	Sep	Seasonal Mean± SD	Oct	Nov	Dec	Jan	Seasonal Mean± SD	Annual Mean± SD
					Sediment pH								
7.03	7.71	7.55± 0.347	7.14	6.57	6.42	6.7	6.708± 0.310	7.1	7.52	7.89	7.42	7.483± 0.325	7.246 ± 0.497
6.81	7.44	7.618± 0.625	7.72	7.2	6.16	4.1	6.295± 1.6	7.4	7.03	7.81	7.94	7.545± 0.413	7.152 ± 1.119
7.29	7.11	7.603± 0.47	7.06	6.7	5.37	5.25	6.095± 0.919	6.45	5.63	6.48	6.31	6.218± 0.398	6.638 ± 0.918
7.043±0.24	7.42±0.3		7.306±0.36	6.823±0.332	5.983±0.546	5.35±1.302		6.983±0.485	6.727±0.980	7.393±0.79	7.223±0.832		
					Moisture %								
7.23	11.81	9.91± 2.185	7.81	7.09	9.34	9.84	8.52± 1.286	9.69	7.86	7.79	7.59	8.232± 0.978	8.887 ± 1.612
10.08	3.27	8.45± 5.977	8.67	15.38	11.03	13.52	12.15± 2.925	13.92	12.48	8.94	15.66	12.75± 2.853	11.117 ± 4.271
7.76	7.27	8.515± 1.562	6.05	12.6	22.08	12.24	13.242± 6.614	13.09	13.45	11.58	13.06	12.795± 0.829	11.517 ± 4.211
8.357±1.515	7.45±4.272		7.51±1.335	11.69±4.219	14.15±6.919	11.87±1.868		12.233±2.241	11.263±2.987	9.437±1.943	12.103±4.119		
					Sand %								
96.7	96.6	95.675± 1.664	93.1	86.5	97.9	77.3	88.7± 8.921	86.4	86.1	92.3	82	86.7± 4.238	90.358 ± 6.596
95.9	72.2	82.925± 13.046	88.6	78.6	91.6	93.3	88.025± 6.577	61.7	81.8	92.6	79.7	78.95± 12.813	83.3 ± 10.865
88.3	90.4	92.875± 4.439	85.3	84.2	75.2	90.8	83.875± 6.464	89.7	78.6	92.6	66.2	81.775± 12.009	86.175 ± 9.021
93.633±4.636	86.4±12.682		89±3.915	83.1±4.063	88.23±11.718	87.13±8.607		79.267±15.302	82.167±3.763	92.5±0.173	75.967±8.536		

Silt %													
0.1	0.3	0.2±0.115	0.2	1.9	1.3	1.4	1.2±0.716	0.2	0.8	0.2	0.1	0.325±0.320	0.575 ± 0.622
0.1	0.1	0.125±0.05	0.1	1.5	0.9	1.0	0.875±0.579	0.1	0.2	0.1	0.2	0.15±0.057	0.383 ± 0.474
0.3	0.2	0.2±0.081	0.1	2.6	0.5	0.3	0.875±1.161	0.1	0.5	6.7	0.2	1.875±3.221	0.983 ± 1.928
0.167±0.115	0.2±0.1		0.133±0.057	2±0.556	0.9±0.4	0.9±0.556		0.133±0.0577	0.5±0.3	2.33±3.782	0.167±0.057		
Clay %													
3.2	3.1	4.125±1.604	6.7	11.6	0.8	21.3	10.1±8.674	13.4	13.1	7.5	17.9	12.975±4.259	9.066 ± 6.4028
4	27.7	16.95±13.070	11.3	19.9	7.5	5.7	11.1±6.314	38.2	18	7.3	20.1	20.9±12.8232	16.317 ± 10.954
11.4	9.4	6.925±4.393	14.6	13.2	24.3	8.9	15.25±6.502	10.2	20.9	0.7	33.6	16.35±14.154	12.842 ± 9.526
6.2±4.521	13.4±12.778		10.867±3.967	14.9±4.403	10.867±12.106	11.97±8.239		20.6±15.325	17.33±3.942	5.167±3.869	23.867±8.5		
Organic carbon (g/kg)													
0.4	24	12.725	10.5	3	4.9	23	10.35	18	36	15	260	82.25	35.108±71.53
1	9	9.75	15	37.5	19	15	21.625	31	16	15	22.5	21.125	17.5±10.4
18.7	14.5	11.975	28	5.5	84	10	31.875	20	12	33	110.5	43.875	29.242±33.35
6.7±10.4	15.83±7.59		17.833±9.09	15.333±19.24	35.967±42.19	16±6.56		23±7	21.333±12.86	21±10.39	131±120.07		
Total Nitrogen (mg/kg)													
700.5	910.65	823.09±144.411	1050.75	700.5	840.6	840.6	858.113 ± 144.411	630.45	700.5	630.45	770.55	682.99±67.0678	788.063 ± 137.286
1190.85	1260.9	1418.51 ± 458.903	840.6	2521.8	1471.05	1331	1541.11 ± 707.465	2311.65	1471.05	980.7	1611.15	1593.6±549.717	1517.754 ± 531.249
840.6	980.7	823.09±144.411	770.55	980.7	3572.55	2172	1873.95 ± 1289.63	700.5	2451.75	2311.65	3292.35	2189.06 ± 1082.758	1628.7 ± 1072.88
910.65±252.568	1050.75±185.334		887.3±145.8207	1401±980.7	1961.4±1430.461	1447.9±673.3497		1214.2±951.064	1541.1±877.724	1307.6±886.992	1891.35±1284.038		

Total Phosphorous (mg/kg)													
15.2	21	15.35± 5.93	12	16	14.6	30.4	18.25± 8.27	14.2	11	9.5	15.6	12.575± 2.81	15.39 ± 6.01
27	42	36.8± 7.47	26.8	33.2	51.8	40	37.95± 10.69	52.8	45.5	50.5	69.6	54.6± 10.45	43.12 ± 12.18
22	19	15.5± 6.12	8.2	17.2	58.2	23.2	26.7± 21.89	9.5	38.5	12.2	54.5	28.675± 21.62	23.6 ± 17.47
21.4± 5.92	27.3±12.74		15.67±9.83	22.1± 9.60	41.5±23.54	31.2±8.43		25.5± 23.76	31.7± 18.24	24.1± 22.93	46.6± 27.86		
Potassium (mg/kg)													
76.0	26.0	42.25± 22.779	112.5	24.4	10.9	21.8	42.4± 47.097	26.5	57.0	47.0	29.0	39.875± 14.619	41.508 ± 28.394
30.0	16.0	29.75± 25.953	127.5	23.3	15.9	0.2	41.725± 57.988	66.0	31.0	32.0	7.0	34± 24.262	35.158 ± 35.890
138.0	75.0	67.25± 52.747	117.5	12.8	25.0	5.0	40.075± 52.268	5.2	79.0	120.0	48	63.05± 48.548	56.792 ± 47.983
81.33±54.197	39±31.575		119.17±7.637	20.17±6.403	17.27±7.148	9.0±11.342		32.57±30.850	55.67±24.027	66.33±47.078	28±20.518		
Sodium (ppt)													
0.707	0.168	0.364± 0.239	0.507	0.0902	0.0441	0.0603	0.1755± 0.222	0.258	0.281	0.511	0.583	0.408± 0.163	0.315± 0.217
0.672	0.071	0.3198± 0.254	0.4975	0.0947	0.0476	0.0443	0.1710± 0.218	0.443	0.573	0.548	0.568	0.533± 0.061	0.341± 0.236
1.355	0.621	0.69± 0.456	0.595	0.0812	0.0561	0.008	0.1851± 0.275	0.027	0.501	1.177	0.082	0.446± 0.530	0.440± 0.448
0.911± 0.384	0.286± 0.29		0.5333± 0.054	0.088± 0.006	0.0493± 0.006	0.0375± 0.026		0.242± 0.208	0.451± 0.152	0.745± 0.374	0.411± 0.285		

Table 2.10. Physico- chemical characteristics of sediment samples from habitats of *Rhizophora mucronata.*

RE MONSOON			MONSOON					POST MONSOON					
Apr	May	Seasonal Mean ± SD	Jun	Jul	Aug	Sep	Seasonal Mean ± SD	Oct	Nov	Dec	Jan	Seasonal Mean ± SD	Annual Mean± SD
						Sediment pH							
7.15	7.27	7.468 ± 0.303	7.12	7.37	7.64	7.8	7.4825 ± 0.299	7.03	7.4	7.81	8.08	7.58 ± 0.461	7.51 ± 0.332
7.05	6.92	7.135 ± 0.246	7	7.46	5.64	6.4	6.625 ± 0.787	6.03	7.11	7.3	7.06	6.875 ± 0.572	6.878 ± 0.567
6.79	7.36	6.945 ± 0.327	7.54	7.03	5.19	5.05	6.2025 ± 1.268	6.26	5.77	6.42	6.12	6.142± 0.276	6.43 ± 0.796
6.997±0.185	7.183±0.232		7.22±0.283	7.287±0.226	6.157±1.304	6.417±1.375		6.44±0.523	6.76±0.869	7.177±0.703	7.087±0.980		
						Moisture (%)							
11.16	1.06	7.092 ± 4.288	6.47	8.83	8.19	8.34	7.957 ± 1.028	9.39	7.46	8.29	5.67	7.702 ± 1.568	7.584 ± 2.473
16.17	21.65	18.632± 4.849	9.85	12.99	12.096	15.03	12.491 ± 2.146	13.55	10.55	9.94	5.22	9.815 ± 3.445	13.646 ± 5.076
8.33	11.23	9.97 ± 1.276	10.78	9.13	10.08	13.07	10.765 ± 1.678	10.83	8.87	7.12	9.67	9.122 ± 1.558	9.953 ± 1.538
11.887±3.970	11.31±10.295		9.03±2.268	10.317±2.32	10.12±1.953	12.15±3.439		11.257±2.112	8.96±1.547	8.45±1.416	6.853±2.449		
						Sand %							
95.5	92.9	91.5 ± 5.119	92.4	93.5	96.8	91.8	93.625 ± 2.23	91	91.1	76.2	86.9	86.3 ± 7.011	90.475 ± 5.678
83.6	81.6	80.75± 2.402	80.3	52.2	52.6	66.7	62.95 ± 13.388	89.3	68.6	82.6	81.3	80.45 ± 8.642	74.717 ± 12.098
44.7	38.8	56.075± 16.773	36.1	38.5	75.2	25.6	43.85 ± 21.637	53.5	55	57.6	60.6	56.675 ± 3.117	52.2 ± 15.657
74.6±26.56	71.1±28.537		69.6±29.636	61.4±28.630	74.867±22.101	61.37±33.420		77.933±21.177	71.567±18.231	72.133±12.986	76.267±13.853		

Silt %												
0.3	0.2	0.2 ± 0.081	0.2	0.1	0.3	0.4	0.25 ± 0.129	0.5	0.3	0.1	0.1	0.25 ± 0.191	0.233 ± 0.130
0.3	0.1	0.15 ± 0.1	0.1	0.5	0.3	0.1	0.25 ± 0.191	0.8	0.2	0.1	0.6	0.425 ± 0.330	0.275 ± 0.237
0.1	0.1	0.275 ± 0.35	0.4	0.3	2.2	0.6	0.875 ± 0.892	0.1	0.2	0.2	0.1	0.15 ± 0.057	0.433 ± 0.6
0.233±0.115	0.133±0.057		0.233±0.152	0.3±0.2	0.933±1.097	0.367±0.251		0.467±0.351	0.233±0.057	0.133±0.057	0.267±0.288		
Clay %													
4.2	6.9	8.3 ± 5.132	7.4	6.4	2.9	7.8	6.125 ± 2.229	8.5	8.6	23.7	13.0	13.45 ± 7.148	9.291 ± 5.724
16.1	18.3	19.1 ± 2.481	19.6	47.3	47.1	33.2	36.8 ± 13.230	9.9	31.2	17.3	18.1	19.125 ± 8.856	25.008 ± 12.11
55.2	61.1	43.65 ± 16.998	63.5	61.2	22.6	73.8	55.275 ± 22.461	46.4	44.8	42.2	39.3	43.175 ± 3.109	47.367 ± 15.912
25.167±26.681	28.77±28.575		30.167±29.5	38.3±28.487	24.2±22.143	38.27±33.29		21.6±21.488	28.2±18.285	27.73±12.930	23.467±13.947		
Organic carbon (g/kg)													
1.5	13	40.125	18	5	2	2	6.75	18	8	36	35	24.25	23.708± 26.35
0.8	7	21.2	15	67	24	29	33.75	34	0.5	20	2	14.125	23.025±21.709
0.5	50.5	27.75	30	34	28	2.5	23.625	6	37	3	5	12.75	21.375±20.01
0.933±0.513	23.5±23.57		21±7.94	35.333±31.02	18±14	11.167±15.45		19.333±14.05	15.167±19.28	19.667±16.50	14±18.25		
Total Nitrogen (mg/kg)													
840.6	1120.8	805.575 ± 232.329	700.5	1050.8	910.65	840.6	875.64 ± 145.84	700.5	630.45	700.5	700.5	682.99 ± 35.025	788.067 ± 166.648
1120.8	1260.9	1138.33 ± 88.1278	1751.25	3362.4	1681.2	2031.45	2206.6 ± 785.268	1541.1	1120.8	770.55	700.5	1033.24 ± 385.275	1459.38 ± 719.245
1401.0	2171.6	1576.15 ± 406.471	2241.6	1541.1	1471.05	2031.45	1821.3 ± 375.056	1401.0	2101.5	1891.4	1331	1681.23 ± 375.050	1692.89 ± 364.399
1120.8±280.2	1517.77±570.552		1564.45±787.348	1984.8±1217.992	1354.3±398.321	1634.5±687.537		1214.2±450.358	1284.25±749.022	1120.82±668.263	910.67±364.019		

Total Phosphorous (mg/kg)													
30.5	30.5	23.25 ± 8.99	18	14.5	12	13.5	14.5 ± 2.55	11.5	14.5	63.2	15.2	26.1 ± 24.79	21.28 ± 14.76
45.5	55	51.6 ± 9.91	66	35	58.6	54.5	53.5 ± 13.24	54.6	57.2	20.2	76.2	52.1 ± 23.31	52.4 ± 14.95
59.2	59.5	61.9 ± 6.66	55.5	32.5	81	60	57.3 ± 19.89	66	61.8	20	65.5	53.3 ± 22.3	57.5 ± 16.40
45.1±14.36	48.3±15.61		46.5±25.23	27.3± 11.18	50.5±35.20	42.7±25.41		44.0± 28.75	44.5±26.08	35±24.88	52.3±32.57		
Potassium (Mg/kg)													
110.0	59.0	61.5 ± 40.087	100.0	14.6	11.8	8.9	33.825 ± 44.178	22.3	71.0	70.0	25.0	47.075 ± 27.074	47.467 ± 36.191
149.0	49.0	72 ± 52.012	100.0	37.3	30.1	26.6	48.5 ± 34.621	28.8	63.0	94.0	121.0	76.7 ± 39.765	65.733 ± 40.768
224.0	240.0	185.25 ± 54.817	117.5	57.1	114.7	225.5	128.7 ± 70.281	93.2	150.0	1400.0	208.0	462.8 ± 626.55	258.917± 363.987
161±57.939	116±107.503		105.83±10.103	36.33±21.266	52.2±54.894	87±120.27		48.1±39.192	94.67±48.086	521.33±761.042	118±91.536		
Sodium (ppt)													
0.782	0.195	0.439 ± 0.279	0.477	0.086	0.056	0.044	0.166 ± 0.208	0.116	0.052	0.657	0.588	0.353 ± 0.313	0.319± 0.272
0.872	0.077	0.343 ± 0.37	0.51	0.105	0.029	0.046	0.172 ± 0.227	0.087	0.025	0.672	0.601	0.347 ± 0.337	0.283 ± 0.299
0.947	0.516	0.664 ± 0.22	0.18	0.087	0.099	0.081	0.112 ± 0.046	0.586	0.608	1.122	1.197	0.878 ± 0.326	0.552 ± 0.395
0.867±0.082	0.263±0.227		0.389±0.181	0.093±0.010	0.062±0.035	0.057±0.02		0.263±0.279	0.229±0.329	0.817±0.264	0.795±0.347		

Table 2.11. Physico- chemical characteristics of sediment samples from habitats of *Sonneratia alba*.

RE MONSOON			MONSOON					POST MONSOON					
Apr	May	Seasonal Mean± SD	Jun	Jul	Aug	Sep	Seasonal Mean± SD	Oct	Nov	Dec	Jan	Seasonal Mean± SD	Annual Mean± SD
					Sediment pH								
8.29	8.05	8.272± 0.162	8.41	6.69	6.75	8.16	7.502± 0.909	7.74	8.04	8.26	8.32	8.09± 0.262	7.955 ± 0.607
8.11	7.87	8.145± 0.219	8.27	6.95	7.08	8.28	7.645± 0.729	8.7	8.1	8.25	8.07	8.28± 0.29	8.023 ± 0.512
7.54	7.6	7.167± 0.471	6.77	6.74	4.66	5.01	5.795± 1.117	6.4	7.32	7.57	7.35	7.16± 0.518	6.707 ± 0.963
7.98±0.391	7.84±0.226		7.817±0.909	6.793±0.13	6.163±1.312	7.15±1.854		7.613±1.155	7.82±0.434	8.027±0.395	7.913±0.503		
					Moisture (%)								
7.2	13.71	9.455± 2.9	12.67	13.97	11.97	10.63	12.31± 1.393	12.43	10.19	7.37	8.55	9.635± 2.193	10.467 ± 2.448
9.12	8.91	8.08± 1.164	7.85	10.99	12.18	10.69	10.427± 1.834	8.78	14.17	7.52	8.08	9.637± 3.065	9.381 ± 2.211
9.38	10.73	10.752± 1.777	9.29	10.61	10.28	7.75	9.482± 1.284	10.89	10.2	10.56	7.73	9.845± 1.437	10.026± 1.478
8.57±1.19	11.117±2.423		9.937±2.474	11.857±1.84	11.477±1.041	9.69±1.68		10.7±1.832	11.52±2.295	8.483±1.8	8.12±0.411		
					Sand %								
79.4	68.6	85.1± 13.578	81.6	86.2	80.6	93.7	85.525± 5.970	93.8	84.9	93.8	88.5	90.25± 4.354	86.958± 8.433
74.7	96.3	89.175± 10.059	82.6	78.3	57.1	93.7	77.925± 15.324	98.5	56.0	96.1	90.4	85.25± 19.793	84.116± 14.906
62.8	72.7	73.4± 8.830	87.0	84.2	50.9	94.4	79.125± 19.302	53.9	82.5	85.0	73.0	73.6± 14.114	75.375± 13.597
72.3±8.556	79.2±14.950		83.73±2.872	82.9±4.107	62.867±15.667	93.93±0.404		82.067±24.506	74.467±16.037	91.633±5.858	83.967±9.544		
					Silt %								
0.4	0.2	0.3± 0.115	0.2	2.4	0.4	0.4	0.85± 1.037	0.3	0.1	0.1	0.1	0.15± 0.1	0.433± 0.631
0.5	0.2	0.3± 0.141	0.1	2.7	0.5	0.7	1± 1.160	0.3	0.1	0.1	0.2	0.175± 0.095	0.491 ± 0.72
0.4	0.1	0.2± 0.141	0.1	1.8	0.8	0.5	0.8± 0.725	0.3	2.6	0.1	0.1	0.775± 1.22	0.591± 0.799
0.433±0.0577	0.167±0.057		0.133±0.057	2.3±0.4583	0.567±0.208	0.533±0.152		0.3±0	0.933±1.443	0.1±1.7E-17	0.133±0.057		

Clay %													
20.2	31.2	14.6±13.601	18.2	11.4	19.2	5.9	13.675±6.235	5.9	15	6.1	11.4	9.6±4.409	12.625±8.455
24.8	3.5	10.525±9.917	17.3	19	42.4	5.6	21.075±15.414	1.2	43.9	3.8	9.5	14.6±19.838	15.4±14.8171
36.8	27.2	26.375±8.794	12.9	14	48.3	5.1	20.075±19.229	45.8	14.9	14.9	26.9	25.625±14.591	24.025±13.733
27.267±8.570	20.63±14.972		16.133±2.836	14.8±3.862	36.633±15.383	5.533±0.404		17.633±24.506	24.6±16.714	8.267±5.858	15.933±9.544		
Organic carbon (g/kg)													
5	4.5	3.375	5.5	26	7.1	29	16.9	32	5	16	115	42	20.758±31.64
5	77	29.25	2	23	7	37	17.25	32	1.5	32.5	27.5	23.375	23.292±21.55
1.2	62	24.175	11	13	15	17	14	19	35	12.5	9.5	19	19.058±15.73
3.733±2.19	47.83±38.27		6.167±4.54	20.667±6.81	9.7±4.6	27.67±10.1		27.667±7.5	13.833±18.4	20.333±10.7	50.667±56.44		
Total Nitrogen (mg/kg)													
560.4	1260.9	700.5±379.392	1050.75	1401.0	1401.0	700.5	1138.31±335.339	560.4	910.65	560.4	630.45	665.48±166.752	834.763±357.75
700.5	420.3	542.89±119.633	1190.85	1260.9	1120.8	700.5	1068.26±251.758	560.4	1260.9	560.4	630.45	753.04±340.181	788.063±321.876
770.55	630.45	409.79±340.56	910.65	770.55	1050.75	1401.0	1033.24±270.547	630.45	770.55	700.5	980.7	770.55±151.325	737.86±359.294
677.15±107.003	770.55±437.462		1050.75±140.1	1144.15±331.043	1190.85±185.334	934±404.433		583.75±40.443	980.7±252.568	607.1±80.886	747.2±202.216		
Total Phosphorous (mg/kg)													
55.6	66	48.8±14.7	44.5	62	39.6	37.5	45.9±11.13	25	26.1	22.5	45.5	29.8±10.59	41.48±14.13
50.2	27	39.7±10.01	42.2	61.5	53.8	23.2	45.2±16.66	13.2	52.1	16	30.8	28.0±17.81	37.64±15.67
22	38	39±13.90	24.5	28.8	15.8	52	30.3±15.46	18	18	21.2	23.5	20.2±2.68	29.82±13.58
42.6±18.04	43.7±20.11		37.1±10.94	50.8±19.03	36.4±19.20	37.6±14.40		18.7±5.93	32.1±17.82	19.9±3.44	33.3±11.21		
Potassium (Mg/kg)													
75.0	116.0	65±40.307	77.5	84.5	18.5	26.5	51.75±34.052	44.0	127.0	71.0	50.0	73±37.815	63.25±35.115
92.0	32.0	44.5±31.764	97.5	59.5	28.8	26.5	53.075±33.218	24.5	134.0	73.0	57.0	72.125±45.920	56.567±36.008
129.0	104.0	100±50.206	40.0	44.3	14.7	45.8	36.2±14.542	47.0	119.0	122.0	97.0	96.25±34.673	77.483 ± 44.779
98.667±27.610	84±45.431		71.667±29.190	62.767±20.298	20.667±7.295	32.93±11.142		38.5±12.2168	126.67±7.505	88.667±28.884	68±25.357		

Sodium (ppt)													
0.707	0.511	0.441±0.224	0.28	0.233	0.822	0.094	0.357±0.319	0.3435	0.792	0.712	0.642	0.622±0.195	0.473±0.255
0.857	0.294	0.443±0.276	0.3875	0.249	0.1355	0.311	0.271±0.106	0.2805	0.772	0.737	0.742	0.633±0.235	0.449±0.250
0.982	0.488	0.652±0.237	0.1675	0.0762	0.0214	0.069	0.084±0.061	0.2815	0.902	1.052	0.842	0.769±0.337	0.501±0.381
0.849±0.137	0.431±0.119		0.278±0.11	0.186±0.095	0.326±0.433	0.158±0.133		0.302±0.036	0.822±0.07	0.834±0.189	0.742±0.1		

As far as sediment pH confining to the habitats of *Avicennia officinalis* is concerned, higher annual average was noticed at Kadalundi 1 of Malappuram district (7.713 ± 0.466), followed by Thekkumbad 1 of Kannur district (6.633 ± 0.953) and Kumbalam 1 of Ernakulam district (6.488 ± 0.994). With respect to *Bruguiera cylindrica*, highest pH was noted at Kadalundi 2 (7.523 ± 0.469) followed by Thekkumbad 2 (6.85 ± 0.637) and Ayiramthengu 1 (6.848 ± 0.739). In the case of *Excoecaria agallocha*, higher pH was recorded at Ayiramthengu 2 (7.247 ± 0.497) followed by Kumbalam 2 (7.153 ± 1.12) and a lower pH of 6.638 ± 0.919 at Thekkumbad 3. The annual mean pH with respect to the habitats of *Rhizophora mucronata* was higher at Ayiramthengu 3 (7.51 ± 0.332) followed by Kumbalam 3 (6.878 ± 0.568) and Thekkumbad 4 (6.43 ± 0.80). With respect to *Sonneratia alba*, mean pH was higher at Kadalundi 4 (8.023 ± 0.513) followed by Kadalundi 3 (7.955 ± 0.608) and Thekkumbad 5 (6.708 ± 0.964).

Annual average of moisture percentage of sediment confining to the habitat of *Avicennia officinalis* was higher at Kumbalam 1 (13.221 ± 4.288 %) followed by Thekkumbad 1 (12.197 ± 4.108 %) and Kadalundi 1 (9.407 ± 2.507 %). With respect to *Bruguiera cylindrica*, highest moisture percentage was noted at Thekkumbad 2 (11.529 ± 2.675 %) followed by Kadalundi 2 (9.85 ± 2.575 %) and Ayiramthengu 1 (7.117 ± 2.246 %). In the case of *Excoecaria agallocha*, higher moisture percentage was noticed at Thekkumbad 3 with 11.518 ± 4.212 % followed by Kumbalam 2 (11.117 ± 4.271 %) and lower at Ayiramthengu 2 (8.888 ± 1.612 %). Among the habitats of *Rhizophora mucronata,* Kumbalam 3 was noted for higher annual mean of moisture percentage (13.646 ± 5.077 %) followed by Thekkumbad 4 (9.953 ± 1.538%) and Ayiramthengu 3 (7.584 ± 2.474 %). With respect to *Sonneratia alba* higher moisture percentage was recorded at Kadalundi 3 (10.467 ± 2.448 %) followed by Thekkumbad 5 (10.027 ± 1.479 %) and Kadalundi 4 (9.382 ± 2.211 %).

Among the habitats of *Avicennia officinalis*, the annual average of organic carbon content was higher at Kumbalam 1 (34.75 ± 29.78 g/kg) followed Thekkumbad 1 (21.37 ± 19.94 g/kg) and Kadalundi 1 (17.93 ± 12.57 g/kg). With respect to

Bruguiera cylindrica, highest organic carbon was noted at Thekkumbad 2 (26.65 ± 41.72 g/kg), followed by Ayiramthengu 1 (21.83 ± 24.14 g/kg) and Kadalundi 2 (20.28 ± 20.09 g/kg). In the case of *Excoecaria agallocha*, higher organic carbon was noticed at Ayiramthengu 2 (35.11 ± 71.53 g/kg) followed by Thekkumbad 3 (29.24 ± 33.35 g/kg) and lower value at Kumbalam 2 (17.5 ± 10.41 g/kg). Among the habitats of *Rhizophora mucronata,* annual mean organic carbon was noticed to be higher at Kumbalam 3 (23.03 ± 21.71 g/kg) followed by Thekkumbad 4 (21.38 ± 21.71 g/kg) and Ayiramthengu 3 (17.33 ± 18.15 g/kg). With respect to the habitats of *Sonneratia alba*, higher organic carbon was recorded at Kadalundi 4 (23.29 ± 21.56 g/kg) followed by Kadalundi 3 (20.38 ± 31.87 g/kg) and Thekkumbad 5 (19.06 ± 15.73 g/kg).

As far as the nitrogen content of sediment confining to the habitat of *Avicennia officinalis* is concerned, higher annual average was noticed at Kumbalam 1 (5610.83 ± 4488.08 mg/kg) followed by Kadalundi 1 (4907.5 ± 1125.5 mg/kg) and Thekkumbad 1 (2269.17 ± _2432.11 mg/kg). With respect to *Bruguiera cylindrica*, highest nitrogen content was noted at Kadalundi 2 (1545.83 ± 395.37 mg/kg) followed by Thekkumbad 2 (1499.167 ± 683.55 mg/kg) and Ayiramthengu 1 (816.67 ± 455.937 mg/kg). Among the habitats of *Excoecaria agallocha,* higher nitrogen was recorded at Thekkumbad 3 (1628.7 ± 1072.88 mg/kg) followed by Kumbalam 2 (1517.75 ± 531.249 mg/kg) and lower nitrogen of 788.06 ± 137.29 mg/kg at Ayiramthengu 2. The annual mean value of nitrogen with respect to the habitats of *Rhizophora mucronata* was higher at Thekkumbad 4 (1692.89 ± 364.40 mg/kg) followed by Kumbalam 3 (1459.38 ± 719.245 mg/kg) and Ayiramthengu 3 (788.067 ± 166.648 mg/kg). With respect to the study sites of *Sonneratia alba*, higher nitrogen was noticed at Kadalundi 3 (834.763 ± 357.758 mg/kg) followed by Kadalundi 4 (788.063 ± 321.877 mg/kg) and Thekkumbad 5 (737.86 ± 359.295 mg/kg).

Considering the phosphorous content of sediments confining to the habitat of *Avicennia officinalis,* higher annual average was noticed at Thekkumbad 1 (0.231 ± 0.072 mg/kg) followed by Kumbalam 1 (0.194 ± 0.076 mg/kg) and Kadalundi 1

(0.097 ± 0.032 mg/kg). With respect to *Bruguiera cylindrica*, highest phosphorous was noted at Kadalundi 2 (0.5802 ± 0.177 mg/kg) followed by Thekkumbad 2 (0.2434 ± 0.111 mg/kg) and Ayiramthengu 1 (0.1148 ± 0.0401 mg/kg). Among the habitats of *Excoecaria agallocha*, higher mean of phosphorous was noticed at Kumbalam 2 (0.431 ± 0.122 mg/kg) followed by Thekkumbad 3 (0.236 ± 0.175 mg/kg) and lower at Ayiramthengu 2 (0.154 ± 0.060 mg/kg). The annual mean phosphorous value with respect to the habitats of *Rhizophora mucronata* was higher at Thekkumbad 4 (0.575 ± 0.15 mg/kg) followed by Kumbalam 3 (0.524 ± 0.15 mg/kg) and Ayiramthengu 3 (0.213 ± 0.148 mg/kg). In the case of *Sonneratia alba*, higher phosphorous value was recorded at Kadalundi 3 (0.415 ± 0.141 mg/kg) followed by Kadalundi 4 (0.376 ± 0.157 mg/kg) and Thekkumbad 5 (0.298 ± 0.136 mg/kg).

Higher annual mean value of potassium with respect to *Avicennia officinalis* was noticed at Kadalundi 1 (76.333 ± 55.296 mg/kg), followed by Thekkumbad 1 (60.45 ± 35.5778 mg/kg) and Kumbalam 1 (55.558 ± 51.78 mg/kg). In the case of *Bruguiera cylindrica*, annual mean potassium level was noticed at Kadalundi 2 (73.583 ± 58.88 mg/kg) followed by Thekkumbad 2 (69.233 ± 70.238 mg/kg) and Ayiramthengu 1 (48.392 ± 38.137 mg/kg). As far as the potassium concentration of sediment confining to the habitat of *Excoecaria agallocha* is concerned, higher annual average was noticed at Thekkumbad 3 (56.792 ± 47.98 mg/l) followed by Ayiramthengu 2 (41.508 ± 28.39 mg/l) and Kumbalam 2 (35.158 ± 35.89 mg/l). Higher annual mean value of potassium with respect to *Rhizophora mucronata* was noticed at Thekkumbad 4 (258.917 ± 363.99 mg/l) followed by Kumbalam 3 (65.733 ± 40.77 mg/l) and Ayiramthengu 3 (47.467 ± 36.19 mg/l). With respect to *Sonneratia alba*, highest potassium level was noted at Thekkumbad 5 (77.483 ± 44.78 mg/l) followed by Kadalundi 3 (63.25 ± 35.12 mg/l) and Kadalundi 4 (56.567 ± 36.01 mg/l).

With respect to *Avicennia officinalis,* higher mean sodium was noticed at Thekkumbad 1 (1.055 ± 1.523 ppt) followed by Kadalundi 1 (0.43 ± 0.24 ppt) and Kumbalam 1 of Ernakulam district (0.342 ± 0.25 ppt). Upon considering the sediment sodium concentration along the habitats of *Bruguiera cylindrica*, highest annual average was noted at Thekkumbad 2(0.677 ± 0.794 ppt) followed by Kadalundi 2(0.490 ± 0.469 ppt) and Ayiramthengu 1(0.342 ± 0.289 ppt). As far as the sediment sodium confining to the habitat of *Excoecaria agallocha* is concerned, higher annual average was noticed at Thekkumbad 3 (0.441 ± 0.48 ppt) followed by Kumbalam 2 (0.341 ± 0.236 ppt) and Ayiramthengu 2 (0.316 ± 0.218 ppt). In the case of *Rhizophora mucronata*, annual mean sodium was higher at Thekkumbad 4 (0.552 ± 0.396 ppt) followed by Ayiramthengu 3 (0.319 ± 0.272 ppt) and Kumbalam 3 (0.287 ± 0.299 ppt).). With respect to *Sonneratia alba*, highest sodium was noted at Thekkumbad 5 (0.502 ± 0.381 ppt) followed by Kadalundi 3 (0.474 ± 0.256 ppt) and Kadalundi 4 (0.449 ± 0.251 ppt).

The result of the textural characteristics revealed that, higher annual mean sand percentage with respect to *Avicennia officinalis* was noticed at Thekkumbad 1 (87.292 ± 10.987 %) followed by Kadalundi 1 (83.783 ± 13.027%) and Kumbalam 1 (78.45 ± 13.935 %). With respect to *Bruguiera cylindrica*, highest percentage of sand was noted at Thekkumbad 2 (86.842 ± 8.902 %) followed by Ayiramthengu 1 (86.075 ± 12.89 %) and Kadalundi 2 (82.025 ± 8.681 %). Among various habitats of *Excoecaria agallocha*, higher sand % was noticed at Ayiramthengu 2 with 90.358 ± 6.596 % followed by 86.175 ± 9.022 % at Thekkumbad 3 and a lower of 83.3 ± 10.865 % at Kumbalam 2. In the case of *Rhizophora mucronata,* annual mean sand % was higher at Ayiramthengu 3 (90.475 ± 5.678 %) followed by Kumbalam 3 (74.717 ± 12.098 %) and Thekkumbad 4 (52.2 ± 15.658 %). With respect to *Sonneratia alba,* higher sand % was noticed at Kadalundi 3 (86.958 ± 8.434 %) followed by Kadalundi 4 (84.117 ± 14.907 %) and Thekkumbad 5 (75.375 ± 13.597 %).

Results of silt % of sediment confining to the habitat of *Avicennia officinalis* revealed that, *higher* annual average was noticed at Kumbalam 1 (0.475 ± 0.673 %) followed by Kadalundi 1 (0.408 ± 0.394 %) and Thekkumbad 1 (0.267 ± 0.215 %). With respect to *Bruguiera cylindrica*, highest silt % was noted at Thekkumbad 2 (0.408 ± 0.513 %) followed by Ayiramthengu 1 (0.433 ± 0.311 %) and Kadalundi 2 (0.333 ± 0.416 %). Among the habitats of *Excoecaria agallocha*, higher silt % was noted at Thekkumbad 3 with 0.983 ± 1.928 % followed by 0.572 ± 0.623 % at Ayiramthengu 2 and a lower of 0.383 ± 0.475 % at Kumbalam 2. In the case of *Rhizophora mucronata*, the annual mean silt % was higher at Thekkumbad 4 (0.433

± 0.601 %) followed by Kumbalam 3 (0.275 ± 0.238 %) and Ayiramthengu 3 (0.233 ± 0.130 %). With respect to Sonneratia *alba*, higher silt % was noted at Thekkumbad 5 (0.592 ± 0.799 %) followed by Kadalundi 4 (0.492 ± 0.720 %) and Kadalundi 3 (0.433 ± 0.632 %).

Among various habitats of *Avicennia officinalis,* the annual mean clay % was higher at Kumbalam 1 of Ernakulam district (21.075 ± 13.947 %) followed by Kadalundi 1 of Malappuram district (15.808 ± 12.759%) and Thekkumbad 1 of Kannur district (12.442 ± 10.858 %). With respect to *Bruguiera cylindrica*, highest clay % was noted at Kadalundi 2 (17.642 ± 8.684 %) followed by Ayiramthengu 1 (13.642 ± 13.013 %) and Thekkumbad 2 (12.725 ± 8.868 %). In the case of *Excoecaria agallocha*, higher clay % was recorded at Kumbalam 2 with 16.317 ± 10.954 % followed by 12.842 ± 9.526 % at Thekkumbad 3 and lower of 9.067 ± 6.403 % at Ayiramthengu 2. The annual mean clay % with respect to *Rhizophora mucronata* was higher at Thekkumbad 4 (47.367 ± 15.912 %) followed by Kumbalam 3 (25.008 ± 12.11 %) and Ayiramthengu 3 (9.292 ± 5.724 %). With respect to *Sonneratia alba*, higher clay % was recorded at Thekkumbad 5 (24.025 ± 13.734 %) followed by Kadalundi 4 (15.4 ± 14.817 %) and Kadalundi 3 (12.625 ± 8.456 %).

Soil texture is the relative proportion of various particles that make up the soil. The texture of soil is a qualitative classification technique used both in the field and laboratory. As a qualitative tool, it is fast, simple and effective to assess the physical characteristics of soils.

The soils/ sediments distributed along the natural habitats of mangrove species *Avicennia officinalis*, *Bruguiera cylindrica*, *Excoecaria agallocha*, *Rhizophora mucronata* and *Sonneratia alba* were subjected to textural analysis. Based on the objective, the estimated percentages of sand, silt and clay were used to determine the textural class of the soil. This was achieved through the triangular textural diagram, proposed by the United States Department of Agriculture (USDA). Based on the physical composition, the textural classes were indicated as sand, loamy sands, sandy loams, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay and clay. Subclasses of sand were subdivided into coarse sand, sand, fine sand and very fine sand. Subclasses of loamy sands and sandy loams, which were based on sand size, were named similarly (USDA, 1993).

In the present study, physical characterization of sand / sediment confining to the natural habitats of 5 mangrove species has been carried out to evaluate the annual average value of % sand, % silt and % clay. Accordingly all the sediment samples have been categorized into different classes (Plate 2.6). The results obtained are depicted in Table 2.12 – 2.13.

Table 2.12. Textural classes of sediments noticed along mangrove habitats under study

Site	Textural class				
	Avicennia officinalis	***Bruguiera cylindrica***	***Excoecaria agallocha***	***Rhizophora mucronata***	***Sonneratia alba***
1.	Sandy Clay Loam	Loamy Sand	Sand	Sand	Loamy Sand
2.	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Clay Loam	Sandy Loam
3.	Loamy Sand	Loamy Sand	Loamy Sand	Sandy Clay	Sandy Clay Loam

Table 2.13. Description of each sediment class noticed in the present study

Sl. No.	Soil / sediment class	Description
1	**Sand**	A total of 25 percent or more very coarse, coarse, and medium sand, a total of less than 25 percent very coarse and coarse sand, and less than 50 percent fine sand and less than 50 percent very fine sand
2	**Loamy sand**	A total of 25 percent or more very coarse, coarse, and medium sand and a total of less than 25 percent very coarse and coarse sand, and less than 50 percent fine sand and less than 50 percent very fine sand
3	**Sandy loam**	A total of 30 percent or more very coarse, coarse, and medium sand, but a total of less than 25 percent very coarse and coarse sand and less than 30 percent fine sand and less than 30 percent very fine sand; or a total of 15 percent or less very coarse, coarse, and medium sand, less than 30 percent fine sand and less than 30 percent very fine sand with a total of 40 percent or less fine and very fine sand
4	**Sandy clay loam**	20 to 35 percent clay, less than 28 percent silt, and more than 45 percent sand

The species *Avicennia officinalis* was growing in the textural classes of Sandy Clay Loam, Sandy Loam and Loamy Sand. As far as *Bruguiera cylindrica* concerned, Loamy Sand and Sandy Loam were suitable for their growth. Sand, Sandy Loam and Loamy Sand are suitable for the establishment of *Excoecaria agallocha. Rhizophora mucronata* mostly preferred Sand, Sandy Clay Loam and Sandy Clay. The sediment classes observed with respect to the species *Sonneratia alba* were Loamy Sand, Sandy Loam and Sandy Clay Loam. Upon considering the annual mean values of textural characteristics with respect to the sites under study, all the mangrove species were noticed to prefer a particular class of sediment. All the 5 species under study have shown maximum growth and proliferation along such sediment habitats. The ideal sediment class in which each *mangrove* species has shown a consistent growth are *Avicennia officinalis* (Sandy Loam), *Bruguiera cylindrica* (Loamy Sand), *Excoecaria agallocha* (Loamy Sand), *Rhizophora mucronata* (Sandy Clay Loam) and *Sonneratia alba* (Sandy Loam).

Data pertaining to climatological attributes like atmospheric maximum – minimum temperature (^{0}C), Total Rainfall (MMS) and Relative Humidity (%) with respect to all the locations under study has been collected and reported. The results are represented in the following tables (Table 2.14 – 2.18).

Table 2.14. Climatological attributes experienced along the habitats of *Avicennia officinalis.*

Season	PRE MONSOON					MONSOON					POST MONSOON					
Station	Feb	Mar	Apr	May	Seasonal Mean± SD	Jun	Jul	Aug	Sep	Seasonal Mean± SD	Oct	Nov	Dec	Jan	Seasonal Mean± SD	Annual Mean± SD
Atmospheric Maximum Temperature (^{0}C)																
S1	32.8	34.1	34.3	33.9	33.8 ± 0.670	32.5	30.5	30.8	30.6	31.1± 0.941	31.1	32.2	32.3	32.8	32.1 ± 0.716	32.325 ± 1.353
S2	33.5	34.8	34.6	33.3	34.1 ± 0.759	30.9	28.0	29.1	29.7	29.4 ± 1.209	30.4	32.0	32.2	33.0	31.9 ± 1.089	31.792± 2.185
S3	34.2	35.4	35.5	34.3	34.9 ± 0.695	32.0	28.0	28.9	30.6	29.9 ± 1.780	31.2	33.2	33.3	33.6	32.8 ± 1.096	32.516± 2.424
Monthly Mean± SD	33.5 ± 0.7	34.77± 0.65	34.8 ± 0.624	33.83± 0.503		3.18 ± 0.818	28.83 ± 1.443	29.6 ± 1.044	30.3 ± 0.519		30.9 ± 0.435	32.47± 0.642	32.6 ± 0.638	33.13± 0.416		
Atmospheric Minimum Temperature (^{0}C)																
S1	22.8	24.2	25.7	25.3	24.5 ± 1.298	24.5	22.1	23.0	24.0	23.4 ± 1.067	22.8	23.3	22.0	22.2	22.575 ± 0.591	23.492 ± 1.242
S2	23.2	25.1	26.1	25.2	24.9 ± 1.219	23.9	22.4	22.8	23.0	23.0 ± 0.634	23.1	23.4	21.6	21.9	22.5 ± 0.883	23.275 ± 1.373
S3	23.9	25.2	26.9	25.7	25.4 ± 1.24	24.6	23.4	23.9	24.0	24.0 ± 0.492	24.1	24.7	22.7	23.2	23.675 ± 0.896	24.358 ± 1.158
Monthly Mean± SD	23.3 ± 0.556	24.83± 0.550	26.23± 0.611	25.4 ± 0.264		24.33 ± 0.378	22.63 ± 0.680	23.23 ± 0.585	23.67± 0.577		23.33 ± 0.680	23.8 ± 0.781	22.1 ± 0.556	22.43± 0.680		
Total Rainfall (MMS)																
S1	5.0	21.8	54.9	316.8	99.6 ± 146.26	412.8	718.7	318.8	276.1	431.6 ± 199.736	331.1	197.3	82.0	0.0	152.6 ± 143.91	227.942± 213.299
S2	1.0	0.0	41.9	189.7	58.2 ± 89.846	477.9	974.5	340.8	354.7	537.0 ± 298.12	139.0	131.7	9.1	6.7	71.6 ± 73.65	222.25 ± 286.323
S3	4.9	0.0	23.1	266.9	73.7 ± 129.166	565.3	1131.6	389.9	276.1	590.7 ± 379.7	286.2	49.8	0.0	0.6	84.2 ± 136.71	249.533± 335.385
Monthly Mean± SD	3.63 ± 2.281	7.27 ± 12.586	39.97± 15.988	257.8± 64.037		485.33± 76.521	941.6 ± 208.407	349.83± 36.401	302.3± 45.38		252.1 ± 100.487	126.27 ± 73.9	30.37± 44.947	2.43 ± 3.707		
Relative Humidity % at 0830hrs																
S1	76	78	79	81	78.5 ± 2.082	88	93	89	91	90.3 ± 2.217	85	81	76	72	78.5 ± 5.686	82.417 ± 6.694
S2	75	74	76	78	75.8 ± 1.708	88	92	89	87	89.0 ± 2.160	86	83	72	74	78.8 ± 6.801	81.167 ± 7.056

S3	76	72	75	79	75.5 ± 2.887	91	97	92	91	92.8 ± 2.872	87	76	65	68	74.0 ± 9.832	80.75 ± 10.48
Monthly Mean± SD	75.67± 0.577	74.67± 3.055	76.67± 2.082	79.33± 1.528		89.0 ± 173	94.0 ± 2.646	90.0 ± 1.732	89.67± 2.309		86.0 ± 1.0	80.0 ± 3.606	71.0 ± 5.568	71.33± 3.055		
Relative Humidity % at 1730hrs																
S1	63	65	74	74	69.0 ± 5.831	81	84	81	84	82.5 ± 1.732	75	73	62	57	66.8 ± 8.655	72.75 ±9.126
S2	56	57	65	70	62.0 ± 6.683	77	86	77	77	79.3 ± 4.5	76	73	58	55	65.5 ± 10.535	68.917 ± 10.414
S3	64	63	67	72	66.5± 4.041	83	94	86	84	86.8± 4.992	82	74	63	66	71.3± 8.539	74.833 ± 10.616
Monthly Mean± SD	61.0 ± 4.358	61.67± 4.163	68.67± 4.725	72.0 ± 2.0		80.33 ± 3.055	88.0 ± 5.291	81.33± 4.509	81.67± 4.041		77.67 ± 3.785	73.33± 0.577	61.0 ± 2.645	59.33± 5.859		

Table 2.15. Climatological attributes experienced along the habitats of *Bruguiera cylindrica*.

Season	PRE MONSOON					MONSOON					POST MONSOON					
Station	Feb	Mar	Apr	May	Seasonal Mean± SD	Jun	Jul	Aug	Sep	Seasonal Mean± SD	Oct	Nov	Dec	Jan	Seasonal Mean± SD	Annual Mean± SD
Atmospheric Maximum Temperature (^{0}C)																
S4	35.5	36.6	36.1	33.7	35.5 ± 1.265	32.2	28.9	30.5	31.1	30.7 ± 1.376	32.0	32.9	32.3	33.6	32.7 ± 0.707	33.0 ± 2.305
S5	33.5	34.8	34.6	33.3	34.1 ± 0.759	30.9	28.0	29.1	29.7	29.4 ± 1.209	30.4	32.0	32.2	33.0	31.9 ± 1.089	31.8 ± 2.185
S6	34.2	35.4	35.5	34.3	34.9 ± 0.695	32.0	28.0	28.9	30.6	29.9 ± 1.780	31.2	33.2	33.3	33.6	32.8 ± 1.096	32.5 ± 2.424
Monthly Mean± SD	34.4 ± 1.014	35.6 ± 0.916	35.4 ± 0.755	33.77 ± 0.503		31.7 ± 0.7	28.3 ± 0.52	29.5 ± 0.872	30.47 ± 0.709		31.2 ± 0.8	32.7 ± 0.625	32.6 ± 0.608	33.4 ± 0.346		
Atmospheric Minimum Temperature (^{0}C)																
S4	20.4	21.5	23.0	23.2	22.0 ± 1.322	22.9	22.9	23.1	22.5	22.9 ± 0.251	22.3	22.4	20.9	20.5	21.5 ± 0.967	22.1 ± 1.036
S5	23.2	25.1	26.1	25.2	24.9 ± 1.219	23.9	22.4	22.8	23.0	23.0 ± 0.634	23.1	23.4	21.6	21.9	22.5 ± 0.883	23.5 ± 1.373
S6	23.9	25.2	26.9	25.7	25.4 ± 1.24	24.6	23.4	23.9	24.0	24.0 ± 0.492	24.1	24.7	22.7	23.2	23.7 ± 0.895	24.4 ± 1.158

Monthly Mean± SD	22.5 ± 1.852	23.93 ± 2.107	25.33 ± 2.059	24.7 ± 1.322		23.8 ± 0.854	22.9 ± 0.5	23.27 ± 0.568	23.17 ± 0.763		23.17 ± 0.901	23.5 ± 1.153	21.73 ± 0.907	21.87 ± 1.35		
Total Rainfall (MMS)																
S4	12.2	42.6	265.8	395.1	178.9 ± 183.176	279.4	463.4	187.8	313.4	311.0 ± 114.613	412.2	287.5	19.5	0.6	180.0 ± 202.828	223.3 ± 167.778
S5	1.0	0.0	41.9	189.7	58.2 ± 89.846	477.9	974.5	340.8	354.7	537.0 ± 298.120	139.0	131.7	9.1	6.7	71.6 ± 73.65	222.3 ± 286.3232
S6	4.9	0.0	23.1	266.9	73.7 ± 129.166	565.3	1131.6	389.9	276.1	590.7 ± 379.698	286.2	49.8	0.0	0.6	84.2 ± 136.706	249.5 ± 335.385
Monthly Mean± SD	6.03 ± 5.685	14.2 ± 24.595	110.27 ± 135.023	283.9 ± 103.749		440.87 ± 146.503	856.5 ± 349.379	306.17 ± 105.407	314.73 ± 39.317		279.13 ± 136.737	156.33 ± 120.749	9.53 ± 9.757	2.63 ± 3.521		
R.H% at 0830hrs																
S4	80	79	88	90	84.3 ± 5.560	92	96	91	88	91.8 ± 3.304	88	85	83	73	82.3 ± 6.5	86.1 ± 6.416
S5	75	74	76	78	75.8 ± 1.707	88	92	89	87	89.0 ± 2.160	86	83	72	74	78.8 ± 6.8	81.2 ± 7.056
S6	76	72	75	79	75.5 ± 2.886	91	97	92	91	92.8 ± 2.872	87	76	65	68	74.0 ± 9.831	80.8 ± 10.48
Monthly Mean± SD	77.0 ± 2.645	75.0 ± 3.605	79.67 ± 7.234	82.33 ± 6.658		90.33 ± 2.081	95.0 ± 2.645	90.67 ± 1.527	88.67± 2.081		87.0 ± 1.0	81.33 ± 4.725	73.33± 9.073	71.67± 3.214		
R.H% at 1730hrs																
S4	55	57	75	80	66.8 ± 12.606	84	84	76	76	80.0 ± 4.618	76	75	71	53	68.8 ± 10.72	71.8 ± 10.844
S5	56	57	65	70	62.0 ± 6.683	77	86	77	77	79.3 ± 4.5	76	73	58	55	65.5 ± 10.535	68.9 ± 10.413
S6	64	63	67	72	66.5 ± 4.041	83	94	86	84	86.8 ± 4.991	82	74	63	66	71.3 ± 8.539	74.8 ± 10.615
Monthly Mean± SD	58.33± 4.932	59.0 ± 3.464	69.0 ± 5.291	74.0 ± 5.291		81.33 ± 3.785	88.0 ± 5.291	79.67 ± 5.507	79.0 ± 4.358		78.0 ± 3.464	74.0 ± 1.0	64.0 ± 6.557	58.0 ± 7.0		

Table 2.16. Climatological attributes experienced along the habitats of *Excoecaria agallocha.*

Season	PRE MONSOON					MONSOON					POST MONSOON					
Station	Feb	Mar	Apr	May	Seasonal Mean± SD	Jun	Jul	Aug	Sep	Seasonal Mean± SD	Oct	Nov	Dec	Jan	Seasonal Mean± SD	Annual Mean± SD
Atmospheric Maximum Temperature (^{0}C)																
S7	35.5	36.6	36.1	33.7	35.5 ± 1.265	32.2	28.9	30.5	31.1	30.7 ± 1.376	32.0	32.9	32.3	33.6	32.7 ± 0.707	32.95 ± 2.305
S8	32.8	34.1	34.3	33.9	33.8 ± 0.670	32.5	30.5	30.8	30.7	31.1 ± 0.925	31.1	32.2	32.3	32.8	32.1 ± 0.716	32.333 ± 1.342
S9	34.2	35.4	35.5	34.3	34.9 0.695	32.0	28.0	28.9	30.6	29.9 ± 1.780	31.2	33.2	33.3	33.6	32.8 ± 1.096	32.516 ± 2.424
Monthly Mean± SD	34.17 ± 1.350	35.37 ± 1.25	35.3 ± 0.916	33.97 ± 0.305		32.23 ± 0.251	29.13 ± 1.266	30.07 ± 1.021	30.8 ± 0.264		31.43 ± 0.493	32.77 ± 0.513	32.63 ± 0.577	33.33 ± 0.461		
Atmospheric Maximum Temperature (^{0}C)																
S7	20.4	21.5	23.0	23.2	22.0 ± 1.322	22.9	22.9	23.1	22.5	22.9 ± 0.251	22.3	22.4	20.9	20.5	21.5 ± 0.967	22.133 ± 1.036
S8	22.8	24.2	25.7	25.3	24.5 ± 1.298	24.5	22.1	23.0	23.2	23.2 ± 0.989	22.8	23.3	22.0	22.2	22.6 ± 0.59	23.425 ± 1.234
S9	23.9	25.2	26.9	25.7	25.4 ± 1.242	24.6	23.4	23.9	24.0	24.0 ± 0.492	24.1	24.7	22.7	23.2	23.7 ± 0.895	24.358± 1.158
Monthly Mean± SD	22.37 ± 1.789	23.63 ± 1.914	25.2 ± 1.997	24.73 ± 1.342		24.0 ± 0.953	22.8 ± 0.655	23.33 ± 0.493	23.23± 0.750		23.07 ± 0.929	23.47 ± 1.159	21.87 ± 0.907	21.97 ± 1.365		
Total Rainfall (MMS)																
S7	12.2	42.6	265.8	395.1	178.9 ± 183.176	279.4	463.4	187.8	313.4	311.0 ± 114.612	412.2	287.5	19.5	0.6	180.0 ± 202.828	223.2917 ± 167.778
S8	5.0	21.8	54.9	316.8	99.6± 146.26	412.8	718.7	318.8	222.9	418.3 ± 214.749	331.1	197.3	82.0	0.0	152.6 ± 143.911	223.508 ± 212.759
S9	4.9	0.0	23.1	266.9	73.7± 129.166	565.3	1131.6	389.9	276.1	590.7± 379.698	286.2	49.8	0.0	0.6	84.2 ± 136.706	249.533 ± 335.385
Monthly Mean± SD	7.37 ± 4.186	21.47 ± 21.302	114.6 ± 131.904	326.27 ± 64.622		419.17 ± 143.056	771.23 ± 337.183	298.83 ± 102.518	270.8 ± 45.482		343.17 ± 63.86	178.2 ± 119.996	33.83 ± 42.837	0.4 ± 0.346		

R.H% at 0830hrs																
S7	80	79	88	90	84.3 ± 5.56	92	96	91	88	91.8 ± 3.304	88	85	83	73	82.3 ± 6.5	86.083 ± 6.416
S8	76	78	79	81	78.5 ± 2.081	88	93	89	87	89.3 ± 2.629	85	81	76	72	78.5 ± 5.686	82.083 ± 6.316
S9	76	72	75	79	75.5 ± 2.8868	91	97	92	91	92.8 ± 2.8723	87	76	65	68	74.0 ± 9.831	80.75 ± 10.480
Monthly Mean± SD	77.33 ±2.309	76.33 ±3.785	80.67 ± 6.658	83.33 ± 5.859		90.33 ± 2.081	95.33 ± 2.081	90.67 ± 1.527	88.67 ± 2.081		86.67 ± 1.527	80.67 ± 4.509	74.67 ± 9.073	71.0 ± 2.645		
R.H% at 1730hrs																
S7	55	57	75	80	66.8 ± 12.606	84	84	76	76	80.0 ± 4.618	76	75	71	53	68.8 ± 10.719	71.833 ± 10.844
S8	63	65	74	74	69.0 ± 5.831	81	84	81	80	81.5 ± 1.732	75	73	62	57	66.8 ± 8.655	72.416± 8.743
S9	64	63	67	72	66.5 ± 4.041	83	94	86	84	86.8 ± 4.991	82	74	63	66	71.3 ± 8.539	74.833 ± 10.615
Monthly Mean± SD	60.67 ± 4.932	61.67 ± 4.163	72.0 ± 4.358	75.33 ± 4.163		82.67 ± 1.527	87.33 ± 5.773	81.0 ± 5	80.0 ± 4		77.67 ± 3.785	74.0 ± 1	65.33 ± 4.932	58.67 ±6.658		

Table 2.17. Climatological attributes experienced along the habitats of *Rhizophora mucronata.*

Season	PRE MONSOON					MONSOON					POST MONSOON					
Station	Feb	Mar	Apr	May	Seasonal Mean± SD	Jun	Jul	Aug	Sep	Seasonal Mean± SD	Oct	Nov	Dec	Jan	Seasonal Mean± SD	Annual Mean± SD
Atmospheric Maximum Temperature (^{0}C)																
S10	35.5	36.6	36.1	33.7	35.5 ± 1.265	32.2	28.9	30.5	31.1	30.7 ± 1.376	32.0	32.9	32.3	33.6	32.7 ± 0.707	32.95 ± 2.305
S11	32.8	34.1	34.3	33.9	33.8 ± 0.670	32.5	30.5	30.8	30.7	31.1 ± 0.925	31.1	32.2	32.3	32.8	32.1 ± 0.716	32.333 ± 1.342
S12	34.2	35.4	35.5	34.3	34.9 ± 0.695	32.0	28.0	28.9	30.6	29.9 ± 1.780	31.2	33.2	33.3	33.6	32.8 ± 1.096	32.516 ± 2.424
Monthly Mean± SD	34.17 ± 1.350	35.37 ± 1.250	35.3 ± 0.916	33.97 ± 0.305		32.23 ± 0.251	29.13 ± 1.266	30.07 ± 1.021	30.8 ± 0.264		31.43 ± 0.493	32.77 ± 0.513	32.63 ± 0.577	33.33 ± 0.461		

Atmospheric Minimum Temperature (^{0}C)																
S10	20.4	21.5	23.0	23.2	22.0 ± 1.322	22.9	22.9	23.1	22.5	22.9 ± 22.85	22.3	22.4	20.9	20.5	21.5 ± 0.967	22.133 ± 1.036
S11	22.8	24.2	25.7	25.3	24.5 ± 1.298	24.5	22.1	23.0	23.2	23.2 ± 23.2	22.8	23.3	22.0	22.2	22.6 ± 0.590	23.425 ± 1.235
S12	23.9	25.2	26.9	25.7	25.4 ± 1.242	24.6	23.4	23.9	24.0	24.0 ± 23.975	24.1	24.7	22.7	23.2	23.7 ± 0.895	24.358 ± 1.158
Monthly Mean± SD	22.37 ± 1.789	23.63 ± 1.914	25.2 ± 1.997	24.73 ± 1.342		24.0 ± 0.953	22.8 ± 0.655	23.33 ± 0.493	23.23 ± 0.750		23.07 ± 0.929	23.47 ± 1.159	21.87 ± 0.907	21.97 ± 1.365		
Total Rainfall (MMS)																
S10	12.2	42.6	265.8	395.1	178.9 ± 183.176	279.4	463.4	187.8	313.4	311.0 ± 114.612	412.2	287.5	19.5	0.6	180.0 ± 202.828	223.292 ± 167.778
S11	5.0	21.8	54.9	316.8	99.6 ± 146.26	412.8	718.7	318.8	222.9	418.3 ± 214.749	331.1	197.3	82.0	0.0	152.6 ± 143.911	223.508 ± 212.759
S12	4.9	0.0	23.1	266.9	73.7 ± 129.166	565.3	1131.6	389.9	276.1	590.7 ± 379.698	286.2	49.8	0.0	0.6	84.2 ± 136.706	249.533 ± 335.385
Monthly Mean± SD	7.37 ± 4.186	21.47 ± 21.302	114.6 ± 131.904	326.27 ± 64.622		419.17 ± 143.056	771.23 ± 337.183	298.83 ± 102.518	270.8 ± 45.482		343.17 ± 63.860	178.2 ± 119.995	33.83 ± 42.837	0.4 ± 0.346		
R.H% at 0830hrs																
S10	80	79	88	90	84.3 ± 5.560	92	96	91	88	91.8 ± 3.304	88	85	83	73	82.3 ± 6.5	86.083 ± 6.416
S11	76	78	79	81	78.5 ± 2.081	88	93	89	87	89.3 ± 2.63	85	81	76	72	78.5 ± 5.686	82.083 ± 6.316
S12	76	72	75	79	75.5 ± 2.886	91	97	92	91	92.8 ± 2.872	87	76	65	68	74.0 ± 9.832	80.75 ± 10.480
Monthly Mean± SD	77.33 ± 2.309	76.33 ± 3.786	80.67 ± 6.658	83.33 ± 5.859		90.33 ± 2.081	95.33 ± 2.081	90.67 ± 1.527	88.67 ± 2.081		86.67 ± 1.527	80.67 ± 4.509	74.67 ± 9.073	71.0 ± 2.645		
R.H% at 1730hrs																
S10	55	57	75	80	66.8 ± 12.606	84	84	76	76	80.0 ± 4.618	76	75	71	53	68.8 ± 10.719	71.833 ± 10.845
S11	63	65	74	74	69.0 ± 5.831	81	84	81	80	81.5 ± 1.732	75	73	62	57	66.8 ± 8.655	72.417 ± 8.743
S12	64	63	67	72	66.5 ± 4.041	83	94	86	84	86.8 ± 4.991	82	74	63	66	71.3 ± 8.539	74.833 ± 10.615
Monthly Mean± SD	60.67 ± 4.932	61.67 ± 4.163	72.0 ± 4.358	75.33 ± 4.163		82.67 ± 1.527	87.33 ± 5.773	81.0 ± 5.0	80.0 ± 4.0		77.67 ± 3.785	74.0 ± 1.0	65.33 ± 4.932	58.67 ± 6.658		

Table 2.18. Climatological attributes experienced along the habitats of *Sonneratia alba*

Season	PRE MONSOON					MONSOON					POST MONSOON					
Station	Feb	Mar	Apr	May	Seasonal Mean± SD	Jun	Jul	Aug	Sep	Seasonal Mean± SD	Oct	Nov	Dec	Jan	Seasonal Mean± SD	Annual Mean± SD
Atmospheric Maximum Temperature (^{0}C)																
S13	35.5	36.6	36.1	33.7	35.5 ± 1.265	32.2	28.9	30.5	31.1	30.7 ± 1.376	32.0	32.9	32.3	33.6	32.7 ± 0.707	32.95 ± 2.305
S14	33.5	34.8	34.6	33.3	34.1 ± 0.759	30.9	28.0	29.1	29.7	29.4 ± 1.209	30.4	32.0	32.2	33.0	31.9 ± 1.089	31.791 ± 2.185
S15	34.2	35.4	35.5	34.3	34.9 ± 0.695	32.0	28.0	28.9	30.6	29.9 ± 1.780	31.2	33.2	33.3	33.6	32.8± 1.096	32.516 ± 2.424
Monthly Mean± SD	34.4 ± 1.014	35.6 ± 0.916	35.4 ± 0.755	33.77 ± 0.503		31.7 ± 0.7	28.3 ± 0.519	29.5 ± 0.871	30.47 ± 0.709		31.2 ± 0.8	32.7 ± 0.624	32.6 ± 0.608	33.4 ± 0.346		
Atmospheric Minimum Temperature (^{0}C)																
S13	20.4	21.5	23.0	23.2	22.0 ± 1.322	22.9	22.9	23.1	22.5	22.9 ± 0.251	22.3	22.4	20.9	20.5	21.5 ± 0.967	22.133 ± 1.036
S14	23.2	25.1	26.1	25.2	24.9 ± 1.219	23.9	22.4	22.8	23.0	23.0 ± 0.634	23.1	23.4	21.6	21.9	22.5 ± 0.883	23.475 ± 1.373
S15	23.9	25.2	26.9	25.7	25.4 ± 1.242	24.6	23.4	23.9	24.0	24.0 ± 0.492	24.1	24.7	22.7	23.2	23.7 ± 0.895	24.358 ± 1.158
Monthly Mean± SD	22.5 ± 1.852	23.93 ± 2.107	25.33 ± 2.059	24.7 ± 1.322		23.8 ± 0.854	22.9 ± 0.5	23.27 ± 0.568	23.17 ± 0.763		23.17 ± 0.901	23.5 ± 1.153	21.73 ± 0.907	21.87 ± 1.350		
Total Rainfall (MMS)																
S13	12.2	42.6	265.8	395.1	178.9 ± 183.176	279.4	463.4	187.8	313.4	311.0 ± 114.612	412.2	287.5	19.5	0.6	180.0 ± 202.828	223.291 ± 167.778
S14	1.0	0.0	41.9	189.7	58.2 ± 89.846	477.9	974.5	340.8	354.7	537.0 ± 298.120	139.0	131.7	9.1	6.7	71.6 ± 73.650	222.25 ± 286.323
S15	4.9	0.0	23.1	266.9	73.7 ± 129.166	565.3	1131.6	389.9	276.1	590.7 ± 379.698	286.2	49.8	0.0	0.6	84.2 ± 136.706	249.533 ±

																335.385
Monthly Mean± SD	6.03 ± 5.685	14.2 ± 24.595	110.27 ± 135.023	283.9 ± 103.749		440.87 ± 146.503	856.5 ± 349.379	306.17 ± 105.407	314.73 ± 39.317		279.13 ± 136.737	156.33 ± 120.749	9.53 ± 9.757	2.63 ± 3.521		
R.H% at 0830hrs																
S13	80	79	88	90	84.3 ± 5.560	92	96	91	88	91.8 ± 3.304	88	85	83	73	82.3 ± 6.5	86.083 ± 6.416
S14	75	74	76	78	75.8 ± 1.707	88	92	89	87	89.0 ± 2.160	86	83	72	74	78.8 ± 6.8	81.166± 7.056
S15	76	72	75	79	75.5 ± 2.886	91	97	92	91	92.8 ± 2.872	87	76	65	68	74.0 ± 9.831	80.75 ± 10.48
Monthly Mean± SD	77.0 ± 2.645	75.0 ± 3.605	79.67 ± 7.234	82.33± 6.658		90.33 ± 2.081	95.0 ± 2.645	90.67 ± 1.527	88.67 ± 2.081		87.0 ± 1	81.33 ± 4.725	73.33 ± 9.073	71.67 ± 3.214		
R.H% at 1730hrs																
S13	55	57	75	80	66.8 ± 12.606	84	84	76	76	80.0 ± 4.618	76	75	71	53	68.8 ± 10.719	71.833 ± 10.844
S14	56	57	65	70	62.0 ± 6.683	77	86	77	77	79.3 ± 4.5	76	73	58	55	65.5 ± 10.535	68.916± 10.413
S15	64	63	67	72	66.5 ± 4.041	83	94	86	84	86.8 ± 4.991	82	74	63	66	71.3 ± 8.539	74.833± 10.615
Monthly Mean± SD	58.33 ±4.932	59.0 ± 3.464	69.0 ± 5.291	74.0 ± 5.291		81.33 ± 3.785	88.0 ± 5.291	79.67 ± 5.507	79.0 ± 4.358		78.0 ± 3.464	74.0 ± 1	64.0 ± 6.557	58.0 ± 7		

With respect to habitats of *Avicennia officinalis*, atmospheric maximum temperature showed a higher annual mean value at Thekkumbad 1 (32.517 ± 2.424 ^{o}C) followed by Kumbalam 1 (32.325 ± 1.354 ^{o}C) and Kadalundi 1 (31.792 ±2.185 ^{o}C). In the case of *Bruguiera cylindrica*, higher atmospheric maximum temperature was noticed at Ayiramthengu 1 (33.0 ±2.305 ^{o}C) followed by Thekkumbad 2 (32.5 ±2.424 ^{o}C) and Kadalundi 2 (31.8 ±2.185 ^{o}C). Atmospheric maximum temperature with respect to *Excoecaria agallocha* was higher at Ayiramthengu 2 (32.95 ±2.305 ^{o}C) followed by Thekkumbad 3 (32.517 ±2.424 ^{o}C) and Kumbalam 2 (32.333 ±1.343 ^{o}C). Among the habitats of *Rhizophora mucronata*, atmospheric maximum temperature showed higher annual mean value at Ayiramthengu 3 (32.95 ±2.305 ^{o}C) followed by Thekkumbad 4 (32.517 ±2.424 ^{o}C) and Kumbalam 3 (32.333 ±1.343 ^{o}C). In the case of *Sonneratia alba,* higher atmospheric temperature was noticed at Kadalundi 3 (32.95 ±2.305 ^{o}C) followed by Thekkumbad 5 (32.517 ±2.424 ^{o}C) and Kadalundi 4 (31.792 ±2.185 ^{o}C).

As far the habitats of *Avicennia officinalis* is concerned, atmospheric minimum temperature was higher at Thekkumbad 1 (24.358 ± 1.159 ^{o}C) followed by Kumbalam 1 (23.492 ± 1.243 ^{o}C) and Kadalundi 1 (23.275 ±1.373 ^{o}C). In the case of *Bruguiera cylindrica*, higher atmospheric minimum temperature was noticed at Thekkumbad 2 (24.4 ±1.159 ^{o}C) followed by Kadalundi 2 (23.5 ±1.373 ^{o}C) and Ayiramthengu 1 (22.1 ±1.037 ^{o}C). Among the habitats of *Excoecaria agallocha* higher annual mean atmospheric minimum temperature was noticed at Thekkumbad 3 (24.358 ±1.159 ^{o}C) followed by Kumbalam 2 (23.425 ±1.235 ^{o}C) and Ayiramthengu 2 (22.133 ±1.037 ^{o}C). With respect to *Rhizophora mucronata,* higher value was noted at Thekkumbad 4 (24.358 ±1.159 ^{o}C) followed by Kumbalam 3 (23.425 ±1.235 ^{o}C) and Ayiramthengu 3 (22.133 ±1.037 ^{o}C). Among the habitats of *Sonneratia alba,* Thekkumbad 5 (24.358 ±1.159 ^{o}C) was noticed for higher value followed by Kadalundi 4 (23.475 ±1.373 ^{o}C) and Kadalundi 3 (22.133 ±1.037 ^{o}C).

Among the habitats of *Avicennia officinalis*, higher mean total rainfall was noted at Thekkumbad 1 (249.533 ± 335.385 MMS) followed by Kumbalam 1 (227.942 ± 213.3 MMS) and Kadalundi 1 (222.25 ± 286.32 MMS). With respect to *Bruguiera* *cylindrica*, higher total rainfall was noticed at Thekkumbad 2 (249.5 ± 335.385 MMS) followed by Ayiramthengu 1 (223.3 ± 167.78 MMS) and Kadalundi 2 (222.3 ± 286.32 MMS). In the case of *Excoecaria agallocha*, higher annual mean total rainfall was experienced at Thekkumbad 3 (249.533 ± 335.39 MMS) followed by Kumbalam 2 (223.508 ± 212.76 MMS) and Ayiramthengu 2 (223.292 ± 167.778 MMS). Among the habitats of *Rhizophora mucronata*, Thekkumbad 4 (249.533 ± 335.39 MMS) was noted for higher total rainfall followed by Kumbalam 3 (223.508 ± 212.76 MMS) and Ayiramthengu 3 (223.292 ± 167.778 MMS). With respect to *Sonneratia alba*, higher mean total rainfall was recorded at Thekkumbad 5 (249.533 ± 335.385 ^{o}C) followed by Kadalundi 3 (223.292 ± 167.778 ^{o}C) and Kadalundi 4 (222.25 ± 286.32 ^{o}C).

Upon assessing the relative humidity (0830 hrs) along the habitats of *Avicennia officinalis,* higher annual average was noticed at Kumbalam 1 (82.417 ± 6.694 %) followed by Kadalundi 1 (81.167 ± 7.056 %) and Thekkumbad 1 (80.75 ± 10.481 %). With respect to *Bruguiera cylindrica*, highest value was noted at Ayiramthengu 1 (86.1 ± 6.417 %) followed by Kadalundi 2 (81.2 ± 7.056 %) and Thekkumbad 2 (80.8 ± 10.481 %). In the case of *Excoecaria agallocha*, higher mean value was noted at Ayiramthengu 2 with 86.083 ± 6.417 %, followed by 82.083 ± 6.317 % at Kumbalam 2 and lower of 80.75 ± 10.481 % at Thekkumbad 3. Among the habitats of *Rhizophora mucronata,* higher annual mean was recorded at Ayiramthengu 3 with 86.083 ± 6.417 %, followed by 82.083 ± 6.317 % at Kumbalam 3 and lower of 80.75 ± 10.481 % at Thekkumbad 4. With respect to *Sonneratia alba*, higher mean relative humidity was noticed at Kadalundi 3 (86.083 ± 6.417 %) followed by Kadalundi 4 (81.167 ± 7.056 %) and Thekkumbad 5 (80.75 ± 10.481 %).

The relative humidity (1730 hrs) with respect to the habitats of *Avicennia officinalis* showed higher annual mean at Thekkumbad 1 (74.833 ± 10.616 %) followed by Kumbalam 1 (72.75 ± 9.127 %) and Kadalundi 1 (68.917 ± 10.414 %). With respect to *Bruguiera cylindrica*, highest value was noted at Thekkumbad 2 (74.8 ± 10.616 %) followed by Ayiramthengu 1 (71.8 ± 10.845 %) and Kadalundi 2 (68.9 ± 10.414 %). In the case of *Excoecaria agallocha,* higher relative humidity was noticed at

Thekkumbad 3 with 74.833 ± 10.6158 % followed by 72.417 ± 8.743 % at Kumbalam 2 and lower value of 71.833 ± 10.845 % at Ayiramthengu 2. Among the habitats of *Rhizophora mucronata*, higher annual mean relative humidity was recorded at Thekkumbad 4 with 74.833 ± 10.6158 % followed by 72.417 ± 8.743 % at Kumbalam 3 and lower value of 71.833 ± 10.845 % at Ayiramthengu 3. With respect to *Sonneratia alba* higher relative humidity was recorded at Thekkumbad 5 (74.833 ± 10.616 %) followed by Kadalundi 3 (71.833 ± 10.845 %) and Kadalundi 4 (68.917 ± 10.414 %).

Upon compiling all the above results, it can be stated that, even though the mangroves are growing in a wider range of environmental conditions, each species has its own range of tolerance to different hydrogeochemical, sedimentological and climatological attributes along their natural habitats. In the present investigation, the range of environmental attributes influencing the growth of selected mangrove species has been categorized into tolerance range and augmented range. **Tolerance range** is the ideal range, at which a particular species can flourish well along their natural environmental settings and the **augmented range** is the range that is acquired by adapting to an uncertain environmental condition. The range of various environmental attributes influencing the growth of mangrove species under study are depicted in the Table 2.19.

Table 2.19. Range of environmental attributes influencing the growth of selected mangrove species

Sl No:	Parameters	*Avicennia officinalis*		*Brugueira cylindrica*		*Excoecaria agallocha*		*Rhizophora mucronata*		*Sonneratia alba*	
		Tolerance range	Augmented range	Tolerance range	Augmented range	Tolerance range	Augmented range	Tolerance range	Augmented range	Tolerance range	Augmented range
1. Hydrological attributes											
1.	**pH**	**6.84–7.61**	3.86-8.16	**7.12–7.75**	6.23-8.6	**6.75–7.39**	5.06-8.31	**6.98–7.38**	3.9-7.93	**7.013–7.988**	6.02-8.57
2.	**Turbidity (NTU)**	**8.64– 7.41**	0.7-29.9	**4.67–20.66**	1.7-44.4	**5.677–9.54**	1.5-26.9	**7.41–21.336**	0.6-60.3	**12.2–15.6**	2.2-53.9
3.	**TS (mg/l)**	**10,733.33–25,444.44**	200-44,400	**23,166.67–26,555.56**	400-51400	**10,433.3–23,500.0**	200-45800	**12050–27,109.09**	400-56,000	**25,916.6–28,836.36**	400-49,400
4.	**TDS (ppt)**	**9.9–22.92**	0.2-42.0	**22.18–26.067**	1-49.6	**9.86–22.7**	0.2-45.6	**11.36–25.546**	0.2-45.8	**25.03–27.673**	0.2-49.0
5.	**TSS (mg/l)**	**833.33–5111.11**	0-41,200	**888.89–2,950.0**	0-18,600	**566.67–1600.0**	0-6000	**683.33–1,563.64**	0-10,200	**683.33–1,163.63**	0-4800
6.	**Acidity (mg/l)**	**22.55– 35.69**	1.32-88.0	**28.56–40.58**	1.76-61.6	**27.13–39.356**	11-63.8	**23.46–34.833**	8.8-61.6	**24.09–47.0**	3.08-74.8
7.	**Alkalinity (mg/l)**	**132.08–164.44**	50-340	**160.417–270.0**	80-1060	**122.08–172.08**	60-215	**112.08–171.67**	40-280	**171.25–172.73**	60-280
8.	**Hardness (mg/l)**	**1,786.17–3,490.75**	26-7,620	**3,130.0–3,282.17**	30-8180	**1736.91–3279.67**	22-7660	**1,852.5–3,660.18**	34-7,660	**3,675.25–4,053.82**	32-8760
9.	**Calcium (mg/l)**	**151.09–308.963**	6.4-801	**289.19–334.81**	6.01-1121.4	**130.83–273.32**	6.41-680.85	**144.12–280.782**	7.21-504.63	**280.28–301.80**	9.62-520.65
10.	**Magnesium (mg/l)**	**343.02–690.693**	0.49-1582.5	**558.54–712.16**	0.49-1558.2	**343.34–598.78**	0.97-1524.09	**363.41–720.47**	1.95-1582.5	**719.10–803.526**	1.46-1830.9
11.	**Chloride (mg/l)**	**8,001.7–15,257.9**	255.6-40,186	**11,833.93–13,144.68**	426-25,560	**7669.78 – 13166.84**	227.2-26,128	**7931.72–15,323.09**	411.8-25,205	**15,460.25–16,918.7**	383.4-41,322
12.	**Sulphate (mg/l)**	**37.375–51.21**	2.0-126	**44.11–54.75**	2-128	**35.27–52.41**	0.5-128	**40.29–51.208**	2-129	**50.59–55.125**	2-127
13.	**Sodium (ppt)**	**5.677–17.85**	0.02-54.6	**13.28–16.29**	0.05-34.1	**8.44–14.30**	0.075-29.8	**7.71–15.33**	0.015-27.4	**14.92–19.912**	0.01-46.8
14.	**Nitrogen (mg/l)**	**56.42 – 68.33**	20-196	**48.58–61.33**	15-210	**63.33–69.75**	22-220	**56.41–75.273**	19-220	**56.0–98.917**	14-490
15.	**Phosphorous (mg/l)**	**22.0– 36.4**	5.0-60.0	**26–42.1**	0.09-115	**18.2–42.6**	0.2-110	**34–38.7**	0.7-117.5	**32.3–39.8**	1.5-115
16.	**Potassium (mg/l)**	**910.42–3,252.73**	0-27800	**211.66–401.67**	0-1800	**120.0–387.08**	0-1700	**317.08–376.25**	0-1800	**292.72–350.83**	0-1650
17.	**Salinity (ppt)**	**8.693–19.677**	0.05-38.05	**18.68–30.97**	0.098-51.72	**8.52–19.067**	0.045-37.21	**9.82–21.344**	0.247-35.62	**20.78–24.56**	0.299-38.5
18.	**Resistivity (Ω)**	**131.12–2,017.66**	17.71-10790	**84.72–898.89**	16.48-5030	**66.07–2317.91**	18.06-12,270	**75.04–499.886**	18.83-1977	**134.41–260.37**	17.49-1634
19.	**Conductivity**	**13.77–29.37**	0.091-55.23	**28.49–31.081**	0.194-59.33	**13.65–29.025**	0.0795-54.24	**15.57–31.826**	0.495-51.76	**31.065–36.236**	0.5996-55.87
2. Sedimentological attributes											
20.	**pH**	**6.63–7.71**	4.08-8.33	**6.84–7.523**	5.57-8.21	**6.63–7.247**	4.1-8.16	**6.43–7.51**	5.05-8.08	**6.708–8.02**	4.66-8.7
21.	**Moisture %**	**9.40–13.22**	4.97-20.15	**7.11–11.529**	3.48-16.38	**8.88–11.518**	4.25-16.2	**7.58–13.646**	1.06-23.61	**9.38–10.467**	6.62-14.17
22.	**Organic carbon (g/kg)**	**17.9–34.75**	1.0-96	**20.28–26.65**	10-155	**17.5–35.1**	0.4-110.5	**17.3–23.03**	0.5-67	**19.06–23.29**	0.5-77
23.	**Total nitrogen (mg/kg)**	**2,269.16–5,610.83**	1050-18840	**816.66–1545.83**	560-2870	**788.06–1628.7**	630.45-3572.55	**788.067–1692.89**	630.45-3362.4	**737.86–834.763**	112.08-1401.0
24.	**Total phosphorous**	**9.7–23.1**	7-38.5	**11.4–58.0**	12-82	**15.4–43.1**	8.2-69.6	**21.3–57.5**	11.5-76.2	**29.8–41.5**	13.2-66

	(mg/kg)										
25.	**Potassium (mg/kg)**	**55.55–76.33**	3.4-240	**48.39–73.583**	8.5-230	**35.158–56.792**	0.2-138	**47.467–258.92**	8.9-1,400	**56.567–77.483**	14.7-139
26.	**Sodium (ppt)**	**0.34–1.055**	0.0775-1.884	**0.34–0.677**	0.0263-1.674	**0.316–0.44**	0.0441-1.355	**0.28–0.55**	0.0255-0.947	**0.449–0.502**	0.2815-1.052
27.	**Sand %**	**78.45–87.29**	51.4-99	**82.025–86.842**	58.7-99	**83.3–90.358**	61.7-97.9	**52.2–74.72**	25.6-96.8	**75.375–86.958**	50.9-98.5
28.	**Silt %**	**0.26–0.475**	0.1-1.2	**0.333–0.433**	0.1-1.8	**0.38-0.983**	0.1-6.7	**0.233–0.433**	0.1-2.2	**0.433–0.592**	0.1-2.7
29.	**Clay %**	**12.44–21.075**	0.8-47.7	**12.725–17.642**	0.8-36.2	**9.067–16.317**	0.7-38.2	**9.292–47.367**	2.9-73.8	**12.625–24.025**	1.2-48.3
3. Climatological attributes											
30.	**Atm.Max.Temp (^oC)**	**31.79–32.52**	28-35.5	**31.8–33.0**	28-36.6	**32.33–32.95**	28-36.6	**32.33–32.95**	28-36.6	**31.79–32.95**	28-36.6
31.	**Atm.Min.Temp (^oC)**	**23.275–24.36**	21.6-26.9	**22.1–24.4**	20.4-26.9	**22.133–24.358**	20.4-26.9	**22.13–24.258**	20.4-26.9	**22.13–24.358**	20.4-26.9
32.	**Total rainfall (MMS)**	**222.25–249.533**	0-565.3	**222.3–249.5**	0-1131.6	**223.29–249.533**	0-1131.6	**223.29–249.533**	0-1131.6	**222.25–249.533**	0-565.3
33.	**R.H % at 0830 hrs**	**80.75–82.42**	65-93	**80.8–86.1**	65-97	**80.75–86.083**	65-97	**80.75–86.083**	65-97	**80.75–86.083**	65-97
34.	**R.H % at 1730 hrs**	**68.92–74.833**	55-94	**68.9–74.8**	53-94	**71.833–74.833**	53-94	**71.833–74.833**	53-94	**68.917–714.833**	53-94

Mangrove ecosystems are under the influence of both marine and freshwater influxes and have developed various physiological adaptations to overcome changes in environmental conditions (Tomlinson, 1986). In the present investigation, considering tolerance range to water pH, *Avicennia officinalis* can flourish in the range of 6.842 to 7.612, while it has got an augmented pH range of 3.86-8.16. The tolerance range of *Bruguiera cylindrica* and *Excoecaria agallocha* were 7.126 to 7.749 and 6.758 to 7.39 respectively whereas, their augmented tolerance range were 6.23 to 8.6 and 5.06 to 8.31 respectively. Hydrological pH range in the habitat of *Rhizophora mucronata* is 6.981 to 7.383 (augmented range; 3.9 to7.93) and that of *Sonneratia alba* is 7.014 to 7.988 (augmented range; 6.02 to 8.57). All the ranges are comparable with those reported in earlier studies. Paramasivam and Kannan, 2005, in their studies on the Muthupettai mangrove ecosystem, showed the range of hydrological pH in mangrove area as 7.1-8.7 and in 2012, Manju et al., studied the entire mangrove ecosystems of Kerala and reported the water pH as 7.1 – 8.05. Recently, in 2016, Shilna et al. reported the annual mean pH of water associated with five mangrove species in Malappuram district of Kerala to be 7.34.

The ideal tolerance range of *Avicennia officinalis* to turbidity is 8.644 to 17.408 NTU (augmented range; 0.7 to 29.9 NTU), and that of *Bruguiera cylindrica* is 4.678 to 20.658 NTU (1.7 to 44.4 NTU). Tolerance range of 5.678 to 9.542 NTU and augmented range of 1.5 to 26.9 NTU for turbidity is noted for *Excoecaria agallocha*. *Rhizophora mucronata* can tolerate the water turbidity of 7.417 to 21.336 NTU while, *Sonneratia alba* can tolerate the turbidity level from 12.2 to 15.6 NTU. A higher range (43 to 260 NTU) has been reported by Srilatha et al. (2013) whereas, values of almost similar range (10.43 NTU) has been reported by Shilna et al. (2016). Tolerance range of *Avicennia officinalis* to total solids is 10733.33 to 25444.44 mg/l (augmented range; 200 to 44,400 mg/l) and that of *Bruguiera cylindrica* is 23166.67 to 26555.56 mg/l (augmented range; 400 to 51400 mg/l). 10433.3 to 23500 mg/l and 12050 to 27109.09 mg/l are the tolerance limits of *Excoecaria agallocha* and *Rhizophora mucronata* respectively. *Sonneratia alba* are with a tolerance range of 25916.6 to 28836.36 mg/l and an augmented range of 400 to 49,400 mg/l. The values are comparable with some of the earlier reports in which the annual average of water turbidity level reported was 47200 mg/l (Alshawafi et al., 2016).

Avicennia officinalis possesses a tolerance range of 9.9 to 22.916 ppt of TDS and 833.33 to 5111.11 mg/l of TSS respectively, and their augmented ranges are 0.2 to 42.0 ppt and 0 to 41,200 mg/l. Likewise, *Bruguiera cylindrica* has a tolerance range of 22.183 to 26.067 ppt and 888.89 to 2950 mg/l respectively. *Excoecaria agallocha* is with a range of tolerance 9.867 to 22.7 ppt and 566.67 to 1600 mg/l respectively towards TDS and TSS. 11.367 to 25.546 ppt and 683.33 to 1563.64 mg/l are the tolerance range of *Rhizophora mucronata* towards TDS and TSS. *Sonneratia alba* have a tolerance range of 25.033 to 27.673 ppt of TDS (augmented range; 0.2 to 49.0 ppt) and 683.33 to 1163.63 mg/l TSS (augmented range; 0 to 4800 mg/l). TDS values of similar range have also been reported by other researchers (Alshawafi et al., 2016 and Shilna et al., 2016).

The ranges of tolerance of acidity for *Avicennia officinalis, Brugueira cylindrica, Excoecaria agallocha, Rhizophora mucronata* and *Sonneratia alba* are 22.55 to 35.69 mg/l, 28.563 to 40.578 mg/l, 27.133 to 39.356 mg/l, 23.467 to 34.833 mg/l and 24.09 to 47 mg/l respectively and that of alkalinity are 132.08 to 164.44 mg/l, 160.417 to 270.0 mg/l, 122.083 to 172.083 mg/l, 112.083 to 171.667 mg/l and 171.25 to 172.727 mg/l respectively. The augmented ranges of acidity and alkalinity for the species are (1.32 to 88.0, 1.76 to 61.6, 11 to 63.8, 8.8 to 61.6 and 3.08 to 74.8 mg/l) and (50 to 340, 80 to 1060, 60 to 215, 40-280 and 60 to 280) respectively. In 2016, Shilna et al., reported the annual range of acidity and alkalinity of the mangrove area with all the selected mangrove species as 8.24 mg/l and 100.79 mg/l respectively and in 2012, Manju et al., reported the annual alkalinity of 77.91 mg/l from the mangrove ecosystems of Kerala.

The tolerance range of *Avicennia officinalis* towards hardness is 1,786.17 to 3,490.75 mg/l and that of *Brugueira cylindrica* is 3130 to 3282.17 mg/l. 1736.917 to 3279.667 mg/l and 1852.5 to 3660.182 mg/l are the tolerance ranges of *Excoecaria agallocha* and *Rhizophora mucronata* towards hardness and that of *Sonneratia alba* is 3675.25 to 4053.82 mg/l. *Avicennia officinalis* has also a tolerance range of

151.09 to 308.963 mg/l and 343.026 to 690.693 mg/l towards calcium and magnesium. *Brugueira cylindrica* possesses the tolerance range within 289.195 to 334.806 mg/l to calcium and 558.543 to 712.159 mg/l to magnesium. The tolerance range of *Excoecaria agallocha* to calcium and magnesium are 130.838 to 273.321 mg/l and 343.348 to 598.789 mg/l respectively. *Rhizophora mucronata* can tolerate calcium and magnesium within the range of 144.121 to 280.782 mg/l and 363.414 to 720.47 mg/l respectively. The tolerance range of *Sonneratia alba* towards calcium and magnesium are 280.283 to 301.797 and 719.101 to 803.526 mg/l. According to Shilna et al. (2016), the annual average of calcium and magnesium from the mangrove area are 429.63 mg/l and 850.33 mg/l, and that of entire Kerala mangrove ecosystem was 127.61 mg/l and 473.13 mg/l respectively (Manju et al., 2012).

Avicennia officinalis, Brugueira cylindrica, Excoecaria agallocha, Rhizophora mucronata and *Sonneratia alba* have the tolerance range of 8001.7 to 15257.9 mg/l, 11833.93 to 13144.68 mg/l, 7669.78 to 13166.84 mg/l, 7931.72 to 15323.09 mg/l and 15460.25 to 16918.7 mg/l respectively towards chloride. The range of tolerances towards sulphate and sodium by the species are 37.375 to 51.208 mg/l and 5.677 to 17.849 ppt, 44.111 to 54.75 mg/l and 13.288 to 16.289 ppt, 35.27 to 52.42 mg/l and 8.447 to 14.303 ppt, 40.292 to 51.208 mg/l and 7.718 to 15.33 ppt and 50.591 to 55.125 mg/l and 14.924 to 19.912 ppt respectively. The augmented ranges of *Avicennia officinalis, Brugueira cylindrica, Excoecaria agallocha, Rhizophora mucronata* and *Sonneratia alba* towards sulphate are 2.0 to 126, 2 to 128, 0.5 to 128, 2 to 129 and 2 to 127 mg/l respectively. In 2012, Manju et al., reported the annual average of sulphate and sodium from mangrove ecosystems of Kerala as 1308.03 mg/l and 2525 mg/l respectively. Shilna et al. (2016) has also reported the annual average of chloride, sulphate and sodium from the mangrove ecosystem of all the species under study along Malappuram district of Kerala as 11199.33 mg/l, 874.05 mg/l and 8640.33 mg/l respectively.

The tolerance and augmentation ranges of *Avicennia officinalis* towards nitrogen, phosphorous and potassium are 56.417 to 68.333 (20 to 196) mg/l, 22.0 to 36.4 (0.5 to 60) mg/l and 910.42 to 3252.73 (0 to 27800) mg/l respectively and that of

Brugueira cylindrica are 48.583 to 61.333 (15 to 210) mg/l, 26.4 to 42.1 (0.09 to 115) mg/l and 211.667 to 401.667 (0 to 1800) mg/l respectively. *Excoecaria agallocha* and *Rhizophora mucronata* have range of tolerance towards N, P, K as (63.33 to 69.75 mg/l, 18.2 to 42.6 mg/l and 120.0 to 387.08 mg/l) and (56.417 to 75.273 mg/l, 34.8 to 38.7 mg/l and 317.083 to 376.25 mg/l) respectively. *Sonneratia alba* has tolerance and augmented range towards N, P and K as 56 to 98.917 (14 to 490) mg/l, 32.4 to 39.8 (1.5 to 115) mg/l and 292.73 to 350.83 (0 to 1650) mg/l respectively. Nitrogen, Phosphorous and Potassium are the major nutrients in the mangrove sediments studied and reported from various natural mangrove habitats of Kerala and the annual average values reported were 88.35 µM, 9.61 µM and 105.38 mg/l respectively (Manju et al., 2012).

Avicennia officinalis has a wider range of tolerance to salinity (8.693 to 19.677 ppt), resistivity (131.123 to 2017.66 Ω) and conductivity (13.77 to 29.37 mS). The augmented ranges were 0.05 to 38.05 ppt, 17.71 to 10790 Ω and 0.091 to 55.23 mS respectively. The range of tolerance of *Brugueira cylindrica, Excoecaria agallocha, Rhizophora mucronata* and *Sonneratia alba* towards salinity, resistivity and conductivity are (18.689 to 30.967 ppt, 84.723 to 898.886 Ω and 28.496 to 31.081 mS), (8.529 to 19.067 ppt, 66.07 to 2314.91 Ω and 13.659 to 29.025 mS), (9.82 to 21.34 ppt, 75.048 to 499.886 Ω and 15.570 to 31.826 mS) and (20.789 to 24.562 ppt, 134.413 to 260.368 Ω and 31.065 to 36.236 mS) respectively. Salinity plays a pivotal role in the species distribution, productivity and growth of mangrove forests (Twilley and Chen, 1998). The annual average of salinity reported from the mangrove ecosystems of Kerala was 16.09 ppt (Manju et al., 2012). Studies have also been reported that mangrove ecosystems with mangrove species *Avicennia officinalis, Brugueira cylindrica, Excoecaria agallocha, Rhizophora mucronata* and *Sonneratia alba* has an annual average values of salinity, resistivity and conductivity as 15.803.67 ppt, 1591.67 Ω and 23.684 m S respectively (Shilna et al., 2016).

Mangrove plants may grow in different types of soils; therefore their vegetation, species composition and structure may vary considerably at the global, regional and local scales (Vilarrubia, 2000). Upon compiling the sedimentological requirements, the range of tolerance to sediment pH by *Avicennia officinalis, Bruguiera cylindrica, Excoecaria agallocha, Rhizophora mucronata* and *Sonneratia alba* were 6.633 to 7.713, 6.848 to7.523, 6.638 to 7.247, 6.43 to 7.51 and 6.708 to 8.023 respectively. Tolerance range to moisture percentage and organic carbon concentration of the species (9.407 to 13.221, 7.117 to 11.529, 8.888 to 11.518, 7.584 to 13.646 and 9.382 to 10.467%), (1.793 to 3.475, 2.028 to 2.665, 1.75 to 3.511, 1.733 to 2.303 and 1.906 to 2.329 g/kg) are reported respectively. The augmented ranges of organic carbon concentration of the species are 1.0 to 96, 10 to 155, 0.4 to 110.5, 0.5 to 67 and 0.5 to 77 g/kg respectively. Saravanakumar et al. (2008) reported the range of organic carbon from the mangrove ecosystem of Kachchh - Gujarat as 2.9 to 25.6 g/kg. The distribution of total organic carbon closely followed the distribution of sediment type i.e., as sediment is low in clay content, the total organic carbon content is also low and as the clay content increased, the total organic carbon content also increased (Reddy and Hariharan, 1986). Various studies have also reported that, soil organic carbon and pH are the major factors having most significant influence on the growth and establishment of mangroves (Clough, l984 and Yang et al., 2013).

The tolerance and augmented range of *Avicennia officinalis* to sediment Nitrogen, Phosphorous and Potassium is 2269.16 to 5610.83 (1050 to 18840) mg/kg, 9.7 to 23.1 (7 to 38.5) mg/kg and 55.558 to 76.333 (3.4 to 240) mg /kg respectively and that of *Bruguiera cylindrica* is 816.667 to 1545.83 (560 to 2870) mg/kg, 11.5 to 58.0 (12 to 82) mg/kg and 48.392 to 73.583 (8.5 to 230) mg/kg respectively. The range of tolerance of *Excoecaria agallocha* and *Rhizophora mucronata* are (788.063 to 1628.7, 15.4 to 43.1 and 35.158 to 56.792 mg/kg) and (788.067 to 1692. 89, 21.3 to 57.5 and 47.467 to 258.917 mg/kg) respectively. The augmented ranges are (630.45 to 3572.55, 8.2 to 69.6 and 0.2 to 138) and (630.45 to 3362.4, 11.5 to 76.2 and 8.9 to 1400) respectively. *Sonneratia alba* has a tolerance range of 737.86 to 834.763, 29.8 to 41.5 and 56.567 to 77.483 mg/kg respectively towards Nitrogen, Phosphorous and Potassium. A recent study carried out in the mangrove ecosystem of Ayiramthengu, Kerala possessing all the 5 mangrove species reported range of P and K as 29.5 to 57.9 Kg/ha and 231 to 440 Kg/ha respectively. Study conducted in the mangrove areas of Karankadu mangrove forest, Tamil nadu, showed a range of N, P and K as 78320 to 102500 mg/kg, 2500 to 3480 mg/kg and 79000 to 92000 mg/kg (Saseeswari et al., 2015).

Avicennia officinalis has a tolerance range of 0.342 to 1.055 ppt towards sediment sodium, and that of 78.45 to 87.29%, 0.267 to 0.475 % and 12.442 to 21.075 % towards sand %, silt % and clay % respectively. *Bruguiera cylindrica* shows a tolerance range of 0.342 to 0.677 ppt towards sodium and 82.025 to 86.842, 0.333 to 0.433 and 12.725 to 17.642 % respectively towards sand, silt and clay percentages. The tolerance range of *Excoecaria agallocha* towards sodium is 0.316 to 0.441 ppt and that of sand, silt and clay percentages are 83.3 to 90.358, 0.383 to 0.983 and 9.067 to 16.317 % respectively. The tolerance range of *Rhizophora mucronata* towards sodium is 0.287 to 0.552 ppt and that of sand, silt and clay percentages are 52.2 to 74.717, 0.233 to 0.433 and 9.292 to 47.367 % respectively. *Sonneratia alba* has a tolerance range of 0.449 to 0.502 ppt towards sodium and 75.375 to 86.958, 0.433 to 0.592, and 12.625 to 24.025% respectively towards sand, silt and clay percentages. More or less similar results have been reported by Saravanakumar et al. (2008). The study reported sediment textures ranges in terms of % of sand, clay and silt as 0.26-19.2, 7.6-47 and 47-87.4 % respectively. The texture triangles studies have revealed that the nature of soil in all the locations studied were silty loam, silty clay and silty clay loam.

From the climatological observations, it can clearly be stated that the mangrove species has its own range of tolerance to different climatic attributes also. The tolerance range of atmospheric temperature maximum and minimum of the selected species include; *Avicennia officinalis* (31.792 to 32.517 and 23.275 to 24.358 ^{o}C), *Brugueira cylindrica* (31.8 to 33.0 and 22.1 to 24.4^{o}C), *Excoecaria agallocha* (32.333 to 32.95 and 22.133 to 24.358^{o}C), *Rhizophora mucronata* (32.333 to 32.95 and 22.133 to 24.358^{o}C) and *Sonneratia alba* (31.792 to 32.95 and 22.133 to 24.358^{o}C).

The tolerance and augmented ranges of total rainfall at which the mangrove species are proliferated well in the study areas are *Avicennia officinalis* (222.25 to 249.533 and 0 to 565.3 MMS), *Bruguiera cylindrica* (222.3 to 249.5 and 0 to 1131.6 MMS), *Excoecaria agallocha* (223.29 to 249.533 and 0 to 1131.6 MMS), *Rhizophora mucronata* (223.292 to 249.533 and 0 to 1131.6 MMS) and *Sonneratia alba* (222.25 to 249.533 and 0 to 565.3 MMS). The relative humidity percentage at 0830 hrs and 1730 hrs of *Avicennia officinalis* (80.75 to 82.417 and 68.917 to 74.833 %); *Bruguiera cylindrica* (80.8 to 86.1 % and 68.9 to 74.8 %), *Excoecaria agallocha* (80.75 to 86.083 and 71.833 to 74.833 %), *Rhizophora mucronata* (80.75 to 86.083 and 71.833 to 74.833 %) and *Sonneratia alba* (80.75 to 86.083 and 68.917 to 74.833 %) are reported.

In general, mangroves are inimitable intertidal ecosystems with unique features, having own adaptations to cope up with extreme environmental conditions. Present study mainly focused on the range of tolerance of selected mangrove species to varying levels of environmental attributes. The results clearly indicated that, in addition to the ideal range of tolerance, each mangrove species acquire an additional capability to acclimatize with disturbed surroundings through its adaptation potentialities. This added range in addition to the tolerance range is depicted in the present investigation as 'augmented range'. The present investigation along with the earlier success stories recommended following at least two major criteria in the subsequent afforestation endeavors; (i) species specific afforestation and (ii) site specific afforestation. Both of them are inter-dependable, because in species specific afforestation, the site selection depends on the tolerance range of the specific species and in the site specific afforestation activities, species selection is based on the characteristics of the site. In other words, the 'tolerance range' of a species with respect to the site is a mandatory requirement towards including them in afforestation purposes whereas the 'augmented range' gains significance only after the acclimatization of the species in the new area. Thus the study emphasizes that all the afforestation/ restoration practices of mangroves must be either species or site specific.

STATISTICAL ANALYSIS

Physico chemical attributes of both water and sediment along selected habitats of 5 mangrove species were further analyzed statistically to find out the discrepancy among different sites and seasons. Seasonal and site specific mean values of each parameters were subjected to two way ANOVA and found out the variations among the locations as well as the seasons. Such variations in each parameter with respect to sites and seasons were considered towards elucidating each of their influence on the growth of mangrove species. Accordingly, the most vital physico chemical attributes of water and sediment that are likely to influence the growth of each mangrove species can be enumerated. Since a uniform pattern of climatological conditions has been experienced along all the locations under study, statistical analysis for elucidating each of their influence on mangrove growth was not attempted. The observations are depicted in the following tables (Table 2.20 – 2.24).

Table 2.20. Comparative study of locations and seasons of *Avicennia officinalis* with respect to water and sediment quality

Sl No	Source of Variation	Average	F- value
WATER ANALYSIS			
pH			
1	Kumbalam 1	6.891667	1.119^{NS}
2	Kadalundi 1	7.512333	
3	Thekkumbad 1	6.892667	
1	Pre monsoon	7.432333	2.610^{NS}
2	Monsoon	6.467667	
3	Post monsoon	7.396667	
Turbidity			
1	Kumbalam 1	8.866667	8.034^{*}
2	Kadalundi 1	17.40833	
3	Thekkumbad 1	7.975	
1	Pre monsoon	7.8	8.793^{*}
2	Monsoon	17.68333	
3	Post monsoon	8.766667	
Total solids			
1	Kumbalam 1	10733.33	3.899^{NS}

2	Kadalundi 1	23900	
3	Thekkumbad 1	26200	
1	Pre monsoon	34816.67	15.928*
2	Monsoon	1783.333	
3	Post monsoon	24233.33	
Total Dissolved solids			
1	Kumbalam 1	9.9	4.140 NS
2	Kadalundi 1	22.91667	
3	Thekkumbad 1	22.22233	
1	Pre monsoon	33.55	20.141*
2	Monsoon	1.389	
3	Post monsoon	20.1	
TSS			
1	Kumbalam 1	833.333	0.755 NS
2	Kadalundi 1	966.667	
3	Thekkumbad 1	3977.777	
1	Pre monsoon	1266.667	0.919 NS
2	Monsoon	377.777	
3	Post monsoon	4133.333	
Salinity (ppt)			
1	Kumbalam 1	8.693	4.091 NS
2	Kadalundi 1	19.677	
3	Thekkumbad 1	20.578	
1	Pre monsoon	28.469	17.874*
2	Monsoon	1.2643	
3	Post monsoon	19.215	
Resistivity (Ω)			
1	Kumbalam 1	503.601	0.972 NS
2	Kadalundi 1	131.123	
3	Thekkumbad 1	2016.519	
1	Pre monsoon	30.769	2.051 NS
2	Monsoon	2558.422	
3	Post monsoon	62.053	
Conductivity (mS)			
1	Kumbalam 1	13.77017	4.044 NS
2	Kadalundi 1	29.36967	
3	Thekkumbad 1	30.15957	
1	Pre monsoon	42.02033	19.686*
2	Monsoon	2.078067	
3	Post monsoon	29.201	
Acidity			
1	Kumbalam 1	22.55	
2	Kadalundi 1	27.97667	
3	Thekkumbad 1	36.54333	7.944 *
1	Pre monsoon	38.68333	
2	Monsoon	19.31	
3	Post monsoon	29.07667	14.976*
Alkalinity			
1	Kumbalam 1	132.0833	1.228 NS

2	Kadalundi 1	160.8333	
3	Thekkumbad 1	168.611	
1	Pre monsoon	185	2.841 NS
2	Monsoon	126.9443	
3	Post monsoon	149.5833	
Hardness			
1	Kumbalam 1	1786.167	2.338 NS
2	Kadalundi 1	3490.75	
3	Thekkumbad 1	3468.667	
1	Pre monsoon	5891.667	20.018*
2	Monsoon	185.75	
3	Post monsoon	2668.167	
Calcium			
1	Kumbalam 1	151.0943	2.457 NS
2	Kadalundi 1	261.2127	
3	Thekkumbad 1	314.7373	
1	Pre monsoon	417.1883	13.875*
2	Monsoon	26.91933	
3	Post monsoon	282.9367	
Magnesium			
1	Kumbalam 1	343.026	2.032 NS
2	Kadalundi 1	690.693	
3	Thekkumbad 1	653.190	
1	Pre monsoon	1180.392	18.798*
2	Monsoon	28.873	
3	Post monsoon	477.644	
Chloride (Mg/l)			
1	Kumbalam 1	8001.7	2.919 NS
2	Kadalundi 1	15257.9	
3	Thekkumbad 1	15368.74	
1	Pre monsoon	22317.67	18.146*
2	Monsoon	1526.106	
3	Post monsoon	14784.57	
Sulphate (Mg/l)			
1	Kumbalam 1	8001.7	2.919 NS
2	Kadalundi 1	15257.9	
3	Thekkumbad 1	15368.74	
1	Pre monsoon	22317.67	18.146*
2	Monsoon	1526.106	
3	Post monsoon	14784.57	
Sodium (ppt)			
1	Kumbalam 1	5.677	3.014 NS
2	Kadalundi 1	13.935	
3	Thekkumbad 1	17.927	
1	Pre monsoon	20.438	7.620*
2	Monsoon	1.368	
3	Post monsoon	15.733	
Nitrogen (mg/l)			
1	Kumbalam 1	59.167	0.244 NS

2	Kadalundi 1	56.417	
3	Thekkumbad 1	66.111	
1	Pre monsoon	46.083	5.052 NS
2	Monsoon	48.861	
3	Post monsoon	86.75	
Phosphorous (mg/l)			
1	Kumbalam 1	22.067	0.642 NS
2	Kadalundi 1	22.1	
3	Thekkumbad 1	47.367	
1	Pre monsoon	51.267	1.056 NS
2	Monsoon	25.367	
3	Post monsoon	14.9	
Potassium (mg/l)			
1	Kumbalam 1	910.417	1.806 NS
2	Kadalundi 1	3105.417	
3	Thekkumbad 1	2987.361	
1	Pre monsoon	4847.5	5.813 NS
2	Monsoon	665.277	
3	Post monsoon	1490.417	
SEDIMENT ANALYSIS			
pH			
1	Kumbalam 1	6.579333	2.002 NS
2	Kadalundi 1	7.561	
3	Thekkumbad 1	6.6785	
1	Pre monsoon	7.403333	1.138 NS
2	Monsoon	6.639167	
3	Post monsoon	6.776333	
Moisture %			
1	Kumbalam 1	13.22333	3.268 NS
2	Kadalundi 1	9.408333	
3	Thekkumbad 1	12.19833	
1	Pre monsoon	10.97	1.808 NS
2	Monsoon	13.29	
3	Post monsoon	10.57	
Sand %			
1	Kumbalam 1	78.45	2.690 NS
2	Kadalundi 1	83.783	
3	Thekkumbad 1	87.292	
1	Pre monsoon	85.333	6.928 NS
2	Monsoon	75.20	
3	Post monsoon	88.992	
Silt%			
1	Kumbalam 1	0.475	0.356 NS
2	Kadalundi 1	0.408	
3	Thekkumbad 1	0.267	
1	Pre monsoon	0.233	0.670 NS
2	Monsoon	0.525	
3	Post monsoon	0.392	
Clay %			

1	Kumbalam 1	23.433	1.977 NS
2	Kadalundi 1	22.642	
3	Thekkumbad 1	16.908	
1	Pre monsoon	14.433	5.035 NS
2	Monsoon	24.275	
3	Post monsoon	24.275	
Organic carbon(g/kg)			
1	Kumbalam 1	33.41667	0.593 NS
2	Kadalundi 1	20.30267	
3	Thekkumbad 1	24.60567	
1	Pre monsoon	25.10833	0.384 NS
2	Monsoon	31.91667	
3	Post monsoon	21.3	
Nitrogen(mg/kg)			
1	Kumbalam 1	5610.833	2.261 NS
2	Kadalundi 1	4907.5	
3	Thekkumbad 1	2269.167	
1	Pre monsoon	4436.667	1.440 NS
2	Monsoon	5573.333	
3	Post monsoon	2777.5	
Phosphorous(mg/kg)			
1	Kumbalam 1	19.433	12.893*
2	Kadalundi 1	9.7	
3	Thekkumbad 1	23.133	
1	Pre monsoon	17.433	1.437 NS
2	Monsoon	19.733	
3	Post monsoon	15.1	
Potassium(mg/kg)			
1	Kumbalam 1	55.558	0.479 NS
2	Kadalundi 1	76.333	
3	Thekkumbad 1	60.45	
1	Pre monsoon	85.917	1.526 NS
2	Monsoon	48.792	
3	Post monsoon	57.633	
Sodium (ppt)			
1	Kumbalam 1	0.342	1.686 NS
2	Kadalundi 1	0.430	
3	Thekkumbad 1	1.055	
1	Pre monsoon	0.666	1.466 NS
2	Monsoon	0.221	
3	Post monsoon	0.940	

***: Significant at 5% level; NS: not significant (critical value of F at 5% level for 3 locations x 3 seasons = 6.944).**

Table 2.21. Comparative study of locations and seasons of *Bruguiera cylindrica* with respect to water and sediment quality

Sl No	Source of Variation	Average	F- value
WATER ANALYSIS			
pH			
1	Ayiramthengu 1	7.470	9.762*
2	Kadalundi 2	7.749	
3	Thekkumbad 2	7.130	
1	Pre monsoon	7.708	17.508*
2	Monsoon	6.971	
3	Post monsoon	7.671	
Turbidity			
1	Ayiramthengu 1	6.983	82.892*
2	Kadalundi 2	20.658	
3	Thekkumbad 2	4.322	
1	Pre monsoon	9.042	3.761 ^{NS}
2	Monsoon	10.222	
3	Post monsoon	12.700	
Total solids			
1	Ayiramthengu 1	23166.67	0.563 ^{NS}
2	Kadalundi 2	25933.33	
3	Thekkumbad 2	27650.00	
1	Pre monsoon	41800.00	41.447*
2	Monsoon	4066.667	
3	Post monsoon	30883.33	
Total Dissolved solids			
1	Ayiramthengu 1	22.183	1.136 ^{NS}
2	Kadalundi 2	22.983	
3	Thekkumbad 2	27.306	
1	Pre monsoon	38.800	49.409*
2	Monsoon	3.822	
3	Post monsoon	29.850	
TSS			
1	Ayiramthengu 1	983.333	0.742 ^{NS}
2	Kadalundi 2	2950.00	
3	Thekkumbad 2	744.443	
1	Pre monsoon	3000.00	0.807 ^{NS}
2	Monsoon	644.443	
3	Post monsoon	1033.333	
Salinity (ppt)			
1	Ayiramthengu 1	18.689	3.852 ^{NS}
2	Kadalundi 2	30.967	
3	Thekkumbad 2	22.045	
1	Pre monsoon	38.824	30.726*
2	Monsoon	4.022	
3	Post monsoon	28.855	
Resistivity (Ω)			

1	Ayiramthengu 1	84.723	1.124 ^{NS}
2	Kadalundi 2	86.831	
3	Thekkumbad 2	886.721	
1	Pre monsoon	20.508	1.526 ^{NS}
2	Monsoon	974.339	
3	Post monsoon	63.429	
Conductivity (mS)			
1	Ayiramthengu 1	28.497	0.333 ^{NS}
2	Kadalundi 2	31.081	
3	Thekkumbad 2	32.156	
1	Pre monsoon	49.076	47.926*
2	Monsoon	5.420	
3	Post monsoon	37.238	
Acidity			
1	Ayiramthengu 1	29.33333	4.882*
2	Kadalundi 2	28.56333	
3	Thekkumbad 2	42.53333	
1	Pre monsoon	40.33333	4.863*
2	Monsoon	24.93333	
3	Post monsoon	35.16333	
Alkalinity			
1	Ayiramthengu 1	160.4167	1.198 ^{NS}
2	Kadalundi 2	161.9167	
3	Thekkumbad 2	268.3333	
1	Pre monsoon	168.3333	0.643 ^{NS}
2	Monsoon	249.1667	
3	Post monsoon	173.1667	
Hardness			
1	Ayiramthengu 1	3282.167	0.161 ^{NS}
2	Kadalundi 2	3135.667	
3	Thekkumbad 2	3490.278	
1	Pre monsoon	6605.00	48.949*
2	Monsoon	425.444	
3	Post monsoon	2877.667	
Calcium			
1	Ayiramthengu 1	289.195	0.273 ^{NS}
2	Kadalundi 2	289.214	
3	Thekkumbad 2	337.224	
1	Pre monsoon	488.602	17.446*
2	Monsoon	59.106	
3	Post monsoon	367.925	
Magnesium			
1	Ayiramthengu 1	623.312	0.758 ^{NS}
2	Kadalundi 2	712.155	
3	Thekkumbad 2	644.789	
1	Pre monsoon	1311.073	137.250*
2	Monsoon	67.674	
3	Post monsoon	601.509	

Chloride (Mg/l)			
1	Ayiramthengu 1	12266.43	0.448 NS
2	Kadalundi 2	14068.85	
3	Thekkumbad 2	14069.04	
1	Pre monsoon	22627.31	41.776*
2	Monsoon	2709.636	
3	Post monsoon	15067.38	
Sulphate (Mg/l)			
1	Ayiramthengu 1	51.167	0.458 NS
2	Kadalundi 2	54.750	
3	Thekkumbad 2	48.472	
1	Pre monsoon	85.667	52.520*
2	Monsoon	18.264	
3	Post monsoon	50.458	
Sodium (ppt)			
1	Ayiramthengu 1	13.288	1.198 NS
2	Kadalundi 2	15.523	
3	Thekkumbad 2	17.034	
1	Pre monsoon	24.867	47.262*
2	Monsoon	2.052	
3	Post monsoon	18.926	
Nitrogen (mg/l)			
1	Ayiramthengu 1	61.333	2.862 NS
2	Kadalundi 2	48.583	
3	Thekkumbad 2	53.917	
1	Pre monsoon	43.417	71.304*
2	Monsoon	29.750	
3	Post monsoon	90.667	
Phosphorous (mg/l)			
1	Ayiramthengu 1	26.410	0.246 NS
2	Kadalundi 2	42.093	
3	Thekkumbad 2	46.527	
1	Pre monsoon	62.533	1.583 NS
2	Monsoon	42.987	
3	Post monsoon	9.510	
Potassium (mg/l)			
1	Ayiramthengu 1	312.083	0.670 NS
2	Kadalundi 2	401.667	
3	Thekkumbad 2	230.833	
1	Pre monsoon	320.833	0.017 NS
2	Monsoon	299.167	
3	Post monsoon	324.583	
SEDIMENT ANALYSIS			
pH			
1	Ayiramthengu 1	6.849	4.243 NS
2	Kadalundi 2	7.523	
3	Thekkumbad 2	6.849	
1	Pre monsoon	7.091	3.652 NS
2	Monsoon	6.704	

3	Post monsoon	7.425	
Moisture %			
1	Ayiramthengu 1	7.117	7.290*
2	Kadalundi 2	9.850	
3	Thekkumbad 2	11.530	
1	Pre monsoon	8.716	3.270 NS
2	Monsoon	11.219	
3	Post monsoon	8.562	
Sand %			
1	Ayiramthengu 1	86.075	0.511 NS
2	Kadalundi 2	82.025	
3	Thekkumbad 2	86.84167	
1	Pre monsoon	82.65	0.553 NS
2	Monsoon	84.36667	
3	Post monsoon	87.925	
Silt%			
1	Ayiramthengu 1	0.408	0.867 NS
2	Kadalundi 2	0.333	
3	Thekkumbad 2	0.433	
1	Pre monsoon	0.208	17.867*
2	Monsoon	0.658	
3	Post monsoon	0.308	
Clay %			
1	Ayiramthengu 1	13.517	0.536 NS
2	Kadalundi 2	17.642	
3	Thekkumbad 2	12.725	
1	Pre monsoon	17.142	0.562 NS
2	Monsoon	14.975	
3	Post monsoon	11.7667	
Organic carbon(g/kg)			
1	Ayiramthengu 1	21.833	0.107 NS
2	Kadalundi 2	20.283	
3	Thekkumbad 2	26.650	
1	Pre monsoon	31.150	0.661 NS
2	Monsoon	14.667	
3	Post monsoon	22.950	
Nitrogen(mg/kg)			
1	Ayiramthengu 1	816.667	16.894*
2	Kadalundi 2	1545.833	
3	Thekkumbad 2	1499.167	
1	Pre monsoon	1341.667	2.741 NS
2	Monsoon	1417.500	
3	Post monsoon	1102.500	
Phosphorous(mg/kg)			
1	Ayiramthengu 1	11.50	28.344*
2	Kadalundi 2	58.033	
3	Thekkumbad 2	24.333	
1	Pre monsoon	36.10	1.928 NS
2	Monsoon	33.567	

3	Post monsoon	24.20	
Potassium(mg/kg)			
1	Ayiramthengu 1	48.392	1.130 ^{NS}
2	Kadalundi 2	73.583	
3	Thekkumbad 2	69.233	
1	Pre monsoon	89.083	3.994 ^{NS}
2	Monsoon	38.442	
3	Post monsoon	63.683	
Sodium (ppt)			
1	Ayiramthengu 1	0.343	3.397 ^{NS}
2	Kadalundi 2	0.490	
3	Thekkumbad 2	0.677	
1	Pre monsoon	0.736	10.011*
2	Monsoon	0.182	
3	Post monsoon	0.591	

***: Significant at 5% level; NS: not significant (critical value of F at 5% level for 3 locations x 3 seasons = 6.944).**

Table 2.22. Comparative study of locations and seasons of *Excoecaria agallocha* with respect to water and sediment quality

Sl No	Source of Variation	Average	F- value
WATER ANALYSIS			
pH			
1	Ayiramthengu 2	7.389	2.436 ^{NS}
2	Kumbalam 2	6.910	
3	Thekkumbad 3	6.759	
1	Pre monsoon	7.272	5.238 ^{NS}
2	Monsoon	6.463	
3	Post monsoon	7.324	
Turbidity			
1	Ayiramthengu 2	7.817	1.110 ^{NS}
2	Kumbalam 2	9.542	
3	Thekkumbad 3	5.067	
1	Pre monsoon	4.250	2.704 ^{NS}
2	Monsoon	6.942	
3	Post monsoon	11.233	
Total solids			
1	Ayiramthengu 2	23500	3.789 ^{NS}
2	Kumbalam 2	10433.33	
3	Thekkumbad 3	24577.78	
1	Pre monsoon	33333.33	15.390 *
2	Monsoon	2177.777	
3	Post monsoon	23000.0	

Total Dissolved solids			
1	Ayiramthengu 2	22.7	4.121 NS
2	Kumbalam 2	9.867	
3	Thekkumbad 3	22.823	
1	Pre monsoon	31.467	16.822*
2	Monsoon	1.989	
3	Post monsoon	21.933	
TSS			
1	Ayiramthengu 2	800.00	2.080 NS
2	Kumbalam 2	566.667	
3	Thekkumbad 3	1755.556	
1	Pre monsoon	1866.667	3.691 NS
2	Monsoon	188.889	
3	Post monsoon	1066.667	
Salinity (ppt)			
1	Ayiramthengu 2	19.068	3.643 NS
2	Kumbalam 2	8.529	
3	Thekkumbad 3	20.110	
1	Pre monsoon	27.339	14.967*
2	Monsoon	1.786	
3	Post monsoon	18.581	
Resistivity (Ω)			
1	Ayiramthengu 2	66.07	1.083 NS
2	Kumbalam 2	284.721	
3	Thekkumbad 3	2292.247	
1	Pre monsoon	29.230	1.387 NS
2	Monsoon	2483.248	
3	Post monsoon	130.559	
Conductivity (mS)			
1	Ayiramthengu 2	29.025	3.690 NS
2	Kumbalam 2	13.659	
3	Thekkumbad 3	29.595	
1	Pre monsoon	40.823	16.621*
2	Monsoon	3.148	
3	Post monsoon	28.309	
Acidity			
1	Ayiramthengu 2	34.650	2.585 NS
2	Kumbalam 2	27.133	
3	Thekkumbad 3	39.783	
1	Pre monsoon	40.883	4.496 NS
2	Monsoon	24.567	
3	Post monsoon	36.117	
Alkalinity			
1	Ayiramthengu 2	172.083	6.247 NS
2	Kumbalam 2	122.083	
3	Thekkumbad 3	154.583	
1	Pre monsoon	177.50	5.543 NS
2	Monsoon	123.75	
3	Post monsoon	147.50	

Hardness			
1	Ayiramthengu 2	3279.667	2.555 NS
2	Kumbalam 2	1736.917	
3	Thekkumbad 3	3607.889	
1	Pre monsoon	5660.00	18.118*
2	Monsoon	359.472	
3	Post monsoon	2605.00	
Calcium			
1	Ayiramthengu 2	273.321	2.444 NS
2	Kumbalam 2	130.838	
3	Thekkumbad 3	297.27	
1	Pre monsoon	407.847	9.690*
2	Monsoon	49.925	
3	Post monsoon	243.657	
Magnesium			
1	Ayiramthengu 2	632.381	2.529 NS
2	Kumbalam 2	343.3477	
3	Thekkumbad 3	697.6966	
1	Pre monsoon	1130.059	20.736*
2	Monsoon	57.2249	
3	Post monsoon	486.141	
Chloride (Mg/l)			
1	Ayiramthengu 2	13107.78	2.646 NS
2	Kumbalam 2	7669.775	
3	Thekkumbad 3	14190.43	
1	Pre monsoon	19465.83	17.072*
2	Monsoon	2005.053	
3	Post monsoon	13497.1	
Sulphate (Mg/l)			
1	Ayiramthengu 2	52.41667	3.375 NS
2	Kumbalam 2	35.27083	
3	Thekkumbad 3	46.08333	
1	Pre monsoon	78.125	50.045*
2	Monsoon	11.35417	
3	Post monsoon	44.29167	
Sodium (ppt)			
1	Ayiramthengu 2	14.303	3.429 NS
2	Kumbalam 2	8.447	
3	Thekkumbad 3	15.107	
1	Pre monsoon	21.629	27.938*
2	Monsoon	1.273	
3	Post monsoon	14.954	
Nitrogen (mg/l)			
1	Ayiramthengu 2	69.75	1.028 NS
2	Kumbalam 2	64.583	
3	Thekkumbad 3	58.917	
1	Pre monsoon	41.75	15.457*
2	Monsoon	68.25	
3	Post monsoon	83.25	

Phosphorous (mg/l)			
1	Ayiramthengu 2	18.242	3.038 ^{NS}
2	Kumbalam 2	20.233	
3	Thekkumbad 3	48.486	
1	Pre monsoon	44.200	2.843 ^{NS}
2	Monsoon	31.086	
3	Post monsoon	11.675	
Potassium (mg/l)			
1	Ayiramthengu 2	387.083	2.385 ^{NS}
2	Kumbalam 2	349.167	
3	Thekkumbad 3	154.167	
1	Pre monsoon	362.500	0.619 ^{NS}
2	Monsoon	292.500	
3	Post monsoon	235.417	
SEDIMENT ANALYSIS			
pH			
1	Ayiramthengu 2	7.247	1.901 ^{NS}
2	Kumbalam 2	7.153	
3	Thekkumbad 3	6.639	
1	Pre monsoon	7.590	6.712 ^{NS}
2	Monsoon	6.366	
3	Post monsoon	7.082	
Moisture %			
1	Ayiramthengu 2	8.888	1.577 ^{NS}
2	Kumbalam 2	11.117	
3	Thekkumbad 3	11.518	
1	Pre monsoon	8.958	1.414 ^{NS}
2	Monsoon	11.304	
3	Post monsoon	11.259	
Sand %			
1	Ayiramthengu 2	90.358	2.578 ^{NS}
2	Kumbalam 2	83.300	
3	Thekkumbad 3	86.175	
1	Pre monsoon	90.492	3.298 ^{NS}
2	Monsoon	86.867	
3	Post monsoon	82.475	
Silt%			
1	Ayiramthengu 2	0.575	0.858 ^{NS}
2	Kumbalam 2	0.383	
3	Thekkumbad 3	0.983	
1	Pre monsoon	0.175	1.619 ^{NS}
2	Monsoon	0.983	
3	Post monsoon	0.783	
Clay %			
1	Ayiramthengu 2	9.067	2.693 ^{NS}
2	Kumbalam 2	16.317	
3	Thekkumbad 3	12.842	
1	Pre monsoon	9.333	2.864 ^{NS}
2	Monsoon	12.150	

3	Post monsoon	16.742	
Organic carbon(g/kg)			
1	Ayiramthengu 2	35.108	0.580 NS
2	Kumbalam 2	17.500	
3	Thekkumbad 3	29.242	
1	Pre monsoon	21.283	2.745 NS
2	Monsoon	49.083	
3	Post monsoon	11.483	
Nitrogen(mg/kg)			
1	Ayiramthengu 2	788.064	3.724 NS
2	Kumbalam 2	1517.740	
3	Thekkumbad 3	1628.700	
1	Pre monsoon	1021.563	1.144 NS
2	Monsoon	1424.391	
3	Post monsoon	1488.550	
Phosphorous(mg/kg)			
1	Ayiramthengu 2	15.392	13.315*
2	Kumbalam 2	43.117	
3	Thekkumbad 3	23.625	
1	Pre monsoon	22.550	1.454 NS
2	Monsoon	27.633	
3	Post monsoon	31.95	
Potassium(mg/kg)			
1	Ayiramthengu 2	41.508	3.212 NS
2	Kumbalam 2	35.158	
3	Thekkumbad 3	56.792	
1	Pre monsoon	46.417	0.190 NS
2	Monsoon	41.4	
3	Post monsoon	45.642	
Sodium (ppt)			
1	Ayiramthengu 2	0.316	0.815 NS
2	Kumbalam 2	0.341	
3	Thekkumbad 3	0.441	
1	Pre monsoon	0.458	5.007 NS
2	Monsoon	0.178	
3	Post monsoon	0.463	

***: Significant at 5% level; NS: not significant (critical value of F at 5% level for 3 locations x 3 seasons = 6.944).**

Table 2.23. Comparative study of locations and seasons of *Rhizophora mucronata* with respect to water and sediment quality

Sl No	Source of Variation	Average	F- value
WATER ANALYSIS			
pH			
1	Ayiramthengu 3	7.383	0.480^{NS}
2	Kumbalam 3	6.995	
3	Thekkumbad 4	7.044	
1	Pre monsoon	7.481	3.835^{NS}
2	Monsoon	6.450	
3	Post monsoon	7.491	
Turbidity			
1	Ayiramthengu 3	9.683	9.634^{*}
2	Kumbalam 3	7.417	
3	Thekkumbad 4	21.119	
1	Pre monsoon	9.986	1.043^{NS}
2	Monsoon	13.725	
3	Post monsoon	14.508	
Total solids			
1	Ayiramthengu 3	23533.33	9.182^{*}
2	Kumbalam 3	12050	
3	Thekkumbad 4	28177.78	
1	Pre monsoon	32394.44	31.161^{*}
2	Monsoon	3816.667	
3	Post monsoon	27550	
Total Dissolved solids			
1	Ayiramthengu 3	22.567	9.745^{*}
2	Kumbalam 3	11.367	
3	Thekkumbad 4	26.689	
1	Pre monsoon	31.456	33.863^{*}
2	Monsoon	3.467	
3	Post monsoon	25.700	
TSS			
1	Ayiramthengu 3	966.6667	0.468^{NS}
2	Kumbalam 3	683.333	
3	Thekkumbad 4	1488.889	
1	Pre monsoon	938.889	1.601^{NS}
2	Monsoon	350.00	
3	Post monsoon	1850.00	
Salinity (ppt)			
1	Ayiramthengu 3	18.92767	10.719^{*}
2	Kumbalam 3	9.819667	
3	Thekkumbad 4	22.468	
1	Pre monsoon	27.026	38.021^{*}
2	Monsoon	3.336	
3	Post monsoon	20.85333	

Resistivity (Ω)			
1	Ayiramthengu 3	75.048	1.325 NS
2	Kumbalam 3	499.886	
3	Thekkumbad 4	162.228	
1	Pre monsoon	30.616	3.272 NS
2	Monsoon	652.695	
3	Post monsoon	53.851	
Conductivity (mS)			
1	Ayiramthengu 3	28.831	12.183*
2	Kumbalam 3	15.570	
3	Thekkumbad 4	33.414	
1	Pre monsoon	40.357	46.316*
2	Monsoon	5.669	
3	Post monsoon	31.789	
Acidity			
1	Ayiramthengu 3	34.833	12.955*
2	Kumbalam 3	23.467	
3	Thekkumbad 4	33.550	
1	Pre monsoon	35.933	26.438*
2	Monsoon	20.350	
3	Post monsoon	35.567	
Alkalinity			
1	Ayiramthengu 3	171.667	2.190 NS
2	Kumbalam 3	112.083	
3	Thekkumbad 4	145.833	
1	Pre monsoon	161.667	0.825 NS
2	Monsoon	125.00	
3	Post monsoon	142.917	
Hardness			
1	Ayiramthengu 3	3273.333	6.193 NS
2	Kumbalam 3	1852.500	
3	Thekkumbad 4	3968.500	
1	Pre monsoon	5635.000	33.307*
2	Monsoon	647.167	
3	Post monsoon	2812.167	
Calcium			
1	Ayiramthengu 3	270.976	10.108*
2	Kumbalam 3	144.121	
3	Thekkumbad 4	297.433	
1	Pre monsoon	379.141	35.872*
2	Monsoon	72.937	
3	Post monsoon	260.453	
Magnesium			
1	Ayiramthengu 3	632.231	5.418 NS
2	Kumbalam 3	363.414	
3	Thekkumbad 4	785.412	
1	Pre monsoon	1141.443	31.780*
2	Monsoon	113.241	
3	Post monsoon	526.373	

Chloride (Mg/l)			
1	Ayiramthengu 3	13566.92	9.641*
2	Kumbalam 3	7931.717	
3	Thekkumbad 4	16134.75	
1	Pre monsoon	19702.33	39.028*
2	Monsoon	3234.05	
3	Post monsoon	14697.00	
Sulphate (Mg/l)			
1	Ayiramthengu 3	51.208	2.121 NS
2	Kumbalam 3	40.292	
3	Thekkumbad 4	51.222	
1	Pre monsoon	80.056	55.138*
2	Monsoon	15.750	
3	Post monsoon	46.917	
Sodium (ppt)			
1	Ayiramthengu 3	13.357	6.539 NS
2	Kumbalam 3	7.718	
3	Thekkumbad 4	16.129	
1	Pre monsoon	19.681	29.889*
2	Monsoon	2.110	
3	Post monsoon	15.412	
Nitrogen (mg/l)			
1	Ayiramthengu 3	56.417	4.369 NS
2	Kumbalam 3	58.917	
3	Thekkumbad 4	72.889	
1	Pre monsoon	44.722	17.198*
2	Monsoon	63.583	
3	Post monsoon	79.917	
Phosphorous (mg/l)			
1	Ayiramthengu 3	34.795	0.494 NS
2	Kumbalam 3	38.685	
3	Thekkumbad 4	43.14	
1	Pre monsoon	75.183	30.616*
2	Monsoon	30.27	
3	Post monsoon	11.167	
Potassium (mg/l)			
1	Ayiramthengu 3	376.25	0.297 NS
2	Kumbalam 3	317.083	
3	Thekkumbad 4	317.083	
1	Pre monsoon	325.00	0.827 NS
2	Monsoon	398.75	
3	Post monsoon	286.667	
SEDIMENT ANALYSIS			
pH			
1	Ayiramthengu 3	7.510	13.740*
2	Kumbalam 3	6.878	
3	Thekkumbad 4	6.430	
1	Pre monsoon	7.183	2.174 NS
2	Monsoon	6.770	

3	Post monsoon	6.866	
Moisture %			
1	Ayiramthengu 3	7.585	3.8681^{*}
2	Kumbalam 3	13.647	
3	Thekkumbad 4	9.953	
1	Pre monsoon	11.899	0.944^{NS}
2	Monsoon	10.405	
3	Post monsoon	8.881	
Sand %			
1	Ayiramthengu 3	90.475	23.013^{*}
2	Kumbalam 3	74.717	
3	Thekkumbad 4	52.200	
1	Pre monsoon	76.108	1.533^{NS}
2	Monsoon	66.808	
3	Post monsoon	74.475	
Silt%			
1	Ayiramthengu 3	0.233	0.556^{NS}
2	Kumbalam 3	0.275	
3	Thekkumbad 4	0.433	
1	Pre monsoon	0.208	0.837^{NS}
2	Monsoon	0.458	
3	Post monsoon	0.275	
Clay %			
1	Ayiramthengu 3	9.292	23.069^{*}
2	Kumbalam 3	25.008	
3	Thekkumbad 4	47.367	
1	Pre monsoon	23.683	1.474^{NS}
2	Monsoon	32.733	
3	Post monsoon	25.250	
Organic carbon(g/kg)			
1	Ayiramthengu 3	23.708	0.0275^{NS}
2	Kumbalam 3	23.025	
3	Thekkumbad 4	21.375	
1	Pre monsoon	29.692	0.791^{NS}
2	Monsoon	21.375	
3	Post monsoon	17.042	
Nitrogen(mg/kg)			
1	Ayiramthengu 3	23.708	0.028^{NS}
2	Kumbalam 3	23.025	
3	Thekkumbad 4	21.375	
1	Pre monsoon	29.692	0.791^{NS}
2	Monsoon	21.375	
3	Post monsoon	17.042	
Phosphorous(mg/kg)			
1	Ayiramthengu 3	21.283	51.151^{*}
2	Kumbalam 3	52.400	
3	Thekkumbad 4	57.500	
1	Pre monsoon	45.583	0.486^{NS}

2	Monsoon	41.767	
3	Post monsoon	43.833	
Potassium(mg/kg)			
1	Ayiramthengu 3	47.467	4.133 NS
2	Kumbalam 3	65.733	
3	Thekkumbad 4	258.917	
1	Pre monsoon	106.250	1.251 NS
2	Monsoon	70.342	
3	Post monsoon	195.525	
Sodium (ppt)			
1	Ayiramthengu 3	0.319	2.114 NS
2	Kumbalam 3	0.287	
3	Thekkumbad 4	0.551	
1	Pre monsoon	0.482	4.304 NS
2	Monsoon	0.150	
3	Post monsoon	0.526	

***: Significant at 5% level; NS: not significant (critical value of F at 5% level for 3 locations x 3 seasons = 6.944).**

Table 2.24. Comparative study of locations and seasons of *Sonneratia alba* with respect to water and sediment quality

Sl No	Source of Variation	Average	F- value
WATER ANALYSIS			
pH			
1	Kadalundi 3	7.988	9.455*
2	Kadalundi 4	7.9548	
3	Thekkumbad 5	6.961	
1	Pre monsoon	7.942	3.808NS
2	Monsoon	7.222	
3	Post monsoon	7.738	
Turbidity			
1	Kadalundi 3	15.6	0.194 NS
2	Kadalundi 4	14.275	
3	Thekkumbad 5	11.675	
1	Pre monsoon	12.492	0.070 NS
2	Monsoon	14.325	
3	Post monsoon	14.733	
Total solids			
1	Kadalundi 3	25966.67	0.031 NS
2	Kadalundi 4	25916.67	
3	Thekkumbad 5	26538.89	
1	Pre monsoon	43216.67	98.449*
2	Monsoon	4922.223	

3	Post monsoon	30283.33	
Total Dissolved solids			
1	Kadalundi 3	25.283	0.014 NS
2	Kadalundi 4	25.033	
3	Thekkumbad 5	25.461	
1	Pre monsoon	41.850	110.679*
2	Monsoon	4.378	
3	Post monsoon	29.550	
TSS			
1	Kadalundi 3	683.333	0.385 NS
2	Kadalundi 4	883.333	
3	Thekkumbad 5	1077.778	
1	Pre monsoon	1366.667	1.834 NS
2	Monsoon	544.444	
3	Post monsoon	733.333	
Salinity (ppt)			
1	Kadalundi 3	20.789	0.179 NS
2	Kadalundi 4	21.617	
3	Thekkumbad 5	22.583	
1	Pre monsoon	35.254	58.252*
2	Monsoon	3.758	
3	Post monsoon	25.977	
Resistivity (Ω)			
1	Kadalundi 3	260.369	0.916 NS
2	Kadalundi 4	134.414	
3	Thekkumbad 5	220.670	
1	Pre monsoon	18.970	21.511*
2	Monsoon	565.482	
3	Post monsoon	31.000	
Conductivity (mS)			
1	Kadalundi 3	31.065	0.130 NS
2	Kadalundi 4	32.391	
3	Thekkumbad 5	33.348	
1	Pre monsoon	51.546	53.884*
2	Monsoon	6.381	
3	Post monsoon	38.876	
Acidity			
1	Kadalundi 3	29.443	6.422 NS
2	Kadalundi 4	24.090	
3	Thekkumbad 5	45.222	
1	Pre monsoon	42.533	9.231*
2	Monsoon	17.906	
3	Post monsoon	38.317	
Alkalinity			
1	Kadalundi 3	171.250	0.049 NS
2	Kadalundi 4	171.667	
3	Thekkumbad 5	167.222	
1	Pre monsoon	200.833	18.416*
2	Monsoon	115.139	

3	Post monsoon	194.167	
Hardness			
1	Kadalundi 3	3679.917	0.021 NS
2	Kadalundi 4	3675.250	
3	Thekkumbad 5	3724.556	
1	Pre monsoon	7280.00	336.792*
2	Monsoon	375.2223	
3	Post monsoon	3424.50	
Calcium			
1	Kadalundi 3	290.926	0.158 NS
2	Kadalundi 4	280.283	
3	Thekkumbad 5	277.627	
1	Pre monsoon	483.942	153.375*
2	Monsoon	49.564	
3	Post monsoon	315.330	
Magnesium			
1	Kadalundi 3	719.101	0.053 NS
2	Kadalundi 4	724.435	
3	Thekkumbad 5	738.053	
1	Pre monsoon	1478.250	282.331*
2	Monsoon	61.243	
3	Post monsoon	642.097	
Chloride (Mg/l)			
1	Kadalundi 3	16385.62	0.474 NS
2	Kadalundi 4	15460.25	
3	Thekkumbad 5	15572.27	
1	Pre monsoon	25169.50	255.366*
2	Monsoon	2653.822	
3	Post monsoon	19594.82	
Sulphate (Mg/l)			
1	Kadalundi 3	55.125	0.733 NS
2	Kadalundi 4	53.083	
3	Thekkumbad 5	47.014	
1	Pre monsoon	84.750	44.391*
2	Monsoon	19.097	
3	Post monsoon	51.375	
Sodium (ppt)			
1	Kadalundi 3	14.924	0.638 NS
2	Kadalundi 4	14.999	
3	Thekkumbad 5	18.297	
1	Pre monsoon	26.200	29.220*
2	Monsoon	1.361	
3	Post monsoon	20.659	
Nitrogen (mg/l)			
1	Kadalundi 3	98.917	1.253 NS
2	Kadalundi 4	56.00	
3	Thekkumbad 5	56.167	
1	Pre monsoon	43.167	1.364 NS
2	Monsoon	94.500	

3	Post monsoon	73.417	
Phosphorous (mg/l)			
1	Kadalundi 3	33.083	0.774 NS
2	Kadalundi 4	39.768	
3	Thekkumbad 5	31.474	
1	Pre monsoon	57.020	17.476*
2	Monsoon	31.764	
3	Post monsoon	15.542	
Potassium (mg/l)			
1	Kadalundi 3	350.833	0.146 NS
2	Kadalundi 4	346.250	
3	Thekkumbad 5	268.611	
1	Pre monsoon	275.00	0.130 NS
2	Monsoon	329.861	
3	Post monsoon	360.833	
SEDIMENT ANALYSIS			
pH			
1	Kadalundi 3	7.955	23.787*
2	Kadalundi 4	8.023	
3	Thekkumbad 5	6.708	
1	Pre monsoon	7.862	10.983*
2	Monsoon	6.981	
3	Post monsoon	7.843	
Moisture %			
1	Kadalundi 3	10.467	0.599 NS
2	Kadalundi 4	9.382	
3	Thekkumbad 5	10.027	
1	Pre monsoon	9.429	0.961 NS
2	Monsoon	10.740	
3	Post monsoon	9.706	
Sand %			
1	Kadalundi 3	86.958	4.609 NS
2	Kadalundi 4	84.100	
3	Thekkumbad 5	75.375	
1	Pre monsoon	82.558	0.164 NS
2	Monsoon	80.858	
3	Post monsoon	83.017	
Silt%			
1	Kadalundi 3	0.433	0.320 NS
2	Kadalundi 4	0.492	
3	Thekkumbad 5	0.592	
1	Pre monsoon	0.267	5.471 NS
2	Monsoon	0.883	
3	Post monsoon	0.367	
Clay %			
1	Kadalundi 3	12.625	4.705 NS
2	Kadalundi 4	15.400	
3	Thekkumbad 5	24.025	
1	Pre monsoon	17.167	0.096 NS

2	Monsoon	18.275	
3	Post monsoon	16.608	
Organic carbon(g/kg)			
1	Kadalundi 3	20.758	0.083 NS
2	Kadalundi 4	23.292	
3	Thekkumbad 5	19.058	
1	Pre monsoon	18.933	0.730 NS
2	Monsoon	16.050	
3	Post monsoon	28.125	
Nitrogen(mg/kg)			
1	Kadalundi 3	834.763	0.699 NS
2	Kadalundi 4	788.063	
3	Thekkumbad 5	737.860	
1	Pre monsoon	551.060	21.539*
2	Monsoon	1079.937	
3	Post monsoon	729.690	
Phosphorous(mg/kg)			
1	Kadalundi 3	41.50	7.671*
2	Kadalundi 4	37.633	
3	Thekkumbad 5	29.833	
1	Pre monsoon	42.50	17.583*
2	Monsoon	40.467	
3	Post monsoon	26.00	
Potassium(mg/kg)			
1	Kadalundi 3	63.25	0.950 NS
2	Kadalundi 4	56.567	
3	Thekkumbad 5	77.483	
1	Pre monsoon	69.833	2.433 NS
2	Monsoon	47.00833	
3	Post monsoon	80.45833	
Sodium (ppt)			
1	Kadalundi 3	0.473	0.107 NS
2	Kadalundi 4	0.449	
3	Thekkumbad 5	0.502	
1	Pre monsoon	0.512	7.555*
2	Monsoon	0.237	
3	Post monsoon	0.675	

***: Significant at 5% level; NS: not significant (critical value of F at 5% level for 3 locations x 3 seasons = 6.944).**

Upon analyzing the results, in the case of *Avicennia officinalis*, the mean pH has ranged from 6.89 and 7.5 between 3 habitats. With respect to different seasons, it varied from 6.46 to 7.43. However, results of statistical analysis showed that variations in pH among sites and also between seasons were not significant. In the case of *Bruguiera cylindrica*, the mean water pH varied from 7.13 to 7.749 among sites and 6.97 to 7.67 among seasons. Upon statistical analysis, average water pH with respect to *B. cylindrica* showed significant variations both between sites and seasons. In the case of *Excoecaria agallocha* and *Rhizophora mucronata*, the mean water pH showed no significant variation between locations and seasons. However, with respect to *Sonneratia alba* the variations in mean water pH was significant among the locations and not significant between seasons.

As far as mean turbidity of water is concerned, significant variation between sampling locations and seasons were noticed in the case of *Avicennia officinalis*. On the other hand, in the case of *Excoecaria agallocha* and *Sonneratia alba*, the mean turbidity values did not show any significant variation between sites and seasons. With respect to *Bruguiera cylindrica* and *Rhizophora mucronata,* the variations in turbidity were significant between locations, but not significant among seasons.

Significant variations in the total solids (TS) and total dissolved solids (TDS) of water confining to the habitats of *Avicennia officinalis, Bruguiera cylindrica, Excoecaria agallocha* and *Sonneratia alba* were noticed among different seasons. However, the variations among sites were not statistically significant. In the case of *Rhizophora mucronata*, significant variation in mean TS and TDS were noticed both between locations and seasons. Total suspended solids (TSS) did not show any significant variation between sites and seasons with respect to all the five mangrove species.

In the case of *Rhizophora mucronata*, mean salinity and conductivity showed significant variation among different seasons and locations. With respect to all other species, the variation was significant only among seasons. The variations in mean resistivity were not significant among sites and seasons with respect to all the species except *Sonneratia alba* wherein, significant variation was noticed among seasons.

Results of the analysis of chemical attributes of water revealed that, the mean acidity with respect to *Avicennia officinalis, Bruguiera cylindrica* and *Rhizophora mucronata* was significantly varied between the three sites and the three seasons under study. In the case of *Sonneratia alba* variations in mean acidity was significant only between seasons whereas, no significant variation among sites and seasons were noticed in the case of *Excoecaria agallocha*. Significant variation in mean alkalinity between seasons has been noticed in the case of *Sonneratia alba*. However, in the case of all other species no significant variation in mean alkalinity has been noticed between different seasons and sites.

Variation in mean values of hardness, calcium, magnesium and chloride between different seasons has been noticed in the case of all mangrove species except *Rhizophora mucronata*. But the variations between different sites were not significant. In the case of *R. mucronata,* calcium and chloride showed significant variations between sites and seasons. The variations in mean sulphate concentration were not significant among locations of all the five mangrove species under study, where as significant variations were noticed between seasons. Sodium concentration with respect to 5 mangrove species showed significant variation among seasons.

In the case of *Avicennia officinalis* and *Sonneratia alba*, results of the statistical analysis revealed no significant variation in mean nitrogen concentration between locations and seasons. With respect to *Bruguiera cylindrica, Excoecaria agallocha* and *Rhizophora mucronata*, significant variation in mean nitrogen was noticed between seasons whereas, the variations between sites were not significant. Significant variation in mean phosphorous concentration has been noticed between seasons in the case of *R. mucronata* and *S. alba,* whereas the variations between sites were not significant. With respect to *A. officinalis, B. cylindrica* and *E. agallocha*, variations in mean phosphorous were not significant both among different sites and seasons. In the case of all five species of mangroves, no significant variation in mean potassium level has been noticed among different sites and seasons.

Results of statistical analysis of sediment quality attributes revealed no significant variation in mean pH between different season and sites in the case *Avicennia officinalis, Bruguiera cylindrica* and *Excoecaria agallocha*. With respect to *Sonneratia alba*, significant variation in pH among sites and also between seasons were noticed. Variations in sediment pH with respect to *Rhizophora mucronata* were significant between sites and not significant among seasons.

The mean moisture percentage did not show any significant variation among sites and seasons in the case of *Avicennia officinalis, Excoecaria agallocha* and *Sonneratia alba* whereas, significant variations between sites were noticed in the case of *Bruguiera cylindrica* and *Rhizophora mucronata*. The textural percentage (sand, silt and clay) did not show any significant variations among different locations and seasons with respect to *A. officinalis, E. agallocha* and *S. alba.* Significant variations in mean silt % between seasons were noticed in the case of *B. cylindrica.* In the case of *R. mucronata*, mean sand and clay % showed significant variation among different locations.

As far as the mean sediment organic carbon with respect to all the five species concerned, no significant variations have been noticed among different sites and seasons under study. The variation in the average nitrogen content was not significant among different sites and seasons in the case of *Avicennia officinalis, Excoecaria agallocha* and *Rhizophora mucronata.* Significant variations in mean nitrogen between the locations in the case of *Bruguiera cylindrica* and between seasons in the case of *Sonneratia alba* have also been noticed.

Significant variations in mean phosphorous concentration between locations have been noticed in the case of all species, except *S. alba* whereas, the variations between seasons were not significant. With respect to *S. alba*, variations in mean phosphorous concentration were significant between different sites and seasons. In the case of all the five mangrove species, mean potassium level did not show any significant variations between different locations and seasons.

With respect to *Bruguiera cylindrica* and *Sonneratia alba*, significant variations in mean sodium level have been noticed between different seasons. No significant variations in sodium among different sites and seasons have been noticed in the case of *Avicennia officinalis, Excoecaria agallocha and Rhizophora mucronata*.

The study as a whole revealed that, in the case of *Avicennia officinalis* no significant variation in water quality attributes like pH, total suspended solids, resistivity, alkalinity, nitrogen, phosphorous and potassium and also with respect to sedimentological attributes like pH, moisture %, organic carbon, nitrogen, potassium, sodium, sand, silt and clay % between different sites and seasons have been noticed (Figure 2.2). The habitats of *Bruguiera cylindrica* is unswerving in their water quality attributes such as resistivity, alkalinity, phosphorous and potassium; and also sedimentological characteristics like sediment pH, sand %, clay %, organic carbon and potassium (Figure 2.3).

The heterogeneous habitats of the mangrove species *Excoecaria agallocha* showed stability in their water quality attributes such as pH, turbidity, total suspended solids, resistivity, acidity, alkalinity, phosphorous and potassium and also with respect to sedimentological characteristics such as pH, moisture %, sand, silt, clay %, organic carbon, nitrogen, potassium and sodium (Figure 2.4). Likewise, the habitats of *Rhizophora mucronata* showed steadiness with respect to water quality parameters such as pH, TSS, resistivity, alkalinity and potassium and also in sedimentological characteristics such as silt %, organic carbon, nitrogen, potassium and sodium without any significant variation (Figure 2.5). The habitats of *Sonneratia alba* under study maintained uniformity with respect water quality attributes such as turbidity, TSS, nitrogen, potassium and sedimentological attributes such as moisture %, sand, silt, clay %, organic carbon and potassium (Figure 2.6).

From the above observations, it can be concluded that all the five mangrove species under study; *Avicennia officinalis, Bruguiera cylindrica, Excoecaria agallocha, Rhizophora mucronata* and *Sonneratia alba* have their own growth sustaining conditions along different habitats in Kerala. The physico-chemical attributes of both water and sediment that showed no significant variations between sites and seasons can be confirmed as the growth promoting factors for each mangrove species under study. The ranges with respect to all such attributes have been confirmed as ideal for the sustenance of each species and confirmed as their **tolerance range**. Even though each species has its own specific growth requirements, existence along habitats with varied water and sediment quality attributes highlights their ability to survive in such conditions. These varied ranges can be confirmed as the **augmented range** acquired by each species towards their growth and survival. Thus, the study as a whole reports the capability of all the five species of mangroves to cope up with different hydrogeochemical and sedimentological conditions in terms of tolerance range or augmented range, as stated in Table 2.19.

Summary and Conclusion

Afforestation of mangroves seems to be a promising solution for the restoration of lost ecosystems. Successful restoration/afforestation practices of mangroves require reliable information on their growth sustaining conditions. The present study has been carried out to evaluate the environmental factors (water, soil / sediment and climate) determining the growth of selected mangrove species (*Avicennia officinalis*, *Bruguiera cylindrica*, *Excoecaria agallocha*, *Rhizophora mucronata* and *Sonneratia alba*) along heterogeneous habitats of Kerala. The natural habitats selected for mangroves include Kumbalam 1 of Ernakulam district (9^{o}54'15.68"N: 76^{o}18'46.59"E), Kadalundi 1 of Malappuram district (11^{o}07'42.49"N: 75^{o}49'53.31"E) and Thekkumbad 1 of Kannur district (11^{o}58'00.10"N: 75^{o}17'49.27"E) (*Avicennia officinalis*), Ayiramthengu 1 of Kollam district (9^{0}07'28.93"N: 76^{0}28'39.18"E), Kadalundi 2 of Malappuram district (11^{o}07'53.40"N: 75^{o}49'45.79"E) and Thekkumbad 2 of Kannur district (11^{o}58'00.12"N: 75^{o}17'50.14"E), (*Bruguiera cylindrica),* Ayiramthengu 2 of Kollam district (9^{o}07'28.71"N: 76^{o}28'38.89"E), Kumbalam 2 of Ernakulam district (9^{o}54'15.02"N: 76^{o}18'45.49"E) and Thekkumbad 3 of Kannur district (11^{o}58'00.71"N: 75^{o}17'49.79"E) *(Excoecaria agallocha),* Ayiramthengu 3 of Kollam district (9^{0}07'28.74"N: 76^{0}28'39.44"E), Kumbalam 3 of Ernakulam district (9^{0}54'22.16"N: 76^{0}18'42.21"E) and Thekkumbad 4 of Kannur district (11^{0}58'02.87"N: 75^{0}17'45.38"E). (*Rhizophora mucronata)* and Kadalundi 3 (11^{o}07'35.14"N: 75^{o}49'51.77"E) and Kadalundi 4 of Malappuram district (11^{o}07'35.42"N: 75^{o}49'50.72"E) and Thekkumbad 5 (11^{o}58'04.32"N: 75^{o}17'45.38"E) of Kannur district (*Sonneratia alba).*

Both surface water and sediment/soil samples were collected on a monthly basis from all the locations under study for a period of one year. The collected samples were brought to laboratory and analyzed for various quality attributes following standard procedures. Characterization of sediment samples using textural triangle have also been worked out. Data on various climatological attributes with respect to all the sites and period of study were procured from India Meteorological Department, Government of India.

Results of water, sediment and climatological attributes revealed that all the parameters were fluctuating between various sites and seasons. The mean annual range of all the parameters was calculated with respect to the study sites of different mangrove species. The mean values of both water and sediment characteristics were further analyzed statistically to find out the variations among different sites and seasons. Two-way ANOVA has revealed the number of most vital physico chemical attributes of water and sediment, that are likely to influence the growth of each mangrove species.

The results as a whole revealed that between different sites and seasons, no significant variations have been noticed in water quality attributes like pH, total suspended solids, resistivity, alkalinity, nitrogen, phosphorous, potassium and sedimentological attributes like pH, moisture %, organic carbon, nitrogen, potassium, sodium, sand, silt and clay % of sites having *Avicennia officinalis*. The habitats of *Bruguiera cylindrica* is unswerving in their water quality attributes such as resistivity, alkalinity, phosphorous and potassium; and also sedimentological characteristics like sediment pH, sand %, clay %, organic carbon and potassium.

The heterogeneous habitats of the mangrove species *Excoecaria agallocha* showed stability in their water quality attributes such as pH, turbidity, total suspended solids, resistivity, acidity, alkalinity, phosphorous and potassium and also in sedimentological characteristics such as pH, moisture %, sand, silt, clay %, organic carbon, nitrogen, potassium and sodium. Likewise, the habitats of *Rhizophora mucronata* showed steadiness with respect to water quality parameters such as pH, TSS, resistivity, alkalinity and potassium and also in sedimentological characteristics such as silt %, organic carbon, nitrogen, potassium and sodium without any significant variation. The habitats of *Sonneratia alba* under study maintained consistency with respect water quality attributes such as turbidity, TSS, nitrogen, potassium and sedimentological attributes such as moisture %, sand, silt, clay %, organic carbon and potassium.

From the above observations, it can be concluded that all the five mangrove species have their own growth sustaining conditions along different habitats in Kerala. The physico-chemical attributes of both water and sediment that showed no significant variations between sites and seasons can be confirmed as the growth promoting factors for each mangrove species under study. The range of all such attributes has been confirmed as ideal for the sustenance of each species and confirmed it as their **tolerance range**. Even though each species has its own specific growth requirements, existence along habitats with varied water and sediment quality attributes highlights their ability to survive in such conditions. These varied ranges can be confirmed as the **augmented range** acquired by each species towards their growth and survival. Thus, the study as a whole reports the capability of all the five species of mangrove to cope up with different hydrological and sedimentological conditions in terms a tolerance range or augmented range.

Results of the textural characterization of sediments revealed the ideal sediment class on which each *mangrove* species showed lushness of growth. These include Sandy Loam (*Avicennia officinalis* and *Sonneratia alba*), Loamy Sand (*Bruguiera cylindrica* and *Excoecaria agallocha*) and Sandy Clay Loam (*Rhizophora mucronata*).

The present investigation concluded that the criteria to be followed in the afforestation of mangroves need to be (i) species specific and (ii) site specific. The study also proposed that, the ‘tolerance range’ of a species with respect to the site is a mandatory requirement towards including them in afforestation purposes whereas the ‘augmented range’ is not a natural one; it is gradually acquired after the acclimatization of the species in the new area. In conclusion, the study emphasized that all the afforestation/ restoration practices of mangroves must be either species or site specific.

CHAPTER 3
DELINEATION OF SITES IDEAL FOR MANGROVE AFFORESTATION IN THE COASTAL ENVIRONMENTS OF KERALA

Introduction

Mangrove forest along the coastal environments of tropical and subtropical countries have great significance as they function towards the sustenance of broader range of living being including human. The uncontrolled exploitation and degradation of mangroves in most of the tropical countries have called for an urgent need of implementing conservation and management strategies.

The drastic decline in global mangrove cover and the continued elimination of mangrove habitats have led many of the governmental and non-governmental organizations to formulate policies and actions (Giri et al., 2011). Protection of mangrove habitat across the world has also been achieved by establishing marine protected areas, including national parks and marine reserves. In India strategies pertaining to the conservation and reforestation of mangroves have initiated along the Central West coast. This was mainly with the intention of creating awareness among public regarding the significance of mangroves, control of intertidal mud banks, new avenues for forestry and social forestry activities, biomass increase along the estuaries to enhance biological productivity and to improve bird and animal life (Untawale, 1996). In Kerala, the most vital approach towards the conservation of mangroves relied on awareness among the public. Novel concepts like mangrove resort and conservation through eco-tourism have also been put forwarded towards the protection of mangroves (George and Fernandez, 1994). For the conservation of mangrove environments of Kerala, better co-ordination among various government agencies are also inevitable.

Silvicultural techniques like regeneration, restoration and afforestation of mangroves can very well reverse the issues of degradation. Mangrove conservation requires a collaborated research involving natural, social and inter-disciplinary approaches. In order to formulate long term conservation strategies, consideration of factors such as monitoring of growth conditions, socio-economic dependency and biodiversity are indispensable (Kiran and Ramachandra, 1999). Other aspects to be covered for proper management of mangrove ecosystems are study of geomorphology, freshwater input, toxic elements, structure and composition of mangrove ecosystem using remote sensing data, aerial photography etc.

Restoring mangroves is often recommended when the ecosystem has been modified to such an extent that it cannot regenerate naturally. Although restoration frequently emphasizes planting as the primary method, mangroves can regenerate naturally if the normal tidal hydrology is restored and the supply of seeds or propagules of mangroves from adjacent stands re-established. If hydrology is normal, but the influx of seeds or propagules is disrupted, then mangroves can be successfully established by planting. Alternatively, when the hydrology is disrupted but the availability of seeds or propagules is normal, then mangroves can be established by hydrological restoration (Kathiresan, 2011).

Planting of mangroves is largely confined to two types: i) direct planting of seeds or propagules in the muddy areas; and ii) planting of seedlings obtained from nurseries. In the first type, propagules can be used directly as long as they are plentiful. The second can be adopted for seeds that are available seasonally and in small quantities. In this type, nurseries are developed in the upper parts of intertidal areas, using polythene bags, for 6–12 months. The plants are then transplanted in the field according to their zoning patterns. Direct planting of propagules is often unsuccessful if the area is exposed, with unfavorable climatic conditions or strong waves or if propagule-eating crabs are abundant. In such areas, nursery seedlings should be used.

Mangrove ecosystems are often cited as being responsive to differences in soil salinity, frequency of tidal inundation, sedimentation, soil chemistry, freshwater influx and groundwater availability. This is said to have led to significant variations noted in mangrove community structure and function, even within small geographic ranges (Ravichandran, 2002). The restoration program should be sensibly designed in such a way that, mass afforestation of the native species and elimination of undesirable species are carried out. Restoration sometimes requires reconstruction of the physical conditions, chemical adjustment of the soil and water, biological manipulation, reintroduction of native flora and fauna, etc. (Zedler, 1996).

Different mangrove species have different requirements. Some are more tolerant to salt than others. Other factors, which affect their distribution, include wave energy, soil oxygen level, drainage and differing nutrient levels, where one species finds its preferred conditions, it tends to become dominant. This leads to zonation among mangroves. The existence of more or less distinct zones, each dominated by different mangrove species is usually evident in well-developed mangals. Mangrove zonation however, is more often manifested as a mosaic that varies with the complex of physical, chemical and biological interaction occurring in a particular area.

Species selection is critical for successful restoration of mangroves. Selection can be based on criteria such as planting purpose, adaptability, occurrence, availability of mature propagules, size of propagules, and zoning pattern of species. Mangrove species selection can be based on species that occur naturally in the locality. It is also necessary to collect data on the historical occurrence of species. Site selection for restoration should be based on criteria such as tidal amplitude, soil conditions, light conditions, sedimentation, pollution status, and weed and pest problems (Kathiresan, 1994).

Most of the mangrove restoration programs focused on the mangrove species, their regeneration potential and also on the method of afforestation. A comprehensive approach in terms of research on various aspects of mangrove eco system of Kerala should be given utmost priority for their effective conservation and restoration. Restoration in terms of afforestation requires detailed comprehension on mangroves with respect to their current status, diversity, threats and growth sustaining conditions. Even though there are a wide variety of restoration techniques, in order to fit restoration efforts with the local physical and ecological settings and selecting the right species and right locations are very important.

As physico- chemical attributes of both water and sediment are a major entity towards the growth and proliferation of mangroves, their comprehension with respect to the targeted afforestation area is very much important. Assessment of the feasibility of the area prior to planting practices will reduce the risk of adaptability of species to such habitats and thereby cut short financial mobilizations to a greater extent. In this background, the present study has been undertaken for the demarcation of ideal sites for afforestation of selected mangrove species along the inland shoreline environments of Kerala.

Review of Literature

The present study is an attempt to delineate regions falling in the coastal environments of Kerala, which are ideal for species specific introduction of mangroves. This is achieved through the standardization of growth requirements of selected mangrove species from heterogeneous coastal environments (as attempted in Chapter 2) and thereby identifying specific habitats ideal for mangrove afforestation through strategic analysis of key inputs required for mangrove establishment. Description on previous attempts in the area of mangrove restoration carried out globally and also on the prospects of other afforestation strategies carried out is summarized below.

Afforestation of mangroves on exposed mud flats, seaward of an eroding shoreline in Malaysia using the species *Avicennia officinalis* has been reported. The study concluded that factors such as strong wave actions, high soil salinity, barnacle infestation, prolonged inundation and lack of tidal flow were adversely affecting the survival and growth of mangrove plants (Chan et al., 1988). The successful afforestation along a larger area in Bangladesh employing direct planting of *Rhizophora mucronata* and *Rhizophora apiculata* has been reported (Saenger and Siddiqi, 1993). For stabilizing coastal areas, forest department of Bangladesh carried out afforestation programmes along selected coastal areas of the country. The species selected for the study were *Sonneratia apetala* and *Avicennia officinalis* and planting has been done in a total area of 320 ha. The study reported that, afforestation of both the species along these sites was highly successful and further contributed to plan large scale programs (Saenger and Siddiqi, 1993).

Afforestation using seedlings of *Avicennia marina, Rhizophora mucronata* and *Sonneratia caseolaris* along the newly formed mud flats of southern Thailand have been conducted and reported. Monthly assessment of the growth performances of all the species revealed that, both *A. marina* and *S. caseolaris* were unable to develop and died in eight months after planting. Severe infestation by barnacles and frequent immersion in seawater during high tide were the reason for seedling mortality. Among the three species, *R. mucronata* showed more resistance to these conditions (Angsupanich and Havanond, 1996). Studies on the re-plantation of mangroves in the seedling stage along the coastal environments of Thailand reported that, even though the afforestation practices conducted in a large area, the success rate of establishment was low as the species used were in the seedling stage (Platong, 1998).

Natural regeneration potential of 11 species of mangrove has been reported in Bangladesh. Among different species, the species showed higher regeneration and lushness of growth were *Sonneratia apetala,* followed by *Bruguiera sexangula*, *Avicennia officinalis, Excoecaria agallocha* and *Ceriops decandra* (Haque et al., 2000). Study conducted in Thailand reported success stories of mangrove afforestation. Here, planting has been carried out on mud flats along a larger area and majority of the species showed enhanced growth rates (Erftemeijer and Lewis, 1999). Studies on the assessment of the hydrology of natural mangrove ecosystems has been carried out in USA to implement strategies for the protection of existing mangroves and to achieve successful and cost-effective ecological restoration (Lewis, 2005).

Mangrove species prefer almost uniform environmental condition for their growth and establishment. This fact is evidenced by studies conducted along coastline of Tamil Nadu, India. The sites for afforestation have been selected after careful study on soil quality, species suitability, natural recruitment, land elevation, water sources, grazing effect and land-use. More than 10,000 mangrove seedlings have been planted. It was reported that survival rate of the propagules varied in accordance with water and soil characteristics. The study concluded that, more emphasis should be given for monitoring different locations prior to afforestation (Balaji and Gross, 2006).

Restoration of mangroves along the coastal environments of Peninsular Malaysia have been conducted and reported. Afforestation of *Rhizophora apiculata* seedlings were carried out within an already established cover of *Avicennia marina* forest. The results revealed that most of the planted seedlings died due to inadequate light and high soil salinity (Ong, 2007). With the objective of protecting the shoreline from coastal erosion, *R. apiculata* seedlings grown in PVC tubes were planted on the mud flats seaward of an existing mangrove forest of mainly *A. marina*. The result revealed that most of the seedlings had disappeared within a week. The study has concluded that, mangroves cannot survive on exposed low-elevation tidal flats (Ong, 2008).

Mangrove planting along a fishpond area in mangrove arboretum belonging to agriculture and marine services of Indonesia has been carried out and reported (Kusmana, 2010). A simple technique called, 'guludan' was applied for the afforestation practices. True mangrove seedlings of *Rhizophora mucronata* / *Avicennia marina* were used and parameters such as stem diameter and height, carbon content, growth and survival rate were assessed. The study highlighted the possibilities of using this technique along other areas wherein, already applied techniques using either large cans-filled soil or bamboo basket which were always failed for growing mangrove seedlings (Kusmana, 2010).

Studies on afforestation of mangroves and their regeneration potential along forest ranges of Bangladesh has been conducted and reported. The mangrove species used were *Sonneratia apetala, Excoecaria agallocha, Avicennia officinalis, Ceriops decandra* and *Bruguiera sexangula*. The results revealed that, the species regeneration were significantly higher for *S. apetala* followed by *E.agallocha, A. officinalis, C. decandra* and then *B. sexangula*. The study as a whole reported that in accordance with species ecology and adaptability to the sites along the coast, their afforestation will show varied growth, regeneration and density (Uddin et al., 2013).

Surveillance on water quality in pursuit of mangrove afforestation along the coastal and inland aquatic environments of Malappuram District, Kerala have been conducted and reported. Collection of water samples were carried out from 38 locations representing diverse habitats during pre-monsoon, monsoon and post-monsoon seasons. On the basis of salinity and related attributes, high salt tolerant species like *Avicennia marina*, *A. officinalis*, *Rhizophora mucronata* and *Aegiceras corniculatum* were found to be ideal for afforestation in 10 sites. Low salt tolerant species like *Sonneratia caseolaris* and *Excoecaria agallocha* were noted to be ideal for planting in 8 sites. Species like *S. alba*, which showed a tolerance limit over a wider range has been found ideal for afforestation in 14 selected sites. However medium salt tolerant species like *R. apiculata*, *Bruguiera gymnorhiza* and *B. cylindrica* were found to be unfit for afforestation in any of the sites studied. The study reported that on the basis of tolerance limit of mangrove species to salinity, 11 inland and estuarine aquatic environments of Malappuram District were ideal for afforestation during all seasons of the year (Shilna et al., 2016).

Studies have been undertaken to demarcate regions ideal for the introduction of mangrove species of *Rhizophora* and *Bruguiera* in the core and buffer areas of Kadalundi community reserve, falling in Kozhikode and Malappuram districts of Kerala, India. During pre monsoon and monsoon season, collection of sediment and water samples was carried out for analytical purposes. The results revealed that, the water samples possessed higher concentrations of salinity, chloride and hardness in pre-monsoon than monsoon season. With respect to the sediment samples, organic carbon and percentage clay content were noted to be higher in both seasons. It has also been reported that, pre monsoon season is ideal for afforestation of both *Rhizophora* and *Bruguiera* species. Based on water and sediment quality, the possibilities of afforestation along all the zones under study have also been reported (Harilal et al., 2017).

All the above studies were carried out on mangroves, either with the intension of introduction or restoration. Even though there were success stories, majority of cases reported setbacks in afforestation / restoration, which can either be due to inadequate knowledge on the physico chemical and environmental setting of the area poised for afforestation or due to lack of knowledge on the growth requirements of mangrove species selected for afforestation. As physico- chemical attributes of both water and sediment are influential on the growth and establishment of mangroves, consolidation of database on the above aspects need to be considered prior to any afforestation / restoration programme. In this context, the present study has been attempted to elucidate regions ideal for species specific mangrove afforestation in the coastal environments falling in 9 districts of Kerala through strategic analysis of the key factors (hydrogeochemical and sedimentological) responsible for the growth of mangroves in the areas proposed for afforestation. This will reduce the risk associated with direct afforestation efforts as the present practice will give prior indices regarding the feasibility of a site for afforestation with respect to a designated species.

Materials and Methods

The present investigation was an attempt to delineate sites ideal for species specific mangrove afforestation along the heterogeneous coastal environments of Kerala. The afforestation possibilities of selected mangrove species were assessed based on their range of tolerance to various hydrogeochemical and sedimentological characteristics as determined in Chapter II. Similarly, for assessing the supportive nature of habitats, the physico-chemical characteristics of both water and sediments associated with such habitats were assessed and compared with those of the tolerance range of selected mangrove species. Altogether 19 habitats falling in Trivandrum and 18 habitats each in Kollam, Alleppey, Ernakulam, Thrissur, Malappuram, Kozhikode, Kannur and Kasaragod districts of Kerala (Figure 3.1 to 3.9) were worked out. Details of districts, together with the specification of sites selected are given below:

1) Trivandrum

Trivandrum is the capital district of Kerala with a total geographic area of 2192 sq. km. Major physiographic unit comprises of midland, together with coastal low lands and high lands. The terrain is characterized by geological formations like crystalline and alluvium. The land use pattern shows both forest cover and agricultural lands. Important soil types in the district are red loam, alluvium, brown hydromorphic soil and lateritic soil. The climate experienced in the district is tropical monsoon with a normal annual rainfall of 2035mm. The mean maximum air temperature and humidity experienced in the district are 34ºC and 90% respectively (CGWB 2013).

Table 3.1. Details of study area falling in Trivandrum district

Location ID.	Location Name	Latitude	Longitude
TVM 1	Edayar	8º26'27.26"N	76º 57'9.46"E
TVM 2	Munnattumukku	8º 26'30.53"N	76º 57'13.45"E
TVM 3	Manamel	8º 25'55.38"N	76º 57'28.55"E
TVM 4	Panathura	8º 25'3.55"N	76º 57'48.37"E
TVM 5	Pachallur	8º 25'18.94"N	76º 57'36.46"E
TVM 6	Thottumukku	8º 25'30.61"N	76º 57'34.99"E
TVM 7	Vallappura	8º 24'30.28"N	76º 58'11.56"E
TVM 8	Vattappara	8º 24'20.97"N	76º 58'16.62"E
TVM 9	Madhavapuram	8º 30'49.30"N	76º 53'25.27"E
TVM 10	Kayikkara kadavu	8º 35'49.56"N	76º 49'44.05"E
TVM 11	Kundavila	8º 36'2.88"N	76º 49'28.85"E
TVM 12	MurukkumPuzha Kadavu	8º 36'34.96"N	76º 49'22.73"E
TVM 13	Kadinamkulam	8º 36'17.50"N	76º 49'13.97"E
TVM 14	Vadakkevila	8º 36'41.78"N	76º 48'55.95"E
TVM 15	Perumathura	8º 37'22.57"N	76º 48'8.94"E
TVM 16	Kottaram Thuruth	8º 37'35.69"N	76º 48'4.61"E
TVM 17	Thazhampally	8º 38'15.25"N	76º 47'3.74"E
TVM 18	Anchuthengu	8º 38'39.13"N	76º 46'44.52"E
TVM 19	Chambavu	8º 39'55.60"N	76º 45'49.27"E

2) Kollam

Kollam district has a total geographic area of 2491 sq. km with coastal plain, mid land and high land as important physiographic units. The terrain is highly complex with geological formations such as recent alluvium, sub-recent laterite, tertiary sedimentary formations, archaean crystallines and forest loam. The major soil types are laterite, brown hydromorphic, grayish onattukara and coastal riverine alluvium. The district experiences a tropical humid climate with definite southwest and northeast monsoon seasons. The normal annual rainfall available in the district is 2428mm. The annual mean maximum temperature and humidity are 36.4ºC and 89% respectively (CGWB 2013).

Table 3.2. Details of study area falling in Kollam district

Location ID.	Location Name	Latitude	Longitude
KLM 1	Kappil	8°46'28.50"N	76°40'47.24"E
KLM 2	Edava	8°47'0.50"N	76°40'20.66"E
KLM 3	Kurumandal	8°49'12.32"N	76°39'34.41"E
KLM 4	Pozhikkara	8°48'56.73"N	76°39'3.88"E
KLM 5	Mukkam	8°49'2.46"N	76°38'47.92"E
KLM 6	Kochuthoppu	8°50'23.17"N	76°37'46.31"E
KLM 7	Adhichamamthoppu	8°50'46.16"N	76°37'29.61"E
KLM 8	Sasthamthodi	8 ° 50'12.76"N	76°38'19.14"E
KLM 9	Neeravil	8 ° 55'21.63"N	76°35'17.05"E
KLM 10	MadathilKayalvaaram	8 ° 55'39.97"N	76°33'43.88"E
KLM 11	Velithuruth	8 ° 57'9.37"N	76°32'43.58"E
KLM 12	Ponmana	9°0'42.95"N	76°31'18.16"E
KLM 13	Kozhikkode	9°1'36.41"N	76°31'9.43"E
KLM 14	Kochochira	9°2'15.41"N	76°30'32.06"E
KLM 15	Cheriyazheekkal	9°3'32.35"N	76°30'0.94"E
KLM 16	Alappadu	9°3'46.57"N	76°29'49.83"E
KLM 17	Srayikkad	9°5'42.87"N	76°28'58.69"E
KLM 18	Pancharathopp	9°7'17.98"N	76°28'13.07"E

3) Alleppey

Alleppey is one among the most established coastal district of Kerala, holding a total area of 1,414 sq.km. There is no reserved forest in the district. The major physiographic units in the district are low land (coastal plain) and mid land. The land use pattern shows built up lands, agriculture lands, water bodies and waste lands of which agriculture land constitutes the major share. There are 4 distinct soil types; coastal alluvium, riverine alluvium, brown hydromorphic soil and lateritic soil. Geological formations like sub-recent laterites and tertiary sediments are distributed along the south east part of the district. The district experiences both tropical humid climate and imperious summer with intermittent seasonal rainfall. The average rainfall accounts for about 2965.4 mm. The mean annual maximum temperature and humidity experienced in the district are 30.7ºC and 87% respectively (CGWB 2013).

Table 3.3. Details of study area falling in Alleppey district

Location ID.	Location Name	Latitude	Longitude
ALP 1	Valiyazheekkal 1	9°8'21.64"N	76°27'44.51"E
ALP 2	Valiyazheekkal 2	9°8'14.5"N	76°27'45.9"E
ALP 3	Tharayilkkadav	9°9'14.82"N	76°27'20.44"E
ALP 4	Arattupuzha	9°10'13.98"N	76°27'26.56"E
ALP 5	Kandallur	9°9'53.80"N	76°27'48.76"E
ALP 6	Manivelikkadav	9°8'56.44"N	76°28'6.58"E
ALP 7	Muthukulam	9°12'7.06"N	76°26'32.30"E
ALP 8	Mahadevikaad	9°14'52.17"N	76°25'23.89"E
ALP 9	Pulikkeril	9 °16'32.46"N	76°24'17.97"E
ALP 10	Kumarakodi	9°18'2.05"N	76°23'45.86"E
ALP 11	Thottappally	9°18'41.89"N	76°23'2.21"E
ALP 12	Purakkad	9°19'19.60"N	76°23'16.82"E
ALP 13	Kannattakkadav	9°21'23.18"N	76°22'57.85"E
ALP 14	Ottamasseri	9°42'25.96"N	76°17'27.31"E
ALP 15	Arattuvazhi	9°43'39.50"N	76°17'19.41"E
ALP 16	Andakaranazhi	9°44'29.21"N	76°17'14.90"E
ALP 17	Pattanakkadu	9°44'48.69"N	76°17'8.08"E
ALP 18	Kuthuthodu	9°46'36.11"N	76°17'11.59"E

4) Ernakulam

Ernakulam district is spanning to an area of 3068 Sq. km. The total area can be divided into three distinct units, namely high land, midland and coastal plain. The major soil types of the district are coastal alluvium, riverine alluvium, brown hydromorphic soil and lateritic soil in which lateritic soil covers the major area. The land use pattern of the district comprises of forests, cultivable land, waste land, uncultivable land and cultivable waste land in which cultivable land constitute the major part followed by forests. The district experiences a wet monsoon type climate with substantial raining during north east and southwest monsoon seasons. The normal average annual rainfall obtained in the district is 3359.2 mm. The annual mean values of climatological attributes like maximum temperature and humidity experienced in the districts are 31.4ºC and 88% respectively (CGWB 2013).

Table 3.4. Details of study area falling in Ernakulam district

Location ID.	Location Name	Latitude	Longitude
EKM 1	Kumbalangi	9°52'26.20"N	76°17'31.22"E
EKM 2	Illikkal	9°52'59.54"N	76°17'24.48"E
EKM 3	Padasekharam road	9°53'47.59"N	76 °17'12.84"E
EKM 4	Vyasapuram	9°55'31.61"N	76°16'45.67"E
EKM 5	Marambally	9°55'43.79"N	76°16'20.81"E
EKM 6	Ponnarimangalam	10°0'5.07"N	76°15'38.24"E
EKM 7	Mulavukadu	10°0'41.78"N	76°15'25.50"E
EKM 8	Moolambilli	10°2'24.55"N	76°15'33.25"E
EKM 9	Kothad Island	10°2'59.78"N	76°16'17.91"E
EKM10	Chathanad	10°4'31.47"N	76°14'22.60"E
EKM 11	Palliyakkal	10°5'17.94"N	76°14'5.69"E
EKM 12	Kadakkara	10°6'8.68"N	76°13'23.13"E
EKM 13	Karuthala west	10°8'34.86"N	76°11'7.58"E
EKM 14	Pallippuram	10°9'4.50"N	76°10'55.29"E
EKM 15	Cherai	10°9'13.47"N	76°10'49.84"E
EKM 16	Mosco road	10°9'42.79"N	76°10'32.37"E
EKM 17	Munambam	10°10'42.31"N	76°10'11.44"E
EKM 18	Munambam-pallippuram	10°10'14.81"N	76°10'11.47"E

5) Thrissur

Thrissur district is located in the central part of Kerala with a total geographic area of 3032 Sq. km, representing 7% of the total area of the state. The geomorphologic categorization include low land (coastal planes and Kole land), mid land and high land. The major soil is of lateritic type. Other types such as brown hydromorphic, river alluvium, coastal soil and forest loam are also present. Archaean crystalline formation, tertiary formation, sub-recent laterite and recent riverine alluvium are the important geological formations within the terrain. The climatic pattern comprises of 4 definite seasons including hot summer, cool winter, northeast and southwest monsoon. The mean annual rainfall experienced in the district is 3198.133 mm. The annual mean maximum atmospheric temperature and relative humidity in the district are 36.2 °C and 93% respectively (CGWB 2013).

Table 3.5. Details of study area falling in Thrissur district

Location ID.	Location Name	Latitude	Longitude
TSR 1	Poochakkadav	10°11'17.22"N	76° 10'2.27"E
TSR 2	Azheekkode	10° 11'37.95"N	76° 9'56.98"E
TSR 3	Marthoma Nagar	10° 11'26.15"N	76° 10'41.20"E
TSR 4	Methala	10° 11'39.11"N	76° 10'54.53"E
TSR 5	Idamukk	10° 11'41.74"N	76° 11'26.50"E
TSR 6	Kuzhivathkadav	10° 14'11.44"N	76° 12'5.63"E
TSR 7	Vayalar	10° 14'30.65"N	76° 11'58.13"E
TSR 8	Ala-Gothuruth	10° 15'3.93"N	76° 11'31.99"E
TSR 9	Veluthakadav	10° 15'2.21"N	76°10'47.31"E
TSR 10	Muttichur kadav	10° 26'32.25"N	76°6'3.49"E
TSR 11	Meenkadav	10° 29'59.78"N	76°4'26.16"E
TSR 12	Orumanayur	10° 34'7.13"N	76°2'6.36"E
TSR 13	Ayodyanagar	10° 33'44.09"N	76°2'21.65"E
TSR 14	Kundukadav	10° 33'16.46"N	76°2'35.67"E
TSR 15	Moonnamkall	10° 32'23.08"N	76°2'51.89"E
TSR 16	Chiplimad	10° 31'20.39"N	76°2'17.90"E
TSR 17	Banglamkadav	10° 30'59.68"N	76°2'29.63"E
TSR 18	Pulikkakadav	10° 31'20.83"N	76°3'57.79"E

6) Malappuram

Malappuram district constitutes 9.13 % of the total area of the state of Kerala and has a total cover of 3550 sq.km. Three physiographic units of the districts are low land, mid land and high land, of which mid land constitutes the major area. The important soil types are laterite, brown hydromorphic, coastal and river alluvium and forest loam. The climate of the district is generally humid with definite dry or wet seasons, with adequate rainfall in the northeast and southwest monsoon seasons. Normal annual average rainfall is 2793.3 mm. Annual average values of climatological attributes like maximum temperature and relative humidity experienced in the districts are 31.8 °C and 92% respectively (CGWB 2013).

Table 3.6. Details of study area falling in Malappuram district

Location ID.	Location Name	Latitude	Longitude
MPM1	Pariyapuram 1	11°0'30.611"N	75°51'58.367"E
MPM2	Pariyapuram 2	11°0'39.587"N	75°51'56.063"E
MPM3	Pariyapuram 3	11°0'33.348"N	75°51'49.320"E
MPM4	Pariyapuram 4	11°0'44.099"N	75°51'54.785"E
MPM5	Poorappuzha Bridge	11°1'2.322"N	75°52'10.319"E
MPM6	Mangalam Bridge	10°50'39.726"N	75°54'22.5"E
MPM7	Koottayi	10°50'35.520"N	75°54'19.343"E
MPM8	Purathur	10°48'21.192"N	75°55'6.000"E
MPM9	Murikkummadu	10°48'13.902"N	75°55'3.965"E
MPM10	Purathur boat jetty	10°48'7.266"N	75°55'8.867"E
MPM11	Chamravattom Kadav	10°49'1.2"N	75°57'14.3994"E
MPM12	Puthuponnani Bridge East	10°44'24"N	75°56'23.9994"E
MPM13	Puthuponnani Bridge west	10°44'31.2"N	75°56'16.8"E
MPM14	Puthuponnani Munambam	10°43'58.8"N	75°56'13.1994"E
MPM15	Thayyilakkadavu	11°5'28.530"N	75°52'29.639"E
MPM16	Olipram kadavu	11°7'41.651"N	75°51'50.981"E
MPM17	Kottakkadavu	11°8'15.594"N	75°50'27.930"E
MPM18	Kottappadi	11°8'18.942"N	75°50'29.969"E

7) Kozhikode

Kozhikode district has a total geographical area of 2344 sq.km. The physiographic units of the districts are low land that stretches along the coastal plane, mid land with rolling or undulating terrain and high land. The important soil types of the district are alluvial, laterite and forest loam. The most common soil is of lateritic type and is distributed mainly along the mid lands. The district experiences tropical monsoon climate with 4 distinct seasons. Tropical rainfall of both southwest and northeast monsoon is contributing to an average annual rainfall of 3698 mm. The average annual maximum temperature and humidity experienced in the district are 30.5 °C and 91% respectively (CGWB 2013).

Table 3.7. Details of study area falling in Kozhikode district

Location ID.	Location Name	Latitude	Longitude
KKD 1	Chaliyam	11°9'39.743"N	75°48'33.473"E
KKD 2	Beypore	11°10'4.745"N	75°48'31.067"E
KKD 3	Chalappuram	11°14'19.494"N	75°47'36.180"E
KKD 4	Thekkeppuram	11°14'2.154"N	75°46'55.643"E
KKD 5	Elathur	11°21'14.195"N	75°44'27.701"E
KKD 6	Korappuzha	11°21'21.456"N	75°44'28.853"E
KKD 7	Puthiyottilkadavu	11°20'57.887"N	75°44'45.071"E
KKD 8	Venkalam	11°21'54.984"N	75°44'53.748"E
KKD 9	Kooniyil kadavu	11°23'3.216"N	75°44'36.150"E
KKD 10	Aanappara	11°22'20.910"N	75°44'48.186"E
KKD 11	Cheliya	11°25'31.427"N	75°44'12.443"E
KKD 12	Nelliyadikadavu	11°29'0.258"N	75°41'23.171"E
KKD 13	Puthuppanam	11°34'14.274"N	75°35'46.596"E
KKD 14	Kuttiyammal	11°34'47.297"N	75°35'23.856"E
KKD 15	Puramkara	11°35'16.854"N	75°35'3.413"E
KKD 16	Mooradu	11°33'49.446"N	75°36'35.615"E
KKD 17	Kottakkal	11°34'7.625"N	75°35'34.824"E
KKD 18	Iringal	11°33'55.229"N	75°35'56.988"E

8) Kannur

Kannur district has a total areal extent of 2966 sq.km. Physiographically, the district has low lands, mid land with undulating terrain of laterite formation and high lands with rugged terrains. The major soil types in the districts are laterite, brown hydromorphic, coastal and river alluvium and forest loam. There are several geological formations like gneiss, schist, charnockite and coastal alluvium. The district experiences a wet climate with heavy rainfall in the southwest and northeast monsoon. The average annual rainfall, maximum temperature and relative humidity experienced in the district are 3438 mm, 23.9 ^{o}C and 88 % respectively (CGWB 2013).

Table 3.8. Details of study area falling in Kannur district

Location ID.	Location Name	Latitude	Longitude
KNR1	Kavumbhagom	11°45'37.28"N	75°29'23.64"E
KNR2	Thiruvangad	11°45'55.24"N	75°29'20.54"E
KNR3	Nettur	11°46'5.25"N	75°29'0.24"E
KNR4	Koduvalli	11°45'57.46"N	75°28'33.07"E
KNR5	Meenthalapeedika	11°46'4.55"N	75°28'14.33"E
KNR6	Moythupaalam	11°46'43.60"N	75°27'40.14"E
KNR7	Mundambalam	11°47'38.56"N	75°27'33.03"E
KNR8	Kulamkadav	11°48'14.44"N	75°27'31.20"E
KNR9	Valapattanam	11°55'39.19"N	75°21'33.58"E
KNR10	Keeriyad	11°55'45.99"N	75°21'17.15"E
KNR11	Kadavath	11°55'50.11"N	75°21'5.86"E
KNR12	Port road	11°55'47.26"N	75°19'44.15"E
KNR13	Kappakkadav	11°56'22.28"N	75°19'19.88"E
KNR14	Iranav	11°57'25.91"N	75°18'55.39"E
KNR15	Mattool south	11°57'28.57"N	75*17'57.81"E
KNR16	Aaruthengu	11°58'39.52"N	75*17'8.44"E
KNR17	Sidhikkabad	11°58'54.84"N	75*17'1.96"E
KNR18	Badikkad	12°0'31.99"N	75*15'44.39"E

9) Kasaragod

Kasaragod is the northernmost district of Kerala with a geographical area of 1992 sq.km. The three distinct physiographic units of the districts are coastal plains, midland and high land. The midlands contain rugged terrain with lateritic, colluvium and alluvium deposits. Lateritic, brown hydromorphic, alluvial and forest loam are important soil types of the district of which lateritic soil have a wider coverage. The climate in the district is that of typical Kerala with heavy rain in the monsoon. The average annual rainfall experienced in the district is 3500 mm. Climatological attributes like maximum temperature and relative humidity has annual average values of 31.3 ^{o}C and 90% respectively (CGWB 2013).

Table 3.9. Details of study area falling in Kasaragod district

Location ID.	Location Name	Latitude	Longitude
KSD1	Udumbumthala	12^o6'21.19"N	75^o10'25.15"E
KSD2	Mothakkadav	12^o6'30.52"N	75^o10'23.43"E
KSD3	Kaikkottukadav	12^o6'58.20"N	75^o10'17.29"E
KSD4	Vellapp	12^o7'56.42"N	75^o9'53.16"E
KSD5	Idayilekkadu Island	12^o8'24.82"N	75^o8'58.04"E
KSD6	Ayittikkadav	12^o8'55.04"N	75^o9'15.64"E
KSD7	Thekkekkadu	12^o10'14.16"N	75^o8'48.43"E
KSD8	Padanna kadappuram	12^o10'5.58"N	75^o8'36.02"E
KSD9	Mattummal	12^o10'37.50"N	75^o8'35.03"E
KSD10	Ori	12^o11'11.01"N	75^o8'16.30"E
KSD11	Ori kadav	12^o11'51.22"N	75^o7'54.01"E
KSD12	Orkkalam	12^o13'5.55"N	75^o7'12.16"E
KSD13	Madakkara,Thuruthi	12^o13'8.13"N	75^o7'52.04"E
KSD14	Orcha	12^o14'47.35"N	75^o7'13.33"E
KSD15	Chithari	12^o22'4.00"N	75^o3'32.60"E
KSD16	Kappil	12^o25'37.16"N	75^o0'51.97"E
KSD17	Keeyoor Kadavath	12^o28'20.47"N	75^o0'8.93"E
KSD18	Chemanad	12^o29'56.58"N	74^o59'58.24"E

Collection of both water and sediment samples were carried out from all the 163 locations falling in 9 districts. Entire collection was carried out during post monsoon season, which is characteristic in having higher concentration of all elements under target. Also this season is reported to be ideal for the introduction of most of the mangrove species. All the collected samples were subjected to physico-chemical analysis either on spot or in the laboratory, following standard methods (APHA, 2005 and Trivedy et al., 1987). The physico chemical parameters analyzed for water samples include pH, turbidity, total solids, total dissolved solids, total suspended solids, salinity, resistivity, conductivity, acidity, alkalinity, total hardness, magnesium, calcium, chloride, sulphate, sodium, total nitrogen, phosphorous and potassium. Similarly, sediment samples were subjected to the analysis of pH, moisture percentage, textural percentage of sand, silt and clay, organic carbon, total nitrogen, phosphorous, potassium and sodium following standard methods (Trivedy et al., 1987 and Jackson, 1973). Analytical procedures followed for both water and sediment samples are depicted in Chapter 2.

The tolerance range of mangrove species towards different physico-chemical parameters have been taken into account for assessing the most significant growth determinants of each mangrove species. The numbers of sites possessing all these attributes or a share were treated as ideal sites for afforestation of respective mangrove species. Based on these, different classes of sites have been described. Sites possessing 0-20% growth sustaining attributes of any mangrove species was treated as A, 21-40 % as B, 41-60% as C, 61-80% as D and 81-100% as E. Sites under category A were treated as non-ideal, B as moderately ideal, C as ideal, D and E are respectively as perfectly ideal and exemplarily ideal for afforestation of mangrove species.

Results and Discussion

An initiative of mangrove afforestation is yet to make a successful leap in the state of Kerala. The present investigation has been carried out to delineate the sites for species specific mangrove afforestation along the coastal districts of Kerala, which include Trivandrum, Kollam, Alleppey, Ernakulam, Thrissur, Malappuram, Kozhikode, Kannur and Kasaragod, based on hydrogeochemical and sedimentological characteristics. The tolerance range of mangrove species towards different physico-chemical parameters have been taken in to account for assessing the most significant growth determinant of each species. The numbers of sites possessing all or a share of these attributes were treated as ideal sites for the introduction of respective mangrove species.

The results on the physico chemical characterization of water and sediment samples from 19 locations (TVM 1 to TVM 19) of Trivandrum district for delineating regions ideal for mangrove introduction are given in Tables 3.10 – 3.11.

Table 3.10. Results on the physico-chemical characterization of water samples along different locations in Trivandrum district

Sl No	Parameters	TVM 1	TVM 2	TVM 3	TVM 4	TVM 5	TVM 6	TVM 7	TVM 8	TVM 9	TVM 10	TVM 11	TVM 12	TVM 13	TVM 14	TVM 15	TVM 16	TVM 17	TVM 18	TVM 19
1	pH	9.55	8.74	6.84	7.36	9.14	9.29	8.16	8.82	7.59	8.11	7.88	7.26	8.05	7.53	8.69	8.77	8.98	7.91	8.81
2	Turbidity (NTU)	0	0.1	0.2	0.1	0.2	0.2	0.1	0.1	0.1	0	0	0	0	0	0	0.1	0.1	0.1	0.1
3	T.S (mg/l)	860	660	840	900	900	980	840	680	860	4160	5660	11100	6920	6660	15520	13940	9320	7840	8260
4	T.D.S (ppt)	0.3151	0.0697	0.0979	0.2256	0.1964	0.2452	0.1527	0.2378	0.2285	2.327	3.594	7.04	4.458	4.244	10.56	9.597	8.955	4.818	5.039
5	T.S.S (mg/l)	544.9	590.3	742.1	674.4	703.6	734.8	687.3	442.2	631.5	1833	2066	4060	2462	2416	4960	4343	365	3022	3221
6	Acidity (mg/l)	26.4	8.8	13.2	30.8	13.2	13.2	17.6	13.2	19.8	13.2	8.8	13.2	17.6	13.2	11	11	8.8	8.8	8.8
7	Salinity(ppt)	0.309	0.071	0.097	0.221	0.192	0.24	0.15	0.225	0.233	2.508	3.95	8.316	5.081	4.809	12.69	11.45	10.24	5.484	5.748
8	Conductivity(mS)	0.615	0.1362	0.1912	0.4401	0.3837	0.4794	0.2991	0.4641	0.4491	4.549	7.026	13.74	8.714	8.31	20.63	18.8	16.9	9.418	9.866
9	Resistivity (Ω)	1590	7178	5108	2221	2548	2039	3270	2104	2173	214.6	139.3	71.15	112.2	117.8	47.31	52.04	57.78	103.6	99.19
10	Alkalinity (mg/l)	190	90	60	130	100	110	100	90	110	120	80	120	100	90	150	110	160	80	90
11	Hardness (mg/l)	28	8	20	20	26	22	16	8	20	60	76	164	100	96	228	210	134	110	112
12	Calcium(mg/l)	5.607	5.607	5.607	4.806	6.408	5.607	4.005	4.005	4.806	8.01	5.607	12.816	9.612	9.612	18.423	16.02	12.015	8.811	8.811
13	Magnesium (mg/l)	3.409	0.974	1.461	1.948	2.435	1.948	1.461	1.948	1.948	9.739	15.095	32.137	18.503	17.529	44.311	41.389	25.32	21.425	21.912
14	Chloride (mg/l)	362.1	305.3	355	312.4	355	404.7	347.9	284	369.2	1846	2655.4	5041	1966.7	2896.8	6177	6958	3180.8	3550	3805.6
15	Sulphate (mg/l)	10	2	0.1	5.5	2.3	1	3	3	4.8	15.5	63	65.5	134	119	122	156	155	137	127
16	Sodium (ppt)	4.56	0.0274	0.0071	0.1505	0.0867	0.1295	0.0403	0.0448	0.1172	1.78	1.48	6.625	3.585	2.49	7.37	6.72	5.635	3.21	3585
17	Potassium (mg/l)	333.484	269.008	253.994	152.998	194.014	178.999	226.506	231.511	175.4.81	328.518	315.498	288.988	301.500	310.493	611.016	613.01	563.509	307.991	305.488
18	Phosphorous (mg/l)	87.5	28.5	165.0	112.0	69.0	52.0	12.5	142.0	26.5	59.0	60.5	15.0	145.0	99.5	122.5	23.5	21.0	4.0	35.0
19	Nitrogen (mg/l)	49	42	35	42	28	35	42	42	56	42	42	42	28	35	42	35	49	42	42

Table 3.11. Results on the physico-chemical characterization of sediment samples along different locations in Trivandrum district

Sl No	Parameters	TVM 1	TVM 2	TVM 3	TVM 4	TVM 5	TVM 6	TVM 7	TVM 8	TVM 9	TVM 10	TVM 11	TVM 12	TVM 13	TVM 14	TVM 15	TVM 16	TVM 17	TVM 18	TVM 19
1	pH	4.78	6.75	4.28	3.94	4.98	5.68	6.06	5.71	7.33	6.09	5.7	4.57	3.19	3.75	6.47	3.77	8.48	6.54	5.14
2	Moisture %	6.8	8.2	9	12.6	8.3	5.5	1.8	21	5.8	3.8	15.8	7.5	9.8	5.5	6.3	16.5	12.3	5.9	6.9
3	Sand %	96.3	73.2	84.1	79.0	94.0	90.2	92.1	91.1	87.3	99.7	93.1	85.7	94.1	90.8	90.4	92.6	90.2	90.3	73.8
4	Silt %	0.1	0.2	0.2	0.3	01	01	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.5
5	Clay %	3.6	26.6	15.7	20.7	5.9	9.7	7.8	8.8	12.6	0.2	6.8	14.1	5.8	9.1	9.4	7.3	9.7	9.6	25.7
6	Organic carbon (g/kg)	8.0	10.0	18.5	23.45	23.5	76.0	38.0	90.0	16.5	25.0	38.0	18.0	27.0	19.5	18.5	24.5	73.5	8.0	7.5
7	Nitrogen (mg/kg)	1260	1890	1050	3080	630	350	560	840	2940	5600	490	1750	2450	770	1050	630	420	420	560
8	Phosphorous (mg/kg)	54.5	57.0	44.5	55.0	31.5	22.5	19.5	34.5	55.0	16.0	6.0	48.0	30.0	10.5	12.5	13.5	14.0	11.0	17.0
9	Potassium(mg/l)	2.502	10.01	10.01	15.01	20.02	12.51	0	10.01	0	10.01	10.01	15.01	7.51	20.02	10.01	15.01	10.01	12.51	2.502
10	Sodium (ppt)	0.045	0.005	0.0675	0.1425	0.0275	0.0175	0.0525	0.0475	0.07	0.1125	0.09	0.45	0.1075	0.1025	0.2525	0.2925	0.135	0.0775	0.145

Upon analyzing the growth requirements of mangrove species with those of site characteristics, sites noted to be ideal (Plate 3.1) for mangrove afforestation in Thiruvananthapuram district were Manamel (TVM 3) for *Excoecaria agallocha* and *Sonneratia alba,* Panathura (TVM 4) and Kundavila (TVM 11) for *Avicennia officinalis* and Murukkumpuzha Kadavu (TVM 12) for *E. agallocha* and *Rhizophora mucronata.* Locations noted to be moderately ideal were Edayar (TVM 1) for *Bruguiera cylindrica*; Munnattumukku (TVM 2) and Thazhampally (TVM 17) for *A. officinalis, B. cylindrica* and *E.* agallocha; Manamel, Kayikkara kadavu (TVM 10) and Kottaram thuruth (TVM 16) for *A. officinalis, B. cylindrica* and *R.* mucronata; Panathura for *E. agallocha*, *R. mucronata* and *S. alba*; Thottumukku (TVM 6) for *E. agallocha*; Madhavapuram (TVM 9) for *B. cylindrica* and *S. alba*; Kundavila for *B. cylindrica* and *R. mucronata*; Murukkumpuzha Kadavu for *A. officinalis, B. cylindrica* and *S. alba*; Kadinamkulam (TVM 13) for *A. officinalis*;. Vadakkevila (TVM 14) for *A. officinalis, E. agallocha* and *R. mucronata*; Perumathura (TVM 15) for *B. cylindrica;* Anchuthengu (TVM 18) for *A. officinalis* and *E. agallocha* and Chambavu (TVM 19) for *A. officinalis, R. mucronata* and *S. alba*.

The results on the physico-chemical characteristics of water / sediment samples from 18 locations of Kollam district are depicted in Tables 3.12-3.13.

Table 3.12. Results on the physico-chemical characterization of water samples along different locations in Kollam district

Sl No:	Parameters	KLM 1	KLM 2	KLM 3	KLM 4	KLM 5	KLM 6	KLM 7	KLM 8	KLM 9	KLM 10	KLM 11	KLM 12	KLM 13	KLM 14	KLM 15	KLM 16	KLM 17	KLM 18
1	pH	8.21	8.27	8.1	7.93	8.02	8.64	7.73	10.19	9.27	8.51	8.57	9.16	7.6	7.38	7.6	7.33	8.46	8.27
2	Turbidity(NTU)	0	0	0.1	0	0	0	0.1	0.3	0	0	0	0.1	0	0.1	0	0	0	0.1
3	T.S (mg/l)	15200	3200	8200	10600	11600	6600	1600	8400	8400	24200	20200	4000	400	600	3000	2800	8400	21800
4	T.D.S (ppt)	11.57	2.422	6.221	8.376	6.557	4.995	0.9032	6.384	6.582	17.42	15.09	3.339	0.3249	0.3588	2.691	1.976	6.739	15.9
5	T.S.S (mg/l)	3630	778	1979	2224	5043	1605	696.8	2016	1818	6780	5110	661	75.1	241.2	309	824	1661	5900
6	Acidity (mg/l)	17.6	6.6	8.8	11	11	17.6	22	15.4	13.2	17.6	8.8	8.8	8.8	8.8	13.2	8.8	17.6	17.6
7	Salinity(ppt)	14.05	2.608	7.16	9.882	7.564	5.647	0.9321	7.362	7.626	22.38	19.12	3.727	0.3225	0.3509	2.904	2.093	7.821	19.94
8	Conductivity(mS)	22.64	4.735	12.16	16.37	12.82	9.766	1.766	12.47	12.83	34.05	29.49	6.533	0.6353	0.7002	5.27	3.863	13.18	31.09
9	Resistivity(Ω)	43.19	206.3	80.47	59.72	76.34	100.1	553.6	78.44	75.8	28.75	33.16	149.7	1519	1396	185.5	253.2	74.19	31.43
10	Alkalinity (mg/l)	140	100	70	90	80	120	110	160	140	180	150	140	70	70	90	80	110	140
11	Hardness(mg/l)	262	50	134	188	142	114	30	142	140	390	336	82	12	30	60	48	142	350
12	Calcium(mg/l)	20.025	4.806	9.612	13.617	10.413	8.01	4.806	12.015	12.015	25.632	24.03	9.612	4.806	4.806	6.408	4.806	9.612	24.831
13	Magnesium(mg/l)	51.615	9.252	26.781	37.494	28.242	22.886	4.382	27.268	26.781	79.37	67.196	14.121	0	4.382	10.712	8.765	28.729	70.118
14	Chloride(mg/l)	8108.2	1760.8	4473	5964	4671.8	3521.6	695.8	4657.6	4813.8	13646.2	8406.4	2229.4	340.8	369.2	2002.2	1320.6	3422.2	10735.2
15	Sulphate(mg/l)	180	98	180	180	180	159	31	174	153	180	180	97	22	8	94	151	138	170
16	Sodium (ppt)	13.15	0.42	1.5	3.26	2.14	2.18	3.385	5.66	2.24	19.8	14.25	1.005	4.235	9.92	5.26	6.82	1.05	15.05
17	Potassium(mg/l)	578.015	323.513	641.983	632.9.9	636.001	637.995	333.484	298.020	636.001	331.011	575.98	318.00	338.49	681.982	662.02	672.012	641.983	556.26
18	Phosphorous(mg/l)	45.0	50.0	8.0	40.0	95.0	10.0	90.0	950.0	450.0	6.0	3.0	5.0	3.0	1500	5.0	5.0	3.0	40.0
19	Nitrogen (mg/l)	42	42	35	35	42	35	42	35	49	28	35	35	35	42	42	28	28	42

Table 3.13. Results on the physico-chemical characterization of sediment samples along different locations in Kollam district

Sl No:	Parameters	KLM 1	KLM 2	KLM 3	KLM 4	KLM 5	KLM 6	KLM 7	KLM 8	KLM 9	KLM 10	KLM 11	KLM 12	KLM 13	KLM 14	KLM 15	KLM 16	KLM 17	KLM 18
1	pH	4.2	4.33	5.53	8.71	8.3	7.59	3.39	6.31	4.72	8.85	6.94	7.12	4.01	7.63	7.61	6.41	7.05	3.85
2	Moisture %	8.5	9.6	12.3	15.5	5.2	3.8	8.7	5.3	11.5	8.8	7.7	6.85	7.55	12.5	8.8	6.3	7.5	5.2
3	Sand %	87.0	92.3	93.3	87.7	97.7	64.4	97.7	89.7	85.1	85.2	80.0	93.4	69.8	70.1	88.3	56.3	97.6	86.2
4	Silt %	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.2	0.1
5	Clay %	12.9	7.6	6.6	12.2	2.1	35.4	2.2	10.2	14.8	14.7	19.7	6.5	30.1	29.8	11.6	43.6	2.2	13.7
6	Organic carbon (g/kg)	73	53.5	2.5	78	5	25	4	12	63.5	39	10.5	3.5	8.5	12	11	15	13.5	15
7	Nitrogen (mg/kg)	1540	630	560	420	560	630	1470	770	1610	910	490	490	560	490	630	420	420	560
8	Phosphorous (mg/kg)	26	12.5	18	31.5	14.5	34	41	57.5	72	26	43.5	9.5	19.5	30.5	26.8	35	28	38.5
9	Potassium(mg/kg)	22.48	24.99	20.02	17.52	17.52	5.01	10.01	0	15.01	7.51	7.51	17.52	12.51	7.51	2.50	195.89	0	15.01
10	Sodium (ppt)	0.2725	0.0875	0.0525	0.0625	0.14	0.27	0.19	0.2875	0.45	0.5325	0.3875	0.045	0.1	0.45	0.185	0.1475	0.2325	0.4025

In Kollam district, KLM 9 (Kochuthoppu) and KLM 16 (Alappadu) were noted to be ideal for afforestation of *Avicennia officinalis*. KLM 8 (Sasthamthodi) was noted to be ideal for *Bruguiera cylindrica* and KLM18 (Pancharathopp) for *Excoecaria agallocha*. Also, the other ideal sites for afforestation were KLM 9 (Neeravil) for *A. officinalis* and *E. agallocha* and KLM 10 (Madathilkayalvaaram) for *B. cylindrica* and *Rhizophora mucronata* (Plate 3.2)

The moderately ideal sites for afforestation were Kappil (KLM 1) for *Avicennia officinalis, Bruguiera cylindrica, Excoecaria agallocha* and *Rhizophora mucronata*; Edava (KLM 2) for *B. cylindrica, E. agallocha, R. mucronata* and *Sonneratia alba*; Pozhikkara (KLM 4) and Cheriyazheekkal (KLM 15) for *A. officinalis* and *B. cylindrica*; Adhichamamthoppu (KLM 7) and Ponmana (KLM 12) for *B. cylindrica, E. agallocha* and *R.* mucronata; Madathilkayalvaaram for *A. officinalis, E. agallocha* and *S. alba*; Sasthamthodi for *R. mucronata* ; Neeravil for *B. cylindrica* and *R. mucronata*; Kochochira (KLM 17) for *A. officinalis* and *E. agallocha*; Alappadu for *A. officinalis* and Srayikkad (KLM 17) for *R. mucronata*.

18 study sites were selected in Alleppey district for assessing the possibility of mangrove afforestation. The physico-chemical characteristics of water and sediment samples worked out in this regard are depicted in Tables 3.14 - 3.15.

Table 3.14. Results on the physico-chemical characterization of water samples along different locations in Alleppey district

Sl No:	Parameters	ALP 1	ALP 2	ALP 3	ALP 4	ALP 5	ALP 6	ALP 7	ALP 8	ALP 9	ALP 10	ALP 11	ALP 12	ALP 13	ALP 14	ALP 15	ALP 16	ALP 17	ALP 18
1	pH	8.26	8.16	8.64	8.6	8.19	8.09	7.2	7	6.65	6.62	7.23	6.62	6.47	7.8	8.2	7.15	7.79	7.23
2	Turbidity (NTU)	0.1	0.5	0	1.2	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0.1
3	T.S (mg/l)	24800	26000	24600	12000	19400	16000	7000	6400	600	600	5000	400	800	6800	11000	9800	12200	18600
4	T.D.S (ppt)	17.3	17.46	16.56	9.073	13.49	11.52	5.277	4.796	0.5544	0.3697	3.945	0.3865	0.7843	5.336	8.172	6.869	9.207	13.39
5	T.S.S (mg/l)	7500	8540	8040	2927	5910	4480	1723	1604	45.6	230.3	1055	13.5	15.7	1464	2828	2931	2993	5210
6	Salinity(ppt)	21.88	22.1	20.81	10.78	16.92	13.98	6.004	5.495	0.55	0.3625	4.374	0.3794	0.7912	6.177	9.593	7.951	10.96	16.46
7	Resistivity(Ω)	28.93	28.63	30.18	55.22	37.04	43.51	94.8	104.3	901.9	1352	126.7	1294	637.5	93.52	61.22	72.79	54.25	37.35
8	Conductivity (mS)	33.82	34.12	32.42	17.72	26.39	22.52	10.32	9.373	1.084	0.7241	7.712	0.7556	1.533	10.43	15.98	13.43	18	26.18
9	Acidity (mg/l)	17.6	17.6	13.2	30.8	22	13.2	8.8	17.6	13.2	13.2	13.2	13.2	17.6	30.8	26.4	48.4	26.4	30.8
10	Alkalinity (mg/l)	150	190	170	330	100	110	100	100	60	70	120	80	60	200	210	200	210	160
11	Hardness(mg/l)	420	432	400	200	308	258	115	110	16	16	92	16	25	128	178	164	204	306
12	Calcium(mg/l)	28.035	28.836	27.234	15.219	20.025	19.224	8.01	8.811	4.806	4.005	7.209	4.005	5.607	13.617	14.418	12.816	18.423	20.826
13	Magnesium(mg/l)	85.213	87.647	80.83	39.441	62.814	51.128	23.129	21.425	0.974	1.461	18.016	1.461	2.678	22.886	34.572	32.137	38.467	61.84
14	Chloride(mg/l)	12297.2	14413	10408.6	7810	9883.2	9528.2	5168.8	3280.2	568	454.4	2840	1533.6	695.8	3692	8292.8	4842.2	6645.6	9641.8
15	Sulphate(mg/l)	180	177	153	131	152	148	127	118	21.5	9	102	16.5	31	120	136	131	138	145
16	Nitrogen (mg/l)	42	28	35	42	42	28	28	28	28	35	28	28	28	35	28	28	28	35
17	Phosphorous (mg/l)	2.0	52	5.0	54	4.5	4.5	2.0	2.5	2.0	2.0	0.4	13.5	1.0	51.5	49.0	57.0	28.5	31.5
18	Potassium (mg/l)	585.99	573.0	681.98	627.9	591.00	625.99	646.99	657.00	677.02	681.98	314.01	338.49	335.9.9	662.00	283.01	290.51	651.99	590.99
19	Sodium (ppt)	12.47	13.35	9.57	4.26	12.07	5.41	0.54	1.81	9.42	9.92	2.33	4.41	3.735	4.46	7.725	6.335	0.57	11.17

Table 3.15. Results on the physico-chemical characterization of sediment samples along different locations in Alleppey district

Sl No:	Parameters	ALP 1	ALP 2	ALP 3	ALP 4	ALP 5	ALP 6	ALP 7	ALP 8	ALP 9	ALP 10	ALP 11	ALP 12	ALP 13	ALP 14	ALP 15	ALP 16	ALP 17	ALP 18
1	pH	9.02	7.85	3.84	7.89	7.81	8.47	5.95	8.49	5.58	5.98	9.02	5.54	5.96	8.49	9.05	8.53	8.23	7.54
2	Moisture %	3.2	16.5	9.5	21.5	13.8	8.8	6.3	3.2	4.6	15.2	3.5	1.55	6.6	11.6	2.3	9.8	6.5	2.3
3	Sand %	87.0	87.4	96.2	89.3	89.1	84.4	97.3	87.1	78.6	46.6	96.0	71.2	78.0	96.5	92.4	73.9	91.1	84.0
4	Silt %	0.2	0.5	0.2	0.2	0.3	0.2	0.1	0.3	0.1	0.2	0.1	0.2	0.2	0.1	0.2	0.2	0.3	0.6
5	Clay %	12.8	12.1	3.6	10.5	10.6	15.4	2.6	12.6	21.3	53.2	3.9	28.6	21.8	3.4	7.4	25.9	8.6	15.4
6	Organic carbon (g/kg)	1.9	88	9.8	94	9.0	1.4	2.8	0.04	0.13	328.7	30.0	0.5	23.7	4.25	0.96	10.5	27.0	0.22
7	Nitrogen (mg/kg)	420	1890	910	1750	490	490	490	560	910	2730	420	1890	1750	560	770	700	2170	1680
8	Phosphorous (mg/kg)	19.5	94.5	43.0	93.5	22.5	19.0	14.5	12.0	21.5	45.5	21.5	59.5	58.0	74.5	29.5	86.0	55.0	62.0
9	Potassium (mg/kg)	10.01	87.51	7.51	55.01	20.02	17.52	0	2.50	2.50	7.51	0	0	0	47.51	2.50	32.49	15.01	12.51
10	Sodium (ppt)	0.5625	1.04	0.585	0.6225	0.46	0.675	0.2575	0.2625	0.235	0.27	0.2925	0.25	0.275	0.34	0.3075	0.5775	0.4575	0.5025

In Alleppey district, the ideal sites for afforestation of different mangrove species were ALP 8 (Mahadevikaad), ALP 11 (Thottappally) and ALP 14 (Ottamasseri) for *Rhizophora mucronata*; ALP 13 (Kannattakkadav) for *Sonneratia alba*; ALP 16 (Andakaranazhi) and ALP 17 (Pattanakkadu) for *Avicennia officinalis* and ALP 18 (Kuthuthodu) for *A. officinalis*, *Excoecaria agallocha* and *Bruguiera cylindrica* (Plate 3.3).

Moderately ideal sites for afforestation were noted to be Manivelikkadav (ALP 6) and Kannattakkadav for *Avicennia officinalis* and *Bruguiera cylindrica*; Valiyazheekkal 1 (ALP 1) for *Rhizophora mucronata*; Valiyazheekkal 2 (ALP 2) for *A. officinalis*; Arattupuzha (ALP 4), Kandallur (ALP 5), Mahadevikaad and Thottappally for *Excoecaria agallocha* and *A.* officinalis; Tharayilkkadav (ALP 3) and Kuthuthodu for *R.* mucronata; Pulikkeril (ALP 9) for *A. officinalis*; Arattuvazhi (ALP 15) and Andakaranazhi () for *B. cylindrica*; Ottamasseri for *E. agallocha* and Pattanakkadu (ALP 17) for *R. mucronata*.

Considering Ernakulam district, 18 sites were selected and the results on the physico-chemical characterization of both water and sediment samples are depicted in Tables 3.16 – 3.17.

Table 3.16. Results on the physico chemical characterization of water samples along different locations in Ernakulam district

Sl No:	Parameters	EKM 1	EKM 2	EKM 3	EKM 4	EKM 5	EKM 6	EKM 7	EKM 8	EKM 9	EKM 10	EKM 11	EKM 12	EKM 13	EKM 14	EKM 15	EKM 16	EKM 17	EKM 18
1	pH	7.03	6.69	7.35	7.27	7.27	7.28	7.47	6.98	6.44	6.92	7.25	7.53	7.33	7.95	8.04	7.93	7.71	7.02
2	Turbidity(NTU)	0.1	0.2	0.9	0.5	0.4	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0	0	0.1	0.2	0.1
3	T.S (mg/l)	5000	5200	7800	6600	5400	9200	7600	2000	800	4600	5200	4800	6400	16000	17600	19400	24800	21600
4	T.D.S (ppt)	3.936	3.111	6.092	5.146	4.464	7.529	6.531	1.687	0.7788	4.002	4.259	4.645	6.226	12.68	12.67	14.8	16.55	17.56
5	T.S.S (mg/l)	1064	2089	1708	1454	936	1671	1069	313	21.2	598	941	155	174	3320	4930	4600	8250	4040
6	Salinity(ppt)	4.372	3.44	6.981	5.891	5.036	8.868	7.605	1.786	0.798	4.505	4.836	5.234	7.166	15.56	15.57	18.54	22.52	20.91
7	Conductivity(mS)	7.694	6.082	11.89	10.06	8.728	14.72	12.74	3.303	1.523	7.82	8.321	9.098	12.17	24.78	24.75	28.94	32.35	34.33
8	Resistivity(Ω)	127	160.7	82.24	97.07	112.3	66.43	76.55	296	642	124.9	117.4	107.5	80.27	39.45	39.5	33.77	30.19	28.5
9	Acidity (mg/l)	17.6	74.8	13.2	48.4	57.2	11	11	11	35.2	13.2	13.2	8.8	17.6	11	13.2	8.8	8.8	26.4
10	Alkalinity (mg/l)	70	110	90	190	230	80	90	70	70	100	120	100	140	130	160	130	120	160
11	Hardness(mg/l)	80	79	141	116	103	168	142	46	26	87	90	103	134	283	284	332	400	378
12	Calcium(mg/l)	8.01	5.607	12.015	9.612	9.612	11.214	12.015	4.806	4.806	8.01	8.01	8.01	10.413	16.821	20.826	23.229	24.03	25.632
13	Magnesium(mg/l)	14.698	15.852	27.025	22.399	19.234	34.085	27.268	8.278	3.409	16.312	17.043	20.208	26.294	58.675	56.484	66.709	82.778	76.448
14	Chloride(mg/l)	2840	4160.6	7440.8	3479	3053	5310.8	4515.6	1235.4	681.6	2840	4458.8	3223.4	4245.8	10337.6	10408.6	12240.4	12609.6	13376.4
15	Sulphate(mg/l)	117	98	135	120	114	137	135	67.5	30.5	115	119	123	133	151	151	156	157.5	157.5
16	Sodium (ppt)	3.48	4.21	2.2	0.07	1.96	0.53	0.15	6.97	9.77	2.46	2.51	0.72	0.59	4.41	10.47	12.57	6.57	14.45
17	Potassium(mg/l)	662.00	662.00	656.99	641.983	651.993	651.993	651.993	672.012	681.982	656.997	656.997	656.997	656.997	630.996	597.995	587.986	620.986	575.982
18	Total Phosphorous(mg/l)	8.0	45.5	12.5	109.5	140.0	4.0	6.0	0.03	0.03	9.5	3.5	0.03	12.5	14.5	6.0	4.5	6.0	15.0
19	Total Nitrogen (mg/l)	42	28	35	28	35	21	28	28	28	21	21	21	35	21	28	21	28	21

Table 3.17. Results on the physico chemical characterization of sediment samples along different locations in Ernakulam district

Sl No:	Parameters	EKM 1	EKM 2	EKM 3	EKM 4	EKM 5	EKM 6	EKM 7	EKM 8	EKM 9	EKM 10	EKM 11	EKM 12	EKM 13	EKM 14	EKM 15	EKM 16	EKM 17	EK M 18
1	pH	6.44	5.76	5.98	6.4	6.69	8.14	6.95	2.87	2.46	6.05	6.74	6.67	7.58	4.29	8.1	8.03	8.5	8.3
2	Moisture %	5.5	13.2	5.2	21.8	8.6	3.3	5.5	8.3	11.5	5.9	3.2	7.36	5.5	12.3	7.5	9.6	13.6	8.6
3	Sand %	64.3	67.2	68.5	45.9	37.3	86.9	57.6	70.3	70.0	97.5	93.2	78.3	86.2	87.7	94.7	82.1	80.8	92.4
4	Silt %	0.2	0.4	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.2	0.3	0.1	0.1
5	Clay %	35.5	32.4	31.2	54.0	62.6	13.0	42.3	29.6	29.9	2.3	6.6	21.5	13.7	12.2	5.1	17.6	19.1	7.5
6	Organic carbon (g/kg)	235.8	421.6	1.03	511.1	597.8	70.2	183.3	90.7	170	0.37	0.26	51.2	47.2	66.4	28.0	75.0	88.4	41.5
7	Nitrogen (mg/kg)	2590	2590	1470	2310	2590	840	1540	2310	3290	770	420	2450	1330	770	1470	840	560	420
8	Total Phosphorous (mg/kg)	117.5	136	35	130	151	92.0	58.8	80	64	34	31	98.5	83.5	51.0	36.0	46.5	79.0	31.0
9	Potassium(mg/kg)	60.61	20.02	62.52	27.49	15.01	60.02	47.51	79.99	77.5	69.99	72.49	39.99	45.00	37.5	60.02	32.49	7.51	57.52
10	Sodium (ppt)	0.0075	0.185	0.17	0.5475	0.6375	0.1125	0.2275	0.055	0.025	0.005	0.015	0.07	0.145	0.6	0.1375	0.4	0.6625	0.317 5

The result showed that the ideal sites in Alleppey district for mangrove introduction were EKM 3 (Padasekharam road), EKM 10 (Chathanad) and EKM 11(Palliyakkal) for *Rhizophora mucronata*; Kumbalangi (EKM 1) for *Avicennia officinalis* and Karuthala west (EKM 13) for *Bruguiera cylindrica* (Plate 3.4).

Moderately ideal sites towards the afforestation of all the 5 species (*Avicennia officinalis, Bruguiera cylindrica, Excoecaria agallocha, Rhizophora mucronata* and *Sonneratia alba*) under study were Ponnarimangalam (EKM 6) and Mosco road (EKM 16). Illikkal (EKM 2), Marambally (EKM 5) and Munambam pallippuram (EKM 18) for 4 species (*A. officinalis, B. cylindrica, E. agallocha* and *R. mucronata*); Vyasapuram (EKM 4) and Cherai (EKM 15) moderately ideal for the three species (*A. officinalis, B. cylindrica* and *R. mucronata*) have also been reported. The other moderately ideal sites were Padasekharam road and Palliyakkal for *A. officinalis, B. cylindrica* and *E. agallocha*; Karuthala west and Pallippuram (EKM 14) for *A. officinalis* and *E. agallocha*; Mulavukadu (EKM 7) for *R. mucronata*; Kothad Island (EKM 9) and Munambam (EKM 17) for *A. officinalis*; Moolambilli (EKM 8) for *R. mucronata*; Kadakkara (EKM 12) for *B. cylindrica*; Chathanad (EKM 10) for *B. cylindrica* and Kumbalangi (EKM 1) for *E. agallocha* and *S. alba*.

As far as Thrissur district is concerned, 18 sites were selected and the physic-chemical analysis of water and sediment samples from all the sites were carried out. The results are depicted in Tables 3.18 – 3.19.

Table 3.18. Results on the physico-chemical characterization of water samples along different locations in Thrissur district

Sl No:	Parameters	TSR 1	TSR 2	TSR 3	TSR 4	TSR 5	TSR 6	TSR 7	TSR 8	TSR 9	TSR 10	TSR 11	TSR 12	TSR 13	TSR 14	TSR 15	TSR 16	TSR 17	TSR 18
1	pH	7.41	7.38	7.02	7.17	7.16	6.62	7.14	7.01	6.93	6.85	7.11	7.13	7.27	7.1	7.7	8.02	7.75	7.61
2	Turbidity (NTU)	1.2	0.1	1.2	0.2	1.2	0.5	0.9	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.6	1.2	0.2
3	T.S (mg/l)	15200	16400	16200	4400	15600	7200	8800	4400	1400	600	5000	13400	16600	18400	23400	39200	42600	18400
4	T.D.S (ppt)	9.675	10.48	10.37	2.642	9.105	4.842	5.807	2.844	1.047	0.1607	3.088	8.863	10.41	12.06	14.87	25.4	25.59	12.49
5	T.S.S (mg/l)	5525	5920	5830	1758	6495	2358	2993	1556	353	439.3	1912	4537	6190	6340	8530	13800	17010	5910
6	Salinity(ppt)	11.68	12.74	12.63	2.875	10.93	5.508	6.684	3.1	1.08	0.1576	3.389	10.64	12.63	14.83	18.72	33.85	34.13	15.37
7	Conductivity (mS)	18.92	20.52	20.27	5.164	17.8	9.471	11.36	5.554	2.046	0.3143	6.042	17.32	20.37	23.62	29.07	49.68	50.03	24.41
8	Resistivity (Ω)	51.74	47.72	48.26	189.1	55.01	103.4	86.1	176.1	478	3105	161.9	56.29	47.94	41.46	33.58	19.68	19.55	40.06
9	Acidity (mg/l)	8.8	22	17.6	28.6	17.6	41.8	17.6	17.6	13.2	17.6	8.8	17.6	13.2	13.2	13.2	15.4	22	8.8
10	Alkalinity (mg/l)	160	180	150	180	170	120	140	130	115	50	90	100	120	130	120	200	190	130
11	Hardness (mg/l)	215	233	230	70	216	102	130	72	28	14	70	196	227	268	336	580	620	282
12	Calcium (mg/l)	15.219	16.821	15.219	7.209	16.02	9.612	10.413	7.209	4.005	4.806	7.209	14.418	16.02	20.025	23.229	40.851	40.851	19.224
13	Magnesium (mg/l)	43.093	46.502	46.745	12.66	42.85	18.99	25.32	13.147	4.382	0.487	12.66	38.954	45.528	53.075	67.683	116.376	126.115	56.971
14	Chloride (mg/l)	6816	7369.8	5949.8	1917	6432.6	3464.8	4451.7	2030.6	781	355	2300.4	6390	9230	8662	10437	17508.6	17068.4	11005
15	Sulphate (mg/l)	155.5	151	161	93	164	130	138	103	44	18.5	109	149	158	163	149	156	145	155
16	Sodium (ppt)	34.1	26.05	29.3	46.35	32.35	41.85	34.6	45.35	50.35	52.6	45.6	30.05	26.4	28.55	14.2	5.65	6.95	6.45
17	Potassium (mg/l)	336.00	333.49	336.00	340.99	335.99	338.50	336.00	340.99	340.99	343.50	340.99	336.00	333.49	335.99	331.00	326.00	328.49	328.49
18	Phosphorous(mg/l)	15.5	27.5	24.0	34.0	82.5	31.5	21.5	4.5	3.5	3.5	0.5	13.5	12.5	7.5	3.5	25.7	20.5	5.0
19	Total Nitrogen (mg/l)	28	28	28	21	35	35	35	42	35	28	28	42	35	35	49	35	35	35

Table 3.19. Results on the physico-chemical characterization of sediment samples along different locations in Thrissur district

Sl No:	Parameters	TSR 1	TSR 2	TSR 3	TSR 4	TSR 5	TSR 6	TSR 7	TSR 8	TSR 9	TSR 10	TSR 11	TSR 12	TSR 13	TSR 14	TSR 15	TSR 16	TSR 17	TSR 18
1	pH	8.51	7.32	7.76	7.44	7.76	6.67	5.54	7.45	5.76	5.57	7.62	7.72	6.76	6.58	5.66	6.57	8.16	5.26
2	Moisture %	6.3	8.2	9.2	7.35	5.32	8.6	4.58	6.28	12.4	9.6	5.6	7.1	6.8	9.12	6.35	8.5	7.25	5.5
3	Sand %	97.2	89.1	81.4	89.0	76.7	69.8	92.3	94.3	81.1	85.1	87.8	78.7	57.5	80.0	75.1	95.8	81.8	59.2
4	Silt %	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.1	0.4	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.1
5	Clay %	2.7	10.8	18.5	10.9	23.2	30.0	7.4	5.6	18.5	14.8	12.1	21.2	42.4	19.9	24.7	4.0	18.1	40.7
6	Organic carbon (g/kg)	9.4	4.4	20.2	12.5	7.1	18.3	9.8	5.1	28.7	14.8	8.8	13.0	41.8	11.1	16.4	4.4	9.0	28.6
7	Nitrogen (mg/kg)	560	1120	1330	630	490	1260	770	420	1330	910	700	910	1120	770	840	560	630	1260
8	Phosphorous (mg/kg)	46.5	42.0	78.5	67.5	53.5	85.0	83.5	14.5	52.5	46.5	75.2	46.0	80.0	55.0	40.0	80.0	54.5	40.0
9	Potassium(mg/kg)	5.01	2.50	22.48	5.01	39.99	22.48	12.51	57.52	12.51	2.50	5.01	27.49	2.50	32.49	34.99	34.99	20.02	24.99
10	Sodium (ppt)	0.415	0.36	0.275	0.21	0.3975	0.255	0.365	0.25	0.355	0.3025	0.31	0.2	0.5275	0.575	0.44	0.94	0.69	0.745

Kuzhivathkadav (TSR 6), Vayalar (TSR 7) and Ala-Gothuruth (TSR 8) of Thrissur district were noted to be perfectly ideal sites for the afforestation of *Rhizophora mucronata.* Azheekkode and Methala were the ideal sites for *Bruguiera cylindrica* and *Excoecaria agallocha.* Marthoma Nagar was the ideal site for *Avicennia officinalis*, *E. agallocha*, *R. mucronata* and *Sonneratia alba.* Kuzhivathkadav and Vayalar were the ideal sites for *E.* agallocha. Ala-Gothuruth and Banglamkadav were ideal for *B. cylindrica.* Veluthakadav was ideal for *A. officinalis, B. cylindrica* and *R. mucronata.* Muttichur kadav*,* Ayodyanagar and Moonnamkall were ideal for *R. mucronata* whereas, Kundukadav was ideal for both *A. officinalis* and *R. mucronata* (Plate 3.5).

The moderately ideal sites for afforestation were Kuzhivathkadav (TSR 6), Vayalar (TSR 7) and Chiplimad (TSR 16) for *A. officinalis* and *B. cylindrica*; Poochakkadav (TSR 1) for *B. cylindrica, E. agallocha* and *R. mucronata*; Azheekkode (TSR 2) and Methala (TSR 4) for *A. officinalis* and *R. mucronata*; Marthoma Nagar (TSR 3) for *B. cylindrica*; Idamukk (TSR 5) for *B. cylindrica, E. agallocha*, *R. mucronata* and *S. alba*; Ala-Gothuruth (TSR 8) for *A. officinalis* and *E. agallocha*; Veluthakadav (TSR 9) and Kundukadav (TSR 14) for *E. agallocha* and *S. alba*; Muttichur kadav (TSR 10) for *A. officinalis, B. cylindrica, E. agallocha* and *S. alba*; Meenkadav (TSR 11) for *A. officinalis, B. cylindrica, E. agallocha* and *R. mucronata*; Orumanayur (TSR 12) for *A. officinalis, R. mucronata* and *S. alba*; Ayodyanagar (TSR 13) for *E. agallocha*; Moonnamkall (TSR 15) for *A. officinalis, E. agallocha* and *S. alba*; Banglamkadav (TSR 17) for *A. officinalis* and *S. alba* and Pulikkakadav (TSR 18) for *A. officinalis, E. agallocha* and *R. mucronata.*

18 sites were selected for assessing the physico-chemical characteristics of water and sediment samples from Malappuram district for elucidating the possibilities of mangrove afforestation. The results are depicted in Tables 3.20 – 3.21.

Table 3.20. Results on the physico-chemical characterization of water samples along different locations in Malappuram district

Sl No :	Parameters	MPM 1	MPM 2	MPM 3	MPM 4	MPM 5	MPM 6	MPM 7	MPM 8	MPM 9	MPM 10	MPM 11	MPM 12	MPM 13	MPM 14	MPM 15	MPM 16	MPM 17	MPM 18
1	pH	7.94	7.91	7.83	7.84	7.58	7.4	7.61	8	7.96	7.42	7.73	7.51	7.91	8	7.14	7.42	7.81	7.78
2	Turbidity (NTU)	0.1	0	1	0	0.1	1.1	31.4	37	34.8	13.3	2.4	0.1	7	3.2	0.4	1	1.6	2
3	T.S (mg/l)	41800	42000	42000	41800	42400	36800	37600	42400	43400	41200	9800	43000	45600	44000	40400	42600	43000	45400
4	T.D.S (ppt)	24.62	24.16	24.86	23.91	24.18	20.86	21.54	24.22	24.15	23.67	5.724	24.54	25.05	24.98	22.83	24.64	25.48	25.29
5	T.S.S (mg/l)	17180	17840	17140	17890	18220	15940	16060	18180	19250	17530	4076	18460	20550	19020	17570	17960	17520	20110
6	Salinity(ppt)	32.72	31.78	32.82	31.34	32.28	27.29	28.07	31.8	32.03	31.12	6.544	32.78	33.48	32.97	30.04	32.76	33.96	34
7	Conductivity(mS)	48.13	47.28	48.61	46.78	47.27	40.73	42.11	47.35	47.2	46.2	11.19	48.05	48.98	48.83	44.64	48.03	49.81	49.43
8	Resistivity(Ω)	20.33	20.66	20.12	20.91	20.67	23.96	23.24	20.64	20.73	21.16	87.35	20.34	19.97	19.99	21.87	20.32	19.64	19.77
9	Acidity (mg/l)	35.2	39.6	39.6	35.2	35.2	30.8	57.2	57.2	39.6	57.2	17.6	35.2	30.8	26.4	35.2	30.8	26.4	26.4
10	Alkalinity (mg/l)	140	130	150	150	150	150	250	170	160	160	110	160	150	150	130	150	150	160
11	Hardness(mg/l)	600	700	602	592	592	518	550	620	390	720	130	392	410	620	356	600	638	630
12	Calcium(mg/l)	38.448	40.05	39.249	37.647	36.045	34.443	34.443	37.647	40.857	39.249	11.214	42.453	39.249	40.851	34.443	36.846	40.05	43.25
13	Magnesium(mg/l)	122.706	146.079	122.706	121.246	122.22	105.177	112.968	128.063	70.118	151.435	24.883	69.631	75.961	126.115	65.736	123.68	130.984	127.08
14	Chloride(mg/l)	14200	19738	14200	17750	19312	17040	18034	19738	20945	19028	5325	13348	21016	20590	11644	19525	20164	20590
15	Sulphate(mg/l)	180	167	180	180	160	160	160	158	154	156	130	158	158	156	156	156	154	152
16	Sodium (ppt)	17.4	8.75	8.55	9	14.8	2.3	10.3	11	18.5	7.75	36.35	14	28.05	23.9	8.9	22.65	3.8	22.55
17	Potassium(mg/l)	320.99	323.5017	323.5017	323.507	320.99	328.49	323.50	320.99	318.00	323.50	338.50	320.99	314.00	316.49	323.50	315.50	328.49	316.49
18	Total Phosphorous(mg/l)	0.6	2.0	1.5	1.5	0.03	6.0	49.5	25.0	7.5	58.0	2.0	6.0	0.9	3.5	0.03	0.5	0.45	0.5
19	Total Nitrogen (mg/l)	28	28	28	28	28	28	35	35	28	35	21	35	35	35	28	28	21	35

Table 3.21. Results on the physico chemical characterization of sediment samples along different locations in Malappuram district

Sl No:	Parameters	MPM 1	MPM 2	MPM 3	MPM 4	MPM 5	MPM 6	MPM 7	MPM 8	MPM 9	MPM 10	MPM 11	MPM 12	MPM 13	MPM 14	MPM 15	MPM 16	MPM 17	MPM 18
1	pH	6.16	5.3	5.1	4.9	6.13	6.46	6.78	6.45	6.34	6.83	6.76	5.26	6.4	6.33	6.69	6.92	7.73	7.21
2	Moisture %	5.26	6.12	9.5	12.5	8.5	6.5	6.84	9.8	8.7	12.58	7.4	11.1	7.8	6.85	12.5	8.5	7.6	9.6
3	Sand %	78.3	89.2	64.3	46.3	81.7	81.7	80.4	58.4	87.4	70.4	89.2	87.8	88.8	89.8	73.9	72.8	61.0	79.3
4	Silt %	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.2
5	Clay %	21.6	10.7	35.6	53.6	18.1	18.1	19.4	41.5	12.5	29.4	10.6	12.1	11.1	10.1	26.0	27.0	38.9	20.5
6	Organic carbon (g/kg)	14.77	19.03	11.15	39.8	9.2	18.89	16.59	17.49	11.58	37.11	2.32	36.17	21.0	5.66	17.28	42.86	16.39	26.06
7	Nitrogen (mg/kg)	560	1120	1540	1260	700	1050	700	700	490	840	350	560	560	420	630	1750	1680	1190
8	Total Phosphorous (mg/kg)	13.5	28.0	62.0	23.5	29.0	59.5	62.5	93.0	50.5	62.5	76.5	0.495	66.0	86.0	61.0	45.5	45.5	60.0
9	Potassium (mg/kg)	2.5	5.00	2.5	39.99	0	20.02	24.99	22.48	5.01	37.5	0	12.51	10.01	0	17.52	39.99	52.51	50.01
10	Sodium (ppt)	0.115	0.0325	0.0175	0.235	0.068	0.0725	0.04	0.0075	0.078	0.0825	0.065	0.105	0.008	0.075	0.06	0.38	0.4375	0.3675

In Malappuram district, Kottappadi (MPM 18) is the most ideal site for afforestation of all the five mangrove species. Mangalam Bridge side (MPM 6), Purathur boat jetty (MPM 10) and Kottakkadavu (MPM 17) were ideal for *Rhizophora mucronata* whereas, Koottayi (MPM 7) and Murikkummadu (MPM 9) were ideal for *Bruguiera cylindrica*. Puthuponnani east (MPM 12) was ideal for *B. cylindrica* and *Excoecaria agallocha* whereas, Pariyapuram 2 (MPM 2) was ideal for *E. agallocha* (Plate 3.6).

Poorappuzha Bridge side was (MPM 5) noted to be moderately ideal for all the five species. Other moderately ideal afforestation sites were Olipram kadavu (MPM 16) for *A. officinalis, B. cylindrica* ,*S. alba*, *E. agallocha* and *R. mucronata*; Purathur boat jetty (MPM 10), Chamravattom Kadav (MPM 11) and Kottakkadavu (MPM 17) for *A. officinalis*, *B. cylindrica* and *E. agallocha*; Pariyapuram 3 (MPM 3) , Pariyapuram 4 (MPM 4) and Puthuponnani west (MPM 13) for *E. agallocha* and *R. mucronata*; Purathur (MPM 8) for *B. cylindrica*; Thayyilakkadavu (MPM 15) for *A. officinalis*; Pariyapuram 1 (MPM 1) and Puthuponnani east (MPM 12) for *S. alba* and *A.* officinalis; Murikkummadu (MPM 9) and Puthuponnani Munambam (MPM 14) for *E. agallocha*; Pariyapuram 2 (MPM 2) for *B. cylindrica* and *R.* mucronata; Mangalam bridge (MPM 6) for *A. officinalis, E. agallocha* and *S. alba* and Koottayi (MPM 7) for *A. officinalis* and *S. alba.*

For assessing the possibilities of mangrove afforestation, physico-chemical analysis of water and sediment samples from 18 sites in Kozhikode district has been carried out. The results are depicted in Tables 3.22 – 3.23.

Table 3.22. Results on the physico chemical characterization of water samples along different locations in Kozhikode district

Sl No :	Parameters	KKD 1	KKD 2	KKD 3	KKD 4	KKD 5	KKD 6	KKD 7	KKD 8	KKD 9	KKD 10	KKD 11	KKD 12	KKD 13	KKD 14	KKD 15	KKD 16	KKD 17	KKD 18
1	pH	7.91	7.98	7.95	7.86	7.71	8	8.03	7.95	7.9	7.97	7.83	7.24	7.98	7.3	7.97	7.83	8.03	7.8
2	Turbidity (NTU)	1.6	0.9	4	2.1	2.1	2.1	2.0	5.6	6	4.8	3.4	1.2	2.8	8.9	6	2.4	4	1.8
3	T.S (mg/l)	42800	41800	36600	41800	41400	41000	41600	42800	41800	44000	33400	20600	34800	38400	38400	28600	35400	34600
4	T.D.S (ppt)	26.59	26.41	23.51	26.22	26.2	26.56	26.2	26.11	25.55	25.77	21.24	15.41	22.51	25.26	25.11	19.11	23.57	21.9
5	T.S.S (mg/l)	16210	15390	13090	15580	15200	14440	15400	16690	16250	18230	12160	5190	12290	13140	13290	9490	11830	12700
6	Salinity (ppt)	35.45	35.22	30.84	35.09	35.2	35.75	34.79	35.05	34.2	34.36	27.69	19.31	29.5	33.2	33.27	24.5	31.22	28.44
7	Conductivity(mS)	52.13	51.63	45.98	51.34	51.22	51.84	51.21	51.05	50.07	50.38	41.54	30.12	44.01	49.18	49.17	37.36	46	42.8
8	Resistivity (Ω)	18.8	18.94	21.27	19.02	19.08	18.83	19.09	19.14	19.53	19.39	23.53	32.43	22.21	19.86	19.92	26.2	21.19	22.87
9	Acidity (mg/l)	17.6	26.4	26.4	26.4	30.8	17.6	17.6	35.2	22	13.2	22	17.6	22	30.8	30.8	22	17.6	17.6
10	Alkalinity (mg/l)	160	150	250	160	160	170	150	170	150	160	150	90	140	190	200	200	160	120
11	Hardness (mg/l)	570	626	462	600	618	460	526	540	494	564	450	274	480	474	560	588	458	384
12	Calcium (mg/l)	42.453	33.642	32.04	38.448	36.846	28.035	36.045	35.244	25.632	29.637	20.826	16.821	25.632	38.448	34.443	24.03	27.234	26.43
13	Magnesium(mg/l)	112.968	131.958	93.004	122.706	128.063	94.951	106.151	110.046	104.69	119.298	96.9	56.484	101.282	92.03	115.402	128.55	94.951	77.42
14	Chloride (mg/l)	22365	22010	18460	22720	21797	21300	21143.8	22720	21087	21300	17210.4	11473.6	19468.2	20149.8	20206.6	15449.6	19198.4	18048.2
15	Sulphate (mg/l)	170	164	161	161	156	159	170	163	161	163	159	152	156	156	159	156	156	156
16	Sodium (ppt)	21.24	21.34	18.54	20.44	11.72	21.34	21.34	21.24	17.44	17.04	15.48	13.24	17.54	23.14	20.04	15.84	15.24	17.54
17	Potassium (mg/l)	163.985	126.019	103.998	126.019	279.96	133.996	133.996	133.996	879.99	153.999	209.7	819.93	859.97	1519.82	1179.99	660.01	620.01	879.99
18	Total Phosphorous(mg/l)	30.0	10.5	17.5	4.5	8.0	16.0	3.5	35.0	2.5	3.5	0.03	0.04	3.5	120.0	15.5	2.5	1.0	1.0
19	Total Nitrogen (mg/l)	35	35	42	28	28	21	35	42	28	21	28	28	35	42	35	28	28	28

Table 3.23. Results on the physico chemical characterization of sediment samples along different locations in Kozhikode district

Sl No:	Parameters	KKD 1	KKD 2	KKD 3	KKD 4	KKD 5	KKD 6	KKD 7	KKD 8	KKD 9	KKD 10	KKD 11	KKD 12	KKD 13	KKD 14	KKD 15	KKD 16	KKD 17	KKD 18
1	pH	7.33	8.15	6.6	6.94	7.55	7.64	7.93	7.4	7.31	7.11	7.21	6.7	7.19	7.65	6.66	7.26	7.89	7.64
2	Moisture %	6.3	5.4	21.36	15.8	6.8	5.4	8.9	7.5	2.5	25.8	6.8	5.7	3.9	11.5	27.3	8.9	5.6	9.5
3	Sand %	93.2	85.9	66.7	80.6	75.4	79.3	67.7	32.4	81.7	62.2	76.0	79.3	76.5	73.1	58.0	50.9	54.8	53.3
4	Silt %	0.2	0.4	0.2	0.2	0.4	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.2	0.3	0.1	0.1
5	Clay %	6.6	13.7	33.1	19.2	24.2	20.6	32.2	67.5	18.2	37.7	23.8	20.6	23.4	26.8	41.8	48.8	45.1	46.6
6	Organic carbon (gm/kg)	1.97	3.29	91.58	12.77	22.74	5.31	35.73	48.2	8.68	98.26	26.76	4.41	0.98	12.62	22.36	155.46	111.26	125.96
7	Nitrogen (mg/kg)	560	840	2240	840	840	420	700	2940	840	1401	1470	770	630	910	1820	1540	1401	1680
8	Total Phosphorous (mg/kg)	32.5	42.0	63.5	39.5	60.5	28.0	38.5	70	55.5	69.5	54.5	32.5	35.0	14.5	68.2	74.5	89.5	130.5
9	Potassium(mg/kg)	17.52	24.99	39.99	10.01	22.48	2.50	12.51	149.99	34.99	60.02	60.02	0	2.50	25.02	67.49	52.51	69.99	74.99
10	Sodium (ppt)	0.7125	0.1075	0.4325	0.1425	0.1775	0.025	0.145	1.2325	0.235	0.5725	0.1675	0.1725	0.0625	0.215	0.5375	0.4325	0.66	0.52

Elathur (KKD 5) and Cheliya (KKD 11) of Kozhikode district were noted to be ideal for the afforestation of *Bruguiera cylindrica* (Plate 3.6). Also, these two sites were moderately ideal for all the other 4 species. Kooniyil kadavu (KKD 9) and Nelliyadikadavu (KKD 12) were moderately ideal for *Avicennia officinalis*. The other moderately ideal sites were Beypore (KKD 2) for all the 5 species under study; Thekkeppuram (KKD 4) and Aanappara (KKD 10) for *A. officinalis, B. cylindrica* ,*S. alba*, *E. agallocha* and *R. mucronata*; Chaliyam for *Avicennia officinalis* and *B. cylindrica*; Venkalam (KKD 8) for *B. cylindrica* and *E. agallocha*; Kuttiyammal (KKD 14) for *A. officinalis* and *E. agallocha*; Puramkara (KKD 15) for *A. officinalis, B. cylindrica* and *R. mucronata*; Mooradu (KKD 16) for *B. cylindrica, E. agallocha* and *R. mucronata*; Kottakkal (KKD 17) for *B. cylindrica* and *R. mucronata*; Puthiyottilkadavu (KKD 7) for *E. agallocha* and Iringal (KKD 18) for *R. mucronata*.

18 sites were selected for assessing the physico chemical characteristics of water and sediments in the district of Kannur to elucidate the possibilities of mangrove afforestation. The results are depicted in Tables 3.24 – 3.25.

Table 3.24. Results on the physico-chemical characterization of water samples along different locations in Kannur district

Sl No :	Parameters	KNR 1	KNR 2	KNR 3	KNR 4	KNR 5	KNR 6	KNR 7	KNR 8	KNR 9	KNR 10	KNR 11	KNR 12	KNR 13	KNR 14	KNR 15	KNR 16	KNR 17	KNR 18
1	pH	7.27	7.14	7.41	7.75	7.94	7.69	7.39	7.15	7.08	7.1	7.54	7.5	7.62	7.88	8.04	7.78	7.19	7.54
2	Turbidity(NTU)	0.1	1.2	0.1	0.3	0.3	0.1	1	1.2	0.6	0.5	0.1	1.2	0.1	0	0.2	0.1	0.7	0.2
3	T.S (mg/l)	21000	24600	26600	28400	35800	45600	25400	17400	17400	16600	21200	25400	23000	33400	34400	27600	25800	20200
4	T.D.S (ppt)	14.58	17.19	18.14	18.91	23.66	17.09	15.89	12.34	12.4	11.76	13.78	17.1	15.73	19.55	22.13	17.81	17.59	13.45
5	T.S.S (mg/l)	6420	7410	8460	9490	12140	28510	9510	5060	5000	4840	7420	8300	7270	13850	12270	9790	8210	6750
6	Salinity(ppt)	18.29	21.8	23.28	24.23	31.18	21.76	20.15	15.21	15.29	14.4	17.19	21.82	19.85	25.2	28.88	22.76	22.42	16.68
7	Conductivity (mS)	28.5	33.53	35.43	36.96	46.25	33.42	31.07	24.1	24.25	22.98	26.94	33.43	30.76	38.22	43.27	34.82	34.38	26.3
8	Resistivity (Ω)	34.32	29.14	27.53	26.45	21.14	29.2	31.42	40.58	40.31	42.53	36.29	29.24	31.78	25.57	22.63	28.09	28.45	37.16
9	Acidity (mg/l)	19.8	26.4	17.6	13.2	17.6	17.6	22	13.2	110	13.2	13.2	8.8	13.2	17.6	13.2	13.2	22	17.6
10	Alkalinity (mg/l)	120	130	130	130	170	140	140	110	400	140	130	160	130	120	130	160	160	140
11	Hardness (mg/l)	332	390	427	440	370	388	350	280	272	270	296	386	346	446	526	416	420	307
12	Calcium (mg/l)	22.428	25.632	29.637	34.443	38.448	27.234	24.03	20.826	18.423	18.423	22.428	26.433	24.03	30.438	34.443	28.035	27.234	21.627
13	Magnesium (mg/l)	67.196	79.37	85.943	86.187	66.71	77.91	70.605	55.51	55.023	54.536	58.432	77.91	69.631	90.082	107.125	84.239	85.7	61.6
14	Chloride (mg/l)	11289	12993	13774	14910	18886	14058	12638	9088	9301	8946	10863	13064	13135	15691	18602	20235	13632	10579
15	Sulphate (mg/l)	156	159	157	157	159	155	155	151	145	148	153	156	155	158	160	156	158	153
16	Sodium (ppt)	14.85	16.9	22.3	4	10.92	29.65	12.85	11.17	8.17	10.12	10.07	10.7	13.55	2.1	22.3	15.05	8.07	11.77
17	Potassium (mg/l)	580.987	331.00	333.49	323.50	601.06	336.00	587.986	601.006	603.000	606.011	603.000	328.497	582.981	326.002	316.49	578.0	615.9	596.001
18	Total Phosphorous(mg/l)	7.5	7.5	0.6	3.0	4.5	4.0	11.0	7.0	29.5	5.5	3.5	18.0	4.5	2.5	0.1	5.5	21.0	0.02
19	Total Nitrogen (mg/l)	28	28	28	28	21	21	28	21	42	28	21	28	35	28	28	21	21	21

Table 3.25. Results on the physico chemical characterization of sediment samples along different locations in Kannur district

Sl No:	Parameters	KNR 1	KNR 2	KNR 3	KNR 4	KNR 5	KNR 6	KNR 7	KNR 8	KNR 9	KNR 10	KNR 11	KNR 12	KNR 13	KNR 14	KNR 15	KNR 16	KNR 17	KNR 18
1	pH	8.56	5.31	7.53	7.76	8.76	8.53	8.1	7	7.36	7.28	4.99	8.5	8.65	8.51	8.6	7.55	6.83	7.7
2	Moisture %	5.5	16.9	8.6	12.9	8.5	5.7	15.5	19.2	9.56	8.54	5.6	7.9	8.2	18.5	6.35	15.8	21.3	5.25
3	Sand %	82.7	59.7	62.3	47.9	87.0	53.4	61.3	71.3	77.8	94.9	83.4	89.1	91.0	85.6	91.6	83.4	66.6	89.9
4	Silt %	0.3	0.3	0.1	0.2	0.1	0.7	0.2	0.3	0.4	0.1	0.2	0.1	6.8	0.5	0.5	0.6	1.7	0.1
5	Clay %	17.0	40.0	37.6	51.9	12.9	45.9	38.5	28.4	21.8	5.0	16.4	10.8	2.2	13.9	7.9	16.0	31.7	10.0
6	Organic carbon (g/kg)	1.5	299.3	62.3	94.1	55.1	8.14	91.7	151.8	102.8	8.02	9.8	12.2	6.7	31	6.22	51.6	175.7	30.7
7	Nitrogen (mg/kg)	1401	3990	1330	1750	770	560	2310	1750	1960	840	560	630	560	490	700	1680	2450	700
8	Total Phosphorous (mg/kg)	71.5	44.5	46.2	80.0	109.5	51.0	85.5	53.5	72.0	63.0	51.0	41.0	85.0	41.0	38.0	61.0	78.0	41.0
9	Potassium (mg/kg)	32.49	55.01	39.99	20.02	0	5.01	34.99	47.51	7.51	2.50	15.01	15.01	5.01	5.01	10.01	5.01	47.51	5.01
10	Sodium (ppt)	0.2425	0.3	0.16	0.21	0.035	0.06	0.41	0.2225	0.015	0.015	0.2375	0.2175	0.0575	0.06	0.0475	0.375	0.475	0.065

The results revealed that, Thiruvangad (KNR 2) was the ideal site for afforestation of for *Excoecaria agallocha* and *Rhizophora mucronata*. Aaruthengu (KNR16) and Valapattanam (KNR 9) were noticed to be ideal for *Bruguiera cylindrica* and *Avicennia officinalis* respectively (Plate 3.7). Kavumbhagom (KNR 1) and Sidhikkabad (KNR 17) were moderately ideal for all the species except *Sonneratia alba*. Mundambalam (KNR 7), Keeriyad (KNR 10) and Aaruthengu were moderately ideal for *A. officinalis, E. agallocha* and *R. mucronata.* The other moderately ideal sites were Thiruvangad and Kadavath (KNR 11) for *A. officinalis* and *B. cylindrical*; Nettur (KNR 3) for *B. cylindrica, E. agallocha* and *R. mucronata*; Koduvalli (KNR 4) for *A. officinalis* and *R. mucronata*; Meenthalapeedika (KNR 5) for *B. cylindrica* and *E. agallocha*; Kulamkadav (KNR 8) for *A. officinalis, B. cylindrica* and *R. mucronata*; Iranav (KNR 14) for *B. cylindrica, E. agallocha* and *Sonneratia alba*; Valapattanam for *B. cylindrica* and *Sonneratia alba*; Port road (KNR 12) for *B. cylindrica* and *E. agallocha* and Badikkad (KNR 18) for *A. officinalis*.

As far as Kasaragod district is concerned, 18 sites were selected and the physico chemical analysis of water and sediment from all the sites has been carried out. The results are depicted in the following Tables 3.26 – 3.27.

Table 3.26. Results on the physico-chemical characterization of water samples along different locations in Kasaragod district

Sl No :	Parameters	KSD 1	KSD 2	KSD 3	KSD 4	KSD 5	KSD 6	KSD 7	KSD 8	KSD 9	KSD 10	KSD 11	KSD 12	KSD 13	KSD 14	KSD 15	KSD 16	KSD 17	KSD 18
1	pH	7.64	7.67	7.36	7.8	7.82	8.1	7.6	7.85	7.68	7.87	8	7.7	7.54	6.96	7.18	6.66	7.37	6.63
2	Turbidity (NTU)	0.1	0.1	0	0	0	0.4	0.1	0.1	0	0.1	0.5	0.1	0.1	0	0	0.1	0.6	0
3	T.S (mg/l)	24000	24200	24200	26200	26600	28400	28400	34000	28800	32600	35800	20200	27600	5000	9400	200	12600	2600
4	T.D.S (ppt)	17.05	17	16.67	17.89	19.04	19.35	19.62	23.31	20.02	22.11	23.72	14.44	19	3.824	7.201	0.1108	9.326	2.259
5	T.S.S (mg/l)	6950	7200	7530	8310	7560	9050	8780	10690	8780	10490	12080	5760	8600	1176	2199	89.2	3274	341
6	Salinity (ppt)	21.76	21.64	21.24	22.89	24.64	25.04	25.42	30.81	25.99	29.05	31.5	18.15	24.59	4.276	8.471	0.1103	11.1	2.443
7	Conductivity (mS)	33.33	33.24	32.64	34.98	37.19	37.83	38.35	45.6	39.14	43.27	46.38	28.23	37.22	7.475	14.08	0.2158	18.23	4.416
8	Resistivity(Ω)	29.33	29.42	29.97	27.95	26.26	25.87	25.48	21.45	24.98	22.61	21.05	34.64	26.28	130.9	69.48	4689	53.75	221.5
9	Acidity (mg/l)	17.6	22	17.6	15.4	19.8	17.6	26.4	22	35.2	22	17.6	11	22	8.8	13..2	17.6	13.2	17.6
10	Alkalinity (mg/l)	140	130	130	130	150	150	170	140	170	150	210	100	140	50	70	50	100	60
11	Hardness (mg/l)	200	392	336	418	445	260	273	368	480	528	372	324	452	87	166	8	216	54
12	Calcium (mg/l)	36.846	32.04	31.239	29.637	32.841	35.244	32.841	42.453	34.443	38.448	37.647	24.03	32.841	8.01	13.617	0.801	16.02	8.01
13	Magnesium (mg/l)	26.294	75.961	62.814	83.752	88.378	41.876	46.502	63.788	95.925	105.177	67.683	64.275	90.082	16.312	32.137	1.461	42.85	8.278
14	Chloride (mg/l)	13135	13774	12567	13490	14129	15194	15123	17963	14981	19525	17750	11573	14910	3337	6248	994	7810	2769
15	Sulphate (mg/l)	166	160	158	152	152	154	140	155	151	155	155	149	151	114	136	12.5	144	92
16	Sodium (ppt)	14.25	12.57	15.35	5.85	15.55	3.6	11.72	1.4	10.92	12.57	17.3	11.42	0.94	3.46	14.85	9.12	6.08	5.68
17	Potassium (mg/l)	578.015	696.997	575.982	328.49	568.002	323.50	592.991	646.999	601.06	696.97	815.86	592.91	646.988	662.002	575.982	681.982	625.991	672.012
18	Total Phosphorous (mg/l)	1.0	0.02	0.03	2.5	2.5	0.35	5.0	11.0	8.0	5.0	6.5	1.5	3.0	0.05	0.8	0.03	20.0	0.05
19	Total Nitrogen (mg/l)	28	35	21	42	21	28	28	21	28	21	35	21	21	28	28	28	35	28

Table 3.27. Results on the physico-chemical characterization of sediment samples along different locations in Kasaragod district

Sl No:	Parameters	KSD 1	KSD 2	KSD 3	KSD 4	KSD 5	KSD 6	KSD 7	KSD 8	KSD 9	KSD 10	KSD 11	KSD 12	KSD 13	KSD 14	KSD 15	KSD 16	KSD 17	KSD 18
1	pH	5.1	4.47	6.32	5.52	8.35	7.58	2.84	8.34	8.08	8.83	8.48	8.66	7.5	3.87	6.73	5.82	7.78	6.93
2	Moisture %	7.75	5.25	8.35	4.8	9.6	24.8	6.8	9.25	6.39	25.8	12.6	18.2	12.5	8.9	6.4	7.5	8.45	6.5
3	Sand %	92.6	93.6	90.8	85.4	86.0	80.9	89.5	95.0	83.1	9.4	93.4	79.0	37.7	73.9	47.5	83.2	79.3	84.2
4	Silt %	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.6	0.1	0.3	0.1	0.2	0.1
5	Clay %	7.2	6.3	9.1	14.5	13.9	18.9	10.4	4.9	16.8	8.5	6.5	20.9	61.7	2.0	52.2	16.7	20.5	15.7
6	Organic carbon (g/kg)	13.3	5.3	8.1	9.0	11.04	4.31	26.44	12.66	13.88	5.3	11.79	6.23	41.61	11.33	31.72	25.22	9.0	19.2
7	Nitrogen (mg/kg)	630	560	700	560	700	420	770	1540	1120	420	560	560	1540	700	1470	910	700	1401
8	Total Phosphorous (mg/kg)	15.5	12.8	12.5	8.5	18.0	13.0	28.0	64.0	42.0	14.5	23.5	36.5	105.5	32.0	48.0	41.0	37.8	37.5
9	Potassium(mg/kg)	12.51	7.51	10.01	15.01	2.50	12.51	22.48	7.51	20.02	2.50	5.01	2.50	64.98	2.50	22.48	0	5.01	15.01
10	Sodium (ppt)	0.2975	0.19	0.22	0.3175	0.1325	0.27	0.225	0.08	0.1275	0.0275	0.045	0.0425	0.45	0.235	0.47	0.2	0.29	0.3925

The results revealed that sites Chithari (KSD 15) and Keeyoor Kadavath (KSD 17) were ideal for *Excoecaria agallocha* and *Avicennia officinalis* respectively whereas, Chemanad (KSD 18) was ideal for *Bruguiera cylindrica* and *Excoecaria agallocha* (Plate 3.7). Udumbumthala (KSD 1) and Keeyoor Kadavath were moderately ideal for *Rhizophora mucronata*. The other moderately ideal sites noticed were Kaikkottukadav (KSD 3) for *E. agallocha*; Idayilekkadu Island (KSD 5), Thekkekkadu (KSD 7) and Mattummal (KSD 9) for *Avicennia officinalis, B. cylindrica* and *E. agallocha*; Madakkara (KSD 13) for *R. mucronata*; Vellapp (KSD 4) for *B. cylindrica*, *E. agallocha*, *R. mucronata* and *S. alba*; Ayittikkadav (KSD 6) for *A. officinalis, B. cylindrica, R. mucronata* and *S. alba*; Orcha (KSD 14) for *A. officinalis, E. agallocha* and *R. mucronata*; Chithari () for *A. officinalis* and *R. mucronata*; Kappil (KSD 16) for *B. cylindrica* and *E. agallocha* and Chemanad for *A. officinalis, R. mucronata* and *S. alba*.

A consolidation of sites ideal for species specific mangrove introduction are given in Table 3.28.

Table 3.28. Details of moderately ideal, ideal and perfectly ideal sites for mangrove afforestation along all the districts under study

Trivandrum					
Class	**Number of sites**				
	Avicennia officinalis	*Bruguiera cylindrica*	*Excoecaria agallocha*	*Rhizophora mucronata*	*Sonneratia alba*
A	5	10	9	10	14
B	11	9	7	8	4
C	3	0	3	1	1
D	0	0	0	0	0
E	0	0	0	0	0
Kollam					
Class	**Number of sites**				
	Avicennia officinalis	*Bruguiera cylindrica*	*Excoecaria agallocha*	*Rhizophora mucronata*	*Sonneratia alba*
A	6	6	8	6	15
B	11	10	8	9	3
C	1	2	2	3	0
D	0	0	0	0	0
E	0	0	0	0	0
Alleppey					
Class	**Number of sites**				
	Avicennia officinalis	*Bruguiera cylindrica*	*Excoecaria agallocha*	*Rhizophora mucronata*	*Sonneratia alba*
A	6	10	11	9	17
B	9	7	6	5	0
C	3	1	1	3	1
D	0	0	0	1	0
E	0	0	0	0	0
Ernakulam					
Class	**Number of sites**				
	Avicennia officinalis	*Bruguiera cylindrica*	*Excoecaria agallocha*	*Rhizophora mucronata*	*Sonneratia alba*
A	2	4	7	4	15
B	15	13	11	9	3
C	1	1	0	5	0

D	0	0	0	0	0
E	0	0	0	0	0
Thrissur					
Class	**Number of sites**				
	Avicennia officinalis	*Bruguiera cylindrica*	*Excoecaria agallocha*	*Rhizophora mucronata*	*Sonneratia alba*
A	3	5	3	2	10
B	12	8	10	7	7
C	3	5	5	6	1
D	0	0	0	3	0
E	0	0	0	0	0
Malappuram					
Class	**Number of sites**				
	Avicennia officinalis	*Bruguiera cylindrica*	*Excoecaria agallocha*	*Rhizophora mucronata*	*Sonneratia alba*
A	8	7	2	6	13
B	9	7	13	8	4
C	1	4	3	4	1
D	0	0	0	0	0
E	0	0	0	0	0
Kozhikode					
Class	**Number of sites**				
	Avicennia officinalis	*Bruguiera cylindrica*	*Excoecaria agallocha*	*Rhizophora mucronata*	*Sonneratia alba*
A	8	8	9	9	15
B	10	8	9	9	3
C	0	2	0	0	0
D	0	0	0	0	0
E	0	0	0	0	0
Kannur					
Class	**Number of sites**				
	Avicennia officinalis	*Bruguiera cylindrica*	*Excoecaria agallocha*	*Rhizophora mucronata*	*Sonneratia alba*
A	7	7	8	9	16
B	10	10	9	8	2
C	1	1	1	1	0

D	0	0	0	0	0
E	0	0	0	0	0
Kasaragod					
Class	**Number of sites**				
	Avicennia officinalis	*Bruguiera cylindrica*	*Excoecaria agallocha*	*Rhizophora mucronata*	*Sonneratia alba*
A	9	10	8	10	15
B	8	7	8	8	3
C	1	1	2	0	0
D	0	0	0	0	0
E	0	0	0	0	0

A: not ideal, B: moderately ideal, C: ideal, D: perfectly ideal and E: exemplarily ideal

From all the results, it can be concluded that, three sites each in Trivandrum, Alleppey and Thrissur; one site each in Kollam, Ernakulam, Malappuram, Kannur and Kasaragod districts are ideal for the afforestation of *Avicennia officinalis*. *Bruguiera cylindrica* was noticed to be ideal for afforestation along five sites in Thrissur, four sites in Malappuram, two sites each in Kollam and Kozhikode and one site each in Alleppey, Ernakulam, Kannur and Kasaragod districts. The species *Excoecaria agallocha* was found to be ideal for afforestation along five sites in Thrissur, three sites each in Trivandrum and Malappuram, two sites each in Kollam and Kasaragod and one site each in Kannur and Alleppey districts. With respect to *Rhizophora mucronata*, six sites in Thrissur, five sites in Ernakulam, four sites in Malappuram, three sites each in Alleppey and Kollam and one site each in Trivandrum and Kannur districts were found ideal for afforestation. Three sites in Thrissur and one site in Alleppey districts were found to be perfectly ideal for the introduction of *Rhizophora mucronata*. The species *Sonneratia alba* was found to be ideal for afforestation along one site each in Trivandrum, Alleppey, Thrissur and Kollam districts.

Thus, out of 163 sites studied the numbers of perfectly ideal, ideal and moderately ideal sites for the afforestation of different mangrove species have been worked out. From the results it can be concluded that, 4 sites are perfectly ideal for the introduction of *Rhizophora mucronata*. The numbers of ideal sites for the afforestation of different species are 14 sites for *Avicennia officinalis*, 17 sites each for *Bruguiera cylindrica* and *Excoecaria agallocha*, 18 sites for *Rhizophora mucronata* and 4 sites for *Sonneratia alba*. Similarly, 95 moderately ideal sites for the introduction of *Avicennia officinalis*, 79 for *Bruguiera cylindrica*, 81 for *Excoecaria agallocha*, 71 for *Rhizophora mucronata* and 29 for *Sonneratia alba* have also been noticed.

Based on the textural classes of soil/sediment preferred by various mangrove species (Plate 3.8), attempt has also been carried out to demarcate ideal sites for mangrove afforestation. The sediment classes worked out for each site along 9 districts under study are depicted in Table 3.29.

Table 3.29. Textural classes of soil / sediment samples along all the sites along 9 districts of Kerala

Sl No:	Textural Class								
	TVM	**KLM**	**ALP**	**EKM**	**TSR**	**MPM**	**KKD**	**KNR**	**KSD**
1.	Sand	Loamy sand	Loamy sand	Sandy clay	Sand	Sandy clay loam	Sand	Sandy loam	Sand
2.	Sandy clay loam	Sand	Loamy sand	Sandy clay loam	Loamy sand	Loamy sand	Loamy sand	Sandy clay	Sand
3.	Sandy loam	Sand	Sand	Sandy clay loam	Sandy loam	Sandy clay	Sandy clay loam	Sandy clay	Sand
4.	Sandy clay loam	Loamy sand	Loamy sand	Sandy clay	Loamy sand	Sandy clay	Sandy loam	Sandy clay	Loamy sand
5.	Sand	Sand	Loamy sand	Clay	Sandy clay loam	Sandy loam	Sandy clay loam	Loamy sand	Loamy sand
6.	Sand	Sandy clay	Sandy loam	Loamy sand	Sandy clay loam	Sandy loam	Sandy clay loam	Sandy clay	Sandy loam
7.	Sand	Sand	Sand	Sandy clay	Sand	Sandy loam	Sandy clay loam	Sandy clay	Loamy sand
8.	Sand	Loamy sand	Loamy sand	Sandy clay loam	Sand	Sandy clay	Clay	Sandy clay loam	Sand

9.	Loamy sand	Loamy sand	Sandy clay loam	Sandy clay loam	Sandy loam	Loamy sand	Sandy loam	Sandy clay loam	Sandy loam
10.	Sand	Loamy sand	Sandy clay	Sand	Loamy sand	Sandy clay loam	Sandy clay	Sand	Sand
11.	Sand	Sandy loam	Sand	Sand	Loamy sand	Loamy sand	Sandy clay loam	Sandy loam	Sand
12.	Loamy sand	Sand	Sandy clay loam	Sandy clay loam	Sandy clay loam	Loamy sand	Sandy clay loam	Loamy sand	Sandy clay loam
13.	Sand	Sandy clay loam	Sandy clay loam	Loamy sand	Sandy clay	Loamy sand	Sandy clay loam	Sand	Clay
14.	Sand	Sandy clay loam	Sand	Loamy sand	Sandy loam	Loamy sand	Sandy clay loam	Loamy sand	Loamy sand
15.	Sand	Loamy sand	Sand	Sand	Sandy clay loam	Sandy clay loam	Sandy clay	Sand	Sandy clay
16.	Sand	Sandy clay	Sandy clay loam	Sandy loam	Sand	Sandy clay loam	Sandy clay	Sandy loam	Sandy loam
17.	Sand	Sand	Sand	Sandy loam	Sandy loam	Sandy clay	Sandy clay	Sandy clay loam	Sandy clay loam
18.	Sand	Loamy sand	Sandy loam	Sand	Sandy clay	Sandy clay loam	Sandy clay	Loamy sand	Sandy loam
19.	Sandy clay loam	-	-	-	-	-	-	-	-

Upon comparing the present result with standard textural class preferred by each mangrove species, the sites ideal for their afforestation have been demarcated. Accordingly the most ideal sites for the afforestation of *Avicennia officinalis* and *Sonneratia alba* were Manamel of Trivandrum district, Velithuruth of Kollam district, Manivelikkadav and Kuthuthodu of Alleppey district, Mosco road and Munambam of Ernakulam district, Marthoma Nagar, Veluthakadav, Kundukadav and Banglamkadav of Thrissur district, Poorappuzha Bridge side, Mangalam Bridge side and Koottayi of Malappuram district, Thekkeppuram of Kozhikkode district, Kavumbhagom, Kadavath, Aaruthengu of Kannur district, and Ayittikkadav, Mattummal, Kappil and Chemanad of Kasaragod district.

Studies based on textural analysis revealed that, the most ideal sites for the afforestation of *Bruguiera cylindrica* and *Excoecaria agallocha* were Madhavapuram and Murukkumpuzha Kadavu of Trivandrum district; Kappil, Pozhikkara, Sasthamthodi, Neeravil, MadathilKayalvaaram, Cheriyazheekkal and Pancharathopp of Kollam district; Valiyazheekkal 1, Valiyazheekkal2, Arattupuzha, Kandallur and Mahadevikaad of Alleppey district; Ponnarimangalam, Karuthala west and Pallippuram, of Ernakulam district; Methala, Muttichur kadav and Meenkadav of Thrissur district; Pariyapuram 2, Chamravattom Kadav, Puthuponnani east, Puthuponnani west and Puthuponnani Munambam of Malappuram district; Beypore of Kozhikkode district; Meenthalapeedika, Port road, Iranav and Badikkad of Kannur district; Vellapp, Idayilekkadu Island, Thekkekkadu and Orcha of Kasaragod district.

The most ideal sites noted for the afforestation of *Rhizophora mucronata* were Munnattumukku, Panathura and chambavu of Trivandrum district; Kochochira of Kollam district; Pulikkeril, Purakkad, Kannattakkadav, Andakaranazhi of Alleppey district; Illikkal, Padasekharam road, Moolambilli, Kothad Island and Kadakkara of Ernakulam district; Idamukk, Kuzhivathkadav, Orumanayur and Moonnamkall of Thrissur district; Pariyapuram 1, Thayyilakkadavu, Olipram kadavu and Kottappadi of Malappuram district; Chalappuram, Elathur, Korappuzha, Cheliya, Nelliyadikadavu, Puthuppanam and Kuttiyammal of Kozhikode district; Kulamkadav, Valapattanam and Sidhikkabad of Kannur district; Orkkalam and Keeyoor Kadavath of Kasaragod district.

On the basis of different textural classes, sites ideal for afforestation of different mangrove species have been demarcated. The results were comparable with that elucidated on the basis of hydrological and sedimentological aspects. All these sites possessed significant share of growth determining attributes of different mangrove species. Thus it can be concluded that out of 163 sites studied, 21 sites each for *Avicennia officinalis* and *Sonneratia alba*; 34 sites each for *Bruguiera cylindrica* and *Excoecaria agallocha*; 30 sites for *Rhizophora mucronata* can be treated as the most ideal sites for the afforestation of such species along 9 districts of Kerala.

Summary and Conclusion

Strategic restoration / afforestation of mangroves require detailed comprehension on their growth sustaining conditions. As physico- chemical attributes of both water and sediment contribute to the growth and establishment of mangroves, consolidation of database concerning these attributes with respect to the area targeted for afforestation is very much significant. Assessment of the feasibility of an area prior to planting practices will reduce the risk of adaptability of species to such habitats and thereby cut short financial mobilizations to a greater extent. In this background, the present study has been undertaken for the demarcation of ideal sites for afforestation of selected mangrove species along the inland shoreline environments of Kerala.

The afforestation possibilities of selected mangrove species were assessed based on their range of tolerance to various hydrogeochemical and sedimentological characteristics as determined in Chapter II. Collection of both water and sediment samples were carried out from 163 locations falling in 9 districts of Kerala such as Trivandrum, Kollam, Alleppey, Ernakulam, Thrissur, Malappuram, Kozhikode, Kannur and Kasaragod. Entire collection was carried out during post monsoon season, which is characteristic in having higher concentration of all elements under target.

The tolerance range of mangrove species towards different physico-chemical parameters have been taken into account for assessing the most significant growth determinants of each mangrove species. The number of sites possessing all these attributes or a share was treated as ideal sites for afforestation of respective mangrove species. Based on these, different classes of sites have been described. Sites possessing 0-20% growth sustaining attributes of any mangrove species was treated as A, 21-40 % as B, 41-60% as C, 61-80% as D and 81-100% as E. Sites under category A were treated as non-ideal, B as moderately ideal, C as ideal, D as perfectly ideal and E as exemplarily ideal for afforestation of mangrove species.

The results revealed that, three sites each in Trivandrum, Alleppey and Thrissur; one site each in Kollam, Ernakulam, Malappuram, Kannur and Kasaragod districts are ideal for the afforestation of *Avicennia officinalis*. *Bruguiera cylindrica* was noticed to be ideal for afforestation along five sites in Thrissur, four sites in Malappuram, two sites each in Kollam and Kozhikode and one site each in Alleppey, Ernakulam, Kannur and Kasaragod districts. The species *Excoecaria agallocha* was found to be ideal for afforestation along five sites in Thrissur, three sites each in Trivandrum and Malappuram, two sites each in Kollam and Kasaragod and one site each in Kannur and Alleppey districts. With respect to *Rhizophora mucronata*, six sites in Thrissur, five sites in Ernakulam, four sites in Malappuram, three sites each in Alleppey and Kollam and one site each in Trivandrum and Kannur districts were found ideal for afforestation. Three sites in Thrissur and one site in Alleppey districts were found to be perfectly ideal for the introduction of *Rhizophora mucronata*. The species *Sonneratia alba* was found to be ideal for afforestation along one site each in Trivandrum, Alleppey, Thrissur and Kollam districts.

Thus it can be concluded that, out of 163 sites studied, 4 sites are perfectly ideal for the introduction of *Rhizophora mucronata*. The numbers of ideal sites for the afforestation of different species include 14 sites for *Avicennia officinalis*, 17 sites each for *Bruguiera cylindrica* and *Excoecaria agallocha*, 18 sites for *Rhizophora mucronata* and 4 sites for *Sonneratia alba*. Similarly, 95 moderately ideal sites for the introduction of *Avicennia officinalis*, 79 for *Bruguiera cylindrica*, 81 for *Excoecaria agallocha*, 71 for *Rhizophora mucronata* and 29 for *Sonneratia alba* have also been noticed.

Based on the textural classes of soil/sediment preferred by various mangrove species, attempt has also been carried out to demarcate ideal sites for mangrove afforestation. The results were comparable with that elucidated on the basis of hydrogeochemical and sedimentological aspects. All these sites possessed significant share of growth determining attributes of different mangrove species. Thus it can be concluded that out of 163 sites studied, 21 sites each for *Avicennia officinalis* and *Sonneratia alba*; 34 sites each for *Bruguiera cylindrica* and *Excoecaria agallocha*; 30 sites for *Rhizophora mucronata* can be treated as the most ideal sites for the afforestation of such species along 9 districts of Kerala.

GENERAL CONCLUSION

Mangroves are one among the most productive and biologically important ecosystem on this planet, providing unique and vital ecosystem services. Besides all these imperative services provided, these fragile ecosystems are under tremendous pressure.

In this context, the present study has been carried out to assess the ecology, extent and diversity of mangrove ecosystems in the coastal environments of Kerala (Chapter I). A survey has been carried out in this regard, which estimated the total extent to be 19.531 Km^2. It has also been highlighted that, out of 10 districts studied, Kannur district occupied maximum mangrove cover with 7.465 Km^2 which is around 38.22 % of the total extent, within the state. This is followed by Ernakulam district with 6.153 Km^2 (31.50 %). Minimum extent has been reported from Trivandrum district with 0.275 Km^2 (1.41 %).

Upon comparing the results of the present study with that of Basha (1991), there is a positive mangrove cover change of about 2.821 km^2 within the last 25 years. Among all the districts under study, Kollam (0.050 km^2), Kozhikode (1.723 km^2) and Kannur (0.085 km^2) showed a decreasing trend of mangrove cover. The study reveals that the mangroves in these districts have shrunken considerably to few patches, mainly in Dharmadom, Nadakkavu, Edakkad, Pappinisseri, Valapattanam, Muzhappilangad, Kunhimangalam, Pazhayangadi, Kavvayi, Thalassery and Ezhimala of Kannur district; Kottooli, Koduvally, Kallai and Kadalundi of Kozhikkode district and Asraamam and Shaktikulangara of Kollam district. High extent of degradation in the total mangrove cover has been noticed in the Kozhikode district. The year wise mangrove declining rate of Kozhikode district (0.069 Km^2/yr) is alarmingly indicating the fact that, the remaining mangrove patches will be degraded within the next 20 years.

Attempt has also been carried out to study true mangrove species of Kerala. The results revealed that, the state is endowed with 15 True mangrove species as a whole. They are *Aegiceras corniculatum, Avicennia marina, Avicennia officinalis, Bruguiera cylindrica, B. gymnorhiza, B. sexangula, Ceriops tagal, Excoecaria agallocha, E. indica, Kandelia candel, Lumnitzera racemosa, Rhizophora apiculata, R. mucronata, Sonneratia alba* and *S. caseolaris* under the families Myrsinaceae, Avicenniaceae, Euphorbiaceae, Rhizophoraceae, Combretaceae and Sonneraceaceae. Among different families reported, Rhizophoraceae possesses the maximum number of species (7) followed by Avicenniaceae (2 species), Euphorbiaceae (2 species), Sonneraceaceae (2 species), Combretaceae (1 species) and Myrsinaceae (1 species). The study revealed that, even though the existing mangrove areas are highly localized, the species diversity is comparatively rich. This indicated the existence of diversified group of mangroves in Kerala.

Even though there was positive mangrove cover change in the State as a whole, drastic degradation has been undergoing in many of the urbanized and semi urbanized areas especially in Kozhikode and Kannur districts. If this unsystematic destruction proceeds unchecked, the mangrove patches may completely wiped out within few years. Since the survival of this eco system is very important for the well being of all coupled flora and fauna, intensive and extensive conservation should be undertaken without delay.

Afforestation of mangroves seems to be a promising solution for the restoration of lost ecosystems. Successful restoration/afforestation practices of mangroves require reliable comprehension on their specific growth sustaining circumstances. In pursuit of this, the present study has been carried out to evaluate the physico-chemical characteristics of water and sediment along with climatological attributes determining the growth and establishment of selected mangrove species *Avicennia officinalis*, *Bruguiera cylindrica*, *Excoecaria agallocha*, *Rhizophora mucronata* and *Sonneratia alba* along heterogeneous natural habitats in Kerala (Chapter II).

The study stated that the ‘tolerance range’ of a species with respect to the site is a mandatory requirement towards including them in afforestation purposes whereas the ‘augmented range’ gains significance only after the acclimatization of the species in the new area. In conclusion, the study emphasized that all the afforestation/ restoration practices of mangrove must be either species or site specific. The study also consolidated the tolerance and augmented range of *Avicennia officinalis*, *Bruguiera cylindrica*, *Excoecaria agallocha*, *Rhizophora mucronata* and *Sonneratia alba* with respect to hydrogeochemical and sedimentological characteristics.

Attempts were also carried out to demarcate the sites ideal for species specific afforestation along the inland coastline environments of Kerala. Altogether163 sites falling under 9 coastal districts of Kerala such as Trivandrum, Kollam, Alleppey, Ernakulam, Thrissur, Malappuram, Kozhikode, Kannur and Kasaragod were selected. The tolerance range of mangroves species towards different physico-chemical parameters have been taken in to account to assess the most significant growth determinants of each mangrove species. The numbers of sites possessing all these attributes or a share were treated as ideal sites for afforestation of respective mangrove species.

Upon considering the hydrogeochemical as well as the sedimentological characteristics of selected locations, all these sites were coming either in the moderately ideal, ideal or perfectly ideal category. Thus it can be concluded that out of 163 sites, 21 sites each for *Avicennia officinalis* and *Sonneratia alba*; 34 sites each for *Bruguiera cylindrica* and *Excoecaria agallocha* and 30 sites for *Rhizophora mucronata* can be treated as the most ideal sites for the species specific afforestation along 9 districts of Kerala.

REFERENCES

Ajithkumar, T. T., Thangaradjou, T. and Kannan, L. (2006). Physico-chemical and biological properties of the Muthupettai mangrove in Tamil Nadu. *Journal of the Marine Biological Association of India:* 48, 131-138.

Aksornkoae, S. (1975). Structure, regeneration and productivity of mangrove in Thailand. *Ph. D. Thesis, Michigan State University*, 109.

Alongi, D. M. (2002). Present state and future of the world's mangrove forests. *Environmental Conservation* 29: 331–349.

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

Alongi, D.M. (2014). Carbon cycling and storage in mangrove forests. *Annual Review of Marine Science*: 6, 195–219.

Angsupanich, S. and Havanond, S. (1996). Effects of barnacles on mangrove seedling transplantation at Ban Don Bay, Southern Thailand. *Proceedings of the Tropical Forestry in the 21st Century (FORTROP '96). Kasetsart University, Bangkok*, 72-81.

Anon. 1997. Estuaries of India: State of the Art Report. ENVIS, Publication Series, 2/97

Anonymous (1984). A profile of the Indian Mangrove. *Bakawan Newsletter:* 3, 10.

Alshawafi, A., Analla, Md., Aksissou, M. and Triplet, P. (2016). Physicochemical Properties of Water, Soil, and Morphological Characteristics of Mangrove Forests in the Island of Kamaran, Al Hodaidah, Yemen. *Journal of Ecosystem & Ecography*: 6, 211.

Anupama, C. and Sivadasan, M. (2004). Mangroves of Kerala, India. *Rheedea:* 14, 9–46.

APHA. (2005), Standard Methods for the Examination of Water and Wastewater. 21st Edition, American Public Health Association/American Water Works Association/Water Environment Federation, Washington DC.

Ashok Prabhu, V., Rajkumar, M. and Perumal, P .(2008). Seasonal variations in physico-chemical characteristics of Pichavaram mangroves, southeast coast of India. *Journal of environmental Biology*: 29, 945-95.

Azariah, J., Azariah, H., Gunasekaran, S. and Selvam, V. (1992). Structure and species distribution in Coringa mangrove forest, Godavari delta, Andhra Pradesh, India. *Hydrobiologia*: 247, 11–16.

Balaji, V. and Gross, O. (2006). MANGREEN - Mangrove restoration and ecology in India. Deepwave Report No. 4/06, pp 40.

Balakrishnan, K.P. and Shynamma, C.S. (1976). Diel vanatlons in hydrographic conditions during different seasons in the Cochin Harbour (Cochin backwater). *Indian Journal of Marine Sciences*: 5 ,190-195.

Ball, M. C. and Pidsley, S. M. (1995). Growth responses to salinity in relation to distribution of two mangrove species, Sonneratia alba and S. lanceolata, in northern Australia. *Functional Ecology :9*, 77-85.

Banerjee, L. K., Sastry, A. R. K.and Nayar, M. P. (1989). Mangroves in India: identification manual. *Calcutta: Botanical Survey of India 113p.-illus., col. illus.. En Icones, Keys. Geog*, *6*.

Basha, S. C. (1991). Distribution of mangroves in Kerala. *Indian forester*: 117, 439-448.

Basha, S. C. (1992). Mangroves of Kerala-A fast disappearing asset. *Indian forester*: 118, 175-190.

Bhatt, J. R. and Kathiresan K. (2011). Biodiversity of mangrove ecosystems in India. In: Bhatt, J. R., Macintosh, D. J., Nayar, T. S., Pandey, C. N and B. P. Nilaratna (eds). Towards conservation and management of mangrove ecosystems in India. International Union for Conservation of Nature, India. 1-34

Blasco, F. (1975). The mangroves of India. Institute Francais de pondicheny, Travauxdela section. Scientific Technique No. 14, pp.175.

Blasco, F. (1977). Outlines of ecology, botany and forestry of the mangals of the Indian subcontinent. In: Chapman, V.J. (ed.), *Wet coastal ecosystems of the world*, Elsevier Scientific Publishing, Amsterdam, pp. 241–260.

Bosold, A. L. (2012). Challenging the "Man" In Mangroves: The Missing Role of Women In Mangrove Conservation.

Boto, K. G. and Wellington, J. T. (1983). Phosphorus and nitrogen nutritional status of a northern Australian mangrove forest. *Marine Ecology Progress Series*, 63-69.

Boto, K. G., (1992). Nutrients and mangroves. In D. W. Connell & D. W. Hawker (eds.), Pollution in tropical aquatic systems. CRC Press, Boca Raton: pp.130–145.

Bouillon, S., Dahdouh-Guebas, F., Rao, A. V. V. S., Koedam, N. and Dehairs, F. (2003). Sources of organic carbon in mangrove sediments: variability and possible ecological implications. *Hydrobiologia*: *495*, 33-39.

Bourdillon, T.F. (1908). *The Forest Trees of Travancore*. Trivandrum, Kerala: Travancore Government Press. pp. 456.

Brahma, G. and Mukherjee, S. K. (2016). Studies on mangrove diversity of India with special reference to Lothian Island Wildlife Sanctuary. *Plant Science Today*: *3*, 25-29.

Carter, H. N., Schmidt, S. W. and Hirons, A. C. (2015). An international assessment of mangrove management: Incorporation in integrated coastal zone management. *Diversity*: 7, 74-104.

Castelle, A. J., Johnson, A. W. and Conolly, C. (1994). Wetland and stream buffer size requirements- a review. *Journal of Environmental Quality*: *23*, 878-882.

Central Ground Water Board (2013). Technical reports: Series ‘D. Ground water information booklet of different districts of Kerala.

Chan, H. T., Chong, P. F., and Ng, T. P. (1988). Silviculture efforts in restoring mangroves in degraded coastal areas in Peninsular Malaysia. *Galaxea*: *7*, 307-314.

Chapman V. J. (1975). *Mangrove vegetation*. J. Cramer Publishers,Germany. pp. 447.

Chapman, V.J. (ed.). (1977). Wet Coastal Ecosystems, Ecosystems of the World 1. Elsevier Scientific Publishing Co., Amsterdam, pp 428.

Chaudhuri, S. G., Dinesh, R., Sheeja, T. E., Raja, R., Jeykumar, V. and Srivastava, R. C. (2009). Physico-chemical, biochemical and microbial characteristics of soils of mangroves of the Andamans: a post-tsunami analysis. *Current Science*: 98-102.

Clough, B. F. (1984). Growth and salt balance of the mangroves Avicennia marina (Forsk.) Vierh. and Rhizophora stylosa Griff. in relation to salinity. *Functional Plant Biology*: 11, 419-430.

Clough, B. F. (1984). Growth and salt balance of the mangroves Avicennia marina (Forsk.) Vierh. and Rhizophora stylosa Griff. in relation to salinity. *Functional Plant Biology*: *11*, 419-430.

da Silva Copertino, M. (2011). Add coastal vegetation to the climate critical list: forests are protected, but carbon sinks in mangroves, seagrasses and marshes are ignored. Margareth da Silva Copertino wants Brazil to change that. *Nature*: 473, 255-256.

Dagar, J.C., Singh, N.T and Mongia, A.D. (1993). Characteristics of mangrove soils and vegetation of Bay Islands in India. Kluwer Academic Publishers, Netherlands, 1, pp. 59–80.

Dahdouh-Guebas, F., Jayatissa, L.P., Di Nitto, D., Bosire, J.O., Lo Seen, D. and Koedam, N. (2005).How effective were mangroves as a defence against the recent tsunami? *Current Biology*: 15, 1337-1338.

Dai, K. H., Johnson, C. E., and Driscoll, C. T. (2001). Organic matter chemistry and Dynamics in clear-cut and unmanaged hardwood forest ecosystems. *Biogeochemistry*: 54, 51-83.

De Lange, W.P. and De Lange, P.J. (1994). An appraisal of factors controlling the latitudinal distribution of mangrove (Avicennia marina var. resinifera) in New Zealand. *Journal of Coastal Research*: 10, 539-548.

Dittmar, T., Hertkorn, N., Kattner, G. and Lara, R.J. (2006). Mangroves, a major source of dissolved organic carbon to the oceans. *Global Biogeochemical Cycles*: 20, 1.

Duke, N.C. (1992). Mangrove floristics and biogeography. In: *Tropical Mangrove Ecosystems* (eds Robertson, A.I. & Alongi, D.M.). American Geophysical Union, Washington, DC. 63–100.

Duke, N., Ball, M. and Ellison, J. (1998). Factors influencing biodiversity and distributional gradients in mangroves. *Global Ecology & Biogeography Letters*: *7*, 27-47.

Duke, N.C., Meynecke, J.-O., Dittmann, S., Ellison, A.M., Anger, K., Berger, U., Cannicci, S., Diele, K., Ewel, K.C., Field, C.D., Koedam, N., Lee, S.Y., Marchand, C., Nordhaus, I. and Dahdouh-Guebas, F. (2007). A world without mangroves?. *Science*: 317, 41–42.

Ellis, J., Nicholls, P., Craggs, R., Hofstra, D. and Hewitt, J. (2004). Effects of terrigenous sedimentation on mangrove physiology and associated macrobenthic communities. *Marine Ecology Progress Series*: *270*, 71-82.

Eong, O. J. (1993).Mangroves—a carbon source and sink. *Chemosphere :* 27, 1097–1107.

Erftemeijer, P. L., and Lewis, R. R. (1999). Planting mangroves on intertidal mudflats: habitat restoration or habitat conversion. In *Proceedings of the ECOTONE VIII seminar enhancing coastal ecosystems restoration for the 21st century, Ranong, Thailand*(pp. 23-28).

FAO (2007). The World's Mangroves 1980-2005. FAO Forestry Paper No. 153. Rome, Forest Resources Division, FAO.77.

Field, C. D. (1995). Impact of expected climate change on mangroves. *Hydrobiologia*: *295*, 75-81.

Forest Survey of India (FSI) Report. (2009). ibid.

Frith, D. W. (1976). Zonation and abundance of macrofauna on a mangrove shore, Phuket Island. Phuket Marine Biological Centre. *Research Bulletin*: *10*, 1-37.

FSI. (1999). State of Forest Report. Dehara Dun. India.

FSI. (2013). India State of Forest Report 2013, Forest Survey of India, Dehradun, India.

George Thomas and Tresa V. Fernandez, (1994). Mangrove and Tourism: Management Strategies. *Indian Forester*: 120 , 406-411.

Ghoshal Chaudhuri, S., Dinesh, R., Sheeja, T. E., Rajal, R., Jeykumar, V., & Srivastava, R. C. (2009). Physicochemical, biochemical and microbial characteristics of soils of mangroves of the Andamans: a post-tsunami analysis. *Current Science*: 97, 98–102.

Gilman, E., Ellison, J., Duke, N.C. and Field, C. (2008). Threats to mangroves from climate change and adaptation options: a review. *Aquatic Botany*: 89, 237–250.

Giri, C., Ochieng, E., Tieszen, L., Zhu, Z., Singh, A., Loveland, T., Masek, J. and Duke, N. (2011). Status and distribution of mangrove forests of the world using earth observation satellite data. *Global Ecology and Biogeography* :20, 154–159.

Giri, C., Pengra, B., Zhu, Z., Singh, A. and Tieszen, L. L. (2007). Monitoring mangrove forest dynamics of the Sundarbans in Bangladesh and India using multi-temporal satellite data from 1973to2000. *Estuarine, coastal and shelf science*: *73*, 91-100.

Gopal, B. and Krishnamurthy, K. (1993). Wetlands of south Asia. In *Wetlands of the world: Inventory, ecology and management Volume I,* Springer Netherlands. pp. 345-414

Goutham-Bharathi, M. P., Roy, S. D., Krishnan, P., Kaliyamoorthy, M. and Immanuel, T. (2014). Species diversity and distribution of mangroves in Andaman and Nicobar Islands, India. *Botanica Marina*:*57*, 421-432.

Gravez, V., Bensted-Smith, R., Heylings, P. and Gregoire-Wright, T. (2013). Governance systems for marine protected areas in Ecuador. In. Moksness, E., Dahl, E., Stottrup, J., Eds. Global challenges in integrated coastal zone management. John Wiley & Sons, Ltd., Oxford, UK, 145-158.

Hamilton, S. (2013). Assessing the role of commercial aquaculture in displacing mangrove forest. *Bulletin of Marine Science*: *89*, 585-601.

Hamilton, S. and Casey, D. (2016). Creation of high spatiotemporal resolution global database of continuous mangrove forest cover for the 21st century: a big-data fusion approach. *Global Ecology and Biogeography :25, 729-738.*

Haque, S. M. S., Hossain, M. K., and Kabir, M. A. (2000). Performance of some common mangrove species in Sitakunda and Mirersarai Forest Ranges under Chittagong Coastal Afforestation Division. *Chittagong University Journal Of Science*: *24*, 1-10.

Hogarth, P.J. (2007). The Biology of Mangroves and Seagrasses (Biology of Habitats), Oxford University Press, New York, USA.

Hoq, M. E., Islam, M. L., Paul, H. K. and Ahmed, S. U. (2002). Decomposition and seasonal changes in nutrient constituents in mangrove litter of Sundarbans mangrove, Bangladesh. *Indian Journal of Marine Sciences*: 31, 130-135.

Jackson, M.L. (1973). Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi, 498.

Jagtap, T. G., Chavan, V. S. and Untawale, A. G. (1993). Mangrove ecosystems of India: a need for protection. *Ambio*: 252-254.

Jarugulla, E. S. and Krishna, P. V. (2016). Assessment of Water quality in terms of physico – chemical parameters of East Godavari mangrove ecosystem (Coringa Wildlife Sanctuary) East Godavari, Andhra Pradesh, India. *International Journal of Advanced Research*:5 , 782-788.

Jennerjahn, T.C. and Ittekot, V. (2002). Relevance of mangroves for the production and deposition of organic matter along tropical continental margins. *Naturwissenschaften* :89, 23–30.

Kathiresan, K. (1994). Propagation of mangroves: some considerations. *Conservation of mangrove forest genetic resources"-A training manual (SV Deshmukh and V. Balaji, eds)*, 303-306.

Kathiresan, K. (1998). India: A pioneer in mangrove research, too. *An anthology of Indian mangroves(A commemorative volume on the Golden Jubilee of India's independence).*, 15-19.

Kathiresan, K. (2010). Importance of mangrove forest of India. *Journal of Costal Environment*:1, 11–26.

Kathiresan, K. and Thangam, T. S. (1990). A note on the effects of salinity and pH on growth of Rhizophora seedlings. *Indian Forester*, *116*, 243-244.

Kathiresan, K., Moorthy, P. and Rajendran, N. (1994). Seedling performance of mangrove Rhizophora apiculata (Rhizophorales: Rhizophoraceae) in different environs. *Indian Journal of Marine Sciences*: 23, 168-169.

Kathiresan, K., Moorthy, P. and Ravikumar, S. (1996). A note on the influence of salinity and pH on rooting of Rhizophora mucronata Lamk. seedlings. *Indian Forester*: *122*, 763-764.

Kathiresan, K., Rajendran, N. and Thangadurai, G. (1996). Growth of mangrove seedlings in the intertidal area of Vellar estuary, southeast coast of India. *Indian Journal of Marine Sciences* :25,240-243.

Kathiresan, K. and Bingham, B.L. (2001). Biology of mangroves and mangrove ecosystems *.Advances in Marine Biology*: 40, 81-251.

Kathiresan, K., 2011. Eco-biology of Mangroves. Pp. 1–50 in: Metras, J.N. (ed.), Mangroves: Ecology, Biology and Taxonomy. New York: Nova Science Publishers, 386 pp.

Kiran, R. and Ramachandra, T. V. (1999). Status of wetlands in Bangalore and its conservation aspects. *ENVIS Journal of Human Settlements*: 16-24.

Kjerfve, B., Lacerda, L.D., Rezende, C.E. and Ovalle, A.R.C. (1999). Hydrological and hydrogeochemical variations in mangrove ecosystems. In : Mangrove ecosystems in tropical America: structure, function and management. Yanez-Arancibia, A. and Lara-Dominquez, A.L. (eds.) Mexico), pp. 71-81.

K'O H, D., Johnson, C. E. and Driscoll, C. T. (2001). Organic matter chemistry and dynamics in clear-cut and unmanaged hardwood forest ecosystems. *Biogeochemistry*: *54*, 51-83.

Krauss, K.W. Allen, J.A. and Cahoon, D.R. (2003). Differential rates of vertical accretion and elevation change among aerial root types in Micronesian mangrove forests. *Estuarine, Coastal and Shelf Science*: 56,251-259.

Krishna Mohan, G. V., Rao, K. K. and Prasada, P. V. V. (2012). Ecological Assessment for Water Quality of Bhavanapadu (Mangrove) Swamps of North Coastal Andhra Pradesh, East Coast of India. *Asian Journal of Water, Environment and Pollution*: *9*, 71-77.

Krishnamurthy, K., Chaudhary, A., and Untawale, A. G. (1987). Mangroves in India: Status Report. *Govt. of India, Ministry of Environment and Forests, New Delhi.* pp 150.

Kumar, R. P., Ranjan, R. K., Ramanathan, A. L., Singh, S. K. and Srivastava, P. K. (2015). Geochemical modeling to evaluate the mangrove forest water. *Arabian Journal of Geosciences*: *8*, 4687-4702.

Kurien N., Samsuddin M., Ramachandran K.K. and Salim.(1994). Resource evaluation using remote sensing for aquaculture site selection. *Proceedings of 6th Kerala Science Congress*.pp.23-25.

Kusmana, C. (2010). The growth of Rhizophora mucronata and Avicennia marina seedlings planted using Guludan technique in coastal area of Jakarta. In *Conference of the Earth and Space Sciences, Indonesia* (pp. 1-7).

Lewis, R. R. (2005). Ecological engineering for successful management and restoration of mangrove forests. *Ecological engineering*: *24*, 403-418.

Lewis, R. R., & Brown, B. (2014). Ecological mangrove rehabilitation–a field manual for practitioners. *Mangrove Action Project, Canadian International Development Agency, and OXFAM*. pp 275.

Lewis, R.R. (1990), ‘Creation and restoration of coastal plain wetlands in Florida’, in J.A. Kusler and M.E. Kentula, eds, Wetland Creation and Restoration: The Status of the Science. Washington: Island Press, 73-101.

Lewis, R.R. and Marshall, M.J.(1997). Principles of successful restoration of shrimp Aquaculture ponds back to mangrove forests. Programa/resumes de Marcuba ’97, Habana, Cuba, pp.126.

Locatelli, T., Binet, T., Kairo, J. G., King, L., Madden, S., Patenaude, G. and Huxham, M. (2014). Turning the tide: how blue carbon and Payments for Ecosystem Services (PES) might help save mangrove forests. *Ambio: 43*, 981-995.

Lugo, A. E. and Snedaker, S. C. 1974. The ecology of mangroves. *Annual Review of Ecology and Systematics :*5, 39-64.

Lugo, A. E., Medina, E. and McGinley, K. (2014). Issues and challenges of Mangrove conservation in the Anthropocene. *Madera y Bosques*: *20*.,11-38.

Luther, D. A. and Greenberg, R. (2009). Mangroves: a global perspective on the evolution and conservation of their terrestrial vertebrates. *BioScience*: *59*, 602-612.

Macintosh, D. J. and Ashton, E. C. (2002). A review of mangrove biodiversity conservation and management. Final Report 10/06/2002. *Centre for tropical ecosystems research, University of Aarhus, Denmark.*

Macintosh, D., Mahindapala, R. and Markopoulos, M. (eds), 2012. Sharing Lessons on Mangrove Restoration. Bangkok, Thailand: Mangroves for the Future and Gland, Switzerland: IUCN.pp.304.

Mandal, R. N., Ghosh, D. C., Sarkar, A. K. and Naskar, K. R. (1995). New distributional record of Scyphiphora hydrophyllacea Gaertn. f. and Atalantia corea M. Roem. from the inter tidal mangrove forests of the Indian Sundarbans. *Journal of National Botanical Society*: *49*, 71-74.

Mandal, R.N. and Naskar, K.R. (2008).Diversity and classification of Indian mangroves: a review. *Journal of Tropical Ecology* : 49,131–146.

Manju, M.N., Resmi, P., Girish Kumar, T.T., Raathesh Kumar, C.S., Rahul, R., Joseph, M.M., Chandramohankumar, N., 2012. Assessment of water quality parameters in mangrove ecosystems along Kerala coast: a statistical approach. *Int. J. Environ. Res*: 6 , 893–902.

Matilal, S., Mukherjee, B. B., Chatterjee, N., & Gupta, M. D. (1986). Studies on soil & vegetation of Mangrove forests of Sunderbans. *Journal of marine sciences*. 15, 181- 184.

Mc Owen, C., Jones, M., van Bochove, J. W., Blyth, S., Stanwell – Smith, D., Sullivan, E. (2016). Chapter 7.4: Extent of Mangroves and drivers of change. In IOC – UNESCO and UNEP (2016). Large Marine Ecosystems: Status and Trends. United Nations Environment Programme, Nairobi, pp 197 – 203.

McKee, K. L., Cahoon, D. R. and Feller, I. C. (2007). Caribbean mangroves adjust to rising sea level through biotic controls on change in soil elevation. *Global Ecology and Biogeography*: *16*, 545-556.

Middelburg, J. J., Nieuwenhuize, J., Lubberts, R. K. and Van de Plassche, O. (1997). Organic carbon isotope systematics of coastal marshes. *Estuarine, Coastal and Shelf Science*: *45*, 681-687.

Mini Mohandas, Lekshmy, S and Tresa Radhakrishnan (2014). Kerala Mangroves– Pastures of Estuaries – Their Present Status and Challenges. *International Journal of Science and Research*: 3, 2804 – 2809.

Mo E F. (1987) Ministry of Environment and Forest, India. Mangroves of India, Status report.

Mohanan, C.N. (1997). Mangroves. The National Resource of Kerala. (Edited by Thampi K B,Nayar N M and Nair C S). Thiruvananthapuram. 149-158.

Mohandas,M., Lekshmy, S. and Radhakrishnan,T. (2014). Kerala Mangroves– Pastures of Estuaries – Their Present Status and Challenges. *International Journal of Science and Research*:3, 2804 – 2809.

Murray, B. C., Pendleton, L. and Sifleet, S. (2011). State of the Science on Coastal Blue Carbon: A Summary for Policy Makers. *Nicholas Institute for Environmental Policy Solutions Report*, 11-06. pp. 1 – 43.

Nagelkerken,I., Blaber, S.J.M., Bouillon, S., Green, P., Haywood, M., Kirton, L.G., Meynecke, J-O., Pawlik, J., Penrose, H.M,. Sasekumar, A. and Somerfield, P.J. (2008). The habitat function of mangroves for terrestrial and marine fauna: A review *Aquatic Botany*: 89, 155-185.

Naskar, K. (2004). Manual of Indian mangroves. Daya Pub. House, New Delhi, India.

Naskar, K. R. and Bakshi, D. G. (1989). Distribution of mangroves in India and abroad and their roles in the estuarine ecosystems. *Monograph*: *9*, 22-23.

Naskar, K. R. and Mandal, R. N. (1999). Ecology and Biodiversity of Indian Mangroves Milton Book company, Dehra Dun, India, pp. 3 - 348.

Naskar, K., and Mandal, R. (1999). *Ecology and biodiversity of Indian mangroves*. Daya Books, New Delhi, India.

Navalkar, B.S. and Bharucha, F.R. (1948). Studies in the ecology of mangroves; The hydrogen ion concentration of seawater, soil solution and leaf cell sap. ot' mangroves. Q. University of Bombay: 5, 35-45.

Notification No. 8/ 10/ 83- FOR dated 11.09.1990

Ong, J.E., 2007. Pre- and post-tsunami coastal planning and land-use policies and issues in Malaysia. In: Broadhead, J.S. & Leslie, R.N. (Eds.) Proceedings of the Workshop on Area Planning and Management Tsunami Affected Countries, 27-29 September 2006, Bangkok, Thailand, pp. 131–146.

Paramasivam, S. and Kannan, L. (2005). Physico-chemical characteristics of Muthupettai mangrove environment, Southeast coast of India. *International Journal of Ecology and Environmental Sciences :* 31, 273-278.

Platong, J., Platong, S.,and Ounsted, R. (1998). *Status of mangrove forests in southern Thailand*. Wetlands International-Asia Pacific.

Polidoro, B. A., Carpenter, K. E., Collins, L., Duke, N. C., Ellison, A. M., Ellison, J.C., Farnsworth, E.J., Fernando, E.S., Kathiresan, K., Koedam, N.E. and Livingstone, S. R. (2010). The loss of species: mangrove extinction risk and geographic areas of global concern. *PloS one*, *5*(4), e10095.

Praseetha, T. and Rajani, V. (2015). A Preliminary Study on Ecology of Ayiramthengu Mangrove – Kollam Dist., Kerala, India. ***International Journal of Innovative Science Engineering and Technology:***2, 234-239.

Qasim, S. Z. (1998). Mangroves, In: Glimpses of the Indian Ocean, University Press, Hyderabad, 123-129.

Radakrishnan, C., Gopi, K. C. and Palot, J. M. (2006). Mangrove and their faunal associates in Kerala, with special reference to northern Kerala. Records of Zoological Survey of India, Occassional paper No. 246, pp.1-81.

Rahees, N., Kiran, M. and Vishal, V. (2014). Phytosociological analysis of mangrove forest at kadalundi-vallikkunnu community reserve, kerala. *International journal of Science, Environment and Technology*:3,2154–2159.

Rahman, M. M., Khan, M. N. I., Hoque, A. F. and Ahmed, I. (2015). Carbon stock in the Sundarbans mangrove forest: spatial variations in vegetation types and salinity zones. *Wetlands Ecology and Management*:*23*, 269-283.

Rahman, M. M., Rahman, M. T., Rahaman, M. S., Rahman, F., Ahmad, J. U., Shakera, B. and Halim, M. A. (2013). Water quality of the world's largest mangrove forest. *Canadian Chemical Transations*: 1, 141-156.

Ram, A.T. and Shaji C.S.(2013). Diversity and distribution of mangroves in Kumbalam Island of Kerala, India. IOSR *Journal of Environmental Science, Toxicology and Food Technology*: 4, 18-26.

Rao, T.A. and Sastry, A.R.K. (1974). An outline of the Coastal Vegetation of India. *Bulletin of the Botanical Survey of India*: 16, 101 – 115.

Ravichandran, K. (2002). Conservation of critical habitats: the mangroves, coral reefs and seagrass beds in Mahatma Gandhi Marine National Park, Wandoor, Andaman and Nicobar Islands. Retrieved from http://www.teriuniversity.ac.in/mct/pdf/assignment/K-Ravichandran.pdf.

Reddy, Venkataswamy, H.R. and Hariharan V. (1986). Distribution of nutrients in the sediments of the Netravathi-Gurupur estuary, Mangalore. *Ind. J. Fish*: 33, 123-126.

Richards, D. R. and Friess, D. A. (2016). Rates and drivers of mangrove deforestation in Southeast Asia, 2000–2012. *Proceedings of the National Academy of Sciences*: *113*, 344-349.

Robertson, A.I. and Alongi, D. M. (eds.). (1992). Tropical Mangrove Ecosystems. Coastal and Estuarine Studies. American Geophysical Union, Washington, DC, pp. 329.

Saenger, P. (2002). *Mangrove ecology, silviculture and conservation*. Springer Science and Business Media. Kluwer, Dordrecht.

Saenger, P. and Snedaker, S.C. (1993). Pantropical trends in mangrove above-ground biomass and annual litter fall. *Oecologia*: 96, 293-299.

Saenger, P., and Siddiqi, N. A. (1993). Land from the sea: the mangrove afforestation program of Bangladesh. *Ocean & Coastal Management*: *20*, 23-39.

Sahoo, K., Jee, P.K., Dhal, N.K., Das, R. (2017) Physico-Chemical Sediment Properties of Mangroves of Odisha, India. *Journal of Oceanography and Marine Research* : 5,162.

Sahu, S. C., Suresh, H. S., Murthy, I. K. and Ravindranath, N. H. (2015). Mangrove area assessment in India: implications of loss of mangroves. *Journal of Earth Science & Climatic Change*: *6*, 1.

Sankaranarayanan, V. N. and Qasim, S. Z. (1969). Nutrients of Cochin backwater in relation to environmental characteristics. *Marine Biology* :2, 236-247.

Santisuk, T. (1983). Taxonomy and distribution of terrestrial trees and shrubs in the mangrove formations in Thailand. *Nat Hist Bull Siam Soc*: *5*, 63-91.

Saravanakumar, A., Rajkumar, M., Serebiah, J. S. and Thivakaran, G. A. (2008). Seasonal variations in physico-chemical characteristics of water, sediment and soil texture in arid zone mangroves of Kachchh-Gujarat. *Journal of environmental Biology*: *29*, 725-732.

Saritha and Tessy, 2011. Mangroves of Poyya backwaters of Thrissur district, Kerala, India. *Journal of the Marine Biological Association of India*:53, 8-13.

Saseeswari, A., Kanimozhi, G. and Panneerselvam, A. (2015). Studies on physicochemical parameter and bacterial populations in sediment soil at Karankadu Mangrove forest, Ramanathapuram (Dt), Tamilnadu. *International Journal of Sci*ence: 4, 886 – 895.

Sasidhar, K. and Rao, P.B. (2015). Conservation and management of mangrove at Nizampatnam and Palarevu. *Asia-Pacific Journal of Research*: 1, 5-15.

Satheeshkumar, P. and Khan, B. A. (2009). Seasonal variations in physico-chemical parameters of water and sediment characteristics of Pondicherry mangroves. *African Journal of Basic and Applied Sciences*:*1*, 36-43.

Schumacher, B.A. (2002). Methods for the determination of total organic carbon (TOC) in soils and sediments(internet). United States Environmental Protection Agency, National Exposure Research Laboratory, Office of Research and Development, Las Vegas, U.S.A.

Selvam, V., Ravichandaran, K.K., Karunakaran, V.M., Mani, K.G. Evanjalin Jessie Beula and Gnanappazham, L. (2010): Pichavaram mangrove wetlands: Situation Analysis, Chennai, 39 pp.

Serrlathan, P.(1988). Use of textural organic matter pattern for identification of depositional processes in the sediments of cauvery delta. Bulletine of Department of Marine Sciences, University of Cochin. 14, 17-26.

Shilna E.P., Sajith U. and Harilal C.C**.** (2016) Surveillance on Water Quality in Pursuit of Mangrove Afforestation along the Coastal and Inland Aquatic Environments of Malappuram District, Kerala, India. *International Research Journal of Environmental sciences*: 5,41-50.

Shilna, E. P., Harilal, C. C., and Sajith, U. (2017). Evaluation of thegrowth performances of the propagules of selected mangrove species along Kadalundi-Vallikkunnu community reserve, Kerala, India. *International journal of Plant, Animal and Environmental Sciences*: 7, 80-86.

Singh, A. K., Ansari, A., Kumar, D. and Sarkar, U. K. (2012). Status, biodiversity and distribution of mangroves in India: an overview. *Uttar Pradhesh Sate Biodiversity Board. Marine Biodiversity: One Ocean, Many Worlds of Life*, 59-67.

Singh, H.S. (2000). Mangroves in Gujarat-Current status and conservation strategy. Gujarat Ecological Education and Research (GEER) Foundation, Gandhinagar: pp.128.

Singh, K., Pandey, V. C., Singh, B. and Singh, R. R. (2012). Ecological restoration of degraded sodic lands through afforestation and cropping. *Ecological Engineering*: *43*, 70-80.

Singh, V. P., Mall, L. P., George, A., & Pathak, S. M. (1987). A new record of some mangrove species from Andaman Islands and their distribution. *Indian Forester*: *113*, 214-217.

Singh, V.P. and A. Garge. (1993). Ecology of Mangrove Swamps of the Andaman Islands. International Book Distributors ,Dehradun, India,.pp 181.

Spalding, M. (2010). *World atlas of mangroves*. Routledge. . ITTO, ISME, FAO, UNEP-WCMC, UNESCO-MAB and UNU-INWEH. Earthscan Publishers Ltd. London.

Spalding, M. D., Blasco, F. and Field, C. D. (1997). *World mangrove atlas*. International Society for Mangrove Ecosystems, Okinawa, Japan.

Sreedharan, M. and Salih, K. Y. M. (1974). Distribution characteristics of nutrients in the estuarine complex of Cochin. *Indian J. Mar. Sci.:* 3,125-130.

Sreeja, P. and Khaleel, K. M. (2010). Status of Mangroves in Thekkumbad, Kannur, Kerala. *Journal of Experimental Sciences*: 1,1-2.

Srilatha, G., Varadharajan, D., Chamundeeswari, K., & Mayavu, P. (2013). Study on physico-chemical parameters in different mangrove regions, Southeast Coast of India. *Journal of Environmental and Analytical Toxicology: 3*, 182.

Stockdale, E. (1991). Fresh water wetlands, urban storm water and non point source pollution control: A literature review & annotated bibliography. Olympia, WA: Washington Department of Ecology.

Subramanyam N.S and Sambamuthy A.V.S.S. (2002). Ecology, Narosa Publishing House, Delhi. 616.

Suma K.P. (1995). Distribution of mangrove vegetation and associated algal flora in Vypeen block. M Phil dissertation, University of Kerala, Thiruvananthapuram.

Sumesh, C., Benno Pereira, F. G., Sini Wilson, S.and Vishnu, S. R. (2014). Distribution of Mangroves in the Ashtamudi Estuary. *Journal of Aquatic Biology & Fisheries*: *2*, 310-312.

Sunilkumar, V., 1993. Occurrence of macrobenthos in Kerala mangroves., Ph.D thesis submitted to Cochin University of Science and Technology.

Sunil, C.N. (2000). Studies on flowering plants diversity of Alappuzha District, Kerala. Ph.D. thesis, University of Calicut.

Tansley, A. G. and Fritsch, F. E. (1905). Sketches Of Vegetation At Home And Abroad. *New Phytologist*: *4*, 27-55.

Thom, B. G. (1967). Mangrove ecology and deltaic geomorphology: Tabasco, Mexico. *The Journal of Ecology:55*, 301-343.

Thomas, K.J. (1962). A survey on vegetation of Veli, with special reference to ecological factors. *Bot. Sco*: 42, 104-131.

Thomas,G. and Fernandez, T.V. (1994). Mangrove and Tourism: Management Strategies, *Indian Forester*: 120, 406-411.

Tomlinson, P.B. (1986). The Botany of Mangroves, Cambridge University Press, ISBN 0-521- 25567-8, New York, USA.

Tomlinson, T. E. (1957). Relationship between mangrove vegetation, soil texture and reaction of surface soil after empoldering saline swamps in Sierra Leone. *Trop. Agric.(Trin.)*: *34*, 41-50.

Trivedi, R.K., Goel, P.K., and Trisal, C.L. (1987). Practical methods in Ecology and Environmental sciences. Environ. Public. Karad, (India).

Twilley, R. R. and Chen, R. (1998). A water budget and hydrology model of a basin mangrove forest in Rookery Bay, Florida. *Marine and Freshwater Research*: *49*, 309-323.

Uddin, M. M., Rahman, M. S., Hossain, M. K., and Akter, S. (2014). Growth density and regeneration of afforested mangroves at Mirersarai forest range in Bangladesh. *Forest Science and Technology*: 10, 120-124.

UNESCO World Heritage. "UNESCO World Heritage Centre - World Heritage List". *whc.unesco.org*.

Untawale, A. G. (1996). Restoration of mangroves along the central west coast of India, in *Restoration of mangrove ecosystems edited by* C.Field, International Tropical Timber Organization and International Society for Mangrove Ecosystems, Okinawa, Japan. Pp 111-125.

Untawale, A. G. and Parulekar, A. H. (1976). Some observations on the ecology of an estuarine mangrove of Goa. *Mahasagar*:*9*, 57-62.

Untawale, A.G. (1987). Indialn: Umali, R.M. et al (Eds.) Mangroves of Asia and the Pacific: Status and Management. Natural Resources Management Center and National Mangrove Committee, Ministry of Natural Resources, Manila, Philippines. . pp 51-87

Upadhyay, V. P., Ranjan, R. and Singh, J. S. (2002). Human-mangrove conflicts: The way out. *Current Science*: *83*, 1328-1336.

USDA Soil Survey Division Staff. (1993). "Soil survey manual." Soil Conservation Service. U.S. Department of Agriculture Handbook 18.

Vaiga, M. and Joseph, S.(2016). Identification of mangrove and mangrove associates in Kannur district of Kerala including their economic–ecological linkages. *International Journal of Botany Studies:* 1, 22-31.

Valiela, I., Bowen, J.L. and York, J.K. (2001). Mangrove forests: One of the world's threatened major tropical environments. *Bioscience*: 51,807–815.

Vidyasagaran, K and Gopikumar, K. (2006). Ecology and plant diversity of mangroves of Kerala", *Proceedings of National Conference on Wetland Biodiversity*, pp.128-135.

Vidyasagaran, K. and Madhusoodanan, V. K. (2014). Distribution and plant diversity of mangroves in the west coast of Kerala, India. *Journal of Biodiversity and Environmental Sci*ences. 4, 38-45.

Vidyasagaran, K. and Madhusoodanan. V. K. (2014). Distribution and plant diversity of mangroves in the west coast of Kerala, India. *Journal of Biodiversity and Environmental Sciences* : 4, 38–45.

Vidyasagaran, K., Ranjan, M. V., Maneeshkumar, M. and Praseeda, T. P. (2011). Phytosociological analysis of Mangroves at Kannur district, Kerala. *International Journal of Environmental Sciences*: *2*, 671.

Vijayan, V., Rahees, N., Vidyasagaran, K. (2015). Plant Diversity And Structural Dynamics Of Mangroves In The Southwest Coast Of Kerala, India. *Applied Ecology And Environmental Research*: 13, 1055-1067.

Vilarrúbia, T. V. (2000). Zonation pattern of an isolated mangrove community at Playa Medina, Venezuela. *Wetlands Ecology and Management*: *8*, 9-17.

Viswanathan, P. K., Pathak, K. D. and Mehta, I. (2011). *Socio-economic and ecological benefits of mangrove plantation: a study of community based mangrove restoration activities in Gujarat.* (No. id: 3852).

Watson, R. T., Albritton, D. L., Barker, T., Bashmakov, I. A., Canziani, O., Christ, R., Cubasch, U., Davidson, O., Gitay, H., Griggs, D. and Houghton, J. (2001). IPCC, 2001: Climate Change 2001: Synthesis Report. A Contribution of Working Groups I, II, and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change.

Webber M. K. and Goodbody I. (1998) "Mangroves," DEMO Palisadoes Project Report, National Resource Conservation Authority, Kingston Jamaica.

Wilkie, M.L., Fortuna, S. and Souksavat, O. (2003) FAO's database on mangrove area estimates. Forest Resources Assessment Working Paper no. 62. Food and Agriculture Organization of the United Nations (FAO), Rome.

www.iucnredlist.org.

www.niobioinformatics.in/mangroves/MANGCD/fact.htm

Yang, S., Lim, R. L., Sheue, C. R. and Yong, J. W. (2011). The current status of mangrove forests in Singapore. In *Proceedings of the Nature Society, Singapore's Conference on 'Nature Conservation for a Sustainable Singapore*. pp. 99-120.

Yang, J., Gao, J., Cheung, A., Liu, B., Schwendenmann, L. and Costello, M. J. (2013). Vegetation and sediment characteristics in an expanding mangrove forest in New Zealand. *Estuarine, Coastal and Shelf Science*: 134, 11-18.

Zedler, J. B. (1996). Tidal wetland restoration: a scientific perspective and southern California focus. *California Sea Grant College System, University of California, La Jolla, Ca (Usa).* Publ. No. T-038.

Zhang, Z. W., Xu, X. R., Sun, Y. X., Yu, S., Chen, Y. S. and Peng, J. X. (2014). Heavy metal and organic contaminants in mangrove ecosystems of China: a review. *Environmental Science and Pollution Research*: *21*, 11938-11950.