IMPACTS OF PROPOSED SEISMIC SURVEY OPERATIONS ON THE AVIFAUNA AND WILDLIFE OF RESERVE FOREST AREAS OF KG BASIN PROJECT OF OIL INDIA LTD.

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Final Report

Submitted to the PCCF & Chief Wildlife Warden Andhra Pradesh



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### 1. INTRODUCTION

Energy is one of the primary requisites for the development of any country and the energy security is one of the prime concerns among countries all over the world. In a developing country like India where the energy sector is struggling to cope with the ever increasing demand necessitate large scale investment in exploring new avenues of energy generation. The growth in the world population and economy are the key factors driving the demand for world's energy. Several of the nations across the globe are facing a crisis situation due to the shortage of energy sources and supply. This has resulted in intensive explorations for energy sources, both conventional and non-conventional. The fossil fuels continue to be a priority in this global quest for energy owing primarily to economic reasons.

#### **1.1 FOSSIL FUELS: GLOBAL SCENARIO**

Since industrialisation, fossil fuels, especially Coal dictated the centres of growth and trade. Over the past several decades, the energy rich crude oil-derived fuels have displaced coal as a transport fuel. According to the global energy consumption pattern during the year 2007, a lion's share of energy generation (86.4% of the total) was met by three fossil fuels; petroleum (36.0%), coal (27.4%) and natural gas (23.0%) (http://www.eia.gov). Further, it is predicted that for the next twenty years fossil fuels will continue to contribute around 64% of the global energy needs (Dudley, 2011). The global demand supply analysis of fossil fuels shows that the gap between demand and supply curves for fossil fuels has started diverging since post industrialisation. The uneven distribution of the energy resources can lead to destabilize relationships between nations (Subudhi, 1993).

According to the forecast by EIA (2003) the world energy demand will rise by 1.8%/ year during the period 2000-2030 (European Communities, 2003). On the other hand the various prediction models on global fossil fuel production shows a considerable decreasing trend in the world wide oil resources. It is estimated that there are sufficient oil reserves worldwide only to satisfy the projected demands for the next three decades. However, the decline in conventional oil reserves constitutes a preoccupying concern beyond 2030.





Figure 1 Demand Vs supply of crude oil forecast

(The blue line historical oil production, the purple line EIA's supply forecast. The red, light green, and dark green lines are production forecasts for Tony Eriksen, Matthew Simmons, and ASPS) [Courtesy: Gail Tverberg. Theoildrum.com]

### **1.2 FOSSIL FUELS: INDIAN SCENARIO**

Home to 17% of the world's human population, India ranks 6<sup>th</sup> in the world in energy consumption with a proposed high average GDP growth rate (8.4 % per annum during the last couple of years). Thus India has high energy consumption, more or less at par with that of developed and highly developing countries. The diverse economic sector of the country is highly dependent on the energy sector dominated by the fossil fuels imported from abroad. About 55% of the energy in the country is produced from coal and 34 % from oil. Currently 35% of the energy needs of the country are met from imports.

The increasing energy need of the country with erratic changes in the price of crude price in the global market has driven India to diversification of its energy resource base as well as to explore for more fossil fuel resources within the country. The KG basin field along the Andhra coast is a promising fossil fuel reserve.





Figure 2 India's demand for petrol (EIA)

### 2. ORIGIN OF STUDY

India, while discerning the need for energy development, at a rapid pace, also recognizes that it is equally important to address issues of environment and ecology adequately for ensuring long-term sustainability of such developmental activities. The Ministry of Environment and Forests (MoEF), which has set out various policies, rules and directives in this regard to ensure proper scrutiny of projects before clearance.

Further to the directive from MoEF, Oil India Limited (OIL) approached Sálim Ali Centre for Ornithology and Natural History (SACON) to carry out a rapid ecological assessment of the impacts of their proposed seismic survey activity in the reserve forest area, in view of its impacts, if any from the birds and wildlife point of view. Thus SACON took up an ecological study in the area for three months (June-August). As a part of the ecological study a field survey was conducted by the SACON team during the second week of June, 2011 to document the ecological setup in and around the proposed project area and examine it in view of the proposed activities.

### **3. OBJECTIVES**

The present study was taken up with the following specific objectives



- Examine impact of the proposed Seismic survey activities by M/s OIL on the Wildlife and avifauna in the Reserve forest areas
- Explore options to minimize and mitigate the impacts if any on Wildlife and Avifauna in these areas

### 4. THE PROPOSED PROJECT ACTICVITIES

M/s Oil India Limited (OIL) is a premier national oil company under the administrative control of Ministry of Petroleum and Natural Gas, Govt. of India. OIL is engaged in the business of Exploration, Development and Production of Crude Oil and Natural Gas, Transportation of Crude Oil and Production of LPG. The Company has over 1 lakh km<sup>2</sup> under license. The company is the pioneer in exploration and production of hydrocarbons in India (<u>http://petroleum.nic.in</u>). The block KG-ONN-2004/1 has been awarded under NELP round–VI to the consortium of Oil India Limited (a Government of India Enterprise) as operator with 90% of PI and GeoGlobal Resources (Inc.), Barbados as the other JV partner with 10% PI for carrying out exploration for oil & gas in the block.

M/s OIL proposes to carryout 3D seismic surveys besides a small volume of 2D seismic surveys in the Reserve forest areas falling within their allotted block, with minimal man & machinery movements.

### 4.1 THE SEISMIC SURVEY

OIL desires to carry out acquisition, processing and interpretation of seismic survey data from 55 km<sup>2</sup> area falling under six different Reserve Forests namely Kothapalem, Kandikuppa, Rathikalava, Masanitippa, Matlatippa and Balusutippa in prolific oil producing zone of East Godavari District of Andhra Pradesh. In this block, oil and gas reservoirs pertaining to Oligocene-Miocene and Palaeocene-Eocene age are expected at depth ranges 3000-3500m and 4200-4700m respectively. Objective of the present 3D Survey is to delineate these different reservoirs and identify stratigraphic and structural prospects in the areas.



**Methodology:** Before starting the survey on the proposed blocks, reference points at different locations around the blocks will be fixed using the Differential Global Positioning System (DGPS). Accurate co-ordinates of these points along with necessary diagrams will be recorded for locating the same in future. OIL has already initiated 3D surveys for identifying potential hydrocarbon reserves in areas other than Reserve Forests. Map showing the proposed shoot and receiver lines with Forest Area boundaries is depicted in Figure 3.



Figure 3 Proposed Area for seismic surveys by OIL with orientation of Shoot lines (in red, at 600m interval) and receiver lines (in green, at 540m interval)

The seismic surveys will be done using latest technology and equipments. The Shoot holes will be made manually avoiding any heavy machinery required to be moved along. Gelatine based explosives will be used as seismic source which will be stored in a licensed Magazine with due license for use and consumption from competent



authorities. Subterranean shooting using explosives and special underwater Air-guns along with geophones and hydrophones will be used in aquatic areas. OIL will also record about 2D Data from the area. The methodology etc will be similar to that of 3D but on a very smaller scale.

Basically the seismic survey will involve generation of a series of controlled seismic

vibrations at around 20m below the land surface using mild explosives. The seismic signals thus generated will travel into the earth and differentially reflected back by various subterranean strata. These signals will be recorded using the network array of geophones on the soil surface. In the case of creeks and water bodies, special Air guns will be used under water for generating the seismic waves without explosives and hydrophone sensors



Figure 4 Shoot hole drilling for seismic survey

will be used instead of geophones. The central control room will record the signals collected through geophones and will be used to find the location and extent of hydrocarbon reserves.

### 5. STUDY AREA

The present study covers the Reserve forest areas proposed for seismic hydrocarbon exploration by OIL in the Krishna Godavari delta in the East Godavari District of Andhra Pradesh (around 16<sup>°</sup> 37' N and 82<sup>°</sup> 17' E). East Godavari District is dominated by a human habitations and agricultural lands. Along the eastern boundary of the district, is the estuarine region where the river Godavari meets the Bay of Bengal and is completely covered with mangrove swamps with salt tolerant species of plants and animals in abundance.

The present study area is along the coastal zone of the district that includes mainly Mangrove forests and plantations. The entire stretch of coastal belt (of about 25km



long and 1.5 km wide) along the margins of the present study area is devoid of natural forests and is dominated by Casuarina plantations in different growth stages. The people inhabiting the study area are mostly dependent on fishing and on aquaculture farms for their livelihoods. The major river channels such as Gautami-Godavari and Nilarava and a large number of associated channels and tributaries criss-cross the study area.

Aquatic plant species such as Ipomoea carnea, Pistia stratiotes, Salvinia molesta, Lemna minor, Nelumbo nucifera, Nymphaea nouchalii, Ipomoea aquatica, Typha and angustifolia Eichhornia crassipes were observed in the ponds and other small water reservoirs, which are located around the human habitations. Coconut, banana, mango and cashew nut are the common horticultural crops grown in the district.



Figure 5 Satellite image of the study area

The estuary of Godavari including the present study area is mostly covered with mangrove forests, while Casuarina and Cashew plantations are found along the sandy coastal plains and beaches. The major plant species seen in the mangrove forests are representatives of the families Rhizophoraceae, Avicenniaceae, Combretaceae, Myrisinaceae, Euphorbiaceae and Sonneratiaceae. The mangrove plants exhibit specialized adaptations such as stilt roots as seen in Rhizophora; pneumatophores in Avicennia and Sonneratia; viviparous seedlings in Rhizophora, Bruguiera and Ceriops.



### 5.1 RESERVE FORESTS IN THE STUDY AREA

Six adjoining Reserve Forest areas coming under the present study area are described below

#### 5.1.1 Kothapalem Reserve forest:

The Reserve Forest is named after the village Kothapalem. The mangrove extent in this R.F. is 121.81 ha including Kothapalem I R.F and Kothapalem II R.F. The species diversity was rich and the vegetation was fairly dense. *Scyphiphora hydrophyllacea* Gaertn. (Rubiaceae), a rare mangrove species, was recorded in this R.F. near the Sacramento lighthouse. Other predominant plant species such as *Excoecaria agallocha, Lumnitzera racemosa, Sonneratia apetala, Rhizophora apiculata, R. mucronata, Xylocarpus granatum, Bruguiera gymnorrhiza, Avicennia marina, A. officinalis were recorded in this R.F. Two stragglers namely <i>Derris trifoliata* and *Sarcolobus carinatus* were commonly seen in this area. Shrubs like *Dalbergia spinosa, Clerodendrum inerme* and the halophytic herbs such as *Suaeda* and *Salicornia* were also recorded in the study area. The nearby aquatic ponds and habitation were constant sources of threat to the mangrove ecosystem in this area. The soil was clayey.

#### 5.1.2 Kandikuppa Reserve forest

This R.F. is about 3302.23 ha. of which healthy mangroves occur in 425 ha. Large areas of *Casuarina* plantation along the shore, was also a part of this R.F. was relatively healthy. Species namely *Sonneratia apetala, Rhizophora apiculata, R. mucronata, Bruguiera gymnorrhiza, B. cylindrica, Ceriops decandra, Xylocarpus granatum, Excoecaria agallocha, Avicennia marina, A. officinalis and <i>Lumnitzera racemosa* were recorded in this R.F. The vegetation in this R.F was disturbed due to the human pressure from the nearby villages namely Molletimuga, Kothapalem, Pandi and Pora. The soil was clayey in the land ward side and it was sandy clay near the seaward side.

#### 5.1.3 Rathikaluva Reserve forest

The total area under this R.F. is 2049.32 ha, of which 805 ha is with dense mangroves. As per the GIS data, the water spread area (Godavari River) accounts for



724 ha. Degraded and partially degraded mangroves account for 214 ha. *Excoecaria* agallocha, Avicennia officinalis, A. alba, Rhizophora apiculata, R. mucronata, Sonneratia apetala, Xylocarpus granatum, Bruguiera cylindrica, B. gymnorhiza occur in this R.F. Trees of Rhizophora, Bruguiera were seen along the creeks reaching about 2-6 m. in height. Large trees of Avicennia officinalis were also found. Tamarix troupii, a mangrove associate was recorded along with Thespesia populneoides, Hibiscus tiliaceus and Clerodendrum inerme. Species of Suaeda, Salicornia, Stunted Excoecaria agallocha, Lumnitzera racemosa were found in the degraded areas. Prosopis juliflora, an invasive species, also commonly seen in this reserve forest.

#### 5.1.4 Masanitippa Reserve forest

Masanitippa R.F. is named after the village Masanitippa. This R.F. extends to an area of 1089.91 ha. of which, 814 ha. is covered with dense mangroves. The species composition and the vegetation pattern in this R.F. are similar to Rathikaluva R.F. *Rhizophora apiculata* and *R. mucronata* of about 5 m heights were seen along the creeks. *Avicennia marina* and *Excoecaria agallocha* were the dominant species and *Sonneratia apetala, Bruguiera gymnorrhiza, Ceriops decandra, Lumnitzera racemosa, Bruguiera cylindrica* were also commonly seen in this R.F. Large areas of mangroves were occurring outside the R.F. towards the Bay of Bengal, which were under severe erosion due to oceanic currents and tides. *Prosopis* thickets were also noticed in this area. The soil of the area was clayey.

#### 5.1.5 Matlatippa Reserve forest:

In Matlatippa R.F., fairly dense mangrove vegetation was found on the eastern side. The western side was elevated and there were no creeks to facilitate tidal flow. According to Forest Department the mangroves are spread in 445.16 ha. out of which 210 ha. is with vegetation. The remaining area was with degraded mangroves and water bodies. The common tree species *Sonneratia apetala, S. caeseolaris, Rhizophora apiculata, Bruguiera gymnorrhiza, Avicennia marina, A. officinalis, A. alba, Lumnitzera racemosa, Ceriops decandra* and *Xylocarpus granatum* were recorded along with the climbers like *Derris trifoliata, Sarcolobus carinatus,* grasses like *Porteresia coarctata, Myriostachya wightiana* and shrubs like *Dalbergia spinosa* and *Acanthus ilicifolius.* The soil of the area was clayey.



#### 5.1.6 Balusutippa Reserve forest

Balusutippa R.F. is named after the village Balusutippa. The extent of mangroves under this R.F. is about 475.91 ha. out of which 427 ha. is under mangrove vegetation. Large trees of *Avicennia officinalis, A. marina, Rhizophora apiculata, R. mucronata, Bruguiera gymnorrhiza, Rhizophora stylosa, Xylocarpus granatum* and *Ceriops decandra* were recorded in this R.F. and large area of mangroves were seen outside the R.F. along the Gautami-Godavari River. Soil of this R.F. was clayey.

#### 5.2 **MANGROVES**

Large scale plantation activities of mangroves could be observed in many of the areas of mangrove forests done by forest department and other private sector were noticed in the huge area. Most predominant mangrove trees in this area are *Excoecaria agallocha, Avicennia marina,* A. *officinalis, Sonneratia apetala, Rhizophora apiculata,* R. *mucronata* etc. The other important mangrove species are *Acanthus ilicifolius, Aegiceros corniculatum, Bruguiera gymnorrhiza, Ceriops decandra,* C. *tagal* and *Lumnitzera racemosa.* The *Avicennia* spp. forms the dominant tree throughout the study area followed by *Excoecaria agallocha.* The plants of Rhizophoraceae family are becoming rarer with exception of *Bruguiera gymnorrhiza. Excoecaria* trees are found in areas with different salinity gradient from estuary to inland area. In open empty areas, plants like *Salicornia brachiata, Ipomoea biloba, Sesuvium portulacastrum, Suaeda maritima, S. monoica* etc. are commonly seen.

### 5.3 AQUACULTURE, FISHING AND FISHERIES

Fish and Prawn culture are widespread in the area. Traditional fishing is also another important livelihood for the local public. Mangrove forest plays an important role in coastal fisheries production. It supports breeding and feeding of various species of fishes, prawns and crabs, thereby enhancing the fishery resources of adjacent coastal waters. However, the large-scale disturbances and waste release from aquaculture operations is a major concern for the health of mangroves of this region. Indiscriminate prawn seed collection in recent years has reportedly depleted the resources.

Impacts of Seismic survey operations on the Wildlife and Avifauna...



### 5.4 CLIMATE

The region experience the tropical climate characterized by high temperatures in summer, high humidity and moderate annual rainfall. The temperature increases from the end of February to the hottest month (May). The temperature in the coldest month (January) is around 22°C. There is little variation in the temperature regime in the area mainly because of the low relief and the moderating effect of the sea. The normal annual rainfall over the area is around 1242 mm.

### 5.5 **SOIL**

During 1985-1988 Andhra University, Vizag had carried out Geo-biological studies on the Mangroves of the Godavari Delta Complex, including sedimentological studies in the Coringa area. Mangrove sediments are characterised by mud followed by Clayey mud and Sandy mud. The study by Andhra University also indicated dominant presence of silt and clay fractions (Seetharamaiah, 2003)

The Godavari delta has undergone phases of erosion and accretion through fluvial and marine agencies during its growth in recent times. Largely due to the detritus materials brought by the river from its drainage basin and subsequent effect of coastal processes over a long period.

### 6. **METHODOLOGY**

The present study involved extensive literature survey for reported impacts of seismic surveys and their impacts. Data was also collected from intensive field surveys conducted in the area during the second and third weeks of June 2011 just before the onset of monsoon. The study team travelled extensively through the reserve forests and surveys the flora and fauna and evaluated the status of the area as wildlife/bird habitat.

Being a rapid study of short duration relevant secondary information from peer reviewed published scientific information was relied upon wherever required to supplement the field data for other seasons of the year.



#### 6.1 FAUNAL SAMPLING

Various groups of animals inhabiting the study area were recorded by both direct and indirect methods during the present study period. Different sampling techniques were applied to record different faunal groups in the study area. Animals recorded in the present study include butterflies, birds and mammals, taking these taxa as indicators.

Таха	Sampling Methods
Butterflies	Random walk, opportunistic observations
Birds	Random walk, opportunistic observations
Mammals	Tracks and signs, and visual encounter survey

#### Table 1 Sampling methods for the study of various faunal species

The butterflies occurred in the study area were documented by direct observations, random walk and opportunistic observations, during early morning (07:00 to 11:00 hrs) and evening (16:00 to 19:00 hrs), by using a pair of binoculars. This timing was found ideal in the area based on preliminary counts done in different times of the day revealed that the maximum butterfly activity was during that time. Butterfly survey was carried out by searching 5 m distance on either side of the pathway. Gunathilagaraj et al. (1998), Kunte (2000) and Kehimkar (2008) were referred for the identification of Butterflies. Larsen (1987-88) was referred for correct scientific nomenclatures of butterflies.

The avifauna in and around the study site were documented by direct observations, Random walk and opportunistic observations, during early morning (06:00 to 10:00 hrs) and evening (17:00 to 19:00 hrs) by using a pair of binoculars. Line transect method was applied for recording the birdlife communities in the study area as mentioned by Bibby et al. (1992) and Sutherland (1996). The quantification of avifaunal species also was done by using line transect method by covering all types of vegetation. The length and numbers of one km transects were selected based on topography, vegetation physiognomy and the availability of the area. Based on the visibility of the researcher the search was done on both sides with the help of 12x 50 m field binoculars from transect. Ali and Ripley (1989) and Grimmet et al. (1998;



2001) were referred for the identification of birds. Grimmet et al. (1998; 2001) were followed for the nomenclature.

To survey the Mammals of the study area, both direct (Visual encounter surveys) and indirect methods (tracks and signs such as pug marks, calls and scats) were used (Bang et al. 1972; Burnham et al. 1980 and Heyer et al. 1994).

### 6.2 FLORA

Vegetation is an integral component of ecosystems, which indicates the effects of changing environmental conditions in an obvious and easily measurable manner and is much important in site evaluation and classification. Hence, careful analysis of vegetation is very important to know the distribution and types of floral components in an ecosystem. For phytosociological analysis quadrat method was used.

To study the plants, quadrats of 25 x 25 m size were laid. A total of 15 such quadrats were laid during the present study period. Species encountered during the vegetation sampling and surveys were recorded. Taxonomic identification of the species encountered in the field was done consulting the flora of Hooker (1872-97), Gamble (1957) and Matthew, (1983), Banerjee et al., (1989) and various relevant literatures. The voucher specimens were collected for each species to confirm their identity. The specimens of unidentified plants were preserved in 10% formaldehyde and brought to the Botanical Survey of India, Madras Herbarium (MH) Coimbatore for further identification by experts. The nomenclature given in the present study was based on the Flora of Tamil Nadu Series 1: Analysis vols. 1-3 (1983-1989).

The vegetation data were analysed to obtain the quantitative structure and composition of plant communities. For understanding the synthetic characters of the forest vegetation, the species richness and diversity of species in the stands are calculated. The vegetation data were tabulated for frequency, density, abundance, relative frequency, relative density, relative abundance, IVI and composition of plant communities, following Curtis and MC Intosh (1950), Philips (1959), Ludwig and Reynolds (1988) and Lande (1996). The Shannon-Wiener's index of diversity (H') was calculated using the software 'Species diversity and richness (version 2.65, Colwell, 1994-2004)' (Table 1).



Parameters	Formula adopted
Frequency (%)	(No. of quadrats in which a species occurred/ Total no. of
	quadrats studied) × 100
Abundance	Total number of individuals of the species/ No. of quadrats in
	which the species occurred
Density	Total no. of individuals of a given species/ Total no. of
	quadrats examined
Relative density	No. of individuals/ No. of individuals of all species
Relative abundance	(Abundance of species x 100)/ Sum of all abundances
Relative frequency	Number of quadrats occurring/ Total no. of quadrats
IVI	Relative density + Relative dominance + Relative frequency
Simpson Index	$D=\Sigma (n/N)^2$

 Table 2 Estimation of quantitative structure and composition of plant communities

### 7. **RESULTS**

During the present study the Reserve forest areas were surveyed by land as well as through creeks and data on floral and faunal components of the area was recorded using standard methods as well as opportunistic observations.

### 7.1 VEGETATION

The type of vegetation is determined by climatic, edaphic and biotic factors. Minor variations in topography, geology and the soil coupled with biotic factors bring considerable change in the floristic components, which determine the type of vegetation.

101 plant species belonging to 74 genera under 34 families were recorded in and around the study area during the present survey (appendix 2). Among these 101 species, 28 species are mangrove species and the rest are mangrove associates, seashore and inland species.

#### 7.1.1 Familial Composition

Of the 34 plants families recorded from the study area, Poaceae is the dominant family and it is represented by 16 species followed by Convolvulaceae 9 species, Rhizophoraceae 8 species, Cyperaceae 7 species and Euphorbiaceae with 6 species.



Figure 6 Dominant plant families of the study area

### 7.1.2 Habit-wise plant composition

Among the 101 species, herbaceous plants were dominant with 32 species (31%) followed by shrubs with 21 species (21%), trees 20 species (20%), climbers and stragglers were 12 species (12%) and grasses 16 species (16%).



Figure 7 Habit wise analyses of plants in the study area

The major trees recorded around the Study area were Avicennia marina, A. officinalis, A. alba, Barringtonia racemosa, Bruguiera cylindrica, B. gymnorrhiza, B. sexangula, Hibiscus tiliaceous, Lannea coromandelica, Morinda tinctoria, Premna latifolia, Rhizophora mucronata, R. apiculata, R. stylosa, Sonneratia apetala, Thespesia populnea, Xylocarpus granatum etc.



The shrubs and small trees such as *Abutilon indicum*, *Acanthus ilicifolius*, *Caesalpinia bonduc*, *Ceriops decandra*, *C. tagal*, *Clerodendrum inerme*, *Dalbergia spinosa*, *Excoecaria agallocha*, *Jatropha tanjorensis*, *Lumnitzera racemosa*, *Cerios decandra*, *C. tagal*, *Aegiceros corniculatum*, etc. are commonly seen in the study area.

Suaeda maritima, S. monoica, Salicornia brachiata, Euphorbia rosea, Cyperus exaltatus, C. rotundus, Fimbristylis ferrugenia, Mimosa pudica, Sebastiania chamelea, Sesuvium portulacastrum, Oldenlandia alata, Heliotropium curassavicum, Phyla nodiflora, Urena lobata etc. are the major herbaceous plants recorded in the study area.

The common climbers/stragglers recorded in and around the study area are *Oxystelma esculentum, Ipomoea biloba, I. aquatica, I. pesti-gridis, I. sepiaria, Pentatropis microphylla, Mukia maderaspatana, Sarcolobus carinatus* etc.

The following grasses viz., Aristida littoralis, Aleuropus lagopoides, Cenchrus ciliaris, C. biflorus, Chloris barbata, Cynodon dactylon, Dactyloctenium aristatum, Eleusine indica, Typha angustifolia etc. are commonly seen in the study area.

#### 7.1.3 Forest types

The study area is mainly occupied by mangrove forests. Mangroves are facultative halophytes, in other words they are able to utilize either fresh water or salt water depending upon availability. These salt water loving trees dominate many coastlines, providing shelter from predators for vulnerable young fish and food for a wide variety of marine species. Very peculiar characteristic of these mangrove forests is the root system. Mangrove have adopted in highly anaerobic soils by developing shallow root system, and unlike most trees they also lack a deep taproot. Roots buried up to 42 cm depth. The mangroves stands, it is found to be completely interpenetrated with roots to a depth of 50 cm or more or maximum 1 meter contribute detritus enhancing the productivity of ecosystem also helps in soil formation by trapping debris. Mangroves encounter damaging winds and waves before inland areas do, the branches in their canopies and their many prop roots create friction that resists and reduces the force of winds and waves. Thus,



coastlines are protected from severe wave damage, shoreline erosion and high winds (Gillet1996).

Some species like red mangroves have developed prop roots from branches and upper parts of the stem that reach down into the soil. The above ground portions of these roots have many lenticels that allow oxygen to diffuse in to the plant and down to the underground roots. Different strategy for survival has been evolved by certain other species, such as the black mangroves. They have system of cable roots, a few centimeters below soil surface, which radiate outward for many meters from the stem base. Extending upward from the cable roots there may be erect aerial roots called pneumatophores. Mangrove canopies and aerial roots offer a wealth of habitat opportunities to many species of estuarine invertebrates, sponges, mollusks, segmented worms, shrimps, insects, crabs and spiny lobsters all utilize mangroves prop roots as habitat for at least part of their life cycle. Prop roots of mangroves trap sediments in low energy estuarine waters and thus assist in preventing coastal erosion. Mangroves also assist in buffering the coastal zone when tropical storms and hurricanes, creating friction that opposes and reduces the force of winds and waves. Thus, coastlines are protected from severe wave damage, shoreline line erosion and high winds.

The major mangrove species such as Acanthus ilicifolius, Aegiceros corniculatum, Avicennia alba, A. marina, A. officinalis, Bruguiera cylindrica, B. gymnorhiza, B. sexangula, Ceriops decandra, C. tagal, Dalbergia spinosa, Excoecaria agallocha, Lumnitzera racemosa, Rhizophora apiculata, R. mucronata, R. stylosa, Sonneratia caseolaris, S. apetala and Xylocarpus granatum were commonly seen in the study area.

#### 7.1.4 Phytosociology (Plant Community Structure)

A total of 4981 individuals, belonging to 38 species 28 genera and spread over 21 families, in 15 quadrats (25 x 25 m), were recorded during the present study period. The vegetation community parameters computed from the data are presented in the Table 2



Among the 38 species, the shrub species, *Acanthus ilicifolius* was represented by maximum number of individuals (n=818) followed by *Avicennia officinalis* (n=513), *Exocaeria agallocha* (n=449), *Avicennia marina* (n=446) and *Aegiceros corniculatum* (n=281). Species such as *Ceasalpinia bonduc* (n=5), *Vernonia cinerea* (n=3), *Abutilon indicum* (n=2), *Oldenlandia alata* (n=2) and *Morinda tinctoria* (n=2) were seen in lowest in number, during the present study.

The maximum density value was recorded for *Acanthus ilicifolius* (54.53) followed by *Avicennia officinalis* (34.20), *Exocaeria agallocha* (29.93), *Avicennia marina* (29.73) and *Aegiceros corniculatum* (20.13).

The highest Important Value Index (IVI) was recorded for *Acanthus ilicifolius* (31.59) followed by *Avicennia officinalis* (22.22), *Excoecaria agallocha* (20.39), *Avicennia marina* (20.03) and *Aegiceros corniculatum* (15.03).

The Shannon-Weiner index of diversity for plants community in the study area was 2.9. The Simpson index of diversity was 0.9.

Name of the species	Family	Den	RD	IVI
Acanthus ilicifolius	Acanthaceae	54.53	16.42	31.59
Avicennia officinalis	Avicnniaaceae	34.20	10.30	22.22
Excoecaria agallocha	Euphorbiaceae	29.93	9.01	20.39
Avicennia marina	Avicenniaaceae	29.73	8.95	20.03
Aegiceros corniculatum	Myrisinaceae	20.13	6.06	15.73
Rhizophora apiculata	Rhizophoraceae	15.67	4.72	12.83
Rhizophora mucronata	Rhizophoraceae	13.93	4.20	12.58
Lumnitzera racemosa	Combretaceae	13.27	4.00	12.00
Bruguiera gymnorrhiza	Rhizophoraceae	13.20	3.98	12.19
Suaeda maritima	Chenopodiaceae	11.73	3.53	11.94
Saliconia brachiata	Chenopodiaceae	11.00	3.31	10.54
Ceriops tagal	Rhizophoraceae	10.60	3.19	10.17
Zoysia materella	Poaceae	10.60	3.19	10.96
Ceriops decandra	Rhizophoraceae	9.33	2.81	9.02
Fimbristylis ferrugenia	Cyperaceae	8.67	2.61	13.23
Unknown grass	Poaceae	8.47	2.55	9.13
Sonneratia apetala	Sonneratiaceae	7.67	2.31	8.14
Xylocarpus granatum	Meliaceae	7.60	2.29	9.24
Dalbergia spinosa	Fabaceae	3.80	1.14	5.58
Rhizophora stylosa	Rhizophoraceae	2.67	0.80	4.14
Phyllanthus rotundifolius	Euphorbiaceae	2.27	0.68	3.79
Bruguiera sexangula	Rhizophoraceae	2.20	0.66	3.69

Table 3 Plant species list with their Density, Relative density and Important Value Index



Name of the species	Family	Den	RD	IVI			
Avicennia alba	Avicnniaaceae	1.87	0.56	3.45			
Aeluropus lagopoides	Poaceae	1.60	0.48	4.52			
Prosopis juliflora	Mimosaceae	1.47	0.44	3.40			
Sesuvium portulacastrum	Aizoaceae	1.20	0.36	2.64			
Morinda citrifolia	Rubiaceae	1.00	0.30	2.34			
Heliotropium curassavicum	Boraginaceae	0.67	0.20	1.87			
Derris trifoliata	Fabaceae	0.60	0.18	2.36			
Ipomoea biloba	Convolvulaceae	0.60	0.18	1.77			
Clerodendrum inerme	Verbenaceae	0.53	0.16	1.94			
Eupatorim odoratum	Asteraceae	0.40	0.12	1.48			
Caesalpinia bonduc	Caesalpiniaceae	0.33	0.10	1.73			
Vernonia cinerea	Asteraceae	0.20	0.06	0.97			
Abutilon indicum	Malvaceae	0.13	0.04	0.80			
Oldenlandia alata	Rubiaceae	0.13	0.04	0.80			
Morinda tinctoria	Rubiaceae	0.13	0.04	0.80			
Where: Den-density; RD-Relative Density; IVI-Important value Index							

### 7.2 AVIFAUNA

The area falls adjacent to an Important Bird Area (Koringa IBA; site code: IN-AP-01, Islam and Rahmani, 2004) with 119 bird species, includes migratory species (50 species) coming from Eastern Europe, Central and North Asia (UNDP, 2011). The mangrove forests in and around the area supports birds such as snipes, ducks, sea gulls and flamingos. During our survey we observed 79 bird species (Table 4). Recently UNDP (2011) documented the presence of the rare winter migrant species Eurasian Golden Plover (Pluvialis apricaria), Eurasian Woodcock (Scolopax rusticola), Common Snipe (Gallinago gallinago), and Long-billed Plover (Charadrius placidus) in around the study area. Little Egret (Egretta garzetta), River Tern (Sterna aurantia), Black-headed Ibis (Threskiornis melanocephalus), House Crow (Corvus splendens), Large-billed Crow (Corvus macrorhynchos), Little Cormorant (Phalacrocorax niger), Common Myna (Acridotheres tristis), Indian Pond-heron (Ardeola grayii), Western Reef-egret (Egretta gularis) are the most sighted species during our field visit. Of these, Little Egret, Little Cormorant, Black-headed Ibis, Indian Pond-heron and House Crow were seen in almost all type of transects including settlements along the river banks, beaches, fishing area, and destructed mangrove forest area. River Tern on the other hand seen aplenty in the locations near to Nilarava estuary and Western Reef-egret were more in those areas where the fishing using traditional fish nets were more active. Species such as Common Myna, Large-billed Crow were



found mostly in and around the settlements. The inland water logged area near the Sacramento beach supports species such as Black-winged Stilt (*Himantopus himantopus*) and Red-wattled Lapwing (*Vanellus indicus*) in large number.

Among the 79 bird species observed during the survey, 23 species are migratory species (Table.4). Out of these 23 migratory species, Tufted Duck, Eurasian Curlew, Black Bittern etc are known to be international migrant birds (Wetland International, 2008).

The mudflats in the river course between Gautami Godavari and Nilarava river, and the sandy beaches and the creek boarded by the verdant mangrove vegetation near Kottapalem provides habitat for waders, and other wetland birds (Figure 8)

	Local name	Scientific name	Status
1	Alpine Swift	Tachymarptis melba	М
2	Ashy Drongo	Dicrurus leucophaeus	М
3	Ashy Prinia	Prinia socialis	R
4	Asian Koel	Eudynamys scolopacea	Μ
5	Asian Openbill	Anastomus oscitans	М
6	Asian Palm Swift	Cypsiurus balasiensis	R
7	Asian Pied Starling	Sturnus contra	R
8	Black Bittern	Ixobrychus flavicollis	М
9	Black Drongo	Dicrurus macrocercus	R
10	Black Kite	Milvus migrans	R
11	Black-crowned Night-heron	Nycticorax nycticorax	М
12	Black-headed Ibis	Threskiornis melanocephalus	М
13	Black-shouldered Kite	Elanus caeruleus	R
14	Black-winged Stilt	Himantopus himantopus	R
15	Blue-tailed Bee-eater	Merops philippinus	R
16	Brahminy Kite	Haliastur indus	R
17	Brown-headed Barbet	Megalaima zeylanica	R
18	Caspian Tern	Sterna caspia	М
19	Cattle Egret	Bubulcus ibis	R
20	Chestnut-headed Bee-eater	Merops leschenaulti	R
21	Common Babbler	Turdoides caudatus	R
22	Common Hoopoe	Upupa epops	R
23	Common Kingfisher	Alcedo atthis	R
24	Common Moorhen	Gallinula chloropus	R
25	Common Myna	Acridotheres tristis	R
26	Common Redshank	Tringa totanus	М
27	Common Sandpiper	Actitis hypoleucos	М
28	Coppersmith Barbet	Megalaima haemacephala	R
29	Crimson Sunbird	Aethopyga siparaja	IR
30	Eurasian Collared Dove	Streptopelia decaocto	R
31	Eurasian Curlew	Numenius arguata	М

#### Table 4 List of birds recorded from the area



32	Fulvous Whistling-duck	Dendrocygna bicolor	R
33	Great Egret	Casmerodius albus	М
34	Greater Coucal	Centropus sinensis	М
35	Greater racket-tailed drongo	Dicrurus paradiseus	R
36	Green Bee-eater	Merops orientalis	R
37	Grey Heron	Ardea cinerea	М
38	Gull-billed Tern	Gelochelidon nilotica	М
39	House Crow	Corvus splendens	R
40	House Sparrow	Passer domesticus	R
41	House Swift	Apus affinis	R
42	Indian Grey-Hornbill	Ocyceros birostris	R
43	Indian Pond-heron	Ardeola grayii	R
44	Indian Robin	Saxicoloides fulicata	R
45	Indian Roller	Coracias benghalensis	R
46	Intermediate Egret	Mesophoyx intermedia	R
47	Jungle Myna	Acridotheres fuscus	R
48	Large-billed Crow	Corvus macrorhynchos	R
49	Lesser Spotted Eagle	Aguila pomarina	R
50	Lesser Whistling-duck	Dendrocygna javanica	R
51	Little Cormorant	Phalacrocorax niger	R
52	Little Earet	Egretta garzetta	R
53	Little Grebe	Tachvbaptus ruficollis	R
54	Little Heron	Butorides striatus	R
55	Oriental Magpie -Robin	Copsychus saularis	M
56	Pallas's fish - Eagle	Haliaeetus leucorvphus	R
57	Pied Kingfisher	Cervle rudis	R
58	Purple Heron	Ardea purpurea	R
59	Purple Sunbird	Nectarinia asiatica	R
60	Red Collared Dove	Streptopelia tranquebarica	R
61	Red-rumped Swallow	Hirundo daurica	R
62	Red-vented Bulbul	Pvcnonotus cafer	R
63	Red-wattled Lapwing	Vanellus indicus	R
64	Red-whiskered Bulbul	Pvcnonotus leucotis	R
65	River Tern	Sterna aurantia	M
66	Rock Pigeon	Columba livia	R
67	Rose-ringed Parakeet	Psittacula krameri	R
68	Ruddy kingfisher	Halcvon coromanda	IR
69	Rufous Treepie	Dendrocitta vagabunda	R
70	Rufous-tailed Shrike	Lanius isabellinus	IR
71	Spot-billed Duck	Anas poecilorhyncha	M
72	Spotted Dove	Streptopelia chinensis	R
73	Spotted Owlet	Athene brama	M
74	Tufted Duck	Avthva fuliqula	M
75	Western Reef-earet	Earetta aularis	M
76	White Wagtail	Motacilla alba	M
77	White-breasted Waterhen	Amaurornis phoenicurus	R
78	White-throated Kingfisher	Halcvon smvrnensis	R
79	Yellow Wagtail	Motacilla flava	M
Comr	non and Scientific names following	Grimmett et al (2007). R- Resident	t M- Mie

Common and Scientific names following Grimmett et al (2007), R- Resident, M- Migrant ,IR- Individual record



### 7.3 OTHER WILDLIFE

The unique morphology of the river Godavari, with dynamic beaches harbours vulnerable species, Olive Ridley Seaturtle (*Lepidochelys olivacea*) during their breeding season (Shekhar and Raju, 2011), especially the Sacramento beach area is one of the reported nesting sites for sea turtle species in the eastern coast. Moreover the offshore beaches in the Kakinada forms route for the mass migration of olive ridley sea turtle to Orissa coast (Tripathy et al, 2003). Further, Tripathy et al (2003) had observed 608 Olive Ridley nests near the Sacramento beach area of the proposed site with a high nest density during February-March. Besides olive ridley sea turtle, the critically endangered Leatherback Turtle (*Dermochelys coriacea*) and green turtle (*Chelonia mydas*) are reported from the area (Reddy and Prasad, 1982).

The Gautami-Godavari estuary is a natural estuarine ecosystem with a very high capacity for cycling of nutrients and trace metals for bioprocess utilisation. According to NEERI (2009) the proposed survey area and nearby locations provides habitat for plenty of fishes (44 species), Prawns (14 species), and crabs (7 species). A similar study conducted by UNDP (2011) has listed 10 species of insects 5 species of amphibians and 27 species of reptiles.

The area support wide range of mammal species including otters, fishing cats and jackals (Reddy and Prasad, 1982). We have observed common mongoose, wild boars and squirrels during our rapid field surveys in the area. Indirectly as scats, and from the local people we could confirm the presence of fishing cats in and around the study area. Since the area is located very close to Coringa Wildlife Sanctuary there is a very high probability of finding more mammal species from the area.





Figure 8 Map of the area showing important areas from wildlife point of view

### 8. IMPACT OF SEISMIC SURVEYS

Presently M/s OIL has proposed seismic surveys at various other parts of the East Godavari district of Andhra Pradesh and Yanam district of Puducherry. The areas under the proposed survey include various Reserve Forests (RF) and beaches traversed by different tributaries and distributaries of Godavari river system extending up to the eastern coast line. The area being located in the vast estuarine delta of Godavari, one of the major east flowing rivers of India, it provides a specialized ecotone at the interface of terrestrial, marine and fresh water systems abound with life. Seismic survey using explosives can induce notable damages to the aquatic life. Such surveys can affect the normal physiology and seasonal activities such as migration, of various classes of animals. Fishes, dolphins, and whales are major aquatic organisms, which are reportedly highly vulnerable to impacts from seismic survey activities (www.akmarine.org).



In view of the studies conducted elsewhere and our assessment based on the field surveys, the probable routes of impact to the system during the seismic surveys to be carried out by OIL are discussed below.

The present study area composed of a dynamic mangrove ecosystem with aquatic organisms aplenty as reported elsewhere in this report. Therefore, it is suggested to avoid any heavy machinery use in the mangrove. It is also advisable to avoid activities in the spawning seasons during the onset of monsoon. As far as the fishes and associated organisms are concerned, besides the direct ecological disturbances on them, the seismic surveys can have indirect impacts on the socio-economic sectors of the area since fisheries and aquaculture practices are the backbone of local economy.

The shore/beaches in the present study area especially in and around locations in the sand spit near the Sacramento beach (between 16° 35' 36.19" to 16° 35' 1.96" North and 82° 17' 52.45" to 82° 17' 54.96" East), the beach area near Goutami Godavari mouth (16° 35' 20.81"N to 16° 31' 2.97"E North and 82° 18' 57.99"N to 82° 11' 3.30"E), and the vast sandy beaches located on the eastern side of Matlatippa RF (16° 35' 45.75" to 16° 44' 10.72" North and 82° 18' 42.45" to 82° 21' 43.67" East) are probable nest sites for Olive Ridley turtles, the critically endangered Leatherback Turtle (*Dermochelys coriacea*) and Green Turtle (*Chelonia mydas*) especially during February-March. Since the nesting time of the species in the eastern coast is during November to March special care may be taken to avoid any activities in these areas during the nesting time. It may be noted that most of the sandy beaches listed above are located outside the reserve forest boundaries.

It is reported that insectivorous birds are highly sensitive to any kind of human activities (Parker et al, 1996). Further, the study conducted by Canaday and Rivadeneyra (2001) in the Amazonian forests observed that the insectivores species are highly sensitive towards the changes brought about by the oil expeditions in the area. Similar consequences may be expected here too. The areas where the presence of birds are more as in the case of the mud flats located near the shore lines of the rivers and creeks near Yanam (16° 43' 2.51"N and 82° 13' 42.17"E) and Masanitippa RF, and the area where active heronries are located near Kothapalem



(around 16°36'2.38"N and 82° 17' 22.96" E) may be excluded from drilling and seismic surveys (Figure 8).

The movement of workers crisscrossing the mangrove area can create notable disturbances in the mangrove ecosystems. The mangrove forest patch of the proposed survey area include one nearly threatened (IUCN) mangrove species (*Ceriops decandra*) the three rare species (*Sonneratia alba, Scyphiphora hydrophyllacea* and *Xylocarpus moluccensis*). Another importance of the area is the only place in the country where three species of Avicennia, i.e. *Avicennia officinalis, Avicennia marina* and *Avicennia alba* are found together in mixed forests (Rao, 2009). During our field visit we observed 104 species of plant from the area. Minimal disturbance (in terms of quantum and duration) to the system should be ensured during the seismic surveys.

### 9. MITIGATION AND MANAGEMENT

As detailed above the Seismic surveys can causes disturbance to the system mainly through the movement of people and materials during the laying of Geophones/ hydrophones, Shoot-hole drilling and during the shooting process. The reserve forest area is dominated by mangroves and has some potentially good bird habitats such as mudflats. There are turtle nesting beaches towards the seaward side. To minimise the impact on these sensitive areas the Seismic surveys should not be carried out along the beaches during the turtle breeding season (Feb-April).

Last remnants of healthy and luxuriant mangrove stands exist mainly in the northern parts of the present study area along the Rathikaluva falling within the Rathikaluva Reserve forest. This patch is relatively free from human disturbances and harbour good biodiversity of mangrove fauna and flora. Shooting within this mangrove patch may be avoided. However Geophone lines may be used in the area if necessary with adequate precautions and completed in minimal time required.

The indicated bird areas and turtle nesting sites may either be excluded from the proposed survey activities or could be appropriately timed and managed avoiding migratory and breeding seasons of birds and turtles.



The following specific safeguards should be followed for minimizing the impact of Seismic surveys on Avifauna and wildlife of the area.

- No cutting or destruction of natural mangroves may be done during the seismic survey operations. Appropriate adjustments may be made in the locations of shoot holes and geophones in order to avoid damage to mangroves
- The seismic survey activity may preferably be restricted to the period between May to November.
- More specifically, no activity should be undertaken from December to February in the mangrove areas
- The survey may be avoided along the 1km wide stretch along the beaches from February to April, which is the reported breeding season of Olive Ridley Turtles (*Lepidochelys olivacea*) in this area.

### **10. CONCLUSION**

M/s IOL proposes conducting seismic survey in the study area. While the seismic survey activities are likely to have some impacts on the avifauna and wildlife of the area, these impacts can be greatly minimised using appropriate strategies. In the present case, the proposed seismic operations by M/s OIL, the impacts can be minimised, provided the suggested safeguards and precautionary measures as detailed under Mitigation and Management (Section 9; page 25) is strictly adhered to. The forest department may develop a monitoring programme to ensure the compliance during the seismic survey operations.

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### **12. APPENDICES**

Name of the species	Ν	QN	Fre	Abu	Den	RF	RA	RDn	IVI
Acanthus ilicifolius	818	14	93.33	58.43	54.53	6.45	8.72	16.42	31.59
Avicennia officinalis	513	14	93.33	36.64	34.20	6.45	5.47	10.30	22.22
Excoecaria agallocha	449	15	100.00	29.93	29.93	6.91	4.46	9.01	20.39
Avicennia marina	446	12	80.00	37.17	29.73	5.53	5.54	8.95	20.03
Aegiceros corniculatum	302	14	93.33	21.57	20.13	6.45	3.22	6.06	15.73
Rhizophora apiculata	235	10	66.67	23.50	15.67	4.61	3.51	4.72	12.83
Rhizophora mucronata	209	13	86.67	16.08	13.93	5.99	2.40	4.20	12.58
Lumnitzera racemosa	199	12	80.00	16.58	13.27	5.53	2.47	4.00	12.00
Bruguiera gymnorrhiza	198	5	33.33	39.60	13.20	2.30	5.91	3.98	12.19
Suaeda maritima	176	4	26.67	44.00	11.73	1.84	6.56	3.53	11.94
Saliconia brachiata	165	5	33.33	33.00	11.00	2.30	4.92	3.31	10.54
Ceriops tagal	159	10	66.67	15.90	10.60	4.61	2.37	3.19	10.17
Zoysia materella	159	4	26.67	39.75	10.60	1.84	5.93	3.19	10.96
Ceriops decandra	140	7	46.67	20.00	9.33	3.23	2.98	2.81	9.02
Fimbristylis aestivalis	130	2	13.33	65.00	8.67	0.92	9.70	2.61	13.23
Unknown grass	127	4	26.67	31.75	8.47	1.84	4.74	2.55	9.13
Sonneratia apetala	115	8	53.33	14.38	7.67	3.69	2.14	2.31	8.14
Xylocarpus granatum	114	12	80.00	9.50	7.60	5.53	1.42	2.29	9.24
Dalbergia spinosa	57	7	46.67	8.14	3.80	3.23	1.21	1.14	5.58
Rhizophora stylosa	40	4	26.67	10.00	2.67	1.84	1.49	0.80	4.14
Phyllanthus rotundifolius	34	4	26.67	8.50	2.27	1.84	1.27	0.68	3.79
Bruguiera sexangula	33	3	20.00	11.00	2.20	1.38	1.64	0.66	3.69
Avicennia alba	28	4	26.67	7.00	1.87	1.84	1.04	0.56	3.45
Aeluropus lagopoides	24	1	6.67	24.00	1.60	0.46	3.58	0.48	4.52
Prosopis juliflora	22	5	33.33	4.40	1.47	2.30	0.66	0.44	3.40
Sesuvium portulacastrum	18	3	20.00	6.00	1.20	1.38	0.89	0.36	2.64
Morinda citrifolia	15	2	13.33	7.50	1.00	0.92	1.12	0.30	2.34
Heliotropium curassavicum	10	2	13.33	5.00	0.67	0.92	0.75	0.20	1.87
Derris trifoliata	9	4	26.67	2.25	0.60	1.84	0.34	0.18	2.36
Ipomoea biloba	9	2	13.33	4.50	0.60	0.92	0.67	0.18	1.77
Clerodendrum inerme	8	3	20.00	2.67	0.53	1.38	0.40	0.16	1.94
Eupatorim odoratum	6	1	6.67	6.00	0.40	0.46	0.89	0.12	1.48
Caesalpinia bonduc	5	3	20.00	1.67	0.33	1.38	0.25	0.10	1.73
Vernonia cinerea	3	1	6.67	3.00	0.20	0.46	0.45	0.06	0.97
Abutilon indicum	2	1	6.67	2.00	0.13	0.46	0.30	0.04	0.80
Oldenlandia alata	2	1	6.67	2.00	0.13	0.46	0.30	0.04	0.80
Morinda tinctoria	2	1	6.67	2.00	0.13	0.46	0.30	0.04	0.80
Where: N= Number of Individuals; Qn= Number of Quadrats where the species occur; Fre-Frequency									

Appendix 1 Phytosiciological parameters of plants in the study are

Where: N= Number of Individuals; Qn= Number of Quadrats where the species occur; Fre-Frequency in percentage; Abu-Abundance; Den-Density; RF-Relative Frequency; RA-Relative Abundance; RDn-Relative Density; IVI-Importance Value Index.

Name of the plant	Family	Habitat
Rhizophora apiculata	Rhizophoraceae	Tree
Bruguiera gymnorrhiza	Rhizophoraceae	Tree
Lumnitzera racemosa	Combretaceae	Shrub
Excoecaria agallocha	Euphorbiaceae	Shrub
Aegiceros corniculatum	Myrsinaceae	Shrub
Avicennia marina	Avicenniaceae	Tree
Avicennia officinalis	Avicenniaceae	Tree
Derris trifoliata	Fabaceae	Straggler
Rhizophora mucronata	Rhizophoraceae	Tree
Ipomoea biloba	Convolvulaceae	Climber
Acanthus ilicifolius	Acanthaceae	Shrub
Suaeda maritima	Chenopodiaceae	Herb
Ceriops decandra	Rhizophoraceae	Shrub
Ceriops tagal	Rhizophoraceae	Shrub
Clerodendrum inerme	Verbenaceae	Shrub
Sonneratia apetala	Sonneratiaceae	Tree
Suaeda monoica	Chenopodiaceae	Herb
Barringtonia racemosa	Lecythidaceae	Tree
Fimbristylis aestivalis	Cyperaceae	Herb
Fimbristylis ovata	Cyperaceae	Herb
Imperata cylindrica	Poaceae	Grass
Chloris barbata	Poaceae	Grass
Elesine indica	Poaceae	Grass
Urena lobata	Malvaceae	Herb
Digitaria bicornis	Poaceae	Grass
Typha angustifolia	Poaceae	Grass
Cyperus exaltatus	Cyperaceae	Herb
Hibiscus tiliaceous	Malvaceae	Tree
Lannea coromandelica	Anacardiaceae	Tree
Mimosa pudica	Mimosaceae	Herb
Alysicarpus rugosus	Fabaceae	Herb
Stachytarpheta jamaicensis	Verbenaceae	Herb
Phargmites karaka	Poaceae	Grass
Prosopis juliflora	Mimosaceae	Tree
Caesalpinia bonduc	Caesalpiniaceae	Shrub
Dalbergia spinosa	Fabaceae	Shrub
Morinda tinctoria	Rubiaceae	Tree
Morinda citrifolia	Rubiaceae	Tree
Fimbristylis argentea	Cyperaceae	Herb
Fimbristylis tetragona	Cyperaceae	Herb
Oldenlandia alata	Rubiaceae	Herb
Oldenlandia stricta	Rubiaceae	Herb
Heliotrophium curassavicum	Boraginaceae	Herb
Abutilon indicum	Malvaceae	Shrub
Abutilon hirtum	Malvaceae	Shrub

### Appendix 2 List of plants recorded in the study area



Name of the plant	Family	Habitat
Phyllanthus rotundifolia	Euphorbiaceae	Herb
Zoysia materella	Poaceae	Grass
Vetiveria zizanioides	Poaceae	Grass
Jatropha tanjorensis	Euphorbiaceae	Shrub
Achyaranthes aspera	Amaranthaceae	Herb
Portulaca quadrifida	Portulacaceae	Herb
Sesuvium portulacastrum	Aizoaceae	Herb
Pentatropis microphylla	Asclepiadaceae	Climber
Oxystelma esculentum	Asclepiadaceae	Climber
Brachiaria reptans	Poaceae	Grass
Phyla nodilora	Verbenaceae	Herb
Vernonia cinerea	Asteraceae	Herb
Chromolaena odorata	Asteraceae	Shrub
Solanum trilobatum	Solanaceae	Straggler
Mukia maderaspatana	Cucurbitaceae	Climber
Cynodon arcuatus	Poaceae	Grass
Croton bonblandianus	Euphorbiaceae	Herb
Trianthema portulacastrum	Aizoacea	Herb
Barringtonia acutangula	Lecythidaceae	Tree
Sphenoclea zeylanica	Sphenocleaceae	Herb
Artrocnemum indicum	Chenopodiaceae	Shrub
Ipomoea aquatica	Convolvulaceae	Climber
Ipomoea pesti-gridis	Convolvulaceae	Climber
Ipomoea carnea	Convolvulaceae	Shrub
Ipomoea sepiaria	Convolvulaceae	Climber
Merremia emarginata	Convolvulaceae	Herb
Merremia tridentata	Convolvulaceae	Herb
Stictocordia tiliifolia	Convolvulaceae	Climber
Euphorbia rosea	Euphorbiaceae	Herb
Premna serratifolia	Verbenaceae	Tree
Clerodendrum phlomides	Verbenaceae	Shrub
Sebastiania chamaelea	Euphorbiaceae	Herb
Suaeda maritima	Chenopodiaceae	Herb
Bruguiera cylindrica	Rhizophoraceae	Shrub
Eichornia crassipes	Pontederiaceae	Herb
Dactyloctnium aristatum	Poaceae	Grass
Cenchrus ciliaris	Poaceae	Grass
Cenchrus biflorus	Poaceae	Grass
Aistida littoralis	Poaceae	Grass
Thespesia populnea	Malvaceae	Tree
Fimbristylis ferruginea	Cyperaceae	Herb
Sarcolobus carinatus	Asclepiadaceae	Climber
Aeluropus lagopoides	Poaceae	Grass
Scyphiphora hydrophyllacea	Rubiaceae	Shrub
Stigmaphylon ciliaris	Malphigiaceae	Straggler
Tamarix troupii	Tamaricaceae	Shrub
Sonneratia caseolaria	Sonneratiaceae	Tree



Name of the plant	Family	Habitat
Cressa cretica	Convolvulaceae	Shrub
Atriplex repens	Amaranthaceae	Herb
Unknown grass	Poaceae	Grass
Azima tetracantha	Salvadoraceae	Shrub
Salvadora persica	Salvadoraceae	Tree
Rhizophora stylosa	Rhizophoraceae	Tree
Bruguiera sexangula	Rhizophoraceae	Tree
Avicennia alba	Avicenniaceae	Tree
Cyperus rotundus	Cyperaceae	Herb









Xylocarpus granatum

Sonneratia apetala



Rhizophora apiculata

**Bruguiera gymnorrhiza** Plate 1. Mangrove Plants







Open bill storks

Brahminy kite



Western Reef Egret



Little heron





Black winged stilt

Plate 2. Some of the bird species recorded from the study area







Fiddler Crab

Plain tiger butterfly







Mud skipper

Plate 3. Biodiversity snap shots from the study area