TECHNICAL REPORT

Habitat Assessment of Mangalavanam Bird Sanctuary, Kerala

Submitted to

Kerala Forest & Wildlife Department

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Acknowledgments

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Project Team

1.0 Preamble

The Kerala Forest and Wildlife Department through the letter DO No. WL 4-424/ 12 dated 22nd May 2013 requested Sálim Ali Centre for Ornithology and Natural History (SACON) to carry out a study regarding the ecological status of the Mangalavanam Bird Sanctuary. As per the letter, the genesis of this assignment was from the reported fact that the Sanctuary in the past attracted large number of birds both migratory and residents. They used to roost and nest in the mangrove area and nevertheless in the recent years there has been a sharp decline in arrival of many migratory birds. Among many reasons attributed, it was thought that the developmental activities taking place in and around the sanctuary and the siltation which has taken place in the water body depleting the fish population are the two major reasons for the presumed less visit of the avifauna especially migratory birds.

The Advisory Committee on Mangalavanam Bird Sanctuary in its meeting held on 16.05.2013 has recommended getting a study done by SACON on this issue and suggests remedial measures including the need and scope for desilting the water body. Accordingly, the following tasks were assigned to SACON as part of the study,

- examine the factors that adversely impacted in the Mangalavanam Bird Sanctuary
- suggest short term and long term measures to restore the bird population

Accordingly studies on the above mentioned tasks were carried out by a multidisciplinary team of scientists from SACON and the results and recommendations are presented in this report.

2.0 Description of the Area

Mangalavanam, often hailed as the green lung of Kochi-Ernakulam urban conglomerate has been declared as a bird sanctuary in 2004. The Sanctuary (MBS) with an area of 2.74 ha of wetlands with mangrove vegetation is an excellent habitat for many resident and migratory birds over the years Figure 1). Geographically, it is located at 9°59' 13" North and of 76°16' 26" East at very close to sea level with flat topography and located very near to the Vembanad lake, one of the Ramasar sites in the State, and it inflows in to the sanctuary during high tide through a canal. North and east of the sanctuary are marked by the land owned by M/s Bharat Petroleum ltd. and south by Ernakulam railway goods station (not operational now) and Kerala High Court and west

by Sálim Ali road and Central Marine Fisheries Research Institute. The wetland area is a shallow pond with high frequency of reflex system on diurnal basis occupying part of the PA with its periphery covered by dense growth of mangrove vegetation.

The sanctuary experiences both southwest and north east monsoon and distinct summer. Monsoon starts from the beginning of May and leads to mid-November and the summer season continue from December to end of May. The average rainfall ranging from 300-400 cm and rainy days extends up to 130-140 days. The temperature ranges from 20-35° C.

Vegetation of the area is characterized by mangrove formation flanked withnon mangrove species which are mostly planted over the years. The mangroves are dominated by *Rhizophora mucronata, Avicennia officinalis,* and *Acanthus ilicifolilus.* Some of the mangrove associates include *Derris trifoliata, Morinda citrifolia*and *Acrostichum aureum.* The species planted that contributed more to the canopy

cover of the sanctuary are*Mangifera indica, Tectona grandis, Polyalthia longifolia, Terminalia catappa, Caryota urens, Ceiba pentandra*, *Azadirachta indica*, *Samania saman, Hydnocarpus alpine, Ficus gibbosa, Pongamia pinnata.*. Other common species found in the area includes *Alternanthera* triandra, *Eclipta alba, Hygrophilla auriculata,* and*Tinospora cordifolia* and many medicinal herbs which are planted for creating awareness on conservation.

Considering the size of the PA, the diversity of fauna is significantly high (Jayson and Easa 1999; Azeez et al 2004). Large number of birds both wetland and others visits the sanctuary. Azeez et al (2004) reported 17 species of butterflies, two species of amphibians, five species of reptiles, 62 species of birds and two species of mammals. Among the mammals, a large colony of fruit bat (*Funambulus sublineatus*) is found in the PA which is one of the major attractions for the local people including students. The sanctuary is visited by many local people including students and the PA managers conduct regular nature awareness camps for the school children.

The strategic location of MBS in Kochi, the commercial capital of Keralaand also denoted as Queen of the Arabian Sea andGateway of South India makes the study area significant in several respects. It is one of the small coastal Protected Areas of the State where large number of nesting and roosting of wetland birds took place in the past and a large colony of flying fox is present. The mangrove vegetation is significant for the association of many aquatic life including fish, shell fish, crustacean, reptiles, mammals, hydrophytes, other invertebrates and roosting and breeding birds almost encircled urban conglomerations. The proximity to many educational institutions and presence of many tourism and other recreational areas in the vicinity of MBA makes this as an excellent opportunity to conductnature awareness programmes. This tidal influenced sanctuary often acts as a sink of garbage and sewage for certain parts of the city.

3.0 Approach and Methods

Considering the logistics and time available for the assignment, primary data collection was carried out only for the environmental parameters such as water and sediment, and on birds existing information (both published and unpublished) were used. However, the composition of waterbirds is known to change with season with the influx of migrants in winter and heronry is also highly seasonal. In view of this, we attempted to analyze the population trends of only the waterbirds and species richness for all the birds reported from here.

3.1 Birds

A cumulative table of all the bird species recorded by various studies (Jayson and Easa 1999; Azeez et al. 2004; Azeez and Bhupathy 2006; and Nameer et al. 2009, 2011, 2012, & 2013)in the past was created. After a thorough and critical review, species which are doubtful being insufficiently documented or plain improbable for the area were removed from the analysis. These include bird species like Collared Kingfisher, Brown-headed Barbet, White-eared Bulbul, Little Spiderhunter, and White Wagtail. Though Mangalavanam with its mangrove vegetation and tidal lake is particularly known for the waterbirds, it encompasses other habitats as well on which several bird species, notably, the passerines, depend on for their survival. These habitats obviously have little in common with regard to their structure and seasonality; it then follows that avifauna of these habitats have to be studied separately for a better understanding of the increasing impacts of habitat deterioration on birds. We classified the birds of Mangalavanam into six groups on the basis of their habitats/habits:

i) Waterbirds: Species that use the water and aquatic vegetation as their prime nesting, foraging, or roosting sites. Include waterfowl, waders, and other aquatic avifauna.
ii) Wetland-dependent birds: Normally terrestrial bird species which are either directly or indirectly dependent on waterbodies and their vegetation for foraging. Include taxa like kingfishers, swallows, and wagtails.
iii) Woodland birds: Species that are restricted to woodlands including overgrown mangrove trees and other arboreal vegetation surrounding the waterbody. Include a large number of passerines and near-passerines.
iv) Understorey birds: Birds, which normally frequent the dense undergrowth and shrubbery occurring on both land and edges of water. Typical birds are prinias, tailorbirds, and some warblers.
v) Open-habitat birds: Birds of open places including openings in woodland, built-up areas, roads, open shore, and air. May include taxa like pigeons, bee-eaters, swifts, crows, sparrows, and other human-associated species.
vi) Raptors: Though raptors do not form a habitat-based class on its own, they are nevertheless treated separately here as their numbers and distribution are governed by common ecological parameters.

Similarly, the birds were classified into different foraging guilds with respect to predominant food habits (following Ali & Ripley, 1978). In total, 13 guilds were identified on the basis of the range of food items in the main diet of each species including aquatic vegetation, seeds and grains, fruits, nectar, terrestrial and aquatic organisms, fishes and insects.

3.2 Environmental Parameters

During the reconnaissance survey, it was observed that both organic and inorganic municipal waste, industrial waste and solid waste from different sources are entering to the sanctuary. Different samples related to environmental components, i.e. water, sediment, planktons were collected following standard field methods. Information on phyto-and zoo-planktons will be baseline for the area since there are no earlier records available. The samples were divided into sub-samples and sanctuary was divided into different sampling locations, and the details are given below (Table 1).The glasswares were acid-treated to remove any sort of contamination. All the chemicals used were of analytical grade and the reagents were prepared in deionized water.

3.2.1 Identifying and defining the study points:

The sanctuary area was divided into different segments based on the nature / likelihood of contamination,thus, the sampling points were decided so as to have representativeness of samples from the MBS. Within the sanctuary, totally five sampling points were identified (Figure 1). The inlet water as feeder canal (the connection with the Vembanad lake), untreated inflow of sewage from the municipal corporation, effluents from the small industry also considered as separate sampling points. All the sampling points were marked with a handheld GPS and geo-coordinates were recorded (Table 1).

MV1- Inside the sanctuary near watch tower; MV2- Inlet point of the sanctuary; MV3- Near railway godown; MV4- Near boundry wall in the last of the sanctuary; MV5- Vembanad lake; MV6- Effluent from Matashya feed Pvt. Ltd.; MV7- Inside the sanctuary water middle point; MV8- Inside the sanctuary water middle point; MV9- Low tide sewage mixing point

Fig 1: Location map of sampling points selected in MBS

Table 1: Details of sampling locations in MBS

S.N	Sampling site	Geo-coordinates	Sample type		Sediment layer (cm)
			Water	Soil	
1.	Inside the sanctuary (near watch tower)	09° 59' 19" N 76° 16' 23" E	MV1	MVS1	0-20
			--		20-40
			--		40-60
2.	Inlet point of the sanctuary	09° 59' 15" N 76° 16' 23" E	MV2	MVS2	0-20
			--		20-40
3.	Near railway godown	09° 59' 19" N 76° 16' 27" E	MV3	MVS3	0-20
			--		20-40
4.	Near boundary wall in the last of the sanctuary	09° 59' 21" N 76° 16' 23" E	MV4	MVS4	0-20
			--		20-40
			--		40-60
5.	Vembanad backwaters	09° 59' 10" N 76° 16' 18" E	MV5	--	NA
6.	Effluent from Matashya feed Pvt. Ltd.	09° 59' 11" N 76° 16' 21" E	MV6	--	NA
7.	Inside the sanctuary (middle point)	09° 59' 21" N 76° 16' 26" E	MV7	MVS7	0-20
			--		20-40
			--		40-60
8.	Sewage mixing point (high-tide)	09° 59' 21" N 76° 16' 26" E	MV8	--	NA
9.	Sewage mixing point (low-tide)		MV9	--	NA
NA: No sediment core was collected					

3.2.2 Water sampling and analysis:

Surface water samples were collected in pre-treated plastic containers, and immediately transferred in an ice box for further processing and analysis. All the water samples were acidified, labeled, coded and stored at 4°C until further laboratory analysis. pH, EC, TDS, Salinity were measured at the site using respective handheld meters. Other water quality parameters were measured following APHA (1992) in triplicates.

3.2.3 Sediment sampling and analysis:

Bed sediment samples (composite) were collected using PVC core sampler (L: 200 cm, D: 05 cm) from the designated locations. The sediment samples were divided into 20 cm segments to study the nutrient composition with respect to depth of the sediment profile. The sediment samples were dried at room temperature, homogenized in a porcelain mortar and pestle, and sieved through a mesh of 2mm size, and stored in acid treated plastic containers for further laboratory analysis. The bottom sediment samples (in triplicate) were processed in the laboratory following standard protocols and data analysis.

3.2.4 Plankton collection and identification:

Plankton (phyto- and zoo-plankton) samples were collected during the initiation of low tide to overcome the influence of high tide and to estimate the true composition of the planktons in MBS. The plankton samples were taken from inlet area of MBS by filtering 150 litres of water through conical plankton net made of nylon bolting cloth having a mesh size of 40 μ, and preserved using 4% formaldehyde.The sample was made up to 10 ml, an aliquot of 1 ml was taken in a counting chamber for identification under a binocular microscope and different groups of planktons were identified using standard keys.

4.0 Results and Discussions

4.1. Birds

4.1.1 Species Richness

In total, 95 species of birds belonging to 15 Orders and 42 Families were found to have been reliably recorded from Mangalavanam [Annexure 1). Of these, 69 species are residents, 13 are local migrants, and another 13 species are winter visitors (Figure 2). The much-acclaimed heronry that Mangalavanam used to host was formed by two species of waterbirds: Black-crowned Night Heron and Little Cormorant. Hundreds of them were known to nest within the precincts of the sanctuary in the last decade. However, their numbers have dwindled drastically to nearly nil in the last couple of years.

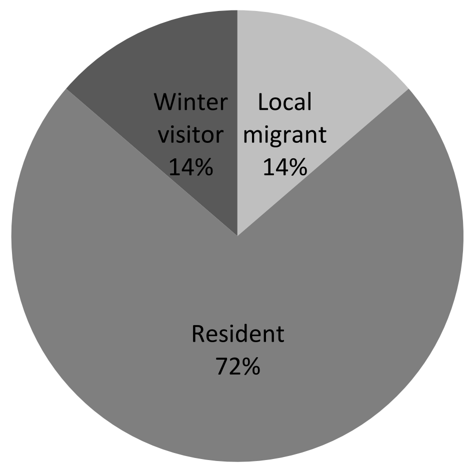

Fig 2: Composition of birds of Mangalavanam with respect to their residency status

With regard to habitats, woodland birds followed by waterbirds form the majority of the sanctuary's avifauna and raptors constitute nearly 7% of the bird species diversity (Figure 3). Though the sanctuary is known for its mangrove vegetation, 21.species of open country avifauna are also recorded from the area probably in response to growing urbanization around the sanctuary.

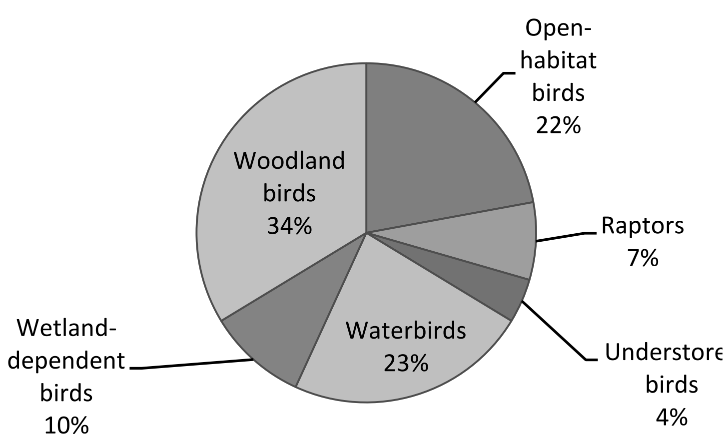

Fig 3. Habitat-wise composition of birds in Mangalavanam

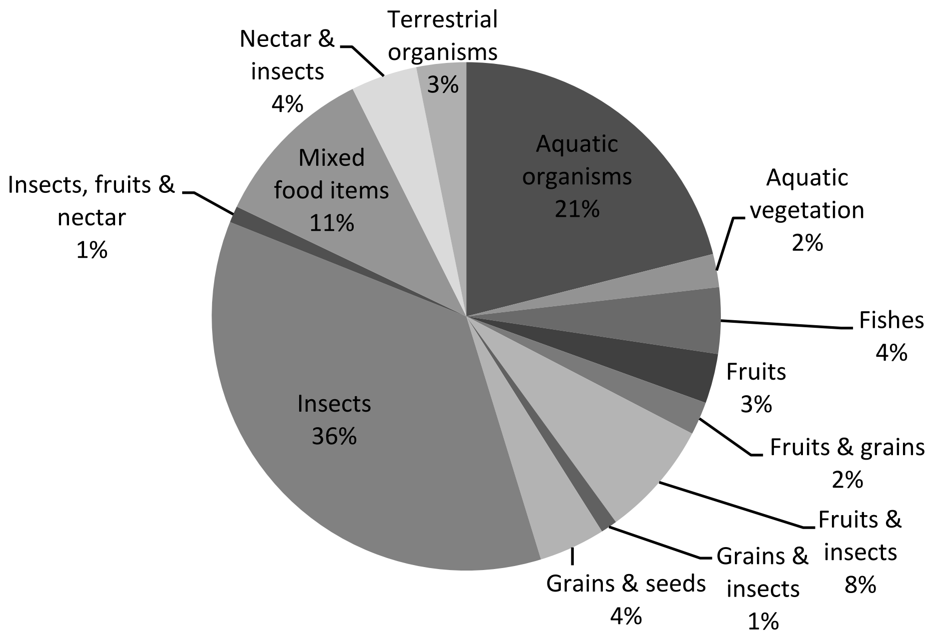

Fig 4. Foraging guilds in birds of Mangalavanam

Our analysis of foraging habits of the birds indicates that insectivores are the predominant guild closely followed by birds that feed on aquatic invertebrates (Figure 4). The importance of fishes as keystone taxa in Mangalavanam is reflected in the presence of four exclusively piscivorous birds;interestingly, at least 14 species have fruits in their mainstay of diet, an indication of the significance of Ficus and other fruit-yielding vegetation in and around the sanctuary. 10 species are omnivorous with mixed food habits (Figure 4).

4.1.2 Trends in bird species richness (1999-2013)

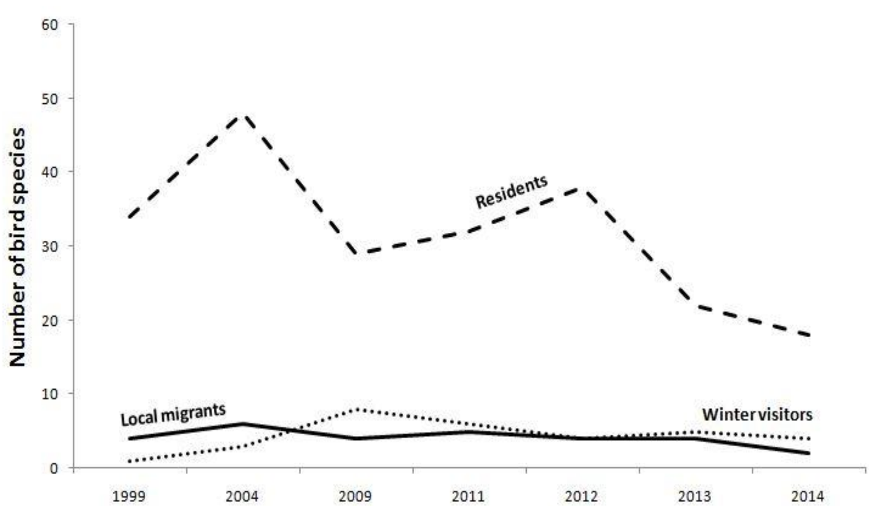

Fig 5. Trends in species richness of birds of Mangalavanam (1999-2013)

Among the Sanctuary's avifauna, the number of species of both local migrants and winter visitors remain more or less stable through the reporting period, but number of resident species has been on decline particularly after 2012 (Figure 5). But this could also be a sampling issue as actual number of species of local migrants and winter visitors recorded from Mangalavanamis much lower compared to the resident birds.

In other words, it is possible that the former two categories of birds, may show disproportionate decrease in population size (if not in the number of species, which is anyway too small to have any significant decline). The fact that the resident birds showed a marked decrease in their species richness after 2010 would also infer that the proverbial breaking-point for habitat deterioration in the PA was likely of more recent origin.

A habitat-wise analysis of the trends in number of species occurring in Mangalavanam during 1999-2014 offers interesting observations (Figure 6).

Among the three major habitat groups, it was the open-habitat birds that showed remarkable decline in species richness; it concurs with our studied opinion that mangrove vegetation is undergoing a

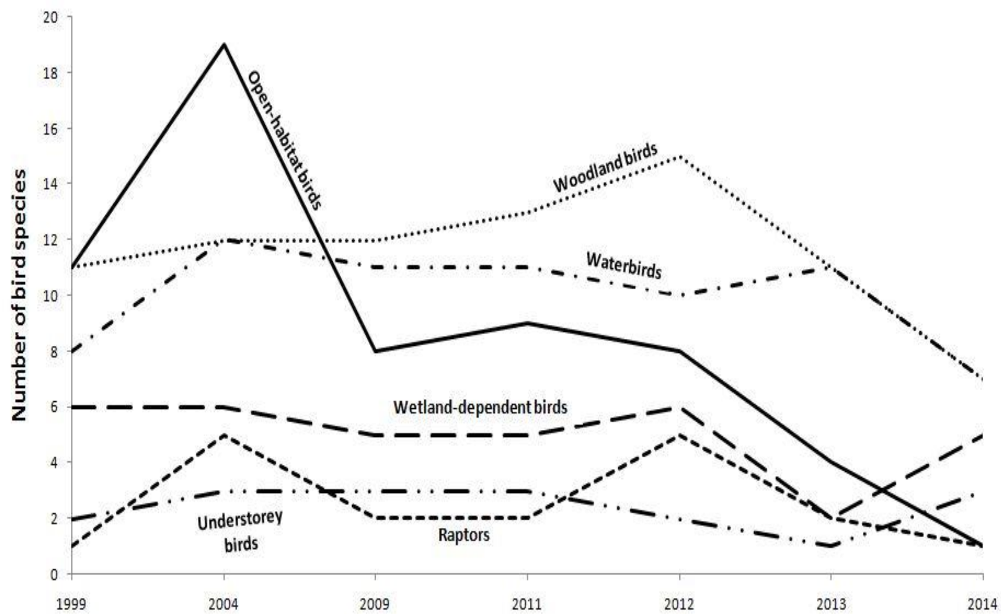

Fig 6. Trends in species richness of birds of various habitat types in Mangalavanam (1999-2013)

disproportionately luscious growth and subsequently expanding inwards rapidly. The spread of dense-canopied vegetation would mean that all open areas available within the sanctuary precincts (including shores, tree-fall gaps, and open waters) are no longer available. Over a period of twelve years(2002-2014) it was found that there is a decrease of about 35% of open water spread area in the sanctuary and in relation to total area of the PA, it has reduced from 33% to 21% (Table 2) which has been overcast by the canopy of mangroves (Figure 7a-f). This can also affect foraging efficiency of nesting waterbirds and fish population in the waters. Our inference is further strengthened by a corresponding increase in woodland bird species richness in the sanctuary noted during the same period till 2012 (after which the counts are rather incomplete). Though open waters are getting scarcer with time, probably from expanding mangroves, the number of species of waterbirds(NOT their population size, though)seems to be relatively stable. This can be explainedby the heavy and clayey deposits of silts and mudin the waters that doubles up as foraging areasfor insectivorous

Table 2: Year wise details of open area in MBS and its proportion to total area of PA

SNo	Year	Water spread area (ha)	% reduction of water spread area*	% of water spread area to total area of PA
1	2002*	0.92	100	33
2	2005	0.90	98	32
3	2006	0.83	90	30
4	2007	0.82	89	29
5	2009	0.84	91	30
6	2010	0.74	81	27
7	2011	0.73	80	26
8	2012	0.69	76	25
9	2013	0.66	72	24
10	2014	0.59	64	21

*base year

waders during low tides. In particular, taxa like sandpipers, egrets, and wagtails are known to favour these exposedmudflats (artificially created through silt deposits); for example, Nameer (2010) recorded 17 Marsh Sandpipers and 15 Wood Sandpipers from this part. This is also the reason why wetland-dependent terrestrial birds (like kingfishers and swallows) show an increasing trend through this period. But such a heavy siltation means that population of aquatic invertebrates or fishes in the backwaters is too low to be of any significant value to nesting waterbirds like Black-crowned Night Heron or Little Cormorant.

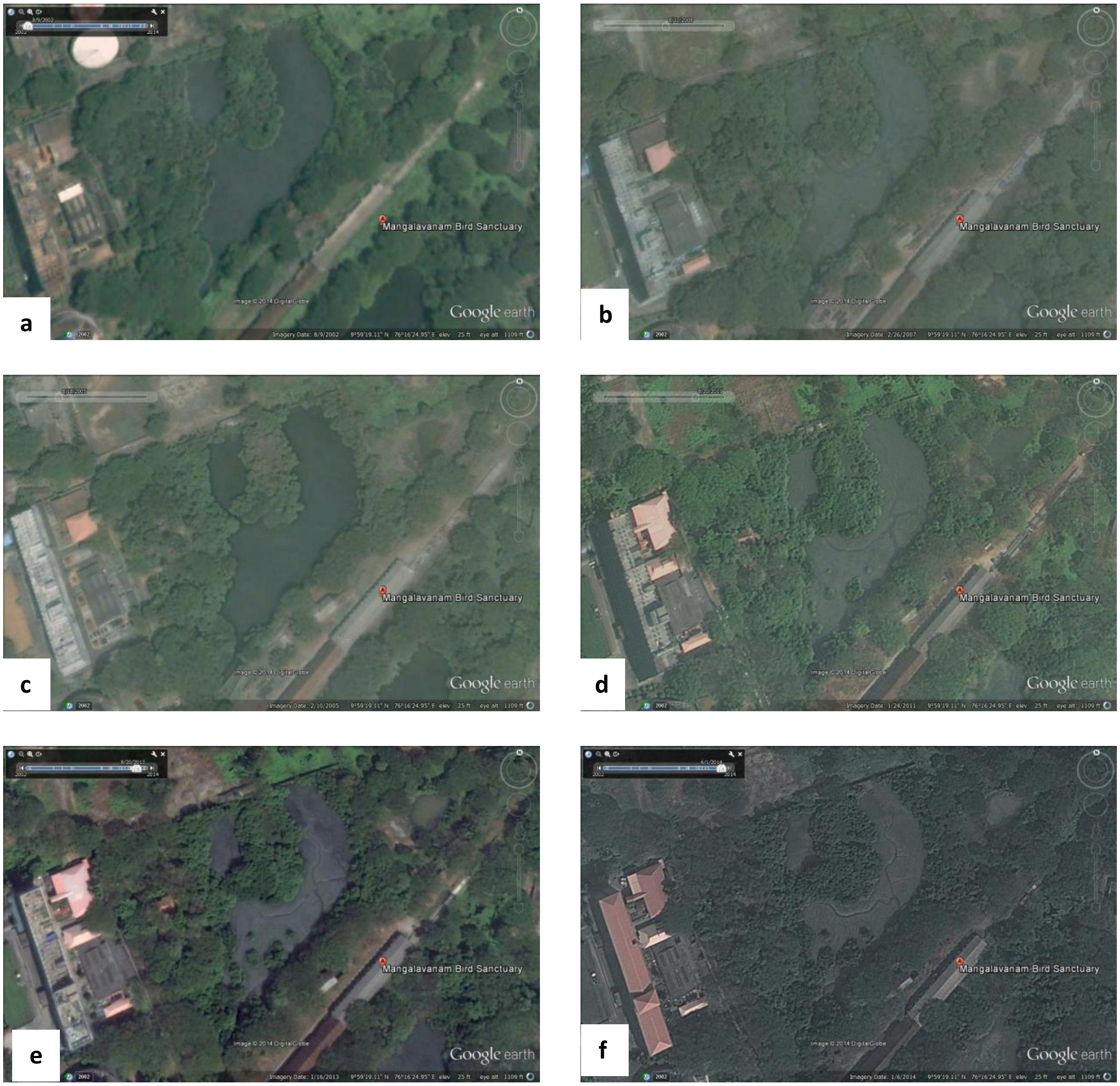

Figure 7a-f: Google image of Mangrove canopy in MBS

4.1.3 Trends in population size of waterbirds (1999-2013)

A much clear picture emerges when abundances of waterbirds are pooled and compared across the years (Figure 8). Contrary to the trend analysis of species richness of waterbirds, the populations of some of the key waterbird taxa show dramatic decline over the period to the extreme that counts of three species (Black-crowned Night Heron, Large Cormorant, and Oriental Darter) drew nil in 2013. [Note that the 2014 data are based on incomplete survey and hence not considered here). What is more distressing is the fact that both the species that comprised the Mangalavanam heronry a decade back viz., Black-crowned Night Heron and Little Cormorant are the ones that underwent the steepest fall in their numbers over the years. This has given rise to the near-closure of the heronry for which the wetland was originally recognized as a PA. The possible reasons for this severe decline are discussed elsewhere in the report.

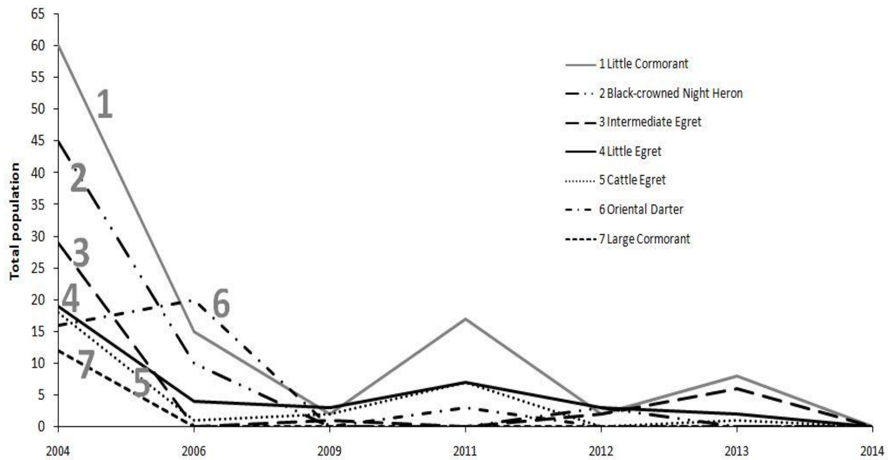

Fig 8. Trends in population status of major waterbirds in Mangalavanam (1999-2013)

4.2 Environmental Parameters

4.2.1 Water Quality*:*

pH of the MBS was alkaline in nature, varying between 7.93 at sewage mixing point (MV9) and 8.17 at inlet point of the sanctuary (MV2), whereas the incoming sewage and the adjacent Vembanad lake had similar level of pH 7.10 - 7.97 and 8.17, respectively (Annexure 2& Figure 9). The effluent from neighboring industry (Matsyafed company i.e. MV6) had lower pH (6.47). The similar level of pH was observed by the team from Cochin University of Science and Technology, Kerala that undertook

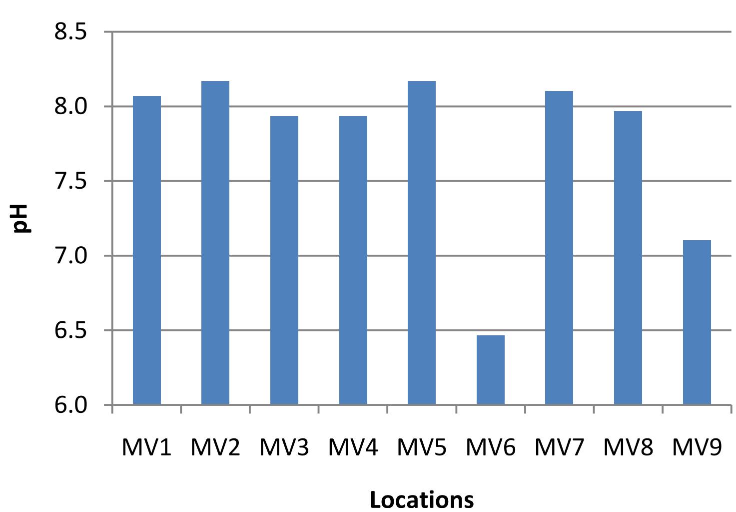

Fig 9: pH level in MBS water

an assessment of water and sediment quality of MBS earlier.
The optimum level of pH recorded from the MBS may be the cause of splashing water from the Vembanad lake to the sanctuary during high tide. As the sanctuary has no water holding area (too shallow to hold water during low tide) the pH is very similar to the lake water and slight decline in pH level is due to the acidic condition in the sludge and sediment of sanctuary.

Electrical Conductivity (EC) and **Total Dissolved Solids (TDS)** were in the same inclinationand changed together in all the sampling locations. As water flows towards sanctuary from Vembanad lake, there seems to be a higher siltation in the sanctuary, which could be ascribed to i) sediment influxfrom Vembanad lake, and ii) silt load from the municipal sewerage system. The locations away from the mouth of the sanctuary (MV1 & MV3) had low EC and TDS except the last location (MV4). The EC ranged from 22.24 to 26.67 mS/cm within sanctuary, whereas the sewage (MV8 & MV9) and effluent (MV6) had less conductivity 1.29 - 5.16 and 3.25 mS/cm, respectively (Annexure 2). Similarly TDS ranged from 11.13 to 13.37 ppt within sanctuary, whereas the sewage (MV8 & MV9) and effluent (MV6) ranged 0.68-2.51 ppt and 1.58 ppt, respectively.

The **Salinity** of the sanctuary water fluctuated from 18 to 20 ppt indicating the influence of the adjacent Vembanad lake (inflow water) (Annexure 2 &Figure10). However, the influx of sewage water (acidic water) is likely to dilute the water quality of the MBS. The variation in salinity recorded 2 ppt from Vembanad Lake within a kilometer of distance. The effluent salinity of 5 ppt is the lowest among all the sampling locations. Though the mixing of sewage water of Cochin Municipal Corporation and Vembanad Lake could reduce the salinity of water in MBS, it has its collateral implications, as the sewage is likely to contain several contaminants and pathogens that could have adverse impact on the biodiversity of the MBS.

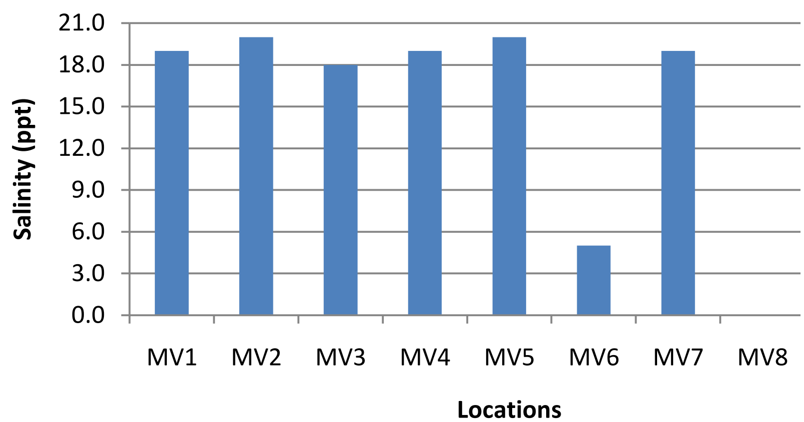

Fig 10: Salinity ranges in MBS water

Free Carbondioxide (FCO_2) ranged between 2.0 and 3.3 mg/l in the sanctuary area, whereas the adjacent Vembanad lake water had around 4.0 mg/l (Annexure 2). The municipal sewage had 1.33 - 2.67 mg/l of FCO_2 and it was least (1.0 mg/l) in the effluent water (MV6). The data from the MBS is clear indicative of noxious condition of water in the sanctuary. Even during the low tide, the sanctuary bed gets washed off naturally by a flush out mechanism, the level of FCO_2 indicates the high organic load to the MBS, as with a pH of water around 8, the FCO_2 are ought to be negligible. However, the present levels of FCO_2 are an indication of higher organic load, and that could due to the sewage influx in addition to the natural sources, i.e. decomposition of mangrove vegetation within the MBS.

The **Dissolved Oxygen(DO)** level in MBS water varied between 4.47 and 8.13 mg/l (Annexure 2). The sampling point MV1, MV3 and MV7 had very low level of DOwhich is not sufficient for the survival of many of the aquatic organisms including benthic fauna, and soft species of fishes, those are often predated upon by birds. The inlet water from Vembanad lake had higher DO level (8.13 mg/l)and it was lowest in the sewage (4.47 mg/l) flowing into the sanctuary. No detectable levels of DO could be observed from the coloured effluents (MV6) entering into the MBS suggestive of the heavy load of chemicals and other organic compounds including recalcitrant chemicals.

The levels of **Chemical Oxygen Demand (COD)** in water revealed the amount of oxygen consumed during the oxidation of organic matter (both autochthonous and allochthonous). Therefore, COD gives an idea of the biodegradable organic material including the oil and grease, and other similar pollutants in the water. The level ranged from 1373.63 to 2582.42 mg/l within the sanctuary. Similar pattern was observed from Vembanad lake (2967.03 mg/l) and the sewage samples (MV8 & MV9) had further lowest level of COD (256.41 - 1208.79 mg/l) and the highest level of COD (13095.24 mg/l) was recorded from the effluent (MV6) which drains to the sanctuary (Annexure 2).

BOD is the level of degradable organic matter present in a water sample and is defined as the amount of oxygen required by microorganisms in stabilizing biologically degradable organic matter under aerobic conditions. Inside the sanctuary it ranged from 8.94 - 15.45mg/l (Annexure 2) and slightly higher level (15.45 mg/l) was recorded from main source of water to the sanctuary at inlet point (MV2), further reduced levels were recorded from sewage (8.13 - 8.54 mg/l) coming from the Ernakulam township (MV8 & MV9).

The **Total Alkalinity** in any aquatic environment play crucial role in the primary production. The slightly higher level of alkalinity shows the better production and the alkalinity level in MBS ranged from 34.67 mg/l at MV2 to 55.33 mg/l at MV1. Similarly, the alkalinity levels in the sewage and the effluent to the sanctuary ranged from 41.33 to 60.67 mg/l and 32.67 mg/l, respectively (Annexure 2). The feeding water to the sanctuary i.e. Vembanad lake (MV5) shows moderate level (46.67 mg/l) of alkalinity.

Chloride in the water plays a combined effect for TDS and salinity. The higher value of chloride is deciding the quality of water in the environment. The marine environment is always composed of higher value of chloride. The chloride levels in the sanctuary water samples ranged from 15.12 to 19.38 hundred mg/l whereas, sewage (MV8 & MV9) and effluent (MV6) ranging between 1.42 mg/l and 3.78 hundred mg/l and the Vembanad lake (MV5) which observed 24.35 hundred mg/l (Annexure 2).

TotalHardness is the identical term used for the portability of water and suitability of water for different purposes. The hardness ranged from 31.40 to 39.20hundred mg/l (Annexure 2) within the sanctuary but the Vembanad lake has higher (43.80 hundred mg/l) hardness than the sanctuary that may be the intrusion of freshwater mixed with sewages and effluent from the city.

The **alkali metals** are earth metals found naturally in the environment. All the alkaline metals (Na, K, Ca, Mg and Li) are found in similar trend of fluctuations in the different sampling points. Among the alkali metals are in range of Na (54.53 - 82.13 hundred mg/l), K (117.67 - 166 mg/l), Ca (16.10 - 22.07 hundred mg/l) and Li (0.90 - 1.30 mg/l), respectively (Annexure 2). The levels of these alkali metals are lower in sewage (Na, K, Ca levels are 0.51 - 5.30, 6.33 - 16.87, 0.64 - 3.40 mg/l, respectively) and in case of effluent it shows range of Na (6.40 mg/l), K (5.10 mg/l), Ca (3.43 mg/l), respectively. In both sewage and factory effluent, Li could not be detected. Magnesium combines with calcium contributes to the total hardness of water. Normally the level of magnesium in the environment is lower than the calcium but in the case of MBS as similar to Periyar lake the magnesium is higher in concentration. Mg level within MBS ranged between 619.27 and 813.01 mg/l and further higher level, i.e. highest among all the locations (932.08 mg/l) was recorded from the inlet water (MV5). Other sites had ranged low levels, i.e. 32.13 - 127.37 mg/l) was observed from sewage (MV8 & MV9) and effluent water (47.25 mg/l) inflows to the sanctuary.

Oil and grease was found only from one location, i.e. at the inlet point of sanctuary (MV2). The level was 720mg/l (Annexure 2). Though oil and grease was detected form other locations, its level of 720 mg/lit is worth mentioning, as this higher level could have severe impact for aquatic fauna.

Total Nitrogen(TN) was recorded from all the sampling points in the sanctuary. The level of TN within the sanctuary varied from 0.26 to 0.47 mg/l (Annexure 2). Outside the MBS, we recorded a level 0.38 to 4.71 mg/l TN from the sewage site (MV8 & MV9). Total nitrogen in effluent mixing point was 1.55 mg/l.

Nitrate-Nitrogen(NO_3-N) is the highly oxidizable form of nitrogen which play a crucial role in metabolism of aquatic life. Its higher value is indicative of organic pollution of the environment. In the present study nitrate ranged from 35.31 - 20.85 mg/l. At effluent mixing point (MV6) it was 115.71 mg/l and sewage point (MV8 & MV9) ranged between (28.51 - 35.09 mg/l) which indicates the very poor water quality (Annexure 2). The level of nitrate more than 0.3 mg/l limits the aquatic plant growth, in such case the level of nitrate in the MBS is in critical limits for survival of all the life forms.

Nitrite-Nitrogen (NO_2-N) is another crucial parameter for pollution identification in the aquatic environment. It ranged from 1.02 - 6.77 mg/l within the MBS and 0.70 mg/l atVembanad lake, 1.11 mg/l at effluent point and 0.18 - 0.20 mg/l at sewage point (Annexure 2). The level of **Sulphate** in all the sampling points is more or less equal in the sanctuary. The higher level of SO_4 was observed in the effluent water (137.93 mg/l) from the neighboring industry (MV6) and the level is ranged from 22.37 - 39.78 mg/l within the sanctuary (Annexure 2).

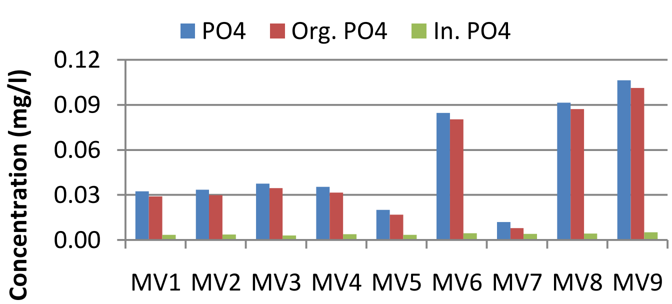

Fig 11: Phosphorus (Total, Inorganic & Organic Phosphorus) in MBS water water

Phosphorus is the vital nutrient for the development and growth of aquatic life. The phosphorus is the naturally occurring compound in the environment and organic form of phosphorus constitute 85% of the total phosphorus. In spite of this inorganic form of phosphorus is only useful for the aquatic forms. In the present study the total phosphorus, organic and inorganic phosphorus (0.091 - 0.106, 0.087 - 0.101 and 0.004 - 0.005 mg/l, respectively) (Annexure 2 & Figure 11) shows the higher levels in sewage samples (MV8 & MV9) followed by the effluent (0.085, 0.080 and 0.004 mg/l, respectively). Within the sanctuary the level of all the forms of phosphorus are similar. The least level of phosphorus (0.020 mg/l) was recorded from Vembanad lake (MV5). The lower level of inorganic phosphorus in all the sampling points indicates the less conversion of organic form to inorganic form.

4.3 Nutrient Load in Sediments

The **pH** ranged from 5.78-7.13 on surface layer (0-20 cm), below the surface layer (20-40cm) 5.67 - 7.47 whereas, sediments of lower layer (40-60 cm) ranged 5.40 - 6.84. All the samples ranged to low pH that shows the high load of organic matters in the sanctuary (Annexure 3 & Figure 12). The surface sediment (0-20 cm) samples of all the locations were acidic except MVS7 which was slightly alkaline (7.13). Among the samples from the sanctuary, the last point of the sanctuary (MVS4) had least record of pH (5.40-5.78) and the highest level of pH (6.84-7.17) recorded from middle point of the sanctuary (MVS7). The variation of pH within the sanctuary area indicates the gradual accumulation of organic materials from the sewage inflow from the municipality. The acidic condition of sediment in the sanctuary can inhibit the growth of macrophytes and mangrove forest and less suitable area for the birds and other aquatic dependent organisms.

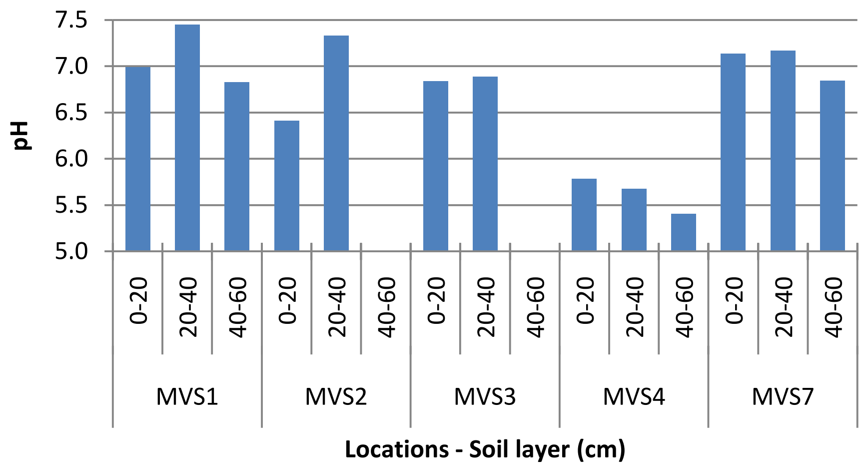

Fig 12: pH in different sediment layers of MBS

Electrical conductivity (EC) and **Water Soluble Substances (WSS)** were in the similar trend. The EC ranged from 1.52 ms/cm (in 20-40cm layer at MVS7) to 4.49 ms/cm (in 20-40 cm layer at MVS2) (Annexure 3). The surface sediment (0-20 cm) ranged from 2.17 - 3.70 ms/cm, below surface level sediment sample ranged (1.52 - 4.49 ms/cm), where as the lower level (40-60 cm) sediments was observed (2.32 - 2.74 ms/cm) ranged between the two upper layers. The samples MVS 1, 3 and 7 shows the higher EC level below surface level layer (20-40 cm) than surface sediment and again lowered by increasing the depth (40-60 cm). Similarly WSS in surface layer ranged from 0.76 ppt (MVS2) to 2.26 ppt (MVS7), and among the sediments layers, as the depth progresses the lower (40-60 cm) layer had less mean value (1.29 ppt) than below surface (1.38 ppt) and surface layer (1.56 ppt).

In the present study the **organic matter** (OM) ranged from 3.92-10.39% and **organic carbon (OC)** ranged from 2.27-6.03%. The least level of OM (3.92%) and OC (2.27%) was recorded at MVS4 (20-40 cm layer) whereas, the higher level of OM and OC was recorded at MVS1 in surface level (0-20 cm) sediment (Annexure 3 & Figure 13). Both the OM and OC at higher and lower level at same sampling points shows the continuous deposition of organic pollutant at constant pressure in the sanctuary. The MBS is a mangrove forest, the external roots which is well known of accumulation and cycling the nutrients in the environment, but the more OM and OC load on surface than lower layer indicates the fresh dumping of organic matter to the sanctuary. These increasing loads on the sanctuary by the domestic, industrial and natural processes are chocking the pond area of the MBS.

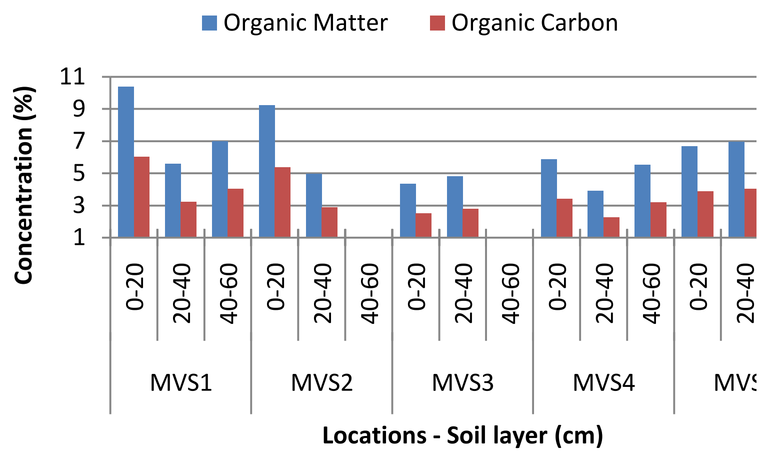

Fig 13: TOM & TOC in different sediment layers of MBS

The **TAP** level in sediment sample varies between 286.4-1034.4 mg/l.The higher soil sample TAP (1034.4 mg/kg) level in surface level at MVS4 and least was recorded in the below surface level (286.4 mg/kg) at MVS4. Surface level (0-20 cm) of sediment samples shows higher range of TAP in most of the cases whereas it goes down by increasing the depth to next level (20-40 cm) and again moves slightly upward by in further depth (40-60 cm).

The **Sulphate** level in the entire sediment sample ranged from 264.82 - 647.19 mg/kg. The low level (264.82 mg/kg) $SO_4$was observed in surface level at MVS3 and the higher range 647.19 mg/kg at MVS4 in below surface level. The sulphate ranged from 264.82 mg/l (MVS3) to 514.10 mg/kg (MVS2) on surface layer (0-20 cm), below the surface layer (20-40cm) 647.19 mg/kg at MVS4 and 357.91 mg/kg at MVS2 whereas, sediments of lower layer (40-60 cm) ranged 301.13 mg/kg (MVS1) to 631.85 mg/kg (MVS4).

The **Alkali andAlkaline Earth Metals (Na, K, Ca, Mg and Li)** in the sediment samples are found in similar trend in the different sampling points. In the present study the Na ranges from 2780 - 8370 mg/kg, K from223.67 - 506.67 mg/kg, Ca from 321.33 - 577.67 mg/kg, Mg from 920 - 3253.33 mg/kg and Li from 2.33 - 6 mg/kg in surface soil sample. But in the case of Na the higher level (8370 mg/kg) was observed in below surface layer (20-40 cm) whereas, in case of other alkali metals higher levels were observed mostly in surface layer (0-20 cm). The low levels of these alkali metals for Na, K, Ca and Li are 2780 mg/kg, 223.67 mg/kg, 321.33 mg/kg and 2.33 mg/kg, respectively and found on the surface level at MVS2. But in case of **Magnesium**, below surface layer (20-40 cm) ranged from 1813.33 mg/kg (MVS7) to 1320 mg/kg (MVS2). The lower surface (40-60 cm) ranged from 2520 mg/kg (MVS4) to 920 mg/kg (MVS1). The relatively higher amount of magnesium than calcium in most of the samples (different layer) indicated a direct impact of sea water and sewage contribution.

Total Nitrogen in the MBS ranged from 35.8 - 23.3 mg/kg in surface layer, 38.3 - 27.4 mg/kg in below surface layer (20-40 cm) and in lower layer (40-6- cm) ranged from 32.6 - 33.1 mg/kg. The highest level of TN was recorded (38.3 mg/kg) below the surface layer at MVS2 and the least was observed at MVS3 on the surface layer.

4.4 Plankton:

In total, we observed four groups of phytoplankton and five groups of zooplanktons from the MBS (Table 3). Among the phytoplankton group diatoms are dominant than the dianoflagelets. Bacillariophyceae (44%) is one among the dominant family followed by Cholrophyceae (40%) (Figure 14), Cyanophyceae (11%) and Euglenophycea (4%) Cocinodiscus Sp. and Navicula Sp. are more common in the aliquot of sample which is clearly an indication of high nutrient load and nitrogenous wastage. Among zooplankton, Copepods and rotifers were the dominant groups observed in the present study. The zooplankton reported were in the order copepods (39%) > rotifers (32%) > nauplii (16%) > cladocera (8%) > polychaete (5%).

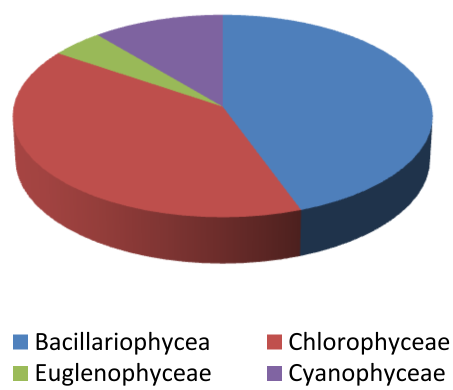

Fig 14: Phytoplankton composition in MBS

The higher number of copepods and Branchionus sp. of rotifer group are indicative of more organic load in the sanctuary water. The combined result from phytoplankton and zooplankton and previous references showed that the MBS is the representative or subset sample of Vembanad lake. But, it is difficult to conclude the effect and impact of pollution on plankton population and primary productivity in the sanctuary due to urbanization and development with limited samples.

Table 3: Plankton groups in MBS

Sl. No.	Plankton groups	
	Phytoplankton	Zooplankton
1.	Bacillariophycea	Copepod
2.	Chlorophyceae	Cladocera
3.	Euglenophyceae	Rotifer
4.	Cyanophyceae	Polychaete
5.		Nauplii

4.5 Observations on Environmental Parameters

Wetlands are one of the most useful natural resource systems, and are “essential life support system”. They take vital role in influencing biogeochemical cycling in the marine environment. Nearly 80% of ocean pollution enters from the land; virtually anthropogenic activities have serious effect on the quality of nearby aquatic environment. The findings from the Mangalavanam Bird Sanctuary reveal that the water holding area of sanctuary has been shrunken in such extent that during low tide there were hardly any water depth (pond area).

The sediments from the sources i.e. Vembanad lake and inflow water from Ernakulam town may be filled the sanctuary so there were no water retention. The litters from the nearby area increase the organic matter load (10.39 %) but it is lesser than the previous report that may be due to the tidal reflux in the sanctuary. The presence of oil and other hydrocarbons found in the samples that cause the death of aquatic animals as well as they may cover the pores of pneumatophores (breathing roots) of mangroves which can cause the death of plant. The presence of this devastating chemical may reduce the flora and fauna of sanctuary.

All the living organisms required the limited amount of nutrients for its survival while excess level can be detrimental to organisms. The presence of toxic chemicals in the water, and in the food web may result in a variety of impacts on wildlife, including impaired reproduction, decreased resistance to disease, eventual development of cancerous tissue growth (particularly in fish), neurological damage, and birth defects in offspring (Prabhahar *et al*., 2012).

In this patchy mangrove forest, tidal flushing causes exchange of different materials such as organic carbon and nutrients with the adjacent water masses. When the tide has ebbed there is no overlying water present and there can be no dissolved output from the sediments which result in increasing the concentrations of dissolved substances which have a source within the sediments. In the present study, lower values for nutrients were observed due to tidal flush in the sanctuary. When water returns to flood the sediment, a high concentration of various substances/chemicals/pollutants may be brought into the PA and absorbed by the substratum. Thus the sediments can act as both the sink and source of different nutrients and different compounds and there is material exchange between the ecosystem and the adjacent water body.

The higher level of COD, Nitrate, Nitrite etc. will harm the normal hematology of any organism and causes fatality. When the organic nitrogenous waste getting decomposes the conversion process reduces the oxygen level in the environment and repels the organism from the locality. The fast moving and air breathing organisms comes away but the sedentary animals like mollusks and other benthic organism's dies due to critical levels of hydrological parameters.

The diversity of plankton and their heterogenic nature in the environment are considered as index of fertility which decides the health of the ecosystem. In the present study the MBS is sampled for plankton study but during low tide the study was unable to conduct due to no water retention in the sanctuary. The plankton data shows the majority of rotifers which is clear indication of organic and nitrogenous based pollution in the sanctuary.

The poor water quality and plankton data indicates that the food chain from primary producers to secondary and tertiary level is in braking links. These loose links will lead to less food availability in the sanctuary and the birds may stop to come and capitalize another source. Furthermore the present study reveals the status of sanctuary is in eutrophication so periodical sampling is required to understand the diurnal and seasonal variation of tides and monsoon on the plankton in the sanctuary and impact on biodiversity.

5.0 Factors affecting the MBS

Mangalavanam , being located amidst a fast growing urban conglomerate, has several management issues and threats to its very existence. Some of the key issues have already been identified in earlier studies as well (Jayson, 2001). See Table 4 for a summary of the threats to Mangalavanam and bird taxa that are potentially affected by each of these threats.

Heavy siltation of the tidal lake: This is probably the most serious threat that the Sanctuary faces. Decades of development activities carried out in the vicinity of the Sanctuary such as Gowshree project, Vallarapadam Container Project, ongoing mass scale construction activities and dumping of both organic and inorganic waste (before it was designated as a Protected Area) have contributed to very high levels of silt in the waterbody, which is over 3 m at places. The presence of railways goods yard (though abandoned now) just next to Mangalavanam in the past had aggravated the siltation rate with the dumping of solid matter including cement bags and obsolete machineries. This has severely depleted the lake of aquatic organisms that form the main prey to several waterbirds and fish population also suffered a major decline affecting the nesting waterbirds of the heronry for which fish is the staple diet. The silt layer gets exposed during low tides; but with extremely low invertebrate populations, even wetland-dependent birds like swallows and wagtails have become much scarcer now.

Pollution of the waterbody: The sustained abuse of the tidal lake for dumping of solid waste materials and urban sewage before it was protected by law has resulted in a high degree of chemical pollution of the waterbody, besides accumulation of silt. We also noticed that the waters in the feeder canal contained significant traces of oil most probably leakage from oil-tankers parked nearby (also see Jayson, 2001). This build-up of these pollutants over the years has gradually degraded the water quality and consequently the biotic diversity of the wetland notably planktons and other key invertebrates. This, in turn, has a deleterious effect on the fish and bird diversity of the sanctuary.

Table 4. Various threats in Mangalavanam and avian taxa directly affected by them

Sl No	Threat	Heronry	Waterbirds	Wetland-dependent birds	Woodland birds	Understorey birds	Open-habitat birds	Raptors
1	Heavy siltation of tidal lake	+	+	+				
2	Heavy pollution of tidal backwaters due to urban sewage, dumping of solid wastes, and oil leak from oil-tankers parked close by	+	+	+			+	+
3	Canopy closure and shrinkage of open waters available for foraging		+	+			+	+
4	High-rise buildings surrounding the tidal lake			+	+	+	+	+
5	Heavy movement of vehicles and people				+	+		

Canopy closure and shrinkage of open waters: As a direct fallout of the presence of heavy organic matter and humus in the ecosystem, the mangroves have expectedly become dense with luxurious growth; they have also begun to spread towards the lake centre curtailing the area of open waters available for foraging by waders and other waterbirds. Though nesting waterbirds used the large trees (*Samanea saman*) in the vicinity of the waterbody for raising the heronry, their foaraging efficiency was well below the optimum because the mangrove vegetation was closing in on the water surface since it could not expand to outwards due to stabilized boundaries.

High-rise buildings around the sanctuary: Kochi-Ernakulam, being one of the fastest growing urban conglomerates in the region, has in recent years, witnessed a substantial vertical growth in the real estate sector resulting in more high-rise buildings than ever before. Naturally, the sanctuary is now surrounded by tall buildings on its southern and eastern sides. As heronries are often located close to and amidst urban settings evidently without much problem (as evident from some of the decades-old colonies of nesting waterbirds in several Indian cities and towns), we do not think proximity to high-rise buildings would be a significant issue to the heronry. Nonetheless, it is not clear how much this would directly impede the movement of foraging waterbirds or would indirectly affect the habitat quality per se.

Disturbance from movement of people and vehicles: As mentioned before, Mangalavanam is located right in the heart of the bustling downtown of Ernakulam city and more particularly next to the Kerala High Court visited by thousands of people in hundreds of vehicles on every working day and a busy Marine Drive road on the west. As such, it witnesses a heavy movement of people and vehicles in its vicinity. Despite this, we did not observe much noise pollution nor vehicular emissions of any grave concern to nesting or foraging waterbirds, though their impacts on woodland and understorey birds could be more likely. However, only a long-term monitoring of these parameters would yield any conclusive results.

5.1 Recommendations for the management

The MBS is situated in the heart of the city is an important roosting and breeding site for many of the migrant and resident, common and rare bird varieties. During the present study it was observed that the sanctuary is facing many management constraints which may be affecting the bird population. Overall it is found that the sediment substratum of the sanctuary is highly polluted with organo-chemical compounds which are detrimental to the growth of many aquatic organisms. It has also found that siltation has reached higher level and mangroves are fast growing as a substratum and the water body is partially covered by the vegetation and will be canopied completely soon. On the basis of theobservations and results of the analysis the following recommendations are suggested but however it is cautioned that the recommendations may be implemented based on the overall management objectives of the sanctuary:

- Regarding de-silting the sanctuary area, it may not be a viable option in the long run since the sanctuary is under tidal influx and sediments may get deposited regularly. Nevertheless on experimental basis without disturbing the mangrove vegetation and on close monitoring an attempt may be made and monitored intensively for the growth of fishes and other organisms that support bird population and visit of the water birds. As the water spread area experiences in-out-flow with respect to tidal effects the quantum of stagnant water even after de-silting may reduce over weeks or months.
- If the objective of MBS management is nurturing the bird population, especially the water birds, then the canopy management (thinning of canopy) may be sought off. Nevertheless before attempting this, a detailed critical analysis of the ecology of the targeted bird species may be studied.
- In order to enrich the food species (plankton, fishes, mollusks, etc) for the birds in the Sanctuary, the substratum may be devoid of pollution or contamination. As the major source of contamination of the substratum (sediment) is identified as sewage and municipal waste water draining through the sanctuary, diversion of sewage canals to prevent such organic load and pollutants to change the quality of aquatic environment may be made. If it enters the sanctuary, ensure the biological treatment of the sewage and the quality should ranges within the limits of CPCB and WHO.
- During the tidal (high) influx large quantity of solid wastes are entering into the sanctuary. In order to prevent this barricading of inlet canal by hard PVC shutters may be thought off.
- Thinning (cutting of branches) of some of the exotic canopy trees (eg *Samanea saman*) may be thought to make the area a little more open
- Regular environmental monitoring (biannual) of soil and water quality, seasonal monitoring of water birds, monitoring of aquatic fauna, population dynamics of birds other than water/wetland, monitoring of bats and changes of mangrove vegetation should be performed and recorded.
- An institutional mechanism should be evolved incorporating the functionaries of Cochin Corporation, High Court of Kerala, Railway, Bharat Petroleum, Central Marine Fisheries Research Institute, relevant department of Cochin University and other stakeholders to get actively involved in the management and monitoring of biological diversity of the sanctuary. The present Management Committee may be suitably modified to achieve this.

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Annexure 1. Annotated list of birds recorded reliably at Mangalavanam since 1990s. See the annotations for habitat, movement, and food codes below the table.

S. No	Family	Scientific name	Common name	Habitat	Movement	Feeding
	Order: ANSERIFORMES					
1	Anatidae	*Dendrocygna javanica*	Lesser Whistling Duck	Wb	LM	AqVeg
	Order: PELECANIFORMES					
2	Threskiornithidae	*Threskiornis melanocephalus*	Black-headed Ibis	Wb	R	AqOrg
3	Ardeidae	*Ixobrychus cinnamomeus*	Cinnamon Bittern	Wb	LM	AqOrg
4	Ardeidae	*Nycticorax nycticorax*	Black-crowned Night Heron	Wb	R	AqOrg
5	Ardeidae	*Butorides striata*	Striated Heron	Wb	R	AqOrg
6	Ardeidae	*Ardeola grayii*	Indian Pond Heron	Wb	R	AqOrg
7	Ardeidae	*Bubulcus coromandus*	Eastern Cattle Egret	OHb	R	Ins
8	Ardeidae	*Ardea cinerea*	Grey Heron	Wb	LM	AqOrg
9	Ardeidae	*Ardea purpurea*	Purple Heron	Wb	LM	AqOrg
10	Ardeidae	*Ardea alba*	Great Egret	Wb	R	AqOrg
11	Ardeidae	*Egretta intermedia*	Intermediate Egret	Wb	LM	AqOrg
12	Ardeidae	*Egretta garzetta*	Little Egret	Wb	R	AqOrg
	Order: SULIFORMES					
13	Phalacrocoracidae	*Microcarbo niger*	Little Cormorant	Wb	R	Fishes
14	Phalacrocoracidae	*Phalacrocorax carbo*	Great Cormorant	Wb	LM	Fishes
15	Anhingidae	*Anhinga melanogaster*	Oriental Darter	Wb	LM	Fishes
	Order: ACCIPITRIFORMES					
16	Accipitridae	*Elanus caeruleus*	Black-winged Kite	Rb	R	TerOrg
17	Accipitridae	*Spilornis cheela*	Crested Serpent Eagle	Rb	R	TerOrg
18	Accipitridae	*Accipiter badius*	Shikra	Rb	R	TerOrg
19	Accipitridae	*Milvus migrans*	Black Kite	Rb	R	MixFd

S. No	Family	Scientific name	Common name	Habitat	Movement	Feeding
20	Accipitridae	*Haliastur indus*	Brahminy Kite	Rb	R	MixFd
	Order: GRUIFORMES					
21	Rallidae	*Amaurornis phoenicurus*	White-breasted Waterhen	Wtb	R	MixFd
22	Rallidae	*Gallicrex cinerea*	Watercock	Wb	LM	AqVeg
	Order: CHARADRIIFORMES					
23	Recurvirostridae	*Himantopus himantopus*	Black-winged Stilt	Wb	LM	AqOrg
24	Charadriidae	*Vanellus malabaricus*	Yellow-wattled Lapwing	OHb	R	Ins
25	Charadriidae	*Vanellus indicus*	Red-wattled Lapwing	Wtb	R	MixFd
26	Scolopacidae	*Tringa totanus*	Common Redshank	Wb	W	AqOrg
27	Scolopacidae	*Tringa stagnatilis*	Marsh Sandpiper	Wb	W	AqOrg
28	Scolopacidae	*Tringa nebularia*	Common Greenshank	Wb	W	AqOrg
29	Scolopacidae	*Tringa ochropus*	Green Sandpiper	Wb	W	AqOrg
30	Scolopacidae	*Tringa glareola*	Wood Sandpiper	Wb	W	AqOrg
31	Scolopacidae	*Actitis hypoleucos*	Common Sandpiper	Wb	W	AqOrg
	Order: COLUMBIFORMES					
32	Columbidae	*Columba livia*	Rock Pigeon	OHb	R	Gr&Seed
33	Columbidae	*Streptopelia decaocto*	Eurasian Collared Dove	OHb	R	Gr&Seed
34	Columbidae	*Spilopelia chinensis*	Spotted Dove	Wlb	R	Gr&Seed
	Order: CUCULIFORMES					
35	Cuculidae	*Centropus sinensis*	Greater Coucal	Usb	R	MixFd
36	Cuculidae	*Clamator jacobinus*	Jacobin Cuckoo	Wlb	R	Ins
37	Cuculidae	*Eudynamys scolopaceus*	Asian Koel	Wlb	R	Fruits
38	Cuculidae	*Hierococcyx varius*	Common Hawk-Cuckoo	Wlb	R	Ins
	Order: STRIGIFORMES					
39	Strigidae	*Glaucidium radiatum*	Jungle Owlet	Rb	R	Ins
40	Strigidae	*Athene brama*	Spotted Owlet	Rb	R	Ins
	Order: APODIFORMES					

S. No	Family	Scientific name	Common name	Habitat	Movement	Feeding
41	Apodidae	*Cypsiurus balasiensis*	Asian Palm Swift	OHb	R	Ins
42	Apodidae	*Apus nipalensis*	House Swift	OHb	R	Ins
	Order: CORACIIFORMES					
43	Coraciidae	*Coracias benghalensis*	Indian Roller	OHb	R	Ins
44	Alcedinidae	*Pelargopsis capensis*	Stork-billed Kingfisher	Wtb	R	AqOrg
45	Alcedinidae	*Halcyon smyrnensis*	White-throated Kingfisher	Wtb	R	AqOrg
46	Alcedinidae	*Alcedo atthis*	Common Kingfisher	Wtb	R	AqOrg
47	Alcedinidae	*Ceryle rudis*	Pied Kingfisher	Wtb	R	Fishes
48	Meropidae	*Merops orientalis*	Green Bee-eater	OHb	R	Ins
49	Meropidae	*Merops philippinus*	Blue-tailed Bee-eater	Wlb	W	Ins
	Order: BUCEROTIFORMES					
50	Upupidae	*Upupa epops*	Eurasian Hoopoe	OHb	R	Ins
51	Bucerotidae	*Ocyceros griseus*	Indian Grey Hornbill	Wlb	R	Fruits
	Order: PICIFORMES					
52	Megalaimidae	*Megalaima viridis*	White-cheeked Barbet	Wlb	R	Fr&Ins
53	Megalaimidae	*Megalaima haemacephala*	Coppersmith Barbet	Wlb	R	Fr&Ins
54	Picidae	*Dinopium benghalense*	Black-rumped Flameback	Wlb	R	Ins
55	Picidae	*Micropternus brachyurus*	Rufous Woodpecker	Wlb	R	Ins
	Order: PSITTACIFORMES					
56	Psittacidae	*Loriculus vernalis*	Vernal Hanging Parrot	Wlb	R	Fruits
57	Psittacidae	*Psittacula krameri*	Rose-ringed Parakeet	Wlb	R	Fr&Gr
58	Psittacidae	*Psittacula cyanocephala*	Plum-headed Parakeet	Wlb	R	Fr&Gr
	Order: PASSERIFORMES					
59	Artamidae	*Artamus fuscus*	Ashy Woodswallow	OHb	R	Ins
60	Aegithinidae	*Aegithina tiphia*	Common Iora	Wlb	R	Ins

S. No	Family	Scientific name	Common name	Habitat	Movement	Feeding
61	Oriolidae	*Oriolus kundoo*	Indian Golden Oriole	Wlb	W	Fr&Ins
62	Oriolidae	*Oriolus xanthornus*	Black-hooded Oriole	Wlb	R	Fr&Ins
63	Dicruridae	*Dicrurus macrocercus*	Black Drongo	OHb	R	Ins
64	Dicruridae	*Dicrurus leucophaeus*	Ashy Drongo	Wlb	W	Ins
65	Dicruridae	*Dicrurus paradiseus*	Greater Racket-tailed Drongo	Wlb	R	Ins
66	Monarchidae	*Terpsiphone paradisi*	Asian Paradise Flycatcher	Wlb	LM	Ins
67	Corvidae	*Dendrocitta vagabunda*	Rufous Treepie	Wlb	R	MixFd
68	Corvidae	*Corvus splendens*	House Crow	OHb	R	MixFd
69	Corvidae	*Corvus culminatus*	Indian Jungle Crow	OHb	R	MixFd
70	Alaudidae	*Eremopterix griseus*	Ashy-crowned Sparrow-Lark	OHb	R	Gr&Ins
71	Pycnonotidae	*Pycnonotus jocosus*	Red-whiskered Bulbul	Wlb	R	Fr&Ins
72	Pycnonotidae	*Pycnonotus cafer*	Red-vented Bulbul	Wlb	R	Fr&Ins
73	Hirundinidae	*Hirundo smithii*	Wire-tailed Swallow	Wtb	LM	Ins
74	Phylloscopidae	*Phylloscopus trochiloides*	Greenish Warbler	Wlb	W	Ins
75	Acrocephalidae	*Acrocephalus dumetorum*	Blyth's Reed Warbler	Usb	W	Ins
76	Cisticolidae	*Prinia socialis*	Ashy Prinia	Usb	R	Ins
77	Cisticolidae	*Orthotomus sutorius*	Common Tailorbird	Usb	R	Ins
78	Leiothrichidae	*Turdoides striata*	Jungle Babbler	Wlb	R	Ins
79	Leiothrichidae	*Turdoides affinis*	Yellow-billed Babbler	OHb	R	Ins
80	Sturnidae	*Acridotheres fuscus*	Jungle Myna	Wlb	R	MixFd
81	Sturnidae	*Acridotheres tristis*	Common Myna	OHb	R	MixFd
82	Turdidae	*Geokichla citrina*	Orange-headed Thrush	Wlb	R	Fr&Ins
83	Muscicapidae	*Copsychus fulicatus*	Indian Robin	OHb	R	Ins

S. No	Family	Scientific name	Common name	Habitat	Movement	Feeding
84	Muscicapidae	*Copsychus saularis*	Oriental Magpie-Robin	Wlb	R	Ins
85	Muscicapidae	*Muscicapa latirostris*	Asian Brown Flycatcher	Wlb	LM	Ins
86	Muscicapidae	*Saxicola caprata*	Pied Bush Chat	OHb	R	Ins
87	Chloropseidae	*Chloropsis jerdoni*	Jerdon's Leafbird	Wlb	R	InsFr&Nec
88	Nectariniidae	*Leptocoma zeylonica*	Purple-rumped Sunbird	OHb	R	Nec&Ins
89	Nectariniidae	*Leptocoma minima*	Crimson-backed Sunbird	Wlb	LM	Nec&Ins
90	Nectariniidae	*Cinnyris asiaticus*	Purple Sunbird	OHb	R	Nec&Ins
91	Nectariniidae	*Cinnyris lotenius*	Loten's Sunbird	Wlb	R	Nec&Ins
92	Passeridae	*Passer domesticus*	House Sparrow	OHb	R	Gr&Seed
93	Motacillidae	*Dendronanthus indicus*	Forest Wagtail	Wlb	W	Ins
94	Motacillidae	*Motacilla flava*	Western Yellow Wagtail	Wtb	W	Ins
95	Motacillidae	*Motacilla maderaspatensis*	White-browed Wagtail	Wtb	R	Ins

Habitat codes: Wb: Waterbirds; Wtb: Wetland dependent birds; Wlb: Woodland birds; Usb: Understorey birds; OHb: Open-habitat birds; Rb: Raptorial birds

Movement codes: R: Residents; LM: local migrants; W: Winter visitors

Food codes; AqOrg: Aquatic organisms; AqVeg: Aquatic Vegetation; Ins: Insects; Fishes: Fishes; Fr: Fruits; Nec: Nectar; Gr: Grains; Seed: Seeds; MixFd: Mixed food types

Annexure 2: Physicochemical parameters of the MBS water

	MV1	MV2	MV3	MV4	MV5	MV6	MV7	MV8	MV9
pH	8.07±0.06	8.17±0.06	7.93±0.06	7.93±0.06	8.17±0.06	6.47±0.06	8.10±0.10	7.97±0.06	7.1±0.10
EC	22.24±0.04	25.09±0.26	23.27±0.11	26.67±0.12	29.67±0.12	3.25±0.01	24.67±0.06	5.16±0.01	1.29±0.0
TDS	11.13±0.01	12.69±0.02	11.60±0.01	13.37±0.01	14.88±0.01	1.58±0.01	12.36±0.01	2.51±0.01	0.68±0.01
Salinity	19±0.00	20±0.00	18±0.00	19±0.00	20±0.00	5±0.00	19±0.00	0±0.00	0±0.00
FCO_2	2.00±0.0	3.33±1.15	2.67±1.15	2.00±0.0	4.00±0.0	1.00±0.0	2.00±0.0	2.67±1.15	1.33±0.58
DO	5.28±0.0	8.13±0.0	5.15±0.23	5.96±0.23	7.59±0.47	0.00±0.0	5.56±0.23	4.74±023	4.47±0.0
COD	2051.28±259.6	2582.42±334.2	1849.82±841.1	2289.38±412.3	2967.03±334.2	13095.24±4160.3	1373.63±1046.8	256.41±83.93	1208.79±1951.13
BOD	8.94±0.0	15.45±0.0	9.49±0.47	15.31±0.94	9.76±0.81	0.00±0.0	9.21±0.47	8.13±0.0	8.54±0.0
Alk.	55.3±1.15	34.7±2.31	40±0.00	50.7±1.15	46.7±1.15	32.7±3.06	52.7±2.31	60.7±2.31	41.3±1.15
Cl	1512.83±227.96	1938.32±295.24	1583.75±216.65	1843.76±187.62	2434.71±717.37	141.83±0.00	1867.40±81.88	378.21.9±40.94	141.83±0.00
TH	3146.7±30.5	3486.7±100.7	3140±105.8	3920±174.4	4380±121.6	466.7±11.5	3773.3±141.8	760±72.11	306.7±50.3
Mg	622.61±13.56	732.89±29.66	619.27±22.40	813.01±66.83	932.08±75.44	47.25±38.44	775.51±39.38	127.37±14.78	32.13±9.64
Na	5453.33±65.1	6160±130.0	5763.67±151.4	6880±86.6	7953.33±217.3	640±30.0	8213.33±217.8	530±26.5	50.67±2.3
K	117.67±6.51	140.33±5.86	123.33±3.21	166±2.00	202.33±4.93	5.10±0.10	148.33±11.37	6.33±0.58	16.87±1.16
Ca	1610±10	1823.33±23.1	1703.33±49.3	1993.33±47.3	2190±34.6	343.33±5.8	2206.7±15.3	340.±0.0	63.7±3.79
Li	0.90±0.0	1.17±0.06	0.97±0.06	1.30±0.0	1.67±0.06	0.00±0.0	1.17±0.06	0.00±0.0	0.00±0.0
NO_3	26.02±10.56	20.85±2.29	27.55±9.48	21.95±1.12	28.15±8.99	115.71±16.72	35.31±6.44	35.09±6.52	28.51±7.96
NO_2	6.77±0.12	1.02±0.13	2.90±0.04	4.56±0.22	0.70±0.03	1.11±0.05	0.52±0.02	0.20±0.01	0.18±0.02
TN	0.26±0.03	0.28±0.03	0.37±0.13	0.29±0.02	0.38±0.12	1.55±0.22	0.47±0.09	4.71±0.88	0.38±0.11
SO_4	29.93±1.66	37.24±1.86	31.22±7.39	22.37±2.28	34.22±7.15	137.93±13.85	39.78±2.45	51.58±4.61	20.19±0.79
In. PO_4	0.004±0.0	0.004±0.01	0.003±0.0	0.004±0.0	0.003±0.0	0.004±0.0	0.003±0.0	0.004±0.0	0.005±0.0
Org. PO_4	0.029±0.01	0.030±0.03	0.035±0.03	0.032±0.01	0.017±0.01	0.080±0.00	0.008±0.00	0.087±0.01	0.101±0.04
PO_4	0.03±0.01	0.03±0.03	0.04±0.03	0.04±0.01	0.02±0.01	0.08±0.0	0.01 ±0.0	0.09±0.01	0.11±0.04
All the parameters are in mg/l except pH, EC (ms/cm) and salinity (ppt)									

Annexure 3: Physicochemical parameters of the MBS sediments (bed sediments)

Sample Code	Sample layer (cm)	pH	WSS	EC	Mg (mg/kg)	Na(mg/kg)	K (mg/kg)	Ca (mg/kg)	Li (mg/kg)	OM (%)	OC (%)	TN (mg/kg)	SO_4 (mg/kg)	TAP(mg/kg)
MVS1	0-20	6.99±0.01	1.13±0.06	2.17±0.06	3253.33±61.10	7996.7±187.71	506.7±24.21	577.67±5.86	6±0.0	10.39±0.04	6.03±0.02	30.2±2.61	439.07±31.20	680.64±35.34
	20-40	7.45±0.01	1.35±0.02	2.63±0.03	1733.33±61.10	4280±320.47	365±2.65	433.33±7.77	4±0.0	5.58±0.04	3.24±0.02	31.39±2.40	357.91±53.70	747.61±207.5
	40-60	6.83±0.05	1.13±0.01	2.32±0.01	920.00±40.00	3426.7±80.21	328±8.19	379.00±9.85	3.7±0.58	6.99±0.04	4.05±0.02	32.74±0.26	301.13±51.97	602.95±131.5
MVS2	0-20	6.41±0.01	1.79±0.01	3.55±0.02	533.33±83.27	2780±36.06	223.7±3.06	321.33±3.51	2.3±0.58	9.24±0.04	5.36±0.02	35.85±0.42	514.10±0.93	712.99±5.88
	20-40	7.33±0.00	0.76±0.01	1.52±0.03	1320.00±40.00	6326.7±390.17	403.7±5.03	501.33±4.62	4.7±0.58	4.97±0.08	2.88±0.05	38.30±0.33	612.46±5.78	580.08±25.46
	40-60	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MVS3	0-20	6.83±0.06	1.34±0.01	2.66±0.01	1293.33±46.19	4153.3±151.44	296.7±1.53	430.67±0.77.374	3±0.0	4.34±0.04	2.52±0.02	23.31±0.27	264.82±15.59	800.98±125.2
	20-40	6.88±0.01	1.42±0.02	2.87±0.01	1493.33±23.09	4590±132.29	332±7.21	445.67±1.53	4±0.0	4.81±0.08	2.79±0.05	33.56±5.47	412.04±1.70	489.82±59.36
	40-60	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MVS4	0-20	5.78±0.03	1.67±0.02	3.39±0.02	2426.67±23.09	5936.7±130.13	365.3±6.81	506.67±2.31	4±0.0	5.86±0.04	3.40±0.02	30.71±2.12	466.24±40.47	1034.45±139.8
	20-40	5.67±0.01	1.11±0.01	2.19±0.01	1786.67±61.10	3046.7±89.63	249±14.11	374.67±4.04	4.7±0.0.58	3.92±0.08	2.27±0.05	30.17±4.82	647.19±3.75	286.43±96.84
	40-60	5.40±0.17	1.39±0.02	2.74±0.00	2520.00±40.00	4883.3±126.62	417.3±3.21	479±7.00	5±0.00	5.51±0.11	3.20±0.06	32.58±3.36	631.85±2.41	647.87±64.96
MVS7	0-20	7.13±0.06	1.86±0.01	3.70±0.01	1520.00±80.00	7666.7±90.74	450.3±21.57	532.33±10.60	5±0.0	6.69±0.14	3.88±0.08	31.30±1.26	468.86±1.57	645.40±39.18
	20-40	7.17±0.06	2.26±0.01	4.49±0.04	1813.33±92.38	8370±176.92	489.7±5.77	577.33±5.51	5.7±0.58	6.97±0.00	4.04±0.00	27.42±1.53	392.88±1.53	566.27±117.16
	40-60	6.84±0.00	1.35±0.01	2.62±0.14	1880.00±69.28	5583.3±220.30	406±13.89	479.67±4.73	4.7±0.58	5.98±0.14	3.47±0.08	33.11±2.59	347.49±1.53	580.70±61.90
	NA = Not Available (sample not found due to shallow depth of silt)													