STUDY ON MANGROVE DIVERSITY ALONG ZUARI RIVER

A Dissertation For

Course Code and Course Title: ESC- 402 Dissertation

Credits : 8

Submitted in partial fulfilment of Master's Degree

MSc in Environmental Sciences

by

VARSHA SARJERAO JADHAV

Seat number: 21P058013

P.R. NO: 201800276

Under the Supervision of

DR. CHANDA BERDE

Marine Microbiology

School of Earth, Ocean and Atmospheric Sciences

GOA UNIVERSITY

April 2024

Examined by

Seal of the School

DECLARATION BY STUDENT

I hereby declare that the data presented in this Dissertation report entitled, **"STUDY ON MANGROVE DIVERSITY ALONG ZUARI RIVER"** is based on the results of investigations carried out by me in the Environmental Sciences at the School Of Earth, Ocean And Atmospheric Sciences, Goa University under the supervision of **Dr. Chanda Berde** and the same has not been submitted elsewhere for the award of degree or diploma by me. Further, I understand that Goa University or it's authorities will not be responsible for the correctness of observations or other findings given in the dissertation.

I hereby authorize the University authorities to upload this dissertation on the dissertation repository or anywhere else as the UGC regulations demand and make it available to any one as needed.

Jadhav

Varsha Sarjerao Jadhav

Seat No : 21P058013

Date : 02/05/2024

Place : Goa University

COMPLETION CERTIFICATE

This is to certify that the dissertation report " **STUDY ON MANGROVE DIVERSITY ALONG ZUARI RIVER**" is a bonafide work carried out by Ms Varsha Sarjerao Jadhav under my supervision in partial fulfilment of the requirements for the award of the degree of Master of Science in the Discipline of Environmental Sciences at the School of Earth, Ocean and Atmospheric Sciences, Goa University.

Date : 02/05/2024

chanda

Dr. Chanda Berde

Marine Microbiology

School of Earth, Ocean and Atmospheric Sciences

Ghadi 31/5/24

Sr. Prof. Sanjeev C. Ghadi

Senior Professor and Dean

School of Earth, Ocean and Atmospheric Sciences

Date : 02/05/2024

Place: Goa University

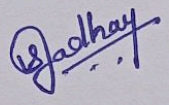
SEOAS, GOA UNIVERSITY TALEIGAO PLATEAU GOA

School Stamp

ACKNOWLEDGMENT

Firstly, I would like to express my immense gratitude and would like to thank our present Dean Sr. Prof. Sanjeev C. Ghadi and previous Dean Dr. C. U. Rivonkar for giving me permission to carry out my dissertation at School of Earth, Ocean and Atmospheric Sciences.

Secondly my guide, Dr. Chanda Berde, Marine Microbiology, School of Earth, Ocean and Atmospheric Sciences, for her valuable guidance, support and untiring effort during the course of the dissertation, she has been a great source of motivation and encouragement for me to take up this topic as my study. Also, I would like to thank Sir Mahesh M Mayekar for helping me in my laboratorical work, I extend my sincere thanks to all the other non-teaching and laboratory staff members and lastly I would like to express my profound gratitude to my parents and my friends for encouragement and support.



Varsha Sarjerao Jadhav

CONTENTS

TABLES

FIGURES

ABSTRACT

Mangroves are dense and salt tolerant ecosystems along the tidal estuaries. They consists of incredibly productive biological diversity. They survive in muddy and anaerobic soils by the presence of pneumatophores. Mangrove have crucial ecological and economic importance. They help in protection of coasts from floods, tsunamis and other disasters. Mangrove leaves and bark are potential sources of pharmaceutical compounds to treat AIDS, jaundice and cancer. Identification of mangrove species is of critical importance in conserving and utilizing biodiversity. In the present study, a field survey of mangrove diversity along Zuari river at different sampling sites such as Siridao, Maina, Quelossim, Cortalim, Verna, Loutolim, Borim etc, was carried out to observe the morphology, and variability in species occurrence. Out of 16 true mangroves species belonging to 8 different families, 14 mangrove species belonging to 8 families were successfully identified and reported in this paper.

CHAPTER 1

INTRODUCTION

Mangrove ecosystem is a complex and dynamic coastal habitat found in tropical and subtropical regions around the world. It comprises a diverse array of salt-tolerant plants, including various species of trees shrubs and mangrove palms. Mangroves are adopted to thrive in the challenging intertidal zone where land and sea meets.The word mangrove can describe a single plant or it can refer to a whole community of plants. The word mangrove comes from the Portuguese word 'mangue' which means "tree" and the English word 'grove' meaning "a stand of trees" The mangrove ecosystem is called as 'Mangal' or 'Manglar ecosystem'. (Giri et al, 2011)

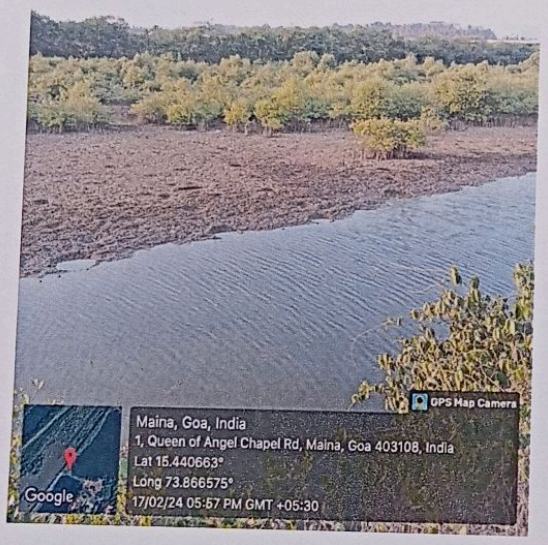


Fig 1.1 Mangroves found in Maina

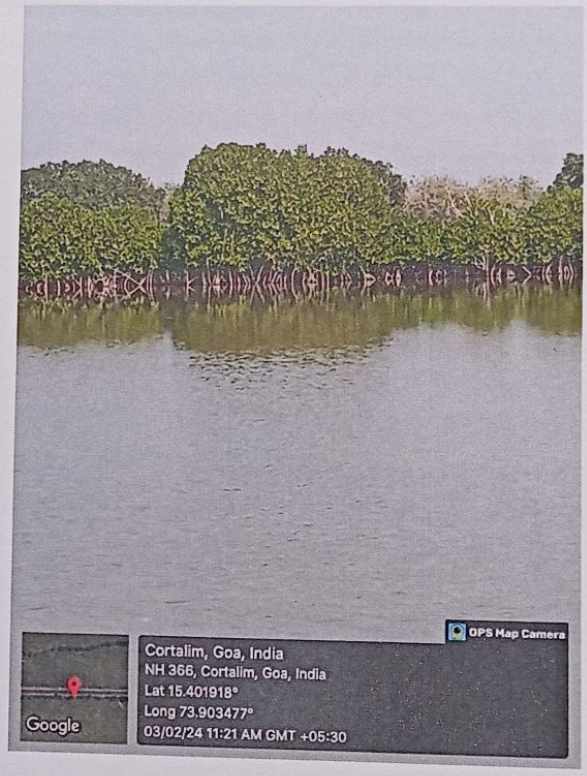


Fig 1.2 Mangroves found in Cortalim

They are referred to the dominant trees from the entire plant community. They can tolerate excess of salt. They are also tolerant to oxygen deficient conditions. They grow on loose substratum, resist physical forcing and can survive in limited fresh water. They do not tolerate cold temperature and die in freezing temperatures. mangroves grow best in sheltered areas with low wave energies. High wave energies destroy the shallow root system of mangroves. High wave energies is also prevent seedling establishment and the build up of fine sediments needed for growth. Primarily mangroves are found in brackish water. Mangrove trees are the dominant vegetation in mangrove forests. They have specialized adaptations to survive in saline water such as pneumatophores (aerial roots) for gas exchange and prop roots for stability in muddy substrate. Mangroves support a rich diversity of flora and fauna .(Srikanth et al, 2015)

They serve as nurseries and habitats for numerous species including fish, crustaceans and mollusks. Birds, reptiles and mammals also reply on mangroves for shelter and food. Mangrove ecosystem play a crucial role in nutrient cycling and water filtration. Fallen leaves and other organic matter are broken down by decomposers which enriches the soil which supports a productive food web. mangroves act as natural buffers against coastal erosion, storm surges, tsunamis, Hurricanes and floods. Their dense root systems stabilize sediments and reduce the force of waves, helping to protect nearby shoreline and communities. Mangroves are highly efficient at storing carbon dioxide. The dense vegetation and anaerobic soil conditions result in significant carbon sequestration, making mangrove forest important contributors to climate change mitigation efforts. Mangrove ecosystem provide numerous benefits to human communities. They support fisheries, providing livelihood and food security for recreation, tourism, scientific reasons and traditional medicine.They represent the littoral forest ecosystem. They are evergreen land plants.(Nagelkerken et al, 2008).

Mangroves prevent soil erosion and helps in stabilization of costs and beaches. It protects land from tidal surges and cyclonic storms. It helps in aquaculture. Mangrove provides fuel wood, green manure, charcoal, timber etc. It is used for boat making. It provides tannin. It is used for thatching material, cordage and rope material, for art and craft, bow-making. It is also used as food beverage. It is widely used for medicinal purpose. It is useful for bee hives and provides wax and honey. It is useful for recreational purpose as Eco-tourism. It also provides excellent home to birds and animals. They also provide numerous employment opportunities to local people. (Badola, 2005)

Mangrove plants form a unique ecosystem. It consists of living organisms and non-living factors such as soil and water. Mangroves are essential to the first link in the food chain. When their leaves fall into the water and are decomposed by bacteria many valuable nutrients are released that are essential to the growth of plankton. Planktons are the producers in mangrove and oceanic ecosystem. Fine, anoxic sediments deposited under mangroves acts as sinks for a variety of heavy metals. The leaf detritus of mangroves also provide food for animals such as worms, snails, mussels, oysters, shrimp, clams and mullets. This detritus eating animals are a source of food for carnivorous such as crabs and fish. These in turn provide food for large fish, reptiles and birds. Mangrove wetlands provide habitat, feeding, breeding and nursery areas for a wide variety of plants and animals including endangered species. Mangroves are actually meant to be tropical and subtropical but they are also found at the coastline that is along some cooler temperatures for example; Australia, China, Southern hemisphere of Africa. They serve as an important buffer between sea and land, They lessen the impact of intense storms, reduces erosion and increase sedimentation. It is a important coastal pioneer species. It acts as basis for a complex, biologically divers and productive ecosystem. Mangroves require high solar radiation to filter saline water through their roots. Mangroves have viviparous mode of reproduction. Leaves of mangrove trees are thick and contains salt-secreting glands. (Kathiresan & Bingham, 2001)

There are three types of mangroves that are red, black and white mangroves. Mangrove enhances the natural recycling of nutrients. Mangroves are typical coastal plants which are subject to periodic tidal inundation. They exhibit a number of morphological and anatomical adaptations and physiological characteristics which enable them to flourish under harsh conditions. Root system of mangroves is not deep and is extensively branched due to poor aeration of the substratum. The surrounding soil is very deficient in oxygen, Therefore mangroves have root adaptations to help them grow well in adverse conditions. Mangroves are open type of ecosystem. They occur in variety of configurations like *Rhizophora*, *Avicennia* etc. (Giri et al, 2015)

There are more than 59 species of mangroves in the world of which, 45 are found in India. Dr. A. Untawale has recorded 53 species in India. Mangroves play an important role as a feeding and nursery ground for a large number of organisms which form the marginal Marine and freshwater habitats. It is estimated that as much as 90% of tropical marine fish species pass some stage of their life cycle in the mangrove estuary. Mangroves are highly productive ecosystems and the trees may vary in height from 8 meters to 20 meters. Goa Houses 16 mangrove species and it has one of the best mangrove forest in the country. (Mangroves - Goa Forest Department). Mangrove trees often have stilt like roots or pneumatophores that extent above the water surface. This structures not only provide stability in muddy substrates but also facilitates gas exchange in oxygen-poor sediments. Mangrove ecosystems of Goa are biodiversity rich environments. The mangrove trees store carbon in their biomass and in the sediments, contributing to the reduction of greenhouse gas concentration in the atmosphere. Mangrove forest comprises of six different types of forests with includes Fringe river mangroves, Riverine mangroves, Basin mangroves, Dwarf mangroves, Over wash mangroves and Hammock mangroves which are actually special form of Basin mangroves. The primary adaptations of Mangrove trees are they have succulent leaves, sunken stomata, aerial breathing roots, called pneumatophores, vivipary type of reproduction, stilt and buttress roots. Despite the ecological importance, mangrove ecosystems are threatened by human activities such as deforestation, aquaculture, urbanization, pollution, over harvesting and climate change. conservation efforts are essential to protect and restore mangrove habitats, safeguarding their ecological functions and benefits for current and future generations. (Untawale, 1973)

MANGROVE SPECIES AND THEIR FAMILIES FOUND IN GOA

Table 1.1 Mangrove species found in Goa. (Claude Alvares, 2002)

FAMILY	MANGROVE SPECIES
Acanthaceae	*Acanthus ilicifolius*
	Avicennia marina
	Avicennia officinalis
Sonneratiaceae	*Sonneratia alba*
	Sonneratia caseolaris
Pteridaceae	*Acrostichum aureum*
Primroses	*Aegiceras corniculatum*
Euphorbiaceae	*Excoecaria agollacha*
Combretaceae	*Lumnitzera racemosa*
Rhizophoraceae	*Rhizophora mucronata*
	Rhizophora apiculata
	Bruguiera gymnorhiza
	Bruguiera cylindrica
	Ceriops tagal
	Kandelia candel
Fabaceae	*Derris trifoliata*

MANGROVE DISTRIBUTION

47% of world's mangrove area is covered with 85% world's mangrove species from different habitats having an important role in coastal biodiversity of 30 countries that bordered the Indian Ocean (Kathiresan & Rajendran, 2005). Approximately 55 mangrove species belonging to 22 genera and 18 families have been recorded in the Indian Ocean.The Indian mangroves comprise approximately 59 species in 41 genera and 29 families. Of these, 34 species belonging to 25 genera and 21 families are present along west coast. There are about 25 mangrove species which have restricted distribution along the east coast and are not found on the west coast. Similarly, there are eight species of mangroves like *Sonneratia caseolaris, Suaeda fruticosa, Urochondra setulose* etc. which have been reported only from the west coast. There are about 16 mangrove species reported from the Gujarat coast, while Maharashtra has around 20 species, Goa houses14 species and Karnataka has 10 mangrove species. There are hardly 3-4 species of mangrove which are rarely found along the Kerala coast. The associated mangrove flora is quite common to both the coasts, with minor variations in distribution. The floral diversity of mangroves of India is comprised of 38 core mangrove species (Kathiresan & Rajendran 2005)

West Bengal has the highest share of mangrove in India with around 42% in 2021. Gujarat has second most highest concentration of mangroves followed by Andaman & Nicobar islands ranking third in the same year. India accounted for nearly five thousand square kilometers of mangrove cover in 2021. (Keelery, 2023)

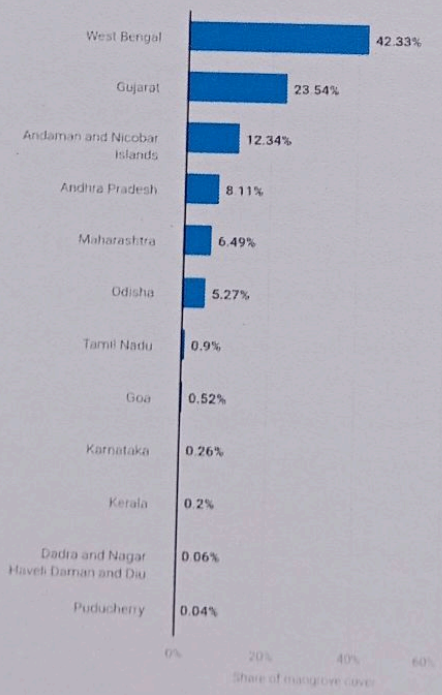


Fig 1.3 State wise mangrove cover distribution in India in 2021 (Keelery, 2023)

About 40% of the world's mangrove cover is found in South East Asia of which India holds 3% of the total cover in South Asia. 15.9 million hectares of mangrove forests are found in the warm waters of tropical oceans around the world. Mangroves are found from Florida till Argentina along the Atlantic coast, they are found on eastern and western coast of Africa. Mangrove stretch into India, Burma and South-east Asia. They are commonly found in New Zealand and Australia. Mangrove cover in the India has increased by 54 sq km as compared to the previous assessment. The current mangrove cover in India is 4,975 sq km which is 0.15% of India's total geographical area.They are found in West Bengal, Odisha, Andhra Pradesh, Tamilnadu, Andaman and Nicobar Islands, Kerala, Karnataka, Goa, Maharashtra and Gujarat. Sunderbans delta and Andaman & Nicobar Islands has the major concentrations of mangroves. However, the mangroves are also found in the deltaic areas of Mahanadi, Godavari and Krishna river basins.The Government of India formed an Indian Mangrove Committee in 1976 and M.S. Swaminathan Research Institute in Chennai is also engaged in management of mangroves in states of Tamil Nadu, Andhra Pradesh and Odisha. In India, mangroves are spread over an area of 4,639sq. km which occupies only 0.14% of Asian mangrove cover. About 80% of the Indian mangrove are confined to the east coast while remaining 20% are distributed along the west coast. The mangrove forest cover along the west coast is rapidly declining and hence needs prompt attention for protection and conservation. The area covered by mangroves worldwide is estimated at almost 150,000km². The distribution, density and species composition are determined by the water and air temperatures during the winter, exposure to wave action and tidal currents. The most highly developed and most species rich mangals are found in Indonesia, Australia and Malaysia. Over the world 54 to 70 species, 20-27 genera and 16-19 families are found. (Simard et al, 2019)

Along the western coast of India mangroves are found in States such as Gujarat, Maharashtra, Goa, Karnataka and Kerala. On the eastern coast mangrove are present in state like Tamil Nadu, Andhra Pradesh, Odisha and West Bengal. In Andaman and Nicobar Island and in the Bay of Bengal harbour extensive mangrove forest are located. The gulf of kutch in Gujarat is known for its significant mangrove cover. The sundarbans mangrove forest, spread across parts of west Bengal and Bangladesh. It is the largest single block of tidal hallophytic mangrove forest in the world. It is famous for it's diversity including the Bengal tiger. (Shetty and Shingadia, 2022)

The major mangrove locations in India are Sundarban Groves, Mahanadi mangroves, Krishna Godavari mangroves, mangroves of Gujarat, Ratnagiri mangroves, Goa mangroves, Cauvery Deltaic mangroves and Andaman Nicobar mangroves. In 2022 an updated view of distribution of mangrove forests was released in the Global Mangrove Watch (GMW) Version 3.0. According to Indian state of Forest Report 2021, the mangrove cover in India is 4,9992 square kilometre, which is 0.15% of the country's total geographical area. There has been increase in mangrove cover as compared to 2019 assessment, that is 17 square kilometres. The states that show significant gain in mangrove cover are Odisha and Maharashtra. Sundarbans Groves which are located in the Northern Bay of Bengal is the world's largest patch of mangrove forest. It is spread

over approximately 10,000 square kilometres, in Bangladesh and India. Sundarbans is the first mangrove forest in the world, which was brought under scientific management as early as in 1892. Mangroves are found in tropical and subtropical intertidal regions of the world, occurring mainly between 24° North and 38° South. Total mangrove cover in the world is 15 Million Hector; that is 1% of the tropical forest of the world. India has about 3% of the total mangrove cover.The mangroves of Sundarbans are the largest single block of tidal halophytic mangroves of the world. The Mangrove vegetation in the coastal zone of Kerala is very sparsh and thin. According to size, mangrove range from bushy stands of dwarf mangroves found in Gulf of kutch, to taller strands found in Sundarbans and the kori Creek mangroves are scubby with stunted growth forming narrow and discontinuous patches on soft clayey mud. Mangroves are typically found in tropical and subtropical regions, along sheltered coastline, estuaries, deltas and lagoons where freshwater mixes with sea water. They thrive in brackish water and are often located in intertidal zones, where they provided vital ecosystem services such as costal protection, Habitat for various species and carbon sequestration. (Sreelekshmi et al, 2020)

There are three types of mangrove ecosystems, which consists of delta mangrove forest which is located at the mouth of the large estuaries on the east coast and the west coast of the Gulf of Kutch and kambhat. They cover up to 53% of all the mangroves in India and Sundarbans cover about 78%. The second type of mangroves are coastal mangroves and they are found in intertidal coasts, small estuaries, which covers upto 12% of the mangrove area of India. The last type of mangroves are Island mangroves found in Shallow sheltered intertidal areas. It covers approximately 16% of the total mangrove area of India. (Singh, 2020)

The mangroves of Bhitarkanika (Orissa) which is second largest in the Indian sub continent, harbour high concentration of typical mangrove species and high genetic diversity. Mangroves of Pichavaram and Vedaranyam are degraded mainly due to the construction of agriculture ponds and salt pans.(Mishra and Upadhyay, 2005)

MAPS SHOWING MANGROVE DISTRIBUTION IN INDIA

Fig 1.4 List of Mangroves Sites in India (Greeks for Greeks, 2023)

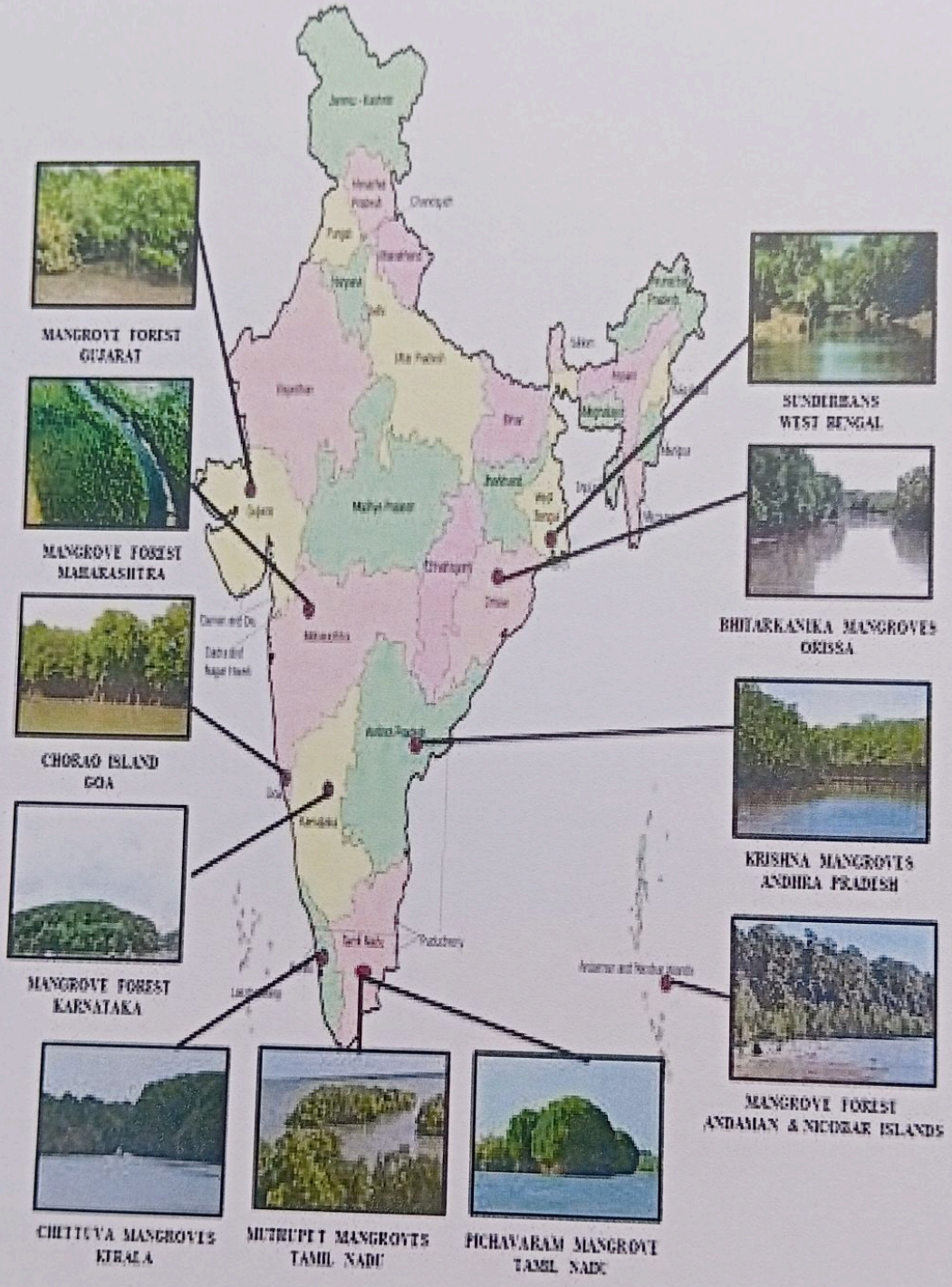


Fig 1.5 India map showing different dense mangrove locations of India. (Chapter 15- Indusrial application of enzymes derived from Indian mangroves, Biotechnological Utilization of Mangrove Resources, 2020)

FIGURE 3.1 Pie Chart showing Mangrove Cover in different States & UTs

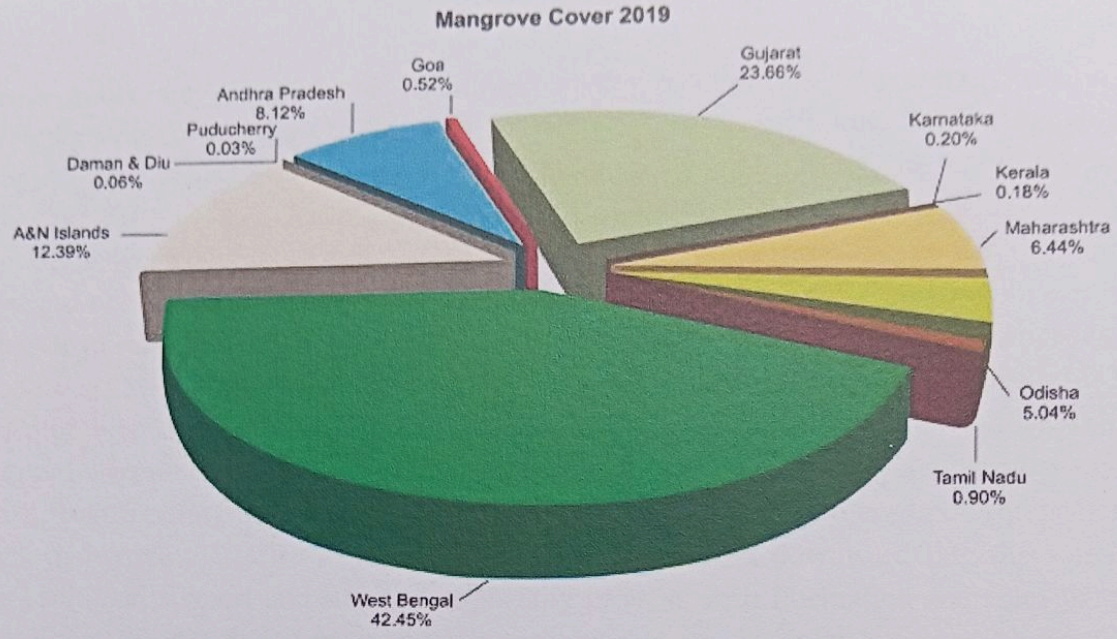


Fig 1.6 Pie chart showing mangrove cover in different states & UTs (Global Mangrove Alliance,2019)

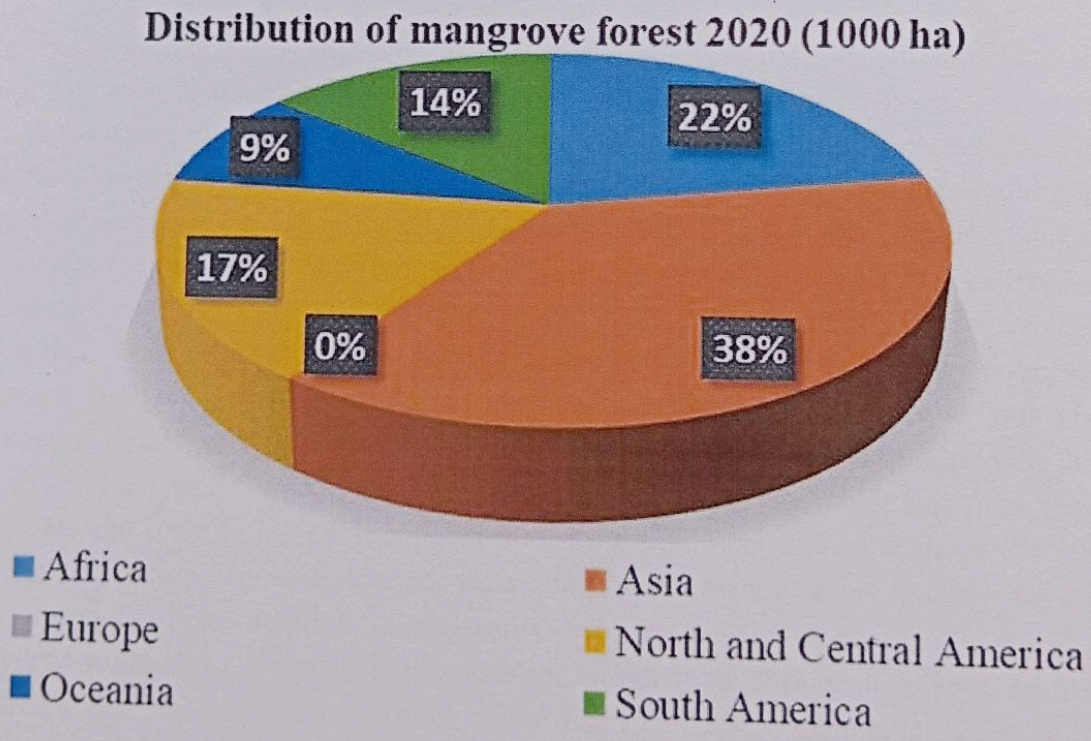


Fig 1.7 Pie chart showing mangrove forest (Conservation and Sustainable Utilization of Bioresources, 2020)

MORPHOLOGY AND ANATOMY

Mangrove Root

Mangrove roots are essential for stabilizing coastal ecosystems, preventing erosion, and providing habitats for various marine species. They also play a crucial role in filtering pollutants and trapping sediments, contributing to water quality. Mangrove roots are highly specialized structures adapted to the challenging conditions of coastal environments. Many mangrove species develop aerial roots, such as pneumatophores, which protrude above the soil and facilitate gas exchange. These roots help the plant cope with waterlogged soils low in oxygen by allowing air to reach the submerged roots. Some mangrove species, like the red mangrove have prop roots that extend vertically from the trunk and anchor the tree in the muddy substrate. These roots also provide structural support, especially in areas prone to tidal currents and waves.Cable roots grow horizontally from the trunk just below the soil surface. They stabilize the tree and prevent it from toppling over in soft, unstable substrates.Stilt roots are common in species like the black mangrove that arise from the lower trunk and extend downward into the soil. They provide additional support and stability, especially in areas with fluctuating water levels. Filter Feeding Roots are developed by some white mangrove species, which are specialized roots called pneumatophores with pores that filter salt from seawater, allowing the plant to obtain freshwater. Like other plants, mangroves have root hairs that increase the surface area for water and nutrient absorption. These microscopic structures are particularly important in nutrient-poor soils characteristic of mangrove ecosystems. (Kathiresan, 2012)

Mangrove roots release organic compounds called root exudates, which contribute to nutrient cycling, soil stabilization, and microbial activity in the rhizosphere. These exudates also play a role in detoxifying pollutants and promoting the growth of beneficial microorganisms. Overall, mangrove roots are integral to the survival and functioning of mangrove ecosystems, providing structural support, facilitating gas exchange, nutrient uptake, and water filtration, and serving as vital habitats for numerous marine organisms. Mangrove roots are highly specialized structures that enable these plants to thrive in challenging coastal environments characterized by high salinity, tidal fluctuations, and waterlogged soils. Mangrove root physiology involves several adaptations that enable these plants to survive and thrive in the unique and challenging conditions of coastal environments. Mangrove roots have mechanisms to cope with high levels of salinity in their environment. Some species are capable of excluding salt from their tissues, while others can tolerate high salt concentrations through mechanisms such as salt secretion or compartmentalization. In waterlogged soils with low oxygen levels, mangrove roots have adaptations to facilitate aeration. Aerial roots, such as pneumatophores, allow gas exchange between the roots and the atmosphere, ensuring an adequate supply of oxygen for respiration. Mangrove roots are adapted to extract water from saline environments. They may possess specialized structures, such as salt glands or selective ion uptake mechanisms, to regulate water and ion uptake while excluding excess salt. (Giri et al, 2014)

Mangrove roots provide anchorage and stability for the trees. Prop roots, stilt roots, and cable roots support the tree and prevent it from being uprooted or destabilized by tidal forces. Mangrove roots have adaptations for efficient nutrient acquisition in nutrient-poor coastal soils. Root hairs and mycorrhizal associations increase the surface area for nutrient absorption and enhance nutrient uptake from the surrounding environment. They have adaptations such as aerenchyma tissue, which contains air-filled spaces that facilitate oxygen transport to the root tissues, enabling aerobic respiration even in oxygen-depleted environments. Mangrove roots often form symbiotic relationships with microorganisms, including nitrogen-fixing bacteria and mycorrhizal fungi. These associations aid in nutrient cycling, nitrogen fixation, and overall plant health. (Srikanth et.al, 2015)

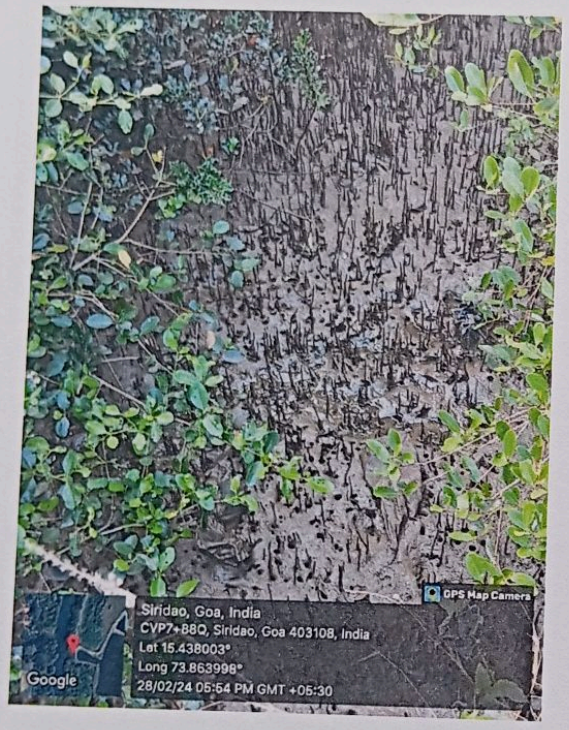


Fig1.8 Pneumatophores observed at Siridao

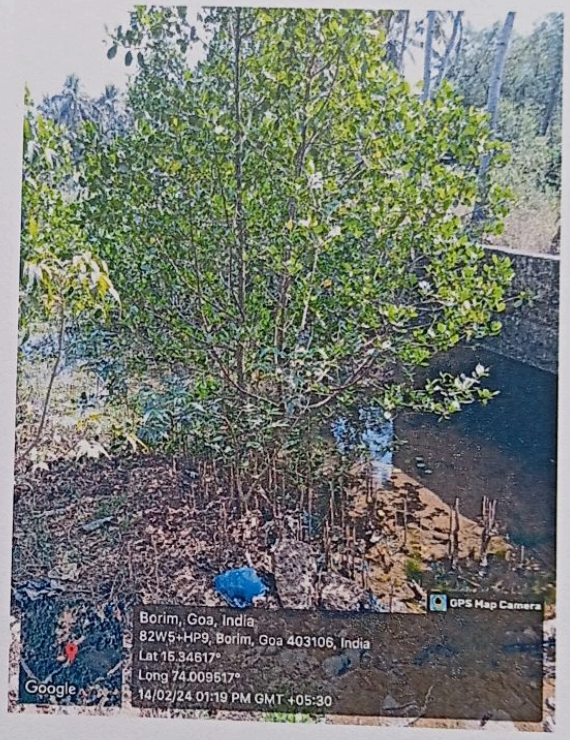


Fig1.9 Pneumatophores observed at Borim

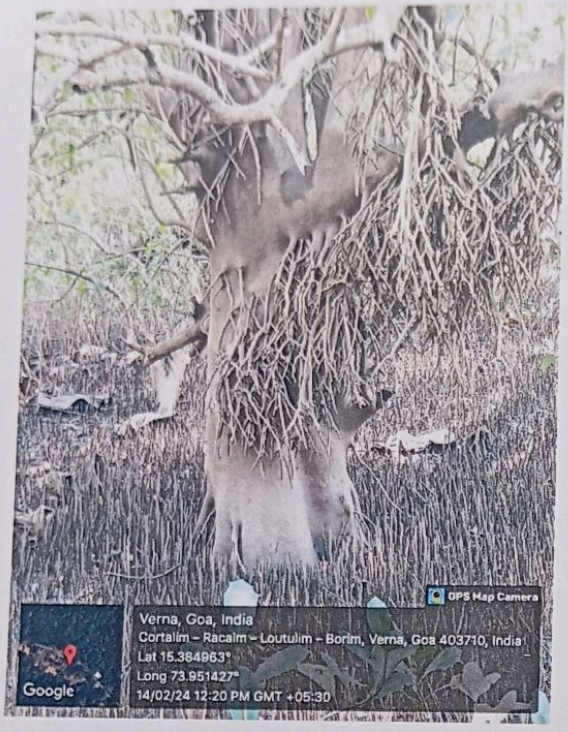


Fig 1.9 Mngrove roots observed at Verna

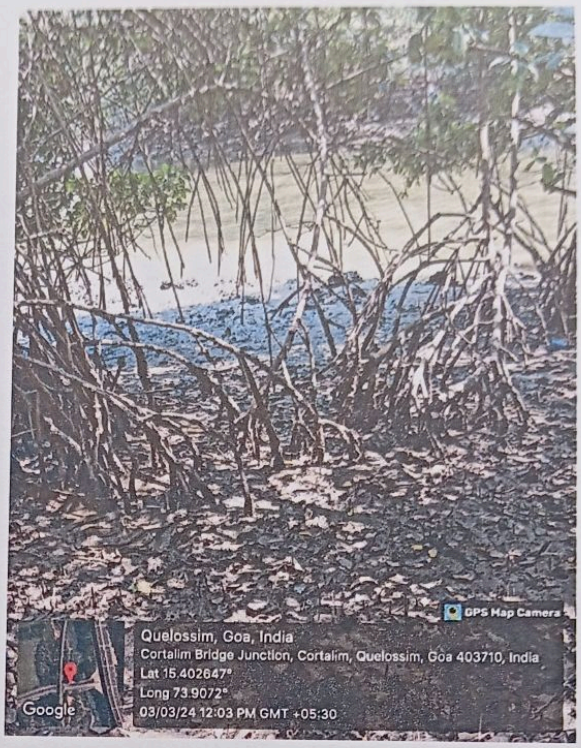


Fig1.10 Mangrove roots observed at Quelossim

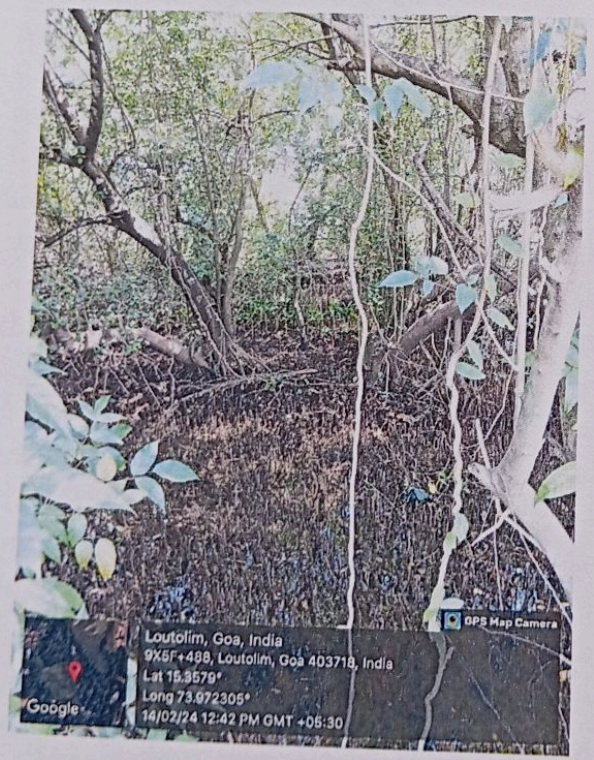


Fig1.10 Mangrove roots observed at Loutolim

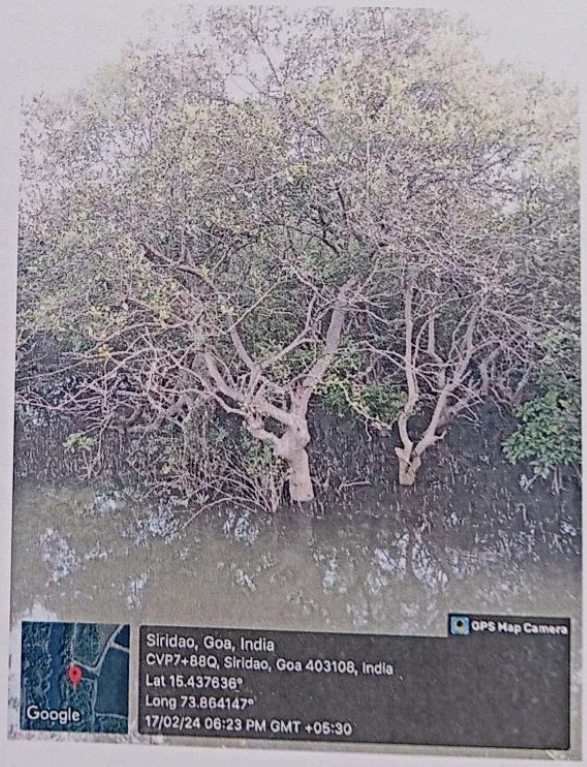


Fig1.11 Mangrove roots observed at Siridao

Mangrove Leaf

Mangrove leaves are specialized to survive in saline, waterlogged environments. Many mangrove species have adaptations to exclude salt from their tissues, preventing salt buildup. Some species have salt glands on their leaves that actively excrete salt, while others have thick cuticles or specialized cells that block salt entry. Mangrove leaves often have thick, waxy cuticles and sunken stomata to reduce water loss through transpiration. This helps them conserve water in the salty coastal environment. Mangrove leaves can tolerate occasional exposure to air during low tide. They may roll or fold their leaves to reduce surface area and minimize water loss when exposed to air. In the shaded regions of mangrove forests, leaves may have adaptations to maximize light capture, such as thin, elongated shapes or chloroplasts positioned along the edges of the leaves. Fallen mangrove leaves contribute to nutrient cycling in the ecosystem. They are broken down by decomposers and microorganisms, releasing nutrients back into the soil and water for uptake by other plants and organisms. Some mangrove species have leaves with antibacterial properties, which help protect them from pathogens in the brackish water. Mangrove leaves are adapted to the challenging conditions of coastal environments, including high salinity, waterlogging, and periodic exposure to air, while also contributing to the productivity and nutrient cycling of mangrove ecosystems. The anatomy of mangrove leaves varies among species, but they generally exhibit several adaptations to thrive in saline, waterlogged environments. Mangrove leaves often have a thick waxy cuticle covering their surface. This helps to minimize water loss through transpiration and reduces salt uptake from the surrounding environment. They have sunken stomata, the tiny pores on the leaf surface through which gas exchange occurs, are often sunken into pits or depressions in mangrove leaves. This adaptation helps to reduce water loss by creating a more humid micro environment around the stomata. Some mangrove species have specialized cells, known as salt glands, located on the leaf surface. These glands actively secrete excess salt, helping to prevent salt buildup in the leaf tissues. Many mangrove leaves have xerophytic adaptations, such as reduced leaf size, thickened cuticles, and modified stomatal structure. These adaptations help the leaves withstand the high salinity and water stress of coastal environments. Halophytes are plants adapted to saline environments, and mangroves exhibit several halophytic adaptations in their leaves. These may include the ability to accumulate compatible solutes specialized mechanisms for ion transport, and tolerance to high levels of sodium and chloride ions. Mangrove leaves often have chloroplasts concentrated in specific regions of the leaf, such as the upper surface or along the leaf margins. This distribution optimizes photosynthetic efficiency in the low-light conditions of mangrove habitats .Mangrove leaves come in various shapes and sizes depending on the species and environmental conditions. (Feller et al, 2023)

Some species have elongated leaves to maximize light interception in the under story, while others have broad leaves for efficient gas exchange and photosynthesis. Mangrove leaves perform photosynthesis to produce energy using sunlight, water, and carbon dioxide. Despite the often low light conditions in mangrove habitats, their leaves are adapted to efficiently capture and utilize available light for photosynthesis. Mangrove leaves have adaptations to regulate water uptake and loss in saline environments. Many mangrove species have mechanisms to cope with high levels of salt in their environment. Some species exclude salt from their tissues, while others have mechanisms to tolerate or sequester excess salt in specialized cells. Mangrove leaves absorb water and nutrients from the surrounding environment through their roots and leaf surfaces. Some species have adaptations to enhance nutrient uptake in nutrient-poor coastal soils. Mangrove leaves may have adaptations to regulate leaf temperature in response to fluctuating environmental conditions. This can include changes in leaf orientation, leaf angle, or leaf morphology to minimize heat stress. Some mangrove species have leaves with antibacterial properties, which help protect them from pathogens in the brackish water and muddy substrates of mangrove habitats. Mangrove leaves often have a leathery texture, which helps to reduce water loss through transpiration and provides protection against salt spray and harsh environmental conditions. Some mangrove species have succulent or fleshy leaves, which store water and provide additional protection against desiccation in saline environments. Mangrove leaves have serrated or waxy margins, which help to reduce water loss and protect against herbivory. Mangrove leaves have oblong or lanceolate leaf blades optimizing light capture in the shaded regions of mangrove forests. (Ghose & Nandy 2001)

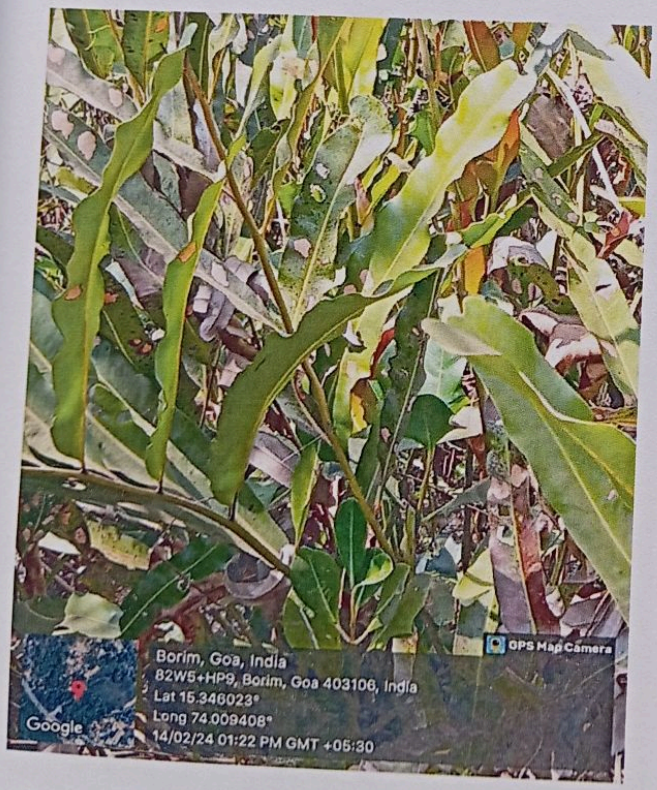


Fig 1.12 Mangrove leaves observed at Borim

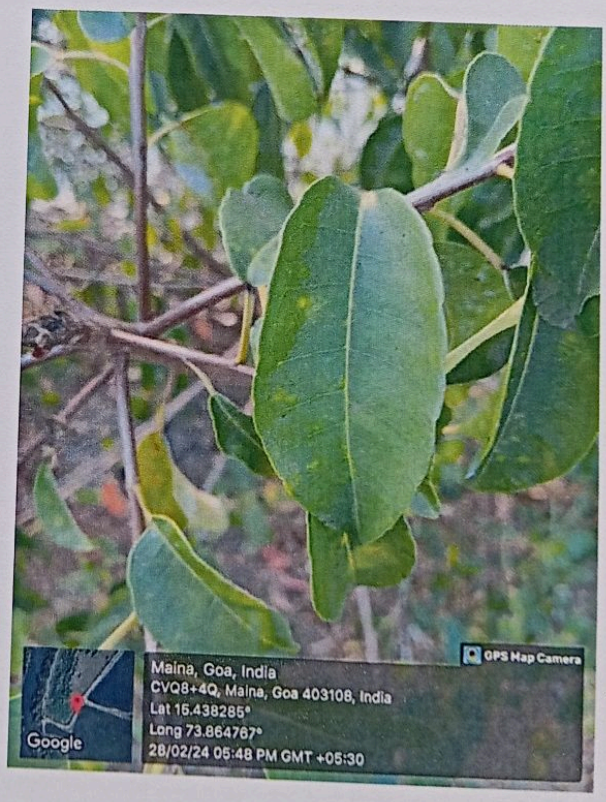


Fig 1.13 Mangrove leaves observed at Maina

Fig1.14 Mangrove leaves observed at Maina

Fig 1.15 Mangrove leaves observed at Verna

Fig1.16Mangrove leaves observed at Maina

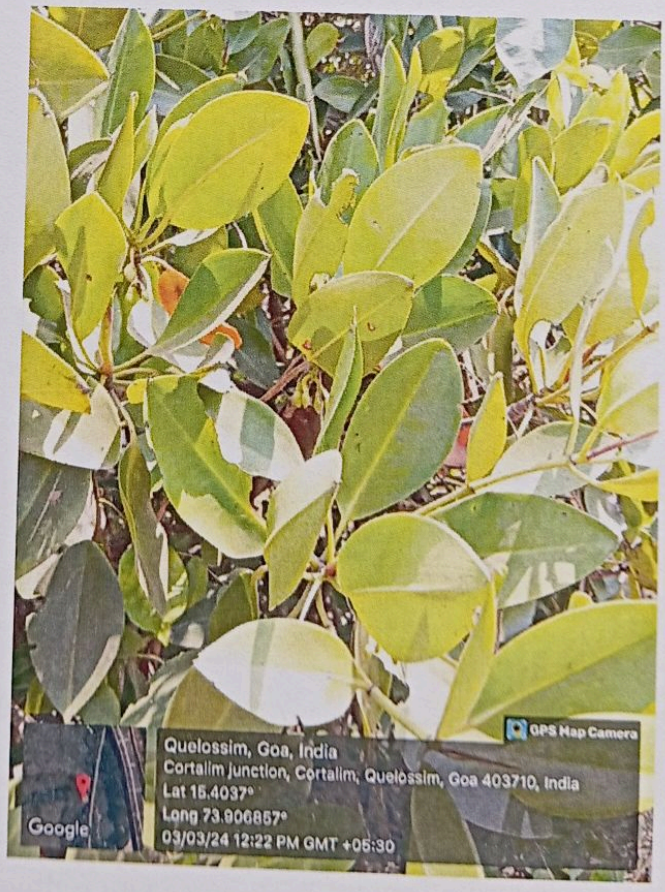


Fig1.17Mangrove leaves observed at Quelossim

HERBARIUM

A herbarium is essentially a library of dried, preserved plant specimens. Herbaria serve several purposes, including botanical research, species identification, conservation efforts, and education. They provide a record of plant biodiversity and distribution over time. For herbarium preparation plant specimens are collected from various locations, habitats, and ecosystems. They can be collected by botanists, researchers, students, or citizen scientists. When collecting specimens, it's important to document details such as location, habitat, date of collection, and the collector's name. Once plant specimens are collected they are pressed and dried to preserve their physical characteristics. This is typically done by placing the plant between sheets of absorbent paper and applying pressure until the specimen is completely dry. After drying, the specimens are mounted on sheets of archival paper using glue or other adhesive. Additional information such as the scientific name, common name, collection details, and any relevant notes are typically included on the mounting sheet. Once the plant specimens are mounted, the specimens are stored in cabinets or drawers in a controlled environment to prevent damage from pests, humidity, and light. Herbarium specimens can last for centuries if properly maintained. Herbarium collections are often accessible to researchers, students, and the public for study and reference. Overall, herbaria play a crucial role in botanical research, conservation efforts, and education by preserving plant specimens for future generations. (Andeson, 1999 and Yadav, 2020)

ADVANTAGES OF HERBARIUM

Documentation of Biodiversity: Herbaria preserve a vast array of plant specimens.

Scientific Research: Herbarium specimens serve as primary data sources for botanical research and facilitating studies.

Species Identification: Herbaria aid in the accurate identification of plant species to classify and categorize plants based on physical characteristics.

Historical Records: Herbarium collections offer historical documentation of plant distributions.

Conservation Efforts: Herbaria contribute to conservation efforts by documenting rare, threatened, and endangered plant species.

Education and Outreach: Herbaria provide valuable resources for educational purposes, offering opportunities for students, educators, and the public too.

Genetic Studies: Herbarium specimens can also be utilized for genetic research, allowing scientists to extract DNA and study genetic diversity within plant populations. (Yadav, 2020)

CHAPTER 2

LITERATURE REVIEW

Pawar (2012), has worked on mangrove flora along the Zuari River, he has reported multiple habitats of sandy beach and mangrove forests from Curtorim village, Goa, India. The survey made from selected sites, showed 5 true mangrove floral species belonging to 4 families. *Acanthus ilicifolius* and *Kandelia candel* are the most dominant mangrove species found in almost all the sites. The next dominating species are *Avicennia officinalis* and *Sonneratia caseolaris*.

Wakle et al. (2018), surveyed upon diversity of mangroves in Goa, Central West Coast of India, They have documented the diversity of true mangroves and mangrove associates in Goa. The selected sites were Zuari, Mandovi, Chapora, Terekhol, Talpona, Galgibag and Salim Ali Bird Sanctuary. They performed several field tours of short and long duration during Jan 2015 to Dec 2017. They observed sixteen true mangrove floral species along the sea coast in saline swamp and the adjacent regions at the study sites.

Silva and Bhat. (2011), has teamed up to analyse diversity status of mangrove species in estuarine regions of Goa, Central West Coast, India, During the study they divided mangroves in two categories, true mangroves and associate mangroves and estuaries of Goa were divided into 3 Sub-stations where station wise mangrove flora, its distribution and variation of different environmental parameters were studied. 15 true mangrove species belonging to 10 genera under 7 families were reported by them. Fringing type mangroves were common in all the minor estuaries, whereas major rivers have both fringing and mangrove swamps.

Attri and Kerkar. (2011), carried out seasonal assessment of heavy metal pollution in tropical mangrove sediments in Goa, India, They assessed the seasonal concentration of metals in sediments of Divar island, which is an anthropogenically-influenced mangrove swamp in the Mandovi estuary in comparison to Tuvem along the Chapora river which is found to be relatively pristine mangrove swamp. They found that the average heavy metal concentration in sediments decreased in the order Fe > Mn > Zn > Cu > Co > Pb > Cr and showed a marked seasonal variability. They reported much greater Pollution Load Index in Divar sediments than that of Tuvem sediments.

DSouza and Rodrigues. (2013), has examined biodiversity of Arbuscular Mycorrhizal (AM) fungi in mangroves of Goa in West India,They surveyed seventeen mangrove species of eight families at seven riverine and fringe habitats in Goa, West India for Arbuscular Mycorrhizal (AM) fungal diversity. They reported that sixteen species were found to be mycorrhizal and one species showed no AM fungal colonization. AM root colonization was recorded at all seven sites and ranged from 6%–77%. *Excoecaria agallocha* showed maximum root colonization (77%) and minimum colonization was seen in *Avicennia marina* (6%).

Fernandes et al. (2014), explored bacterial diversity in relatively pristine and anthropogenically-influenced mangrove ecosystems of Goa, India,They carried out parallel tag sequencing of V6 region of 16S rDNA and observations made by them in comparison to Divar and Tuvem mangrove ecosystems, they found out that phylum Proteobacteria was seen dominant at both the locations comprising 43-46% of total tags. Gammaproteobacteria were recorded higher at Divar than at Tuvem. These findings suggested that the quantity and quality of pollutants at Divar are still at a level to maintain high diversity. They also observed the possibility of Gammaproteobacteria contributing to modulating excess nitrate.

Kharangate-Lad and Bhosale. (2018), has worked upon mineralization of mangrove leaf litter by consortium of adhered bacterial isolates from mangrove ecosystem of Goa, India, In this research work, they observed that the presence of the bacterial consortium decreases the weight of the plant litter by 4% and the proteins and the sugar content are increased by 15% and 12 % respectively. They observed the activity of bacterial consortium when added to unsterile soil, it showed a remarkable decrease in the weight of plant litter of 35% and an elevation of sugar and protein content of 69% and 82% respectively. Hence they reported that the presence of bacterial consortium enhanced mineralisation of plant litter and therefore this consortium can find use in solid and agricultural waste management.

Badola et al. (2005), did analysis on storm protection function of Bhitarkanika mangrove ecosystem in Odisha, India, This study was based on the perception of local people regarding the services provided by mangrove forest in protecting lives and properties of coastal communities from storms and cyclones. People in the area were aware that the Bhitarkanika mangrove forest have protected status. A high percentage of people agreed to cooperate with the forest department in mangrove restoration.

Brahma and Mukherjee. (2016), surveyed mangrove diversity of India with special reference to Lothian island wildlife Sanctuary, India, Lothian Island is the second largest Wildlife Sanctuary located in Indian Sundarbans. They had conducted study only in the mangrove forest area and not in the reclaimed lands. In this survey they reported 30 mangrove species during the field visits. Among them 16 species were true mangroves and 14 were mangrove associates belonging to 23 families.

Thivakran et al. (2020), has worked on status, structure and environmental variations in semi-arid mangroves of India, They evaluated structural attributes of Gulf of Kachchh, 10 selected locations of mangrove ecosystem and their governing environmental variables using the line intercept transect in order to promote their conservative.They also demonstrated various physical and chemical factors in relation to salinity in determining the vegetation structure of mangroves.

Sreelekshmi et al. (2020), studied mangrove species diversity, stand structure and zonation pattern in relation to environmental factors at Sundarban Delta, east coast, India, Altogether they recorded, 27 true mangrove species representing 13 families and 16 genera from the selected 10 islands of Sundarban mangrove ecosystem. They observed dominance of *Avicennia marina* in each of the 10 islands.

Kathiresan (2000), has explored Pichavaram mangrove of south East India, He extensively studied Total 13 species of mangrove trees over three decades, unfortunately he observed that 90% of the mangrove cover in the study area was degraded. Possible factors that caused degradation were reported as high solar and UV-B radiations, high temperature, low rainfall, maximum salinity, soil conditions, tidal gradients and other coastal ecological changes as well as anthropogenic activities. Remedial measures were suggested and techniques for regeneration of degraded area were proposed by him.

Sahu et al. (2015), did assessment on mangrove area and implications of loss of mangrove in India, Mangroves are extremely important bio-resources which are crucial and are declining rapidly due to anthropogenic activities. They assessed the status, extent and trends of mangrove area in India and mitigation options for climate change, better planning for rehabilitation of degraded mangroves and creation of awareness to local communities to conserve, protect and restore the valuable mangrove wetland ecosystems.

Harilal et al. (2018), has surveyed on diversity and distribution of mangroves from the coastal ecosystems of Kerala, India,They carried out this survey to assess the extent and diversity of mangroves confining to 10 districts of Kerala by consistent field visits, google images and GPS. They revealed the existence of 15 true mangrove species falling under 9 genera and 6 families. Their observations concluded that, most of the major mangrove growing areas are under drastic pressure. They suggested inevitable reinstatement programmes for survival of this ecosystem.

Ramasubramanian et al. (2006), has analyzed mangroves of Godavari, Andhra Pradesh, India, They recorded that extent of mangroves was changed due to the erosion of mangroves along the coast and accretion near river mouths which formed new mangrove areas. They analyzed changes in the extent of mangroves through remote sensing. The Godavari mangroves and coastline have undergone drastic change within a short period of about 60 years due to both natural and anthropogenic causes. They reported that area of accretion and restored mangrove was almost equal to the area of degradation.

Nathan et al. (2020), did assessment on comparison of bacterial diversity from two mangrove ecosystems at Mangalavanam and Puthuvype of Cochin, India. They stated that bacterial diversity in mangrove sediments may be dependent on the environmental parameters as well as the anthropogenic effects like pollution. They analyzed that the major physico-chemical parameters of the sediment of Mangalavanam was rich in nitrogen and Sulphur, on the other hand the sample collected from Puthuvype was rich in Carbon. They compared the two different mangrove ecosystems and the observations revealed both ecosystems show growth of different bacterial communities, as the environments were different.

Singh. (2020), has worked on structural characteristics of mangrove forest in different coastal habitats of Gulf of Khambhat, arid region of Gujarat, West coast of India. He selected four sampling sites namely Bhavnagar Ghogha coast, Bharuch, Dahej coast Surat, Dumas beach Navsari, Purna estuaries based on the availability of mangroves on the inter-tidal area. They applied quadrate techniques..A total of six true mangrove species belonging to three families and five genera and ten mangrove associates from eight families were recorded. Shannon diversity index for mangrove species was recorded highest in Navsari, Purna estuaries followed by Surat whereas Bhavnagar and Bharuch showed zero index value. They stated that if Shannon's index falls within in the range of 1.5–3.5 considered as well-diversified area and if it is zero then there's no diversity.

Ragavan et.al (2016), has reviewed on the mangrove floristics of India. The review showed the species composition in the mangrove habitats of India. They reported that the Indian mangroves consist of 46 true mangrove species belonging to 14 families and 22 genera, which includes 42 species and 4 natural hybrids, that is about 57% of the world's mangrove species are represented in India. They recorded that West coast has 27 species belonging to 11 families and 16 genera, and the Andaman and Nicobar Islands have 38 species belonging to 13 families and 19 genera. They observed highest diversity in the Andaman and Nicobar Islands they also concluded that in terms of mangrove diversity, India is the third richest country in the world.

Agoramoorthy et al. (2007), experimented on antibacterial and anti fungal activities of fatty acid Methyl Easters of the Blind-your-eye mangrove (*Excoecaria agallocha*). For the first time, they determined the fatty acid composition and the antibacterial and anti fungal activities of Fatty Acid Methyl Esters (FAME) of the blind-your-eye mangrove plant found along the coastal areas of south India. The analysis of FAME extract of *Excoecaria agallocha* by gas chromatography revealed higher amount of saturated fatty acids than unsaturated fatty acids.

Giri et al. (2011), has carried out analysis on status and distribution of Mangrove forests of the world using earth observation satellite data. They mapped the status and distributions of global mangroves using recently available Global Land Survey (GLS) data and the Landsat archive, They attempted it at 30-m spatial resolution. They reported that Approximately 75% of world's mangroves are found in just 15 countries, and of which only 6.9% are protected under the existing protected areas. They confirmed that the findings of bio geographic distribution of mangroves is generally confined to the tropical and subtropical regions and it revealed that largest percentage of mangroves is found between 5° N and 5° S latitude.

CHAPTER 3

METHODOLOGY

PREPARATION OF HERBARIUM

How the herbarium was prepared :

1 Collected healthy mangrove species with leaves, stems, flowers or fruits from different locations of Goa.

2 Placed the collected plants between newspaper sheets assuring the parts of the plants do not overlap and get damaged, this newspaper sheets containing plant specimens were pressed under flat plywood by keeping books weight on it.

3 Allowed the specimens to dry completely for 4-6 days

4 Once they dried, carefully mounted the specimens assuring all parts are visible and securely attached on the cardboard using glue, tap and transparent sheet.

5 Labeled each specimen with essential information such as scientific name, date of collection etc.

6 Stored the mounted specimen in a cool, dry and dark area to prevent deterioration as well as to avoid them from insect and pest damage.

CHAPTER 4

RESULTS

SELECTED WORKING SITES IN GOA

Zuari Estuary -

The mouth region of the estuary is approximately 5 km wide while upstream its width narrow down to less than 1 km. Marked tidal amplitude with heavy wave action is present up to Siridao head. In this region sandy beaches interspersed with rocky portions are present from Dona Paula to Siridao head and from Vasco to near St Jasinto Island on the northern and southern banks respectively. The estuarine environment extends upsteam up to Savardem (28km).

1. Siridao - Siridao has mangrove vegetation along its edges providing a unique habitat for various bird species.

2. Maina - Maina is known for its dense mangove cover, providing habitat for various species of plants and animals.

3. Quelossim - Quelossim is located near the mouth of the Zuari river and has mangrove habitat in the surrounding wetlands and marshy areas.

4. Cortalim - Cortalim is a village situated along the bank of the Zuari river, where mangroves are found in the estuarine areas and along the river bank.

5. Verna - Verna is another area along the zuari river where mangroves thrive. It's known for its industrial estate but also has pockets of mangrove vegetation along Zuari river.

6. Loutolim - Loutolim village situated in North Goa includes mangrove habitat and supports vital mangrove ecosystem along Zuari river.

7. Borim - Borim is known for its dense mangrove forests and divers wildlife.

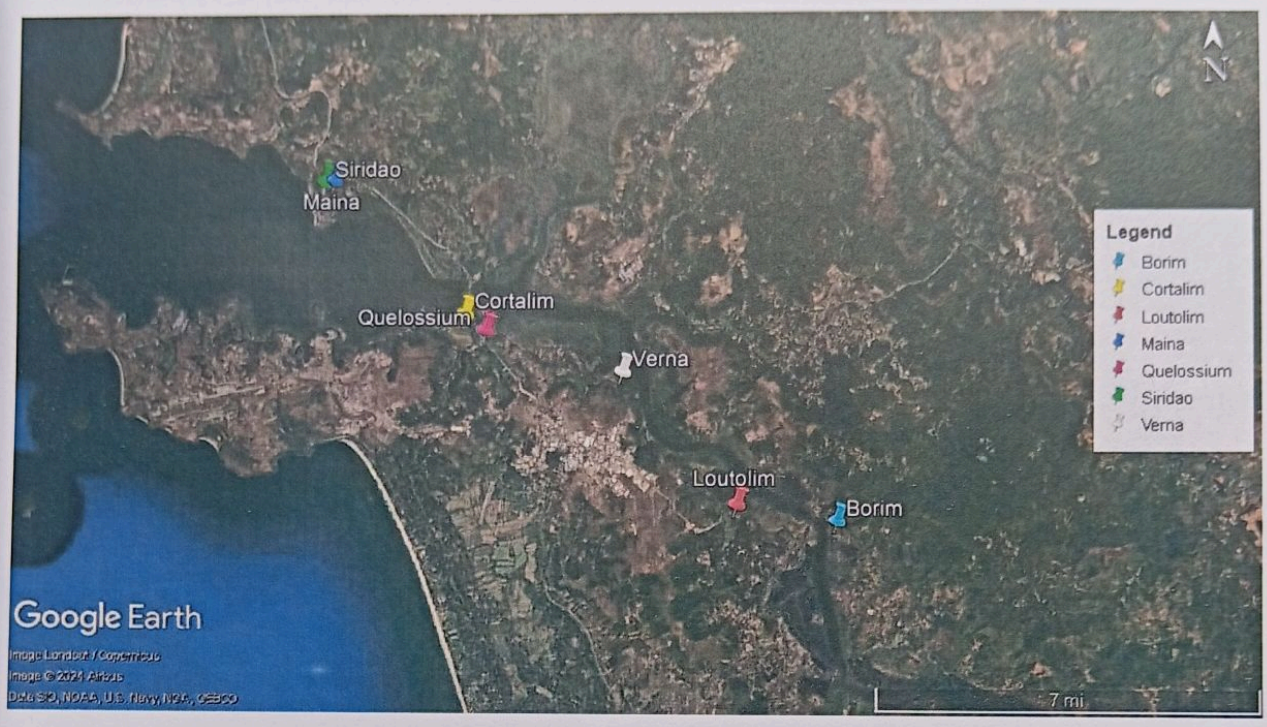


Fig 4.1 Google Earth map showing selected sampling sites in Goa

Working sites	Latitude	Longitude
Siridao	15.441131°N	73.864058°E
Maina	15.439527°N	73.865369°E
Quelossium	15.403762°N	73.903992°E
Cortalim	15.391561°N	73.906825°E
Verna	15.385323°N	73.950332°E
Loutolim	15.357862°N	73.972288°E
Borim	15.346556°N	74. 009282°E

TABLE 4.1 Showing latitude and longitude of selected sampling sites in Goa

MANGROVES OF GOA

1. *Rhizophora mucronata*

Mangrove species is found in Siridao and Cortalim, Goa.

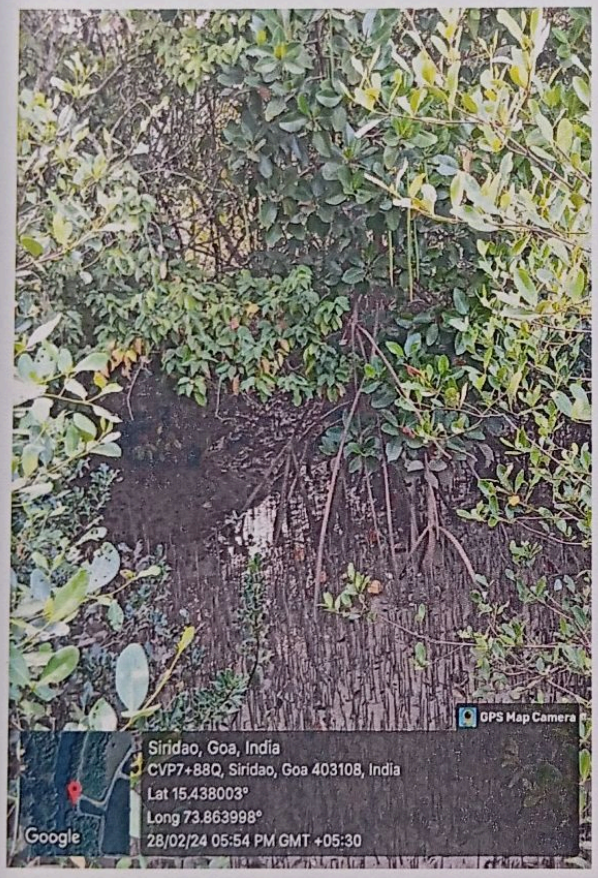


Fig 4.2 Mangroves found at Siridao

Fig 4.3 Mangroves found at Cortalim

Rhizophora mucronata

Scientific classification :

Kingdom: Plantae

Phylum: Tracheophytes

Class: Angiosperms

Order: Malpighiales

Family: Rhizophoraceae

Genus: *Rhizophora*

Species: ***R. mucronata***

DESCRIPTION :

The identified mangrove species is known as ***Rhizophora mucronata.***

▪ *Rhizophora mucronata* is a species of mangrove tree belonging to the family Rhizophoraceae. It is commonly found in coastal areas with brackish water. This species is known for its ability to withstand harsh conditions, such as tidal fluctuations and saline environments, making it an important component of mangrove ecosystems.

Morphology: It is a medium-sized tree that can reach heights of up to 25 meters.The bark is smooth, grayish-brown. The leaves are leathery, elliptical to obovate in shape, and arranged opposite and the size of the leaves is 12cm long and 6cm wide.

Root System: One of the distinctive features of *Rhizophora mucronata* is its pneumatophores, also known as aerial roots or breathing roots. These specialized roots emerge vertically from the soil and help the tree to absorb oxygen in waterlogged soils.

Reproductive Structures: *Rhizophora mucronata* produces small, yellowish flowers with four petals. The fruit is a greenish-brown, ovoid-shaped capsule that measures around 3 cm in length.

Ecological Importance: *Rhizophora mucronata* root system stabilizes coastal sediments, reducing erosion and protects shorelines. The dense canopy of *Rhizophora mucronata* provides habitats for various species of birds, mammals, reptiles, and invertebrates. It also serves as a nursery ground for many commercially important fish and crustaceans, contributing to the productivity of coastal fisheries.

2. Kandelia candel

Mangrove species is found in Siridao and Maina, Goa.

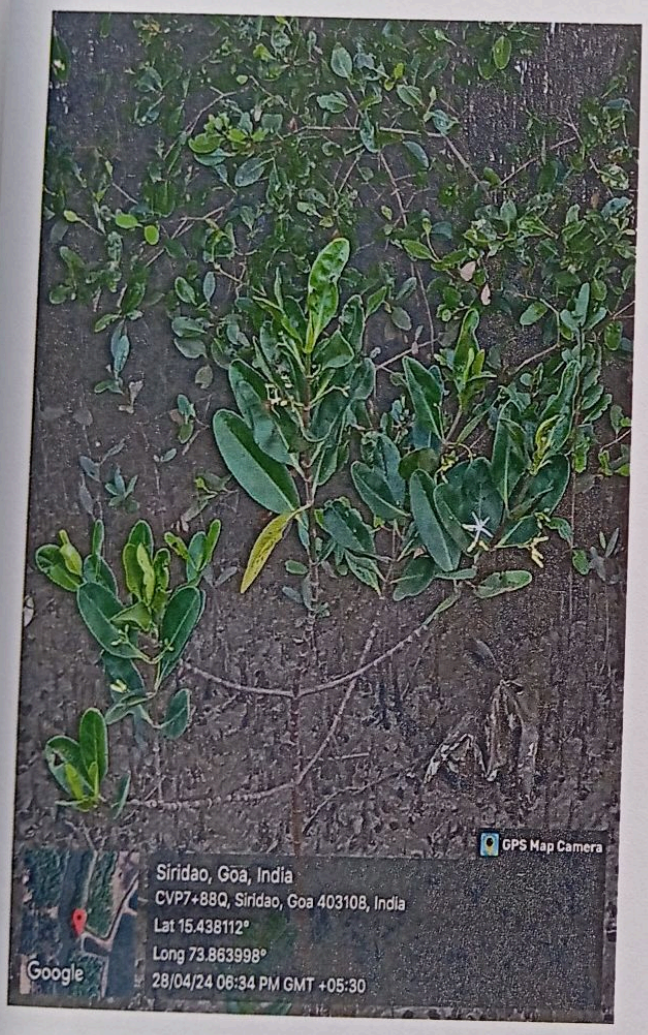


Fig 4.4 Mangroves found in Siridao

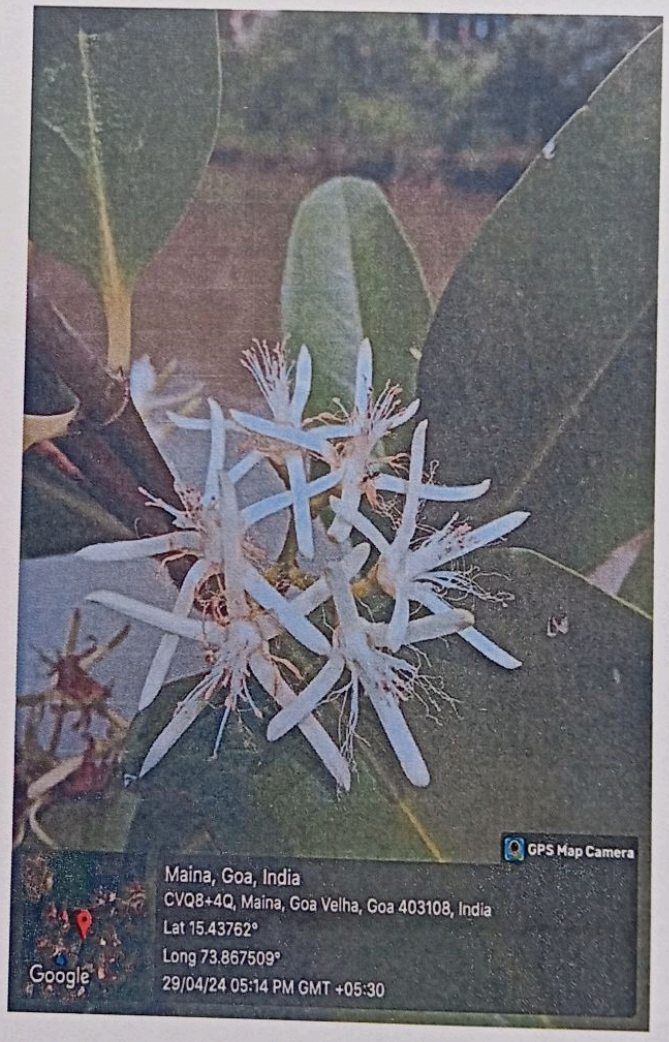


Fig 4.5 Mangroves found in Maina

Kandelia candel

Scientific classification:

Kingdom: Plantae

Phylum: Tracheophytes

Class: Angiosperms

Order: Malpighiales

Family: Rhizophoraceae

Genus: *Kandelia*

Species: ***K. candel***

DESCRIPTION :

The identified mangrove species is known as ***Kandelia candel.***

▪ *Kandelia candel,* commonly known as the "spurred mangrove" or "thorny mangrove," is a species of mangrove plant belonging to the family Rhizophoraceae. It is primarily found in the coastal regions of East and Southeast Asia.

Morphology: This mangrove species typically grows as a shrub or small tree, reaching heights of up to 4-5 meters. It has dark green, leathery leaves that are elongated with pointed tips and arranged opposite to each other on the stem.

Reproductive structures: The plant produces small, white or pale pink flowers with five petals. Fruits are ovoid, green, long and cylindrical propagule.

Root system: Aerial roots known as pneumatophores, which help with gas exchange in waterlogged soils. These roots also provide stability in soft sediments and allow the plant to access oxygen.

Ecological Importance: Like other mangrove species, *Kandelia candel* plays a vital role in coastal ecosystems. It provides habitats and nursery grounds for numerous marine species, including fish, crabs, and mollusks. Mangroves also act as a buffer against coastal erosion, storm surges, and tsunamis, while trapping sediment and filtering pollutants from the water.

3. *Sonneratia caseolaris*

Mangrove species is found in Siridao and Borim, Goa.

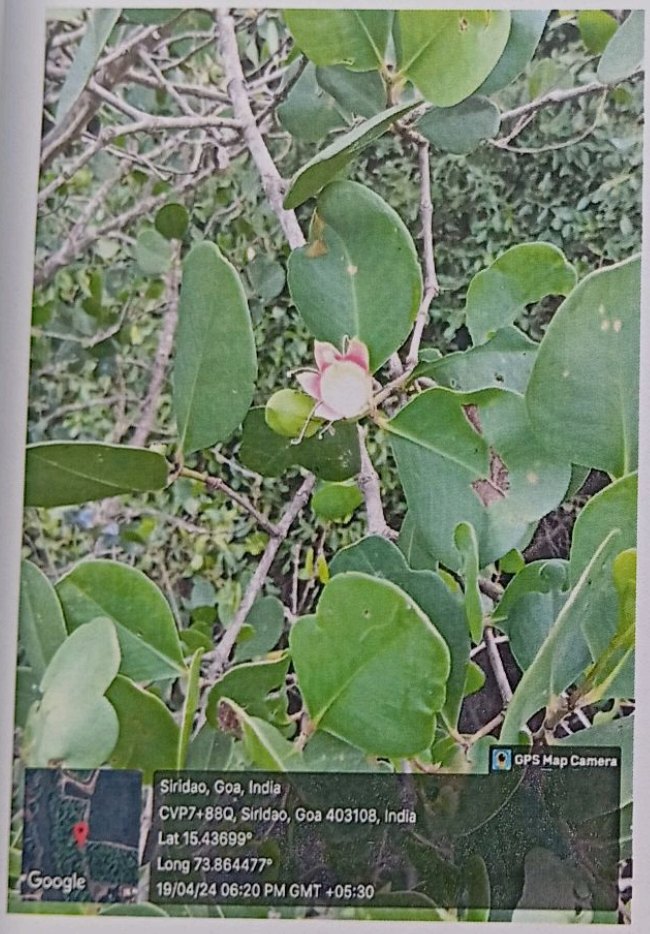


Fig 4.6 Mangroves found at Siridao

Fig 4.7 Mangroves found at Borim

Sonneratia caseolaris

Scientific classification :

Kingdom: Plantae

Phylum: Tracheophytes

Class: Angiosperms

Order: Myrtales

Family: Lythraceae

Genus: *Sonneratia*

Species: ***S. caseolaris***

DESCRIPTION :

The identified mangrove species is known as ***Sonneratia caseolaris.***

▪ *Sonneratia caseolaris*, commonly known as the mangrove apple or crabapple mangrove, is a species of mangrove tree in the family Lythraceae.

Morphology: The tree can reach heights of up to 15 meters. The leaves are elliptical or obovate, leathery, and glossy green, with a waxy coating to minimize water loss.

Reproductive Features: *Sonneratia caseolaris* produces small, white flowers with five petals. The flowers are often pollinated by insects. Its fruit is a rounded, greenish-yellow berry, resembling a small apple or crabapple.

Root system: It has distinctive pneumatophores (aerial roots) that protrude from the soil, aiding in gas exchange in waterlogged soils.

Ecological Importance: Mangroves, including *Sonneratia caseolaris*, play crucial roles in coastal ecosystems. They stabilize coastlines, provide habitats for diverse flora and fauna, and act as nurseries for various marine species.

4. *Excoecaria agallocha*

Mangrove species is found in Maina and Goa

Fig 4.8 Mangroves found at Maina

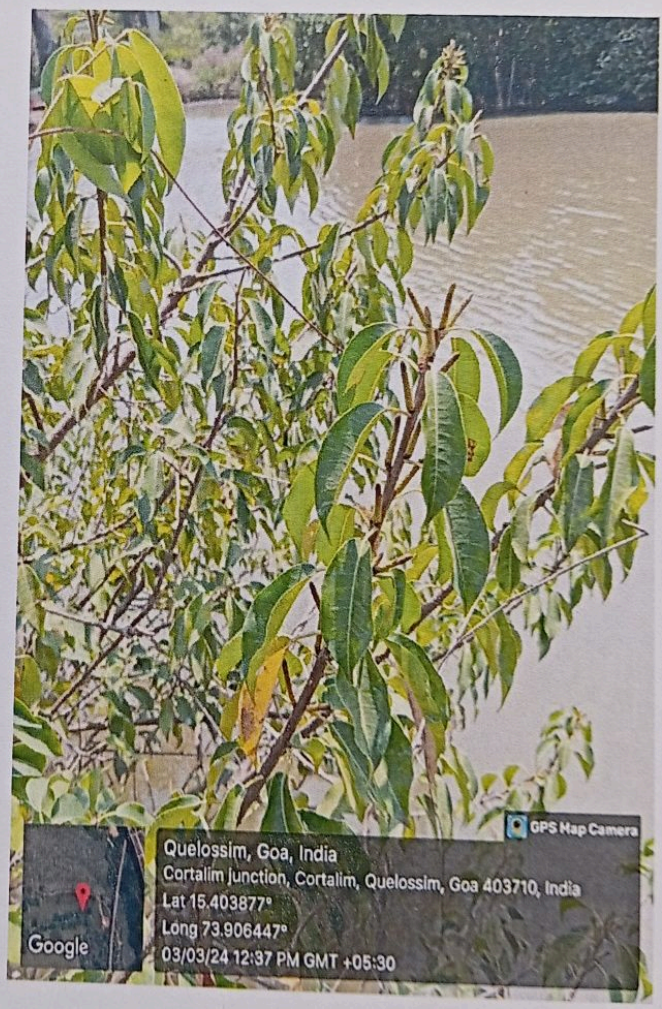


Fig 4.9 Mangroves found at Quelossim

Excoecaria agallocha

Scientific classification :

Kingdom: Plantae

Phylum: Tracheophytes

Class: Angiosperms

Order: Malpighiales

Family: Euphorbiaceae

Genus: *Excoecaria*

Species: ***E. agallocha***

DESCRIPTION :

The identified mangrove species is known as ***Excoecaria agallocha.***

▪ *Excoecaria agallocha*, commonly known as the Blind-your-eye mangrove or milky mangrove, is a species of mangrove tree in the family Euphorbiaceae.

Morphology: This mangrove species is characterized by its milky white latex sap, which is toxic and can cause irritation or even blindness.

Reproductive structures: *Excoecaria agallocha* typically produces small, inconspicuous flowers. The fruits are often capsule-like structures

Root System : Its roots are often submerged in waterlogged soils and are capable of filtering out salt, allowing the plant to extract freshwater from saline environments.

Ecological Importance: Mangroves, including *Excoecaria agallocha*, provide essential ecosystem services. They serve as nurseries for fish and other marine organisms, help to stabilize shorelines, and mitigate the impacts of storms and tsunamis by acting as natural buffers.

5. *Avicennia officinalis*

Mangrove species is found in Maina and Siridao, Goa.

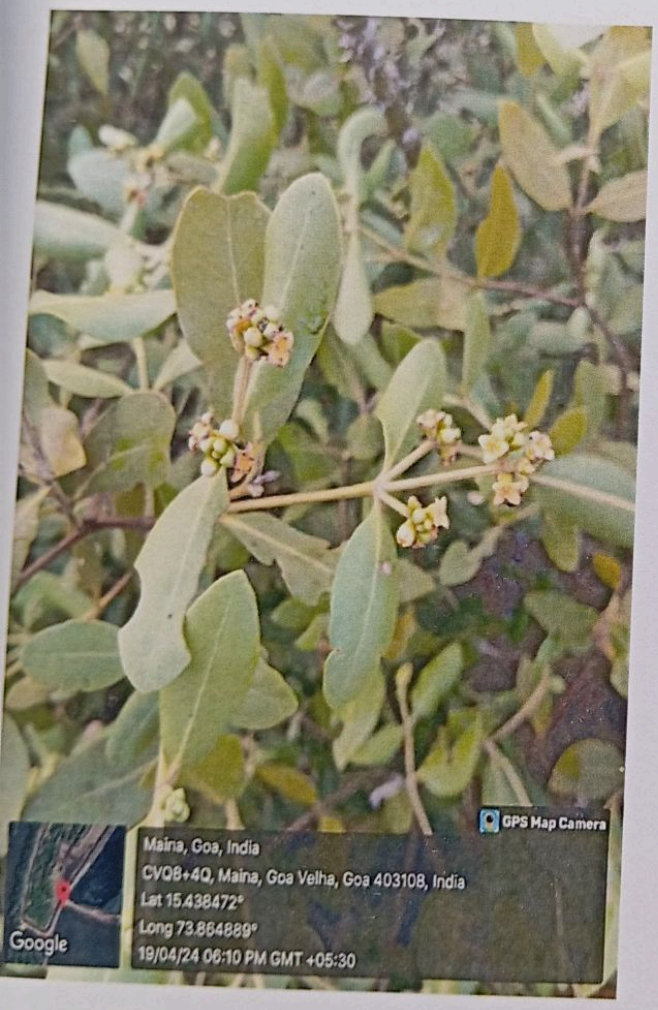


Fig 4.10 Mangroves found at Maina

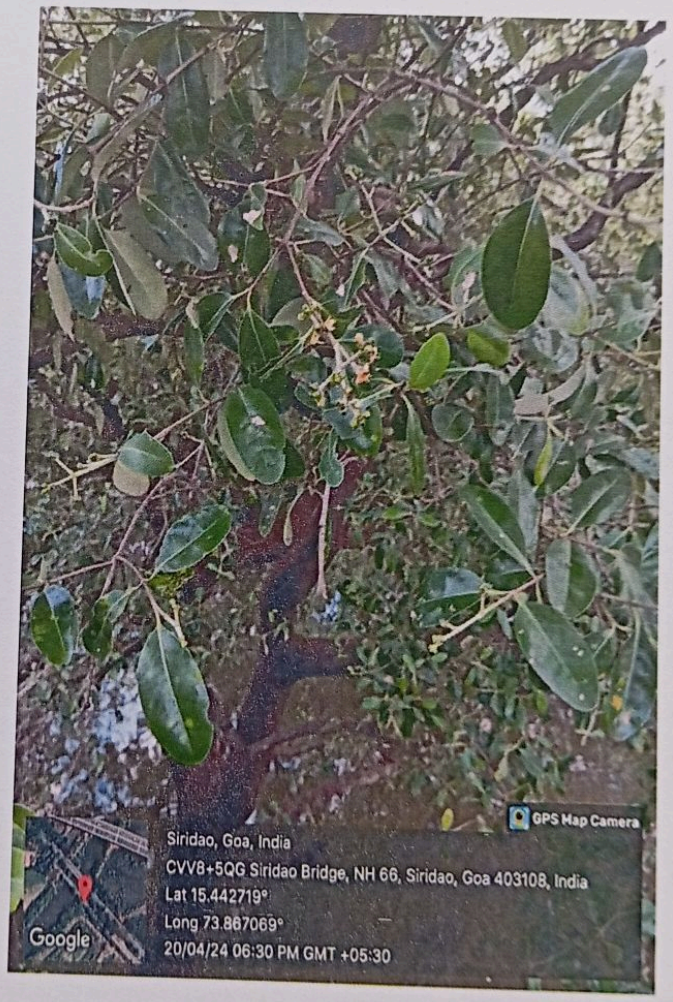


Fig 4.11 Mangroves found at Maina

Avicennia officinalis

Scientific classification :

Kingdom : Plantae

Phylum : Tracheophytes

Class : Eudicots

Order : Asterids

Family : Acanthaceae

Genus : *Avicennia*

Species : ***A. officinalis***

DESCRIPTION :

The identified mangrove species is known as ***Avicennia officinalis*** **.**

▪ *Avicennia officinalis*, commonly known as Indian mangrove or Indian grey mangrove, is a species of mangrove tree found primarily in the Indian subcontinent and Southeast Asia. The tree typically grows up to 20 meters in height and has a dense, spreading crown.

Morphology: *Avicennia officinalis* thrives in tidal areas along coastlines, estuaries, and river deltas. It prefers saline or brackish waterand is often found in muddy or sandy substrates.

Reproductive structures: Its bark is smooth and greyish, leaves are elliptical or lanceolate, with a leathery texture and glossy green color. The roots include pneumatophores, specialized structures that protrude from the soil to facilitate gas exchange.

Roots system: They have aerial roots that provide stability in muddy substrates and facilitate oxygen uptake.

Ecological Importance: They play vital roles in coastal ecosystems. Mangrove forests also help to stabilize coastlines, protect against erosion, and mitigate the impacts of storms and tsunamis.

6. *Avicennia marina*

Mangrove species is found in Maina and Cortalim, Goa

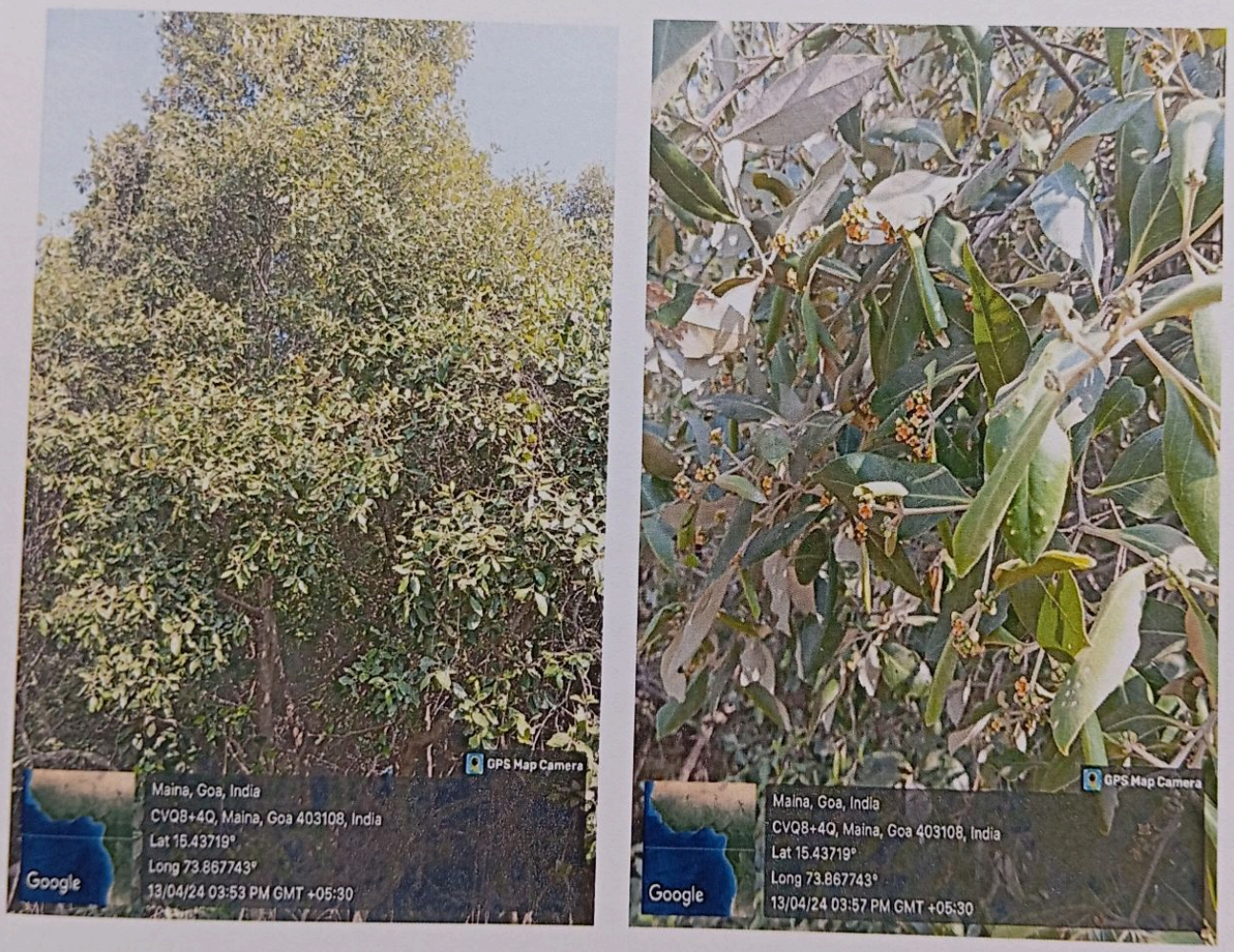


Fig 4.12 and Fig 4.13 Mangroves found at Maina

Avicennia marina

Scientific classification :

Kingdom : Plantae

Phylum : Tracheophytes

Class : Eudicots

Order : Asterids

Family : Acanthaceae

Genus : *Avicennia*

Species : ***A. marina***

DESCRIPTION :

The identified mangrove is known as ***Avicennia marina***

▪ *Avicennia marina*, commonly known as the grey mangrove, is a species of mangrove tree that belongs to the family Acanthaceae. It's widely distributed along sheltered coastlines and estuaries in tropical and subtropical regions around the world.

Morphology: *Avicennia marina* has unique adaptations to its environment. Its roots are equipped with pneumatophores, these pneumatophores allow the tree to access oxygen, even when submerged during high tide. The leaves are thick, leathery, and have salt-excreting glands that help to excrete excess salt absorbed from the surrounding water.

Reproductive Structures: Grey mangroves reproduce through seeds, which are typically dispersed by water. The seeds germinate while still attached to the parent tree, producing a long, slender propagule. Once the propagule falls into the water, it can float for an extended period before eventually settling in suitable substrate to establish a new plant.

Root system : They have pneumatophores with lateral root system.

Ecological Importance: Its dense root systems stabilize shorelines, reducing erosion and providing protection against storm surges. The mangrove forests supports the livelihoods of coastal communities and contributes to marine biodiversity.

7. Lumnitzera racesosa

Mangrove species is found in Quelossim and Borim, Goa.

Fig 4.14 Mangroves found at Quelossim

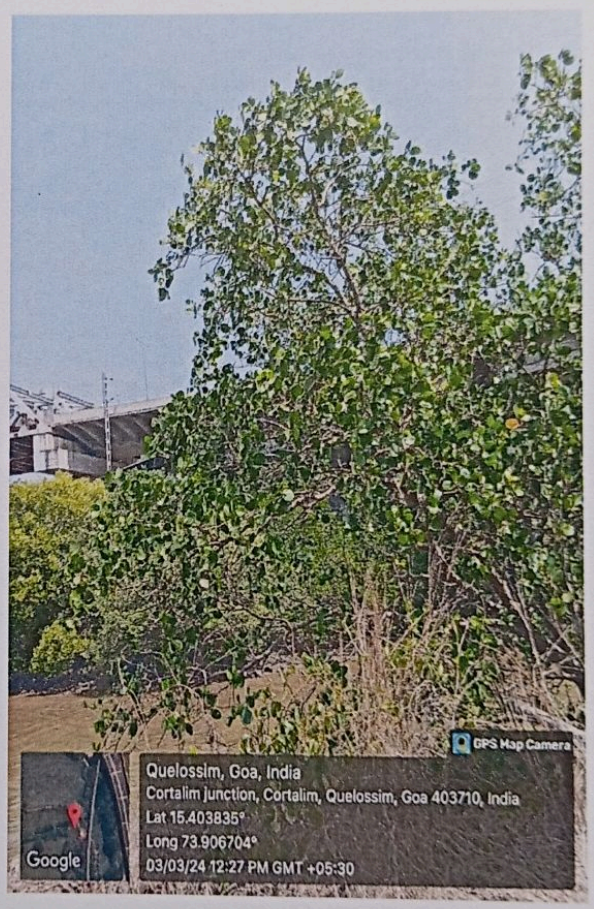


Fig 4.15 Mangroves found at Quelossim

Lumnitzera racesosa

Scientific classification :

Kingdom: Plantae

Phylum: Tracheophytes

Class: Angiosperms

Order: Myrtales

Family: Combretaceae

Genus: *Lumnitzera*

Species: ***L. racemosa***

DESCRIPTION :

The identified mangrove species is known as ***Lumnitzera racesosa.***

▪ *Lumnitzera racemosa*, commonly known as the White-flowered Mangrove or Black Mangrove, is a species of mangrove tree in the family Combretaceae.

Morphology : *Lumnitzera racemosa* typically grows in coastal areas with muddy or sandy substrates, often alongside other mangrove species.

Reproductive structure : It has distinctive white flowers, which give it the common name "White-flowered Mangrove." The leaves are elliptical to lanceolate in shape, with a leathery texture and a glossy green upper surface.

Root system: *Lumnitzera racemosa* has specialized aerial roots called pneumatophores.

Ecological Importance: Its dense root system helps to stabilize shorelines and prevent erosion, while providing habitat and nursery grounds for various marine organisms.

8. *Bruguiera gymnorhiza*

Mangrove species is found in Quelossim and Cortalim, Goa.

Fig 4.16 Mangroves found at Quelossim

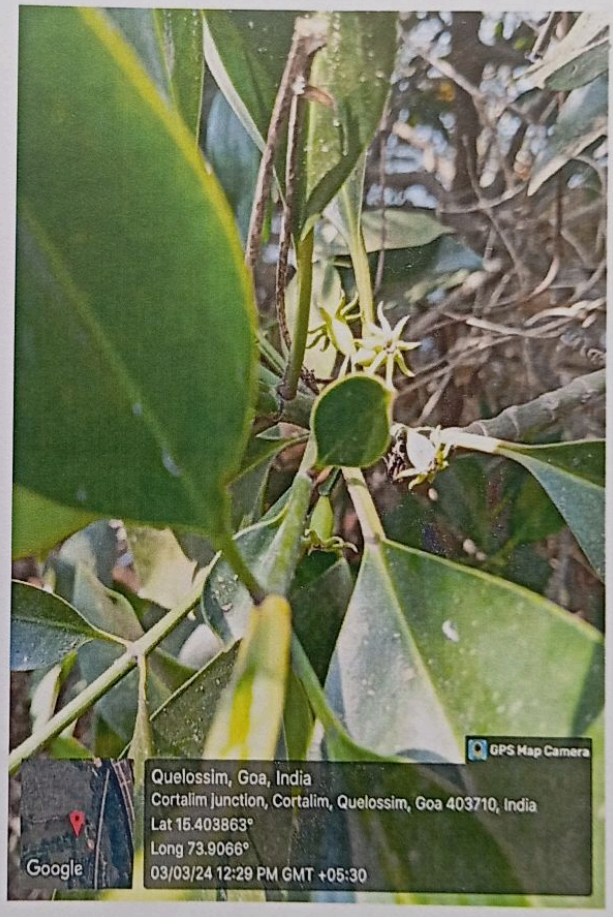


Fig 4.17 Mangroves found at Quelossim

Bruguiera gymnorhiza

Scientific classification :

Kingdom: Plantae

Phylum: Tracheophytes

Class: Angiosperms

Order: Malpighiales

Family: Rhizophoraceae

Genus: *Bruguiera*

Species: ***B. gymnorhiza***

DESCRIPTION:

▪ The identified mangrove species is known as ***Bruguiera gymnorhiza.***

Bruguiera gymnorhiza, commonly known as the black mangrove, is a species of mangrove tree native to coastal regions of the Indian Ocean and the western Pacific Ocean.

Morphology: It typically grows as a medium-sized tree, reaching heights of up to 20 meters (65 feet). The bark is dark grey to black, often with fissures and rough texture. The leaves are opposite, elliptical to oblong-lanceolate in shape, and leathery.

Reproductive Features: The flowers are small, white, and occur in clusters. The species has viviparous seeds, meaning the seeds germinate while still attached to the parent tree, producing seedlings that drop into the water and float until they establish themselves in the substrate.

Root System: *Bruguiera gymnorhiza* has distinctive stilt roots that emerge from the trunk above ground level and then arch downward into the soil. These roots provide stability and facilitate gas exchange.

Ecological Importance: It provides habitat and nursery grounds for various marine organisms, including fish, crustaceans, and mollusks. The dense root system helps stabilize coastal sediments and protect shorelines from erosion. Mangroves also sequester carbon dioxide from the atmosphere, helping mitigate climate change.

9. *Bruguiera cylindrica*

Mangrove species is found in Quelossim and Siridao, Goa.

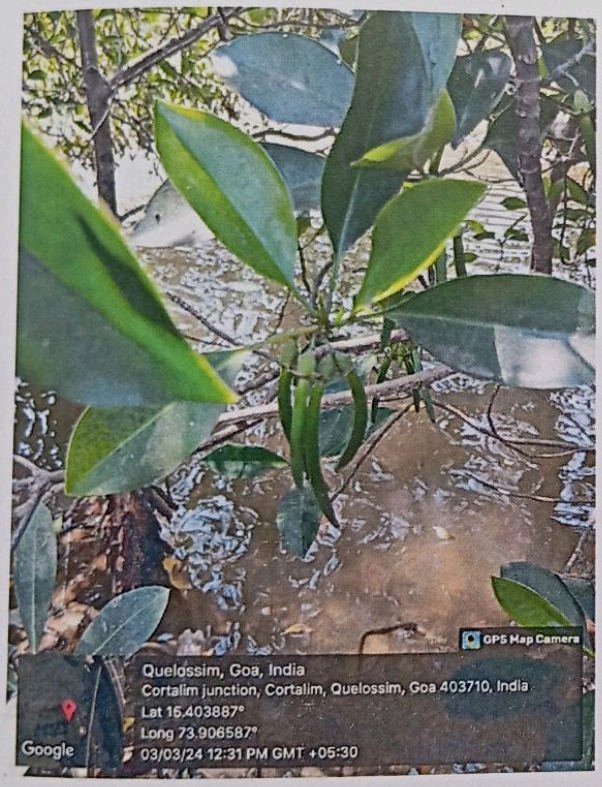


Fig 4.18 Mangroves found at Quelossim

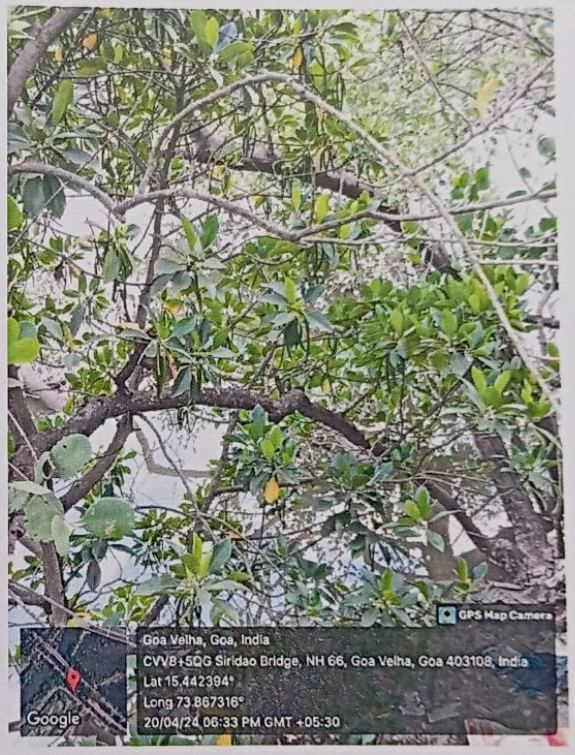


Fig 4.19 Mangroves found at Siridao

Bruguiera cylindrica

Scientific classification :

Kingdom: Plantae

Phylum: Tracheophytes

Class: Angiosperms

Order: Malpighiales

Family: Rhizophoraceae

Genus: *Bruguiera*

Species: ***B. cylindrica***

DESCRIPTION :

The identified mangrove species is known as *Bruguiera cylindrica.*

▪ *Bruguiera cylindrica* is commonly known as the cylindrical mangrove. It is a species of mangrove tree native to the Indo-Pacific region.

Morphology : It is a medium-sized mangrove tree that can grow up to 20 meters tall. Its trunk is cylindrical and smooth, often with a greyish-brown bark. The leaves are leathery, glossy green, and elliptical in shape, with pointed tips. They are arranged opposite each other on the stem.

Reproductive structures : The flowers are small, white, and occur in clusters at the ends of branches. They have five petals and are pollinated by insects. The fruit is a cylindrical, green or brown, elongated capsule, containing a single seed.

Root system : The aerial roots or pneumatophores project out from the soil in knee shaped loops.

Ecological Importance: *Bruguiera cylindrica* plays a crucial role in coastal ecosystems. Its dense root system stabilizes coastal sediment, prevents erosion, and provides habitat for various marine organisms. It also serves as a nursery ground for fish and other aquatic species.

10. Derris trifoliata

Mangrove species is found in Quelossim and Maina, Goa.

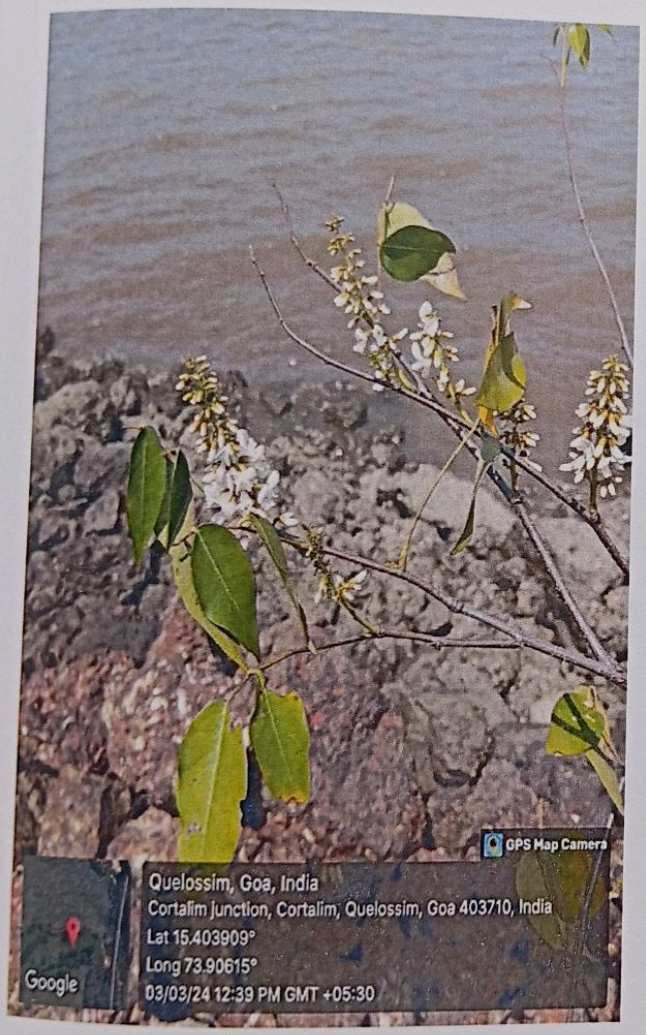


Fig 4.20 Mangroves found at Quelossim

Fig 4.21 Mangroves found at Quelossim

Derris trifoliata

Scientific classification :

Kingdom: Plantae

Phylum: Tracheophytes

Class: Angiosperms

Order: Myrtales

Family: Fabaceae

Genus: *Faboideae*

Species: ***D. trifoliata***

DESCRIPTION :

The identified mangrove species is known as ***Derris trifoliata***.

▪ *Derris trifoliata*, commonly known as "longbean," is a tropical leguminous plant native to Southeast Asia. It belongs to the Fabaceae family.

Morphology : *Derris trifoliata* is a climbing perennial vine that can grow up to several meters in length. It has trifoliate leaves, meaning each leaf is composed of three leaflets, hence the species name "trifoliata."

Reproductive structure: flowers are small, white to pale pink. They are zygomorphic and bisexual. It has disc-like fruits, green in color.

Ecological Importance: *Derris trifoliata* can have significant ecological impacts due to its ability to climb over and smother native vegetation.

11. *Aegiceras corniculatum*

Mangrove species is found in Cortalim and Loutolim, Goa.)

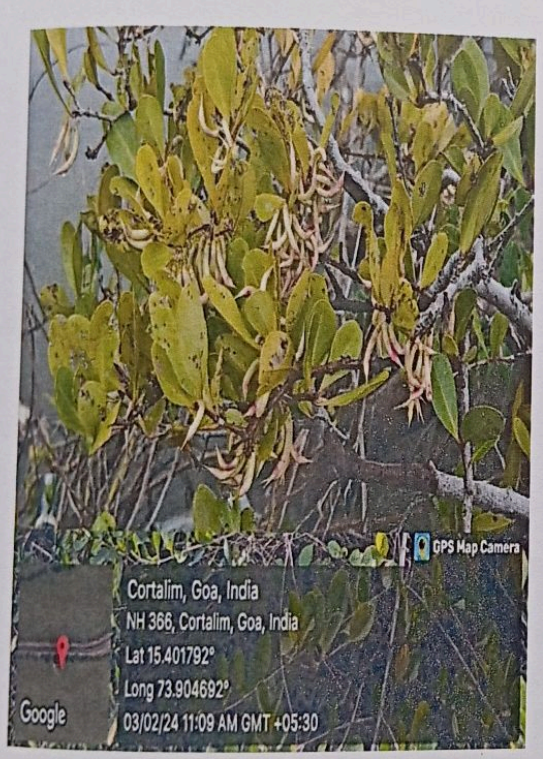


Fig 4.22 Mangroves found at Cortalim

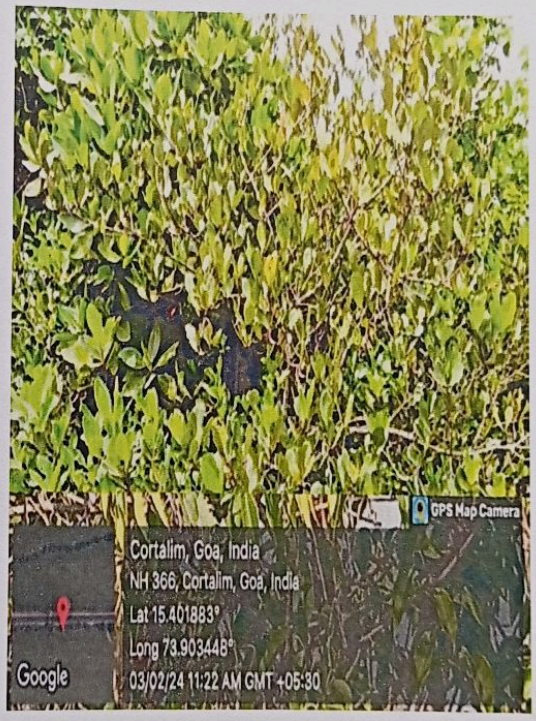


Fig 4.23 Mangroves found at Cortalim

Aegiceras corniculatam

Scientific Classification :

Kingdom : Plantae

Phylum : Trachephytes

Class : Angiosperms

Order : Ericales

Family : Primulaceae

Genus : *Aegiceras*

Species: ***A. corniculatum***

DESCRIPTION :

The identified mangrove species is known as ***Aegiceras corniculatum*** **.**

▪ *Aegiceras corniculatum*, commonly known as the River Mangrove or Black Mangrove, is a species of mangrove plant found in coastal regions of Asia, Africa, Australia, and the Pacific Islands.

Morphology: *Aegiceras corniculatum* is a small to medium-sized evergreen shrub or tree, typically growing up to 5-10 meters in height. It has smooth, pale grey bark and glossy, dark green leaves that are elliptical or lanceolate in shape, arranged in opposite pairs along the stems.

Reproductive structures: The plant produces small, fragrant white or pale yellow flowers with five petals. These flowers are typically pollinated by insects. The fruit is a woody capsule containing numerous seeds, which are dispersed by water.

Root system: *Aegiceras corniculatum* has specialized aerial roots called pneumatophores that emerge from the soil around the base of the plant. These roots help the plant obtain oxygen in waterlogged soils.

Ecological Importance: Its dense root system helps trap sediment and reduce erosion, while its leaves provide organic matter that supports detritus-based food webs.

12. *Acanthus illicifolius*

Mangrove species is found in Verna and Cortalim, Goa.

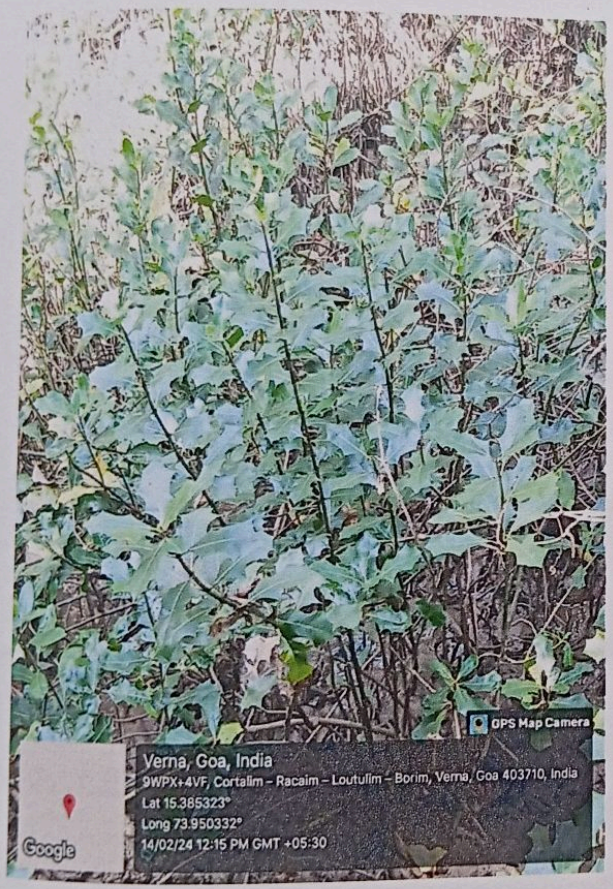


Fig 4.24 Mangroves found at Verna

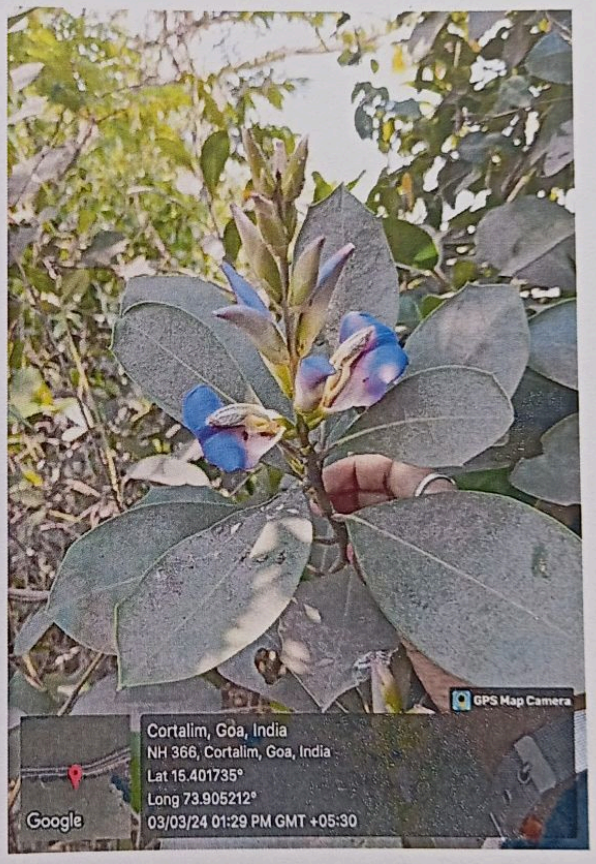


Fig 4.25 Mangroves found at Cortalim

Acanthus illicifolius

Scientific classification :

Kingdom: Plantae

Phylum: Tracheophytes

Class: Angiosperms

Order: Lamiales

Family: Acanthaceae

Genus: *Acanthus*

Species: ***A. ilicifolius***

DESCRIPTION :

The identified mangrove species is known as ***Acanthus illicifolius***.

▪ *Acanthus illicifolius*, commonly known as sea holly or holly-leaved acanthus, is a species of shrub native to coastal areas in Asia and Oceania.

Morphology : *Acanthus illicifolius* is a low-growing shrub that typically reaches a height of about 1 to 1.5 meters. It has glossy, dark green leaves with spiny margins.

Reproductive structures : *Acanthus illicifolius* produces small, tubular flowers arranged in terminal spikes. The flowers are typically white or pale pink in color and fruits are small capsules that contain numerous seeds.

Root System : *Acanthus illicifolius* often develops prop roots that arise from the lower nodes of its stem. It may also develop adventitious roots. These roots emerge from the stem or branches.

Ecological Importance: It stabilizes coastal ecosystems, preventing erosion, and providing habitat for various organisms. It also helps in nutrient cycling.

13. *Acrostichum aureum*

Mangrove species is found in Loutolim and Borim, Goa

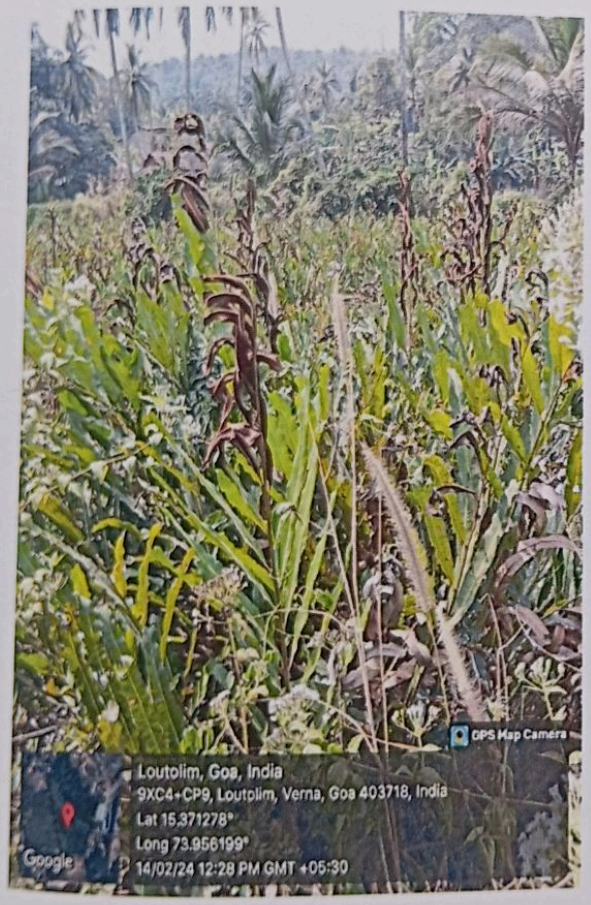


Fig 4.26 Mangroves found at Loutolim

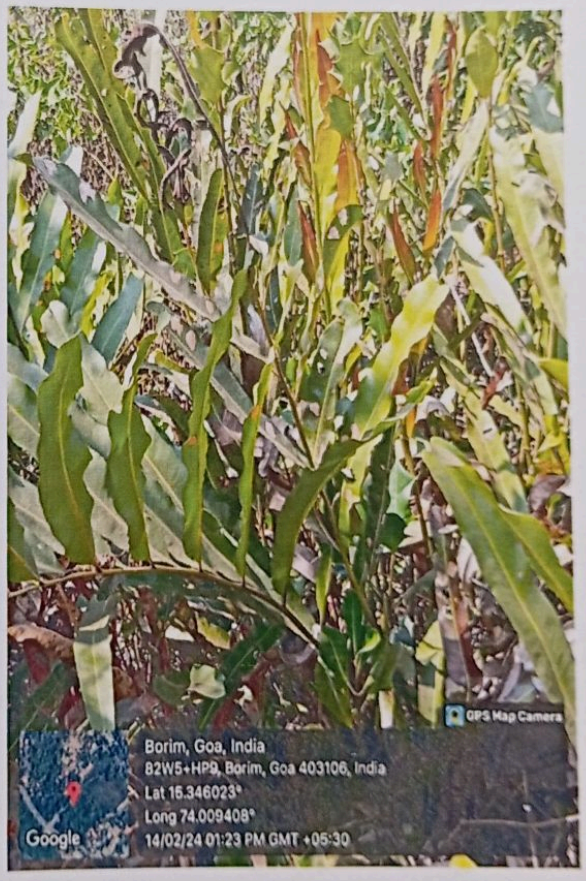


Fig 4.27 Mangroves found at Borim

Acrostichum aureum

Scientific classification :

Kingdom: Plantae

Phylum: Tracheophytes

Class: Polypodiopsida

Order: Polypodiales

Family: Pteridaceae

Genus: *Acrostichum*

Species: ***A. aureum***

DESCRIPTION :

The identified mangrove species is known as ***Acrostichum aureum.***

▪ *Acrostichum aureum*, commonly known as the mangrove fern or golden leather fern, is a species of fern that belongs to the family Pteridaceae.

Morphology: This fern is characterized by its large, leathery fronds that can grow up to several meters in length. The fronds are typically golden-green in color, giving the plant its common name, "golden leather fern."

Reproductive structure : Like other ferns, *Acrostichum aureum* reproduces via spores, which are produced on the undersides of the fronds in structures called sori.

Root System : Adventitious roots.

Ecological Importance: Mangrove ferns play a significant role in coastal ecosystems by stabilizing sediments, providing habitat for various organisms, and contributing to nutrient cycling.

14. *Sonneratia alba*

Mangrove species is found in Borim and Siridao, Goa.

Fig 4.28 Mangroves found at Borim

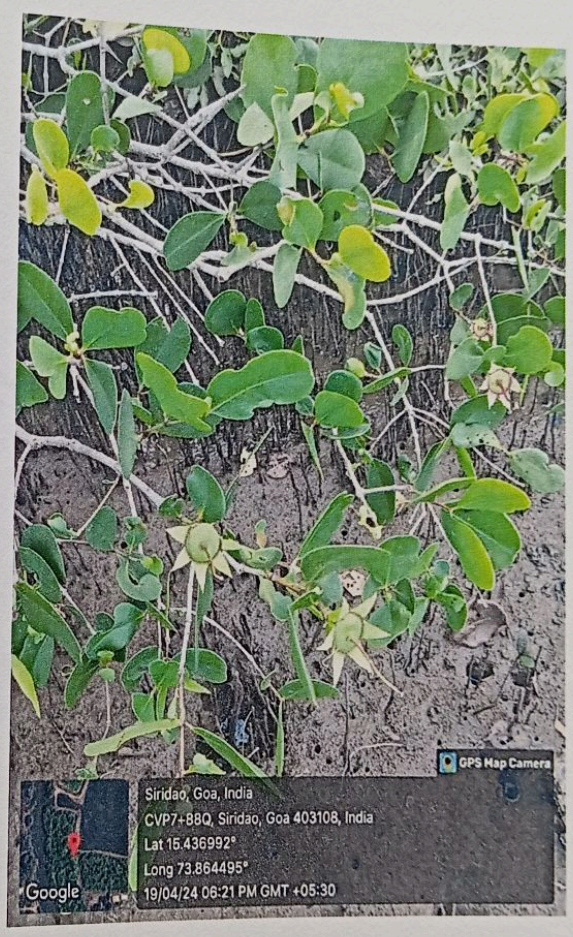


Fig 4.29 Mangroves found at Maina

Scientific Classification :

Kingdom : Plantae

Phylum : Tracheophytes

Class : Angiosperms

Order : Myrtales

Family: Lythraceae

Genus: *Sonneratia*

Species: ***S. alba***

DESCRIPTION :

The identified mangrove species is known as ***Sonneratia alba.***

▪ *Sonneratia alba*, also known as the White Mangrove, is a species of mangrove tree belonging to the family Lythraceae.

Morphology: *Sonneratia alba* typically grows as a medium-sized tree, reaching heights of up to 25 meters. The bark is smooth and whitish-gray in color. The leaves are elliptical or oblong, arranged oppositely on the branches.

Reproductive features: The flowers are white and fragrant, with five petals. They are often found in clusters and bloom throughout the year. The fruit is a cylindrical capsule with persistent sepals. When mature, the fruit splits open to reveal numerous seeds embedded in a fleshy pulp.

Root system: Like other mangrove species, *Sonneratia alba* develops pneumatophores, specialized aerial roots that protrude from the soil and aid in gas exchange in waterlogged and anaerobic sediments.

Ecological Importance: *Sonneratia alba* provides essential habitat and food sources for various organisms, including fish, crustaceans, and birds. Mangrove forests, including those dominated by *Sonneratia alba*, help protect coastlines from erosion by stabilizing sediments and reducing the impact of waves and storms. Mangroves play a significant role in carbon sequestration, storing large amounts of carbon in their biomass and sediments.

Mangrove associates found along Zuari river, Goa.

Fig 4.30 *Derris heterophylla*

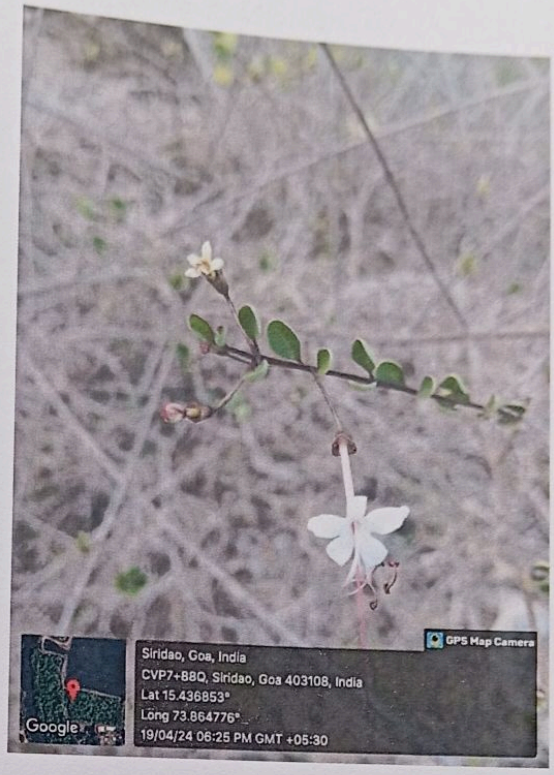


Fig 4.31 *Clerodendron inermi*

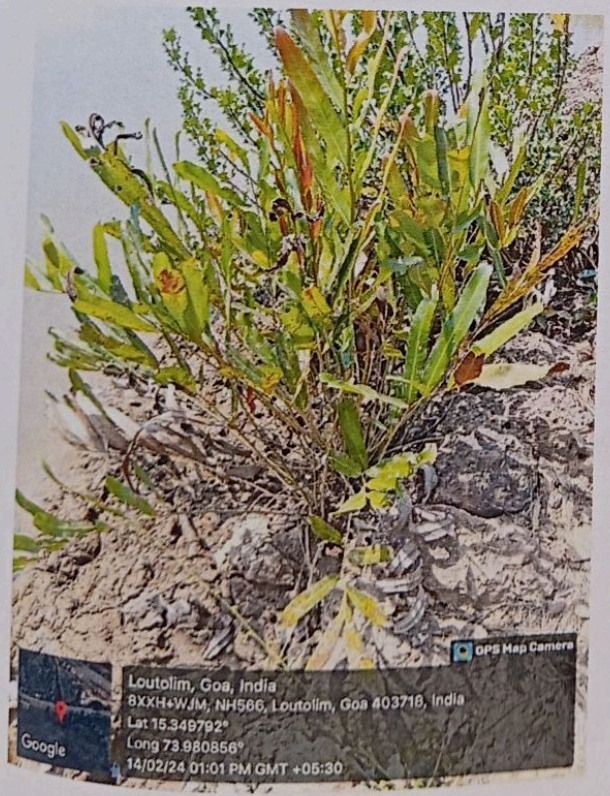


Fig 4.32 *Acrostichum aureum*

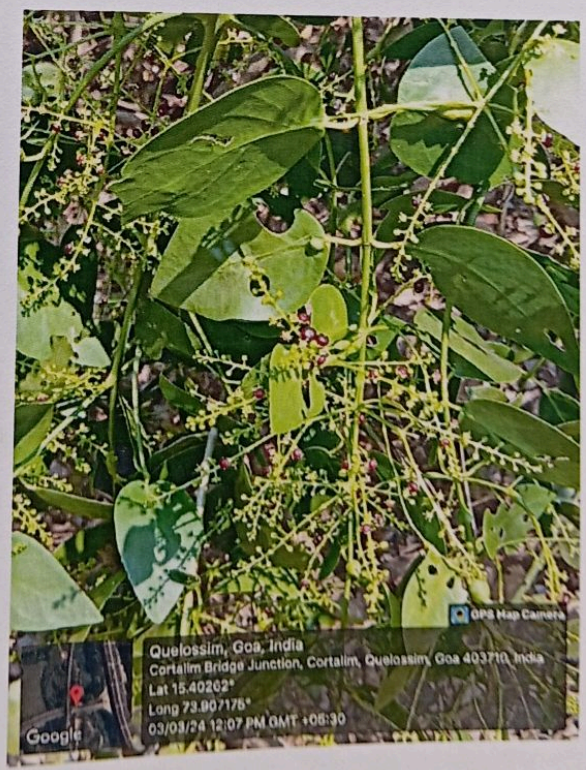


Fig 4.33 *Salvadora persica*

Fig 4.34 ***Abrus precatorius***

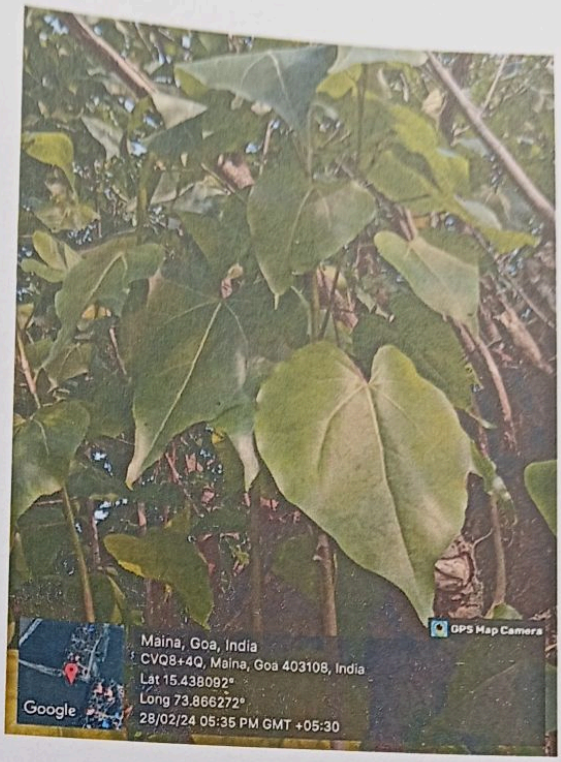


Fig 4.35 ***Thespesia populnea***

Fig 4.36 ***Sesuvium portulacastrum***

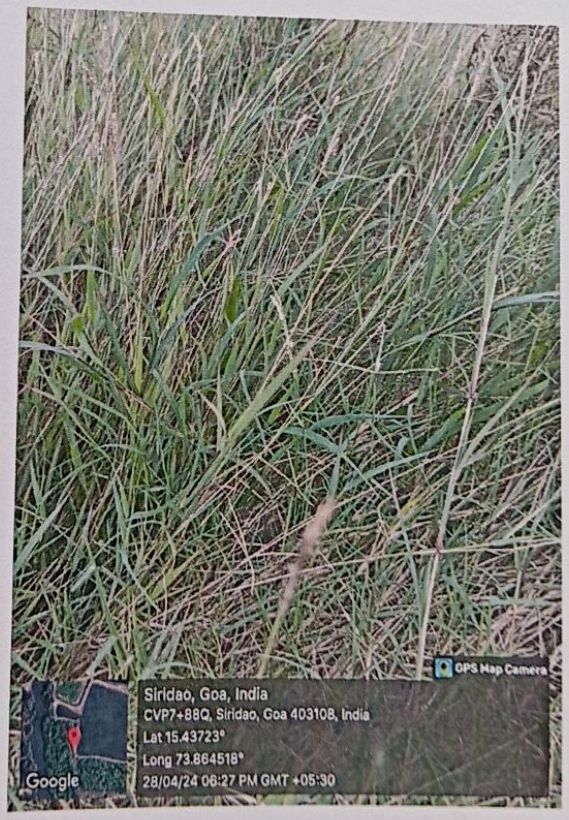


Fig 4.37 ***Porteresia coarctata***

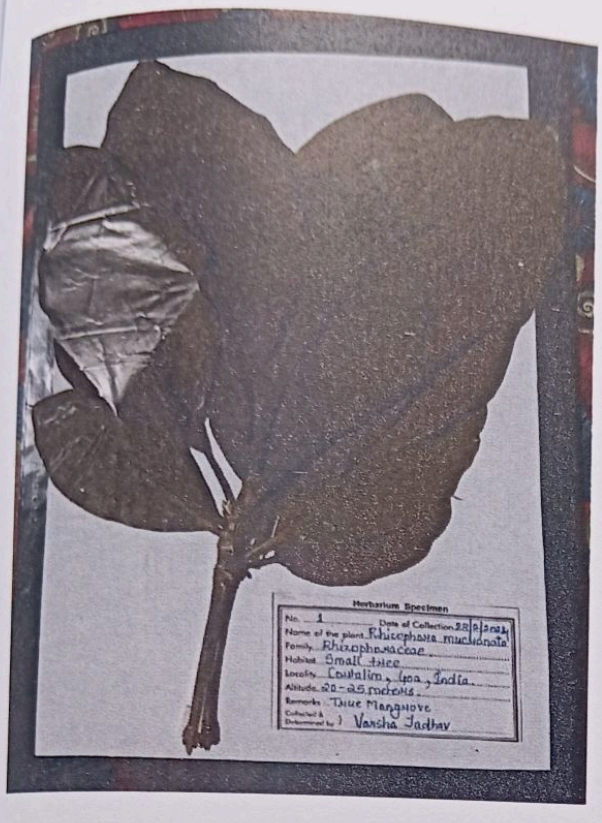


Fig 4.38 *Rhizophora mucronata*

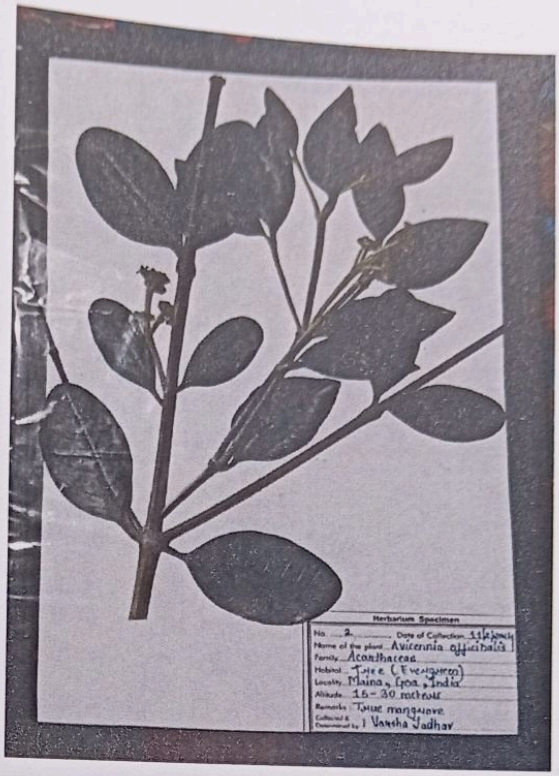


Fig 4.39 *Avicennia officinalis*

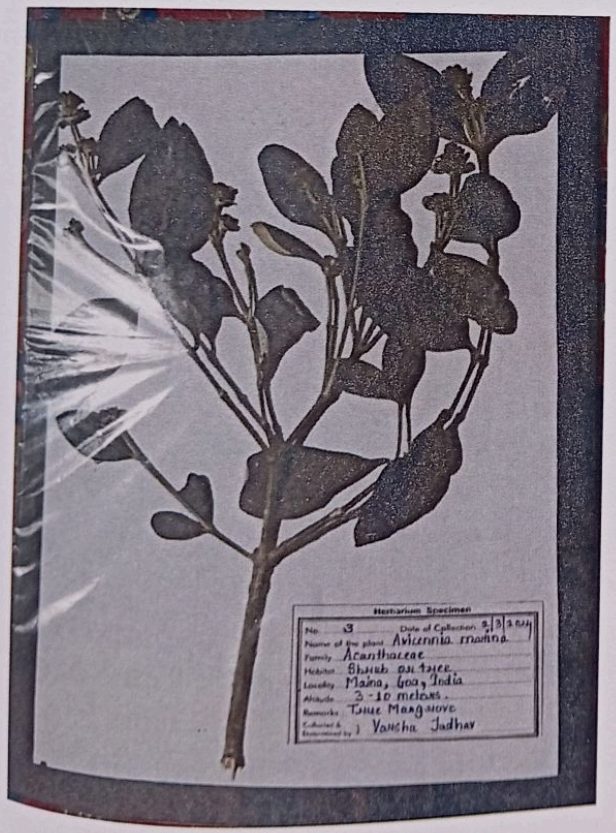


Fig 4.40 *Avicennia marina*

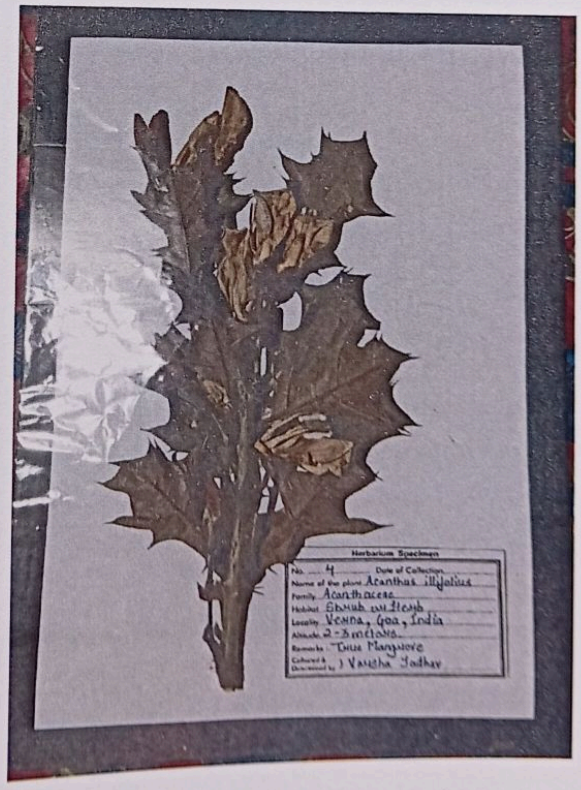


Fig 4.41 *Acanthus ilifolius*

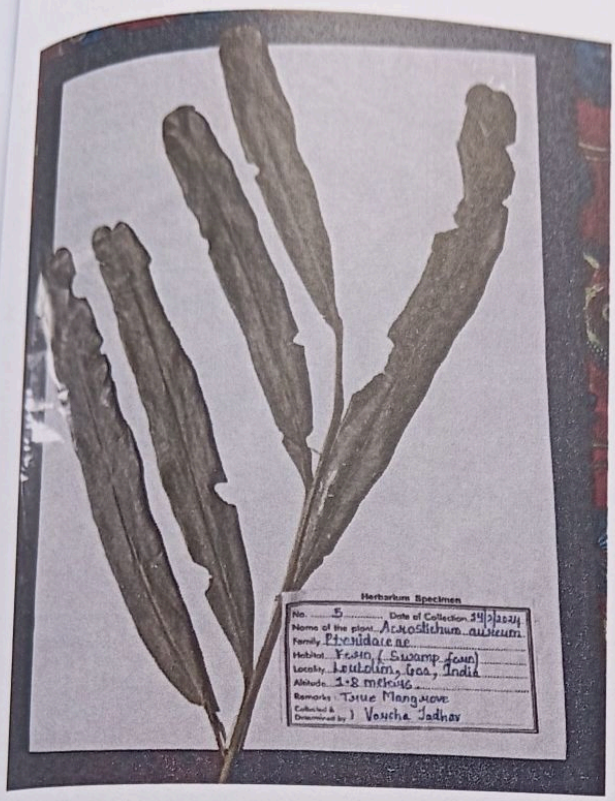


Fig 4.42 *Acrostichum aureum*

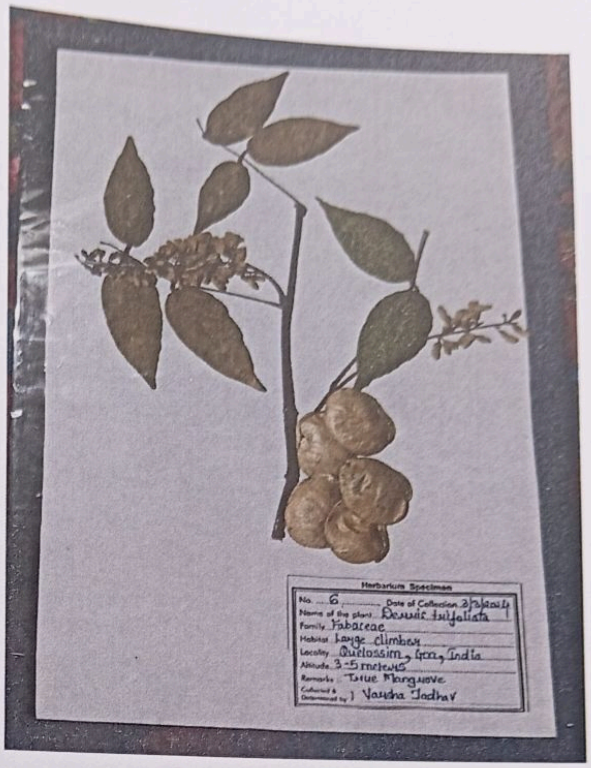


Fig 4.43 *Derris trifoliata*

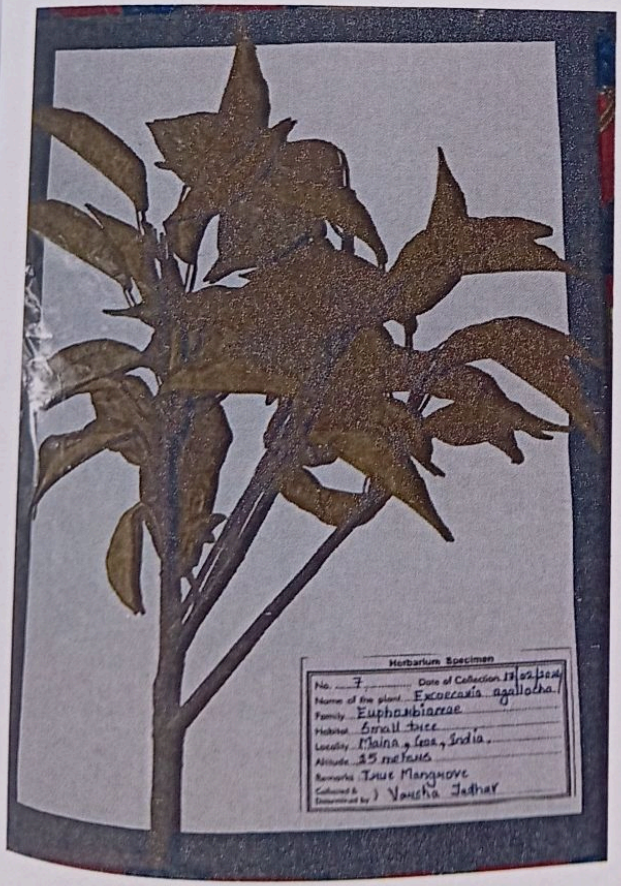


Fig 4.44 *Excoecaria agallocha*

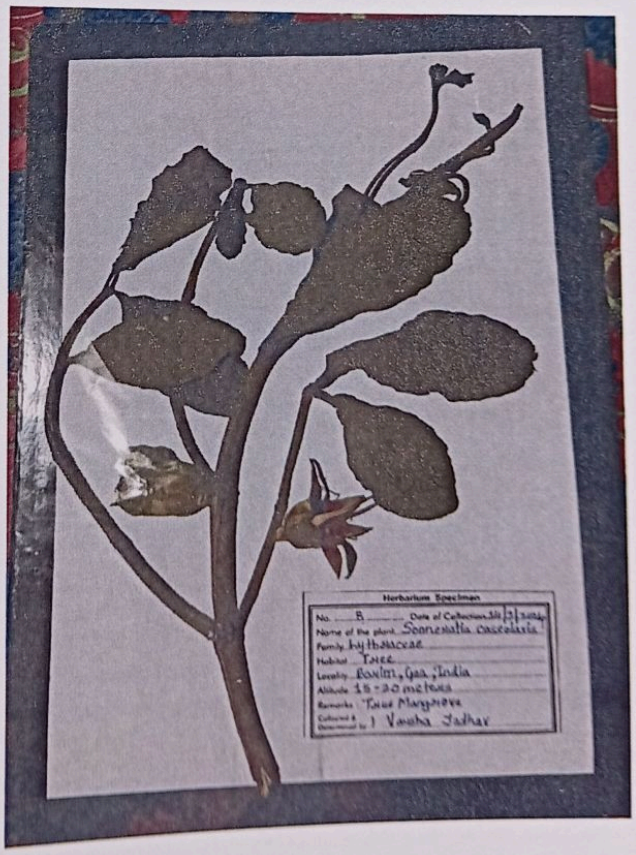


Fig 4.45 *Sonneratia caseolaris*

Salinity was found highest at Cortalim and lowest at Verna.

pH was observed highest at Cortalim and was lowest at Loutolim.

Temperature was noted highest at Verna and lowest at Maina.

All the observations are tabulated below (Table 3.2)

Table 3.2 Showing Salinity, Temperature and pH of water samples.

LOCATION	SALINITY	TEMPERATURE	pH
Siridao	15.2 M	28.1 °C	8.1
Maina	14.8 M	28 °C	8.2
Quelossim	15.3 M	28.1 °C	8.2
Cortalim	15.4 M	28.2 °C	8.3
Verna	14.7 M	28.4 °C	8.1
Loutolim	15.1M	27.8°C	8
Borim	15.2 M	28.1 °C	7.8

CHAPTER 5

DISCUSSION

To the best of our knowledge, on the basis of this field survey study highlights on varieties of mangrove species, adaptive features and it's biological diversity in Goa, along Zuari river. In this present study we performed assessment of available mangrove species of Goa based on morphological characteristics. Parani et al. 1997, Lakshmi et al. 2000, Untawale and Jagtap 1992, besides this there are many reports of mangrove identification based on morphological characteristics. This field survey shows diversity of true mangroves and their associates from selected sampling sites of Goa, namely Siridao, Maina, Quelossim, Cortalim, Verna, Loutolim and Borim.

The research highlights that the identification of mangrove species is of critical importance in order to monitor mangrove ecosystems and conserve them. Identification of mangrove species will ultimately help in protection and conservation of mangrove ecosystem as mangrove have crucial ecological and economic importance. This research paves the way to further research on mangrove diversity and identification in terms of taxonomy.

The field survey documented by Wakle et al, 2018 conducted research on diversity of mangroves in 7 selected sampling sites of Goa which includes Terekhol estuary, Mandovi estuary, Zuari estuary, Sal estuary, Talpona estuary, Galgibag estuary and Chapora estuary. They reported 16 different mangrove species namely *Rhizophora mucronata, Rhizophora apiculata, Bruguiera gymnorrhiza, Bruguiera cylindrica, Ceriops tagal, Kandelia candel, Sonneratia alba, Sonneratia caseolaris, Lumnizera racemosa, Avicennia officinalis, Avicennia marina, Aegiceras corniclatum, Acanthus illicifolius, Excoecaria agallocha, Acrosticum aureum* and *Derris trifoliata*.

In our field survey of assessment of mangrove diversity, we have selected 7 sampling sites along Zuari river, Goa which includes Siridao, Maina, Quelossim, Cortalim, Verna, Loutolim and Borim. Out of 16 floral mangrove species 14 were morphologically identified and reported successfully. The true mangrove species we found are *Rhizophora mucronata, Kandelia candel, Bruguiera gymnorrhiza, Bruguiera cylindrica, Sonneratia alba, Sonneratia caseolaris, Avicennia marina, Avicennia officinalis, Lumnizera racemosa, Acanthus illicifolius, Excoecaria agallocha, Aegiceras corniclatum, Acrosticum aureum* and *Derris trifoliata*. The mangrove associates reported at the sampling sites include *Derris trifoliata, Clerodendron inermi, Acrosticum aureum, Salvadora persica, Abrus precatorius, Sesuvium portulacastrum* and *thespesia populnea*. From this *Acanthus illicifolius* are found to be common in all the sampling sites. Other species are not so common but they are found in abundance at the particular sampling site.

We also recorded the GPS locations of the selected sampling sites that are latitudes and longitudes. They are found between latitudes of 15.441131°N to 15.385323°N and longitudes between 73.864058°E to 73.950332°E. I reported longitudes and latitudes of the sampling sites with the help of GPS Map Camera. Additionally parameters such as Salinity, pH and temperature were reported of the water samples collected around mangrove ecosystem from the selected sampling sites of Goa which are Siridao, Maina, Quelossim, Cortalim, Verna, Loutolim and Borim. The average temperature at which mangrove survive was recorded between 28°C-28.1°C. The optimum average salinity of the water around mangrove areas was observed between 15M-15.3M and the pH was recorded to be around 8-8.1

CHAPTER 6

CONCLUSIONS

The field survey was conducted to highlight that the identification of mangrove species is of critical importance in order to monitor mangrove ecosystem and conserve them. Identification of mangrove species will ultimately help in protection and conservation of mangrove ecosystem as they have ecological and economic importance. This research paves the way to further research on mangrove diversity and identification in terms of taxonomy. This research was done to understand the varieties of mangroves, morphology and adaptations and to identify them in terms of their taxonomy.

Mangrove species identification is described by Wakle et al, (2018). They have documented the diversity of true mangrove and mangrove associates in Goa. The selected sites were Zuari, Mandovi, Chapera, Terekhol, Talpona, Sal and Galgibag estuary. As per their reports Goa has 16 mangrove species namely *Rhizophora mucronata, Bruguiera gymnorrhiza, Bruguiera cylindrica, Ceriops tagal, Kandelia candel, Sonneratia alba, Sonneratia caseolaris, Lumnizera racemosa, Avicennia officinalis, Avicennia marina, Aegiceras corniclatum, Acanthus illicifolius, Excoecaria agallocha, Acrosticum aureum* and *Derris trifoliata* comparing this 16 species, 14 were taxonomically identified and recorded in the selected sampling sites surveyed by us.

Pawar (2012), has worked on mangrove flora from Curtolim village along Zuari river, Goa, has reported 5 true mangrove species belonging to 4 families .*Acanthus illicifolius* are the most dominant mangrove species found in almost all sites. The next dominating species are Sonneratia *caseolaris and Avicennia officinalis.* The observation made by us in comparison to this survey our field work showed similar results.

Silva and Bhat (2011), had teamed up to analyse diversity status of mangrove species in Goa. They divided mangroves in two categories such as true mangroves and mangrove associates. Their distribution and variation of different environmental parameters were studied. They observed 15 true mangrove species. In comparison to this analysis our field assessment has reported 14 true mangrove species.

In our field research, we have selected 7 sampling sites namely, Siridao, Maina, Cortalim, Quelossim, Verna, Loutolim and Borim. 14 mangrove species belonging to 8 different families which includes *Rhizophora mucronata, Kandelia candel Bruguiera gymnorrhiza, Bruguiera cylindrica, Sonneratia alba, Sonneratia caseolaris, Avicennia marina, Avicennia officinalis, Lumnizera racemosa, Acanthus illicifolius, Excoecaria agallocha, Aegiceras corniclatum, Acrosticum aureum* and *Derris trifoliata* were reported. Few mangrove associates like *Derris trifoliata, Clerodendron inermi, Acrosticum aureum, Salvadora persica, Abrus precatorius, Sesuvium portulacastrum, thespesia populnea* and *Porteresia coarctata* were reported based on the identification.

We did analysis of the water samples of the visited mangrove sites. It helped us to know the survival conditions of the mangrove ecosystem. Temperature, pH and salinity are the parameters which we recorded and found out the optimum temperature of mangrove surviving in the water is 28°C-28.1°C. We found average salinity between 15M-15.1M and the average pH being 8-8.1 which is slightly basic, near the estuaries. Whereas coastal water is around Neutral.

Besides field survey and analysis of water samples, we also prepared some herbariums, which is generally a method in which plant specimen is collected, press dried and used for study of taxonomy of plant. Herbariums are beneficial to know the plant parts.and study about it more efficiently.

Thorough this field study we can conclude that there are various different types of mangroves species available at different places of mangroves in Goa. In Goa there are 16 mangrove species belonging to 8 different families, among which we mainly focused on 14 mangrove species belonging to 8 different families and studied its morphology, anatomy, distribution, variability in species and adaptations thoroughly.

CHAPTER 7

BIBLIOGRAPHY

Agoramoorthy, G., Chandrasekaran, M., Venkatesalu, V., & Hsu, M. J. (2007). Antibacterial and antifungal activities of fatty acid methyl esters of the blind-your-eye mangrove from India. *Brazilian journal of Microbiology, 38*, 739-742.

Attri, K., & Kerkar, S. (2011). Seasonal assessment of heavy metal pollution in tropical mangrove sediments (Goa, India). *Journal of Ecobiotechnology, 3*(8).

Badola, R., & Hussain, S. A. (2005). Valuing ecosystem functions: an empirical study on the storm protection function of Bhitarkanika mangrove ecosystem, India. *Environmental Conservation, 32*(1), 85-92.

Brahma, G., & Mukherjee, S. K. (2016). Studies on mangrove diversity of India with special reference to Lothian Island Wildlife Sanctuary. *Plant Science Today, 3*(1), 25-29.

Chieppa, J., Feller, I. C., Harris, K., Dorrance, S., Sturchio, M. A., Gray, E., & Aspinwall, M. J. (2023). Thermal acclimation of leaf respiration is consistent in tropical and subtropical populations of two mangrove species. *Journal of Experimental Botany, 74*(10), 3174-3187.

D'Souza, J., & Rodrigues, B. F. (2013). Biodiversity of Arbuscular Mycorrhizal (AM) fungi in mangroves of Goa in West India. *Journal of Forestry Research, 24*(3), 515-523.

Fernandes, S. O., Kirchman, D. L., Michotey, V. D., Bonin, P. C., & LokaBharathi, P. A. (2014). Bacterial diversity in relatively pristine and anthropogenically-influenced mangrove ecosystems (Goa, India). *Brazilian Journal of Microbiology, 45*, 1161-1171.

Giri, C., Ochieng, E., Tieszen, L. L., Zhu, Z., Singh, A., Loveland, T., ... & Duke, N. (2011). Status and distribution of mangrove forests of the world using earth observation satellite data. *Global ecology and biogeography, 20*(1), 154-159.

Kathiresan, K. (2000). A review of studies on Pichavaram mangrove, southeast India. *Hydrobiologia, 430,* 185-205.

Kharangate-Lad, A., & Bhosle, S. (2018). Studies on mineralization of mangrove leaf litter by consortium of adhered bacterial isolates from mangrove ecosystem of Goa, India. *North East Centre for Environmental Education and Research (NECEER)*

Krishnamurthy, P., JYOTHI-PRAKASH, P. A., Qin, L. I. N., He, J. I. E., Lin, Q., LOH, C. S., & Kumar, P. P. (2014). Role of root hydrophobic barriers in salt exclusion of a mangrove plant A vicennia officinalis. *Plant, Cell & Environment, 37*(7), 1656-1671.

Mishra, P. K., Sahu, J. R., & Upadhyay, V. P. (2005). Species diversity in Bhitarkanika mangrove ecosystem in Orissa, India. *Lyonia, 8*(1), 73-87.

Nagelkerken, I. S. J. M., Blaber, S. J. M., Bouillon, S., Green, P., Haywood, M., Kirton, L. G., & Somerfield, P. J. (2008). The habitat function of mangroves for terrestrial and marine fauna: a review. *Aquatic botany, 89*(2), 155-185.

Nandy, P., & Ghose, M. (2001). Photosynthesis and water-use efficiency of some mangroves from Sundarbans, India. *Journal of Plant Biology, 44*, 213-219.

Nathan, V. K., Vijayan, J., & Ammini, P. (2020). Comparison of bacterial diversity from two mangrove ecosystems from India through metagenomic sequencing. *Regional studies in marine science, 35*, 101184.

Pawar, T. A., & Kolapkar, R. (2013). Mapping of Mangrove area of Curtorim Village-South Goa District-Goa-India-Using Remote Sensing and GIS Techniques. In *National conference on biodiversity: status and challenges in conservation–'FAVEO,* 94-96.

Pillai, N. G., & Harilal, C. C. (2018). Inventory on the diversity and distribution of mangroves from the coastal ecosystems of Kerala State, India. *Int J Recent Sci Res, 9*(2), 24002-24007.

Ragavan, P., Saxena, A., Jayaraj, R. S. C., Mohan, P. M., Ravichandran, K., Saravanan, S., & Vijayaraghavan, A. (2016). A review of the mangrove floristics of India. Taiwania, 61(3).

Ramasubramanian, R., Gnanappazham, L., Ravishankar, T., & Navamuniyammal, M. (2006). Mangroves of Godavari–analysis through remote sensing approach. *Wetlands ecology and management, 14*, 29-37.

Sahu, S. C., Suresh, H. S., Murthy, I. K., & Ravindranath, N. H. (2015). Mangrove area assessment in India: Implications of loss of mangroves. *J. Earth Sci. Clim. Change, 6*(5), 280.

Saravanan, K. R. (2005). A study on the diversity and management of Pondicherry mangroves. *Department of Science, Technology and Environment, Government of Pondicherry.*

Silva, C., & Bhat, U. G. (2011). Diversity Status of Mangrove Species in Estuarine Regions of Goa, Central West Coast, India. *Nature, Environment and Pollution Technology, 10*(4), 651-654.

Simard, M., Fatoyinbo, L., Smetanka, C., Rivera-Monroy, V. H., Castaneda-Moya, E., Thomas, N., & Van Der Stocken, T. (2019). Global mangrove distribution, aboveground biomass, and canopy height. *ORNL DAAC*.

Singh, J. K. (2020). Structural characteristics of mangrove forest in different coastal habitats of Gulf of Khambhat arid region of Gujarat, west coast of India. *Heliyon, 6*(8).

Sreelekshmi, S., Nandan, S. B., Kaimal, S. V., Radhakrishnan, C. K., & Suresh, V. R. (2020). Mangrove species diversity, stand structure and zonation pattern in relation to environmental factors—A case study at Sundarban delta, east coast of India. *Regional Studies in Marine Science, 35*, 101111.

Srikanth, S., Lum, S. K. Y., & Chen, Z. (2016). Mangrove root: adaptations and ecological importance. *Trees, 30*, 451-465.

Thivakaran, G. A., Sharma, S. B., Chowdhury, A., & Murugan, A. (2020). Status, structure and environmental variations in semi-arid mangroves of India. *Journal of forestry research, 31*(1), 163-173.

Untawale, A. G., Dwivedi, S. N., & Singbal, S. Y. S. (1973). Ecology of mangroves in Mandovi and Zuari estuaries and the interconnecting Cumbarjua canal of Goa.

Wakle, V. B., Khomne, A. V., & Dhabe, A. S. (2018). Diversity of mangroves in Goa, central west cost of India. *International Journal of Botany Studies, 3*, 65-67.

Websites referred :

1. https://en.m.wikipedia.org/wiki/Mangrove

2. https://forest.goa.gov.in/mangroves

3. https://www.britannica.com/plant/mangrove

4. https://www.sciencedirect.com/topics/earth-and-planetary-sciences/mangrove

Books referred :

1. Khedekar, V. V. (2013). Eco-culture Goa Paradigm. *Broadway Publishing House,* 235

2. Khedekar, V. V. (2016). Goa : Land, Life and Legacy. *Directorate of Art and Culture,* 596

3. Kothari, M. J., Rao, K. M. (2002). Mangroves of Goa. *Botanical Survey of India,* 155

4. Alvares, C., Gadgil, V. (2002). Fish, Curry and Rice. *Goa Foundation,* 377