"The Biodiversity and Ecology of the Fragile Ecosystem of Goa: The Mangroves and the Saltpans"

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Abstract

Mangroves represent unique ecosystems consisting of salt tolerant shrubs or the woody plants that occupy the intertidal zone between the land and the sea, along the tropical and subtropical regions. Their environment is characterized by various extremities such as high salinity, extreme tides, strong winds, high temperatures and muddy, anaerobic soils in response to which they have developed various adaptations. It is an extremely productive ecosystem that provides us with numerous ecosystem services. Not only that but it also helps in the prevention of coastal erosion, stabilizes the shorelines and protects the coast by acting as wind breakers and barriers against storms and heavy tides. This ecologically rich ecosystem is home to numerous different floral and faunal species, harbouring rich biodiversity ranging from micro to macro-organisms that also contribute towards smooth functioning of this ecosystem in addition to various abiotic factors. Changes in these factors is what causes adverse effects on the mangrove vegetation.

India has a long coastline and contributes significantly to the global mangrove cover. Goa being a coastal state is a home to dense mangrove forests mostly located on the banks of the river Mandovi and Zuari. In the recent years the mangrove vegetation in the state of Goa has witnessed immense loss due to the anthropogenic activities prevailing in the state. One such site is the stretch of mangrove vegetation along the NH 66 Highway at Merces, St. Cruz. This stretch of mangroves is highly deteriorated with very few healthy mangrove plants visible.

Any sort of urbanization and development results in partial clearing of certain vegetation but not immediate destruction and mass killing. Many articles in the local newspapers highlighted the construction of NH66 highway being the reason for the massive death of the mangrove vegetation in the study site (St. Cruz-Merces) without scientific evidence. However, our keen investigation on the area proved that the Government of Goa and the National Highways Authority of India (NHAI) has taken all the precautionary measurements for the survival of the mangrove vegetation across both sides of the highway by inserting six big pipes across the highway to facilitate exchange of saline water during tidal flux which is one of the prerequisite for the mangrove survival. If construction of the highway had to be the reason for the massive killing of the mangroves, then this should have been observed throughout the highway and not just at one patch of the St. Cruz-Merces region. Using Google Earth Satellite images, it was evident that, landfilling and concretization activities on the

opposite side (influx point of the Mandovi estuary) had an adverse impact on mangrove ecosystem, leading to complete loss of the mangrove vegetation. The landfilling and concretization resulted in blockage of the tidal water causing hinderance for the tidal influx and efflux. Poor water exchange resulted in semi-stagnant conditions which eventually resulted in hypersalinity conditions due to evaporation of this water under natural sunlight. Hypersalinity and accumulation of loads of organic matter are conditions which are deadly for the growth and functioning of the mangrove ecosystem, which ultimately resulted in massive death of the mangroves along the NH66 highway at St. Cruz-Merces.

The microbiological analysis of the mangrove sediment and water samples revealed the presence of pathogenic bacteria. While the chemical analysis made it more evident that there was chronic hypersalinization of the sediment and water due to improper tidal flux which resulted in constant accumulation of salts thereby proving detrimental to the mangrove vegetation.

*Upon conducting surveys of this mangrove vegetation and the avian fauna dependent on it, it was revealed that a lot of birds still use this degraded habitat for feeding and roosting purposes. Globally threatened species such as **Black Headed Ibis** (Threskiornis melanocephalus), **Lesser Adjutant Stork** (Leptoptilos javanicus) and **Alexandrine Parakeet (Palaeornis eupatria)** having the IUCN status of 'near threatened', 'vulnerable' and 'near threatened' respectively are found in this region which gives us another reason to rejuvenate these mangroves.*

This study hence holds great significance especially today, as we are losing our mangrove vegetation at alarming rates. It shows us how anthropogenic activities without any checks can cause serious environmental damage without us noticing.

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1. Introduction to Mangroves

Mangroves are defined as the salt tolerant shrubs or the woody plants occupying the interface between the land and the sea, along the tropical and subtropical regions. The "mangrove forest community" or "mangal" comprises of the plants, animals and the unseen microbes, while the "mangrove ecosystem" is composed of the mangal and the abiotic factors associated with it (Kathiresan and Bingham, 2001; Mitra, 2013).

Fig. 1.1: Healthy Mangrove vegetation along the Mandovi estuary.

Mangroves are commonly found occurring between the latitudes of 32^{o}N and 38^{o}S. The ideal habitat for a luxuriant growth of these shrubs is made up of sheltered environments having brackish water influx, muddy soil of estuarine and deltaic origin, rainfall in the range of 1000-3000 mm and a temperature between 26 to 35^{o}C (Chauhan, 2017). The mangrove ecosystem is known to play significant role in terms of ecology as well as economy (Kamboj and Das, 2019).

India is among the 17 mega biodiversity countries in the world, well known for its terrestrial, coastal, and marine biodiversity (Saravanan et al., 2013). India has a long coastline, of which 7516.6 kilometre's is occupied by mangroves, including the islands (Sahu et al., 2015). Mangroves occupy 0.14% of the country's land area, making India fourth largest contributor to the global mangrove cover (Deshpande and Kerkar, 2023). They can be seen either as narrow strips or as extensive patches (Ajai et al., 2013).

1.2 . Mangroves Vegetation of Goa-India

The coastal state of Goa contributes 0.5% to the total mangrove cover of India (Mesta et al., 2014). According to the recent data published by the India State of Forest Report (2021), Goa has a mangrove cover of 27 km^2 (Singh et al., 2004). Goa, lying on the Western Coast of India (1455°' N to 1545°' N and 7440°' E to 7410°' E) is a home to numerous estuaries supporting mangrove vegetation. These estuaries include Terekhol, Chapora, Mandovi, Zuari, Sal, Talpona, and Galgibag (Nagi et al. 2014). Among these, Mandovi estuary extends to 68 kilometers and is a home to luxuriant mangrove vegetation. Cumbarjua estuarine Canal is 15 kilometers long and joins Mandovi and Zuari estuaries, thus forming the "Mandovi-Zuari-Cumbarjua estuarine complex" (Nagi et al., 2014). Most of the mangroves in Goa are fringing mangroves bordering the estuaries and creeks (Jagtap et al., 2001; Mesta et al, 2014). Amongst all these estuaries, large number of mangrove species in Goa are found along the Mandovi River (Ragavan et al., 2016). *Avicennia*, *Sonneratia* and *Rhizophora* species dominate the Mandovi-Zuari-Cumbarjua estuarine complex (Ajai et al., 2013).

Mangroves in comparison to terrestrial forests have a relatively simple structure with the forest canopy cover that usually constitutes the main branches and leaves of the trees, while the floor of the forest has few smaller plants (Kathiresan and Bingham 2001). Mangroves lack the vines and shrubs which are commonly found in a tropical terrestrial forest but instead they often have the forest floor covered in a carpet of mangrove seedlings. This is mainly due to the harsh conditions and lack of sunlight that prevails in these forests (Chauhan, 2017).

As reported by Giri et al., 2010, the area covered by mangroves globally is 13.77 million hectares which spreads over 118 countries. Asia is a home to the largest mangrove cover (42%), followed by Africa (20%), North and Central America (15%), Oceania (12%) and South America (11%). Amongst the various countries, Indonesia harbours largest mangrove cover of 22%, Australia second largest with 7.1%, while India contributes 3.1% to the Global mangrove cover.

On a global scale, the sheltered tropical and subtropical coastlines covered by mangroves are greater than 200,000 km^2 and are disappearing every year by 1 to 2% at a rate greater than or equal to degradation of coral reefs and tropical rainforests. This loss is being faced by every other country harbouring mangrove at rates alarmingly high, that continue to increase rapidly in developing countries that are home to more than 90% of the world's mangroves (Duke et al., 2007).

The mangrove cover in India spreads to over 4500 square kilometers with only 14% of contribution by the west coast while the east coast has a major contribution of 60% and Andaman and Nicobar makes up for the rest 26% of mangrove cover (Giri et al., 2015). The state of Goa, located on the west coast of India has a vast coastline stretched over a distance of 105 km (Kunte et al., 2014). Along the coast of Goa, seven estuaries are found fringed with mangroves (Mangroves of Goa, Goa Forest Department, Government of Goa). The two major rivers of the state of Goa i.e., river Mandovi finds its origin in the Western Ghats, making its way into the state via the Sattari sub district in the north and ultimately pouring into the Arabian Sea. While the largest river of the state, River Zuari has its origins in the Hemad-Barshem in the Western Ghats. The two river channels of Mandovi and Zuari are linked by a 15 km long

Cumbarjua canal, thus forming a very important estuarine complex which supports a significant mangrove cover. The Mandovi-Zuari estuarine complex of Goa is considered among the best mangrove forests on the West Coast of India (Giri et al., 2015) with 90% of mangroves in Goa, which are found distributed along this estuarine complex (Jagtap, 1985).

The west coast of India is a home to 36 species, 25 genera, and 21 families of mangroves, while Goa has 16 mangrove species. Chorao island in the backwaters of Mandovi estuary harbours a dense mangrove cover. It is known to be one of the best mangrove forest and houses most of the species found in the state of Goa (Mangroves of Goa, Goa Forest Department, Government of Goa). Government of Goa has declared this forest as Dr. Salim Ali Bird Sanctuary for the purpose of conservation (Giri et al., 2015). The whole sanctuary area is covered with mangroves, with interspersed water channels and has tidal variation. No major anthropogenic activities are observed except for the aquaculture practiced on nearby land. It has very rich avifauna and consists of resident as well as migratory birds. The 16 mangrove species found in Goa include *Rhizophora mucronate, Rhizophora apiculate, Bruguiera gymnorrhiza, Bruguiera cylindric, Ceriops tagal, Kandelia candel (K. rheedi), Avicennia officinalis, Avicennia marina, Sonneratia alba, Acrostichum aureum, Sonneratia caseolaris, Aegiceras corniculatum, Acanthus illici folius, Excoecaria agallocha, Lumnitzera racemose and Derris heterophylla* (Mangroves of Goa, Goa Forest Department, Government of Goa).

The composition as well as the configuration of the mangrove species in an estuarine environment varies on the basis of the salinity gradient which varies from the mouth of the river to the rise of the river. As one moves from the mouth to the upstream of the river, the gradient is observed to decrease. Variation in this gradient is also observed from day to day due to the high -low tide phenomena. The canopy forms a compact mass from high tide level to the low tide level with distinct colours from pale green, pale yellowish green to dark green and brackish green thus forming the longitudinal and vertical strata. The size of the propagules from various species in various zones plays a crucial role in the establishment of these species which are formed from the high tide level to the low tide level at varying depths of silt in the substratum (Mangroves of Goa, Goa Forest Department, Government of Goa).

Mangroves have a very unique environment characterized by high salinity, extreme tides, strong winds, high temperatures and muddy, anaerobic soils. Hence, they have developed mechanisms and exhibit an array of adaptations (morphological, physiological, anatomical, physiognomical). In order to tolerate high salt levels and take up water against strong osmotic potential some genera takes up salt, which is then excreted through specialized glands. Some are also known to transfer salts into senescent leaves, others store it in the bark or in the woody part and pneumatophores. Some of the specialized morphological modifications of mangroves include profuse lateral roots that help in anchoring the trees in the loose sediments, aerial roots/ pneumatophores or lenticels for gaseous exchange and viviparous germination (Kathiresan and Bingham 2001; Tomlinson, 1986).

1.3. Flora and Fauna of the Mangroves Vegetation of Goa-India

This ecologically unique mangrove environment is host to a rich flora and fauna. The muddy sediments are a home to various epibenthic, infaunal and meiofaunal invertebrates. They also support vast communities of phytoplanktons, zooplanktons and fish. The mangal may also serve as floanursery habitat for juvenile fish whose adults might later occupy other habitats. (eg. Coral reefs and seagrass beds). Mangrove roots, trunks and branches submerged in loose sediments form islands of habitats attracting rich communities of bacteria, fungi, macroalgae and invertebrates. Many crab species live among the roots, on trunks as well as forage the canopy. Mangrove habitats also serve as nesting and migratory sites for a huge number of bird species. The shallow waters of mangroves along with the exposed mud flats provide rich feeding grounds for many large and spectacular bird species and about 121 species of resident as well as migratory birds are found in the mangrove forests. Some of the birds reported from the Goan mangroves include Little Cormorant (*Microcarbo niger*), Black Headed Ibis (*Threskiornis melanocephalus*), Great White Egret (*Ardea alba*), Little egret (*Egretta garzetta*), Indian pond heron (*Ardeola grayii*), Striated heron (*Butorides striata*), Common kingfisher (*Alcedo atthis*), White-throated kingfisher (*Halcyon smyrnensis*), Black Capped Kingfisher (*Halcyon pileata*), Stork-billed kingfisher (*Pelargopsis capensis*), Purple heron (*Ardea purpurea*), Grey heron (*Ardea cinerea*), Black-crowned night heron (*Nycticorax nycticorax*), Lesser Adjutant Stork (*Leptoptilos javanicus*), Bhahmini kite (*Haliastur indus*), Black Kite (*Milvus migrans*), House crow (*Corvus splendens*) etc.

Other organisms thriving in this habitat include insects, reptiles, amphibians and mammals. Some of the common fishes found in the mangroves of Goa are Pearl spot, Giant Perch, Scatophagus argus, Mugil cephalus, etc. (Kathiresan and Bingham, 2001; Chauhan, 2017; Mangroves of Goa, Goa Forest Department, Government of Goa). The mangrove ecosystems are highly productive with productivity about 20 times more than the average oceanic production. It is a 'detritus-based' ecosystem transferring organic matter and energy from the land to marine ecosystem unlike other coastal ecosystems, which are 'plankton-based' and forms a crucial part of the marine ecosystem (Mitra, 2013; Chauhan, 2017). Mangroves not only serve as a habitat for rich biodiversity but also help in the prevention of coastal erosion, they stabilize the shorelines and protect the coast by acting as wind breakers and barriers against storms and heavy tides. They sequester and store carbon by removing it from the atmosphere. Mangroves also contribute towards the livelihoods of the locals living in its vicinity in terms of forest produce and fishery resources, being heavily used for food, timber, fuel and medicine and play a key role in human sustainability. These wetlands act as recreational site for fishing, boating, bird watching, sightseeing and photography. Mangrove ecosystems are self-generating, self-perpetuating and highly resilient littoral formations which plays a crucial role in the global carbon, nitrogen and sulphur cycle. They act as a sink for the detritus and sediments draining from the coasts (Chauhan, 2017).

Fig. 1.2: Crabs at the Mangrove vegetation of St. Cruz-Merces Highway.

1.4. Global Mangroves Vegetation Scenario: Factors influencing the same

Despite of the immense significance of the mangroves they are disappearing globally with a loss rate of 35% in the last 20 years (Carugati et al., 2018). The area under mangrove cover has declined by 30-50% during the last 50 years which is at rate, higher than most other habitats (Chauhan, 2017). By the year 2030 the global loss mangrove forest is estimated to be as high as 60% (UNEP-WCMC 2006; Alongi, 2002; Valiela et al., 2001). The mangrove ecosystem is highly threatened and was estimated to lose about 50% in the second half of the 20th century which places this habitat under "headed for extinction'' category of the International Union for the Conservation of Nature and Natural Resources (IUCN) (Oceans and Aquatic Ecosystems - Volume II).

Climate changes including sea level rise and altered rainfalls; human activities such as urbanisation, aquaculture, mining, oil pollution, felling of mangroves, overexploitation of timber, fish, crustaceans and shellfish are amongst the major threats for mangrove habitats (Carugati et al., 2018). Reclamation of mangrove ecosystem as shrimp aquaculture ponds is a major human induced threat that has caused a loss of about 20-50% mangrove cover globally. Disposing of sewage, solid and toxic wastes is another anthropogenic threat to this ecosystem. Movement of barge in rivers leads to strong wave action as a result of which young saplings get uprooted and also leads to erosion on the banks of rivers. Inadequate infrastructure for protection also causes difficulties in mangrove conservation (Chauhan, 2017).

Mangrove habitat loss has put about 40% of the animal species that are restricted to this habitat at an elevated risk of extinction under the (IUCN) (Mangroves of Goa, Goa Forest Department, Government of Goa). The destruction and depletion of mangrove forest poses a most serious threat to the world. Mangroves are slow to recuperate from cutting and several species are unable to re-sprout after being cut and only solution is to replant. Hence there is an urgent need of conservation measures and afforestation strategies. Attention should be given to the studies pertaining to hydrological patterns that control distribution and successful establishment and growth of mangroves. An appropriate mangrove restoration site should be selected that is hydrologically and ecologically likely to rehabilitate a healthy mangrove ecosystem. Awareness and Community participation should be an important component in mangrove development and management programme (Mangroves of Goa, Goa Forest Department, Government of Goa).

1.5. Occurrence of white-water lily (*Nymphaea tetragona*) in the deteriorated mangroves Vegetation along the St. Cruz-Merces Highway

During the month of September-October, 2023 the surface water of the mangrove habitat of St. Cruz-Merces was seen blooming with small white-water lily or pygmy waterlily (*Nymphaea tetragona*) also locally known as *"salkam"* (Fig. 1.3).

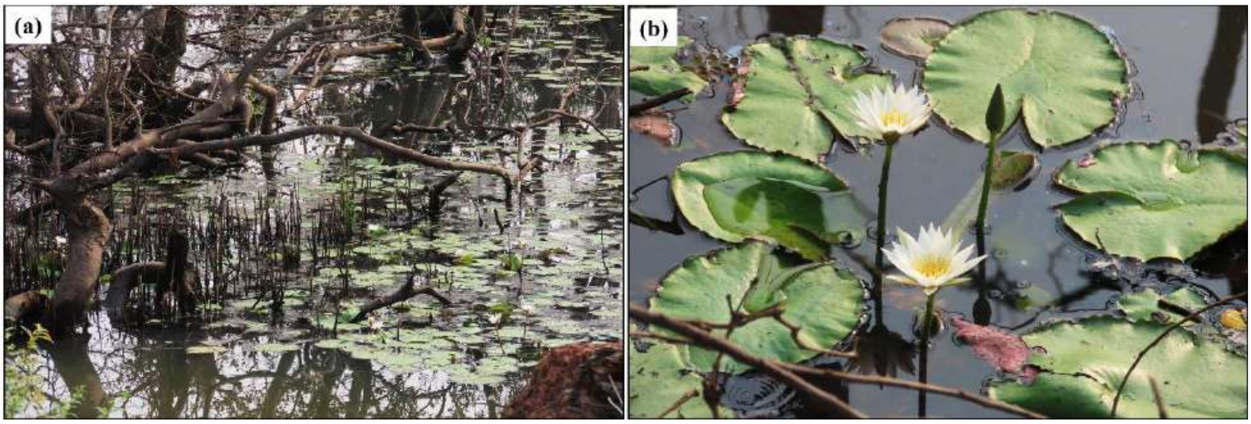

Fig. 1.3: White-water lily or pygmy waterlily (*Nymphaea tetragona*) at the Mangrove vegetation along the St. Cruz-Merces Highway.

Pygmy waterlily usually inhabits fresh waters of ponds, lakes, and quiet streams; however, their presence in the mangrove vegetation of St. Cruz-Merces indicates that there is no tidal influx occurring resulting in the semi-stagnant water. Also, due to the recent uneven rains, the salinity in the mangrove vegetation is diluted to levels which supports the growth and propagation of such fresh water lilies.

2. Factors affecting the health and wellness of the mangrove ecosystem

2.1 Introduction

Mangrove forests represent dynamic ecosystems. The growth and survival of the mangroves is influenced by several factors such as sedimentation rates, soil subsidence, freshwater run-off, tidal forces, and changes in sea level. As a result of these factors, the mangroves arrange themselves in a zonal fashion reflecting geomorphological and hydrological gradients (Lugo, 1980). Eventually, significant changes in the environmental conditions result in alterations in the vigor or zonation of vegetation which may even include widespread tree mortality (Jimenez et al., 1985). There are various factors that govern the smooth functioning of the mangrove ecosystem, and hence alterations to these factors can be detrimental to the ecosystem. Some of these factors include light, wind, coastal changes, soil, salinity etc. The response of mangroves and mangrove ecosystem to the alterations in some of these factors is discussed below.

Mangroves are usually in close-knit with the coastal environments which they inhabit. In addition to being greatly influenced by the chemical and physical factors associated with their environment, mangroves also stimulate the prevalence of these factors. Consequently, the disturbances caused to this system can result in cascade reactions having long-term effects (Kathiresan and Bingham, 2001).

Alterations in the coastal mangals can be attributed to changes in the hydrology pattern. Some of these changes can be favourable, resulting in the creation of new mangal such as the increase in the frequency of tidal inundation adjacent to established mangrove stands (Lee et al., 1996). However, changes in hydrology, generally result in destruction of mangroves. Changes in topography and tidal flushing causes large-scale degradation of mangroves, like in the case of Pichavaram, south India. On flat lands, the mangroves appear healthy and diverse. However, during reduced water flow, flat lands turn into shallow basins. The poor flushing results in hypersalinity (excessive salts) that causes the mangroves to stunt and replaces them with saltmarsh or barren soil that is devoid of vegetation. However, simply increasing the free flow of the tidal waters can reverse this process (Selvam and Ravichandran, 1998).

Soil also plays a very important role in the nutrition and growth of the mangroves that thrive in it. Some of these important properties include siltiness, electrical conductivity, pH, cation exchange capacity and nutrient concentrations. Mangrove environment is well balanced and represents an efficient nutrient sink for dissolved nitrogen, phosphorus, and silicon, which are mostly linked to plant assimilation and microbial mineralization (Kathiresan and Bingham, 2001).

Presence of sulphides is one of the characteristic features of mangrove sediments that influences mangrove distributions. Tidal mixing, bioturbation, and the mangroves themselves control the distributions and concentrations of the sulphides. However, high levels of sulphide is detrimental and causes damage to mangrove seedlings, causing stomatal closure, reduced gas exchange, reduced growth and high mortality (Youssef and Saenger, 1998). Mangrove deforestation, or formation of gaps in the canopy can alter the physicochemical characteristics of the underlying soils leading to anaerobiosis and increased sulphide content in the sediments (Kathiresan and Bingham, 2001). Normally, these sulphides combine with metals available in sediments and precipitate out as metal sulphides. However, upon exhaustion of these metals, H_2S is formed. This H_2S accumulates in cable roots of *Avicennia* species as the sediments age and can kill the mangroves if their pneumatophores are covered by silt and cannot transport oxygen to the rhizospheres. *Rhizophora* species have aerial roots and can better survive on aged mangrove soils high in H_2S (Kryger and Lee, 1995).

Salinity in the mangrove environment depends upon climate, hydrology, topography and tidal flooding and has significant impact on the productivity and growth of mangrove forests. The distribution of plant species within the mangal is dependent on salinity gradient. Generally, lower salinities support more luxuriant mangrove vegetation. However, the plants must have some salinity tolerance to thrive in this habitat. Mangrove seedlings require low salinity but their salt tolerance tends to increase as they grow. Chronic hypersalinity, is always disastrous to the mangroves. High salinities may stunt tree growth, reduce biomass and denature terminal buds in some species (Kathiresan and Bingham, 2001). It can also result in reduction of leaf area, increases leaf sap osmotic pressure, increases the leaf area/weight ratio and decreases total N, K, and P (Medina et al., 1995). Salinity fluctuations also result in significant negative effects on photosynthesis and growth of the plants (Lin and Sternberg, 1993).

One of the key factors causing mangrove stress is modified tidal flows and exchange, which has an analogy to blocked blood flow to heart. It can result in degradation to nearly complete lack of cover causing deforestation and significantly reducing ecological functions and hence it is termed as "mangrove forest heart attack". Blocked water flow reduces flushing from the seaward side, causing higher salinity and reduction in sediments when the flow is blocked landward. Long term decline in function causes acute mortality brought about by acute events. Generally, the mangrove cover disappears within a year but vulnerability is set in years before, when the so-called harmless modifications are made (e.g., road construction, blocked tidal channels), (Lewis et al., 2016).

As described by Botero and Salzwedel, the mangrove ecosystem is highly impacted by anthropogenic alterations mainly its hydrological regime through the construction of roads, dikes and berms along the river and its tributaries. Fresh water flow from river to the estuarine system is thus interrupted. This can result in hypersalinization of mangrove soils which results in the death of mangrove forests (Botero and Salzwedel, 1999). Any extreme reduction in the intensity and frequency of runoff and flushing within the mangroves often causes changes in the structure, vigor and mortality patterns (Lugo and Snedaker, 1974).

Terrestrial runoff diversion, reduced river discharge, alterations in tidal regime, and reduced rainfall are the main factors causing alterations in edaphic characteristics like salinity, fertility, degree of anoxia, etc. For instance, reduced runoff and flushing causes the toxic sulphides to increase while the availability of nutrients in mangrove soil decreases (Carter et al., 1973). As a result of reduced freshwater input the salts in the soil concentrate and causes hypersalinity in arid or seasonal climates (Cintron et al., 1978). Decrease in the flooding causes the reduced compounds in the soil to oxidise thus causing drastic lowering of pH. These factors or their combinations have been associated with massive tree mortalities (Jimenez et al., 1985).

2.2. Study site

The mangrove vegetation of the site under study is represented in Fig.2.1. The map of the state of Goa marked with a red dot is St. Cruz-Merces region, within lies the site under study. The yellow lines are joined to form a polygon covering the mangrove vegetation that stretches along the NH66 Merces-St Cruz highway thus marking the site under study. This patch of mangrove extends over a distance measuring 415.45m along the highway and does not fail to catch an eye of anyone passing by that route due to the dead mangroves standing out. This mangrove region has undergone extensive degradation with dead and dry mangroves standing upright in the partially stagnant water, with greens that are long lost, and whatever remains are the remnants of the once lush green mangroves (Fig. 2.2).

Fig. 2.1: The site under study: The mangrove vegetation that stretches along the NH66 Merces-St Cruz highway.

Fig. 2.2: The extensive degradation of Mangrove vegetation: Dead and dry mangroves standing upright in the partially stagnant water along the NH66 Merces-St Cruz highway.

2.3. Reasons for the decline of the mangrove cover in Goa

In Goa, the twin rivers, Mandovi and Zuari support the largest mangrove cover in the state. These mangroves are vulnerable to various anthropogenic activities taking place in these rivers and along their banks which includes settlement, bridge construction, widening of roads, agriculture, aquaculture, salt extraction, tourism, etc. In recent years, vast mangrove areas in Goa are being reclaimed for developmental purposes such as settlements, industrial establishment, road extension, construction of bridges, harbors, jetties, dredging and discharge of sediments, dumping of garbage, pollution, etc. which has led to severe damage to the fragile ecosystem of Goa i.e. mangroves (Dhargalkar and Kavlekar, 2019).

In recent years, anthropogenic pressures have caused significant damage to the world's mangroves. Despite of the immense significance they hold, mangroves are disappearing globally with unimaginable numbers. According to Carugati et al (2018) the global mangrove loss rate around the world has been recorded to be 35% in the last 20 years. In the last 50 years the area under mangrove cover has declined by 30-50%, which is at a rate higher than most other habitats (Chauhan, 2017). If the loss of mangrove habitat continues to occur at current alarming rates, the whole mangrove biome is estimated to disappear in the next 100 years (Duke et al., 2007).

Since this ecologically unique habitat is a host to a rich flora and fauna (Kathiresan and Bingham, 2001) its destruction has posed a serious threat to the biodiversity dependent on it. As a result of extensive mangrove degradation caused mainly due to anthropogenic activities, 16% of mangrove species have already been declared as critically endangered, endangered or vulnerable and 10% are near-threatened (Polidoro et al., 2010). Mangrove ecosystem destruction has also pushed more than 40% of the mangrove-endemic vertebrates at risk of extinction due to habitat loss (Luther and Greenberg, 2009).

2.4. Understanding the Present Scenario of the Mangrove Vegetation at the Site under study.

As one moves along the NH 66 Merces- St Cruz highway towards Bambolim, one cannot avoid but witness the sight of dead mangroves lying in the semi stagnant water on the left-hand side of the highway. However, on the right-hand side lies some of the luxuriant mangrove vegetation (Fig. 2.3). A question therefore arises, as to why the two points (A) and (B) lying at a distance of few meters from each other have such different conditions with respect to the health of the mangrove vegetation.

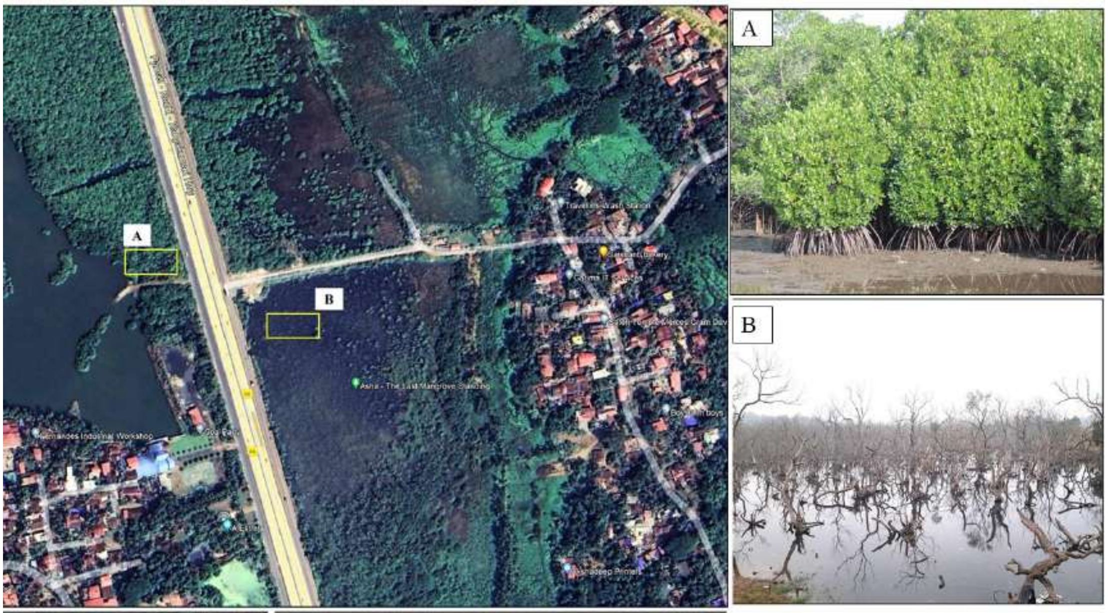

Fig. 2.3: (A) Healthy and luxuriant mangrove vegetation along the NH 66 highway (B) Highly deteriorated mangrove vegetation lying on the opposite side (site under study).

2.4.1. A Brief History of the Mangrove vegetation along the NH66 Merces-St. Cruz Highway

In order to understand the present scenario of Mangrove deterioration, it is of uttermost importance to know the history of mangrove vegetation at the site under study.

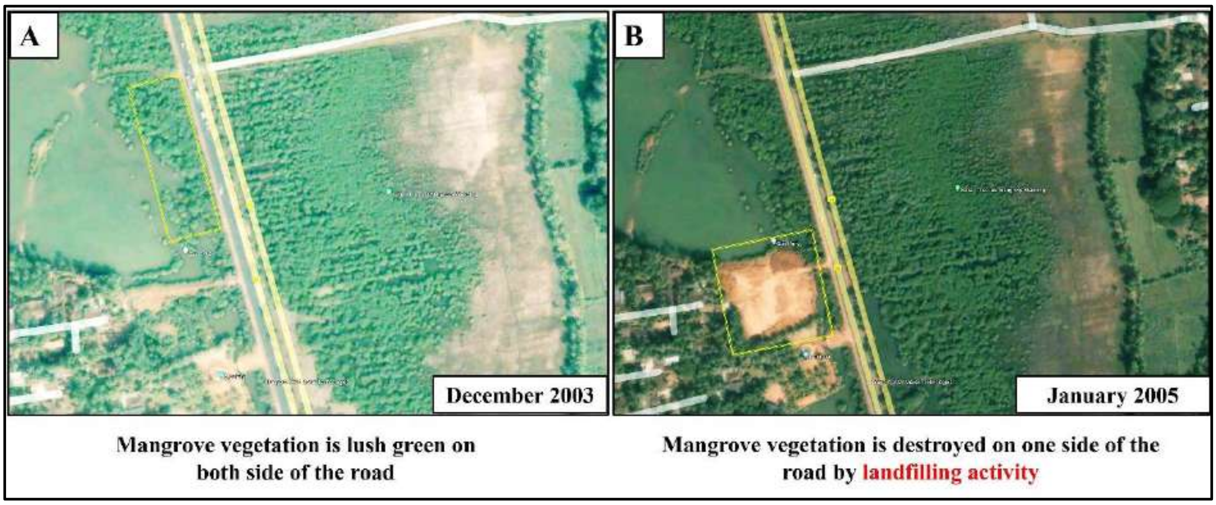

Fig. 2.4: Mangrove vegetation along the NH 66 highway in (A) December 2003 and (B) January 2005 (site under study).

By using the Google Earth Pro Satellite images, the state of the mangroves near St. Cruz- Merces highway was studied for a period of 20 years from 2003 to 2023. It was very clearly observed that in the year 2003 (Fig. 2.4 A), both sides of the NH66 St. Cruz- Merces Highway had thick lush green mangrove cover. However, by January 2005 (Fig. 2.4 B), on one side of the highway the mangrove vegetation was destroyed due to landfilling activities (as demarcated in yellow box).

As the years proceeded, the mangrove vegetation proliferated as clearly observed in Fig. 2.5. It was also observed that, the landfilling activity that had started in the year 2005 (Fig. 2.4 B), had increased by November 2018 (Fig. 2.5 C), causing further destruction of the mangrove vegetation in that area, that was once present in that landfilled patch (demarcated in yellow boxes). It didn't stop there, the landfilling further continued to extend through the year 2019 (Fig. 2.5 D, Fig. 2.6 E & F) setting the destruction of the mangrove vegetation not only in the area of landfilling activity but also beginning the massive destruction of mangrove vegetation on the opposite site where the lush green mangrove vegetation supporting biodiversity had flourished since 2003.

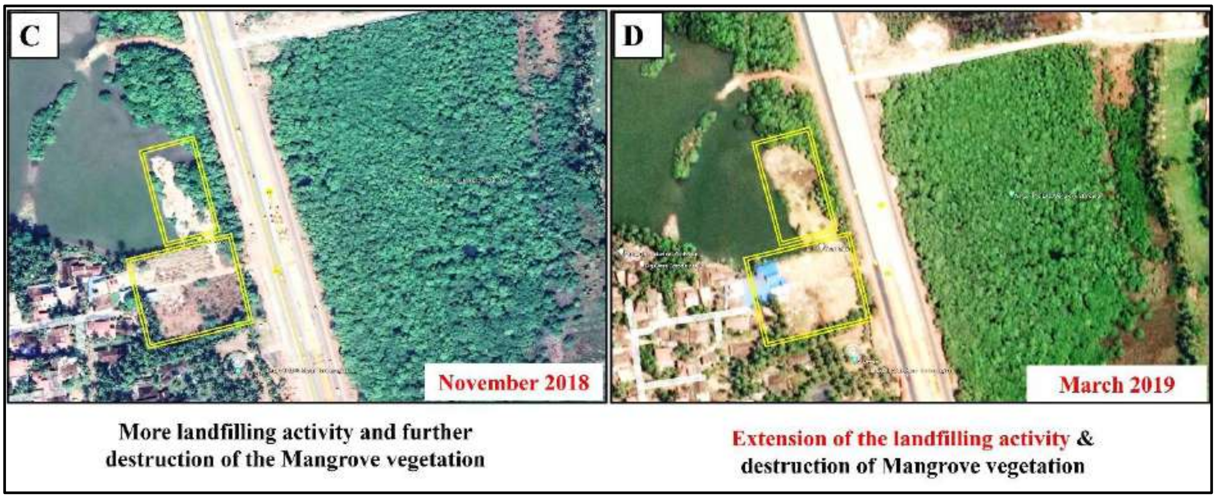

Fig. 2.5: Mangrove vegetation along the NH 66 highway in (C) November 2018 and (D) March 2019 (site under study).

Fig. 2.6: Mangrove vegetation along the NH 66 highway in (E) November 2019 and (F) December 2019 (site under study).

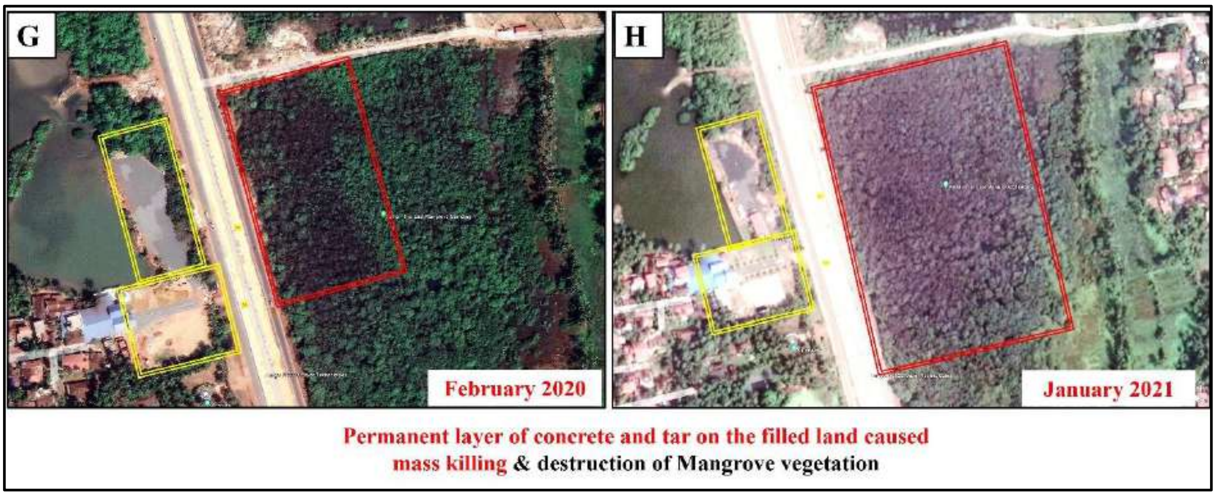

Fig. 2.7: Mangrove vegetation along the NH 66 highway in (G) February 2020 and (H) January 2021 (site under study).

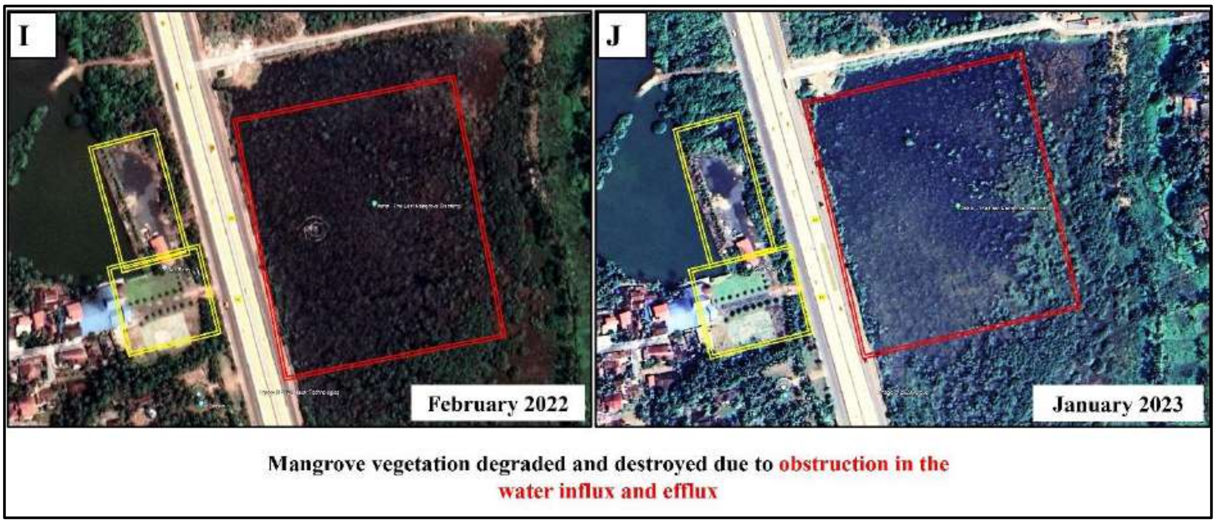

Fig. 2.8: Mangrove vegetation along the NH 66 highway in (I) February 2022 and (J) January 2021 (site under study).

By February 2020 (Fig. 2.7 G) the extended landfilled patch was developed further with a permanent layer of concrete and tar. One of the important factors for the survival of mangrove vegetation is the continuous exchange of nutrients through the tidal influx and efflux of water. The extended permanent landfilled activity (Fig.2.7 as demarcated in yellow box) caused hinderance in the flow of water from the Mandovi estuary thereby causing the sudden and massive death of the lush green mangrove vegetation on the opposite side (Fig.2.7 as demarcated in red box). This destruction of the mangrove vegetation only escalated through the years 2021 (Fig. 2.7 H), 2022 (Fig. 2.8 I) to 2023 (Fig. 2.8 J), killing almost everything that once occupied the mangrove stretch now called Asha-the last mangrove standing (Google Earth Pro Satellite images).

2.4.2. Effects of Anthropogenic activities at the Mangrove Vegetation near St Cruz-Merces highway, Goa

The mangrove stretch along the Merces-St Cruz highway has faced massive degradation of vegetation. And what now remains is being converted into a dumping ground to dispose off anything from domestic waste, plastic, garbage, construction debris, scrap, etc. (Fig. 2.9) and it is a very sad site to take in. These mangroves are an ecologically sensitive zones, with the site under study requiring special attention if one wants to revive it. But if this dumping of wastes persists, the tiny possibility of reviving this stretch will also vanish into thin air. The dumped waste mostly consists of plastic products, and other debris. The mangroves consist of specialised modifications of roots called pneumatophores (aerial roots) that get entangled with plastic products. This causes pneumatophores to suffocate, weaken, and can potentially kill the trees by suffocating the trees and preventing their roots from absorbing CO_2. Land based sewage may remain stagnated in the blocked lagoons which can cause the pneumatophores to get poisoned. According to the findings of a 2016 study by the United States National Oceanic and Atmospheric Administration- Marine debris can cause the death of the animals that live in the mangroves and suppress their habitat. It can also be detrimental to the nearshore habitats and their associated species. It can inhibit tidal flushing and increase salinity levels, thereby stressing the habitat.

Fig. 2.9: Anthropogenic activities and construction effects/debris dumped at the Mangrove vegetation near Merces-St Cruz

As discussed earlier in the section 2.2, there are numerous factors that ensure smooth functioning of the mangrove ecosystem. Disturbing these factors can result in having adverse effects that can ruin this ecosystem. In this case, the landfilling and concretising the same to increase the land area obstructs the flow of water and blocks the tidal flow of water from the river Mandovi to the mangrove ecosystem to cause degradation of mangrove vegetation and significantly reducing ecological functions (Lewis et al., 2016). Also, anthropogenic activities as described by Botero and Salzwedel in 1999, may alter the hydrological regime causing deterioration of the mangrove vegetation as seen in this scenario.

3. Sampling and description of the sampling sites

Figure 3.1 depicts the sampling sites lying on both sides of the NH 66 Merces -Bambolim highway. Site-1 represents the primary site under study, with no mangrove vegetation left, but only remnants of the once luxuriant green forest. Site- 2, lying on the other side of the highway, is also represented by the somewhat dry mangroves lying in eutrophied stagnant water. The sampling site-3 also lies on the opposite side of the road, and was considered as healthy mangrove vegetation as compared to the former two sites due to its dense vegetation and good water influx and efflux.

Fig. 3.1: The sampling sites at the Mangrove vegetation (red boxes): Sampling site-1, sampling site- 2 and sampling site- 3 lying on both sides of the NH66 St. Cruz-Merces Highway.

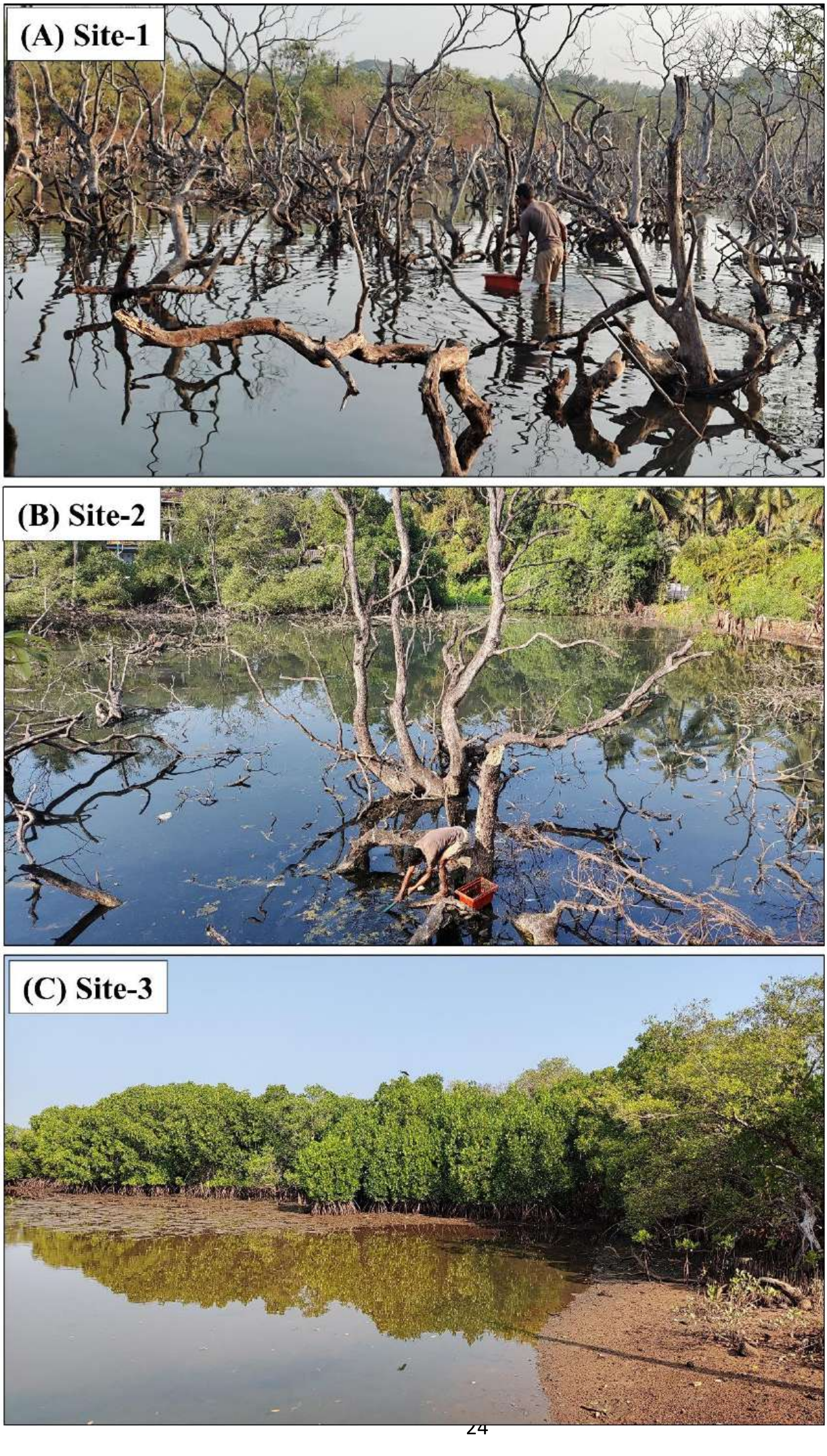

Fig. 3.2: The sampling site 1 (A), having dead and deteriorated mangrove vegetation, site 2 (B), having dead mangrove vegetation in semi stagnant eutrophic water and sampling site 3 (C), having healthy mangrove vegetation along the Mandovi Estuary.

Fig. 3.3: Sediment sample collection (A) and processing of the sediment sample (B) by quadrant method (C).

3.1. Analysis of the Mangrove Samples:

The mangrove samples collected from three different sites (Fig. 3.1) were analysed for their Physico-chemical as well as microbiological properties.

3.1.1. Physico-chemical analysis of the Mangrove Samples:

The Physico-chemical analysis was performed for both the water as well as the sediment samples. The various parameters analysed for the sediment samples were the hydrogen ion concentration (pH), Electrical Conductivity (EC), Organic Carbon (OC), as well as the micro and the macro nutrients such as Nitrogen (N), Phosphorous (P), Potassium (K), Iron (Fe), Manganese (Mn), Copper (Cu), Zinc (Zn) were analysed. The various parameters analysed for the water samples were the pH, EC, Fe, MN, Cu, Zn.

Table 3.1. Physico-chemical analysis of the various sediment samples from different Mangrove vegetation sites.

sites	Parameters analysed									
	pH	EC (ds/m)	OC (%)	N (Kg/ha)	P (Kg/ha)	K (Kg/ha)	Fe (ppm)	Mn (ppm)	Cu (ppm)	Zn (ppm)
1	3.19	36.04	14.85	451.58	88.14	80.40	81.20	25.60	0.13	6.71
2	4.54	10.37	3.72	137.98	70.55	188.80	74.03	7.19	0.72	2.60
3	4.58	16.64	3.83	-	16.11	97.40	-	-	-	-

Ds/m decisiemens per meter; ppm parts per million; Kg /ha Kilogram per hectare; % percentage

(a) pH of the samples

The pH of the mangrove sediments remained acidic at site-1, site-2 and site-3 with values ranging from 3.19, 4.54 and 4.58 respectively. Site-1 sediment sample recorded the lowest and most acidic pH value of 3.19. According to the limits proposed by the Central Pollution Control Board (CPCB) pH 6.5 to 8.5 is optimum for the propagation of wild life and fisheries. However, the pH obtained for the mangrove sediment samples was extremely acidic (3.19 - 4.58) and was much less as compared to the lowest pH value of 5.87 reported for the mangrove sediments by Sohaib et al (2023). The various reasons for the acidic pH are atmospheric carbon dioxide deposition, acid precipitation by sulphate or nitrogen oxides, microbial activity in anoxic sediments, or due to the addition of acid/acidic drainage directly without treatment (Sohaib et al., 2023). Other reasons for differences in pH levels in mangrove ecosystems may be due to ocean acidification and putrefaction of organic matter (Dattatreya et al., 2018).

Table 3.2. Physico-chemical analysis of the various water samples from different Mangrove vegetation sites

sites	Parameters analysed					
	pH	EC (ds/m)	Fe (ppm)	Mn (ppm)	Cu (ppm)	Zn (ppm)
1	8.25	40.19	0.26	ND	0.135	0.0823
2	8.38	32.75	0.24	ND	0.143	0.0800
3	8.37	42.94	0.30	ND	0.136	0.0771

Ds/m deciSiemens per meter; ND Non detectable; ppm parts per million

The water samples from site-1, site-2 and site-3 had alkaline pH values of 8.25, 8.38 and 8.37, respectively. The pH values obtained from our study were compared well with the ones reported by Ramamurthy et al (2012) for Vedaranyam mangrove forest in Tamil Nadu having pH in the range 7.6, 8.3, 8.7 and 8.2. Such alkaline pH values have also been well documented in coastal saline samples of Sundarbans and this behaviour is attributed to high salt content (Dasgupta et al., 2018).

(b) Electrical Conductivity (EC) of the samples

The EC measures the current carrying capacity and gives a clear idea of the soluble salts present in the soil. EC value is directly proportional to the salinity value of soil and plays a major role in the salinity of soils (Ravikumar, 2013). The EC of the mangrove sediment and water samples tested was variable. Sediment samples from site-1, site-2 and site-3 recorded EC values of 36.04, 10.37, and 16.64, respectively. While the mangrove water samples from site-1, site-2 and site-3 was found to have EC as 40.19, 32.75 and 42.94, respectively. A sharp increase in the conductivity was observed for sediment samples, exhibiting an EC trend of site-1> site-3> site-2. While the EC trend followed by the mangrove water samples was water site-3> site-1 > site-2. The EC of sediment sample from site-1 was quite high compared to the other two samples. Such high values of EC are attributed to the accumulation of salts as in the case of disturbed sites such as that reported by Chaudhuri et al., 2009 for Andaman mangroves (33.8–41.5 dS m^{-1}). Dasgupta et al (2018) also reported high EC values which might have been caused as a result of mangrove soil being subjected to irregular and poor inundation by tidal water and maintaining no equilibrium with the salinity of the estuarine water.

(C) Organic Carbon (OC) of the samples

Total organic carbon of sediment has a significant role in maintaining the fertility of the soil and thereby ensuring that the biological activity flourishes (Kumar, 1996). The organic carbon (OC) of mangrove sediment from site-1, site-2 and site-3 was recorded as 14.85%, 3.72%, and 3.83%, respectively. The low OC value indicates higher biological activity characterized by rapid mineralization of organic carbon which is usually seen in natural mangrove ecosystem. In case of degraded and disturbed mangrove ecosystem, mineralization of organic carbon will be slowed down (Nsombo et al., 2016) as seen in the case of site-1 having higher OC value where the mangrove vegetation is dead.

(d) Nitrogen (N) of the samples

The available nitrogen varied from 451.58 Kg/ha at site-1 and 137.98 Kg/ha at site-2 sediments. At site 3 the N content could not be estimated. High value of the recorded available nitrogen at the site-1 and site-2 is a result of improper tidal flux at the degraded mangrove sites which results in the trapping of the detritus by means of finer particles causing proliferation of bacterial population. This inturn increases the level of nitrogen in the semi-stagnant waters. The high value of available nitrogen is due to the excess amount of organic matter (KM and Kumara, 2020).

(e) Phosphorus (P) of the samples

The available phosphorus concentration was recorded as 88.14 Kg/ha, 70.55 Kg/ha, 16.11 Kg/ha for mangrove sediment from site-1, site-2 and site-3, respectively. Sundarban forests have also recorded a varied quantity of phosphorus ranging from 53.16 to 62.56 kg/ha (Khan and Amin, 2019). When mangroves are subjected to destruction, there is a lack of organic matter decomposition which can cause sediment oxidation. This results in sediment acidification accompanied with phosphorous deficiency (Kathiresan et al., 2014). The higher rate of accumulation of organic matter in mangrove soils may also result in increased availability of phosphorus in such soil, as Cleary seen in site-1 and site-2 of the degraded mangrove vegetation in the present study (Dasgupta et al., 2018).

(f) Potassium (K) of the samples

The available potassium differed from 80.40 Kg/ha, 188.80 Kg/ha and 97.40 Kg/ha for mangrove sediment samples from site-1, site-2 and site-3 respectively. Sundarban mangroves have reported average potassium values ranging from 250 to 750 kg/ha in Bangladesh (Dasgupta et al., 2018). The high potassium content may result due to weathering or high organic matter in soil and accumulation of deteriorated organic matter which promotes release of potassium into the soil (Reef et al., 2010).

(g) Trace metals (Fe, Mn, Cu, Zn) of the samples

The trace metals that were analysed included Fe, Mn, Cu, Zn for mangrove water as well as sediment samples. The trace metal concentration recorded for the mangrove sediment samples from site-1 and site-2 are as follows: Fe, 81.20 ppm and 74.03 ppm; Mn, 25.60 ppm and 7.19 ppm; Cu, 0.13 ppm and 0.72 ppm; Zn, 6.71 ppm and 2.60 ppm. The trace metal contents for sediment samples recorded were in the following order for site-1 and site-2: Fe > Mn > Zn > Cu. Similarly, the concentration of trace metals determined for mangrove water samples from site-1, site-2 and site-3 are as follows: Fe, 0.26 ppm, 0.24 ppm and 0.30 ppm; Cu, 0.135 ppm, 0.143 ppm and 0.136 ppm; Zn, 0.0823 ppm, 0.0800 ppm, 0.0771 ppm. (Mn not defined). The trace metal content for water sample was in following order for site-1, site-2 and site-3: Fe > Cu > Zn.

Dookie et al (2022), reported the trace metals concentration values of mangrove ecosystems from Guyana, Egypt, where Zn concentration values ranged from 0.55– 2.60 ppm, Mn concentration values fluctuated between 57.91–85.85 ppm, and concentrations of copper varied from 0.09–0.59 ppm, while iron concentration values shifted from 0.60–21.62 ppm.

Sohaib et al (2023), also reported the trace metal concentrations for water and sediment samples from mangrove ecosystem along the Arabian Gulf and Red Sea Coast. Fe was most abundant in soil samples with an average of 0.22 %, followed by Mn (91.9 ppm), Zn (66.11 ppm), Cu (31.06 ppm). While in water samples, the concentrations were as followed: Fe (0.1016 ppm), Mn (0.0356 ppm), Cu (0.0317 ppm), and Zn was not detected.

Generally, heavy metal concentrations are lower in water than in sediments owing to their poor solubility. They tend to bound to particulate matter and accumulate in the sediments. Sediments function as traps as they can readily bind with metals (Costa-Böddeker et al., 2017). This is also true for the sediment and water samples analysed in our study.

As observed while sampling, this study revealed that mangrove plants in site 1 were exposed to water deprivation and drying, thus leading the way to their death. Out of the 3 sampling sites, site-1 consisted of dried remnants of the already dead mangroves standing in hypersaline and water deprived conditions. Site-2, also had dried mangroves but in eutrophic conditions, probably due to the residential area present in its proximity. Site-3 consisted of healthy mangrove vegetation that is well inundated and has equilibrated influx and efflux. As for the site-1, in the last 6-7 years, it has witnessed significant changes around that stretch of mangroves due to extensive human interventions. Urban expansion along the coastal sites thus remains one of the leading cause of mangrove vegetation deterioration.

3.1.2. Microbiological analysis of the Mangrove Samples:

Both qualitative and quantitative estimation of microbial load in the sediment and water samples was done.

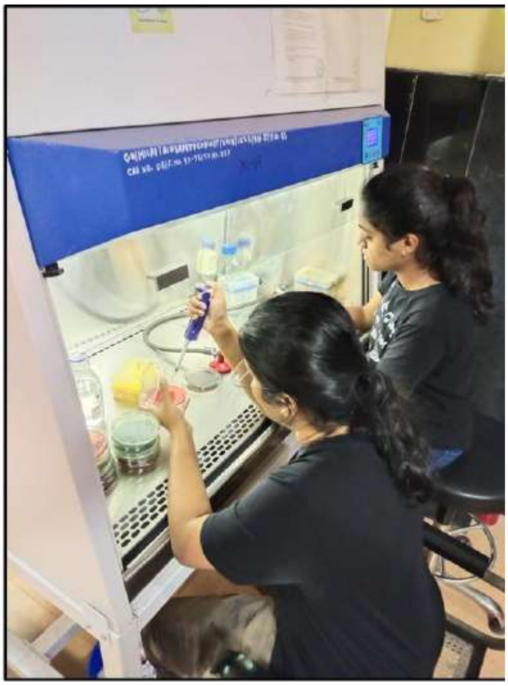

Fig. 3.4: Processing of the water and sediment samples for microbiological analysis at Microbiology Research Laboratory 1 of Goa University.

(a) Qualitative estimation of the microbial population

The qualitative estimation of the microbial population sizes was done using the most probable number (MPN) technique. MPN is a technique used to qualitatively estimate coliform population sizes when quantitative assessment of individual cells is not possible. Generally, measuring the exact number of individual organisms in soil or water can be difficult due to heterogenous populations or unavailability of a suitable diagnostic media. Despite the emergence of more precise and sophisticated methods of microbial enumeration in soils, water, and agricultural products, the MPN technique continues to remain an important means of assessing microbial populations (Woomer, 1994). The tests were done by following the standard protocol using double strength and single strength Mac Conkey's broth in a set of 5 tubes each. Each tube containing inverted Durham's tube for determining whether the microbial load is producing gas along with lactose fermentation. On incubation of the tubes with the water samples for 24 hours, the MPN was recorded by referring to Mc Crady's probability table (McCrady, 1915) which gave a count of 350, 920, 26 MPN/100 ml for site-1, site-2 and site-3, respectively. The heaviest coliform load was observed for the stagnant eutrophic water at site-2 followed by the semi-stagnant water of the dead mangrove vegetation at the site-1, whereas the least was observed for the healthy mangrove ecosystem at the Mandovi estuary at site-3.

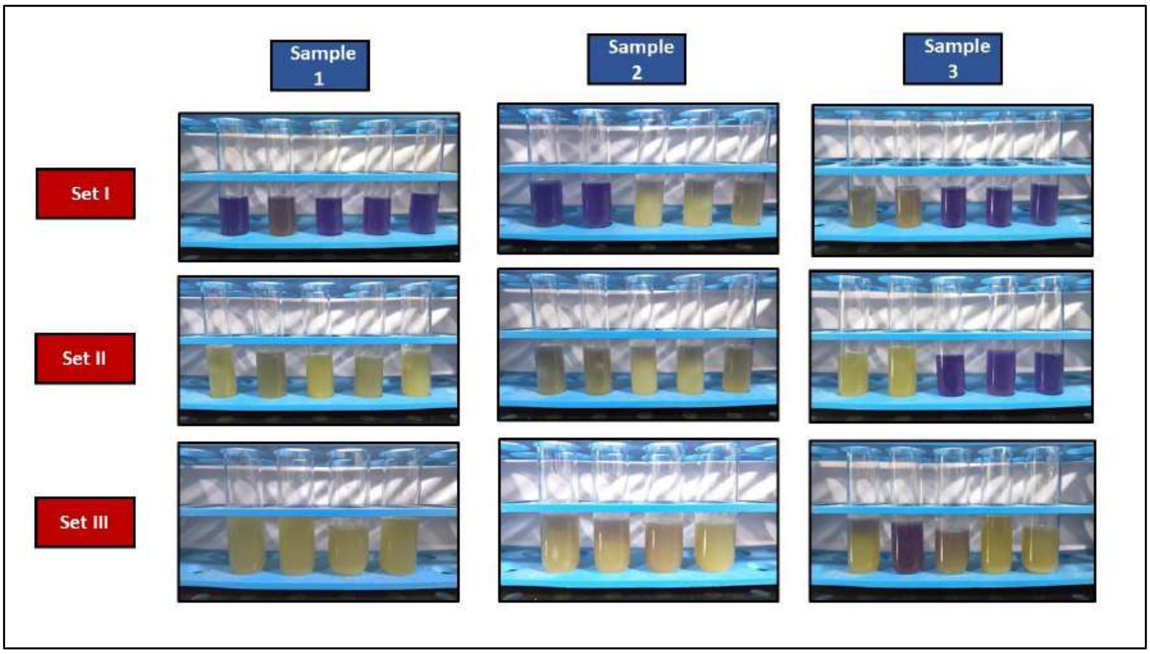

Fig. 3.5: MPN analysis of the water samples from various Mangrove vegetation sites.

Similar high MPN values as site-1 and site-2 have also been reported at the Sundarbans i.e. 620 MPN/100 ml - 1700 MPN/100 ml, 490 MPN/100 ml -1300 MPN/100 ml and 170 MPN/100 ml - 600 MPN/100 ml at western, central and eastern Indian Sundarbans. This high coliform load is attributed to anthropogenic pollution, primarily untreated sewage (Sengupta and Mitra, 2020). Domestic sewage discharge thus remains one of the leading causes of marine pollution and is associated with an increased fecal bacterial contamination (Abbu and Lyimo, 2007) This is also true for site-1 and site-2 in our study which have been a subject to human interventions due to the settlements in its proximity.

Whereas, the comparatively lower MPN values for site-3 suggests Low levels of contamination that may be caused by dilution effects as site-3 is well inundated with water and has balanced influx and efflux.

(b) Quantative estimation of the microbial population

The enumeration of the total heterogenous marine microbial load was done by surface spread plating the samples on Zobell marine agar. Bacterial population was enumerated by employing specific media.

Table 3.3. The various selective and differential microbiological media employed for microbiological analysis of the sediment and water samples from various Mangrove vegetation sites.

Sr. No.	Media	Microorganisms	Infections /Diseases
1.	ZMA	Marine organisms counts	-
2.	MCA	Coliform counts	Enteric microorganisms
3.	CA	*Pseudomonas aeruginosa*	Meningitis, Pneumonia, and Septicemia
4.	SSA	*Salmonella* spp. *Shigella* spp.	Salmonellosis: diarrhea, fever & stomach pains. Shigellosis: Bloody Diarrhea
5.	TCBS	*Vibrio cholerae* & *Vibrio parahaemolyticus*	Cholera is an acute diarrhoeal infection
6.	EMB	*Escherichia coli*	Opportunistic pathogen
7.	MSA	*Staphylococcus aureus*	Skin infections: cellulitis

ZMA Zobell marine agar; MCA MacConkey agar, CA Cetrimide agar; SSA Salmonella Shigella Agar; TCBS Thiosulfate–citrate–bile salts–sucrose agar; EMB Eosin Methylene Blue Agar; MSA Mannitol Salt Agar

Different morphological characteristics of the isolates were studied according to the Bergey's Manual of Determinative Bacteriology (Salah et al., 2014). Hundred microliters of the water and sediment were inoculated on specific media targeting specific microorganism for example for enumeration of *Escherichia coli* MacConkey agar and EMB agar were employed. Pathogens such as *Vibrio cholerae* and *V. parahaemolyticus* were enumerated using TCBS (Thiosulfate citrate bile salts sucrose agar), *Salmonella* and *Shigella* were enumerated using Salmonella-Shigella agar, *Pseudomonas aeruginosa* was enumerated using Cetrimide agar and

Staphylococcus aureus was enumerated using Mannitol Salt agar. All the chemicals and media were purchased from Hi-Media. Sample from each site were aseptically inoculated on each of the above mentioned media, followed by incubating the plates at a temperature of 28 ± 2°C for 24 to 48 hours. After incubation, colonies obtained from each sample were counted and expressed as colony forming units in sediment (CFU/mg) and water samples (CFU/ml).

Fig. 3.6: Coliform counts obtained on Mac Conkey's agar from the sediment samples of dead and deteriorating mangrove vegetation at site-1.

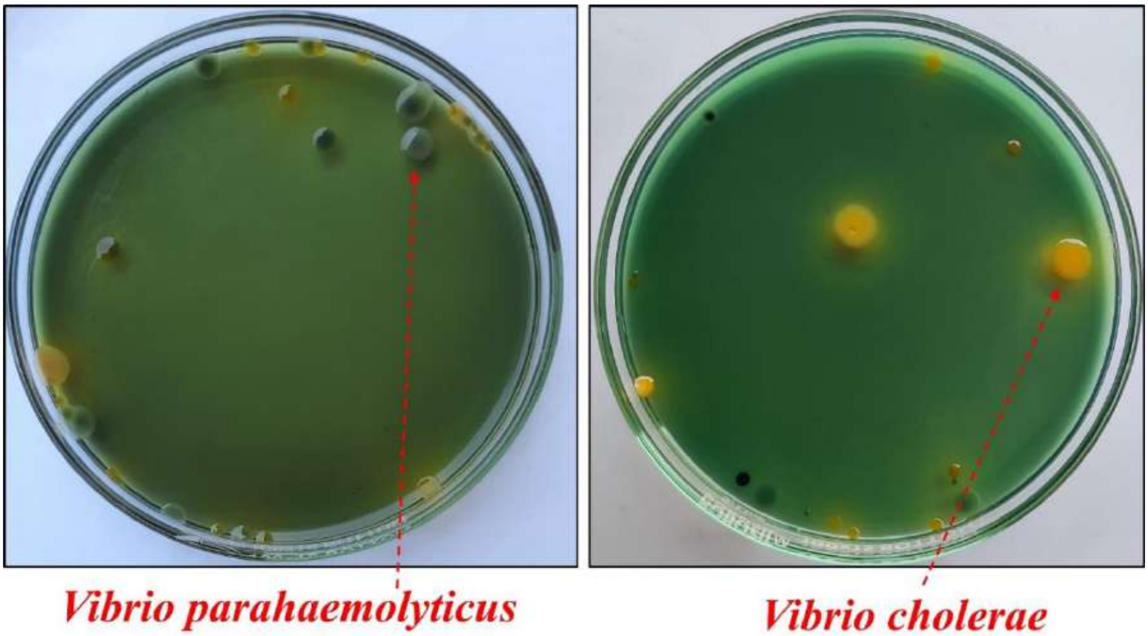

Fig. 3.7: Counts of *Vibrio parahaemolyticus* and *Vibrio cholerae* obtained on TCBS agar from the sediment samples of dead and deteriorating mangrove vegetation at site-1.

Table 3.4. Viable Counts obtained on Various Media for water sample obtained from various mangrove sites.

Sr. No.	Media	CFU/ml		
		Site-1	**Site-2**	**Site-3**
1.	ZMA	6.7 x 10^2	8.7 x 10^2	7.3 x 10^2
2.	MCA	0.5 x 10^2	6.3 x 10^2	2.5 x 10^2
3.	CA	3.3 x 10^2	5.9 x 10^2	6.0 x 10^2
4.	EMB	2.4 x 10^2	4.1 x 10^2	7.5 x 10^2
5.	TCBS	0.8 x 10^2	1.8 x 10^2	1.8 x 10^2
6.	MSA	0.6 x 10^2	0.4 x 10^2	0.5 x 10^2
7.	SSA	0.1 x 10^2	0	0

CFU/mL Colony forming Unit per milliliter; ZMA Zobell marine agar; MCA MacConkey agar, CA Cetrimide agar; SSA Salmonella Shigella Agar; TCBS Thiosulfate–citrate–bile salts–sucrose agar; EMB Eosin Methylene Blue Agar; MSA Mannitol Salt Agar

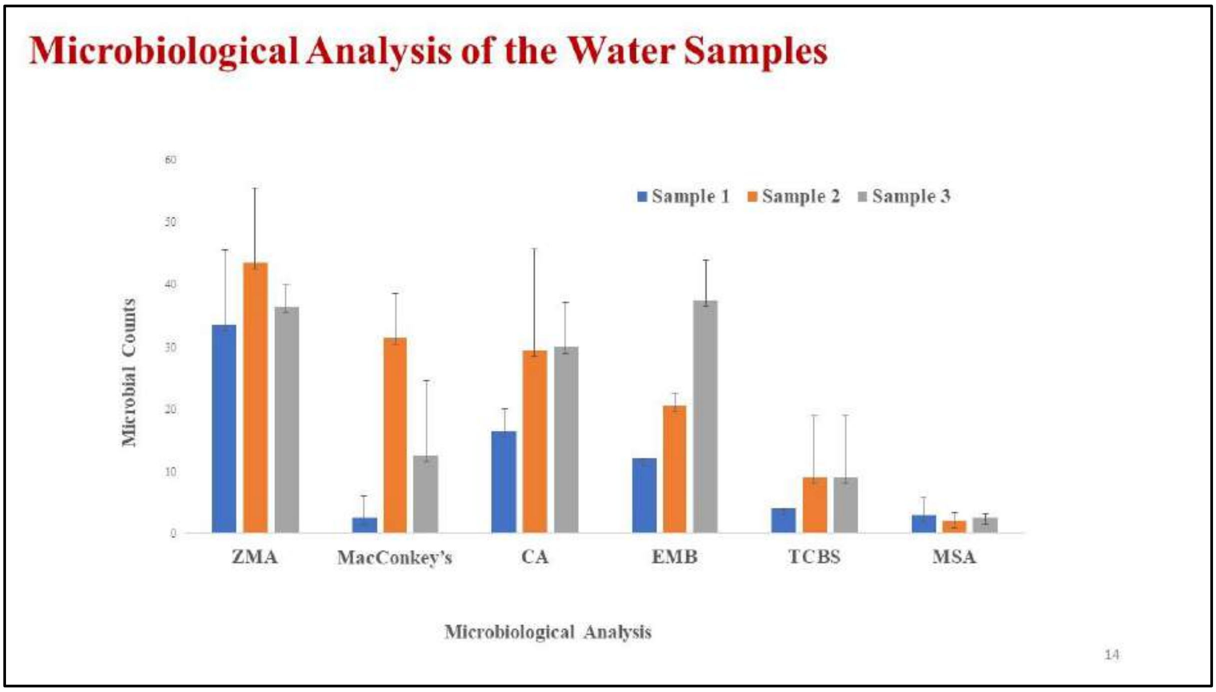

Fig. 3.8: Graph represents the trend in viable number of organisms obtained on different organism specific media for Water Samples

(b) Microbial Counts for Water Samples

Water sample at site-2 had highest number of colony forming units on ZMA medium plates followed by site-3 and site-1. On Mac Conkey's agar water sample site-2 gave highest number of counts, followed by site-3 and site-1. These high counts for water sample at site-2 were probably because the sample was obtained from a site that appears to be an eutrophied region closer to a residential area, which is not well exposed to tidal flux thereby making the water semi stagnant. On cetrimide agar water sample site-3 gave highest number of counts followed by site-2, followed by site-1. Also, Site-3 had the highest count on EMB agar, followed by Site-2 and Site-1. On TCBS agar Site-2 and Site-3 had equal number of counts followed by Site-1. While on Mannitol salt agar, Site-1 had greater colony count as compared to Site-3 which was followed by Site-2. Though the site-3 is a Mandovi estuary which is having healthy mangrove vegetation, the high coliform and other microbial counts may be due to the drainage of the sewage from the residential area surrounding the same.

(c) Microbial Counts for Sediment Samples

For the sediment samples, matt growth was obtained on the ZMA plates for all the three sites indicating heavy load of marine microorganisms. On MacConkey's agar site-2 had highest number of counts followed by site-3 and site-1. Site-2 had highest number of counts on cetrimide agar followed by site-3 and site-2. Very low count was obtained EMB agar for all three sediment samples with site-2 and site-3 having slightly higher value than site-1. Site-1 had highest number of counts on TCBS agar followed by site-3 and no growth on site-2. On mannitol salt agar site-3 had highest number of counts followed by site-1 while for site-2, the counts were too numerous to count.

The total heterotrophic bacterial load (THB) load recorded on ZMA for water samples from site-1, site-2 and site-3 was 6.7 x 10^2, 8.7 x 10^2 and 7.3 x 10^2 respectively. While for all the three sediment samples matt growth was obtained. Similarly, the THB value reported by Mayavu,(2011) range from 40 x 10^5 cfu/ml to 73 x 10^5 cfu/ml for mangrove water samples and from 43 x 10^6 cfu/g to 77 x 10^6 cfu/g. Our findings in this study are in accordance with Ravikumar (1995), who stated that the microbial load in the mangrove sediment is greater than the mangrove water.

Table 3.5. Viable Counts obtained on Various Media for the sediment sample obtained from various mangrove sites.

Sr. No.	Media	CFU/ml		
		Site-1	**Site-2**	**Site-3**
1.	ZMA	TNTC	TNTC	TNTC
2.	MCA	2.1×10^2	6.8×10^2	4.2×10^2
3.	CA	8.6×10^2	11.4×10^2	9.6×10^2
4.	EMB	0.2×10^2	0.5×10^3	0.5×10^2
5.	TCBS	5.9×10^2	0	1.9×10^2
6.	MSA	19.2×10^2	TNTC	20.6×10^2
7.	SSA	0.2×10^2	0	0.3×10^2

CFU/mL Colony forming Unit per mililiter; TNTC Too Numerous To Count; ZMA Zobell marine agar; MCA MacConkey agar, CA Cetrimide agar; SSA Salmonella Shigella Agar; TCBS Thiosulfate–citrate–bile salts–sucrose agar; EMB Eosin Methylene Blue Agar; MSA Mannitol Salt Agar

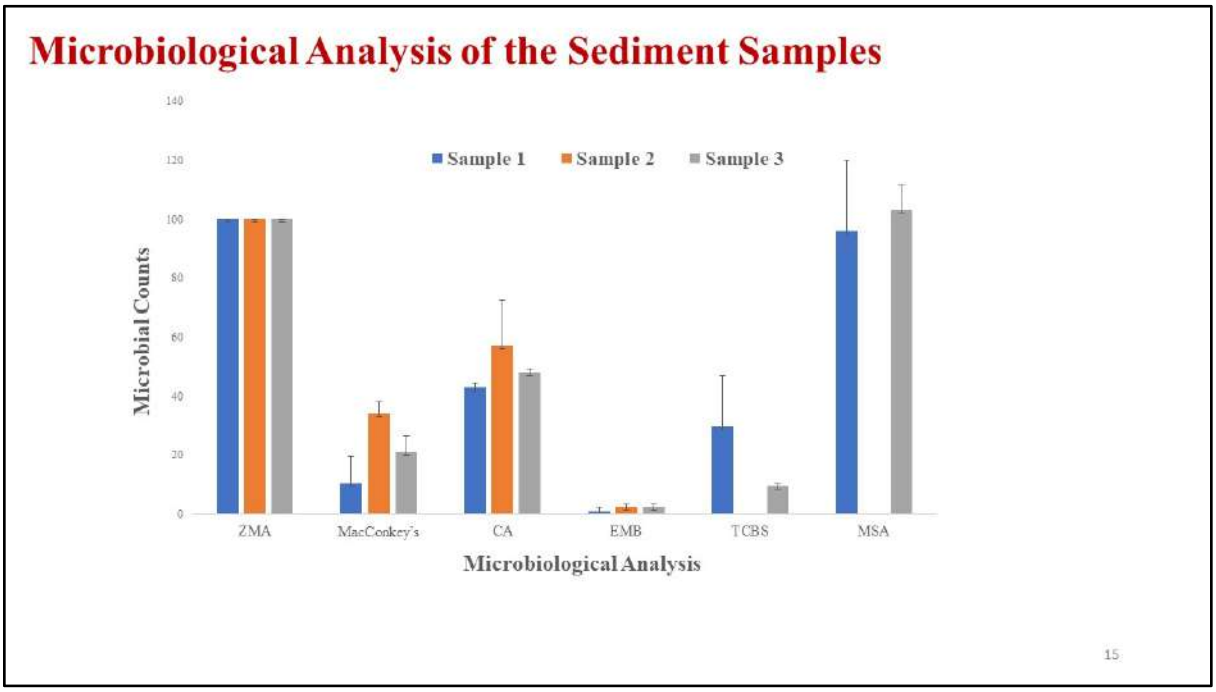

Fig. 3.9: Graph represents the trend in viable number of organisms obtained on different organism specific media for sediment Samples

Mac Conkey's agar was used for enumeration of total coliforms. Sediment samples from site-2 had highest count of 6.8×10^2 cfu/g$^-$ followed by water sample from the same site (6.3×10^2 cfu/ml). Hence it is clearly seen that site-2 which was eutrophic has highest load of coliforms. The presence of coliforms is evident of fecal contamination due to fecal and sewage pollution associated with human activities around the region.

E. coli is one of most important coliforms and its presence is indicative of recent fecal contamination. Hence, EMB agar, selective for *E. coli* was used for enumeration. However, typical colonies with green metallic sheen were not obtained indicating absence of *E. coli.* This observation is in accordance with studies suggesting that *E. coli* are less resilient and decay at a faster rate in saline waters as compared to *Enterococci* (Ghaderpour et al., 2014). *Enterococcus* is a potential pathogenic bacterial genus known to cause serious infections in humans such as urinary tract infections and wound infections, bacteremia and nosocomial infections, with high mortality rate (Reid et al., 2001). Similarly, *E. coli* is a well-known human pathogen and some of its infections include enteric/diarrhoeal disease, urinary tract infections (UTIs) and sepsis/meningitis (Kaper et al., 2004).

Cetrimide agar (CA) was used for the enumeration of *Pseudomonas aeruginosa* having luxuriant yellow colour (Manivasagan et al., 2009). Fairly high microbial counts were obtained on CA for sediment sample as compared to the water samples. Sediment sample from site-2 was seen having highest microbial load of 11.4 x 10^2 cfu/g. Various infections caused by this pathogen include nosocomial infections, urinary tract infections, bacterial keratitis (Streeter and Katouli, 2016).

Mannitol salt agar (MSA) was used inorder to enumerate *Staphylococcus aureus.* The counts obtained on MSA were clearly greater for the sediment samples as compared to the water samples, with site-2 having highest number of colony forming units. This may also be attributed to pollution caused due to discharge of domestic sewage (Grisi and Gorlach-Lira, 2010). Some of the life-threatening infections caused by *S. aureus* include bacteremia, endocarditis and metastatic infections with a tendency to spread to bones, joints, kidneys, and lungs (Lowy, 1998).

Salmonella-shigella agar (SSA) was used to enumerate salmonella and shigella. However, characteristic colonies typical of Salmonella shigella were not obtained.

Thiosulfate citrate bile salts sucrose agar (TCBS) was for the enumeration of *Vibrio cholerae* and *V. parahaemolyticus* showing yellow and green colonies respectively. Sediment sample at site-1 had highest load for *Vibrio* species, i.e. 5.9 x 10^2 cfu/g. V*ibrio sp*. are ubiquitous in brackish or limnic waters and require high salinities and nutrients to flourish. *V. parahaemolyticus* is well-known pathogen involved in seafood borne diseases and infections (Khandeparker et al., 2017). *Vibrio cholerae* is the causative agent of cholera (Baker-Austin et al., 2018).

As can be seen in the tables 3.4 and 3.5 the site-1 had fairly low counts on organism specific agar medium plates such MacConkey, cetrimide, EMB, MSA this may be due to the hypersalinity in the degraded patch of dried mangrove as seen in the chemical analysis report. Such high salt levels are inhibitory to the common mesophilic bacterial species owing to the low counts. However, high counts on TCBS in the case of site-1 samples shows how high salinities support the growth of *Vibrio* sp., which fail to occur abundantly in the site-2 and site-3, where the salinity levels are fairly low. Whereas, site-2 being close human settlements and having optimum conditions for mesophilic organisms has highest total coliform count and highest counts for *Pseudomona*s and *S. aureus.* Hence, we can say that the mangrove site-1 and site-2 are a hub for many pathogens as can be seen in our study.

4. Avian fauna associated with the Mangrove Wetlands

The birds that occupy wetlands and depend on it directly or indirectly for feeding, breeding, nesting or roosting are commonly called as water birds or wetland birds (Kumar and Gupta, 2013). Migratory waterfowls are a significant element of the biodiversity around the world (Li and Mundkur, 2004). These waterbirds, in addition to being the most important attractants of wetlands, they are also brilliant bio-indicators and effective models for investigating a variety of environmental issues. (Urfi et al., 2005). About 310 wetland bird species are found in India, half of which are migratory having their breeding grounds in China, Russia, central Asia, Tibet and from across the entire range of the Himalaya (Manohara et al., 2016). The South Asian wetlands are under grave pressure due to anthropogenic activities and can greatly alter the bird community structure (Datta, 2011).

Fig. 4.1: Birds roosting at the Mangrove vegetation along the Mandovi Estuary of Goa.

Waterfowls tend to select the appropriate wetland, depending on various characteristics like water chemistry, aquatic vegetation, invertebrate fauna and physical features (Heglund et al., 1994). Valuable insight on the ecological health and status of wetlands can be obtained by monitoring wetland birds and thus serve as a crucial tool for developing awareness regarding conservation of wetlands. By gaining the knowledge of the bird community of a region one can very well understand the importance of local landscapes for conservation of avifauna (Kattan and Franco, 2004).

Sometimes the migratory birds cover long distances that extend upto thousands of kilometers and hence the availability of habitats for feeding and roosting becomes very important. Various wetlands in India have been recognised as internationally significant under the Ramsar Convention as these wetlands act as a wintering ground for several trans-equatorial species of migratory birds (Prasad et al., 2002). However, the overwhelming pressure on Indian wetlands due to anthropogenic activities can be detrimental to the bird community structure (Manohara et al., 2016). The ecological and economic importance held by wetlands is significant. Although wetlands are reservoirs of productivity, they are ecologically fragile and liable to rapid degradation and decline due to the human induced disturbances (Gupta and Singh, 2003). The wetland habitat destruction due to direct and indirect human involvement has resulted in reduced number of water birds. Hence it is very important to study the causative factors resulting in the population decline and to control them inorder to prevent the loss of components essential to the biodiversity of the wetlands (Datta, 2011).

Birds use mangrove habitats for roosting, breeding and refuge, based on the foraging guild to which they belong. But they occupy other coastal habitats for the purpose of foraging (e.g. rainforest, tidal mudflat and marine-pelagic environments. There are not many mangrove-bird species that depend entirely on mangrove habitat in-order to survive, thus indicating the potential for extensive widespread connectivity with other habitats (Manohara et al., 2016). Their dependence on other habitats for foraging indicates that many mangrove birds are “link species” that perform ecological functions and services essential for the functioning of the ecosystem (Lundberg and Moberg, 2003). These avian ecological functions include: seed dispersal to suitable nursery habitats by frugivorous birds, and translocation pf nutrients from aquatic ecosystems to terrestrial ecosystems by piscivorous birds (Sekercioglu, 2006). The destruction and fragmentation of these mangrove habitats has resulted in the significant reduction of mangrove-dependent bird population (Alongi, 2009).

Various fish-eating birds such as wading birds (e.g.herons, egrets, cranes), seabirds and carnivorous forest birds (e.g. kingfishers, raptors) use coastal habitats for feeding. Mangrove forests offer these wading birds with unique foraging opportunities by supplying them with freshwater as well as marine foraging habitats. The freshwater mangrove swamps hold particular value as they retain their water continuously offering year around access to prey and drinking water (Ramo and Busto, 1993; Woodin, 1994). Mangroves provide high quality nursery habitat with access to food and shelter thus allowing the wading birds to use mangroves as a breeding habitat in addition to foraging (Ghasemi et al., 2012).

The Indian subcontinent is a part of the vast Oriental Bio-geographic regions and has abundant biodiversity. Out of the approximate 9,990 bird species recorded on the planet, India is a home to 1,313 bird species (Grimmett et al., 1999). Birds can provide us with a picture of overall habitat quality while acting as bioindicators of inhabited areas (Blair et al., 1999). The trends in population of avifauna can also provide us with the data as to how efficiently is the ecosystem functioning (Grimmett et al., 1999). The insight on the degree of pollution in aquatic as well as terrestrial ecosystems can be obtained through the bird numbers which act as very sensitive indicators. These birds are also essential for the functioning of the ecosystems as they undertake various roles as scavengers, pollinators, seed dispersal agents and predators of insect pest. However, anthropogenic activities and climate change has resulted in the significant reduction of the global bird diversity. According to the latest IUCN Red list assessment, in the year 2015, 1,375 bird species have gained the status of being globally "threatened with extinction", 84 of which are from India (Datta, 2016).

4.1. Avian fauna associated with the deteriorating mangrove Vegetation along the St. Cruz Merces Highway

According to the previous studies carried by us, including the avifaunal survey of the study site and other regions in its proximity it was revealed that three species of birds i.e. **Black Headed Ibis** (*Threskiornis melanocephalus*), **Lesser Adjutant Stork** *(Leptoptilos javanicus)* and **Alexandrine Parakeet (***Palaeornis eupatria***)** having the IUCN status of 'near threatened', 'vulnerable' and 'near threatened' respectively (The IUCN Red List of Threatened Species. Version 2022-23) are a part of this ecosystem. This makes it all the more important to protect the remaining mangroves near NH66 Merces-St Cruz highway and other habitats in its vicinity that serve as nesting and feeding sites for these avian species.

(a) Black Headed Ibis (*Threskiornis melanocephalus*) (IUCN Status: Near Threatened)

The Black-Headed Ibis (*Threskiornis melanocephalus*) is a 65- 75 cm long, medium sized bird belonging to the family Threskiornithidae (Hancock et al., 2010). It is a nomadic Ciconiiform waterbird, that mostly inhabits shallow habitats (Hancock et al., 2010; Ali and Ripley, 2007). It is commonly found in India, Pakistan, Sri Lanka, Nepal, China, Bangladesh, Myanmar, Thailand, Vietnam, Cambodia, while it is a rare visitor to Japan, Indonesia and Philippines (Hancock et al., 2010; Ali and Ripley, 2007; BirdLife International 2016). It forms colonies called "heronries or egretries", inorder to roost and nest and are usually seen in and around wetlands (Balakrishnan and Thomas, 2004).

A platform like structure of twigs and sticks, lined with grass and thread, is what forms the nest of black-headed ibis. It is constructed on the top of trees and shrubs, such as *Acacia, Prosopis,* and many species of *Ficus.* Although the nesting material is usually collected from trees, but reports on the use of threads and pieces of plastic bags are also available (Senma and Acharya, 2010). Since the availability of food is higher in seasonal wetlands than in perennial wetlands, black-headed ibis is usually seen feeding in seasonal wetlands (Sundar, 2006; Chaudhury and Koli, 2018). Black-headed ibis are known to have few nesting colonies in India. The state of Gujarat in the west and the state of Kerala in the south, has reported nesting (Chaudhury and Koli, 2018).

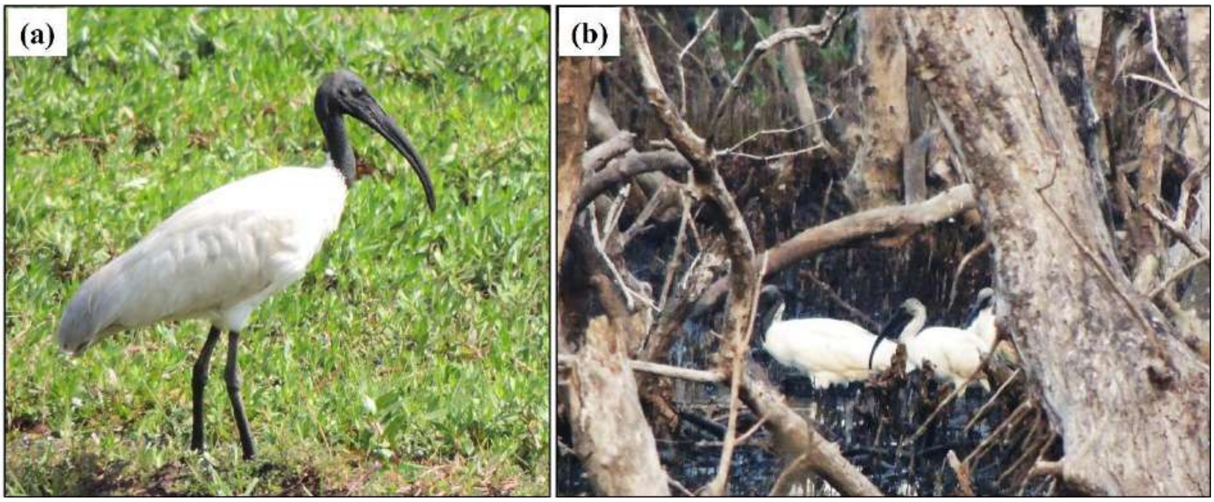

Fig. 4.2: (a) Black Headed Ibis in the fields besides the Mangrove vegetation and (b) Black Headed Ibis roosting in the destroyed Mangrove vegetation along the St.cruz-Merces highway.

IUCN (International Union for Conservation of Nature) has classified this species as **"Near Threatened"** while the Indian Wildlife Protection Act (1972) places it under the "Schedule IV" due to the rapid decline in its numbers seen during the last few decades (BirdLife International 2016). The major threats faced by the species includes hunting, trade, agricultural pollution, habitat destruction and degradation (Chaudhury and Koli, 2018). Other threats encountered by their habitat include discharge of chemicals from industries, deposition of solid waste, spray of pesticides in the agricultural land area, and agricultural land conversion which leads to their population decline (Choudhury, 2012).

Estimating the population of bird species aids in assessing the interaction between species, current status of the species, the extent of threats faced by the species, and the energy flow within the trophic levels. Identifying the declining population before it's too late can help in focusing on research management strategies for threatened species and their habitat before extinction sets in (Thomas and Martin, 1996; Holmes and Sherry, 2001). As reported earlier the decreasing population of black-headed ibis in India makes it even more important to undertake more species-specific research on these aquatic bird species (Chaudhury and Koli, 2018).

**(b) Lesser Adjutant Stork (*Leptoptilos javanicus*)
(IUCN Status: Vulnerable)**

Lesser Adjutant Stork (LAS) *(Leptoptilos javanicus)* is distributed in Nepal and India including most of the south and south-east Asia (Sharma, 2006). It is a vagrant species in south India with scattered occurrence (Taher, 1999, Singha et al., 2002, Sreeker et al., 2010). It occurs in the entire lowland Nepal (Poudyal et al., 2010).

Fig. 4.3: Lesser Adjutant Stork in the fields near the destroyed Mangrove vegetation along the St.Cruz-Merces highway.

This wetland-dependent bird is found mainly in the riverbeds, floodplains, rice (paddy) fields, swamps, lakes and forest pools (Pokhrel, 1998; Bhattarai, 2012), including in mangrove, mudflats, coastal swamps and marshes, flooded grassland and drying ponds where the fishes are abundant (Karki and Thapa, 2013). According to a study conducted by Karki and Thapa (2013) LAS colonies are more likely to be found in farmlands and swamps. And they prefer trees above 30 m height for their nests which are at an average height of 42.5 ± 6.8 m. Upon attaining an age of 3-5 years, LAS becomes mature for breeding (Karki and Thapa, 2013). The breeding season mostly lasts from July to October. Nesting sites are usually close to the human settlements (Baral and Inskipp, 2004). LAS prefers tall trees for nesting such as Karam (*Adina cordifolia*) and Simal (*Bombax ceiba*). The nests are seen located on the topmost parts of the canopy of these trees (Tamang, 2003).

The major threats to the LAS population decline are habitat destruction, over-hunting, and human disturbances. This has resulted in LAS being globally categorized as a **"Vulnerable"** species. However, there has been lack of scientific information which has led to lack of attention towards its conservation (Baral and Inskipp, 2004; Chaudhary, 2007). Few studies have been conducted on habitat characteristics, population size, and threats to LAS. Hence, there is a need for more such studies, adequate efforts and appropriate action for the conservation of these significant bird species. For successful conservation of LAS, protection of large *B. ceiba* trees, minimizing human disturbance including collection of prey species, and raising awareness to reduce human activities harmful to LAS is important.

(c) Little Cormorant (*Microcarbo niger*)
(IUCN Status: Least concerned)

Little cormorant (***Microcarbo niger)*** commonly inhabits the inland waters, brackish lagoons, tidal creeks and is widespread in the Indian subcontinent. They commonly built their nests on trees close to human settlements and water bodies. The major nesting trees of the colony includes *Albizzia procera, Mangifera indica, Ficus* spp*., Streblus asper* and *Cocos nucifera.* Rarely, the nesting trees may be distanced away from the water bodies (Zeenath and Zacharias, 2010). The nests are usually constructed at a distance of 13.5 m to 17.5 m height from the ground (Begum, 1997). The nesting material includes twigs, sticks, and sea-weeds. The nest represents cup shaped structure with a depression in the middle. The female as well as the male partner participates in the collection of the nesting material, arranging the material and construction of the nest. They use their breast, legs and bill to give a suitable shape to the nest (Naher et al., 2009).

Fig. 4.4: Little Cormorant (a & b) perching in the destroyed Mangrove vegetation along the St. Cruz-Merces highway.

The breeding season of little cormorant begins in the month of May and continues till October. However, changes in the monsoon season could result in minor variations in the breeding season. The peak nesting month for little cormorant is reported to be August in Bangladesh while in the Indian state of Kerala, February to July is reported as the peak nesting period (Naher et al., 2009). The little cormorant is a small sized bird, with 50 to 55 cm in length and weighing 360 to 520 grams. However, the male bird is slightly larger. It has a wingspan of 90 cm. Adults can be identified by a small erectile crest on the fore crown. The breeding cormorants have black or brown-black plumage and a long tail while the non-breeding ones have a white patch on the throat. Their feet are webbed and black. Little cormorants are known to make low roaring, grunting and groaning sounds (Birds of India, Bird world). Cormorants typically dive by propelling themselves with their feet and forage by taking series of dives from the surface of water combined with brief recovery periods at the surface (Cooper, 1986). Generally, the duration of dives is directly proportional to the surface pauses (Casaux, 2004). During the low tide little cormorants forage in shallow water and optimally feed on fishes shoaling close to the surface which justifies their preference for shallow water (Zeenath and Zacharias, 2010).

(d) Black-crowned night heron (*Nycticorax nycticorax*)
(IUCN Status: Least Concerned)

The **black-crowned night heron (*Nycticorax nycticorax*)** belongs to the Ardeidae family of herons. The black-crowned night heron is commonly found distributed around Asia, Indian Subcontinent, Africa, Europe and America (Birds of India, Bird world). This species is known to inhabit fresh, brackish or saline waters with aquatic vegetation and forested margins of shallow rivers, pools, lagoons, ponds, lakes, mangroves and marshes for roosting and nesting, with preference for islands and areas that are predator-free. It is mostly seen feeding on the pastures, aquaculture ponds, and rice-fields with upto 96% of a colony being dependent on rice-fields for food resources (Kushlan and Hancock, 2005; del Hayo et al., 1992). It has an opportunistic feeding behaviour as it feeds on fish, tadpoles, frogs turtles, lizards, snakes, adult and larval insects, crustaceans, molluscs, small rodents, bats, etc. (del Hayo et al., 1992).

Its nest is placed at a height of 2-50 m above water or land near water bodies in the form of platform that is constructed of sticks and vegetation in trees, bushes, reedbeds, or cliff ledges in protected sites (Kushlan and Hancock, 2005; del Hayo et al., 1992; Snow et al., 1998). The species might reuse the nesting sites in consecutive years or occupy new sites. Depending upon the distance from feeding areas, the colony sites may be dispersed throughout the landscape (Kushlan and Hancock, 2005).

The black-crowned night heron measures 55 to 65 cm in length while weighing 250 to 1100 grams for a medium sized bird. It has wingspan of 105 to 110 cm. The back and the crown are blackish or dark grey whereas, the underside of the body is whitish grey and wings light grey. Other striking characters include, red eyes, a dark bill and legs that are light yellow or orange. It also has a presence of two to three long plumes that extend from the back of the head (Birds of India, Bird world).

Fig. 4.5: Black-crowned night heron in the destroyed Mangrove vegetation along the St. Cruz-Merces highway.

(e) Great White Egret (*Ardea alba*)
(IUCN Status: Least Concerned)

Great White Egret (*Ardea alba*) is known to inhabit all kinds of inland and coastal wetlands. It commonly occupies river margins, lake shores, marshes, floodplains, damp meadows, rice-fields, aquaculture ponds, reservoirs, salt lakes, saltpans, mangroves and estuaries when in coastal locations (del Hoyo et al., 1992; Kushlan and Hancock, 2005). Post breeding dispersive movements are common among the populations of these species (del Hoyo et al., 1992). The Great Egret species generally breeds in colonies that can extend in numbers from tens, hundreds to even a thousand pairs, and sometimes other species can also be involved. While some populations might also tend to breed solitarily or in small groups. Although this species is a diurnal feeder in nature, it is most active at dawn and dusk and roosts at night in trees adjacent to lakes or rivers or in mangroves, often with other species. The species might tend to feed solitarily or in small groups of 12-50 individuals outside of the breeding season (del Hoyo et al., 1992; Kushlan and Hancock, 2005; Brown et al., 1982).

Its diet can vary based on the habitat it occupies. In aquatic habitats its diet involves fish, amphibians, snakes, aquatic insects and crustaceans, whereas in drier habitats terrestrial insects, lizards, small birds and mammals are more common (del Hoyo et al., 1992).

Fig. 4.6: Great White Egret feeding in the destroyed Mangrove vegetation along the St. Cruz-Merces highway.

The species usually nests colonially in single- or mixed-species groups where nests may be less than 1 m apart or touching, although they are usually placed more spread out in reedbeds. Breeding pairs may also reuse nests from previous years. Their nests are generally placed over water at a height of 1-15 m and are constructed using sticks and vegetation. These nests are placed in reedbeds, bamboos, bushes, trees, mangroves and other plants near water or on islands in sites that are protected from ground predators (Kushlan and Hancock, 2005).

(f) Grey heron (*Ardea cinerea*)
(IUCN Status: Least Concerned)

The grey heron also called as *Ardea cinerea*, belongs to the Ardeidae family of herons (Bhatnagar and Shekhawat, 2014). They are large heron species, grey in colour, having white crown, white and black markings on their black feathers (The Herons of India, Natureinfocus). It is an arboreal rooster and prefers areas with trees. Its habitat includes shallow water, which could either be fresh, brackish or saline, flowing or standing (Kushlan and Hancock 2005).

Fig. 4.7: Grey heron in the destroyed Mangrove vegetation along the St. Cruz-Merces highway.

The species is found inland occupying broad rivers, narrow streams, lake shores, fish-ponds, marshes, flood-plains, reeds swamps, rice-fields and other irrigated areas, inland deltas, etc. While on the coast the species is known to frequently occur in deltas, salt-marshes, mangroves, estuaries, tidal mudflats, muddy and sandy shores, and sand-spits (IUCN 2023, IUCN Red List of Threatened Species). It is a regional bird in India and other areas such as Nepal, Pakistan, Ceylon, Maldives and Andaman and Nicobar Islands (Ali and Ripley, 2007). The breeding season of this species varies across the Indian subcontinent. From March to June is the breeding period of grey heron in Kashmir, in northern India it breeds from July to October while in Southern India the breeding season extends from November to March. In India this species is known to have two well known breeding sites, that is Keoladeo Ghana National Park, Bharatpur in Rajasthan and Vadanthangal Bird Sanctuary in Tamil Nadu (Bhatnagar and Shekhawat, 2014).

The nest of a grey heron is like a platform made up of small sticks and dried twigs and is often reused over consecutive years. The nest can be positioned high up on a tall tree (50 m) or on the ground, cliff edges, in reedbeds or in bushes. The nesting sites are usually located at a convenient flying distance from the feeding areas (Kushlan and Hancock, 2005; Bhatnagar and Shekhawat, 2014). The Grey Heron is usually a solitary bird, however sometimes it occurs in small groups and is gregarious when nesting (Trivedi and Parasharya, 2019). Its diet primarily includes fish and eels, amphibians, crabs, molluscs, crustaceans, aquatic insects, snakes, small rodents, small birds as well as plant matter. It may feed at any time, day or night. However, it is most active at dawn or dusk (Brownn et al., 1982; Kushlan and Hancock, 2005).

(g) Purple heron (Ardea purpurea)
(IUCN Status: Least Concerned)

Purple heron is characterised by a riot of chestnut, grey and brown colours. This species of heron has a narrow body and an elongated neck and head. (The Herons of India, Natureinfocus).

The species is known to inhabit wetlands, and prefer dense, flooded, freshwater reedbeds in temperate areas. Other habitats occupied by them include river margins, ditches, canals, brackish water lagoons, rice-fields, mangroves and coastal mudflats which are known to occur throughout India (del Hoyo et al., 1992, Kushlan and Hancock, 2005; The Herons of India, Natureinfocus). The breeding season of purple heron species extends from April to June in the western Palearctic, during the rains in Africa, while from June to October in north India and November to March in the south India (del Hoyo et al., 1992). The autumn migration within migratory population takes place from August to October with return passage in the spring in March. The migratory group size is small with the highest recorded size being 300-400 individuals. The species feeds solitarily, however roosting is communal, usually undertaken in groups of 100 individuals. (Brown et al., 1982; Hancock and Kushlan, 1984, del Hoyo et al., 1992).

Fig. 4.8: Purple heron in the shrubs surrounding the destroyed Mangrove vegetation along the St. Cruz-Merces highway.

They are usually known to forage in deep waters, by keeping their bills close to the water surface inorder to strike the prey. They feed on small and medium sized fish, frogs, reptiles, insects, crustaceans, molluscs, small birds, mammals, snakes, etc. (BirdLife International, 2023; The Herons of India, Natureinfocus).

The nest consists of a platform like structure of reeds and sticks positioned over a water body at a 3 m height, while in the mangroves, at a height of 3- 4 m. (del Hoyo et al., 1992; Kushlan and Hancock, 2005). Nesting is usually in loose, single or mixed species colonies having large groups extending to 1,000 pairs (Hancock and Kushlan 1984, del Hoyo et al. 1992, Kushlan and Hancock 2005).

(h) Indian pond heron (*Ardeola grayii*)
(IUCN Status: Least Concerned)

Ardeala grayii also known as paddy bird is a long-legged wetland bird species that has a long bill and belongs to Ardiedae family (Dwivedi and Elangovan, 2020; Roshnath, 2015). When in rest, it is earthy brown in colour but during flight glistening white tail and rump is prominently visible. However, maroon hair like plumes on the back and long occipital crest becomes visible during the breeding season (Ali, 2003). This waterbird either feeds alone or by forming small groups and is known to occupy all kinds of wetlands. It usually feeds on insects, amphibians, annelids, crustaceans and plant waste. However, during its breeding season feeding on fishes is preferred (Dwivedi and Elangovan, 2020).

During the Heronry survey of 2013 at Kunnur, it was observed that most of the heronry sites occurred in regions with high disturbances as the paddybird tends to show minimal response to the human disturbances (Roshnath et al., 2013; Vos et al., 1985).

Fig. 4.9: Indian pond heron feeding in the destroyed Mangrove vegetation along the St. Cruz-Merces highway.

(i) Little egret (*Egretta garzetta*)
(IUCN Status: Least Concerned)

Little egret is a slim, graceful white bird that mostly occupies the marshes. It is small and more gregarious than the large and median Egret. Little egret has a black bill with grayish lores, and black legs with yellow feet that differentiate it from the cattle egret (Indian Biodiversity Portal). During the breeding period, a white crest of two narrow plumes, and delicate plumes on back and breast can be seen. It is mostly seen moving in scattered flocks and is known to occupy marshland, paddy fields, reservoirs and other inland waters while feeding on insects, fish, frogs and small reptiles (del Hoyo et al., 1992). A twig platform lined with straws forms its nest that is placed on the trees at a shallow height, near villages. Sometimes they may repair and use the same nests year after year. During flight its neck is pulled in like a heron while it uses steady wing beats (Indian Biodiversity Portal).

The breeding period of little egret usually occurs in July and August in North India while November to February in the South. It nests singly or in colonies of mixed species where the nests may be kept at distance of 1 to 4 m apart. It breeds in heronries that include paddy Birds, cormorants and other marsh birds. The eggs are usually 4 in number. They are moderately broad, oval shaped and pale bluish -green in colour (Kushlan and Hancock, 2005; Indian Biodiversity Portal).

Fig. 4.10: Little egret in the destroyed Mangrove vegetation along the St. Cruz-Merces highway.

They wade in search of food through shallow water or stalk about on the soft mud, grasslands and display a preference for shallow waters that are 10-15 cm deep where fish are concentrated at the water surface and roosts in the trees in the night. Their food mainly consists of insects, frogs, small reptiles and fish. (Kushlan and Hancock, 2005; Indian Biodiversity Portal; IUCN Red list of Threatened Species, 2022-2).

(j) Bhahmini kite (*Haliastur indus*) (IUCN Status: Least Concerned)

The brahminy kite can be easily identified due to is distinctly characteristic colour. It has a chestnut plumage, white head and breast with black wing tips. The juveniles are brown in colour but can be easily differentiated from the black kites by their paler appearance, shorter wings, and rounded tail and is similar in size to black kite (Rasmussen and Anderton, 2005). The kite is commonly seen in Sri Lanka, Nepal, India, Iran, Pakistan, Bangladesh, southeast Asia, Australia and are known to have seasonal movements associated with rainfall (Hill, 1966). The breeding season in South Asia extends from December to April. The nests are constructed using small branches and sticks and lined with leaves, and located in various trees, often mangroves. In some cases, they have also displayed nesting on the ground, under trees (Beruldsen and Chapman, 2003; Balachandran and Sakthivel, 1992). The species is scavenger by nature and mainly feeds on dead fish and crabs, in wetlands and marshes. However, they may also be seen hunting live prey such as hares and bats (Manakadan and Natarajan, 1992; Mikula et al., 2016).

Fig. 4.11: Bhahmini kite in the destroyed Mangrove vegetation along the St. Cruz-Merces highway.

(k) Striated heron (*Butorides striata*) (IUCN Status: Least Concerned)

Striated heron is also known as Little Heron, Green-backed Heron, Little Green Heron is small with a thick neck, relatively stocky dark back, thick short legs, and grey neck. An adult striated heron is characterised by a glossy green black crown with a short erectile crest. Its eyes are distinctive, with lores that are dull yellow green above and black on the lower portion while the irises are orange yellow. It has a dark bill, with upper brown black and lower dusky green. The sides of the head, neck and breast are light grey to buff in colour, while the legs appear olive grey in front and yellow green at the back. Juvenile striated heron is much smaller and slender than juvenile Black-crowned Night-Heron. It has long streaks on the chest and spots present only on the wings. Typically, the species is solitary and is found standing quietly around the wetland habitats such as marshes, agricultural fields, rivers, and lakes (Kushlan,1983; Heron Conservation, striated heron).

Fig. 4.12: Striated heron in the destroyed Mangrove vegetation along the St. Cruz-Merces highway

The species prefers forested habitats in close proximity to water bodies such as mangrove-lined shores and estuaries, dense woody vegetation fringing ponds, rivers, lakes and streams. Other habitats include river swamps, canals, artificial ponds, salt-flats, mudflats, tidal zones, pastures, rice-fields (del Hoyo et al., 1992, Kushlan and Hancock, 2005). Its nest is small and is constructed using twigs. It is kept well hidden in the branches of the trees such as *Rhizophora* and *Avicennia* species of mangroves (del Hoyo et al., 1992; Kushlan and Hancock, 2005). Its diet typically includes fish, amphibians like frogs, insects like grasshoppers, dragonflies, spiders, crustaceans like crabs and prawns, reptiles, molluscs, etc. (del Hoyo et al., 1992, Kushlan and Hancock, 2005)..

(I) White-throated kingfisher (*Halcyon smyrnensis*)
(IUCN Status: Least Concerned)

White-breasted Kingfisher Halcyon smyrnensis (Linnaeus, 1758) is a common species found all over India, Pakistan, Sri Lanka, Myanmar, Bangladesh, Egypt and Iraq generally occupying the plains and lower hills (Ali and Ripley, 1983). They are commonly found occupying the agricultural landscapes, swamps, marshes, near ponds, lakes, parklands, mangrove swamps, and gardens (Anderton and Rassmussen, 2005). Both sexes are alike, with juveniles duller than the adults. The adult displays a characteristic colour with a bright blue back, wings and tail. Its head, shoulders, flank sand lower belly are chestnut, and the throat and breast are white. The large bill and legs are bright red. During flight the white-breasted king-fisher is rapid and direct, with short rounded wings (Ali et al., 2010). The white-throated kingfisher prefers sandy riverbanks for the construction of their nests. However, they tend to lay eggs in ant hills, rock crevices, under projecting stones on the bank of channels, decaying trees, natural holes found inside wells, and under bridges (Naher and Sarker, 2016).

Fig. 4.13: White-throated kingfisher in the destroyed Mangrove vegetation along the St. Cruz-Merces highway.

(m)Common kingfisher (*Alcedo atthis*)
(IUCN Status: Least Concerned)

The common kingfisher, *Alcedo atthis* (Linnaeus 1758) belongs to the order Coraciiformes and Family Alcedinidae. It is a fish-eating species that prefers to breed along natural watercourses or smaller water bodies. It generally nests in holes in sandy or loamy embankments due to the soil particle composition of nesting banks and other factors like compactness, porosity, etc. It prefers rivers with the availability of fish, about 54-60 mm shallow waters and sandy or loamy banks for nesting while avoiding the sites with very less to too dense vegetation. Thus, habitat plays an important role in shaping the distribution and settlement of species (Heneberg, 2004; Turčoková et al., 2016).

Kingfishers live solitarily outside the breeding season. However, during the breeding season, part of the population is socially monogamous, but polygamic/polyandric pairs have also been observed (Turčoková et al., 2016).

Fig. 4.14: Common kingfisher in the destroyed Mangrove vegetation along the St. Cruz-Merces highway.

(n) House crow (*Corvus splendens*)
(IUCN Status: Least Concerned)

The house crow (*Corvus splendens*), is native of the Indian subcontinent. However, it has spread globally with rapid habitat expansion ranging from across Europe, the Middle East, Eastern Africa, the Indian Ocean Islands, East Asia and Australia and the Americas. The sexes are phenotypically similar and are often mis-identified. The males have a characteristic smoky-grey collar and are slightly larger in size (Ryall, 2016). It is an adaptable, gregarious, noisy, commensal bird, which only lives in close association with humans in urban/semi-urban areas (Lim et al., 2003; Nyari et al., 2006) They are also known to be associated with coastal human inhabited area and although, foraging independently and in small groups during the day, they roost in groups at night (Behrouzi-Rad, 2013).

The Indian house crow was frequently sighted in and around the destructed mangrove vegetation near Merces- St. Cruz highway. Usually, they were seen in groups perching in the dried mangrove vegetation. However, individual species were also seen wandering around and collecting dried twigs which were probably meant for the construction of nests. At dusk, following the sunset, large groups of crows were seen roosting in the dried mangrove vegetation.

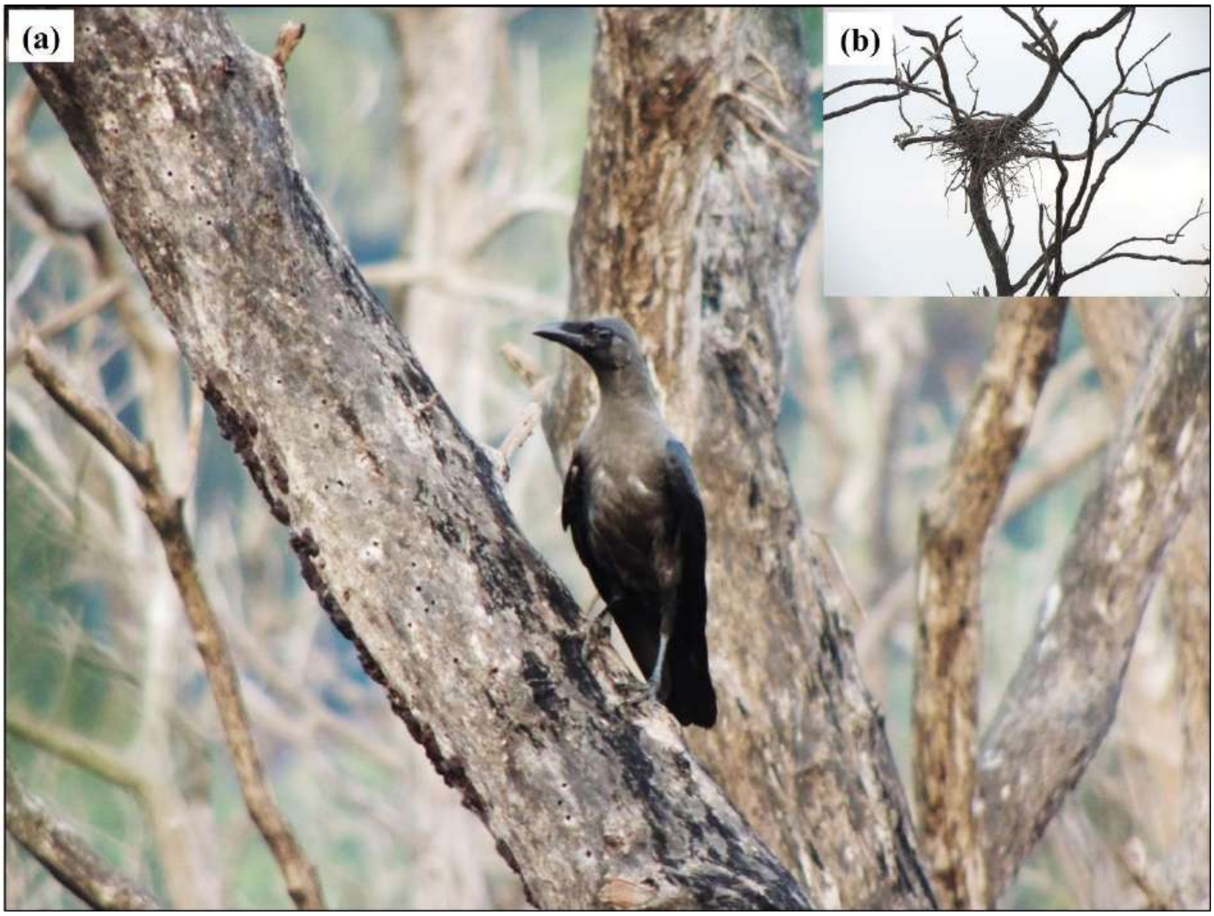

Fig. 4.15: (a) House crow and (b) nest of the house crow (inset) in the destroyed Mangrove vegetation along the St. Cruz-Merces highway.

(o) Alexandrine Parakeet (*Palaeornis eupatria*)
(IUCN Status: Near Threatened)

Alexandrine Parakeet (*Palaeornis eupatria)*, formerly known as *Psittacula eupatria* has most recently been assessed and listed as **Near Threatened** Species for *The IUCN Red List of Threatened Species* in 2016 (IUCN Red List, 2016).

Alexandrine Parakeet is commonly found in South and South-East Asia, ranging from Pakistan, India (including the Andaman Islands and Narcondam Island), Sri Lanka, Nepal, Bhutan and Bangladesh (including Cocos Island), southern and central Myanmar, central Thailand, southern and western Laos, much of Cambodia and southern Vietnam. It has also been observed to show seasonal movements as well as nomadism in the regions where it occurs (Juniper and Parr, 1998). The populations in the north and north-east of Cambodia are said to remain healthy and widespread across near-continuous habitat. However, in other parts of Cambodia its population is destroyed (Goes and Furey, 2013). It has been found to be localised in Laos (Thewlis et al.,1998), while in Thailand its population has almost entirely disappeared, and only remaining are small populations close to human settlements that perhaps have originated from escaped cage-birds (Round, 1990). In India the species is common in Jharkhand, and appears to be increasing in Gujarat (Parekh and Gadhvi, 2013). In north Bengal two small breeding populations were known to occur, but recent searches have failed to find them (Thompson et al., 2014). Overall, the population is suspected to be progressing towards its decline.

The species commonly occupies moist and dry forests, woodlands, cultivated lands, as well as mangroves and plantations. It generally feeds on various wild and cultivated seeds, flowers, flower buds, nectar, grains, fruits and vegetables. It nests in tree cavities, palms, and very rarely buildings. Its breeding season extends from November to April, depending on the location (Juniper and Parr, 1998). Alexandrine Parakeet is widely captured and traded as a cage-bird in many regions around the world which poses a main threat (Goes and Furey, 2013). Despite its near-disappearance in regions like Thailand, nestlings still appear in illegal trade (Round, 1990). Illegal trade, in addition to destruction of the nest sites threatens the species in Pakistan. Extensive poaching by the tribes has threatened its existence in regions like Gujarat. Habitat loss and degradation are also serious threats to the population of these species (IUCN Red List of threatened species, 2023).

In addition to being categorized as Near Threatened, it is also listed under CITES Appendix II for conservation. Looking at the global trends in the population destruction of these species it becomes even more important to protect these species. This can be carried out by conducting regular surveys to monitor the species population trend and status. Monitor the rates of habitat loss and degradation across the species range. Enforce restrictions on trade and raise awareness to discourage its capture and trade. Ensure legal protection in countries that lack it (IUCN Red List of threatened species, 2023).

4.2. Avian fauna associated with the fields and wetlands surrounding the deteriorating mangroves Vegetation along the St. Cruz Merces Highway

Fig. 4.16: Avian fauna documented during our field survey on 14th December 2022 at the field of St. Cruz surrounding the Mangrove vegetation. (A) Asian openbill stork (*Anastomus oscitans*) (B) Wood sandpiper (*Tringa glareola*) (C) Common redshank (*Tringa tetanus*) (D) Glossy ibis (P*legadis falcinellus*) (E) Cattle egret (*Bubulcus ibis*) (F) Common snipe (*Gallinago gallinago*)

Fig. 4.17: Avian fauna documented during our field survey on 14th January 2023 at the healthy mangrove vegetation of St. Cruz (A) Black-winged stilt (*Himantopus himantopus*) (B) Red-wattled lapwing (*Vanellus indicus*) (C) Common sandpiper (*Actitis hypoleuco*) (D) Great egret (*Adrea alba*)

Table 4.1: List of Avian fauna documented during our field survey on 29th November 2022 at the Mangrove vegetation of St. Cruz-Merces, Panaji, Goa.

Sr. no.	Common name	Scientific name	Number	IUCN
1	Great egret	***Ardea alba***	4	Least concern (LC)
2	Cattle egret	***Bubulcus ibis***	2	Least concern (LC)
3	House crow	***Corvus splendens***	9	Least concern (LC)
4	Little egret	***Egretta garzetta***	3	Least concern (LC)
5	Alexandrine parakeet	***Psittacula eupatria***	1	Near threatened (NT)
6	Indian golden oriole	***Oriolus kundoo***	1	Least concern (LC)
7	Wood sandpiper	***Tringa glareola***	2	Least concern (LC)
8	Black kite	***Milvus migrans***	3	Least concern (LC)
9	Little cormorant	***Microcarbo niger***	4	Least concern (LC)
10	Common sandpiper	***Actitis hypoleucos***	3	Least concern (LC)
11	White throated kingfisher	***Halcyon smyrnensis***	1	Least concern (LC)
12	Purple heron	***Ardea purpurea***	1	Least concern (LC)
13	Black-crowned night heron	***Nycticorax nycticorax***	1	Least concern (LC)
14	Stork billed kingfisher	***Pelargopsis capensis***	1	Least concern (LC)
15	Common kingfisher	***Alcedo atthis***	2	Least concern (LC)
16	Black headed ibis	***Threskiornis melanocephalus***	3	Near threatened (NT)
17	White-breasted waterhen	***Amaurornis phoenicurus***	3	Least concern (LC)
18	Asian koel	***Eudynamys scolopaceus***	1	Least concern (LC)
19	Collared kingfisher	***Todiramphus chloris***	1	Least concern (LC)
20	Ashy prinia	***Prinia socialis***	2	Least concern (LC)

Table 4.2: List of Avian fauna documented during our field survey on 14th December 2022 at the Mangrove vegetation of St. Cruz-Merces, Panaji, Goa.

Sr. no.	Common name	Scientific name	Number	IUCN
1	Little cormorant	*Microcarbo niger*	8	Least concern
2	Common sandpiper	*Actitis hypoleucos*	4	Least concern
3	Red wattled lapwing	*Vanellus indicus*	2	Least concern
4	Asian koel	*Eudynamys scolopaceus*	2	Least concern
5	Indian pond heron	*Ardeola grayii*	8	Least concern
6	Common kingfisher	*Alcedo atthis*	4	Least concern
7	White breasted kingfisher	*Halcyon smyrnensis*	8	Least concern
8	Rose ringed parakeet	*Psittacula krameri*	5	Least concern
9	Great egret	*Ardea alba*	4	Least concern
10	Feral piegeon	*Columba livia domestica*	3	Least concern
11	**Black headed ibis**	***Threskiornis melanocephalus***	**4**	**Near threatened**
12	Common swift	*Apus apus*	3	Least concern
13	Black kite	*Milvus migrans*	7	Least concern
14	Brahminy kite	*Haliastur indus*	2	Least concern
15	Jungle myna	*Acridotheres fuscus*	6	Least concern
16	Little egret	*Egretta garzetta*	3	Least concern
17	Asian green bee eater	*Merops orientalis*	3	Least concern
18	Wood sandpiper	*Tringa glareola*	2	Least concern
19	White-cheeked barbet	*Psilopogon viridis*	1	Least concern
20	Barn swallow	*Hirundo rustica*	2	Least concern
21	Blue tailed bee eater	*Merops philippinus*	1	Least concern
22	Indian crow	*Corvus splendens*	16	Least concern
23	Red-whiskered bulbul	*Pycnonotus jocosus*	1	Least concern
24	Warbler		2	Least concern
25	Rosy starling	*Pastor roseus*	5	Least concern
26	white-breasted waterhen	*Amaurornis phoenicurus*	4	Least concern
27	Glossy ibis	*Plegadis falcinellus*	5	Least concern
28	Purple swamp hen	*Porphyrio porphyrio*	5	Least concern
29	Shikra	*Accipiter badius*		Least concern
30	Cattle egret	*Bubulcus ibis*		Least concern

Table 4.3: List of Avian fauna documented during our field survey on 14th December 2022 at the field of St. Cruz surrounding the Mangrove vegetation.

Sr. no.	Common name	Scientific name	Number	IUCN
1	Little cormorant	*Microcarbo niger*	1	Least concern
2	Common Sandpiper	*Actitis hypoleucos*	2	Least concern
3	Red wattled lapwing	*Vanellus indicus*	2	Least concern
4	Asian koel	*Eudynamys scolopaceus*	1	Least concern
5	Indian pond heron	*Ardeola grayii*	2	Least concern
7	White breasted kingfisher	*Halcyon smyrnensis*	1	Least concern
8	Rose ringed parakeet	*Psittacula krameri*	2	Least concern
9	Great egret	*Ardea alba*	1	Least concern
10	Feral piegeon	*Columba livia domestica*	5	Least concern
11	Black Kite	*Milvus migrans*	2	Least concern
12	white-breasted waterhen	*Amaurornis phoenicurus*	1	Least concern
13	Glossy ibis	*Plegadis falcinellus*	5	Least concern
14	Purple swamp hen	*Porphyrio porphyrio*	5	Least concern
15	Shikra	*Accipiter badius*	1	Least concern
16	**Lesser adjutant**	***Leptoptilos javanicus***	**1**	**Vulnerable**
17	Cattle egret	*Bubulcus ibis*	3	Least concern

5. Floral diversity associated with mangroves

During the survey of the mangrove vegetation at NH66 St. Cruz-Merces highway, various plants and shrubs were seen to grow in the vicinity of the mangrove vegetation. Some of these shrubs associated with the mangrove vegetation in the study site has been documented (**Fig. 5.1- 5.6)**

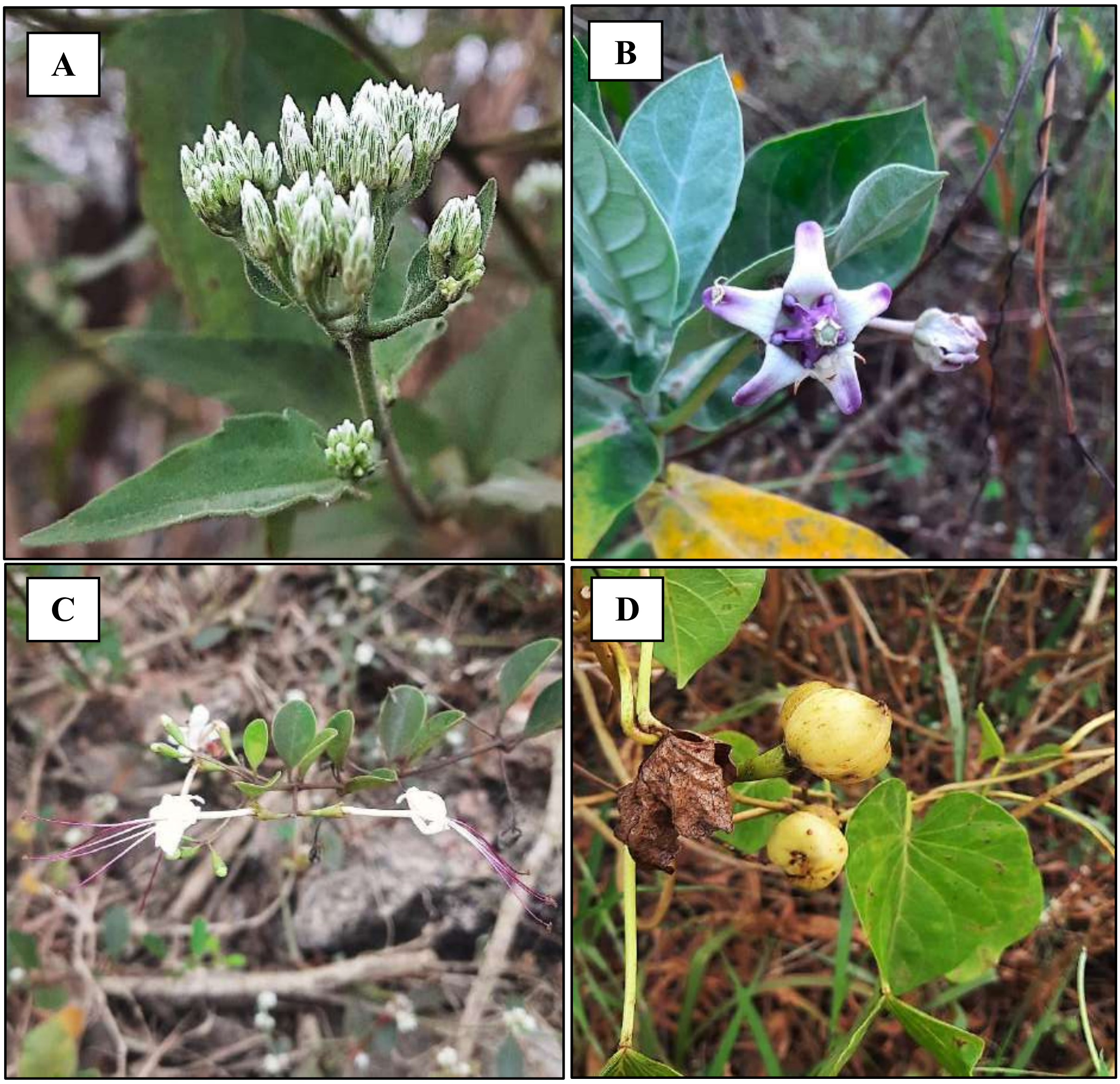

Fig. 5.1: A) ***Chromolaena odorata*** **B)** ***Calotropis gigantea*** **C)** ***Volkameria inermis*** **D)** ***Ipomea violacea***

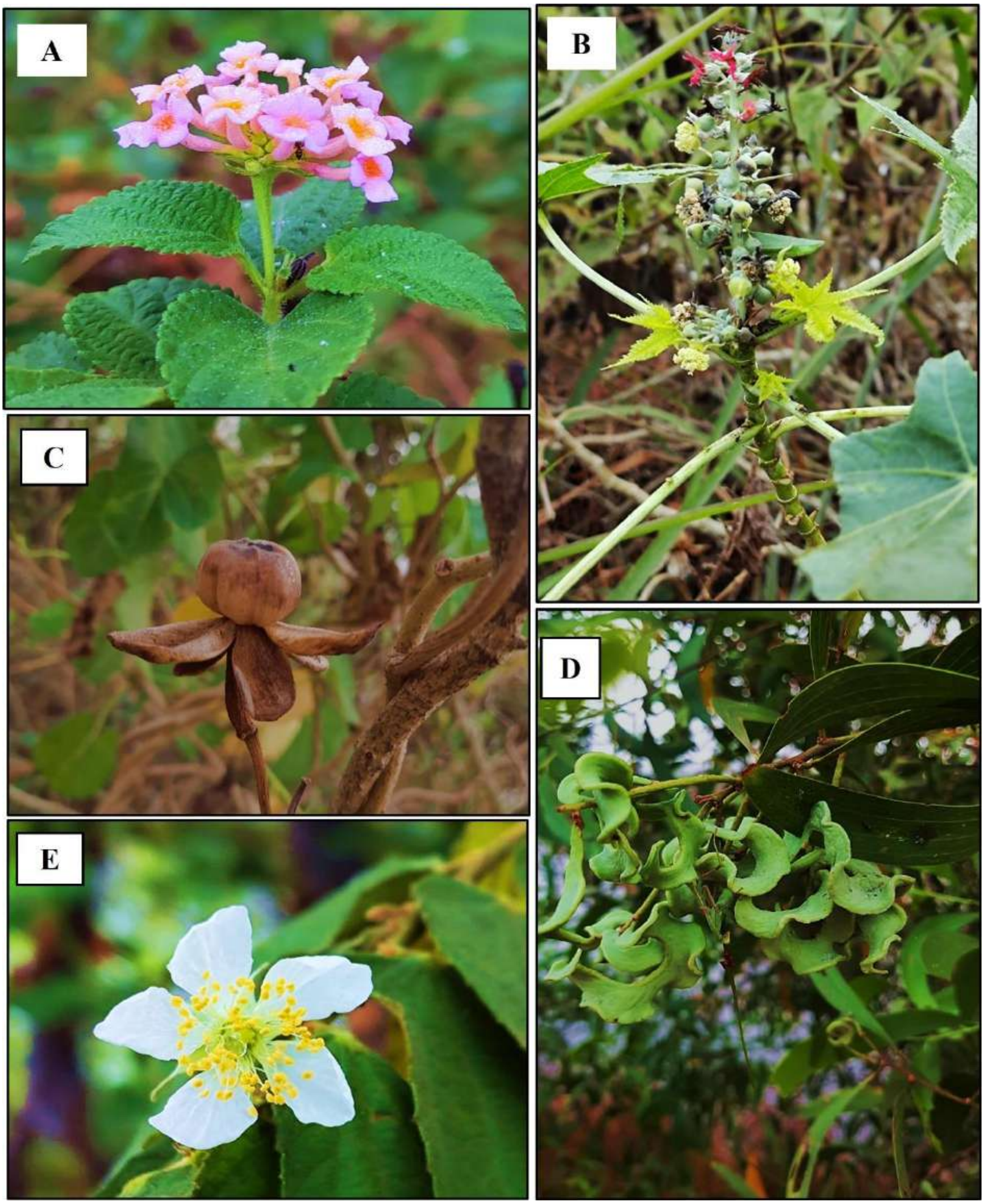

Fig. 5.2: A) ***Lantana camara*** **B)** ***Ricinus communis*** **C)** ***Ipomea violacea*** **D)** ***Acacia auriculiformis*** **E)** ***Muntingia calabura***

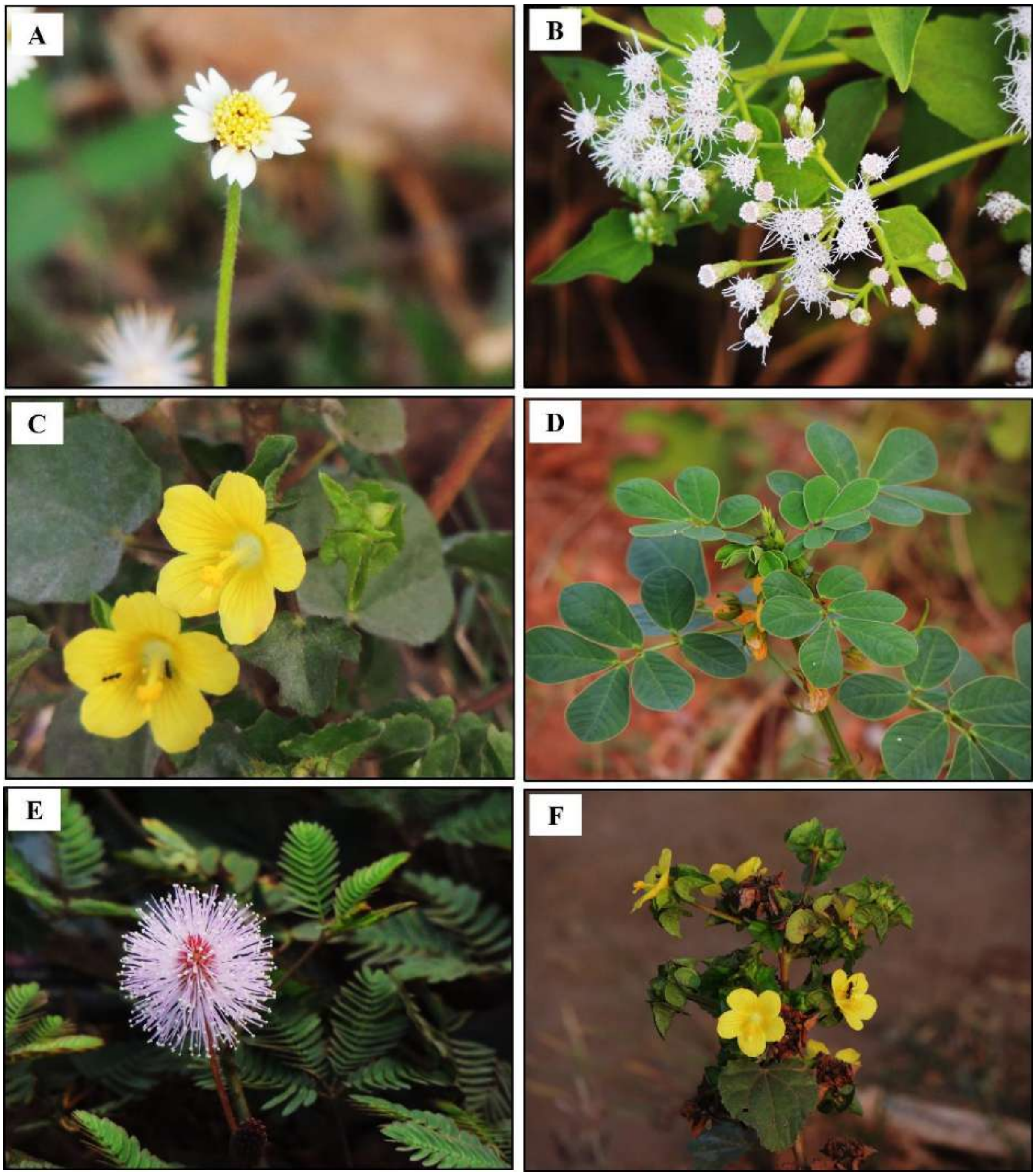

Fig. 5.3: A) ***Tridax procumbens*** **B)** ***Chromolaeana odorata*** **C)** ***Malachra capitata*** **D)** ***Senna obtusifolia*** **E)** ***Mimosa pudica*** **F)** ***Malachra capitata***

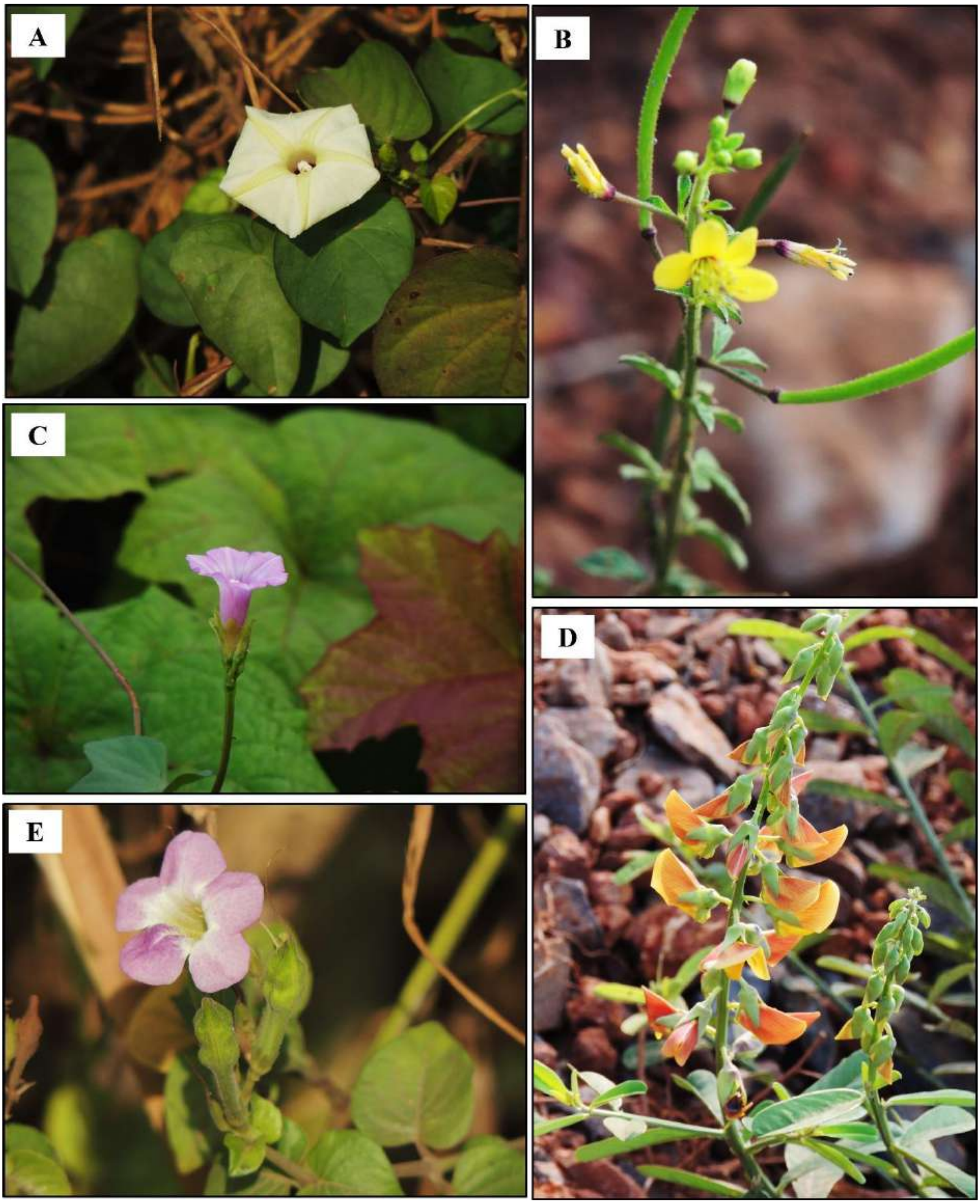

Fig. 5.4: A) ***Ipomea obscura*** **B)** ***Cleome viscosa*** **C)** ***Ipomea triloba*** **D)** ***Crotalaria retusa*** **E)** ***Asystasia gangetica***

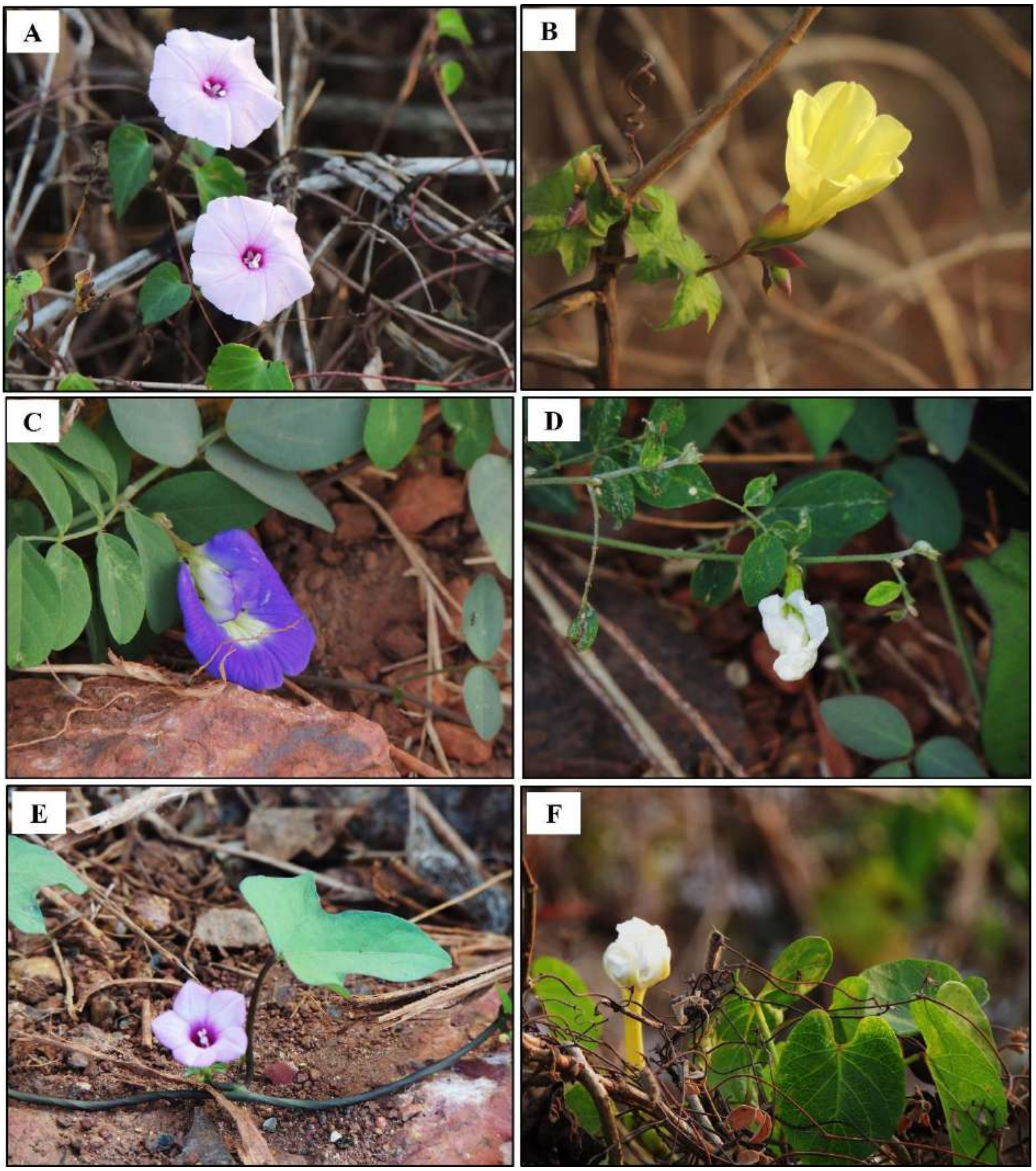

Fig. 5.5: A) *Ipomea turbinata* B) *Oenothera odorata* C) *Clitoria ternatea* D) *Clitoria ternatea* (white) E) *Ipomea triloba* F) *Ipomea violacea*

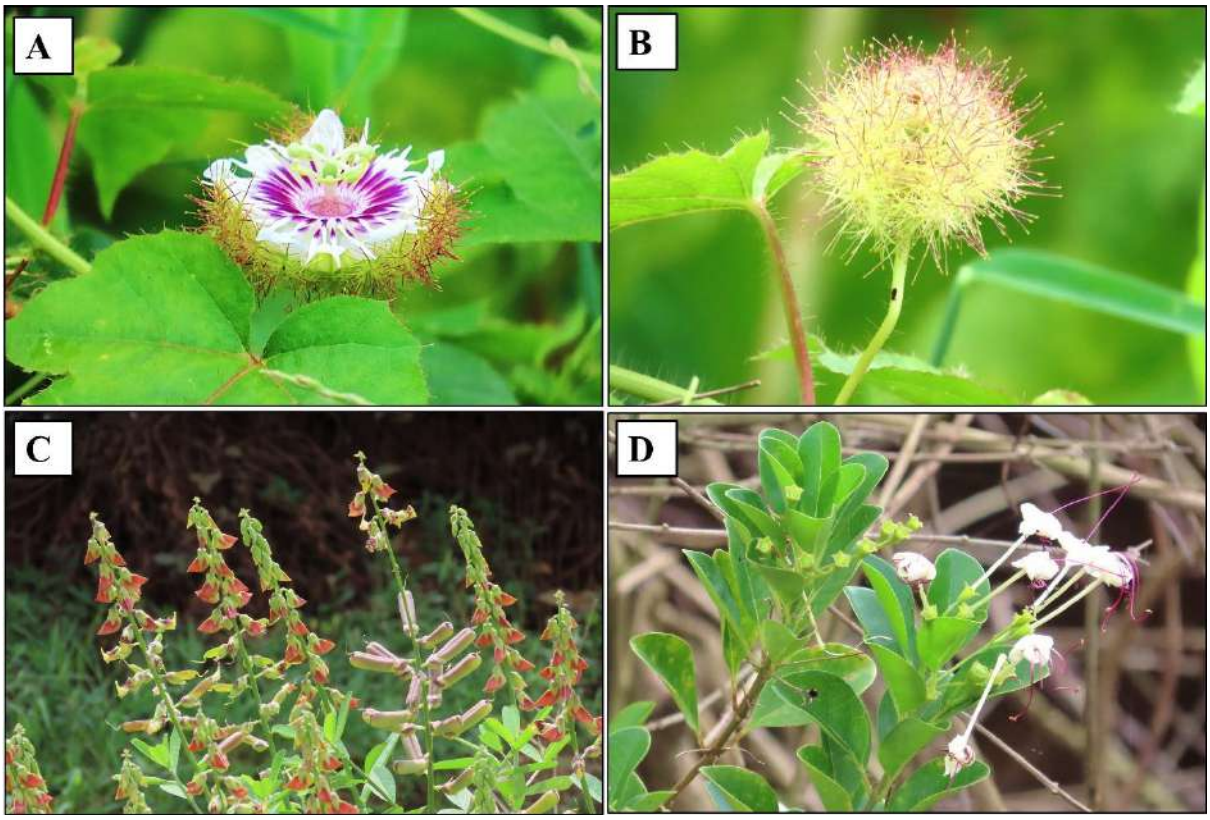

Fig. 5.6: A) *Passiflora foetida* B) *Passiflora foetida* (bud) C) *Crotal retusa* D) *Volkameria inermis*

Conclusion

- India has a long coastline and contributes significantly to the global mangrove cover. Goa being a coastal state is a home to dense mangrove forests mostly located on the banks of the river Mandovi and Zuari. In the recent years the mangrove vegetation in the state of Goa has witnessed immense loss due to the anthropogenic activities prevailing in the state. One such site is the stretch of mangrove vegetation along the NH 66 Highway at Merces, St. Cruz. This stretch of mangroves is highly deteriorated with very few healthy mangrove plants visible.
- Many articles in the local newspapers highlighted the construction of NH66 highway being the reason for the massive death of the mangrove vegetation in the study site (St. Cruz-Merces) without scientific evidence. However, our keen investigation on the area proved that the Government of Goa and the National Highways Authority of India (NHAI) has taken all the precautionary measurements for the survival of the mangrove vegetation across both sides of the highway by inserting six big pipes across the highway to facilitate exchange of saline water during tidal flux which is one of the prerequisites for the mangrove survival.
- If construction of the highway had to be the reason for the massive killing of the mangroves, then this should have been observed throughout the highway and not just at one patch of the St. Cruz-Merces region. Using Google Earth Satellite images, it was evident that, landfilling and concretization activities on the opposite side (influx point of the Mandovi estuary) had an adverse impact on mangrove ecosystem, leading to complete loss of the mangrove vegetation. The landfilling and concretization resulted in blockage of the tidal water causing hinderance for the tidal influx and efflux. Poor water exchange resulted in semi-stagnant conditions which eventually resulted in hypersalinity conditions due to evaporation of this water under natural sunlight.

Hypersalinity and accumulation of loads of organic matter are conditions which are deadly for the growth and functioning of the mangrove ecosystem, which ultimately resulted in massive death of the mangroves along the NH66 highway at St. Cruz-Merces.

- The microbiological analysis of the mangrove sediment and water samples revealed the presence of pathogenic bacteria. While the chemical analysis made it more evident that there was chronic hypersalinization of the sediment and water due to improper tidal flux which resulted in constant accumulation of salts thereby proving detrimental to the mangrove vegetation.
- Upon conducting surveys of the avian fauna dependent on this mangrove vegetation, it was revealed that a lot of birds still use this degraded habitat for feeding and roosting purposes. Globally threatened species such as Black Headed Ibis (*Threskiornis melanocephalus*), Lesser Adjutant Stork *(Leptoptilos javanicus)* and Alexandrine Parakeet (*Palaeornis eupatria)* having the IUCN status of 'near threatened', 'vulnerable' and 'near threatened' respectively are found in this region which gives us another reason to rejuvenate these mangroves.
- This study hence holds great significance especially today, as we are losing our costal defence "the mangrove vegetation" at an alarming rate. It shows us how anthropogenic activities without any checks can cause serious environmental damage without realizing.

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Appendix

1. Sanction Order

Government of Goa
Office of the Dy. Conservator of Forests,
Research & Utilisation Division,
Aquem, Margao-Goa. 403 601
Phone/Fax: - 0832-2750099 E mail: *dcfru-forest.goa@nic.in*

No 2/5 RFS/ACCTS/CAMPA/RAC/2022-2023/ 1142

Date :- 06 08-2022
Bhadra 15 Saka-1944

ORDER

In exercise of the Financial Powers delegated by the governing body, Goa State CAMPA, Administrative & Financial sanction of this office is hereby conveyed to incur an expenditure of ₹ 4,98,000/- (Four Lakhs Ninety Eight Thousand Only) towards Research proposal on "The Biodiversity and Ecology of the Fragile Ecosystem of Goa: The Mangroves and The Saltpans".

The expenditure on account of this work is debitable under the following budget Head of Account: -

Net Present Value (NPV)

IV. Management of Biological Diversity and Biological Resources

5. Short term studied to collect baseline data on floral and faunal diversity of different protected areas through reputed scientific organisations for scientific and sustainable management of Biological Diversity and Biological Resources

Yasodha K., IFS
Dy.Conservator of Forests,
Research & Utilisation Division,
Margao- Goa.

To,
Prof. V. S. Nadkarni,
Registrar,
Goa University, Taleigao Plateau – Goa: With instruction to carry out the said expenditure as per the MoU signed dated 03rd August 2022.

Copy To: - 1) The Chief Conservator of Forests (Development), Panaji
2) Dy. Conservator of Forests (Monitoring & Evaluation) Panaji
3) Accounts Section of this division

"स्वच्छ भारत नितळ गोंय"
Towards Cleaner and Greener India
Goa Forest Department 24 X 7 Helpline No: (North Goa) 0832-2228772 (South Goa) 0832-2750246
Please visit: www.forest.goa.gov.in

2. MOU

MOU for undertaking project/study on The Biodiversity and Ecology of the Fragile Ecosystems of Goa: The Mangroves and the Saltpans.

This agreement is made at Margao on Third day of August in the year two thousand twenty two between Dy. Conservator of Forest, Research & Utilization Division, Margao hereinafter referred to as "the Authority" of one part and Dr. Bhakti B. Salgaonkar, Assistant Professor, Goa University, Taleigao Plateau-Goa, hereinafter referred to as the "Project Proponent" through the Registrar of Goa University, Taleigao Plateau-Goa the other part. This agreement shall come into force from 03-08-2022.

Whereas:

a. A proposal has been received from the project proponent to render financial assistance to support the project as per the approved APO of CAMPA for the year 2022-23.
b. The Authority has decided to carry out research on "The Biodiversity and Ecology of the Fragile Ecosystems of Goa: The Mangroves and the Saltpans" based on the decision of the Research Advisory Committee (RAC).
c. The project proponent has submitted the detailed proposal as under:-

Plan of Work

- Phase 1 (0-3 months): Collection of recent literature, appointment of staff (Research Scholar), procurement of equipment and chemicals. Initiating the survey on mangroves and saltpans.
- Phase 2 (3-6 months): Survey of the Mangrove vegetation and saltpans of Goa. Analysis of the water/brine and sediment samples for the presence of harmful chemicals such as herbicides, heavy metals, etc.
- Phase 3 (6-9 months): Survey of the flora and fauna during the seasonal variations would be studied and documented.
- Phase 4 (9-12 months): Study on the Microbial diversity of the saline regions and dying mangroves patches. Screening for the presence of human pathogens.

	Achievable targets			
Period of study	0-3 months	3-6 months	6-9 months	9-12 months
Phase 1				
Phase 2				
Phase 3				
Phase 4				

Objective of the Project/ Study

a. To study the effects of the rapid development and urbanization on the Mangrove vegetation and saltpans of Goa
b. Biotic Abiotic reasons for damage for mangrove in some parts of Goa.

Payment Terms and condition:-

The payment would be made by the Dy. Conservator of Forest, Research & Utilization Division on behalf of the Forest Department as per the payment schedule mentioned below.

Sr. No.	Phase No.	Item	Amount
1.	First Instalment	30% of the total project cost	After receiving timeline of research work approval and completion of the Agreement
2.	Second Instalment	40% of the total project cost	After submission of draft project report
3.	Final Instalment	30% of the total project cost	After submission of final project report

Roles, Duties and Responsibility:-

The Project Proponent:-

1. To study the effects of the rapid development and urbanization on the Mangrove vegetation and saltpans of Goa and Biotic Abiotic reasons for damage for mangrove in some parts of Goa.
2. To strictly adhere to the schedule and activities mentioned in the project proposal.
3. The outcome of the research study shall be the Joint Rights of both project proponent and the Forest Department, and the Forest Department's permission is essential for publishing any Research Papers, on the findings of the project.
4. All material purchased must be handed over to the authority after completion of the project before receipt of final payment.

The Authority:-

1. To provide all the necessary assistance as may be reasonably required by the project proponent for carrying out the project successfully.
2. If at any given point of time Forest Department is not satisfied with the progress of the study, the department will stop releasing the subsequent instalment and the amount which has already been released to the Project Proponent shall be refunded by the Project Proponent with prevailing rate of interest.

Settlement of Disputes

Any Dispute or difference, which shall arise between parties hereto, whether in relation to interpretation of this agreement or to any act or omission by either party to the dispute or as to any act which ought to be done by the parties in dispute or either of them or in relation to any other matter whatsoever touching upon this Agreement shall be referred to the Principal Chief Conservator of Forest, Goa, whose decision shall be final and binding to both parties.

IN WITNESS WHEREOF THE COMMON SEAL OF THE AUTHORITY HAS BEEN HEREUNTO AFFIXED AND THE COMMON SEAL OF THE PROJECT PROPONENT HAS BEEN HEREUNTO AFFIXED ON THE DAY AND WEEK FIRST HEREIN ABOVE WRITTEN.

The common seal of the Department, Government of Goa. has been hereunto affixed and signed by Deputy Conservator of Forests, Research & Utilization Division, Margao

3/8/22.

In presence of:

Forests Research & Utilization Division GOVT. OF GOA MARGAO GOA

____

____

The common seal of Name: Prof. V. S. Nadkarni

Designation: Registrar

Institution: Goa University, Taleigao Plateau-Goa has been hereunto affixed and signed by:

05/08/22

REGISTRAR
GOA UNIVERSITY
TALEIGAO GOA
403 206.

____

GOA UNIVERSITY GOA

03/08/2022

Dr. Bhakti B. Salgaonkar,
(Assistant Professor)

In presence of:

R. S. Gad

Dr. Lakshangy S. Chary

CERTIFICATE

1. Certified that amount claimed for the work of The Biodiversity and Ecology of the Fragile Ecosystems of Goa: The Mangroves and the Saltpans, is not claimed and paid previously.

2. Certified that the work will be carried out by Goa University, Taleigao Plateau-Goa./ draft report has been prepared based on study carried out as per the submitted and approved proposal/ final report has been prepared based on the comments of RAC on the draft report.

3. Certified that the Agreement has been signed between Goa University, Taleigao Plateau-Goa & DCF (R&U), Margao.

Accepted and passed for an amount of Rs 30% (1st Instalment) is **Rs. 1,49,400/- of total budget Rs. 4,98,000/-**

3. Advertisement for Project Fellow

C|120

गोंय विद्यापीठ
ताळगांव पठार,
गोंय - ४०३ २०६
फोन : +९१-८६६९६०९०४८
फॅक्स : +०९१-८३२-२४५११८४/२४५२८८९

GOA@60

Goa University
Taleigao Plateau, Goa-403 206
Tel : +91-8669609048
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E-mail : registrar@unigoa.ac.in
Website : www.unigoa.ac.in

(Accredited by NAAC with Grade 'A')

Ref.No.GU/D-RDRM/GFD/BBS/Micro-SBSB/66/2021-22/01/617 Date: 04/10/2022

PRESS NOTE

Applications are invited for the post of Research Fellow to work on the research project entitled ***"The Biodiversity and Ecology of the Fragile Ecosystems of Goa: The Mangroves and the Saltpans"*** funded by the Research & Utilisation Division, Goa Forest Department, Government of Goa.

Sponsoring Agency: Goa Forest Department, Government of Goa

Number of Positions: One

Principal Investigator: Dr. Bhakti Balkrishna Salgaonkar

Department/School/Centre: Microbiology Programme, School of Biological Sciences & Biotechnology (SBSB), Goa University

Essential Qualifications : First class M.Sc. degree in Microbiology / Marine Microbiology / Botany/ Zoology /Biological or Life Sciences.

Desirable Qualifications: Knowledge of Biodiversity studies of Mangroves and Saltpans

Fellowship Amount: Rs. 20,000/- per month (Consolidated)

Duration of Project :One Years

Application Deadline:WALK-IN interview on 14-10-2022

Interested and eligible candidates may appear for the WALK-IN interview on 14th October, 2022 (Friday) at 10:00am at the Microbiology Programme, School of Biological Sciences & Biotechnology (SBSB) Goa University. The candidates should write an application on plain paper addressed to Dr. Bhakti B. Salgaonkar (Principal Investigator), Microbiology Programme, SBSB, Goa University, Taleigao Plateau, Goa 403206. The candidates should submit, the self attested photocopies of the relevant certificates along with the application.The candidates should carry their original certificates for cross verification. No T.A./D.A. would be applicable to attend the Interview.The interview would be conducted following the SOP of COVID pandemic.

03/10/22

Prof. Vishnu S Nadkarni
Registrar, Goa University

Ref.No.GU/D-RDRM/GFD/BBS/Micro-SBSB/66/2021-22/01/617 Date: 04/10/2022

REGISTRAR
GOA UNIVERSITY
TALEIGAO GOA
403206

Copy forwarded to editors of Navhind Times, Gomantak Times, OHeraldo, Times of India, Tarun Bharat, Gomantak, Lokmat, Navaprabha, Dainik Herald, Goa Doot and Bhaangarbhuin with a request to publish the above press note as a news item for free of charges.

Copy forwarded to DIQA/IQAC, Goa University with request to upload on Goa University, website.

4. Appointment of the Project Fellow

गोंय विद्यापीठ
ताळगाव पठार 403206
गोंय, भारत

Goa University
Taleigao Plateau 403206
Goa, India

Tel: 8669609093
Fax: 0832-2451184/ 2452889/ 2456153

State Public University since 1985
Recognized by UGC u/s 12-B
(Accredited by NAAC with A Grade)

Email: rdrm@unigoa.ac.in
Website: www.unigoa.ac.in

No.GU/D-RDRM/GFD- Project/BBS/SBSB-Microbiology/2022/60 Date: 26.10.2022. 27

MEMORANDUM

Sub: Appointment to the post of Research Fellow in (Goa Forest Department) Sponsored Project entitled "The Biodiversity and Ecology of the Fragile Ecosystems of Goa: The Mangroves and the Saltpans".

Based on the recommendations of the selection committee, approval of the authorities is hereby conveyed to the Principal Investigator to appoint Ms. Gandisha Masso Pawar as Research Fellow on the above research project for one year as per the terms and conditions of the Project. The offer letter should clearly state that the appointment is purely temporary and is subject to termination with one months' notice. It should also state that the appointee shall have no claim to permanent employment with Goa University.

27/10/22
(Leo Macedo)
Dy. Registrar (Directorates)

To
Dr. Bhakti B. Salgaonkar,
Principal Investigator,
School of Biological Sciences & Biotechnology,
Goa University.

Copy to:

The Dean, SBSB, Goa University. 27/10/22

5. Release of the First Instalment

PRE-STAMP RECEIPTS

Received from the Dy. Conservator of Forests, Research & Utilisation Division, Aquem, Margao-Goa, a sum of **Rs. 1,49,400/-** (Rupees **One Lakh Forty Nine Thousand Four Hundred only**) towards payment of first instalment (**30%** of the total cost project) of the Research project title **The Biodiversity and Ecology of the Fragile Ecosystems of Goa: The Mangroves and the Saltpans** vide sanction order **No. 25RESACCTS/CAMPA/RAC/2022-2023/11142** dated **6th August 2022**. The cheque/amount may be issued/transferred in favour of **The Registrar, Goa University**.

07/09/22

The Registrar
Goa University

REGISTRAR
GOA UNIVERSITY
TALEIGAO GOA
403206.

GOA UNIVERSITY GOA

Stamp/Signature of
Name/Designation

Place :- Goa University, Taleigao Plateau.

Date :- 07/09/2022

6. Release of the Second Instalment

गोंयविद्यापीठ
ताळगांवपठार
गोंय - ४०३२०६
फोन: +९१-८६६९६०९०४८

(Accredited by NAAC)

Goa University
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Email : registrar@unigoa.ac.in
Website: www.unigoa.ac.in

Ref. No.:GU/D-RDRM/GFD/BBS/Micro-SBSB/66/2021-22/100 Date:-02/02/2023

PRE-STAMP RECEIPTS

Received from the Dy. Conservator of Forests, Research& Utilisation Division, Aquem, Margao-Goa, a sum of **Rs. 1,99,200/-** (Rupees **One Lakh Ninty Nine Thousand Two Hundred only**) towards payment of Second instalment (**40%** of the total cost project) of the Research project title **The Biodiversity and Ecology of the Fragile Ecosystems of Goa: The Mangroves and the Saltpans**vide sanction order **No. 2/5/RES/ACCTS/CAMPA/RAC/2022-2023/1142**dated**6th September2022**. The cheque/amount may be issued/transferred in favour of **The Registrar, Goa University**.

GOA UNIVERSITY GOA

Offg. Registrar
Goa University

Stamp/Signature of
Name/Designation

REGISTRAR
GOA UNIVERSITY
TALEIGAO GOA
403 206

Place :**Taleigao Plateau, Goa**

Date :**02-02-2023**