

1	Title of the Project	<b>Mangroves for Fisheries and Environmental Enhancement in Cochin-“a comprehensive intervention through participatory approach”</b>
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4	Implementing Institution	<b>Kerala University of Fisheries and Ocean Studies, Panangad, Kochi.</b>
5	Other collaborating institutions	<b>Nil</b>
6	Date of commencement	<b>21-3-2016</b>
7	Planned date of completion	<b>31-3-2018</b>
8	Actual date of completion	<b>31-3-2018</b>
9	Objectives as stated in the project	<ol style="list-style-type: none"> <li><b>1. Asses the biodiversity of the mangrove ecosystem in the Puduveypu area Ernakulam District.</b></li> <li><b>2. Evaluate the efficiency of the mangroves as the bio-sorbent of toxic materials, heavy metals and other nutrients causing eutrophication.</b></li> <li><b>3. Create awareness of the benefits of mangroves among the public.</b></li> <li><b>4. Restoration of mangrove forests in suitable areas through women and youth participation.</b></li> <li><b>5. To associate with Department of Forests and Wildlife, LSGs Research Organizations and NGOs towards attaining the objectives.</b></li> </ol>
10	Experimental work giving full details of experimental set up, methods adopted, data collected supported by necessary table, charts, diagrams & photographs:	

**EXPERIMENTAL WORK GIVING FULL DETAILS OF EXPERIMENTAL SET UP, METHODS ADOPTED, DATA COLLECTED SUPPORTED BY NECESSARY TABLE, CHARTS, and DIAGRAMS & PHOTOGRAPHS:**

**1. THE AREA OF STUDY**

Kerala is one of the maritime States of India, which extends between the latitudes 8" 18' and 12' 48' N and longitudes 71" 53' and 77" 24' E with an area of about 38863 sq. km. It has a coastline of 590 km, which occupies about 7% of the country's total coastline. The State of Kerala has been blessed with extensive water bodies like estuaries, lakes and lagoons. The backwater area of Kerala is estimated as 2,42,000 ha out of which 65000 ha is suitable for brackishwater aquaculture. Kerala has 44 rivers, 45000 ha of reservoirs and almost 1.2 lakh ha of fresh water ponds. The State has a wetland area of approximately 16,60,590 ha. Among these wetlands, Islets of Cochin comes second in size with an area of 25,065 ha which is 10.41% of Cochin's geographical area. The total number of wetlands in Cochin is estimated as 354. Wetlands of Vypin as a single lot, is one of the largest among these, which is sandwiched between Cochin backwaters and Arabian Sea. It has an area of 100 sq.km with a length of 25 km and an average width of 4 km. It is situated only 0.75 meters above Mean Sea Level. The Islets of Vypin was formed as a result of the silt deposition from the river Periyar after a catastrophic deluge occurred in 1341 AD. The island is boarded by Arabian sea in the western side and Vembanad lake in the eastern side. Southern and Northern borders are connected with Cochin and Azhikode estuaries respectively. Cochin bar mouth in Ernakulam District has been a major attraction to the foreign traders, and fisher folk from time long past.

The study area, selected under the current project was Puduveypu, which is situated close to Cochin barmouth and having exemplary environmental and ecological characteristics. It is endowed with 3000 acres of newly formed wetlands. It was formed in recent years and thus the name got "Puduveypu" which means newly formed land in local language, "Malayalam". The area is inundated by semidiurnal type of tidal rhythm in Cochin bar mouth. The area accreted so far is exclusive marshy with extensive mangrove vegetation and is a potential breeding/ rearing/ grazing ground of Pearl spot, Grey Mullet (*Thirutha*), Milk fish (*Poomeen*), Asian seabass (*Kalanji*), Tiger shrimp (*Kara*), Indian white shrimp (*Naran*) and Mud crab (*Scylla serrata*). The spawn and fry of these fishes getting drifted along with the tidal inflow and reach the mangrove rich areas of Puduveypu and the area serves as the nursery grounds of these species. Owing to the undisturbed environment prevailed in the

past made this area rich and productive with abundance of commercially important fish and shell fish. Historically, this made the region's local economy to rely on inland fishing extensively and the major income source of the local inhabitants was fishing and ancillary jobs.

In the recent years, the rate of anthropogenic interventions increased in this area by way of intensive dredging, mangrove destruction and land filling which ultimately led to the deteriorated environmental quality. Recently, the fish availability rates got reduced and many were forced to quit fishing. This caused great havoc among the local economy. The current project was mainly focusing on this issue and major objective was to find out how to effectively use the mangrove ecosystem of Puduveypu for the enhancement of the local economy. The project was mainly concentrated on Fisheries Station, Puduveypu. The Station has been acting as a Centre of brackish water fish seed rearing and distribution since its inception in 1979. This Station also has a Mangrove Research Centre with an area of 25 acre mangrove area along the banks of Royal Man Power Canal (RMP). Now the Station finds it difficult to maintain the mandates like rearing of indigenous brackish water fish species and fish seed distribution to the farmers due to the shortage of fish seed availability from the natural creek of the Station. This has to be immediately addressed for the sustainable development of the area by captivity producing the fish seed through modern techniques. It is essential to create an immediate awareness on the importance of mangrove conservation among the local people and to encourage the use of mangrove ecosystem for fish culture for a sustainable revenue generation.

## **2. Activities undertaken**

### **Biodiversity assessment**

Biodiversity is the expression used to refer the variety of life in a place which includes plants, animals, microorganisms, ecosystems and ecological processes in a functional unit. The biodiversity values of an ecosystem indicate the state of conservation of the same. Many parameters are employed to measure the biodiversity of an ecosystem, which can be used for the conservation efforts, management and environmental monitoring.

### **Study on Mangrove diversity**

In the first year, study was concentrated at Fisheries Station, Puduveypu. The Station has a Mangrove Research centre in its campus. The major mandates of this research centre

are to make natural conservation of the existing mangrove forest of the region and to promote the scientific research on sustainable utilization of the same. The study site has a total area of 50 acre in which 25 acres are occupied by native mangrove forest. The region is one of the most species rich brackish water ecosystems in the district with less human disturbance. The average rainfall per year is more than 3000 mm and annual average temperature of the area is approximately 27°C. According to the Koppen's climate classification, the climate of the region is classified as tropical monsoon climate. Average relative humidity of the region is 75%. Sunshine ranges from 4.3 to 9.7 hours/day. Soil type is a mixture of hydromorphic saline, Riverine alluvium and Coastal alluvium. The soil is composed of sandy to clayey loam and is comparatively rich in plant nutrients. The predominant forest vegetation belongs to the mixed mangrove species. The study was for a period of two years. During this period distribution and density of the mangrove vegetation and the varying hydrological conditions of the estuary were studied. Methods used for the study were Quasi- quantitative and rapid assessment technique. Rapid assessment technique allowed wide coverage of many sites and quantitative plot method which was carried out at selected sites. Initially a detailed survey of mangrove flora was conducted. Details like number of species, area occupied, nature of spread, morphological peculiarities, special adaptations and other details connected with mangroves and associated flora were collected from each study area.

### **3. The selection of sampling stations**

Preliminary surveys were conducted to identify the mangrove growing area in Puduveypu. According to the survey 19 mangrove growing area in the south Puduveypu region were identified. In all the sites coastal fishery and traditional aquaculture are the essential revenue generation activities among the local people. Quadrant analyses were done to study the distribution pattern of mangrove and associate species (Michael,1984). In the current study the quadrant size used was 10x10 m. The number and position of all species at each station were accurately marked on a chart. The density index was calculated by using Shannon- Wiener function. The species of mangroves and other vegetable flora were identified by its vegetative and floral morphological characteristics based on previously published data.

#### **Mangrove density of Fisheries Station: Rapid Assessment with Wide Coverage**

In this method, random sites were selected along the mangrove ecosystem of South Puduveypu and recorded the data. At each site, quasi- quantitative observations were made

with respect to mangrove density, height, seedlings and species. The observations were also made from dinghy in thick forest region because of the difficulty in entering into the forest. All the data were recorded on an ordinal scale of 0-5 points, where 0 is nil, 1- very low, 2- low, 3- moderate, 4- high and 5- very high. Using this method, 15 sites were examined in the mangrove ecosystem of Fisheries Station, Puduveypu and four sites outside the Station.

Obviously, adherent limitations are there in this method, i.e. the data recorded are based on the visibility from the edge of the canal, thus the zones away from the canal edge might have left unnoticed, so the possibility of observer error may be high. Still, this rapid assessment technique was helpful to get a broad picture or rough estimate of Mangrove area available in Puduveypu region.

### **Species diversity in selected sites**

Site 1. This area is in the western side of the Station, which holds large mangrove trees. According to the density data, *Bruguiera cylindrica* and *Avicennia officinalis* are the most abundant species in this area. Site 1 also contains a small group of large *Rhizophora mucronata* trees, which forms a good canopy over the area.

The mangrove density of the Site 2 gives the data of the northern region of the Station which is rich with the species *Avicennia officinalis*, *Bruguiera cylindrica* and *Rhizophora mucronata*. Species named *Excoecaria agallocha* and *Bruguiera gymnorrhiza* are present in a scattered manner. No other species are present in this area. Site 3 and Site 4 are the area west to the Vannamei pond of the Station, which show the same species which seen in site 2. *Avicennia officinalis* is the species abundant in these areas.

Site 5 denotes the species abundance of the northern end of the Station. The area is rich with *Rhizophora mucronata*, *Avicennia officinalis* and *Bruguiera cylindrica*. Site 6, 7, 8 and 9 depict the abundance of mangroves along the eastern side of the feeder canal. Both the Southern and Northern ends of the eastern side are canopied with *Avicennia officinalis* and *Rhizophora mucronata*. The western side of the sluice gate (Site 10) especially on the banks of the feeder canal running in the East- West direction is rich with *Bruguiera gymnorrhiza*. A small portion near the sluice gate is planted with species collected from various parts of Kerala including *Kandelia candal* and *Lumnitzera racimosa*

The Sites 11 and 12 (both sides of the RMP canal) have large trees of *Avicennia officinalis*. The area is a thick mangrove forest with relatively high basal area. Eastern side of

the RMP canal is abundant with seedlings of *Bruguiera cylindrica* in a scattered manner. There are small patches of *Acanthus ilicifolius* in between the mangrove forests of the western side of the RMP canal.

Site 13 is the area situated in the South- west edge of the RMP canal which holds both *Avicennia officinalis* and *Bruguiera cylindrica*. Most of the plants seen in this area are large and healthy. Sites 14 and 15 are the end portion of RMP canal which is situated close to the starting point of RMP canal. Similar to all other sites the most dominating species is *A. officinalis*. The area is also occupied by species like *Sonneratia alba*, *Sonneratia caseolaris*, *Bruguiera cylindrica* etc.

Site 16 was in South Puduveypu. This area holds a blend of various mangrove species where the most dominant species is *B. gymnorrhiza*. The area also consists of mangrove associates. Sites 17 and 18 are falling under Belbo junction area and Njarakkal area respectively. In Njarakkal area the mangrove vegetation is seen along the coastal belt and along the banks of the canals and prawn filtration field. The mangrove species prevalent in these regions are *Rhizophora mucronata*, *B. gymnorrhiza*, *B. cylindrica* and mangrove associates. Site 19 is located in Malippuram, which is 7 km away from Fisheries Station. The mangrove vegetation present in this region is strictly adhering to the pattern observed in the coastal belt. In this area *R. mucronata* and *B. gymnorrhiza* are the common species. In this area most of the houses near to the sea are fenced with *B. gymnorrhiza*. It is a common practice in the south of Puduveypu that *Bruguiera spp.* has been used to fence the land boundaries. From the survey conducted among the local residents, it is understood that people have a positive attitude towards this species and the species is supposed to have an ornamental value and treated as a garden plant. It is known that, people in this region are not considering *Bruguiera spp.* as a menace but they possess a tendency to keep the plant in their premises.

### **Quantitative assessment of selected sites**

Method used for the quantitative assessment of mangrove vegetation in selected sites was the transect line plots method (English *et al.*, 1994). This method was used to assess Mangrove abundance and species diversity. In each site, transects (each 10 m x 10 m) were taken perpendicular to vertical tidal zones. In total, 10 plots were examined in the Mangrove ecosystem area. Within each plot, all mangroves were identified to species level and counted according to three maturity categories: seedling (< 1 m in height), sapling (height > 1 m, girth

< 4 cm) and tree (girth > 4 cm). The girth at breast height (GBH, standardized at 1.3 m above ground) was measured for all trees and saplings. To assess the mangrove abundance, GBH measurements were taken into account to calculate the basal area.

### **Mangrove density and Dominance**

Density is defined as the number of plants of a single species / unit area and total number of plants/unit area. Initially the plants were divided into strata and counted the plants for each stratum. The selected standard stratum were 1) canopy, which can be recognized by density in number per hectare. 2) sub-canopy (density in number per 100 m<sup>2</sup>) herb layer (density in number per 4 m<sup>2</sup>). Dominance of the species can be determined by the canopy layer of the forest. The dominance can be calculated by the density per unit area.

Based on the survey, Mangrove species richness was higher in North – East side of the Station. Studies show that distribution of species has a direct relationship to the factors like freshwater flow, sediment load and differences in tidal amplitudes which determine the availability of nutrients to the vegetation (Mitsch & Gosselink, 1986). From the data, it is noted that all the eight indigenous species of Mangroves present in Puduveyyu are comparatively common throughout Kerala (Basha 1992). In general, the study area is dominated with *Avicennia officinalis* which is very common in Riverine and Basin mangrove wetlands. Interestingly, this species can grow in the area where high sulphides are found in the soil substrates (Thibodeau and Nickerson, 1986). The presence of numerous pneumatophores may be the helping factor for this special adaptation. Pneumatophores of the *Avicennia* sp. have lenticels, through which oxygen enters into the plant during low tide. Some of this entrapped oxygen diffuses out of the roots through a system of aerenchyma tissues, which helps to maintain an aerobic microlayer around the root system. Experiments on the importance of oxygen transport from the aerial organs to sediments proved that pneumatophores in *Avicennia* help the plant to produce an oxidized rhizosphere (Thibodeau and Nickerson, 1986). Based on the quantitatively sampled sites, the southeast side of the Station mangrove forest area had higher basal area (2.8 m<sup>2</sup> / 100 m<sup>2</sup>) than Northern side. The height of mangrove trees was moderate to very high in most sites in southern part, while it is moderate in other parts. As has been pointed out earlier, the growth and distribution of mangroves are determined by various ecological factors like salinity, tidal inflow, wind, sediment supply etc. Among these factors salinity of the soil plays a critical role in determining the diversity. Mangroves are generally known as the plant groups that are

capable of tolerate saline conditions but for attaining growth they need fresh water supply. Studies showed that *Avicennia spp.* have high level of salinity tolerance, which ranges from 0ppt to 35ppt. This clearly explains why the mangrove habitat of Puduveyypu is rich with *Avicennia officinalis* as the hydrology study conducted in the Puduveyypu water shows the salinity variation in the RMP canal ranges from 3ppt to 35 ppt. The RMP Canal receives freshwater during monsoon and sea water from Cochin bar mouth. The sites away from the RMP canal show low salinity tolerant species like *Bruguiera* and *Rhizophora spp.* Soil texture and particle size also affect the distribution nature of mangrove species. Generally, mangroves prefer two types of soils, sandy and muddy. It is noted that *Avicennia spp.* prefer sandy conditions, which will be the reason for the abundance of *Avicennia officinalis* with maximum basal area ( $2.875 \text{ m}^2 / 100 \text{ m}^2$ ) along the banks of RMP canal, which receives sandy soil from sea. *Rhizophora spp.* prefer muddy or sandy/muddy conditions which may be the reason why this species is dominant in the area near the ponds.

#### **4. HYDROGRAPHICAL PARAMETES**

It is a fact that hydrographical parameters of a region influence the diversity of species. Information on various physio-chemical and biological processes will help to know the ecological processes of the region which support the plant and fishery resources. As part of the current project, study was conducted to understand the temporal variation of hydrographical parameters of the backwaters of the Puduveyypu region to know how much it affects the species richness of the area. The primary study area was the mangrove ecosystem of Fisheries Station, Puduveyypu. Aquaculture activities of the Station are carried out in an area of 10 acres of pond system and rest of the portions are of low lying marshy land covered with different species of mangroves.

##### ***Importance of hydrology study of a wetland***

Hydrology conditions are extremely important for the maintenance of a wetland's structure and function. They influence many abiotic factors, including soil anaerobiosis, nutrient availability and coastal wet land salinity. These factors determine the biota of the respective wetland. The hydrologic signature of a wetland is the result of the balance between outflows and inflows of water (called the water budget), basin geomorphology and subsurface conditions. The major determinant of the wetland process is the seasonal and year to year variations in the hydroperiod. Hydrology affects species composition and richness,



primary productivity, organic accumulation and nutrient cycling in wetlands. So, hydrology study can contribute to a better understanding of wetland function.

### ***Salinity***

Salinity is the major indicator of estuarine water system and also an important water parameter that regulates the water quality, extent of dissolution of gases and pH of brackish water. Salinity fluctuations normally depend on weather, hydrology, rainfall, topography and tidal flooding. The bottom sediment salinity is influenced significantly by local precipitation, subterranean seepage, terrestrial runoff, evaporation and tidal flushing. High salinity controls the biological activities by reducing the availability of nutrients. The most dominant feature of the estuarine environment is the fluctuation in salinity. Fresh water discharge from Periyar, the tidal flow from the Arabian sea, the coastal upwelling and sinking etc., are the major factors affecting the hydrological conditions of Cochin backwaters. It is reported that salinity values were maximum in the pre-monsoon months in Cochin backwater. About 70% of rainfall in Cochin occurs during monsoon and so during this season there is strong flow of fresh water and consequently the salinity of backwater reduces to much lower value. Usually salinity decreases during monsoon season to reach the value of 0ppt. Annual salinity range from 1-32 ppt in the region.

The salinity of the backwaters of Puduveypu ranged between 6 to 34 ppt. The average salinity during the study period was 23. During the study period, the values showed an increasing trend in the post monsoon period (Oct-Nov) and the trend continued in the December to February. The maximum value was recorded in January. According to Menon (1989) convective thunder showers increase over Kerala progressively as the hot season (pre- monsoon season) advances. In Kerala, 75% of the annual rainfall occurs during monsoon. The strong flow of rain to the backwater during the monsoon reduces the salinity. During the present study also, it was observed that as the monsoon started the salinity further decreased due to heavy rainfall.

### ***Hydrogen ion concentration or pH***

This is an important hydrological factor that affects the metabolism and other physiological processes of aquatic organisms. pH range of 6.5- 8.5 has been reported to be the most ideal for fish culture. Several studies showed that pH value of Cochin backwaters exhibits considerable variations between 7.0 to 8.5. Higher values were recorded during the

season of pre-monsoon, when the salinity values were also high. pH is low in monsoon due to fresh water influx and high in winter and summer seasons. pH value of the study region varied between 7.0 to 8.5.

### **Water temperature**

The change in surface water temperature follows the change in air temperature. Kerala being a tropical State, temperature variations are not as significant as pertaining to salinity regimes. Maximum evaporation takes place in the post monsoon season at Cochin backwaters. The influx of fresh water into the estuarine system is not the sole factor in bringing down the water temperature, but the cold water from the sea may also be contributing to the same. During the study period, the temperature of Puduveyppu area ranged between 26<sup>0</sup> C to 31<sup>0</sup> C.

### **Dissolved oxygen**

Dissolved oxygen is an essential factor in the aquatic ecosystems and an important indicator of water quality. The air-water interaction, respiration and photosynthetic processes influence dissolved oxygen status of water bodies. Primary source of oxygen in the water is photosynthesis by phytoplankton. The solubility of oxygen in water is mainly influenced by temperature and salinity, which decreases with increase in salinity and temperature. Higher values of dissolved oxygen were recorded during monsoon months. Kumaran and Rao (1975) reported that the lowest dissolved oxygen in the Cochin backwater was found during the post monsoon months i.e. October to December and the highest was in the monsoon months (July). The biological process of an estuary is affected by dissolved oxygen content of water. Its utilization and release (respiration and photosynthesis) indirectly affect the pH of estuarine water. The higher dissolved oxygen values that were observed during monsoon might be due to the intrusion of fresh water from rivers and resulting mixing and circulation of water. The dissolved oxygen of the study sites varied from 2.3 to 6 ppm.

### **Total alkalinity**

The alkalinity of water refers to the total concentration of bases in water. It mainly depends on carbonates and bi-carbonates of Calcium and Magnesium. It is the quantity of hydrogen in millimole (mmol) to neutralize the weak bases in 1 kg of sea water. The capacity of a solution to neutralize a dilute acid is termed as total alkalinity in terms of CaCO<sub>3</sub> (Grasshoff *et al.*, 1983). The alkalinity of water is a very important factor which influences

the productivity of an ecosystem. The variation in alkalinity in Cochin backwater was less during the premonsoon months. Generally, it assumes higher values during summer months and starts decreasing with the advent of monsoon. The total alkalinity varied from 93 to 400 ppm.

### **Method used to assess the hydrological parameters**

#### ***Temperature***

Temperature was measured using a precision mercury thermometer with an accuracy of  $\pm 0.01$  °C.

#### **3.9.2. Salinity**

Salinity was measured using a hand-held refractometer.

#### **4.5.2. pH**

pH measurements were made with a pH meter (with an accuracy of  $\pm 0.01$ ).

#### ***Dissolved oxygen***

D. O. was determined by Winkler's method (Strickland and Parsons 1972). Water samples were collected in 125 ml BOD bottles and fixed using Winkler's A&B solutions followed by titration.

#### ***Total Alkalinity***

Total alkalinity estimation was done by using acidimetric titration (Lenore *et al.*, 1998). The titration was carried out by using standard hydrochloric acid and methyl orange taken as the indicator.

#### ***Total Hardness***

### **5. BIOLOGICAL PARAMETERS**

#### ***Primary productivity***

Primary productivity gives essential information about the fertility of the aquatic system. From the current study the primary productivity of Puduveypu water body ranged from 1104 mgC/ m<sup>3</sup> / day to 1786 mgC/ m<sup>3</sup> / day. Highest rate was in November and the lowest was in July. The readings showed slight variations depending upon the season.

### ***Method used***

The estimation of primary productivity was done by Gaarder and Graan's light and dark bottle method. Samples were collected in one dark and two light bottles of 125 ml capacity. One light bottle was fixed immediately and the rest of the bottles were incubated in the water for four hours and fixed after incubation. The DO of the three bottles were determined by Winkler's method and the differences in DO of dark and light bottles were taken and calculated the gross primary productivity.

### **6. Netting of fishes**

For collection of fishes, shellfishes and crabs, cast net was used as the main gear. Netting was done fortnightly. The specimens collected were identified to the species level.

### ***Fishes***

36 species of finfishes were collected during the study period. The collected fishes can be categorized into 10 Orders and 26 Families. *Mugil cephalus*, *Liza parsia*, *L. macrolepis*, *Etroplus suratensis*, *Siganus javus*, *Lutjanus fluviflammus*, *Epinephelus tauvina*, *Lates calcarifer*, *Arius subrostratus*, *Chanos chanos*, *Therapon jarbua*, *Megalops cyprinoids* etc. are the major commercially important fishes collected during the study.

### ***Shellfishes***

*Penaeus monodon*, *P. indicus*, *Metapenaeus dobsonii* and *M. Monoceros* have been collected from the study area. The penaeid shrimps constituted an important fishery in the backwaters of Cochin. These shrimps enter the backwater quite early in life (in the larval and post-larval phases) and after a few months of growth there, return to the sea for breeding

### **7. Assessing the population of polychaetes**

Since the polychaetes are considered to be one of the most important groups in nutrient recycling in coastal ecosystems, their population was estimated as part of the study. To assess the population of polychaetes, mud samples were collected from 5 random points of the Fisheries Station within the depth of 20 cm having a pit diameter of 10 cm as had been done. The mud collected was sieved and the animals retrieved in the sieve were preserved in 5% formaldehyde.

## **8. Assessment of mangrove crab population**

The benthic fauna associated with mangrove forests is typically dominated by various burrowing decapods. They include sesarmid crabs and fiddler crabs. They are referred as ecosystem engineers because they can directly or indirectly modulate the availability of natural resources to other species by causing physical state changes in the abiotic or biotic factors/entities. It means they can modify, maintain and create habitats. These are the major macrofauna, ecologically engineering the mangrove ecosystem through digging burrows and manipulating the dynamism of the area. Two major species are *Sesarmid* (Grapsidae) and fiddler crabs. Crabs dig burrow shelters in the forest floor as a protection from predation. These burrows can act as the interactive zone between groundwater, substrates and nutrients. These burrows can affect the sediment topography and biogeochemistry of the mangrove ecosystem by improving soil particle size, distribution, drainage, redox conditions, organic matter availability and food storage. These crabs are herbivorous and feed on leaf litter and macroalgal mats. This process helps towards improved decomposition and prevents nutrient loss through tidal flow. Crabs can increase the nutrient availability of the ecosystem upto 75% by helping decomposition. They play a critical role in the nutrient recycling in the mangrove ecosystem by making nutrient availability to other flora, fauna and microbes in the system.

Assessment of mangrove crab population was done by counting the number of crab burrows in the selected sites. A total number of 25 sites were selected. At each site, three 5 m × 5 m plots (the same plots that were used to sample the vegetation) were established for sampling with at least 10 m distance between the sampling plots. Each site contained eight 1 m × 1 m subplots. Crab burrows were sampled during ebb tides. The complete survey of all plots was finished within 4–5 h on each survey day. To avoid possible time bias, the sequence of field measurements was chosen randomly.

## **9. Faunal diversity noted during the study**

From the study conducted in the mangrove region of Puduveypu, a total of 33 species of invertebrates were recorded. These species belonged to 4 Phylas- Mollusca, Arthropoda, Annelida and Platyhelminthes. The Phylum Arthropoda had the most number of species recorded.

## **Ashtoret lunaris**

*Ashtoret lunaris*, which is a Crustacean commonly, encountered in the sandy and muddy shores, especially near seagrass beds from the intertidal zone to a depth of 50m. It is usually nocturnal and spends the day buried in the substrate just below the surface creating breathing channels to the surface of the sand. They hunt small shellfish, worms and other animals during the night. They are known to take other small crabs also. When threatened, a lunaris often draws its legs up under the overlapping edges of the carapace and appears to be 'dead' and this may make it difficult for a predator to dismember the crab. The specific name, lunaris refers to the moon while the generic name Ashtoret refers to the Phoenician.

## **Barnacles**

Barnacles are exclusively marine and tend to live in shallow and tidal waters, typically in erosive settings. They are sessile (non motile) suspension feeders. Barnacles are encrusters, attaching themselves permanently to a hard substrate. Free-living barnacles are attached to the substratum by cement glands that form the base of the first pair of antennae; in effect, the animal is fixed upside down by means of its forehead. In some barnacles, the cement glands are fixed to a long, muscular stalk, but in most they are part of a flat membrane or calcified plate. A ring of plates surrounds the body, homologous with the carapace of other crustaceans. These consist of the rostrum, two lateral plates, two carinolaterals and a carina. In sessile barnacles, the apex of the ring of plates is covered by an operculum, which may be recessed into the carapace. The plates are held together by various means, depending on species in some cases remain solidly fused. Barnacles have no true heart and the blood vascular system is minimal. Similarly, they have no gills, absorbing oxygen from the water through their limbs and the inner membrane of their carapaces. The excretory organs of barnacles are maxillary glands. Barnacles have two distinct larval stages, the nauplius and the cyprid, before developing into a mature adult.

## **Onchidium griseum**

The orange-footed mangrove onch slug, *Onchidium griseum* is usually found on mangrove tree trunks or on the shore. They have greyish brown body with a length of 4-5cm. Ridges and small bumps run down the center of the slug's body and the dorsal side is yellow or orange. The feet of these creatures, as the name suggests are orange.

## **Scylla serrata**

*Scylla serrata* (mud crab) is an economically important species of crab found in the estuaries and mangroves. It contributes significantly to the protein and economic security of the local folk. The shell colour varies from a deep green to very dark brown. These crabs are highly cannibalistic in nature. The females can give birth to a million offspring, which can grow up to 3.5 kg (7.7 lb) in size and have a shell width of up to 24 cm (9.4 inch) wide. They have high demand in the market. They are tolerant to extreme water conditions.

## **Thalmita danae**

*Thalmita danae* is one of the common brachyuran crabs. They are active crabs inhabiting the upper region of intertidal zone. They feed heavily on local intertidal bivalves and are believed to have profound influence on the population structure of the prey. Carapace is covered with a short, thick fur, with 3 pairs of gastric ridges, epibranchial ridge interrupted by cervical groove, cardiac and mesobranchial ridges appear merely as smooth areas among the hairs. Upper surface of cheliped palm contains 2 spines on outer and 2 spines on inner sides. Posterior border of propodus of swimming leg contains 10-12 small spines. In males, the first pleopod smoothly curved, regularly tapering with blunt oblique tip; about 11 bristles merging to a clump distally.

## **Pseudobiceros sp.**

*Pseudobiceros* is a genus of flatworms. Like all flatworms, *Pseudobiceros* are also hermaphrodites. This particular genus engages in 'penis fencing'. When the "winner" touches its penis to the 'skin' of the other, insemination occurs and the "loser" has to bear the burden of motherhood. They show the presence of two male gonopores, duplicated male reproductive structures, smooth dorsal surface, complex folded pseudotentacles and simple ruffled pharynx.

## **Orange tailed marsh dart**

This species breeds in a wide variety of standing water habitats, from drains in town and cities to marshes and swamp forest and the landward margins of mangrove swamps. Male: Eyes: Dark olivaceous above, pale green below. Thorax: Green above fading to blue on the sides and yellow below. Legs: Yellow, with short black spines. Wings: Transparent. Wing spot: Amber coloured. Abdomen: Multicoloured. Segments 1-2 and 7-10 brick red. Central segments (3-7) blue grey with dorsal black band. Female: Very similar to the male,

however, the red abdominal segments 7-10 are much duller.

### **Paragomphus lineatus**

*Paragomphus lineatus*, Lined hooktail, is a species of dragonfly in the family Gomphidae. It is a widespread species. The habitat of this fly is poorly known although it does include open, sluggish and changes with seasons. *Paragomphus lineatus* is widespread in northern India and Nepal and occurs west to the Turkish Mediterranean coast.

### **Pantala flavescens**

*Pantala flavescens*, the globe skimmer, globe wanderer or wandering glider, is a wide-ranging dragonfly of the family *Libellulidae*. This species and *Pantala hymenaea*, the "spot-winged glider", are the only members of the genus *Pantala* from the subfamily *Pantalinae*. It was first described by Fabricius in 1798. Sexual dimorphism is evident. Male has narrow apical brown spot at the hind border of wings. Female lacks apical brown patches in wings. The dragonfly is up to 4.5 cm long. The front side of the head is yellowish to reddish. The thorax is usually yellow to golden colored with a dark line and hairy. The wings are clear and very broad at the base. There are some specimens with olive, brown and yellow wings. On Easter Island, there are wandering gliders with black wings. The pterostigma turns yellowish. The transparent wings may turn a yellowish shade towards the tip. The chestnut-red eyes take up most of the head, as is usual in the large dragonflies.

### **Rhyothemis variegata**

*Rhyothemis variegata*, known as the common picture wing or variegated flutterer, is a species of dragonfly of the family *Libellulidae*. It breeds in marshes, ponds and paddy fields. They appear to have weak flight and can easily be mistaken for butterflies. The species is widely distributed from India to Japan. The species is found in ponds, lakes, reservoirs, marshes, paddyfields, irrigation canals etc.

### **Junonia atlites**

*Junonia atlites*, the gray pansy, is a species of nymphalid butterfly found in South Asia. Upper side of both sexes is pale lavender brown, apical half of wings paler. Females are larger in size, bodies grey above and white beneath. In females, the markings are heavier and distinct, the space between the various transverse fasciae tinged with ochraceous. Forewing:



Cell with, three transverse, short, sinuous black bands. Hindwing: a short slender black loop from veins 6 to 4 at apex of cell-area. Larvae feed on *Asteracantha longifolia*, *Alternanthera philoxeroides*, *Barleria*, *Hygrophila lancea* and *Hygrophila salicifolia*.

### **Acraea terpsicore**

*Acraea terpsicore*, the tawny coster, is a small, 53–64 millimetres (2.1–2.5 inch), leathery, winged butterfly which is common in grassland and shrub habitats. It belongs to the Family *Nymphalidae* or brush-footed butterfly family. It has a weak fluttery flight. It is avoided by most insect predators because of the reason stated elsewhere. This species and the yellow coster (*Acraea issoria*) are the only two Indian representatives of the predominantly African tribe *Acraeini*.

This species does not fly high, but seems to keep within 3 m of the ground and tends to rest on vegetation in the regions of a meter off the ground. *Acraea terpsicore* can be seen in abundance wherever its larval food plant (*Passiflora* sp.) is found. The adult tends to avoid dense undergrowth and shady areas, instead keeping open spaces associated with all types of vegetation.

The adult flies slowly with weak seemingly unsteady wing beats. It is one of the boldest butterflies, protected from predators by a nauseous chemical. When attacked, it plays dead and exudes an obnoxious yellowish fluid from glands in the joints of the legs. Like all butterflies *Acraea terpsicore* has a tough exoskeleton, which enables the adult to survive a few pecks of a bird or even the bites of a lizard. Once left alone, the adult immediately takes off and resumes its uncaring flight.

### **Acraea terpsicore fabricius**

When feeding on flowers, this butterfly is unhurried, often spending a long time sitting on the same flower. When sitting, it either spreads its wings or closes them over its back; the hindwings covering the forewings to a large extent. Sometimes the butterfly will not sit, but rest gently on the flower while feeding, while doing this, to maintain balance; it beats only its forewings while keeping the hindwings completely steady.

### **Pachliopta aristolochiae**

*Pachliopta aristolochiae* (the common rose) is a swallowtail butterfly belonging to the *Pachliopta* genus, the roses, or red-bodied swallowtails. It is a common butterfly which is

extensively distributed across South and Southeast Asia. Females are similar to the males; they differ from the male only in the comparatively broader wings and this is most conspicuous in the forewing. It is the commonest of the large-tailed butterflies of India. The red body, slow peculiar flight, bright colouration and specific pattern of the wings are meant to indicate to predators that this butterfly is inedible, being well protected by the poisons it has sequestered from its larval food plant. It also emits a nasty smelling substance when handled to further enhance its unappealing qualities. Hence, it is rarely attacked by predators, a strategy so successful, that edible butterflies have evolved to mimic it, the classic example being that of the female morph of the common Mormon that is *Papilio polytes*.

The common rose frequently visits flowers such as Lantana, Cosmos, Zinnia, Jatropha and Clerodendron. The butterfly occasionally also visits wet patches. In parts of Sri Lanka, the males are known to congregate and form a beautiful sight while mud-puddling.

### **Neptis hylas**

*Neptis hylas*, the common sailer, is a species of nymphalid butterfly found in the Indian subcontinent and South-East Asia. It has a characteristic stiff gliding flight achieved by short and shallow wing beats just above the horizontal.

Dry-season form-Upperside black, with pure white markings. Forewing discoidal streak clavate (club shaped), apically truncate, subapically either notched or sometimes indistinctly divided; triangular spot beyond broad, well defined, acute at apex, but not elongate; discal series of spots separate, not connate (united), each about twice as long as broad; postdiscal transverse series of small spots incomplete, but some are always present. Hindwing: Sub basal band of even or nearly oven width; discal and sub terminal pale lines obscure; postdiscal series of spots well separated, quadrate or sub quadrate, very seldom narrow. Underside from pale golden ochraceous to dark ochraceous almost chocolate; white markings as on the upperside, but broader and defined in black. Forewing: Interspaces from base to near the apex shaded with black, some narrow transverse white markings on either side of the transverse postdiscal series of small spots. Hindwing a streak of white on costal margin at base, a more slender white streak below it; the discal and subterminal pale lines of the upperside replaced by narrow white lines with still narrower margins of black. Antennae, head, thorax and abdomen black; the palpi, thorax and abdomen beneath dusky white. Wet- season form - Differs only in the narrowness of the white markings and in the slightly darker ground colour and broader black margins to the spots and bands on the underside.

### **Zizula hylax**

This is one of the smallest butterflies in the world. The extent of the blue areas in the wings of the female is variable, and sometimes it is nearly absent. The flight is weak and fluttery, when the butterflies flying close to the ground, usually near their host plants. Interestingly, when at rest this butterfly moves its hindwings sideways rather than alternately up and down in a scissor-like motion. Due to its small size it is easily overlooked in the field.

### **Amata passalis**

*Amata passalis*, a defoliator of sandalwood in India, is also known to occur on various other host plants (e.g. cowpeas and various other pulses, and ornamental plants). The species completes its life cycle in  $62.94 \pm 1.78$  days with 8 larval instars. First and last instar larvae measure  $1.97 \pm 0.06$  mm and  $29.29 \pm 2.52$  mm in length, respectively. Adults emerge within 1-2 hours of sunrise and are ready for mating a day after. A fertilized female lays an average  $305.68 \pm 122.30$  eggs in a lifespan of  $3.87 \pm 0.89$  days. The species breeds throughout the year and passes through 6-11 generations a year. *Amata passalis* is a species of moth of the family Erebidae, found in Sri Lanka and India.

### **Pseudocoladenia dan**

*Pseudocoladenia dan*, commonly known as Sahyadri Fulvous Pied Flat, is a butterfly belonging to the family *Hesperiidae*. Wings above are rufous-brown; anterior wing with four discal grayish white spots, posterior wing with discal and outer marginal dark fasciae. Body and legs are more or less concolorous with wings.

### **Praying mantis**

Mantises are an order (*Mantodea*) of insects that contains over 2,400 species in about 430 genera in 15 families. They have triangular heads with bulging eyes supported on flexible necks. Their elongated bodies may or may not have wings, but all *Mantodea* have forelegs that are greatly enlarged and adapted for catching and gripping prey; their upright posture, while remaining stationary with forearms folded, has led to the common name 'Praying mantis'.

Mantises are mostly ambush predators, but a few ground-dwelling species are found actively pursuing their prey. They normally live for about an year. In cooler climates, the

adults lay eggs in autumn, then die. The eggs are protected by their hard capsules and hatch in the spring. Females sometimes practice sexual cannibalism, eating their mates after copulation.

As their hunting relies heavily on vision, mantises are primarily diurnal. They both camouflage themselves and remain stationary, waiting for prey to approach, or stalk their prey with slow, stealthy movements.

### **Pyrrhocoris apterus**

The firebug, *Pyrrhocoris apterus*, is a common insect of the family *Pyrrhocoridae*. Easily recognizable due to its striking red and black coloration, but may be confused with the similarly coloured but unrelated *Corizus hyoscyami* (cinnamon bug, squash bug). Firebugs generally mate in April and May. Their diet consists primarily of seeds from lime trees and mallows. They can often be found in groups near the base of lime tree trunks, on the sunny side. They can be seen in tandem formation when mating which can take from 12 hours up to 7 days.

### **Oecophylla smaragdina**

*Oecophylla smaragdina* has a widespread distribution in tropical Asia and Australia, its range extending from India through Indonesia and the Philippines to Northern Territory and Queensland in Australia. It is an arboreal species, making its nests among the foliage of trees.

Weaver ants of this species are important parts of the ecosystem in tree canopies in humid tropical regions. The nests of this species are constructed by the workers, with leaves being woven together and secured by silk produced by the larvae. First, a row of ants line up along the edge of a green leaf and, grasping a nearby leaf, pull the two leaves together, edge to edge. Other workers on the far side of the leaves, each carrying a larva in its mouth, apply the tips of the abdomens of the larvae to each leaf edge in turn. This produces a suture of fine silken threads that secures the leaves together. More leaves are attached in a similar manner to enlarge the nest. Weaver ants feed on insects and other invertebrates, their prey being mainly beetles, flies and hymenopterans. They do not sting, but have a painful bite into which they can secrete irritant chemicals from their abdomens.

### **Cyrtophora moluccensis**

*Cyrtophora moluccensis* is a tent-web spider in the orb-weaver family. It is often found in disturbed or open habitats from coasts to forest and mountainous interiors. The abdomen is high and the anterior end overhangs the cephalothorax. It can be distinguished from similar species by the two tubercles on its abdomen, its elaborate pattern, and, in females, the shape of the median septum of the epigyne. In males, the embolus of the pedipalp is enclosed within the conductor. Females and immature spiders are yellow to green in color. Webs built by *Cyrtophora* species are different than typical webs built by orb-weavers. The orb web is built horizontally with a finely meshed dome or bowl shape, hence the name "tent-web spider". The non-sticky spiral is left intact and webs are without a sticky spiral. These webs are durable, sometimes lasting several weeks, so they don't need to be remade every day like the webs of most spiders.

Webs can be either solitary or colonial, though even in groups, each web is defended by its owner. Colonial groups can cover an area of fifteen meters squared and include over four hundred individuals, including fifty adults. Young spiders will often build their nests within the space of that of their parent's. Webs of this spider have also been known to be host to *Argyrodus miniaceus* or young spiders of other species. The spiders often live in loose colonies where the webs may not be joined, but are often built very close each other. The spiders mostly hang in the bottom of the web, upside down. Egg sacs are strung above the dome. The male is much smaller than the female.

### **Gasteracantha geminate**

*Gasteracantha geminata* is a species of spider of the genus *Gasteracantha*, found in India and Sri Lanka. It is known as the oriental spiny orb-weaver. Rather than possessing sexual dimorphism, both male and female have black and white transverse bands on the abdomen. Abdomen has three pairs of long stout lateral spines. The female of the species is characterized by having a highly sclerotized "spiny" abdomen, which is a common feature of the genus. Female also has varying numbers of sigillae in both dorsal and ventral abdominal surfaces. Male is somewhat smaller than the female and with lesser coloration and abdominal spines. The oriental spiny orb-weaver constructs vertical orb webs, normally within open spaces between the branches of tall shrubs and thorns.

### ***Oxyopes* sp.**

*Oxyopes* is a genus of lynx spiders found worldwide. It includes around 300 species and is classified under the lynx spider family *Oxyopidae*. Like other lynx spiders, they are easily recognizable by the six larger eyes arranged hexagonally on top of the head (prosoma), with the remaining smaller two eyes in front. They are also characterized by long spine-like bristles (setae) on their legs. They are ambush predators, actively hunting prey by sight. Though they produce and use silk, they do not build webs to capture prey. The generic name means "keen-eyed", Lynx spider is the common name for any member of the family *Oxyopidae*. Most species make little use of webs, instead spending their lives as hunting spiders on plants. They tend to tolerate members of their own species more than most spiders do, and at least one species has been identified as exhibiting social behaviour. Lynx spiders, in spite of being largely ambush hunters, are very speedy runners and leapers, alert and with good vision. Except when defending egg purses, many tend to flee rapidly when approached by predators or large creatures such as humans. They tend not to be very aggressive towards other members of their own species, and sometimes meet casually in small groups. Possibly as an extreme example, at least one member of the genus *Tapinillus* is remarkable as being one of the few social spiders, living in colonies with communal feeding, cooperative brood care, and generational overlap.

### ***Tetragnatha viridorufa***

It belongs to family *Tetragnathidae*. This is a nocturnal spider but instead of frequenting water it spins its webs among bushes in the jungle. It can be easily distinguished in field by the bright green of its lateral sides and reddish brown on the dorsum of abdomen. The characteristic colouration makes it well camouflaged in the leaves.

### ***Cassidula* sp.**

*Cassidula* sp. is a genus of small air breathing salt marsh snails, pulmonate molluscs in the family *Ellaboiidae*. These are mainly seen on mangrove trees. Shell opening resembles an ear. It grazes on algae growing on mangrove trees and on the ground. Shell is thick oval, plain dark and underside with white or pale rim and mouth at the shell opening.

### ***Dostia violacea***

It is a species of intertidal grazing gastropod with rounded globose shell and semi-circular calcified operculum. This species is diadromous. Their larvae hatch in fresh water

and then migrate to saltwater where it grow to maturity and again it migrate back to fresh water stream where it was born. It is recognized from below by the orange flaved aperture and the dorsal surface is a well camouflaged mottle brown.

### **Haminoea sp.**

They are tiny nondescript snails often seen in groups. It is more active at nights. The body of snail can be expanded to be much larger. Some release a sticky purple secretion when disturbed. It has a shield over the front of the body which is used to plough through sediments. It has no operculum and no tentacles. It grazes on algae.

### **Littoraria sp.**

They are well adapted to terrestrial life and are most of the time out of water. However young ones are released into the sea either in egg capsules or in swimming larvae. It lives on leaves and trunks of mangrove trees grazing on the leaf hair and epilithic algae. Some are common on walls at monsoon rains.

### **Metopograpsus messor**

*Metopograpsus messor* is a species of crab that lives in mangroves. It grows up to 30 millimetres (1.2 inch) wide. The carapace and legs are mottled brownish green, while the claws are brownish red. *M. messor* lives in mangroves (including *Avicennia marina* and *Sonneratia alba*), as well as on rocky shores. It lives under rotting wood, and is capable of climbing trees. Its common name is shore crab.

### **Neopisesarma (Selatium) brockii**

This species of crab is one of the few tree-dwelling mangrove crabs on Earth. They are found usually in holes of tree trunks and will come out of their hiding palce during the night time to feed. By hiding and feeding at night, they reduce the chance of being eaten by hungry predators such as fishes, snakes or birds. Their nocturnal activity is one of the methods for reducing desiccation.

### **Nerita sp.**

The thick shell is broadly ovate or globular and low-spired. It has a smooth surface. The shells are spirally ribbed or show some axial *sculpturing*. *They have a distinctive smooth and polished shell, up to 4 cm, smooth columella with 2-4 weak teeth on the edge. Colour*

variable, mottled grey, red or cream, sometimes with axial bands. Operculum smooth and creamy to black. Littoral fringe of rocky shores is the habitat.

### **Sesarmops sp.**

This is a common brachyuran crab found in the mangrove ecosystems. Carapace mostly smooth, sparsely covered in short hairs broader than long. Frontal area between the eyes is deeply excavated with upper and lower margins projecting forward. Dorsal surface of carapace and limbs are mainly dark purple. Ventral surface is pale creamy yellow.

### **Uca annulies**

They are commonly called as porcelain fiddler crab. The most striking feature of this species is the enlarged pincers of the males, which may be used for courtship. There is a wide gap between the fingers and the movable upper finger is curved inward at the tip and it extends past the immovable lower finger. Colour of carapace is black with white or yellow stripes and is in the shape of sub-quadrilateral with moderately convergent lateral borders.

### ***Avian diversity***

Diversity study revealed the occurrence of major wetland birds such as Little Egrets, Cattle Egrets, Purple Heron, Grey Heron, White breasted Water hen, Little Cormorants, Brown Headed Gull, Black Headed Gull, Eurasian Moorhen, Pacific Golden Plover and Wood Sandpiper and Lesser Whistling Duck etc. Most of these are migratory birds from Eurasia region and Himalaya region and their migratory pattern proves that this mangrove habitat is one of the important destinations of the migratory birds in Kerala.

The survey result shows the Puduveypu mangrove region is a natural habitat of Indian python which, is a highly arboreal snake, once common throughout the jungles of India is now listed in CITES Appendix I.

### **Australian white ibis *Threskiornis molucca* (Cuvier, 1829)**

Kingdom	:	Animalia
Phylum	:	Chordata
Class	:	Aves
Order	:	Pelecaniformes
Family	:	<i>Threskiornithidae</i>
Subfamily	:	<i>Threskionithinae</i>



Genus : *Threskiornis*  
Species : *T. moluccus*

### ***Species description***

The Australian White Ibis is identified by its almost entirely white body plumage and black head and neck. The head is featherless and its black bill is long and down-curved. During the breeding season the small patch of skin on the under-surface of the wing changes from dull pink to dark scarlet. Adult birds have a tuft of cream plumes on the base of the neck. Females differ from males by being slightly smaller, with shorter bills. Young birds are similar to adults, but have the neck covered with black feathers. In flight, flocks of Australian White Ibis form distinctive V-shaped flight patterns. Another common name for this bird is Sacred Ibis, but this more appropriately refers to a closely related African species.

### **Snowy Egret *Egretta thula* Molina, 1782**

Order : *Ciconiiformes*  
Family : *Ardeidae*  
Genus : *Egretta*

*Egretta thula* is a member of the Order *Ciconiiformes* (Hérons and storks) which encompasses the long-necked wading birds. The Family *Ardea* includes the herons, egrets, bitterns, etc. *E. thula* is a medium sized egret whose body color is entirely white. It has a thin black bill, and black legs which have a yellow stripe posteriorly. A major distinguishing feature of this species is its bright yellow feet, which are used to startle prey while feeding. When in breeding plumage, thin, wispy plumes grow along the neck, breast and back. Those growing on the back turn outward at the tail, while plumes on the breast and neck remain straight. *Egretta thula* grows to approximately 20 - 24 inches, with a wingspan of 38 inches. These are medium-sized herons with long, thin legs and long, slender, bills. Their long, thin neck sets the small head well away from the body.

Adult Snowy Egrets are all white with a black bill, black legs, and yellow feet. They have a patch of yellow skin at the base of the bill. Immature Snowy Egrets have duller, greenish legs.

## Grey heron *Ardea cinerea* Linnaeus, 1758

### *Species description*

Grey herons are comparable in size to great blue herons (*Ardea herodias*) of North America. Body length in grey herons typically ranges from 84 to 102 cm. Like all “great herons” (*Ardea* sp.), grey herons are fairly large birds. In contrast, other genera of herons (Family *Ardeidae*), such as pond herons (*Ardeola* sp.), rarely exceed average body lengths of 49 cm. Body weight of grey herons typically ranges from 0.226 to 1.36 kg. This species exhibits a distinct arched wing when flying, with a wingspan of 155 to 175 cm. (Dharmakumarsinhji, 1957; Hancock, *et al.*, 1984; Mullarney, *et al.*, 2009; Peterson, *et al.*, 1967)

As their common name suggests, grey herons have predominantly grey plumage covering their wings, dorsum, and most of the neck. Subspecies *Ardea cinerea monicae* is distinguished by its lighter plumage and shorter crest. In all grey heron adults, the head is white with long black feathers that extend from the eyes to the beginning of the neck, forming a large, impressive crest. Juveniles retain a dark crown of grey feathers into their first winter, after which they begin to develop the white forehead and distinctive black crest; typical of adults. Grey herons have yellow bills through most of the year, but these acquire an orange tint during the breeding season. As with other herons (Family *Ardeidae*), grey herons fly with their head pulled back toward the body while keeping their legs extended behind them. This body positioning during flight distinguishes herons from cranes (Family *Gruidae*), which fly with their neck extended. (Arlott, 2009; Hancock, *et al.*, 1984; Mullarney, *et al.*, 2009; Peterson, *et al.*, 1967)

### *Food habits*

Grey herons feed on a wide range of prey items but are primarily piscivores. In addition to fish (Class *Actinopterygii*), their diet consists of insects (Class *Insecta*), crustaceans (Subphylum *Crustacea*), frogs (Class *Amphibia*) and small mammals. They sometimes even ingest tiny birds. Recent studies have documented grey herons attempting to prey upon and consume white-throated rails (*Dryomnas cuvieri aldabranus*). This is the largest bird species upon which grey herons attempt to prey. While it is not clear how often grey herons succeed in feeding on rails, injuries have been noted after feeding attempts. (MacGillivray, 1852; Pistorius, 2008)

To locate food, grey herons wade through shallow water or move on land. They are thought to be most successful in capturing prey in the moonlight. Usually, these herons stand still and wait for prey to approach in the water. They capture prey with their bills and generally swallow it whole, in one swift gulping action. Like other herons (*Ardea* sp.), grey herons in deeper water typically stand still on one foot and wait, sometimes for extended periods of time, for potential prey to swim near. (MacGillivray, 1852; Pistorius, 2008)

**Purple heron (*Ardea purpurea*) Linnaeus, 1766**

Order : Pelecaniformes  
Family : *Ardeidae* (Herons)

**Little Gull, *Hydrocoloeus minutus* (Pallas, 1776)**

Order : Charadriiformes  
Family : *Laridae*

The Little Gull is the smallest gull. It has light gray wings; pale underwings; white shoulders, neck, underparts; little bill; red legs. Breeding has black hood. Nonbreeding has residual black spots on head.

This is the smallest gull species, with a length of 25–30 cm (9.8–11.8 in), a wingspan of 61–78 cm (24–31 in), and a mass of 68–162 g (2.4–5.7 oz). It is pale grey in breeding plumage with a black hood, dark underwings and often a pinkish flush on the breast. In winter, the head goes white apart from a darker cap and eye-spot. The bill is thin and black and the legs dark red. The flight on rounded wings is somewhat tern-like. After breeding usually gathers in small flocks, occasionally in large groups of thousands,

**Eastern Great Egret *Ardea modesta* (John Edward Gray, 1831)**

***Species description***

The Great Egret's overall plumage is white, and, for most of the year, when not breeding, the bill and facial skin are yellow. The feet are dark olive-grey or sooty black, as are the legs. During the breeding season, the bill turns mostly black and the facial skin becomes green. Also at this time, long hair-like feathers (nuptial plumes) hang across the lower back, and the legs become pinkish-yellow at the top. Young Great Egrets are similar to the adults, but have a blackish tip to the bill.

### ***Habitat***

Great Egrets prefer shallow water, particularly when flowing, but may be seen on any watered area, including damp grasslands. Great Egrets can be seen alone or in small flocks, often with other egret species, and roost at night in groups.

### ***Feeding***

The Great Egret usually feeds alone. It feeds on molluscs, amphibians, aquatic insects, small reptiles, crustaceans and occasionally other small animals, but fish make up the bulk of its diet. The Great Egret usually hunts in water, wading through the shallows, or standing motionless before stabbing at prey. Birds have also been seen taking prey while in flight.

### ***Breeding***

The Great Egret breeds in colonies, and often in association with cormorants, ibises and other egrets. Both sexes construct the nest, which is a large platform of sticks, placed in a tree over the water. The previous years' nest may often be re-used. Both sexes also incubate the eggs and care for the young (usually two or three).

### **Little black cormorant (*Phalacrocorax sulcirostris*)**

Kingdom	:	Animalia
Phylum	:	Chordata
Class	:	Aves
Order	:	Pelecaniformes
Family	:	<i>Phalacrocoracidae</i>
Genus	:	<i>Phalacrocorax</i>

### ***Description***

It is a small, slender and elegant water bird; the little black cormorant (*Phalacrocorax sulcirostris*) has black or brownish-black plumage, which is covered in a dull, green gloss. The feathers of the back and wings are grey, and are accentuated by dark edges, giving the little black cormorant a scalloped appearance.

During the breeding season, breeding adults differ from non-breeding individuals in having narrow white markings over the eyes and on the head, and a more bronze-washed sheen. Non-breeding adults are generally duller. There is no visible difference in plumage

colouration between the sexes, and juveniles are similar in appearance to the adults but tend to be both duller and browner.

The little black cormorant has dark facial skin, except for the skin around the eyes and the patch joining the lower part of the beak to the neck which is strongly tinged with blue. This species has a long, thin, lead-grey bill, green eyes and black feet.

**Blue-tailed bee-eater *Merops philippinus* Linnaeus, 1766**

Order : Coraciiformes  
Family : *Meropidae*  
Genus : *Merops*  
Species : *M. philippinus*

**Indian spotted eagle *Clanga hastata* (Lesson, 1834)**

Family : *Accipitridae*  
Genus : *Aquila*  
Species : *A. hastata*

Indian Spotted Eagles are medium-sized, brown eagles that occur in Pakistan, India, and parts of Southeast Asia.

***Species description***

Indian Spotted Eagles are entirely brown with contrasting wing coverts and flight feathers. The gape-flange—the fleshy area where the mandibles meet—is large and extends out to the centre of the eye. The wings and tail are short, and the head is large relative to body size. Their call is a high-pitched cackle.

Length : 65 cm  
Wingspan : 154-168 cm

***Habitat and distribution***

They live in wetlands, open forest, forest clearings, and cultivated areas. They are fairly tame and have been observed perching in paddyfields and even urban parks. Their range spans from Pakistan, northern India, and Bhutan to Bangladesh, Myanmar, and Cambodia. Indian Spotted Eagles are non-migratory. There are approximately 2,500-9,999 individuals across 1,260,000 km<sup>2</sup>.

### ***Diet and Hunting:***

Most of their diet is mammals, which are caught on the ground. They also eat frogs and birds.

### ***Reproduction***

Breeding displays consist of "wing-winnowing" (where the wings are raised at a sharp angle), "heart dives" (which is when they pull back their wings into a so-called heart shape), and looping flight. The breeding season is from March-May.

The nest is a flat platform placed in the fork of a tree. It is built mainly by the female, though males will sometimes bring sticks to the nest site. Clutch size is 1-2 eggs, usually 1, and both the female and the male incubate it for at least 31 days. Fledging takes around 71 days.

### **Brahminy kite (*Haliastur indus*) (Boddaert, 1783)**

Kingdom	:	Animalia
Phylum	:	Chordata
Class	:	Aves
Order	:	Falconiformes
Family	:	<i>Accipitridae</i>
Genus	:	<i>Haliastur</i>

With its sharply contrasting plumage, the widespread Brahminy kite is an unmistakable bird of prey. While its head, neck, throat, upper belly, and flanks are generally white, the rest of the body, including the wing coverts, thighs and tail, is largely bright chestnut. The only conspicuous exceptions are the black outer flight feathers and the white tipped tail. The sexes are similar in appearance but while there is some overlap in size, females tend on average to be slightly larger than the males. Juvenile Brahminy kites are various shades of brown, with darker upperparts and a lighter head and under parts. Four subspecies, occupying different ranges and differing slightly in appearance, are currently recognised: *Haliastur indus indus*, *H. i. intermedius*, *H. i. girrenera* and *H. i. flavirostris*.

Also known as Chestnut-white kite, red-backed kite, rufous eagle, rufous-backed kite, white and red eagle-kite, white-headed fish eagle, white-headed kite, and white-headed sea-eagle.

### ***Species description***

Size: Brahminy Kites measure about 18 - 20 inches (45 - 51 cm) in length, and have a wingspan of 3.6 - 4.1 feet (109 - 124 cm). They weigh between 11.3 - 24 oz (320 - 670 g). The females tend to be slightly larger than the males.

Plumage Details / Adults: This kite has a sharply contrasting plumage; with a mostly bright chestnut body, except for white head, neck, throat, upper belly and flanks; a white-tipped tail and black outer flight feathers.

### **10. Trial on Pokkali cultivation**

Pokkali is a unique saline tolerant rice variety that is cultivated in the water logged coastal regions of Kerala. The brand “Pokkali” has received a GI tag from the Geographical Indications Registry Office, Chennai. It is a saline tolerant variety even though it is cultivated from June to early November when the salinity level of the water in the fields is low. It is a variety grows up to 130-140 cm height. The organically grown Pokkali is farmed for its peculiar taste and its high protein content. It is a system of integrated farming, which does not affect the natural ecological processes. This system does not require any external inputs (Kerala State Biodiversity Board,2009). Vypin is one of the area where Pokkali farming is prevailing still along with the prawn farming. As part of the mangrove integrated fish culture experiment, Pokkali trial cultivation was done at Fisheries Station, Puduveypu. As part of the experiment, paddy shoots procured from Rice Research Station, Vyttila were planted in the 15 cents of land area with mangroves trees all around. After 35 days, formation of panicles were observed. The cultivation had to be abandoned as there was less inflow of water to the field due to severe siltation and blockage.

### **11. Mangrove based crab cultivation trial**

Rapid urban development has put enormous pressure on the coastal ecosystems, leading to degradation and destruction of the ecosystem especially mangroves. In early days, mangroves were considered as a beneficial plant group due to the extensive utilization of the same for wood, fodder, tanin and honey extraction. The common men used these areas for fishing too. But later on, while the population increased there appeared the problem of land shortage for living and developmental activities. So the attitude of people towards mangroves changed drastically, which made them believe that mangrove is a menace. The lack of awareness on the ecological benefits of mangroves also catalized to ascertain this belief

system even among the educated communities. Fortunately, nowadays the attitude is slowly getting improved owing to the mangrove protection rules and the conservation efforts by various organizations including Department of Forests, Universities and NGOs.

As part of finding out the attitude of people, special surveys and awareness programmes were conducted during the project period. The data from the survey revealed that many fishermen are aware about the importance of these species for the coastal protection and fisheries enhancement. “We have come to realize that “kandal” (the vernacular name of Mangrove) forms a very important link in the marine food chain and helps recycle nutrients in coastal waters,” Mrs. Leela, a fisherwoman in her mid-50s who lives at South Puduveyppu expressed her view. Another fisherman, Mr. Velayudhan (67) of Malippuram, also shared similar thoughts that “Mangroves are important nursery and feeding habitats for many marine and coastal species and a major source of food and income for us indirectly. Now we are getting reduced catches because of the vast destruction of mangroves around us in the recent past”.

In Vypin, fishing villages are generally located in the fringes of arable land along coastal plains and the people are dependent on fishing as a source of income. This region is rich with the presence of large areas of tidal flats with existing mangroves. To utilize the aquaculture potential of these mangrove areas, a feasibility study was conducted using mud crab as a candidate species for integrating with mangroves. This was conceptualized to introduce this system as an alternative livelihood means for the fishermen in the village. Mud crab or green crab (*Scylla serrata*) has always been a sought after sea food item in the market both domestically and internationally. Usually, the villagers are collecting the crabs from the crab holes in the mangrove mud flat, which has been a major revenue source for them since long. The method adopted for Mangrove integrated crab farming was pen culture method in existing water body surrounded by mangroves, maintaining the tidal water flow to the area.

An extent of 20 cents was selected in the mangrove ecosystem of the Fisheries Station. The rearing system was designed in such a way that, it allowed inundation during the high tides. Bunds were raised and strengthened to minimize siltation and ensure retention of the required water depth. The present study was undertaken to determine the performance of the mud crab, *Scylla serrata* in this type of rearing system. The stocking density was 1/m<sup>2</sup>. The natural food available in the mangrove area was the major food item for the crabs. Whenever, there was availability of trash fish, it was also given in small quantities. The bund was covered with silpauline sheets to avoid the climbing and escape of crabs. The outer



boundary of the area was covered with iron mesh for further protection. The bottom part of the mesh was buried to the soil upto 20 cm and the inner side of the upper portion of the mesh was curved inward to protect the crab. Lateral trenches with greater depth levels were provided to accommodate the crabs even in low tides. The experimental set-up used to get flooded during high tides. Drain canals inside the system allowed draining of the area to avoid continuous submergence of mangrove roots. Whenever the trash fish was given, the crabs were fed 10% of the biomass daily when the carapace length was  $\leq 6$  cm and 5% when  $\geq 6$  cm, with 40% of the daily feed ration given at morning and 60% at evening hours. Culture duration was for six months. From the economic point of view, the study showed that mud crab culture in tidal flats with existing mangroves is a viable aqua-mangrove integrated farming method, if the crop is properly monitored and maintained.

## **12. Tapping the indigenous knowledge on mangroves**

As part of the project, a survey was conducted among the local community residing around the Fisheries Station to assess the attitude of the people on the conservation of mangroves. The major objective of this survey was to assess the knowledge level of local inhabitants on the ecosystem services of mangroves and their perception on mangrove conservation. To have a firsthand estimate about the overall public knowledge on mangrove habitat, a questionnaire survey was carried out with the help of 25 Kudumbasree Groups (bonafide groups formed under the women empowerment programme by the State Poverty Eradication Mission (SPEM) of the Government of Kerala). Altogether 1966 people were surveyed under the programme. The questions used for the survey were both semi-structured and open ended, which helped to derive qualitative and quantitative information (Guba and Lincoln, 1994). The data were collected on many aspects including: 1. Personal information 2. Economic activities 3. Awareness regarding the ecological services of mangroves. 4. Knowledge level on the nearest mangrove ecosystem 5. Attitude towards conservation and developmental issues. Descriptive statistics was used to summarize the data.

## **13. Attitude of local inhabitants towards mangrove ecosystem**

Among the respondents, 52.4% were under 26 to 35 years of age group and 34.4 % respondents were in the age group of 36 to 45 years. The comparatively young respondents (15-25 years old) were less in number (6.2%) and the elderly adults (50-70 years old) participated in the survey were constituted 7.8%. According to the survey, all the respondents were literate and had exposure at least to the primary level. 59.4% had completed their

graduation, while the highest level of education was Post Graduation (21.6 %). Daily labour (52.9%) and small scale business (47.1%) were the major livelihood agenda for the local communities. The average land holding size was about 4 to 20 cents. Families which have the land area of more than 40 cents were very less. The average monthly income of the respondents ranged between Rs. 5000/- and Rs. 9000/-.The data showed that all the households had mangrove plants in their premises. Ample percentage of the households (65.3%) had high density of mangrove plants with more than one species in their premises. 51.9% of the respondents had reported that they have already heard about the benefits of mangrove ecosystem. Though, only 4.9% of them were well versed about the mangrove ecosystem near their premises. In general, the respondents were not much skilful in identifying mangrove plants from other coastal vegetation. Among the total respondents, 39.7% felt that mangrove vegetation nearby their premises is a nuisance to them as it restricts the developmental activities. It is also noted that, the people living near the mangrove ecosystem of Puduveyypu were not directly using these plants in their day to day life. But the elderly people reported that, they had used mangroves as fire wood and for house construction in their early ages.

#### **14. Awareness programmes**

##### ***“Mangroups”***

As part of the awareness programmes, 5 groups of school children were formed in the name of “Mangroups” selected from 5 Vocational Higher Secondary Schools situated in Thevara, Arthunkal, Njarakkal, Kadamakkudy and Kaipamangalam in and around Kochi. Each group comprised of 5 plus one students with one parent and teacher each. This group mainly focused to spread the ecological importance of mangroves among the school children and local people in the respective localities.

##### ***Mangrove festival***

As part of the project, the Fisheries Station conducted a grand Mangrove festival in the name of “Kandal Mahotsavam” in association with Central Marine Fisheries Research Institute (C.M.F.R.I.), Central Institute of Fisheries Technology (C.I.F.T.), Cochin Shipyard and Indian Science Congress Association (I.S.C.A.) Cochin Chapter. Around 1200 students from 20 schools and 3 colleges in and around the city participated in the festival.

The festival was inaugurated by Dr. A. Ramachandran, Hon'ble Vice Chancellor, KUFOS in presence of Sri. S. Sharma, Hon'ble MLA, Vypin Constituency; Dr. Bransdon S. Corrie, IFS., Director, Kerala Forest Research Institute; Prof. (Dr.) K. Padmakumar, Pro- Vice Chancellor, KUFOS; Dr. V.M. Victor George, Registrar, KUFOS; Dr. K.V Jayachandran, Director of Research, KUFOS; Dr. K.S. Purushan, Former Dean, College of Fisheries, Panangad and Dr. V.J. Dominic, Controller of Examinations, Sacred Heart College, Thevara. The event was planned on behalf of the mangrove projects operated at Fisheries Station funded by the Government of India and Government of Kerala under the Principal Investigator-ship of Dr. K. Dinesh, Associate Professor and Head of the Station.

The festival witnessed lectures and orientation classes on Mangroves by renowned experts like Dr. V.J. Dominic, Sacred Heart College, Thevara, Sri. K. K. Reghuraj, KUFOS, Sri. V.K. Madhusoodanan, Mangrove expert from Kollam, Dr. P. Sujanapal, Senior Scientist, Kerala Forest Research Institute and Sri. Martin Lowel, Assistant Conservator of Forest, Government of Kerala.

In the closing ceremony, five scientists (Dr. K.S. Purushan, Former Dean, College of Fisheries, Panangad, Dr. Jayasree Vadhyar, Former Professor, College of Fisheries, Panangad, Dr. I.S. Bright Singh, Former Professor, Cochin University of Science and Technology, Dr. Bransdon S. Corrie, Director, Kerala Forest Research Institute and Sri. V.K. Madhusoodanan, renowned environmentalist) and ten fisher folk from Puduveypu locality (Mrs. Sarasa Sathyan, Mrs. Vilasini Lakshmanan, Mrs. Valsala Karthikeyan, Mrs. Sarasa Ponnappan, Mrs. Radha Prabhakaran, Mrs. Sarasa Babu, Sri. Kumaran Bava, Sri. Suresh and Sri. Kunjappan and Sri. Ravi M.K.) were duly honored by Prof. (Dr.) A. Ramachandran, Hon'ble Vice Chancellor, KUFOS.

The exhibition elucidating the socioeconomic importance of mangroves and traditional fishing gears was the major attraction of the event. Classes on mangroves and environmental protection were also conducted by various eminent scientists and subject matter specialists. Drawing and quiz competition on ecological importance of mangroves were also carried out. The event was a big success in terms of participation of students and involvement of subject area experts.

### *Seminar on best management practices in aquaculture*

As part of the project, KUFOS organized a One- Day international seminar on “Recent Trends in Best Management Practices of Aquaculture” on 25<sup>th</sup> November, 2017 at KUFOS in association with Centre of Excellence in Sustainable Aquaculture and Aquatic Animal Health Management, KUFOS in association with Science and Engineering Research Board, Department of Science and Technology, Government of India, National Academy of Agricultural Science (NAAS) Kochi Chapter and World Aquaculture Society Asian Pacific Chapter. The seminar was awe- inspiring with the outstanding presentations and talks of world renowned dignitaries in the field of fisheries ecosystem and aquaculture. The Hon’ ble Vice Chancellor of Kerala University of Fisheries and Ocean Studies Prof. (Dr.) A. Ramachandran officially inaugurated the programme along with the graceful presence of all the dignitaries including Prof. (Dr.) K. Padmakumar, Pro Vice Chancellor, KUFOS, Dr.

V.M. Victor George, Registrar, KUFOS, Dr. R. Sankar, Director of Research, KUFOS, Dr. M. S. Raju, Dean, Faculty of Fisheries, KUFOS, Sri. Joby V George, Finance Officer, KUFOS, Dr. K. Gopakumar, Professor of Eminence, KUFOS, Dr. Daisy C Kappen, Director of Extension, KUFOS, Dr. K.V. Jayachandran, President, I.S.C.A. Cochin Chapter (Former Director of Research, KUFOS), Dr. Riji John (Professor, College of Fisheries, Tuticorin), Dr. B. Manoj Kumar, KUFOS, Dr. Devika Pillai, KUFOS, Dr. I. S. Bright Singh, Cochin University of Science and Technology, Dr. Meryl J Williams, World Fish Centre, Australia, Dr. Yew Hu Chien, National Taiwan Ocean University, Taiwan, Dr. Sagiv Kolkowski, Government of Australia, Dr. M. Harikrishnan, CUSAT, Dr. Mark Watson, Design Thinking, Australia and Dr. P. Anil Kumar, Marine Products Export Development Authority, Kochi.

The major recommendations put forward by the experts were, implementation of strict regulations in 1. Design and construction of farms 2. Minimizing the impact of water usage 3. Responsible use of broodstock and postlarvae 4. Efficient use of feeds and feed management 5. Good health management 6. Ensure environmental and social responsibility. The session also identified that, there is a considerable need for research and farm trials related to environmentally safe aquaculture production. It was also recommended that, due importance should be given to develop species specific best management practices for new aquatic species.

### ***Awareness classes***

The Station has been the authorized training centre for vocational higher secondary students and farmers since long. During the training period in the Station, they are also provided with the subject based classes and identification programmes related to mangroves.

We organized a one day awareness programme on 9th January, 2017 at Kadamakkudy Panchayath as per the request from the Principal of G.V.H.S.S. Kadamakkudy and brought out a highly rich data of floral and faunal diversity of the area with special reference to mangroves.

The project team visited the Department of Environmental Science, Calicut University to study about the mangrove afforestation methods successfully adopted by the University to further popularize this technology. Dr. K. Dinesh, Principal Investigator of the project participated in the Biodiversity seminar organized by the Department of Environmental Science, Calicut University and gave a presentation on the ecological importance of Mangrove ecosystem with special reference to its social and economical significance.

### **15. Afforestation programmes**

The project team planted thousands of mangrove saplings around the premises of the Station with the help of students and farmers as part of the World environment day celebrations and Global Wetland day celebrations organized in a befitting manner. The species used for afforestation were *Rhizophora mucronata* and *Bruguiera gymnorhiza*.

The project team is maintaining a mangrove germplasm conservation centre and nursery in association with Fisheries Station, Puduveypu to supply the saplings to the Government projects and private agencies to support the mangrove afforestation programmes organized and funded by the Department of Forests and Wild Life, Government of Kerala. The Station hitherto supplied more than 5 lakhs seedlings to various mangrove afforestation projects.

The Germplasm conservation centre of Fisheries Station, Puduveypu consists of species which are not indigenous to Cochin mangrove ecosystem. The centre is also protecting the species *Xylocarpus granatum* procured from Andaman and Nicobar islands.

## 16. Detailed analysis of results indicating contributions made towards increasing the state of knowledge in the subject

### *Mangrove diversity*

According to the data collected from the survey it was noticed that the diversity of mangrove species in the mangrove habitat of Puduveypu is limited to 8 species. Among these, two or three species show richness in abundance. One of the most abundant species in this area is *Avicennia officinalis* followed by other species like *Bruguiera cylindrica*, *Rhizophora mucronata* and *Bruguiera gymnorrhiza*. It was reported that the growth and distribution of mangroves are determined by various ecological factors like salinity, tidal inflow, wind, sediment supply etc. Among these factors, salinity condition of the soil, ground water and running water play critical role in determining the diversity, biomass and productivity of mangrove wetlands which always rely upon the quantity and periodicity of fresh water inflow. Mangroves are generally known as the plant groups that are capable of tolerating saline conditions. Though, many observations and studies show that these plant groups can tolerate salinity upto 90%, for attaining growth they prefer low salinity levels. Experiments showed that the optimal soil salinity for the growth of mangroves ranges from 10‰ to 20‰. Obviously, the growth rate falls by at least 50% with an increase in salinity from 20‰ to 35‰. It is mainly due to the high rate of iron transport to the shoot of the mangrove plant which gets saturated and as a result, shoot growth continues only with a lesser rate. Similarly, the rate of photosynthesis also low in high salinity due to high water loss through leaves, which create water imbalances in the leaves. Studies show that *Avicennia* spp. have high level of salinity tolerance range, which is 0‰ to 35‰. This clearly explains why the mangrove habitat of Puduveypu is rich with *Avicennia officinalis*. The hydrology studies conducted in the Puduveypu water show that the salinity variation in the RMP canal ranges from 5ppt to 35 ppt. This water inlet receives high flow of freshwater during monsoon apart from the sea water intake through Cochin bar mouth. The species diversity of the various sites away from the RMP canal is comprised of low salinity tolerant species like *Bruguiera*. Soil texture and particle size also affect the distribution and nature of mangrove diversity. Generally, mangroves prefer two types of soils, sandy and muddy soils. Sandy soil is formed by the accumulation of sediments from coastal or river bank erosion. Sediments transported from inland areas alongwith the rivers and canals provide fine mud too. It is noted that *Avicennia* spp. prefer sandy conditions which will be the reason for the abundance of *Avicennia officinalis* with maximum basal are (2.875 m<sup>2</sup> / 100 m<sup>2</sup>) along the banks of RMP

canal which receives sandy soils from sea. *Rhizophora* spp. prefer muddy or sandy/muddy conditions which may be reason why this species is prevalent in the area near the ponds.

Erosion was another issue observed during the study, which was particularly affected the seaward portion of the banks of RMP canal. It is alarming to note that the area under mangrove distribution has been found reduced compared to the previous data and it will become a matter of concern in next future.

## **17. Conclusions summarising the achievements and indication of scope for future work**

Salt marshes are among the most important ecosystems on earth which are distributed worldwide along the coastlines in the middle and high latitudes. They are generally found near river mouths, in bays, on protected coastal plains and lagoons. These ecosystems are dominated by different plant groups in different regions. In tropical and sub tropical regions, mangroves are the dominant plant groups along the salt marsh areas. These plant groups include halophytic trees, shrub and other plants which can grow in brackish to saline tidal waters. Mangrove plants are rich in terms of diversity with seventy taxonomically different trees, shrubs and ferns (Tomlinson,1986). These plant groups have several physiological and morphological adaptations like prop roots, drop roots, pneumatophores, viviparous seedlings, salt secreting glands etc. to survive in high salinity, harsh weather and anoxic soil conditions. Mangrove forests are differentiated into four major categories based on their hydrogeomorphology. They are 1) Fringe mangroves 2) Riverine mangroves 3) Basin mangroves and 4) Dwarf mangroves which are basically shrub mangroves. Mangroves provide many ecological services which are not yet understood fully. They have high productivity which is estimated as  $218 \pm 72$  teragrams  $^{-1}$  C yr $^{-1}$  (Bouillon *et al.*, 2008). Mangrove swamps are important exporters of organic materials to the estuaries. Mangroves have much higher rate of Carbon sequestration than the terrestrial up land forests and the recent meta estimates of mangrove carbon sequestration is  $160 \pm 40$  g  $^{-1}$  C m $^{-2}$  yr $^{-1}$  to  $226 \pm 39$  g  $^{-1}$  C m $^{-2}$  yr $^{-1}$  (Mcleod *et al.*, 2011). Another most cited ecosystem function of mangrove forest is that they are the major source of food for estuarine fisheries. Studies conducted on the organic fluxes in the mangrove habitat show that mangrove production is important for the carbon budget of the adjacent estuary and to the microbial food chains. The detrial export of mangroves is important for sport and commercial fisheries in estuaries (Odum,1970). It is noted that wind and waves are rapidly reducing as they pass through mangroves which can reduce the damage during coastal storms and Tsunamis. The dense and

tangled roots of mangroves help to bind and build soils which can prevent coastal erosion. This soil build up ability of mangroves can increase the surface soil and cop up with sea level rise. The word mangrove comes from the Portuguese word “mangue” and English word “grove” which both refer to groups of plant. The geological extent of world mangroves usually found in between 25° S to 25° N latitude. Mangroves are not seen in cold climate regions. It is noted that more than half of the world mangroves found in the latitudinal belts between 0° and 10°. According to the global distribution pattern studies, the mangrove ecosystems can be divided into Old World mangrove swamps and the New World and West African mangrove swamps (Chapman,1976). It is estimated that around 138000 to 170000 km<sup>2</sup> mangrove wetlands are found throughout the world (Giri *et al.*,2011). It is noted that Indian subcontinent accommodates 7% of these world mangroves (Krishnamoorthy *et al.*, 1987). Major portion of the Indian mangrove forests are distributed along the East Coast of India (Chapman, 1976). The four major Indian deltas those hold mangrove vegetations are Sunderbans of Ganges in Bengal, Mahanadi of Orissa, Godavari and Krishna mangroves of Andhra Pradesh Cauvery deltas of Tamilnadu and Andaman and Nicobar Islands (Blasco, 1977). Kerala, one of the maritime States of India with a coastline of 590 km which is more than 7% of the country’s total coast line holds only less than 1% of mangrove forest of the country. Earlier data on the mangrove distribution of the region shows Kerala had a rich account on mangrove habitat of 700 km<sup>2</sup> which has been decreased into 17 km<sup>2</sup> recently. Kannur district of Northern Kerala accommodates maximum extent of mangroves in Kerala. Another mangrove destination of Kerala is Cochin backwaters area and is one of the areas where huge destruction of mangroves happened within the period of last 50 years. The latest report from State Wetlands Inventory has included Puduveypu as one among the fastest depleting wetlands in Kerala. The mangrove habitat of Puduveypu has come down from 314 acres to 185 acres over the last five years. The massive reclamation of land for various infrastructure project, LNG terminal and urbanization led to the depletion of the area’s mangrove habitat. This area also faces the reduction in the availability of fish seeds and many brackish water fishes. The area also faces issues related to land erosion and sea invasion. The present study aimed to have a look into the mangrove extent of South Puduveypu which was once flourished with rich mangrove habitat and fishery. The current project was planned on a vision to protect this depleting mangrove ecosystem of Puduveypu through continuous awareness among the local inhabitants and afforestation programmes of relevance. The other major objectives of the project were to have a biodiversity study and also to find out the ability of mangrove ecosystem in environment protection.



## **18. S&T benefits accrued**

- a. The ecology, biodiversity and social benefits of mangrove ecosystem of Cochin were extensively studied.
- b. Could bring out a biodiversity map of the area with special reference to mangroves and the associated flora and fauna.
- c. Ecological benefits of mangroves were studied and disseminated to the public, students and stakeholders.
- d. The role of mangroves on enhancing the fishery and aquaculture was studied and disseminated to the needy.
- e. Many trials linking with mangroves and livelihood enhancement were tried.
- f. Awareness programmes were conducted extensively to pass on the message of mangrove conservation.
- g. “ManGroups” for protecting the mangroves including school children were formed.
- h. Helped to cultivate a better attitude among the locals about the mangrove conservation by educating them about the ecological benefits of this plant group.
- i. Organized a Mangrove Festival which was first of its kind in the history of Kerala inviting attention of the scientific fraternity and the public.
- j. Mangrove afforestation was done in many areas to improve the ecology of the regions under study.
- k. Cooperated with the Government agencies, private agencies and NGOs for mangrove afforestation.
- l. Could bring out papers, presentations and literature on the subject for creating mass awareness on mangroves.

## **19. Manpower trained on the project**

- |   |   |                      |
|---|---|----------------------|
| i. Research Scientists or Research Associates | : | 2                    |
| ii. No. of Ph.D. produced                     | : | Nil                  |
| iii. Other Technical Personnel trained        | : | Farmers and students |

**20. Patents taken, if any : No**

**21. Financial Position: (see annexure)**

b) Plans for utilising the equipment facilities in future: The equipments procured in the project were handed over to the University for Research and education of the students.

Name and Signature with Date

a. \_\_\_\_\_

(Principal Investigator)

**Table 1**

<b>Water Quality Parameters of Puduveyppu Mangrove area</b>			
<b>Parameters</b>	<b>Pre monsoon</b>	<b>Monsoon</b>	<b>Post monsoon</b>
Salinity (ppt)	26.2± 4.6	3.2± 3.8	15.2± 5.9
pH	7.4± 0.8	7.0± 0.1	8.5± 0.1
Dissolved Oxygen (mg L <sup>-1</sup> )	5.2± 0.9	6.1± 0.1	5.6± 1.2
Alkalinity (mg/l)	261.2± 8.1	400.1± 0.1	93± 2.3
Water Temperature (°C)	31.2± 4.6	26.2± 4.6	28.2± 2.0

**Table 2**

<b>Level of Knowledge of Kudumbasree Members on the Ecological Importance of Mangroves</b>						
<b>Sl. No</b>	<b>Name of Group</b>		<b>Name of Members</b>	<b>Level of Knowledge</b>		
				<b>Very Good</b>	<b>Good</b>	<b>Poor</b>
1	Manimithu	1	Shemitha Thanzeer			*
		2	Anitha Anzar		*	
		3	Sunitha Navas			*
		4	Shamsudheen			*
		5	Asma Junaid			*
		6	Liji Arunkumar		*	
		7	Sanooja Anas			*
		8	Shameera Ashkar			*
		9	Ansila Aneesh			*
		10	Sunhara Bheevi			*
		11	Farisa Sudheer			*
		12	Sajana Nissam			*
		13	Subaida Kunjachu			*
2	Nanma	1	Aarifa K.A.			*
		2	Rinsila K.A.			*
		3	Shamladharar			*
		4	Ansila Lanin			*
		5	Saajitha P.K.			*
		6	Shabna			*
		7	Faumi.A.A.			*
		8	Keerthi Sumesh			*
3	Nirmalyam	1	Shakeela			*
		2	Fasila			*
		3	Alice			*
		4	Nejuma			*
		5	Shaji.T.M.			*
		6	Reghu Raman			*
		7	Rafeek			*
		8	Naufal			*

		9	Haneef			*
		10	Pushpan K.G.			*
4	Manjima	1	Raneesh N.I.		*	
		2	Sulekha Muhammed		*	
		3	Sunitha Sudheer			*
		4	Noorji Ummar		*	
		5	Ubaid Muhammed		*	
		6	Sainaba Abhu			*
		7	Nazar		*	
		8	Sabiya Jalal			*
		9	Aisha Bheevi		*	
		10	Siyaadh		*	
		11	Raneesh Sadhaam			*
		12	Reshma Babu			*
5	Vandhanam	1	Sulekha Sivadhas			*
		2	Ajith P.K.	*		
		3	Shivan K.S.			*
		4	Sarojini Chandran		*	
		5	Girija Krishnankutty			*
		6	Hilan K.S.			*
		7	Muraleedharan T.R.		*	
		8	Shantha Paramu			*
		9	Sabu			*
		10	Vanaja Sadhan			*
6	Geethanjali	1	Shahina Kabheer			*
		2	Haseena Rahim			*
		3	Salin Husain			*
		4	Saleem			*
		5	Shakeela Navas			*
		6	Shareena Rafeek			*
		7	Nasara Nissam			*
		8	Rasina Shajahan			*
		9	Seenath Rafeek			*
		10	Nasira Faisal			*
		11	T.K. Rukhiya			*
7	Snehanjali	1	Noufal N.H. Fousi			*
		2	Rahnas Naseer			*
		3	Naseema			*
		4	Sabeena Samadh			*
		5	Sunitha Ajib			*
		6	Bushara Hamsakoya			*
		7	Jasmi Shameera			*
		8	Fasila Shamsudheen			*
		9	Usha Sivan			*

		10	Mani Ravi			*
8	Thriveni	1	Ramlath P.K.			*
		2	Munthas Yunas			*
		3	Rani Halsath			*
		4	Sabu Noushad			*
		5	Najma Subair			*
		6	Ramlath Ismail			*
		7	Suhara Shaheer			*
		8	Haseena			*
		9	Jasmi Abu			*
		10	Seenath Riyas			*
		11	Nabeesa Kamarudheen			*
		12	Rasiya Shamsu			*
		13	Shahitha Shakeer			*
		14	Manila Sukumaran			*
		15	Prema Gopi			*
		16	JoJo			*
9	Saraswathi	1	Leela K.A.		*	
		2	Khadeeja Saleem		*	
		3	Laila			*
		4	Geeji Sugathan		*	
		5	Rajani		*	
		6	Kavitha Sajeevan		*	
		7	Bindhu Roy			*
		8	Mahitha			*
		9	Asha Babu			*
		10	Rema A.K.	*		
		11	Renuka Shaji			*
10	Sayoojyam	1	Santhosh			*
		2	Leela.P			*
		3	Joshy			*
		4	Thankappan			*
		5	Unnikrishnan			*
		6	Salin George			*
		7	M.S.Joseph			*
		8	Antony			*
		9	Arjunan			*
		10	Jessy			*
		11	Joy.T.A.			*
		12	Mary Michael			*
		13	Eashamma			*
		14	Salin Osho			*
		15	Pushpavalli Sidharthan			*

		16	K.S.Vipinan			*
		17	Charlie.T.R.			*
		18	Sudha Vasu			*
		19	Antony			*

**Table 3**

Abundance and Species Diversity of Puduveyyu Mangroves																				
Sl. No	Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	<i>Aegiceras corniculatum</i>	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	<i>Avicennia marina</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	<i>Avicennia officinalis</i>	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	3	3	2	3
	<i>Bruguiera cylindrica</i>	5	5	5	5	5	1	1	2	0	0	1	1	4	4	4	4	5	5	4
	<i>Bruguiera gymnorrhiza</i>	0	0	0	0	1	4	0	0	0	5	3	3	4	5	5	5	5	5	5
	<i>Bruguiera sexangula</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	<i>Excoecaria agallocha</i>	0	0	0	0	0	0	0	0	0	0	0	0	4	3	3	4	5	5	5
	<i>Kandelia candel</i>	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0
	<i>Rhizophora apiculata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	<i>Rhizophora mucronata</i>	4	4	4	4	5	5	5	5	5	5	0	0	0	1	1	3	5	5	5
	<i>Sonneratia alba</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	1	0	0	0
	<i>Sonneratia caseolaris</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	1	0	1	0
	<i>Xylocarpus granatum</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0

**Table 4: Distribution of respondents based on their knowledge and perception on mangrove ecosystem**

	(Total No.- 1966)	A	B	C
Sl. No.	Area of knowledge	Good understanding	Heard about/ want to know more	No knowledge/ want to know more
1	Ecological services of mangrove ecosystem	148 (7.5%)	1046.5 (53.2)	662 (33%)
2	I know my mangrove ecosystem	97.23 (4.9%)	1004.5(51.9)	781 (39.7%)
3	I am familiar with the local names of the species	0	1004.5(51.9)	148 (7.5)
4	I can differentiate mangroves from other plant groups.	97.23 (4.9%)	761 (38.7%)	1024.5(52.0)

**Table 5: Distribution of respondents by their demographic profile**

	Total No. 1966		
Sl. No.	Demographic profile	Number of respondents	Percentage (%)
I	Age (years)		
1	15 – 25	122	6.2
2	26 - 35	1032	52.4
3	36- 45	678	34.4
4	50- 70	134	6.8
II	Education		
1	Upto primary	43	2.1
2	High school	328	16.6
3	Graduation	1169	59.4
4	Post Graduation	426	21.6
III	Family annual income (Rs.)		
1	50,000- 70,000	62	20.6
2	70,000- 90,000	146	48.6
3	90,000- and above	92	30.6
IV	Average land holdings		
1	Upto 10 cents	182	60
2	10 to 20 cents	56	18.6
3	20 to 50 cents	46	15.3
4	Above 50 cents	16	5.3
V	Mangroves in the premises		
1	Low density	92	30.6
2	Medium density	196	65.3
3	High density	12	4

# Awareness programmes

Students from various institutions





## BIODIVERSITY STUDY





*ATTITUDE SURVEY*









*Mangrove festival*



STUDY ON SALINITY TOLERANCE OF MANGROVES

