**Mangrove & Marine Biodiversity Conservation Foundation of Maharashtra, Mumbai funded Project titled,**

# "The Species Diversity and Foraging Behavior of Waders in Wetlands around Jasai, Uran and Flamingo Bird Sanctuary of Thane Creek".

# PROJECT REPORT

**By**


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**Acknowledgement**

Thane creek has been studied extensively for exploring its Mangrove flora, associated fauna and pollution impact for decades. Yet, foraging behavior of the avifauna of this ecosystem was to be worked upon. This is the first attempt to understand an aspect of avian behavior from this location.

I could conceive and propose a project on this particular activity due to the financial assistance by Mangrove Foundation, Mumbai. I wish to express my deep sense of gratitude towards Mr. N. Vasudevan, Additional Principal Chief Conservator of Forest, Mangrove Cell, Mumbai and Executive Director, Mangrove and Marine Biodiversity Conservation Foundation of Maharashtra for the funding given to me for this project.

I take this opportunity to thank Dr. Deepak Apte, Director, BNHS, Mumbai who encouraged me during the work.

The analytical and compilation work was carried out in my college laboratory. I am grateful to Vidya Prasarak Mandal and Dr. M. K. Pejaver Principal, B. N. Bandodkar college of Science, Thane for giving me the facilities at college.

Dr. Manas Manjarekar (Assistant Director, Research, Mangrove and Marine Biodiversity Conservation Foundation of Maharashtra) and Mr. Siddhesh Surve (Capacity Building Officer, Mangrove and Marine Biodiversity Conservation Foundation of Maharashtra) helped me in administrative formalities at Mangrove Foundation. I thank them for the help they offered from time to time.

The fishermen from Airoli and Vitawa were instrumental in onshore visits to the creek areas. I do recognize their contribution to the project.

I appreciate the support offered by my department colleagues Dr. S. D. Rathod, Dr. V. D. Manjramkar, Dr. K. M. Pariya, Mr. Ashutosh Joshi, Mr. Viki Patil and Mr. Kaushik Koli.

The role played by Dr. Nirmalkumar Kurve was crucial in completion of the work. I wish to thank him for the same. I also thank Dr. Siddhisha Kurve who maintained my morale during the project.

# CHAPTER 1

# INTRODUCTION

## 1.1 INTRODUCTION:

'Wetland' a land which is saturated with waters either permanently or seasonally. These are the transitional lands between terrestrial and aquatic ecosystem where the water table is usually at or near the surface or the land is covered by shallow water (Cowardin *et al.*, 1979). They are considered as most threatened of all biomes on earth and are among the most productive life – support system having enormous socio – economic and ecological importance to mankind. (Hemambika *et al.*, 2014)

Wetlands may vary widely with respect to local and regional differences in topography, climate, water and soil chemistry leading to variation in floral and faunal diversity.

According to Ramsar convention wetlands are areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water which is static or flowing, fresh, brackish or salty, including areas of marine water the depth of which at low tide does not exceed six meters.

The United States Geological Survey (USGS) defined wetland as a general term applied to land areas which are seasonally or permanently waterlogged, including lakes, rivers, estuaries, and freshwater marshes; an area of low lying land submerged or inundated periodically by fresh or saline water. Wetlands are one of the most threatened habitats of the world.

In the creek, estuary or backwater ecosystems, freshwater influx controls the environmental variability hence these are dynamic ecosystems. The wetlands in coastal regions work as the key habitats and attract huge number of migratory and resident species of birds as its sediment has high rate of productivity as well as nutritional values. Along with mangroves, the benthic fauna is also responsible for regeneration of nutrients in the sediment. Further,the benthic invertebrates are a major link in the energy flow between

primary producers and larger consumers such as fish and shore birds(Edgar & Shaw, 1995;Quadros, 2001).

Waders are important and a major biological component of coastal wetlands by acting both as primary and tertiary consumers cum predators and maintain the ecological balance. (Nachane *et al.*, 2015). Water birds procure important nutrients by feeding on plankton and benthic fauna. The abundance of these organisms is influenced by physico-chemical variables. (Manikannan *et al.*,2012).

The studies of physico-chemical parameters of water are important because they indicate the status of different metabolic processes in the water body that significantly influence the aquatic life (Quadros 2001). The water quality is important in water bird habitat assessment because a host of interacting physical and chemical factors can influence the level of primary productivity in aquatic ecosystems and thus influence total biomass throughout the aquatic food web (Manikannan *et al.*, 2012).

Use of wetlands for commercial development, drainage, overfishing, tourism, siltation, pesticide discharges from nearby agricultural land, harmful and toxic pollutants from industries and the construction of dams are major threats to wetlands everywhere.

**1.2 LITERATURE REVIEW:**

According to the National wetland atlas Maharashtra, a research done by Space Applications Centre (ISRO), Ahmadabad and Maharashtra Remote Sensing Applications Centre (MRSAC), Nagpur in May 2010, there are Total 23,046 wetlands found by 1:50,000 scale mapping. Which showed that, the total wetland area estimated is 3.3% out of the total geographic area. The wetlands are further classified as estuaries, bays and creeks (Chaudhari 2015). The creeks account for 4.10% and Mangroves for 2.98% among the total wetland area. These wetlands have critical ecological significance as they support large variety of flora and fauna adapted to fluctuations in water levels.

Wetlands exhibit enormous diversity in terms of their genesis, geographical location, water regime and chemistry, dominant plants and soil or sediment characteristics. Apart from that, wetlands also provide different services to the millions of people who are directly and indirectly dependent on it hence they are the first target of human interference and are among the most threatened of all natural resources.

**A Saravanakumar *et al.*2005** studied benthic macrofauna consisting of total 62 species in 5 groups, viz. crustaceans (18), gastropods (17), bivalves (16), polychaetes (9) and fishes (2), in western Kachchh mangroves near Gujarat. The population densities of benthic macrofauna ranged from 424 to 2393 ind.$m^{-2}$, the diversity ranging from 1.84 to 2.45 bits ind.$^{-1}$, the richness varied between 0.82 and 0.98, and the evenness varied between 0.64 and 0.81. Two maximum diversity values were recorded during winter and summer. The salinity saw found to be from 34 to 44, while temperature varied between 17 and 37°C, and the acidity ranged from 7 to 8.9.

**Athalye *et al.*, 2012** studied the environmental management activities for creeks and estuaries and elaborated the case study of thane creek, India. They concluded that, because of increased industrialization followed by urbanization, the rate of heavy pollution and degradation of the creek ecosystem increasing day by day consequently leads to the decline in the dissolved oxygen and salinity, growth of silicates, siltation, loss of biodiversity like decrease in the fish production, migration of the Polychaetes and mudskippers to the downstream due to anoxic mudflat, elimination of the prawns from the creek and more destruction of mangroves etc. This is the main threat to the bird species specially waders who are dependent on the Thane creek.

**Edelaar and Renema (2003)** examined the foraging behavior, competition and distribution of a sexually dimorphic bird species, the Bar-tailed Godwit *Limosa lapponica*, with females being bigger than males during September 1996 at

Dutch Wadden Sea. It is an autumn stopover site. They examined differences between the sexes in habitat selection, and the likelihood of being kleptoparasitic. The sexes of (Bar-tailed Godwits) *Limosa lapponica* were determined using a field estimate of general body size and bill length. The method of observation was the spatial variation in distribution of both sexes and was measured by counting the number of males per ten foraging individuals, for all the foraging Godwits within about 500 m from the observers. Foraging habitat was subdivided into waterline (mudflat covered with shallow water) and mudflat (exposed mudflat). Foraging behavior was observed and the results showed that, Bar-tailed Godwits mainly forage during low tide on the mudflats. Males took more prey per two minute periods than females, while the habitat difference in prey number appeared to be significant, with more prey being taken in the waterline. The most important prey items were worms from the genus *Arenicola* and *Nereis.* In the two-minute protocols 3.2% of the prey was lost by intra- and inter-specific kleptoparasitic actions together, while 1.5% of the prey was gained by kleptoparasitism. The observation that sexes were more segregated than expected within habitats suggesting that the competition between sexes rather than habitat preference caused the differential distribution.

**K.M. Rajesh, *et al* 1998** studied primary productivity of brackish water impoundments along Nethravathi estuary from Feb 1998 to Jan 1999. The primary productivity values varied from 1.78 to 13.47 mgC/m3/h and it exhibited bimodal pattern of distribution with primary peak in may followed by secondary peak in September. Lower values were recorded during monsoon season (June- August). Chlorophyll-a values were also observed and it ranged from 2.83 to 9.71 mg/m3 having higher values in monsoon and lower in the months of Dec/Jan. on studying phaeopigment trimodal peak was observed during March, November and July.

**Kumar *et. al.*, 2007** studied the seasonal abundance and diversity in the water-bird community of Nal lake bird sanctuary, Gujarat. The research was

conducted in the proposed Ramsar site for 1 year; the study area was divided into 8 selected sites. Monthly data collection was done for the quantification of seasonal changes in diversity and density. Results showed that, the diversity was high at locations with profuse growth of aquatic vegetation and low human disturbance while it was low at sites that experience high levels of pollution and tourism. So it was concluded that, the abundance and composition of the water-bird was affected due to habitat destruction and presence of core refugial habits. So recommendations for management and research were made to ensure the effective conservation of water bird populations and their habitats in that region.

**N. M. Groen *et. al.*, 2009** studied a quantitative characterization of agricultural habitats and their use by Blacktailed Godwits *Limosa l. limosa* in the south-western part of the province of Friesland, The Netherlands, in 2009, to provide a yardstick to evaluate further change. Since long, agricultural areas have considerable ornithological value, an ecological richness which in The Netherlands was epitomized by the term 'meadow birds'. However, over the last half century, agricultural intensification has negatively affected the quality of meadow bird habitats.

**Norazlimi and Ramli (2015)** studied the relation between morphological characteristics and foraging behavior of four species of shorebirds and water birds in the tropical mudflats of west coast of peninsular Malaysia. The study was conducted from August 2013 to July 2014,using direct observation techniques. The focal observation was done during low tide period of actively foraging bird species. The different bird species were chosen because of their different sizes and different foraging techniques. The three different techniques such as tactile hunting, foraging technique, visual feeding techniques and Pause travel species technique were selected. the bill length and leg length were also used to estimate probing depth, prey size and water or mud depth respectively. The results showed that the different foraging techniques used by the birds involve different time spans for foraging. They

also stated that these birds prefer foraging in interspecies or intra-species flock in order to reduce the risk of predation and the need for vigilance.

**Pierce in 1985** had done research on the feeding of pied stilts (*Himantopus leucocephalus*) and black stilts (*Himantopus novaezelandiae*) and their responses to changes in prey availability. The study was conducted from February to June 1983 and February-March 1984,at New South Wales and Queensland and at Bharatpur and Jaisalmer in India respectively. The time budgets activity of individuals was recorded where number of occurrences of each type of feeding action included in the methodology. The density of amphipods and chironomids at feeding area were also recorded. The effects of wind on foraging stilts were also recorded by using a hand-held anemometer at 0.35 m above the ground. Pierce concluded that, Stilts readily switch between feeding methods based on the changes in the behavior or availability of their prey while choice of food is not always energetically optimal. A total of nine feeding methods have been recorded used by both the stilts. The feeding methods included Pecking, Swallowing, Plunging, Snatching, Filtering, Probing, Scything, Lateral probing and Raking. The observations also stated that Pied and black stilts spend more time during early morning and late afternoon for feeding, more ingesting the food. Changes in prey behavior included the temperature-dependent activity of wetland. Other conditions such as changes in wind speed, wave action, air temperature, water depth, precipitation and encounters with potential predators and competitors caused a sudden change in the catching ability of stilts. These conditions do not necessarily result in a change of feeding style, but may simply result in a changed rate of ingestion.

**Quadros *et al.*, 2003** studied Deterioration of thane creek ecosystem over the period of 20 years i.e. from 1981 to 2000 and concluded that, there is adverse effect of pollution on the biodiversity of Thane creek. The changes in the physico-chemical parameters of water, affects the fish production. The destruction of the mangrove habitat because of various anthropogenic

activities, lowered the fish production, affected the water flow. The ecosystem health has adverse effect due to the solid waste dumping in the creek from the past 20 years.

They used a Principal Component Analysis to summarize landscape characteristics and found that much of the habitat variation is explained by a combination of herb richness of the vegetation, the presence or absence of foot drains and groundwater level. The modern agricultural landscape of southwest Friesland consists of 80% of uniform, intensively managed landscape with herb-poor meadows and low groundwater levels, the remaining 20% being taken by remnants of the former herb-rich meadows. They searched whole study area weekly and Black-tailed Godwits were mapped between arrival and egg-laying. They got positive relationship between godwit density and the first PC axis indicates that Black-tailed Godwits preferred herb-rich polders with high groundwater levels and the presence of foot drains. Soil texture was poorly correlated with godwit breeding densities for intensively managed (herb-poor) parcels, but for herb-rich meadows, soils of sandy clay loam and sandy clay harbored the highest densities of godwits. From the study they conclude that to protect Black-tailed Godwits, areas should have an herb-rich vegetation, contain foot drains and high groundwater tables should be re-established.

**Ullal *et.al.*, 2001** studied the blooms of *Leptocylindrus* species and their sub-surface aggregation in Thane Creek, India. The study was conducted from October 1991 to April 1993 at spring high tide and from January 1992 to April 1993 at neap high tide in narrow (width range 200 to 500 m) and shallow (average depth 0.5m) region of Thane creek. The hydrological parameters like temperature, dissolved oxygen, salinity, nitrates, phosphates and silicates were analyzed along with the density and types of phytoplankton. Thane Creek experienced prolonged existence of diatom blooms indicating eutrophication. Blooms of *Leptocylindrus* species occurred during post-monsoon period with intermediate salinity (24 to 33 ppt.). High nutrients and abrupt salinity change

at the onset of bloom favored heavy growth of *Leptocylindrus* species resulting in depletion of nutrients (especially nitrates) which affected their energetic to cause sinking and coagulated subsurface aggregate formation. The blooms terminated due to depleted nitrates associated with rising salinity and temperature during summer. Serious toxic effects of the blooms were not noticed.

### 1.3 SIGNIFICANCE OF THE STUDY:

Jasai wetland being in the vicinity of JNPT, is facing rising stress due to consistently increasing anthropogenic activities. The land filling has become a regular practice, leading to habitat destruction of waders. The area being earmarked for proposed Navi Mumbai Airport, is being reclaimed accordingly posing a serious threat to the existing faunal diversity especially the avifaunal diversity (Rahmani 2013).

Another area of study is newly formed Flamingo bird sanctuary of Thane creek. Thane creek is surrounded by urbanization and industrialization. Every day it is facing heavy load of domestic and industrial waste and plastic pollution is of major concern.

For such ecosystems which, are under stress of anthropological activities, careful and continuous monitoring of different ecological aspects is necessary to assess the status and impact of pollution and productivity.

The study will help to decide conservation strategies of remaining wetlands situated around the Jasai, Uran of district Raigad and Flamingo bird sanctuary of Thane creek, district Thane.

The aim of this research is to prepare a baseline data of wader diversity, impact of surrounding changing environment and anthropologic activities on wader community in Jasai wetland and Flamingo bird sanctuary of Thane creek.

## 1.4 OBJECTIVES:

- **To document the species diversity of the waders community.**
- **To study the population abundance of the waders.**
- **To study the foraging behaviour of any two waders found in the study area.**
- **To assess anthropological activities causing threat to the bird diversity.**

## 1.5 STUDY LOCATIONS:

**Site 01 – Jasai wetland, Uran**


Geographically Uran is situated along the eastern shore of Mumbai harbour, opposite Colaba with the population of 1, 60,303 (Census of India, 2011).'Uran village' was primarily a fishing &agriculture village but now has developed into the special economic zone.

Uran village ranges from northern end of palm beach road in Navi Mumbai, to Funde village, past the JNPT police station and is situated about 60 km from Mumbai. The study area Jasai wetland is located from Dastan fata to Sonari (18°55'39"N and 73°00'56"E). Jasai wetland is surrounded by grasses and shrubs from three sides and the boundary wall runs parallel to the main road on the fourth side. This wetland is isolated yet connected to the sea by water channels and the water level changes according to the tidal cycles. The wetland area is reserved for 12.5% scheme of JNPT hence the wetland patch

is getting land-filled and soon will get converted into the land for plot construction.

**Site 02 – Flamingo bird sanctuary, Thane creek**


The part of Thane creek located (19°07’21”N and 72°58’06”E) between the Airoli and Vashi bridges that connect Mumbai with Navi Mumbai forms the Flamingo Bird Sanctuary area. The total area of the sanctuary is 1,690 hectares includes 896 ha of mangroves and 794 ha of adjacent water body located on the western bank.

Thane creek mudflats act as feeding ground in the winter season for huge number of migratory birds including many threatened species. ‘Birdlife International’ has already declared Thane creek as an Important Bird Area (IBA) now. Maharashtra state forest department has declared the northern part of Thane creek as a Flamingo Bird Sanctuary under section 18 of the Wildlife

Protection Act, 1972. It is the state's second marine sanctuary after Malvan Marine Sanctuary, Malvan.

Quadros, (2001) stated that the creek is tidally influenced by dominance of neritic waters and negligible freshwater flow except during monsoon; also, this site is highly productive ecosystem because of presence of mangroves along both the banks. Further Quadros, (2001) stated that Thane creek receives effluents from the residential and industrial areas and is indiscriminately used as a dumping ground for huge quantity of solid wastes.

# CHAPTER 2

# MATERIAL AND METHODS

## 2.1 MATERIAL AND METHODS:

The study was conducted for seven months, from January 2017 to July 2017. For the present study, the following different components were assessed.

**Species diversity and population abundance study:**

Methods recommended by Bibby *et al.*, (2012) were followed to assess the species diversity and population abundance in study areas using Point count method and Total bird count method. Minimum two visits per month were undertaken for bird count and bird behavioural observation. All the birds observed by using 8 X 40 binocular and were photographed by Canon SX 50 HS digital camera. Recorded birds were identified according to their characteristic features by using field guide 'Birds of the Indian subcontinent' by Richard Grimmett, Carol Inskipp and Tim Inskipp. For Scientific names and common names of birds, 'Birds of South Asia' The Ripley Guide by Rasmussen, P.C. & Anderton, J.C. 2012 was referred.

**Point count method:**

For observation of wader species diversity suitable stations were selected and birds which are heard and seen were recorded. Location of the study site was marked with the help of GPS. In Flamingo Bird Sanctuary for bird identification and counting boat trips along mudflats were also carried out as area is quite large and surrounded by mangroves it is difficult to locate some birds from land.

**Total bird count method:**

For population abundance study, Total Bird Count Method was used. Bird counting was done in the active period of day by boat trip along mudflats in the Flamingo Bird Sanctuary and by walking along the road parallel to the wetland in Jasai wetland area.

For observing bird diversity and their counting data sheets were made and use for recording the data on field.

| TOTAL COUNT AND SPECIES DIVERSITY DATA SHEET | | | | |
|---|---|---|---|---|
| **Location –** | **GPS -** | **Humidity -** | **Tide type -** | **Date -** |
| **Time –** | **Temperature -** | **Weather -** | **Habitat -** | **Distance -** |

| **Name of the species** | **Flock No.** | **Count** | | **Angle to contact** | **Spatial position** | **Distance to contact** | | | **Activity** | **Flock structure** |
|---|---|---|---|---|---|---|---|---|---|---|
| | | ♂ | ♀ | | | **0 – 15 meter** | **15 – 30 meter** | **30 – 50 meter** | | |
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| **Additional information -** | | | | | | | | | | |

## Field visit:


**Total Bird count at FBS (Airoli)**

**Statistical Analysis –**

The quantification of biological diversity can be done in different ways. The richness and evenness are the main factors that need to be taken into consideration. Species richness is quantification of different kinds of organisms present in a particular area, while similarity of the population size of each of the species can be termed as Evenness of the species. The data was analyzed using the Shannon-Wiener index, Pielou's measure of evenness, Margalef's diversity index, Simpson's dominance index and Jaccard Index of similarity.

**1. For Measurement of diversity,** α- diversity is used, which is the diversity of species within a community or habitat. The number of species per sample is a measure of richness. The more species present in a sample, the 'richer' the sample. The diversity index was calculated by using the Shannon – Wiener diversity index (1949).
Shannon-Wiener index Measures the average diversity of a sample and is given by equation:

**Shannon-Wiener diversity index $H = -\Sigma Pi \ln Pi$**

Where $Pi = ni/N$

ni= number of individuals of a particular species,
N = total number of all individuals of all species in the sample.

The Shannon Wiener index is an information statistic index, which means it assumes all species are represented in a sample and that they are randomly sampled. In the Shannon index, p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N)

**2. For Measurement of evenness,** the Pielou's Evenness Index (e) was used (Pielou, 1966). Pielou's Index measures evenness where individuals were

distributed among the species. Evenness is a measure of the relative abundance of the different species making up the richness of an area.

**Pielou's Evenness Index e = H / In S**

H = Shannon – Wiener diversity index
S = total number of species in the sample

**3. For Measurement of species richness,** Margalef's index was used as a simple measure of species richness (Margalef, 1958).

**Margalef's index = (S – 1) / In N**

S = total number of species
N = total number of individuals in the sample

**4. For Measurement of species dominance,** Simpson's Index was used. In ecology, it is often used to quantify the biodiversity of a habitat. The Simpson index is a dominance index because it gives more weight to common or dominant species. In this case, a few rare species with only a few representatives will not affect the diversity. Simpson's Diversity Index is a measure of diversity which takes into accounts both richness and evenness. A community dominated by one or two species is considered to be less diverse than one in which several different species have a similar abundance. Simpson's Index (D) measures the probability that two individuals randomly selected from a sample will belong to the same species (or some category other than species). With this index, 0 represents infinite diversity and 1represents no diversity. That is, the bigger the value of D, the lower the diversity.

**Simpson's Diversity Indices $D = \Sigma (n / N)^2$**

n = the total number of organisms of a particular species
N = the total number of organisms of all species

This does not seem intuitive or logical, so some texts use derivations of the index, such as the inverse (1/D) or the difference from 1 (1-D). The equation used here is the original equation as derived by Edward H. Simpson in 1949.

**5. For Measurement of species similarity,** Jaccard Index was used. It is also known as the Jaccard similarity coefficient which was originally coined as 'coefficient decommunauté' by Paul Jaccard, 1912. In ecology, it is often used to quantify the Presence and absence of the species in the two habitats. It is a statistic used for comparing the similarity and diversity of species. The Jaccard coefficient measures similarity between finite sample sets, widely used to assess similarity of quadrates. Mathematically, it is defined as

**Jaccard Index J(X, Y) = |X∩Y| / |X∪Y| *100**

**Jaccard Index = (the number in both sets) / (the number in either set) * 100**

In Steps,
a) |X∩Y| = the number of members which are shared between both sets.
b) |X∪Y| = Count of the total number of members in both sets (shared and un-shared).
Division of the number of shared members (a) by the total number of members (b);
Multiplication of the number found by 100.

**This percentage states how similar the two sets are.**

1. Two sets that share all members would be 100% similar. The closer to 100%, the more similarity.
2. If they share no members, they are 0% similar.
3. The midway point — 50% — means that the two sets share half of the members.

## 2.2 FORAGING BEHAVIOR STUDY:

Foraging is searching for food resources in wild. It affects animal's fitness because it plays an important role in ability of an animal to survive and

reproduce. Foraging behavior study comes under behavioral ecology that studies the foraging behavior of animals in response to the environment where the animal lives. Foraging behavior was recorded for 3min for few birds but it was not possible in case of all the birds. Hence, the data was collected for 1min.

The foraging behavior study in the study areas were undertaken using Focal animal sampling method.

**Focal animal sampling method:** (Bibby *et al.*, 2012)

To study the foraging behavior of waders, focal animal sampling method was used. The waders which are common and which are in flocks were chosen for sampling. Small proportion of bird flock were chosen to avoid pseudo – replication. Then by focusing on each bird for specific period of time all different activities performed by that bird were recorded and rated from 1 to 5 with respect to frequency of that particular behavior.8 X 40 binocular and Canon SX 50 HS digital camera were used to observe and record the bird activities. Selected stations for Focal animal sampling are shown in fig.

**Jasai Station 1**


**Jasai Station 2**

**FBS Site**

For on field recording of Focal animal sampling, data sheets were made and use for note down the data.

| **FOCAL SAMPLING DATA SHEET** | | | | |
|---|---|---|---|---|
| **Location –** | **GPS -** | **Humidity -** | **Tide type -** | **Date -** |
| **Time –** | **Temperature -** | **Weather -** | **Habitat -** | **Distance -** |

| **Event** | **Frequency** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Paces** | | | | | | | | | | |
| **Scanning** | | | | | | | | | | |
| **Trial probing** | | | | | | | | | | |
| **Pecking** | | | | | | | | | | |
| **Swishing** | | | | | | | | | | |
| **Picking** | | | | | | | | | | |
| **Prey intake rate** | | | | | | | | | | |
| **Pause** | | | | | | | | | | |
| **Preening** | | | | | | | | | | |
| **Flying** | | | | | | | | | | |

## 2.3 PHYSICO – CHEMICAL PARAMETERS:

As foraging behavior of waders is dependent on wetland characters such as size and quality of water and sediment, availability and distribution of food resources etc. Hence, analysis of following parameters was carried out.

**Water parameters:**

| Parameters | Methods |
|---|---|
| Temperature | 0° to 110° Alcohol Thermometer |
| pH | Universal pH indicator method |
| Salinity (ppt.) | Argentometric method |
| Dissolved oxygen (mg/l) | Wrinkler'smethod |
| Nitrate-nitrogen (mg/l) | Phenol disulphonic acid method |
| Inorganic phosphorous | Ammonium molybdate method |

**Sediment parameters**

| Parameters | Methods |
|---|---|
| pH | Universal pH indicator method |
| Sediment texture | Buchanan's pipette method |
| Percentage chlorides | Argentometric method |
| Percentage organic carbon | Walkley and black method |
| Percentage available phosphorous | Ammonium molybdate method |

**Water sample Collection**

**Phytoplankton Collection**

**Phytoplankton Identification**

## 2.4 BIOLOGICAL PARAMETERS:

### Phytoplankton diversity:

Planktons are organisms which have no or very little capacity of self-movement in the water. They usually drift in the water and get transported by water currents. Phytoplanktons are photosynthesizing microscopic organisms that inhabit the upper sunlit layer of almost all oceans and bodies of fresh water on Earth. They play significant role in the energy transfer at primary production level of aquatic ecosystem.

In addition, (Lodh 1990; Quadros 2001) the plankton diversity indicates biological sensitivity of the area hence they are duly taken into consideration in the pollution monitoring surveys. Being a part of the food web, many species of plankton found in mangrove habitats are linked directly or indirectly to existence of the waders and other fauna. They are one of the major components of the lowest level of the producers so the fluctuations of water regime also influence the diversity and abundance of this lowest level of the food web.

For water sample collection, 500 ml wide mouth bottles were used. Lugol's iodine solution was used for immediate on the field fixation and long term preservation. Later the Phytoplankton was concentrated by allowing them to settle down for 2-3 days and then upper water was decanted by using 1-meter-long rubber tube. The Phytoplankton were observed under the compound light microscope, photographs were taken by using Canon SX 50 HS digital camera and identified using standard keys.

### Benthic faunal diversity:

Benthic organisms are the organisms that form the intertidal life of marine ecosystems like creek, estuaries and backwaters. They are creeping and sedentary organisms of the bottom that also include benthic algae. According to Pearson and Rosenberg, (1978) and Quadros (2001) the benthos is the

resident fauna and because of its sedentary nature has a lot of significance in assessment of the ecosystem. The benthic in-fauna are also important mediators of nutrient recycling from the sediments into the water column. Parulekar *et al.* (1982) and Quadros(2001) estimated that benthic abundance is necessary as they are part of food web of all marine ecosystem and important food resource for the demersal fishes. Benthos, being sedentary and resident fauna, they respond to the sediment pollution and contamination stress so their analysis is important to define the quantity and quality of changes and pollution impact as well the diversity of marine organisms specially wader species which aredependent on it.

For macro-benthos the sediment samples were collected from the intertidal region because the diversity and abundance is maximum at this region and most of the waders used to feed in this region only. The collection was done from 10cm depth of soil surface with the help of 10cm X10cm metal scoop,(Kiceniuk and Williams, 1987;Quadros 2001). 2 scoops were randomly collected and pooled together. The samples were collected and fixed in 1: 500 rose-bengal formalin and in plastic bags (Tiegtan,1969; Quadros 2001). In the laboratory, the sediment samples were drained through a sieve of mesh size 0.425mm to separate the macro benthos. (Bachelet,1990; Quadros2001). The fauna collected on the sieve was preserved in 4% formalin prepared from the water samples taken from the study sites. The preserved sample was separated, observed with magnifying glass and identified. They were separated into broad categories such as nematoda, oligochaeta, polychaeta, foraminifera, etc.

**Fish diversity:**

The coastal waters of both the study areas show good diversity of crustaceans and fishes as many of them spend a part of their life cycle in the creeks or brackish water wetland. The presence of mangroves, sea grass-beds in such ecosystem act as a nursery for fishes (Quadros and Athalye, 2012). Loss of

fishery not only indicates the economic crisis for fishermen population but also indicates disturbance in the food web. Being one of the important components of the food web the fish diversity study was necessary. Hence the fish samples were collected from both the sites during four-month period from the local fishermen of Thane, Airoli and Jasai, Uran area. Thefishes were identified using standard keys.

# CHAPTER 3

# RESULT AND DISCUSSION

## 3.1 OBSERVATIONS:

## Species diversity of waders:

Waders observed at Jasai wetland, Uran between January 2017 to July 2017

**Table 1.1**

| FAMILY | SCIENTIFIC NAME | COMMON NAME | STATUS | SIGHTING |
|---|---|---|---|---|
| **Order Charadriiformes** | | | | |
| Scolopacidae | *Limosa limosa* | 'Western' Black-tailed Godwit | NT | *** |
| | *Ereunetes minutes* | Little Stint | LC | **** |
| | *Tringa erythropus* | Spotted Redshank | LC | * |
| | *Tringa tetanus* | Common Redshank | LC | ** |
| | *Actitis hypoleucos* | Common Sandpiper | LC | **** |
| | *Erolia ferruginea* | Curlew Sandpiper | NT | ** |
| Laridae | *Chroicocephalus genei* | Slender-billed Gull | LC | *** |
| Recurvirostridae | *Himantopus himantopus* | Black-winged Stilt | LC | *** |
| | *Recurvirostra avosetta* | Pied Avocet | LC | * |
| Sternidae | *Gelochelidon nilotica* | Gull-billed Tern | LC | *** |
| | *Chlidonias hybrida* | Whiskered Tern | LC | *** |
| | *Thalasseus sandvicensis* | Sandwich Tern | LC | *** |
| Charadriidae | *Charadrius dubius jerdoni* | Little Ringed Plover | LC | ** |
| | *Vanellus indicus* | Red-wattled Lapwing | LC | ** |
| Jacanidae | *Metopidius indicus* | Bronze-winged Jacana | LC | ** |
| | *Hydrophasianus chirurgus* | Pheasant-tailed Jacana | LC | * |
| **Order Anseriformes** | | | | |
| Anatidae | *Anas poecilorhyncha* | Indian Spot-billed Duck | LC | * |
| | *Tadorna ferruginea* | Ruddy Shelduck | LC | * |
| **Order Suliformes** | | | | |
| Phalacrocoracidae | *Phalacrocorax fuscicollis* | Indian Shag | LC | **** |
| | *Microcarbo niger* | Little Cormorant | LC | ** |
| **Order Gruiformes** | | | | |
| Rallidae | *Porphyrio (Porphyrio) poliocephalus* | Purple Swamphen | LC | ** |
| **Order Ciconiiformes** | | | | |
| Ciconiidae | *Mycteria leucocephala* | Painted Stork | NT | ** |
| | *Anastomus oscitans* | Asian Openbill | LC | *** |
| **Order Phoenicopteriformes** | | | | |
| Phoenicopteridae | *Phoenicopterus roseus* | Greater Flamingo | LC | ***** |
| | *Phoeniconaias minor* | Lesser Flamingo | NT | **** |
| **Order Pelecaniformes** | | | | |
| Threskiornithidae | *Threskiornis melanocephalus* | Black-headed Ibis | NT | *** |
| | *Plegadis falcinellus* | Glossy Ibis | LC | ** |
| | *Platalea leucorodia* | Eurasian Spoonbill | LC | ** |
| Ardeidae | *Ardeola grayii* | Indian Pond-heron | LC | **** |
| | *Egretta alba* | Great Egret | LC | *** |

| | | | | |
|---|---|---|---|---|
| | *Ardea cinerea* | Grey Heron | LC | * |
| | *Egretta intermedia* | Intermediate Egret | LC | ** |
| | *Egretta garzetta* | Little Egret | LC | **** |
| | *Ardea purpurea* | Purple Heron | LC | * |

**Avifauna at Jasai**

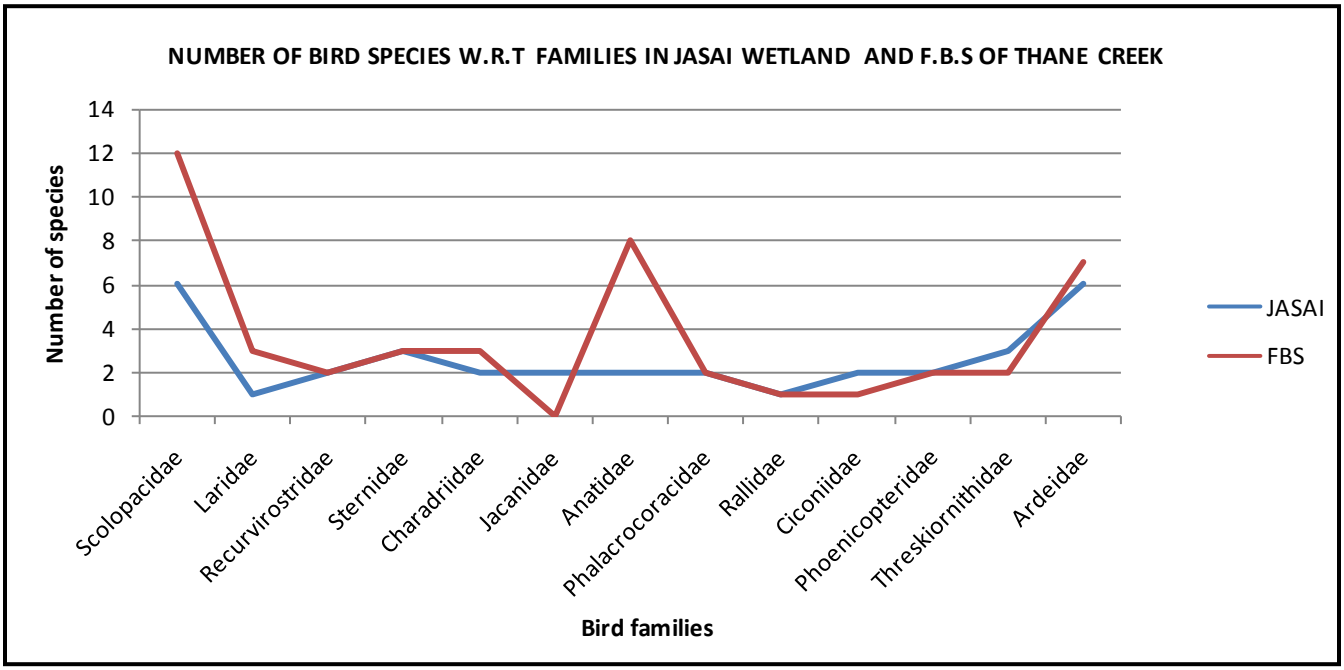
## Waders observed at FBS of Thane creek, Thane between January 2017 to July 2017

| FAMILY | SCIENTIFIC NAME | COMMON NAME | STATUS | SIGHTING |
|---|---|---|---|---|
| **Order Charadriiformes** | | | | |
| Scolopacidae | *Limosa limosa* | 'Western' Black-tailed Godwit | NT | *** |
| | *Tringa erythropus* | Spotted Redshank | LC | * |
| | *Tringa tetanus* | Common Redshank | LC | ** |
| | *Actitis hypoleucos* | Common Sandpiper | LC | **** |
| | *Tringa nebularia* | Common Greenshank | LC | * |
| | *Erolia ferruginea* | Curlew Sandpiper | NT | **** |
| | *Xenus cinereus* | Terek Sandpiper | LC | * |
| | *Ereunetes albus* | Sanderling | LC | ** |
| | *Ereunetes minutes* | Little Stint | LC | **** |
| | *Numenius arquata* | Eurasian Curlew | NT | ** |
| | *Tringa stagnatilis* | Marsh Sandpiper | LC | ** |
| | *Tringa glareola* | Wood Sandpiper | LC | ** |
| Laridae | *Chroicocephalus ridibundus* | Black-headed Gull | LC | * |
| | *Chroicocephalus genei* | Slender-billed Gull | LC | *** |
| | *Chroicocephalus brunnicephalus* | Brown-headed Gull | LC | *** |
| Recurvirostridae | *Himantopus himantopus* | Black-winged Stilt | LC | *** |
| | *Recurvirostra avosetta* | Pied Avocet | LC | * |
| Sternidae | *Gelochelidon nilotica* | Gull billed Tern | LC | *** |
| | *Thalasseus sandvicensis* | Sandwich Tern | LC | *** |
| | *Chlidonias hybrida* | Whiskered Tern | LC | *** |
| Charadriidae | *Charadrius mongolus* | Lesser sand Plover | LC | *** |
| | *Charadrius dubius jerdoni* | Little Ringed Plover | LC | ** |
| | *Vanellus indicus* | Red-wattled Lapwing | LC | ** |
| **Order Anseriformes** | | | | |
| Anatidae | *Spatula clypeata* | Northern Shoveller | LC | ** |
| | *Dendrocygna javanica* | Lesser Whistling-duck | LC | * |
| | *Anas acuta* | Northern Pintail | LC | ** |
| | *Anas poecilorhyncha* | Indian Spot-billed Duck | LC | ** |
| | *Anas crecca* | Common Teal | LC | * |
| | *Tadorna ferruginea* | Ruddy Shelduck | LC | * |
| | *Tadorna tadorna* | Common Shelduck | LC | * |
| | *Querquedula querquedula* | Garganey | LC | * |
| **Order Suliformes** | | | | |
| Phalacrocoracidae | *Microcarbo niger* | Little Cormorant | LC | ** |
| | *Phalacrocorax fuscicollis* | Indian Shag | LC | *** |
| **Order Gruiformes** | | | | |
| Rallidae | *Amaurornis phoenicurus* | White-breasted Waterhen | LC | ** |
| **Order Ciconiiformes** | | | | |
| Ciconiidae | *Mycteria leucocephala* | Painted Stork | NT | *** |

| | | | | |
|---|---|---|---|---|
| **Order Phoenicopteriformes** | | | | |
| Phoenicopteridae | *Phoenicopterus roseus* | Greater Flamingo | LC | **** |
| | *Phoeniconaias minor* | Lesser Flamingo | NT | ***** |
| **Order Pelecaniformes** | | | | |
| Threskiornithidae | *Threskiornis melanocephalus* | Black-headed Ibis | NT | *** |
| | *Platalea leucorodia* | Eurasian Spoonbill | LC | ** |
| **Order Pelecaniformes** | | | | |
| Ardeidae | *Ardeola grayii* | Indian Pond-heron | LC | *** |
| | *Egretta alba* | Great Egret | LC | *** |
| | *Ardea cinerea* | Grey Heron | LC | ** |
| | *Egretta intermedia* | Intermediate Egret | LC | *** |
| | *Egretta garzetta* | Little Egret | LC | **** |
| | *Ardea purpurea* | Purple Heron | LC | * |
| | *Butorides striata* | Striated Heron | LC | * |

**Table 1.2**

IUCN status: LC - Least Concerned; NT - Near Threatened;
Population status: **** abundant, *** medium, **average, * meager




**Graph showing Number of bird species with respect to families in Jasai wetland and Flamingo Bird Sanctuary of Thane creek**

**Population abundance of waders:**

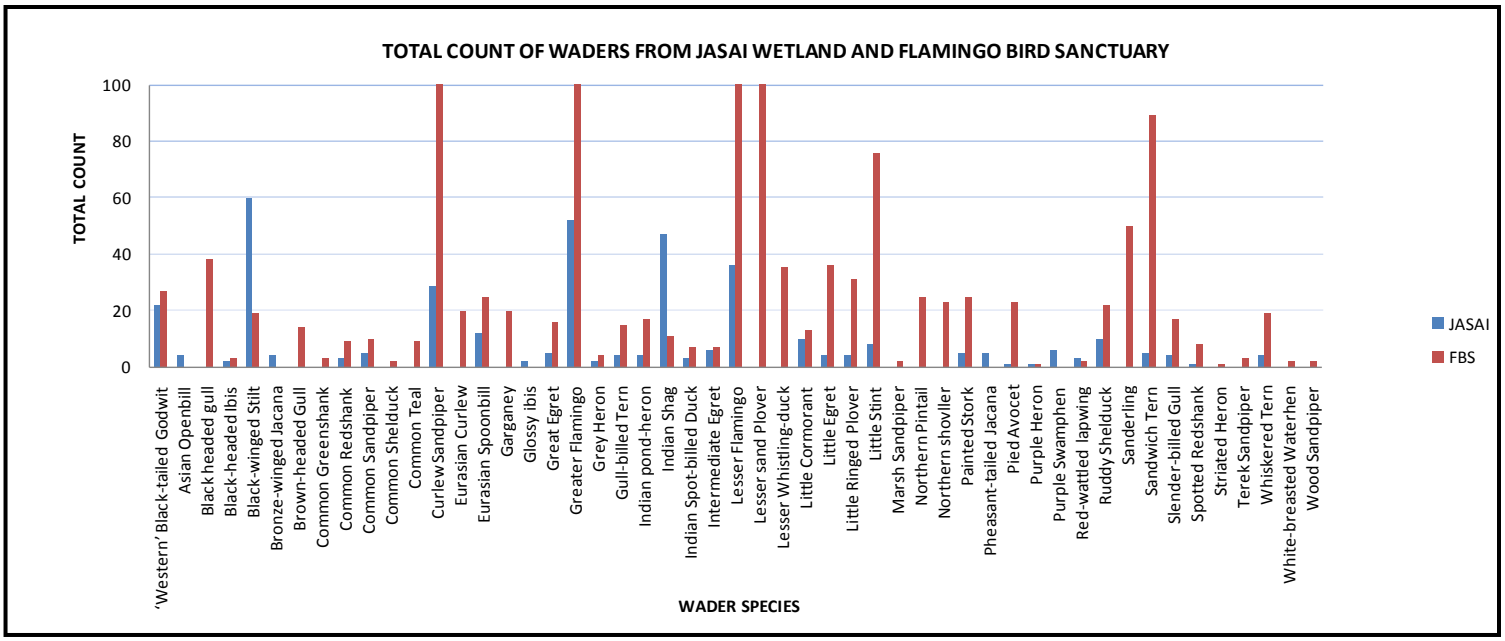
**Total count of Species of waders observed at Jasai wetland, Uran between January 2017 to July 2017.**

| Sr. No. | Wader species (Common name) | Wader species (Scientific name) | Bird Count |
|---|---|---|---|
| **1** | Asian Openbill | *Anastomus oscitans* | 4 |
| **2** | Black-headed Ibis | *Threskiornis melanocephalus* | 2 |
| **3** | 'Western' Black-tailed Godwit | *Limosa limosa* | 22 |
| **4** | Black-winged Stilt | *Himantopus himantopus* | 60 |
| **5** | Bronze-winged Jacana | *Metopidius indicus* | 4 |
| **6** | Common Redshank | *Tringa tetanus* | 3 |
| **7** | Common Sandpiper | *Actitis hypoleucos* | 5 |
| **8** | Curlew Sandpiper | *Erolia ferruginea* | 29 |
| **9** | Eurasian Spoonbill | *Platalea leucorodia* | 12 |
| **10** | Glossy ibis | *Plegadis falcinellus* | 2 |
| **11** | Great Egret | *Egretta alba* | 5 |
| **12** | Greater Flamingo | *Phoenicopterus roseus* | 52 |
| **13** | Grey Heron | *Ardea cinerea* | 2 |
| **14** | Purple Swamphen | *Porphyrio (Porphyrio) poliocephalus* | 6 |
| **15** | Gull-billed Tern | *Gelochelidon nilotica* | 4 |
| **16** | Indian Shag | *Phalacrocorax fuscicollis* | 47 |
| **17** | Indian Pond-heron | *Ardeola grayii* | 4 |
| **18** | Indian Spot-billed Duck | *Anas poecilorhyncha* | 3 |
| **19** | Intermediate Egret | *Egretta intermedia* | 6 |
| **20** | Lesser Flamingo | *Phoeniconaias minor* | 36 |
| **21** | Little Cormorant | *Microcarbo niger* | 10 |
| **22** | Little Egret | *Egretta garzetta* | 4 |
| **23** | Little Ringed Plover | *Charadrius dubius jerdoni* | 4 |
| **24** | Little Stint | *Ereunetes minutes* | 8 |
| **25** | Painted Stork | *Mycteria leucocephala* | 5 |
| **26** | Pheasant-tailed Jacana | *Hydrophasianus chirurgus* | 5 |
| **27** | Pied Avocet | *Recurvirostra avosetta* | 1 |
| **28** | Purple Heron | *Ardea purpurea* | 1 |
| **29** | Red-wattled lapwing | *Vanellus indicus* | 3 |
| **30** | Ruddy Shelduck | *Tadorna ferruginea* | 10 |
| **31** | Sandwich Tern | *Thalasseus sandvicensis* | 5 |
| **32** | Slender-billed Gull | *Chroicocephalus genei* | 4 |
| **33** | Spotted Redshank | *Tringa erythropus* | 1 |
| **34** | Whiskered Tern | *Chlidonias hybrida* | 4 |
| **Total bird count** | | | **373** |

**Total count of Species of waders observed at Flamingo Bird Sanctuary, Thane creek between January 2017 to July 2017.**

| Sr. No. | Wader species (Common name) | Wader species (Scientific name) | Bird Count |
|---|---|---|---|
| **1** | Black headed gull | *Chroicocephalus ridibundus* | 38 |
| **2** | Black-headed Ibis | *Threskiornis melanocephalus* | 3 |
| **3** | 'Western' Black-tailed Godwit | *Limosa limosa* | 27 |
| **4** | Black-winged Stilt | *Himantopus himantopus* | 19 |
| **5** | Brown-headed Gull | *Chroicocephalus brunnicephalus* | 14 |
| **6** | Common Greenshank | *Tringa nebularia* | 3 |
| **7** | Common Redshank | *Tringa tetanus* | 9 |
| **8** | Common Sandpiper | *Actitis hypoleucos* | 10 |
| **9** | Common Shelduck | *Tadorna tadorna* | 2 |
| **10** | Curlew Sandpiper | *Erolia ferruginea* | 221 |
| **11** | Eurasian Curlew | *Numenius arquata* | 20 |
| **12** | Eurasian Spoonbill | *Platalea leucorodia* | 25 |
| **13** | Common Teal | *Anas crecca* | 9 |
| **14** | Garganey | *Querquedula querquedula* | 20 |
| **15** | Great Egret | *Egretta alba* | 16 |
| **16** | Greater Flamingo | *Phoenicopterus roseus* | 488 |
| **17** | Grey Heron | *Ardea cinerea* | 4 |
| **18** | Gull-billed Tern | *Gelochelidon nilotica* | 15 |
| **19** | Indian Shag | *Phalacrocorax fuscicollis* | 11 |
| **20** | Indian Pond-heron | *Ardeola grayii* | 17 |
| **21** | Indian Spot-billed Duck | *Anas poecilorhyncha* | 7 |
| **22** | Intermediate Egret | *Egretta intermedia* | 7 |
| **23** | Lesser Flamingo | *Phoeniconaias minor* | 1492 |
| **24** | Lesser sand Plover | *Charadrius mongolus* | 143 |
| **25** | Lesser Whistling-duck | *Dendrocygna javanica* | 35 |
| **26** | Little Cormorant | *Microcarbo niger* | 13 |
| **27** | Little Egret | *Egretta garzetta* | 36 |
| **28** | Striated Heron | *Butorides striata* | 1 |
| **29** | Little Ringed Plover | *Charadrius dubius jerdoni* | 31 |
| **30** | Little Stint | *Ereunetes minutes* | 76 |
| **31** | Marsh Sandpiper | *Tringa stagnatilis* | 2 |
| **32** | Northern Pintail | *Anas acuta* | 25 |
| **33** | Northern shovller | *Spatula clypeata* | 23 |
| **34** | Painted Stork | *Mycteria leucocephala* | 25 |

| | | | |
|---|---|---|---|
| **35** | Pied Avocet | *Recurvirostra avosetta* | 23 |
| **36** | Purple Heron | *Ardea purpurea* | 1 |
| **37** | Red-wattled Lapwing | *Vanellus indicus* | 2 |
| **38** | Ruddy Shelduck | *Tadorna ferruginea* | 22 |
| **39** | Sanderling | *Ereunetes albus* | 50 |
| **40** | Sandwich Tern | *Thalasseus sandvicensis* | 89 |
| **41** | Slender-billed Gull | *Chroicocephalus genei* | 17 |
| **42** | Spotted Redshank | *Tringa erythropus* | 8 |
| **43** | Terek Sandpiper | *Xenus cinereus* | 3 |
| **44** | Whiskered Tern | *Chlidonias hybrida* | 19 |
| **45** | White-breasted Waterhen | *Amaurornis phoenicurus* | 2 |
| **46** | Wood Sandpiper | *Tringa glareola* | 2 |
| **Total bird count** | | | **3125** |




**Graph showing Average total count of waders from Jasai wetland and Flamingo Bird Sanctuary**

**Comparative Jaccard's Index**

| Sr .No | Families | Species from Jasai, Uran | Species from FBS, Thane | Common species |
|---|---|---|---|---|
| | | **X** | **Y** | **$\|X \cap Y\|$** |
| 1 | Scolopacidae | 6 | 12 | 6 |
| 2 | Laridae | 1 | 3 | 1 |
| 3 | Recurvirostridae | 2 | 2 | 2 |
| 4 | Sternidae | 3 | 3 | 3 |
| 5 | Charadriidae | 2 | 3 | 2 |
| 6 | Jacanidae | 2 | 0 | 0 |
| 7 | Anatidae | 2 | 8 | 2 |
| 8 | Phalacrocoracidae | 2 | 2 | 2 |
| 9 | Rallidae | 1 | 1 | 1 |
| 10 | Ciconiidae | 2 | 1 | 1 |
| 11 | Phoenicopteridae | 2 | 2 | 2 |
| 12 | Threskiornithidae | 3 | 2 | 2 |
| 13 | Ardeidae | 6 | 7 | 6 |
| | | **34** | **46** | **30** |
| | | | | |
| | | **$\|X \cup Y\|$ =** | **$\|X\| + \|Y\| - \|X \cap Y\|$ =** | **50** |
| | | **$\|X \cap Y\|$ =** | | **30** |
| | | | | |
| | **Jaccard Index J (X, Y) =** | **$\|X \cap Y\| / \|X \cup Y\|$ =** | | **0.6** |
| | | | | |
| | **Jaccard distance $d_j$ (X, Y) =** | **1 - J (X, Y) = $\|X \cup Y\| - \|X \cap Y\| / \|X \cup Y\|$** | | **0.4** |

**FBS, Thane Creek**

| | | |
|---|---|---|
| **Total no. of sps counted** | **(S)** | **34** |
| | | |
| **Total No. of Individuals Counted** | **(N)** | **373** |
| | | |
| **Species Richness** | **S / sqrt(N)** | **1.76045** |
| | | |
| **Richness Index** | **(S-1) / log N** | **12.83193** |
| | | |
| **Diversity Index (D)** | **Σ n (n-1) / Σ N (N-1)** | **0.08314** |
| | | |
| **Simpson Index of Diversity** | **= 1 - D** | **0.91686** |
| | | |
| **Shannon Diversity Index (H)** | **- Σ [sps Fract X ln (sps frac)]** | **2.86690** |
| | | |
| **Evenness Index** | **(SW index) / Ln(S)** | **0.81299** |
| | | |
| **Standard deviation** | **SD = $\sqrt{\Sigma \left| n - \bar{n} \right|^2 / X}$** | **15.16281305** |

**JASAI WETLAND, URAN**

| | | |
|---|---|---|
| **Total no. of sps counted** | **(S)** | **46** |
| | | |
| **Total No. of Individuals Counted** | **(N)** | **3125** |
| | | |
| **Species Richness** | **S / sqrt(N)** | **0.822873016** |
| | | |
| **Richness Index** | **(S-1) / log N** | **12.87608902** |
| | | |
| **Diversity Index (D)** | **Σ n (n-1) / Σ N (N-1)** | **0.262145762** |
| | | |
| **Simpson Index of Diversity** | **= 1 - D** | **0.737854238** |
| | | |
| **Shannon Diversity Index (H)** | **- Σ [sps Fract X ln (sps frac)]** | **2.149459394** |
| | | |
| **Evenness Index** | **(SW index) / Ln(S)** | **0.561415701** |
| | | |
| **Standard deviation** | **SD = $\sqrt{\Sigma \left| n - \bar{n} \right|^2 / X}$** | **226.0255278** |

# Avifauna at Jasai

Purple heron

Asian Openbill

Black headed ibis

Glossy ibis

Median egret

Painted stork

# Avifauna at Jasai

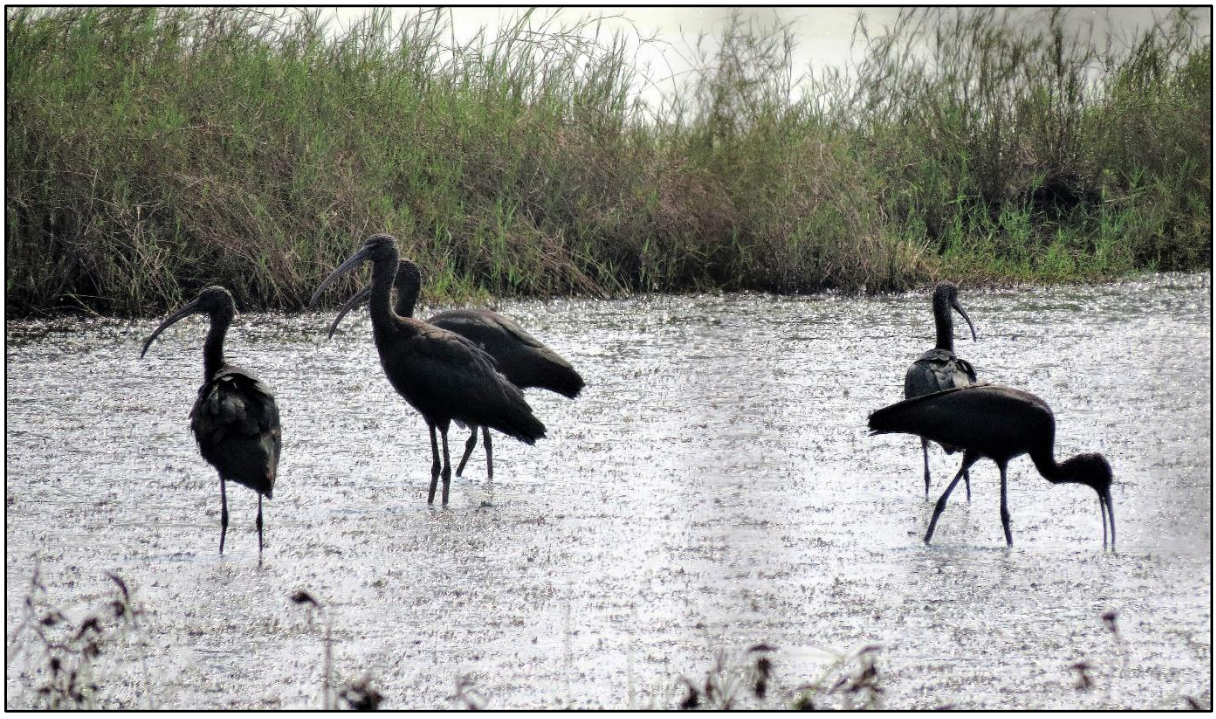
**Black winged stilt**

**Eggs of Red wattled lapwing**

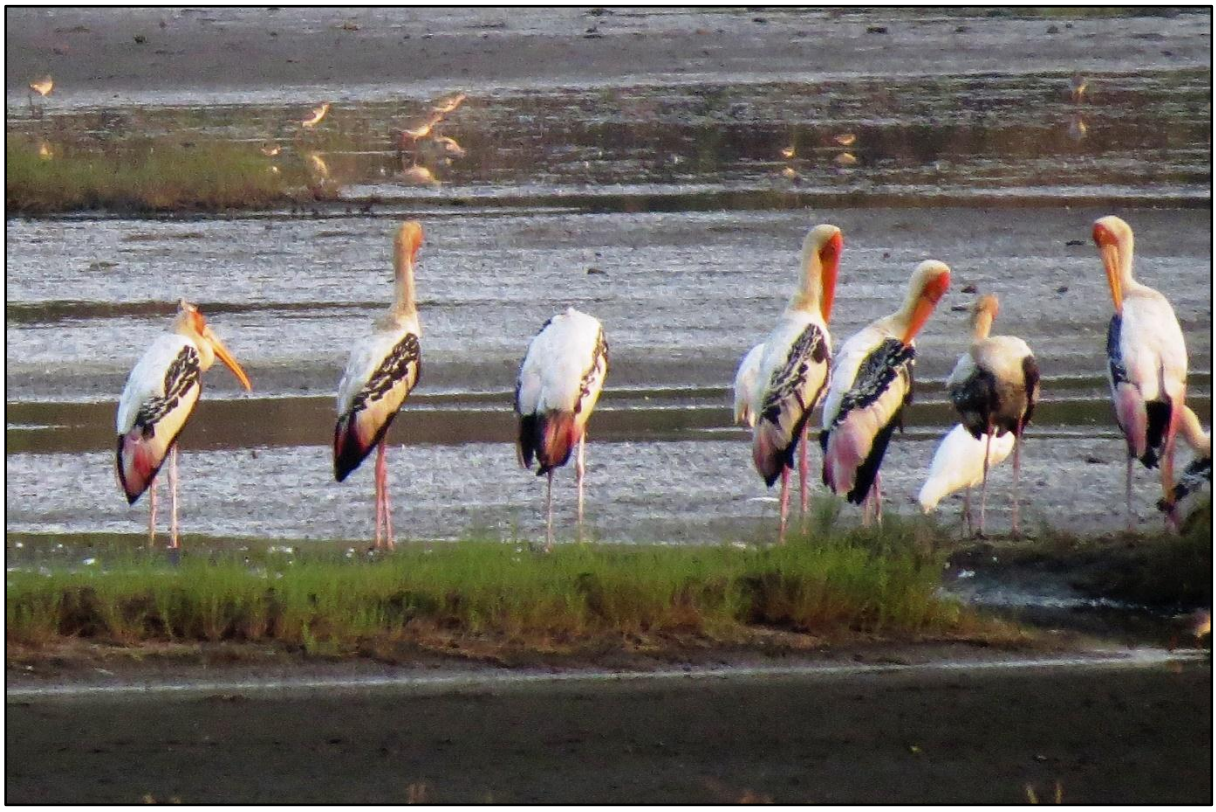
**Eurasian Spoonbill**

**Avocet**

**Flock Structure**



## Flock Structure



## Flock Structure

**Flock Structure**

## 3.2 FORAGING BEHAVIOR STUDY OF WADERS:

### FLAMINGO BIRD SANCTUARY, THANE CREEK

Black winged Stilt, Black-tailed Godwit, Lesser Flamingo and Greater Flamingo were found appropriate for focal sampling in FBS of Thane creek; so these birds were chosen for foraging behavior study in FBS of Thane creek.

| OBSERVATION | BIRD SPECIES | NUMBER | PACES | SCANNING | TRIAL PROBING | PECKING | SWISHING | PICKING | PREY INTAKE RATE | PAUSE | PREENING | FLYING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | BLACK WINGED STILT | 1 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 2 | 0 | 1 |
| 1 | BLACK WINGED STILT | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 |
| 1 | BLACK WINGED STILT | 3 | 2 | 2 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 |
| 1 | BLACK WINGED STILT | 4 | 3 | 2 | 2 | 1 | 2 | 1 | 1 | 1 | 0 | 1 |
| 1 | BLACK WINGED STILT | 5 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 2 | 0 | 1 |
| 1 | BLACK WINGED STILT | 6 | 3 | 3 | 2 | 1 | 2 | 1 | 2 | 1 | 0 | 2 |
| 1 | BLACK WINGED STILT | 7 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 3 | 0 | 1 |
| 1 | BLACK WINGED STILT | 8 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 |
| 1 | BLACK WINGED STILT | 9 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 |
| 1 | BLACK WINGED STILT | 10 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 |
| **Average Rate** | | | 2.2 | 1.5 | 0.8 | 0.4 | 0.6 | 0.4 | 0.5 | 1.8 | 0 | 1.1 |

| OBSERVATION | BIRD SPECIES | NUMBER | PACES | SCANNING | TRIAL PROBING | PECKING | SWISHING | PICKING | PREY INTAKE RATE | PAUSE | PREENING | FLYING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | BLACK WINGED STILT | 1 | 3 | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 2 | 0 |
| 2 | BLACK WINGED STILT | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 |
| 2 | BLACK WINGED STILT | 3 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 2 | 0 |
| 2 | BLACK WINGED STILT | 4 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 1 | 0 |
| 2 | BLACK WINGED STILT | 5 | 3 | 3 | 3 | 3 | 0 | 1 | 2 | 1 | 0 | 1 |
| 2 | BLACK WINGED STILT | 6 | 4 | 3 | 1 | 1 | 0 | 3 | 4 | 0 | 0 | 0 |
| 2 | BLACK WINGED STILT | 7 | 4 | 3 | 4 | 3 | 0 | 1 | 1 | 0 | 0 | 0 |
| 2 | BLACK WINGED STILT | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 |
| 2 | BLACK WINGED STILT | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 0 |
| 2 | BLACK WINGED STILT | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 0 |
| **Average Rate** | | | 1.8 | 1 | 1.1 | 0.7 | 0 | 0.5 | 0.7 | 2.1 | 1.4 | 0.1 |

| OBSERVATION | BIRD SPECIES | NUMBER | PACES | SCANNING | TRIAL PROBING | PECKING | SWISHING | PICKING | PREY INTAKE RATE | PAUSE | PREENING | FLYING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | BLACK TAILED GODWIT | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 0 | 0 | 1 |
| 1 | BLACK TAILED GODWIT | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 4 | 1 | 0 | 0 |
| 1 | BLACK TAILED GODWIT | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 4 | 1 | 0 | 0 |
| 1 | BLACK TAILED GODWIT | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 0 | 0 | 0 |
| 1 | BLACK TAILED GODWIT | 5 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 0 | 0 | 0 |
| **Average Rate** | | | 2.6 | 3 | 3 | 3 | 3 | 3.2 | 4 | 0.4 | 0 | 0.2 |

## Foraging behavior study of waders

| OBSERVATION | BIRD SPECIES | NUMBER | PACES | SCANNING | TRIAL PROBING | PECKING | SWISHING | PICKING | PREY INTAKE RATE | PAUSE | PREENING | FLYING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | BLACK TAILED GODWIT | 1 | 2 | 3 | 2 | 2 | 2 | 4 | 5 | 0 | 0 | 0 |
| 2 | BLACK TAILED GODWIT | 2 | 2 | 3 | 2 | 2 | 2 | 4 | 5 | 0 | 0 | 0 |
| 2 | BLACK TAILED GODWIT | 3 | 2 | 3 | 2 | 2 | 2 | 4 | 5 | 0 | 0 | 0 |
| 2 | BLACK TAILED GODWIT | 4 | 2 | 3 | 2 | 2 | 2 | 4 | 5 | 0 | 0 | 0 |
| 2 | BLACK TAILED GODWIT | 5 | 2 | 3 | 2 | 2 | 2 | 4 | 5 | 0 | 0 | 0 |
| Average Rate | | | 2 | 3 | 2 | 2 | 2 | 4 | 5 | 0 | 0 | 0 |

| OBSERVATION | BIRD SPECIES | NUMBER | PACES | SCANNING | TRIAL PROBING | PECKING | SWISHING | PICKING | PREY INTAKE RATE | PAUSE | PREENING | FLYING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | BLACK TAILED GODWIT | 1 | 2 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | BLACK TAILED GODWIT | 2 | 4 | 2 | 3 | 1 | 1 | 2 | 2 | 0 | 0 | 0 |
| 3 | BLACK TAILED GODWIT | 3 | 3 | 2 | 3 | 1 | 1 | 1 | 2 | 0 | 0 | 0 |
| 3 | BLACK TAILED GODWIT | 4 | 3 | 2 | 2 | 1 | 1 | 1 | 2 | 0 | 0 | 0 |
| 3 | BLACK TAILED GODWIT | 5 | 3 | 2 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 3 | BLACK TAILED GODWIT | 6 | 1 | 1 | 3 | 3 | 1 | 1 | 3 | 1 | 0 | 0 |
| 3 | BLACK TAILED GODWIT | 7 | 1 | 2 | 2 | 3 | 2 | 2 | 3 | 3 | 0 | 0 |
| 3 | BLACK TAILED GODWIT | 8 | 2 | 2 | 2 | 3 | 2 | 2 | 4 | 4 | 0 | 0 |
| 3 | BLACK TAILED GODWIT | 9 | 3 | 2 | 2 | 3 | 1 | 1 | 3 | 1 | 0 | 0 |
| 3 | BLACK TAILED GODWIT | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 4 |
| Average Rate | | | 2.2 | 1.6 | 2.3 | 1.6 | 1 | 1.2 | 2.2 | 1.1 | 0 | 0.4 |

| OBSERVATION | BIRD SPECIES | NUMBER | PACES | SCANNING | TRIAL PROBING | PECKING | SWISHING | PICKING | PREY INTAKE RATE | PAUSE | PREENING | FLYING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | BLACK TAILED GODWIT | 1 | 4 | 4 | 3 | 3 | 1 | 1 | 3 | 1 | 0 | 0 |
| 4 | BLACK TAILED GODWIT | 2 | 3 | 4 | 2 | 3 | 1 | 2 | 3 | 2 | 0 | 0 |
| 4 | BLACK TAILED GODWIT | 3 | 4 | 4 | 2 | 4 | 1 | 2 | 4 | 0 | 0 | 0 |
| 4 | BLACK TAILED GODWIT | 4 | 3 | 3 | 3 | 3 | 0 | 2 | 3 | 1 | 0 | 0 |
| 4 | BLACK TAILED GODWIT | 5 | 3 | 3 | 2 | 3 | 0 | 3 | 3 | 1 | 0 | 0 |
| 4 | BLACK TAILED GODWIT | 6 | 3 | 3 | 3 | 3 | 0 | 2 | 3 | 1 | 0 | 0 |
| 4 | BLACK TAILED GODWIT | 7 | 4 | 4 | 2 | 4 | 2 | 4 | 4 | 0 | 0 | 0 |
| 4 | BLACK TAILED GODWIT | 8 | 4 | 4 | 1 | 4 | 2 | 3 | 4 | 0 | 0 | 0 |
| 4 | BLACK TAILED GODWIT | 9 | 3 | 3 | 2 | 3 | 1 | 3 | 3 | 2 | 0 | 0 |
| 4 | BLACK TAILED GODWIT | 10 | 4 | 4 | 1 | 3 | 1 | 3 | 4 | 0 | 0 | 0 |
| Average Rate | | | 3.5 | 3.6 | 2.1 | 3.3 | 0.9 | 2.5 | 3.4 | 0.8 | 0 | 0 |

## Foraging behavior study of waders

| OBSERVATION | BIRD SPECIES | NUMBER | PACES | SCANNING | TRIAL PROBING | PECKING | SWISHING | PICKING | PREY INTAKE RATE | PAUSE | PREENING | FLYING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | LESSER FLAMINGO | 1 | 3 | 2 | 2 | 2 | 1 | 3 | 4 | 1 | 0 | 1 |
| 1 | LESSER FLAMINGO | 2 | 3 | 3 | 2 | 2 | 1 | 3 | 4 | 0 | 0 | 1 |
| 1 | LESSER FLAMINGO | 3 | 3 | 3 | 2 | 2 | 1 | 3 | 4 | 1 | 0 | 0 |
| 1 | LESSER FLAMINGO | 4 | 3 | 2 | 2 | 2 | 1 | 3 | 4 | 0 | 0 | 0 |
| 1 | LESSER FLAMINGO | 5 | 3 | 2 | 2 | 2 | 1 | 3 | 4 | 0 | 0 | 0 |
| 1 | LESSER FLAMINGO | 6 | 3 | 2 | 2 | 2 | 1 | 3 | 4 | 0 | 0 | 0 |
| 1 | LESSER FLAMINGO | 7 | 3 | 3 | 2 | 2 | 1 | 3 | 4 | 0 | 0 | 0 |
| 1 | LESSER FLAMINGO | 8 | 3 | 2 | 2 | 2 | 1 | 3 | 4 | 0 | 0 | 0 |
| 1 | LESSER FLAMINGO | 9 | 3 | 3 | 2 | 2 | 1 | 3 | 4 | 0 | 0 | 0 |
| 1 | LESSER FLAMINGO | 10 | 3 | 3 | 2 | 2 | 1 | 3 | 4 | 0 | 0 | 0 |
| Average Rate | | | 3 | 2.5 | 2 | 2 | 1 | 3 | 4 | 0.2 | 0 | 0.2 |

| OBSERVATION | BIRD SPECIES | NUMBER | PACES | SCANNING | TRIAL PROBING | PECKING | SWISHING | PICKING | PREY INTAKE RATE | PAUSE | PREENING | FLYING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | LESSER FLAMINGO | 1 | 3 | 3 | 0 | 0 | 0 | 2 | 4 | 0 | 0 | 0 |
| 2 | LESSER FLAMINGO | 2 | 3 | 2 | 0 | 0 | 0 | 2 | 4 | 0 | 0 | 0 |
| 2 | LESSER FLAMINGO | 3 | 3 | 3 | 0 | 0 | 0 | 2 | 4 | 0 | 0 | 2 |
| 2 | LESSER FLAMINGO | 4 | 3 | 3 | 0 | 0 | 0 | 2 | 4 | 1 | 0 | 2 |
| 2 | LESSER FLAMINGO | 5 | 3 | 3 | 0 | 0 | 0 | 2 | 4 | 0 | 0 | 0 |
| 2 | LESSER FLAMINGO | 6 | 1 | 2 | 0 | 0 | 0 | 3 | 3 | 0 | 0 | 0 |
| 2 | LESSER FLAMINGO | 7 | 1 | 2 | 0 | 0 | 0 | 3 | 3 | 0 | 0 | 0 |
| 2 | LESSER FLAMINGO | 8 | 1 | 4 | 0 | 0 | 0 | 4 | 4 | 1 | 0 | 0 |
| 2 | LESSER FLAMINGO | 9 | 1 | 4 | 0 | 0 | 0 | 4 | 4 | 1 | 0 | 0 |
| 2 | LESSER FLAMINGO | 10 | 1 | 3 | 0 | 0 | 0 | 3 | 4 | 0 | 0 | 0 |
| Average Rate | | | 2 | 2.9 | 0 | 0 | 0 | 2.7 | 3.8 | 0.3 | 0 | 0.4 |

## Foraging behavior study of waders

| OBSERVATION | BIRD SPECIES | NUMBER | PACES | SCANNING | TRIAL PROBING | PECKING | SWISHING | PICKING | PREY INTAKE RATE | PAUSE | PREENING | FLYING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | LESSER FLAMINGO | 1 | 2 | 4 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 |
| 3 | LESSER FLAMINGO | 2 | 2 | 4 | 0 | 0 | 0 | 0 | 5 | 1 | 0 | 0 |
| 3 | LESSER FLAMINGO | 3 | 2 | 4 | 0 | 0 | 0 | 0 | 5 | 1 | 0 | 0 |
| 3 | LESSER FLAMINGO | 4 | 2 | 4 | 0 | 0 | 0 | 0 | 5 | 1 | 0 | 0 |
| 3 | LESSER FLAMINGO | 5 | 2 | 3 | 0 | 0 | 0 | 0 | 4 | 2 | 0 | 0 |
| 3 | LESSER FLAMINGO | 6 | 2 | 4 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 |
| 3 | LESSER FLAMINGO | 7 | 2 | 4 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 |
| 3 | LESSER FLAMINGO | 8 | 2 | 4 | 0 | 0 | 0 | 0 | 4 | 1 | 0 | 0 |
| 3 | LESSER FLAMINGO | 9 | 2 | 3 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 |
| 3 | LESSER FLAMINGO | 10 | 2 | 2 | 0 | 0 | 0 | 0 | 2 | 3 | 3 | 0 |
| **Average Rate** | | | 2 | 3.6 | 0 | 0 | 0 | 0 | 4.4 | 0.9 | 0.3 | 0 |

| OBSERVATION | BIRD SPECIES | NUMBER | PACES | SCANNING | TRIAL PROBING | PECKING | SWISHING | PICKING | PREY INTAKE RATE | PAUSE | PREENING | FLYING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | GREATER FLAMINGO | 1 | 3 | 4 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 |
| 1 | GREATER FLAMINGO | 2 | 3 | 5 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 |
| 1 | GREATER FLAMINGO | 3 | 4 | 5 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 |
| 1 | GREATER FLAMINGO | 4 | 3 | 4 | 0 | 0 | 0 | 0 | 4 | 1 | 2 | 0 |
| 1 | GREATER FLAMINGO | 5 | 3 | 4 | 0 | 0 | 0 | 0 | 4 | 2 | 3 | 0 |
| 1 | GREATER FLAMINGO | 6 | 3 | 4 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 |
| 1 | GREATER FLAMINGO | 7 | 2 | 3 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 0 |
| 1 | GREATER FLAMINGO | 8 | 2 | 3 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 |
| 1 | GREATER FLAMINGO | 9 | 3 | 3 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 |
| 1 | GREATER FLAMINGO | 10 | 3 | 4 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 |
| **Average Rate** | | | 2.9 | 3.9 | 0 | 0 | 0 | 0 | 4.1 | 0.4 | 0.5 | 0 |

**Foraging behavior study of waders**

| OBSERVATION | BIRD SPECIES | NUMBER | PACES | SCANNING | TRIAL PROBING | PECKING | SWISHING | PICKING | PREY INTAKE RATE | PAUSE | PREENING | FLYING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | GREATER FLAMINGO | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 1 | 0 |
| 2 | GREATER FLAMINGO | 2 | 1 | 3 | 0 | 0 | 0 | 0 | 3 | 1 | 1 | 0 |
| 2 | GREATER FLAMINGO | 3 | 2 | 3 | 0 | 0 | 0 | 0 | 3 | 2 | 1 | 0 |
| 2 | GREATER FLAMINGO | 4 | 2 | 3 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 0 |
| 2 | GREATER FLAMINGO | 5 | 2 | 3 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 0 |
| 2 | GREATER FLAMINGO | 6 | 1 | 3 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 |
| 2 | GREATER FLAMINGO | 7 | 2 | 4 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 |
| 2 | GREATER FLAMINGO | 8 | 1 | 4 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 |
| 2 | GREATER FLAMINGO | 9 | 1 | 2 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 0 |
| 2 | GREATER FLAMINGO | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 |
| Average Rate | | | 1.2 | 2.5 | 0 | 0 | 0 | 0 | 2.5 | 1.1 | 1 | 0 |

**JASAI WETLAND**

Black winged Stilt, Greater Flamingo, Indian shag and Great Egret were found appropriate for focal sampling in Jasai wetland; so these birds were chosen for foraging behavior study in Jasai wetland.

| OBSERVATION | BIRD SPECIES | NUMBER | PACES | SCANNING | TRIAL PROBING | PECKING | SWISHING | PICKING | PREY INTAKE RATE | PAUSE | PREENING | FLYING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | BLACK WINGED STILT | 1 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 1 | BLACK WINGED STILT | 2 | 2 | 1 | 1 | 0 | 0 | 1 | 0 | 3 | 0 | 1 |
| 1 | BLACK WINGED STILT | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 |
| 1 | BLACK WINGED STILT | 4 | 2 | 1 | 0 | 0 | 0 | 1 | 0 | 3 | 0 | 1 |
| 1 | BLACK WINGED STILT | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 |
| 1 | BLACK WINGED STILT | 6 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 0 | 0 |
| 1 | BLACK WINGED STILT | 7 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 |
| 1 | BLACK WINGED STILT | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 |
| 1 | BLACK WINGED STILT | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 |
| 1 | BLACK WINGED STILT | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 |
| Average Rate | | | 0.9 | 0.4 | 0.3 | 0 | 0 | 0.2 | 0 | 2.8 | 0 | 0.3 |

## Foraging behavior study of waders

| OBSERVATION | BIRD SPECIES | NUMBER | PACES | SCANNING | TRIAL PROBING | PECKING | SWISHING | PICKING | PREY INTAKE RATE | PAUSE | PREENING | FLYING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | BLACK WINGED STILT | 1 | 4 | 4 | 3 | 3 | 3 | 2 | 3 | 0 | 0 | 0 |
| 2 | BLACK WINGED STILT | 2 | 4 | 3 | 2 | 2 | 2 | 1 | 2 | 0 | 0 | 0 |
| 2 | BLACK WINGED STILT | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 0 | 0 | 0 |
| 2 | BLACK WINGED STILT | 4 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 0 | 0 | 0 |
| 2 | BLACK WINGED STILT | 5 | 4 | 4 | 3 | 3 | 3 | 2 | 3 | 0 | 0 | 0 |
| 2 | BLACK WINGED STILT | 6 | 4 | 3 | 3 | 3 | 3 | 2 | 3 | 0 | 0 | 0 |
| 2 | BLACK WINGED STILT | 7 | 4 | 4 | 3 | 3 | 3 | 2 | 3 | 0 | 0 | 0 |
| 2 | BLACK WINGED STILT | 8 | 3 | 3 | 2 | 2 | 2 | 1 | 2 | 0 | 0 | 0 |
| 2 | BLACK WINGED STILT | 9 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 0 | 0 | 0 |
| 2 | BLACK WINGED STILT | 10 | 3 | 3 | 2 | 2 | 2 | 1 | 2 | 0 | 0 | 0 |
| **Average Rate** | | | 3.5 | 3.3 | 2.5 | 2.5 | 2.5 | 1.7 | 2.5 | 0 | 0 | 0 |

| OBSERVATION | BIRD SPECIES | NUMBER | PACES | SCANNING | TRIAL PROBING | PECKING | SWISHING | PICKING | PREY INTAKE RATE | PAUSE | PREENING | FLYING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | GREATER FLAMINGO | 1 | 2 | 2 | 0 | 0 | 0 | 1 | 1 | 2 | 3 | 0 |
| 1 | GREATER FLAMINGO | 2 | 2 | 2 | 0 | 0 | 0 | 1 | 1 | 2 | 3 | 0 |
| 1 | GREATER FLAMINGO | 3 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 1 | GREATER FLAMINGO | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| 1 | GREATER FLAMINGO | 5 | 3 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 0 |
| 1 | GREATER FLAMINGO | 6 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 0 |
| 1 | GREATER FLAMINGO | 7 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 0 |
| 1 | GREATER FLAMINGO | 8 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 0 |
| 1 | GREATER FLAMINGO | 9 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 0 |
| 1 | GREATER FLAMINGO | 10 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 |
| **Average Rate** | | | 3 | 0.5 | 0.1 | 0.1 | 0.2 | 0.3 | 0.3 | 2.1 | 2.2 | 0 |

| OBSERVATION | BIRD SPECIES | NUMBER | PACES | SCANNING | TRIAL PROBING | PECKING | SWISHING | PICKING | PREY INTAKE RATE | PAUSE | PREENING | FLYING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | GREATER FLAMINGO | 1 | 2 | 3 | 0 | 0 | 0 | 0 | 4 | 1 | 1 | 0 |
| 2 | GREATER FLAMINGO | 2 | 1 | 4 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 |
| 2 | GREATER FLAMINGO | 3 | 1 | 4 | 0 | 0 | 0 | 0 | 4 | 1 | 2 | 0 |
| 2 | GREATER FLAMINGO | 4 | 1 | 3 | 0 | 0 | 0 | 0 | 3 | 2 | 1 | 0 |
| 2 | GREATER FLAMINGO | 5 | 1 | 4 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 |
| 2 | GREATER FLAMINGO | 6 | 1 | 4 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 |
| 2 | GREATER FLAMINGO | 7 | 1 | 4 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 |
| 2 | GREATER FLAMINGO | 8 | 2 | 4 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 |
| 2 | GREATER FLAMINGO | 9 | 2 | 4 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 |
| 2 | GREATER FLAMINGO | 10 | 1 | 4 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 |
| **Average Rate** | | | 1.3 | 3.8 | 0 | 0 | 0 | 0 | 3.9 | 0.4 | 0.4 | 0 |

## Foraging behavior study of waders

| OBSERVATION | BIRD SPECIES | NUMBER | PACES | SCANNING | TRIAL PROBING | PECKING | SWISHING | PICKING | PREY INTAKE RATE | PAUSE | PREENING | FLYING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | INDIAN SHAG | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 |
| 1 | INDIAN SHAG | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 |
| 1 | INDIAN SHAG | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 |
| 1 | INDIAN SHAG | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 |
| 1 | INDIAN SHAG | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 |
| 1 | INDIAN SHAG | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 0 |
| 1 | INDIAN SHAG | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 0 |
| 1 | INDIAN SHAG | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 0 |
| 1 | INDIAN SHAG | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 |
| 1 | INDIAN SHAG | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 |
| **Average Rate** | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3.7 | 1.4 | 0 |

| OBSERVATION | BIRD SPECIES | NUMBER | PACES | SCANNING | TRIAL PROBING | PECKING | SWISHING | PICKING | PREY INTAKE RATE | PAUSE | PREENING | FLYING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | INDIAN SHAG | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 |
| 2 | INDIAN SHAG | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 |
| 2 | INDIAN SHAG | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 2 | 0 |
| 2 | INDIAN SHAG | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 3 | 0 |
| 2 | INDIAN SHAG | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 |
| 2 | INDIAN SHAG | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 0 |
| 2 | INDIAN SHAG | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 0 |
| 2 | INDIAN SHAG | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 0 |
| 2 | INDIAN SHAG | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 1 | 0 |
| 2 | INDIAN SHAG | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 |
| **Average Rate** | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3.6 | 1.9 | 0 |

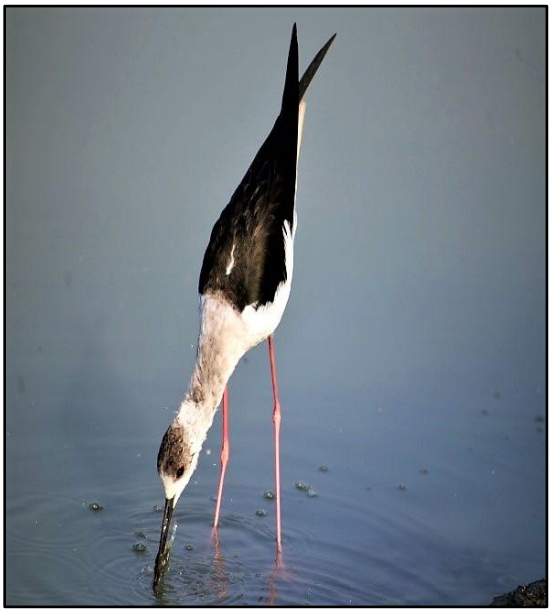
| OBSERVATION | BIRD SPECIES | NUMBER | PACES | SCANNING | TRIAL PROBING | PECKING | SWISHING | PICKING | PREY INTAKE RATE | PAUSE | PREENING | FLYING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | GREAT EGRET | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 |
| 1 | GREAT EGRET | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 1 |
| 1 | GREAT EGRET | 3 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| 1 | GREAT EGRET | 4 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| 1 | GREAT EGRET | 5 | 3 | 3 | 3 | 2 | 2 | 3 | 3 | 2 | 0 | 1 |
| **Average Rate** | | | 0.9 | 0.7 | 0.3 | 0.2 | 0.2 | 0.3 | 0.3 | 2.66 | 0.29 | 0.2 |

| OBSERVATION | BIRD SPECIES | NUMBER | PACES | SCANNING | TRIAL PROBING | PECKING | SWISHING | PICKING | PREY INTAKE RATE | PAUSE | PREENING | FLYING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | GREAT EGRET | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 |
| 2 | GREAT EGRET | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 1 |
| 2 | GREAT EGRET | 3 | 3 | 3 | 1 | 1 | 1 | 0 | 0 | 2 | 0 | 0 |
| 2 | GREAT EGRET | 4 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 3 | 0 | 0 |
| 2 | GREAT EGRET | 5 | 3 | 4 | 3 | 2 | 2 | 3 | 3 | 2 | 0 | 1 |
| **Average Rate** | | | 1.79 | 1.77 | 0.83 | 0.62 | 0.62 | 0.73 | 0.73 | 2.166 | 0.029 | 0.32 |

**Foraging activity: Black winged stilt**

**Scanning**

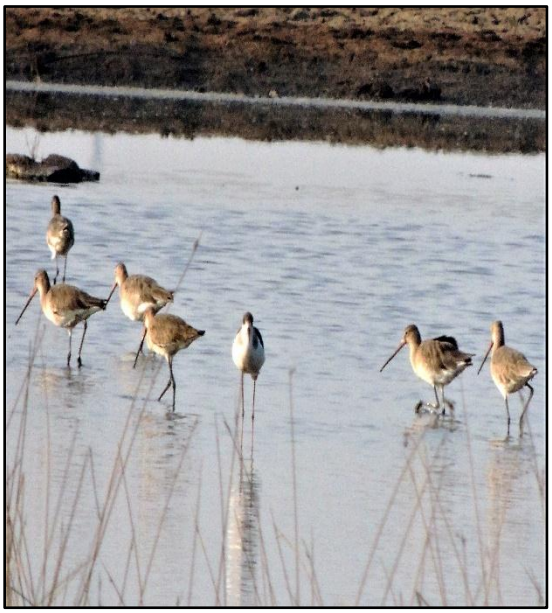
**Picking**



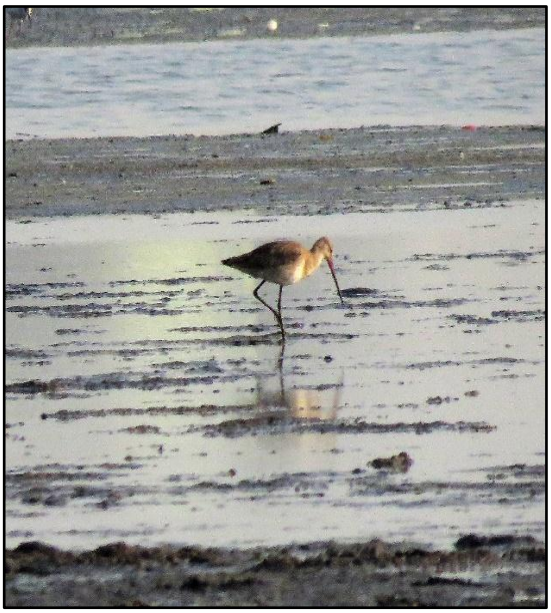
**Probing**

**Captured prey**

**Foraging Activity: Black tailed Godwit**

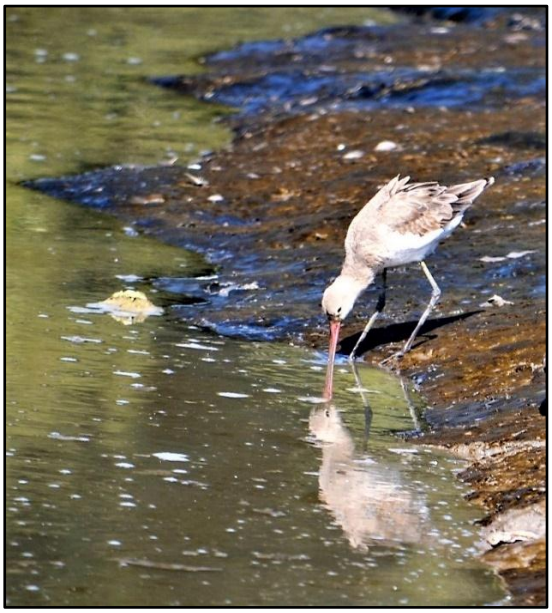


**Flock**



**Scanning**

**Picking**

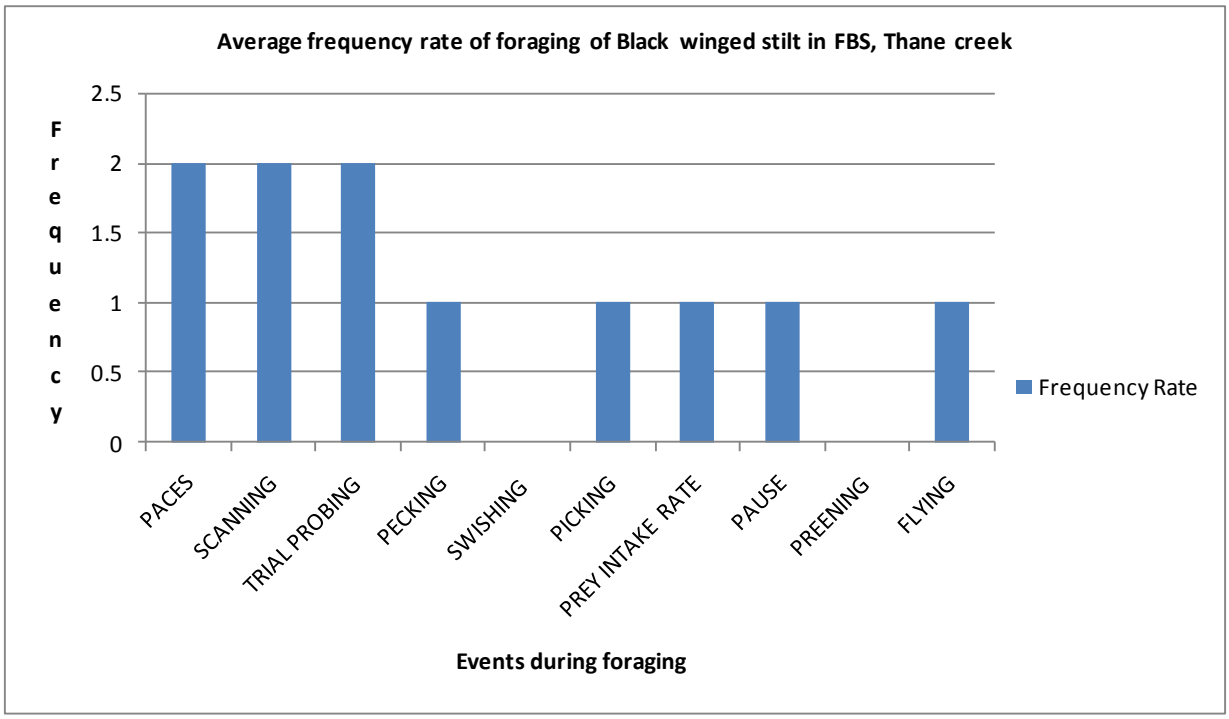


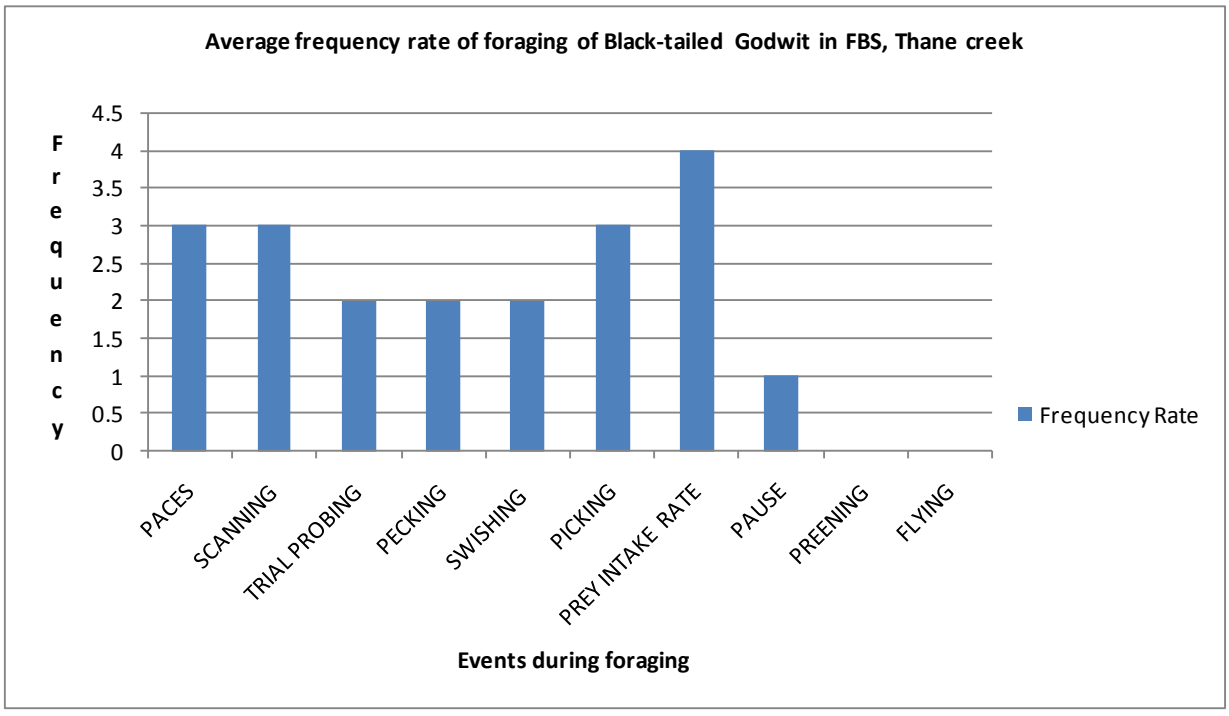
**Picking**

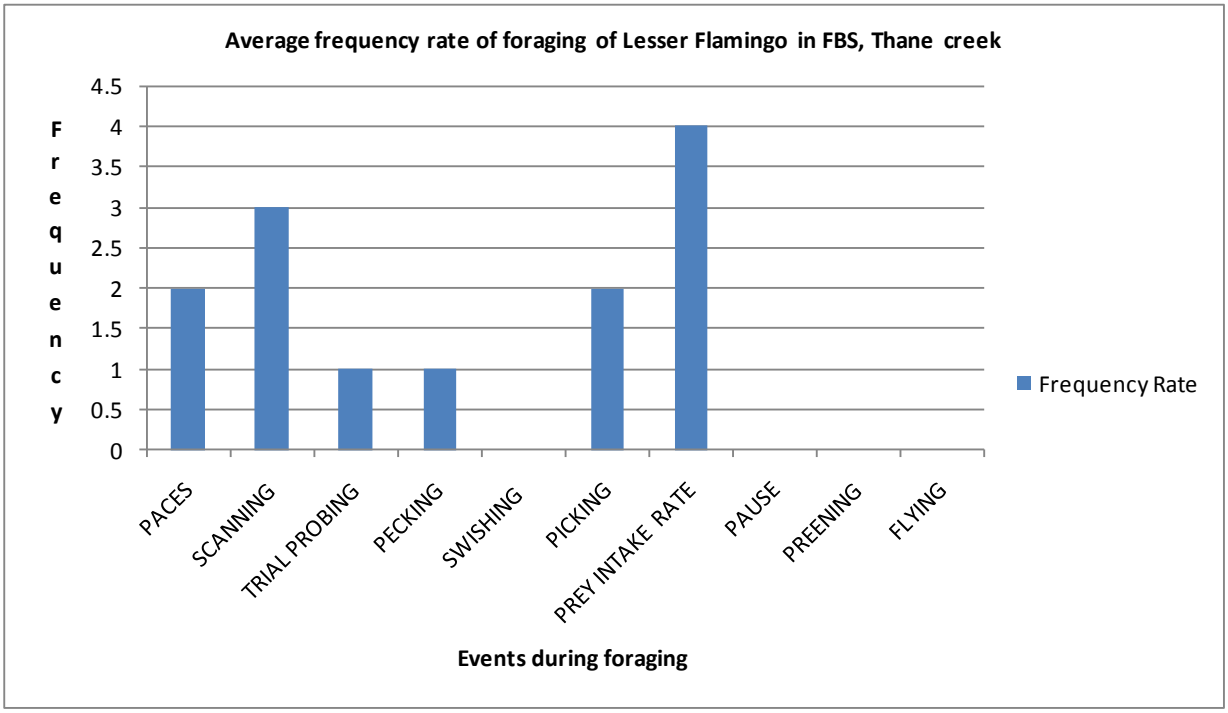
**Foraging of Flamingoes (FBS)**

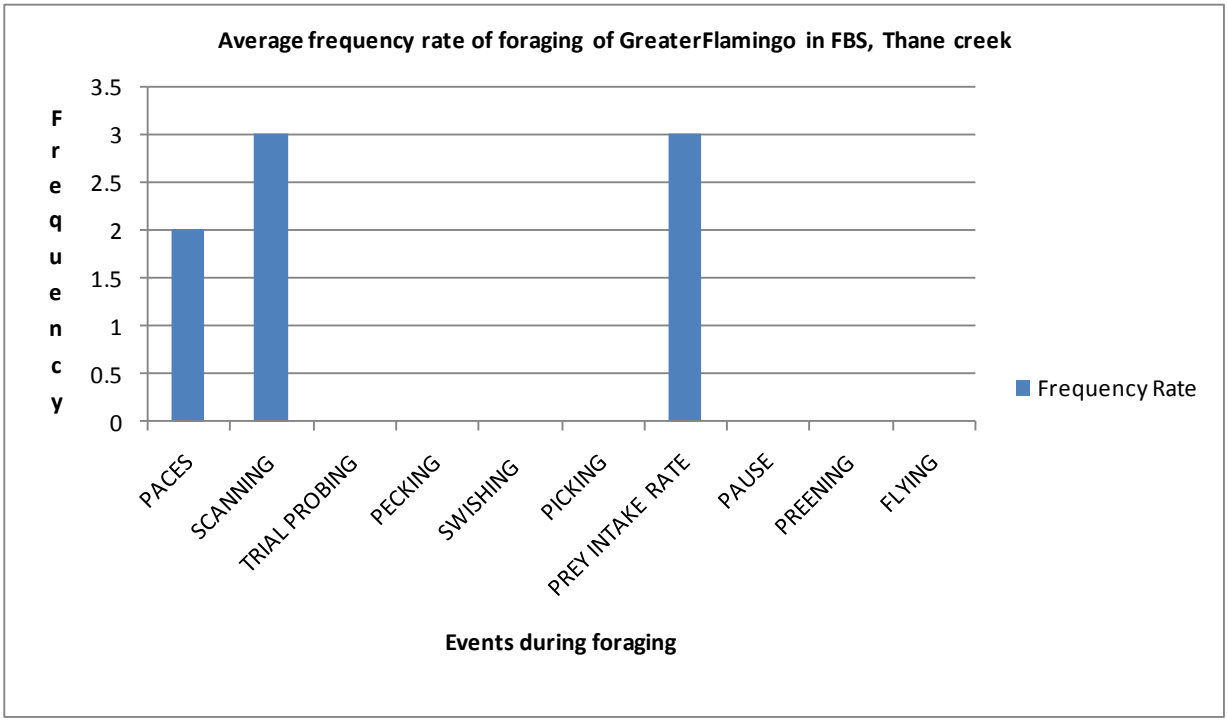
**Flamingo Flock: Dance/Marching for attracting females**

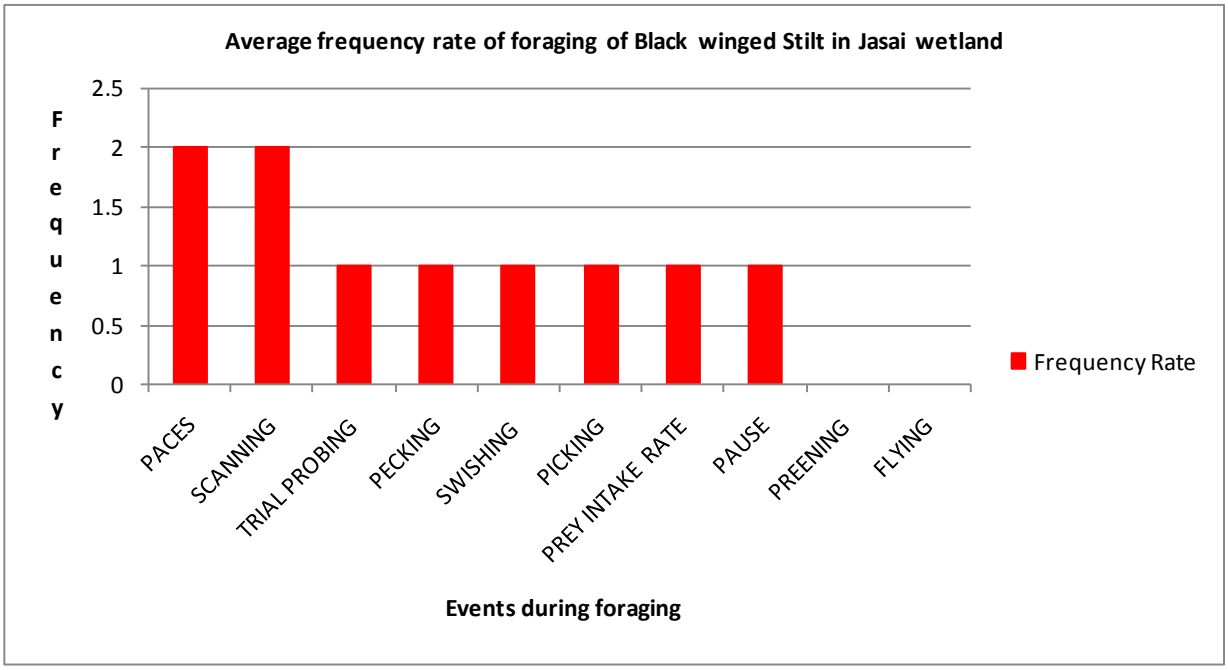
Following graphs showing the average frequency rates of waders while foraging from FBS, Thane creek and Jasai wetland.

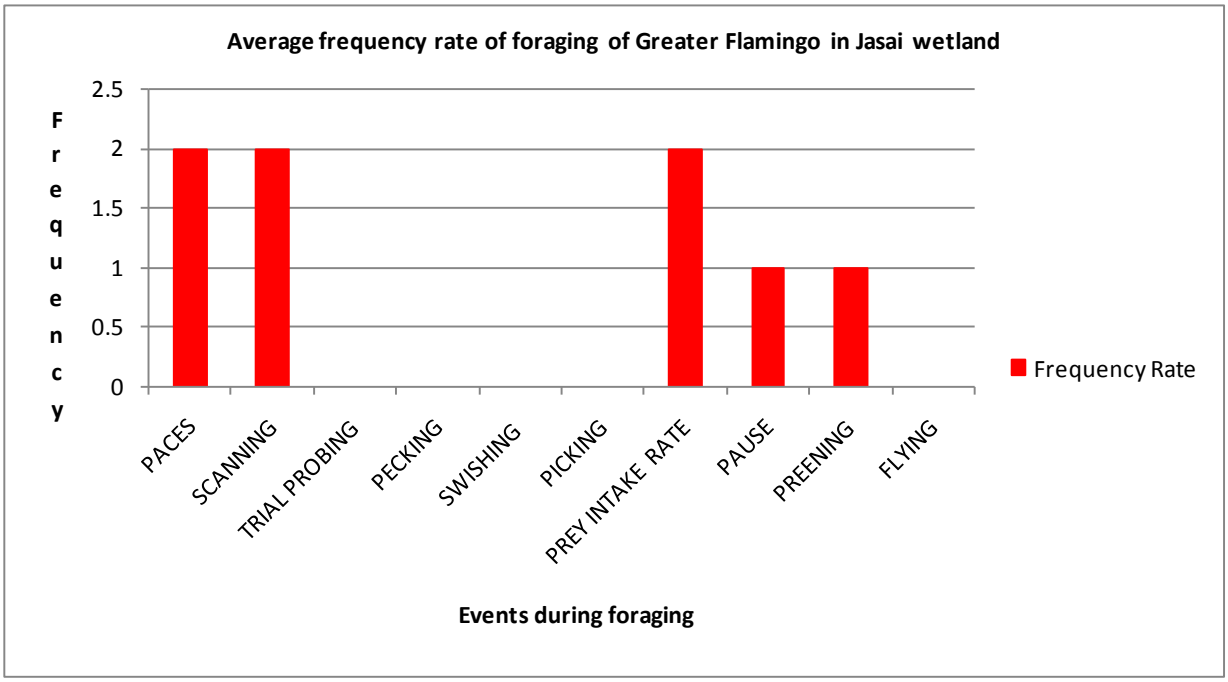


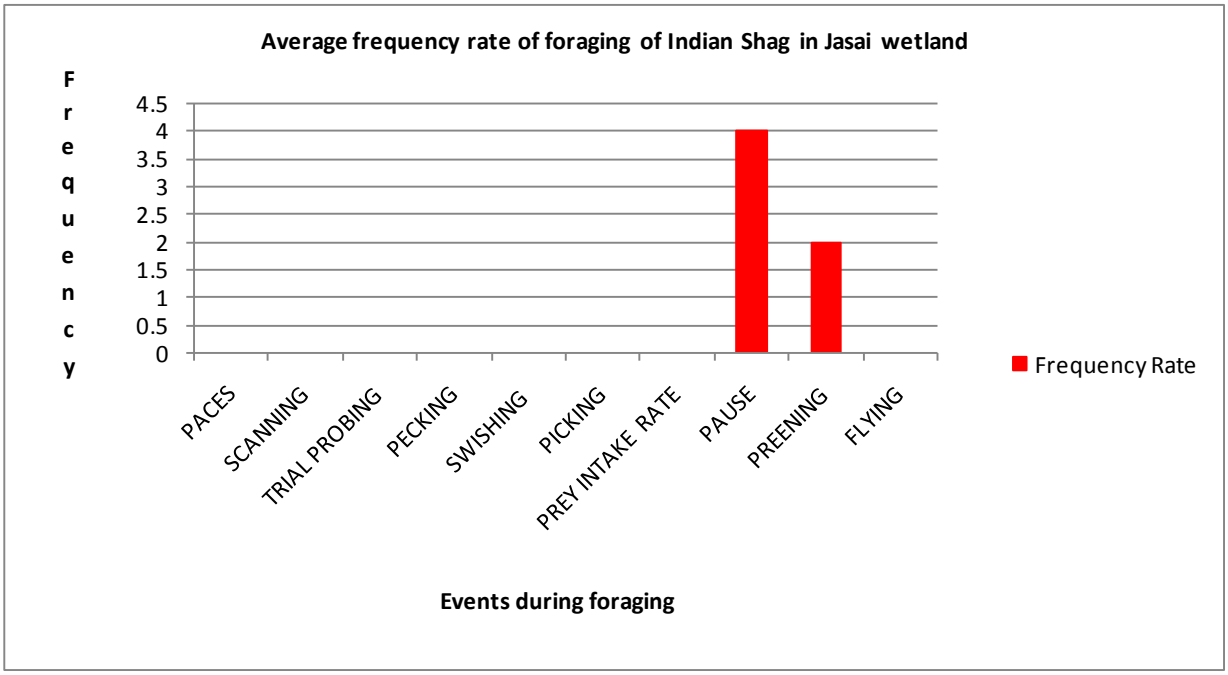



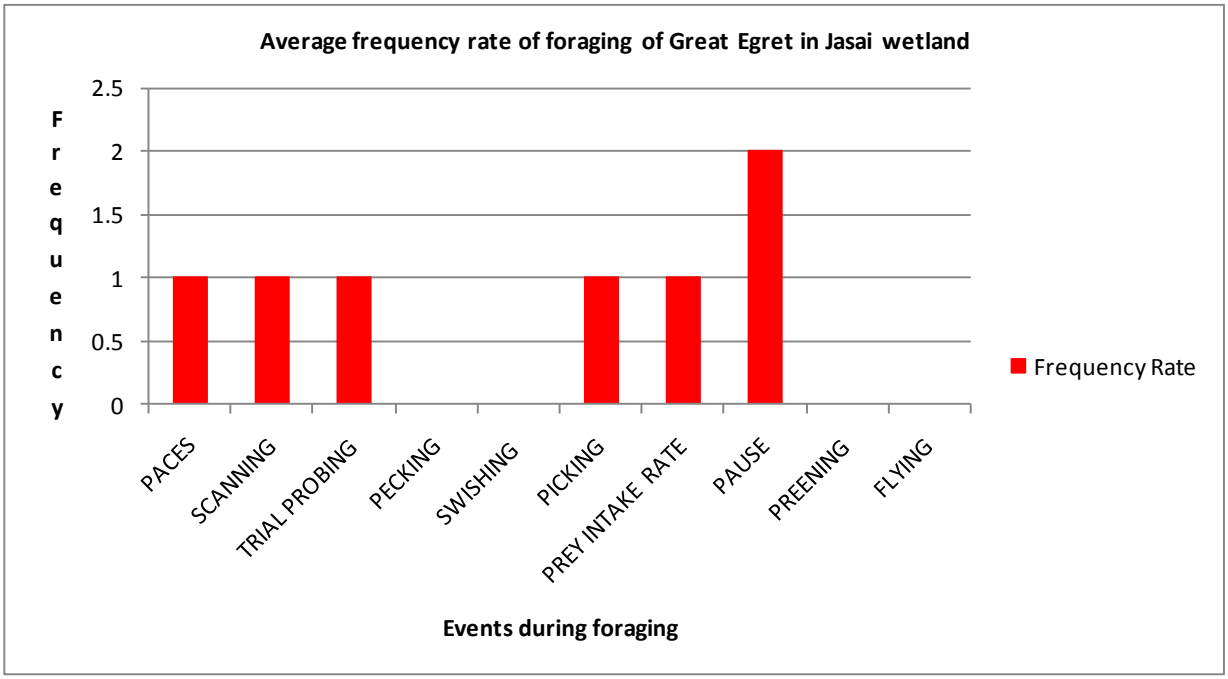

Average frequency rate of foraging of Lesser Flamingo in FBS, Thane creek
Frequency
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
PACES
SCANNING
TRIAL PROBING
PECKING
SWISHING
PICKING
PREY INTAKE RATE
PAUSE
PREENING
FLYING
Frequency Rate
Events during foraging


Average frequency rate of foraging of GreaterFlamingo in FBS, Thane creek
Frequency
3.5
3
2.5
2
1.5
1
0.5
0
PACES
SCANNING
TRIAL PROBING
PECKING
SWISHING
PICKING
PREY INTAKE RATE
PAUSE
PREENING
FLYING
Frequency Rate
Events during foraging


Average frequency rate of foraging of Black winged Stilt in Jasai wetland
Frequency
2.5
2
1.5
1
0.5
0
PACES
SCANNING
TRIAL PROBING
PECKING
SWISHING
PICKING
PREY INTAKE RATE
PAUSE
PREENING
FLYING
Frequency Rate
Events during foraging


Average frequency rate of foraging of Greater Flamingo in Jasai wetland
Frequency
2.5
2
1.5
1
0.5
0
PACES
SCANNING
TRIAL PROBING
PECKING
SWISHING
PICKING
PREY INTAKE RATE
PAUSE
PREENING
FLYING
Frequency Rate
Events during foraging




## 3.3PHYSICO – CHEMICAL PARAMETERS:

Water and sediment samples were collected monthly from study area during the low tide and parameters were assessed by following standard methods.

Results of water parameters are given in Table 1.3 and soil parameters are given in Table 1.4

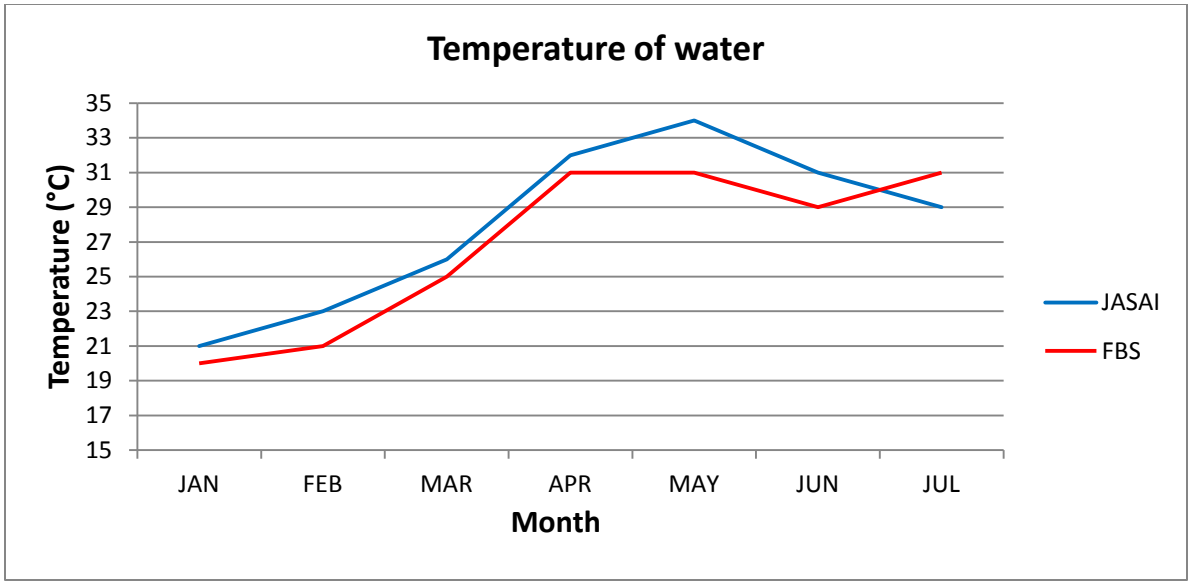
## Water analysis:

**Table 1.3 Parameters of waters of Jasai wetland, Uran and FBS of Thane creek.**

| LOCATION | MONTH | TEMP (°C) | pH | SALINITY (‰) | DO (ppm) | NITRATE (ppm) | INORGANIC PHOSPHOROUS (ppm) |
|---|---|---|---|---|---|---|---|
| JASAI | JAN | 21 | 7.5 | 7.662 | 3.624 | 0.55 | 0.36 |
| | FEB | 23 | 8.5 | 3.674 | 3.422 | 0.56 | 0.64 |
| | MAR | 26 | 8.5 | 8.582 | 3.02 | 1 | 0.98 |
| | APR | 32 | 8.5 | 9.94 | 4.429 | 0.96 | 0.36 |
| | MAY | 34 | 5 | 9.62 | 3.521 | 0.5 | 0.179 |
| | JUN | 31 | 6 | 9.94 | 3.423 | 0.5 | 0.199 |
| | JUL | 29 | 6 | 0.33 | 15.303 | 40 | 0.31 |
| | | | | | | | |
| FBS | JAN | 20 | 7.5 | 2.972 | 4.63 | 0.78 | 0.14 |
| | FEB | 21 | 7.5 | 3.279 | 4.228 | 0.67 | 0.42 |
| | MAR | 25 | 8.5 | 3.761 | 4.832 | 1.12 | 0.64 |
| | APR | 31 | 7.5 | 4.681 | 4.026 | 1 | 0.51 |
| | MAY | 31 | 6 | 4.43 | 4.233 | 30 | 0.004 |
| | JUN | 29 | 6 | 4.80 | 3.021 | 7.5 | 0.01 |
| | JUL | 31 | 6 | 0.35 | 4.429 | 30 | 0.54 |

**Temperature (°C):**

Temperature is an important environmental parameter as it affects the rate of metabolism, growth, feeding, distribution, reproductive cycle and migratory behaviour of aquatic animals. (Quadros 2001, Chaudhary 2015).

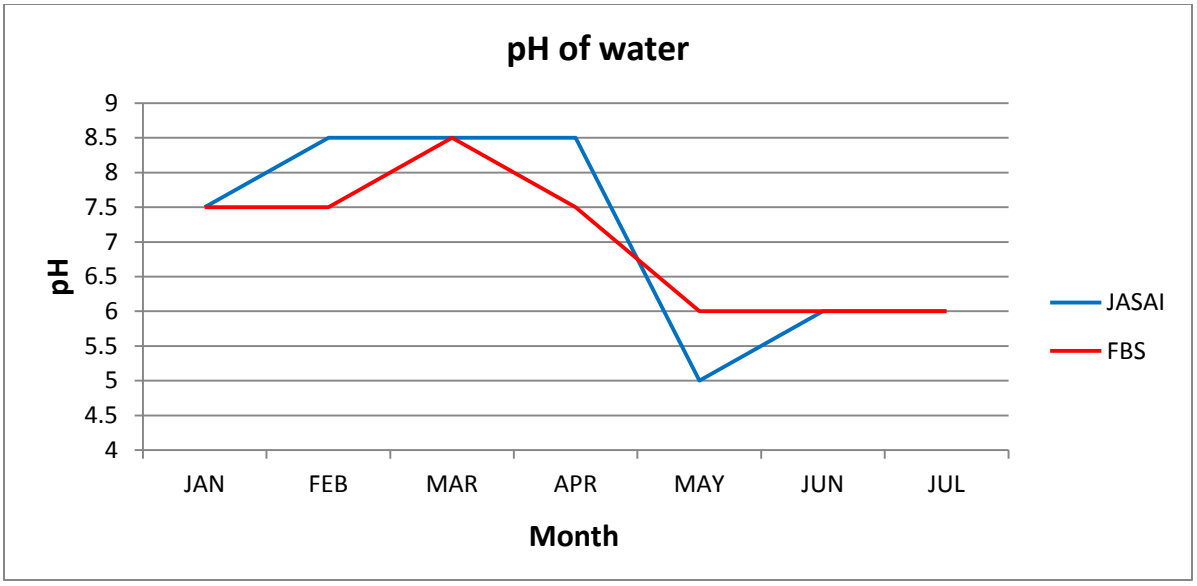



Graph showing monthly variation in water temperature at both the study areas

During the study period water temperature varied from 21 to 34 °C and average temperature was 28 °C in Jasai wetlands. In Flamingo Bird Sanctuary, Thane creek minimum temperature was 20 and maximum was 31 °C and average temperature was 27 °C.

**pH:**

In aquatic ecosystems the pH is a function of the dissolved carbon dioxide content (Odum,1971). In freshwaters the dissolved carbon dioxide makes the pH slightly acidic, whereas in marine water, along with dissolved carbon dioxide there are other weakly ionizing chemicals and salts, which make the pH slightly alkaline around 8 (Levinton, 1982). The estimation of pH, can thus illustrate the status of decomposition, respiration and photosynthesis in water. Moreover, pH changes cause reshuffling of ionic properties of suspended particles and metals, leading sometimes to their precipitation; they also govern leaching of nutrients and other chemicals from the sediments.

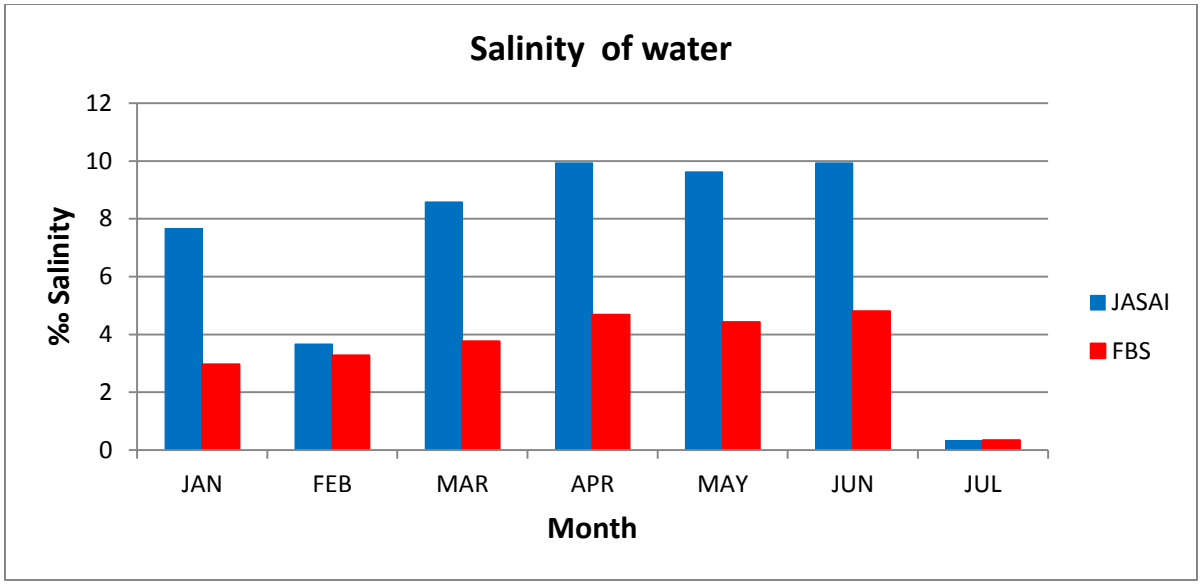



Graph showing monthly variation in pH of water at both the study areas

At Jasai wetlands the maximum pH recorded was 8.5 and minimum was 5.0. From January to April it was from7.5 to 8.5. From May to July pH was reduced to acidic. At Flamingo Bird Sanctuary maximum pH was 8.5 and minimum was 6.0. Here also from May to July pH reduced to slightly acidic.

**Salinity:**

Salinity is another important water parameter in estuaries and creeks. It is largely influenced by influx of freshwater and intrusion of seawater (Anirudhan & Nambissan 1990). Salinity changes with the flood and the ebb tides. These changes in salinity present significant physiological challenges to the organisms affecting their occurrence and distribution (Levinton, 1982).

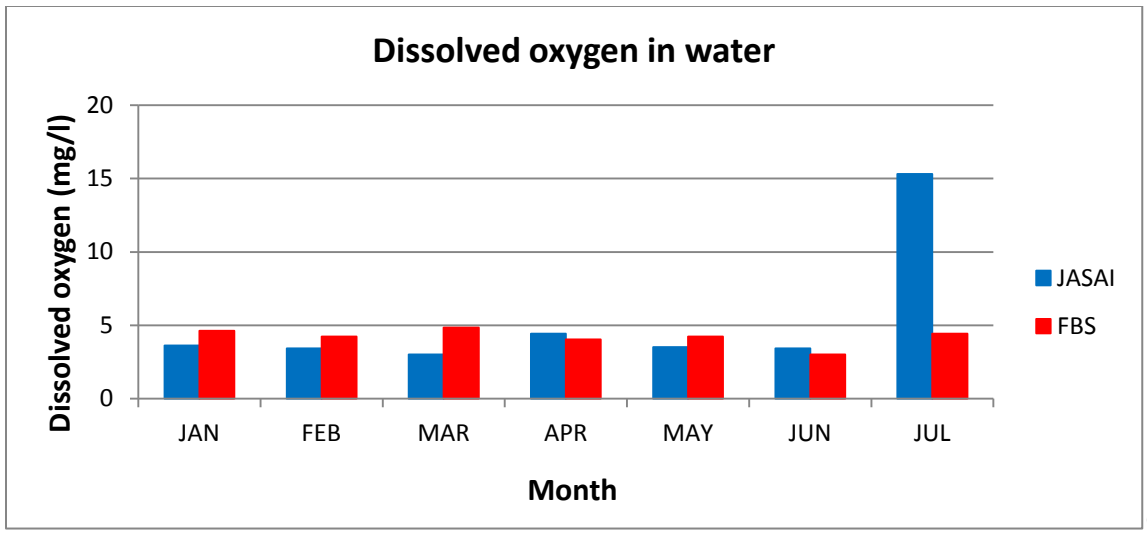



Graph showing monthly variation in salinity of water at both the study areas

In Jasai wetlands the minimum salinity was 0.33 ‰ and maximum salinity was 9.94‰. Average salinity was 7.12 ‰. In Flamingo Bird Sanctuary minimum salinity was 0.35‰ and maximum salinity was 4.8‰. Average salinity was 3.47 ‰.

**Dissolved Oxygen:**

Dissolved oxygen level in water reveals much about the metabolism of water and is used as an index of water quality, primary productivity and pollution. The sources of dissolved oxygen are, from the atmosphere and the photosynthetic processes of the green plants. Active photosynthesis and respiration of planktonic organisms in surface waters can significantly change the oxygen concentration over short periods of time. Moreover, decomposing bacteria, can rapidly remove oxygen from the waters (Levinton, 1982).

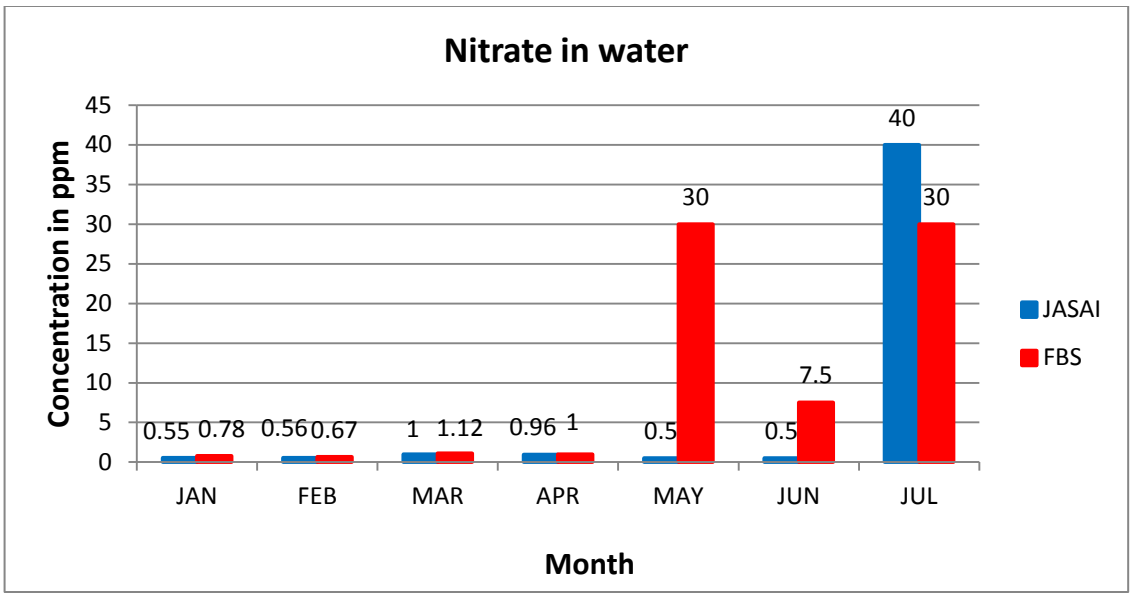


Graph showing monthly variation in dissolved oxygen in water at both the study areas

In Jasai wetlands maximum Dissolved oxygen level was 15.303 mg/l and minimum was 3.02 mg/l. In Flamingo Bird Sanctuary Maximum Dissolved oxygen level was 4.832 mg/l and minimum was 3.021 mg/l. Average Dissolved oxygen level was 5.25 mg/l and 4.20 mg/l at Jasai wetlands and Flamingo Bird Sanctuary respectively.

**Nitrate:**

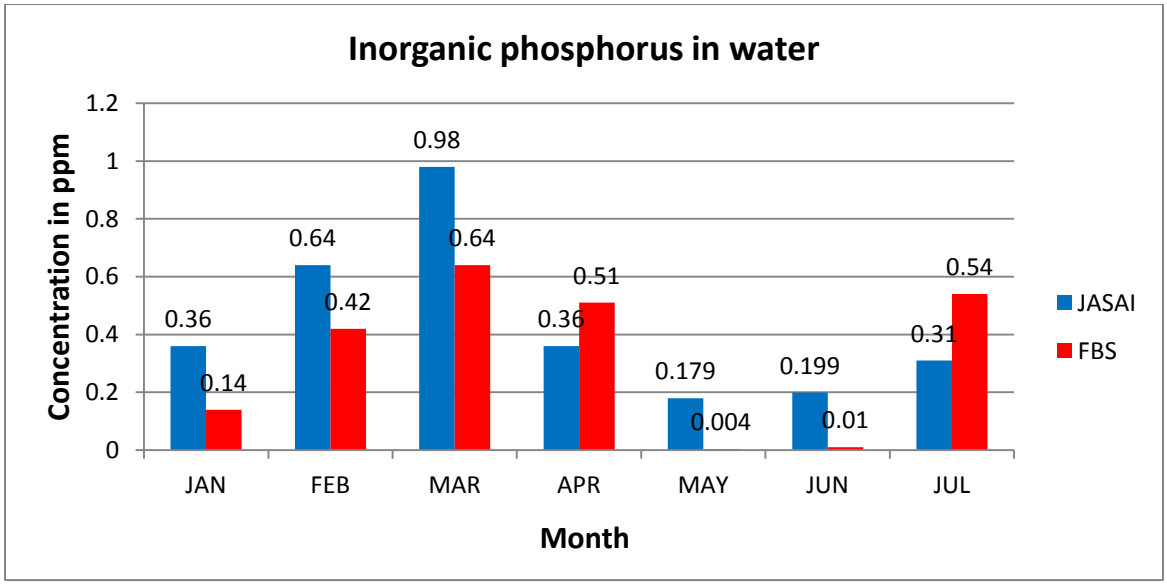
Nitrogen is a parameter that significantly affects phytoplankton growth in natural waters. In an aquatic biotope inorganic nitrogen is present as oxidized nitrite ($NO_2$) and nitrate ($NO_3$) and as reduced ammonia ($NH_4$) the most abundant form being nitrate (Nair *et al.*,1983; Athalye 1988).




Graph showing monthly variation in concentration of Nitrate in water at both the study areas

At Jasai wetlands maximum concentration of Nitrate was 40 ppm and minimum was 0.5 ppm. At Flamingo Bird Sanctuary maximum concentration of Nitrate was 30 ppm and minimum was 0.67 ppm. Average concentration of Nitrate was 6.30 and 10.15 ppm at Jasai wetlands and Flamingo Bird Sanctuary respectively.

**Inorganic phosphorus:**




Graph showing monthly variation in concentration of Inorganic phosphorus in water at both the study areas.

Minimum concentration of Inorganic phosphorus during study period was 0.18 ppm and maximum was 0.98 ppm at Jasai wetlands. At Flamingo Bird Sanctuary minimum concentration of inorganic phosphorus was found to be 0.004 ppm and maximum was found to be 0.64 ppm. Average concentration was 0.43 ppm and 0.32 ppm at Jasai wetland and Flamingo Bird Sanctuary respectively.

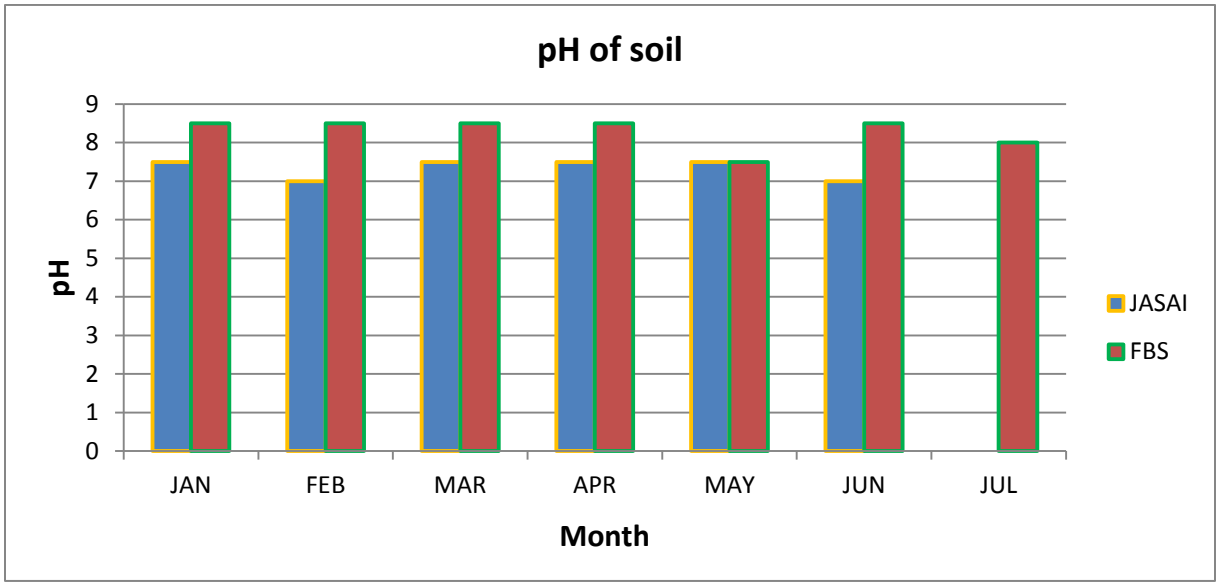
## Sediment Analysis:

**Table 1.4 Parameters of soil of Jasai wetland, Uran and FBS of Thane creek.**

| LOCATION | MONTH | SOIL TEXTURE | % CHLORIDE | % ORGANIC CARBON | % ORGANIC MATTER | % AVAILABLE PHOSPHOROUS | pH |
|---|---|---|---|---|---|---|---|
| JASAI | JAN | Sandy Clay | 1.988 | 1.382 | 2.38 | 0.0065 | 7.5 |
| | FEB | Sandy Clay | 2.733 | 1.224 | 2.108 | 0.0085 | 7 |
| | MAR | Sandy Clay | 3.131 | 1.244 | 2.143 | 0.01 | 7.5 |
| | APR | Sandy Clay | 3.677 | 1.165 | 2.007 | 0.0125 | 7.5 |
| | MAY | Sandy Clay | 2.797 | 1.384 | 2.387 | 0.092 | 7.5 |
| | JUN | Sandy Clay | 3.145 | 1.846 | 3.182 | 0.058 | 7 |
| | | | | | | | |
| FBS | JAN | Clayey Fine Silt | 2.037 | 1.047 | 1.803 | 0.015 | 8.5 |
| | FEB | Clayey Fine Silt | 2.38 | 1.145 | 1.974 | 0.014 | 8.5 |
| | MAR | Fine Silty Clay | 2.932 | 1.185 | 2.041 | 0.011 | 8.5 |
| | APR | Clayey Fine Silt | 3.429 | 1.283 | 2.21 | 0.012 | 8.5 |
| | MAY | Clayey Fine Silt | 2.851 | 1.846 | 3.182 | 0.045 | 7.5 |
| | JUN | Clayey Fine Silt | 3.045 | 2.307 | 3.970 | 0.003 | 8.5 |
| | JUL | Clayey Fine Silt | 0.575 | 3.230 | 5.568 | 0.27 | 8 |

**pH:**

pH is a parameter that plays an important role in the recycling of nutrients between water and sediments of an estuary (Nasnolkar *et al.*, 1996). The oxic and anoxic conditions indirectly affect the soil pH, rendering it from acidic to alkaline.

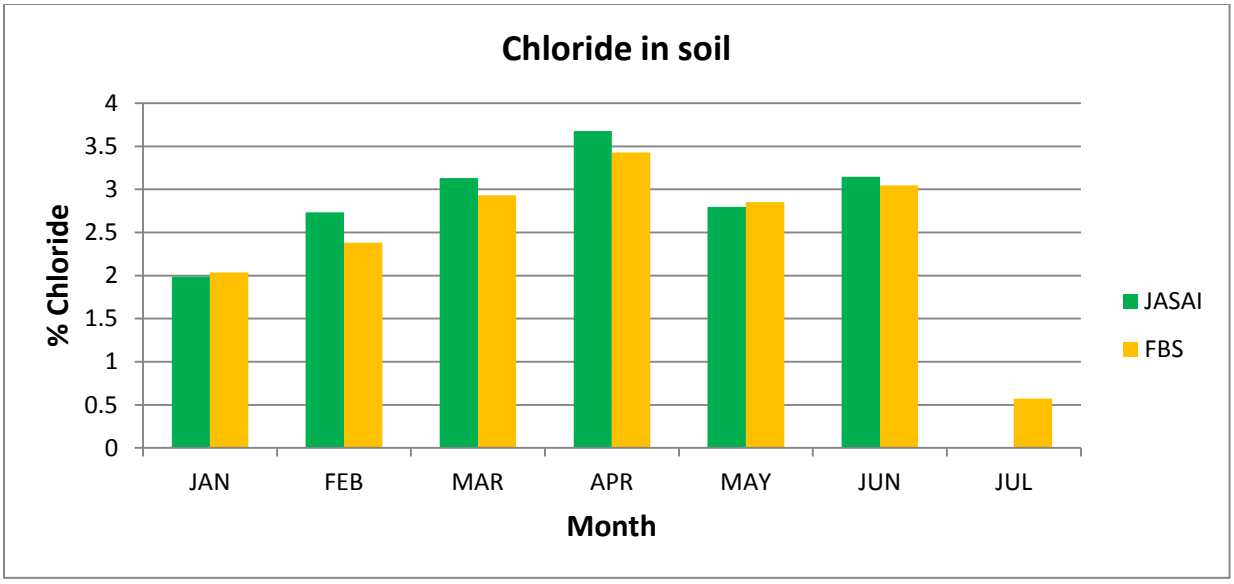



Graph showing monthly variation in pH of soil at both the study areas.

Minimum pH was 7.0, maximum pH was 7.5 and Average pH was 7.3 at Jasai wetlands. Minimum pH was 7.5, maximum pH was 8.5 and average pH was 8.3 at Flamingo Bird Sanctuary.

**Chloride:**

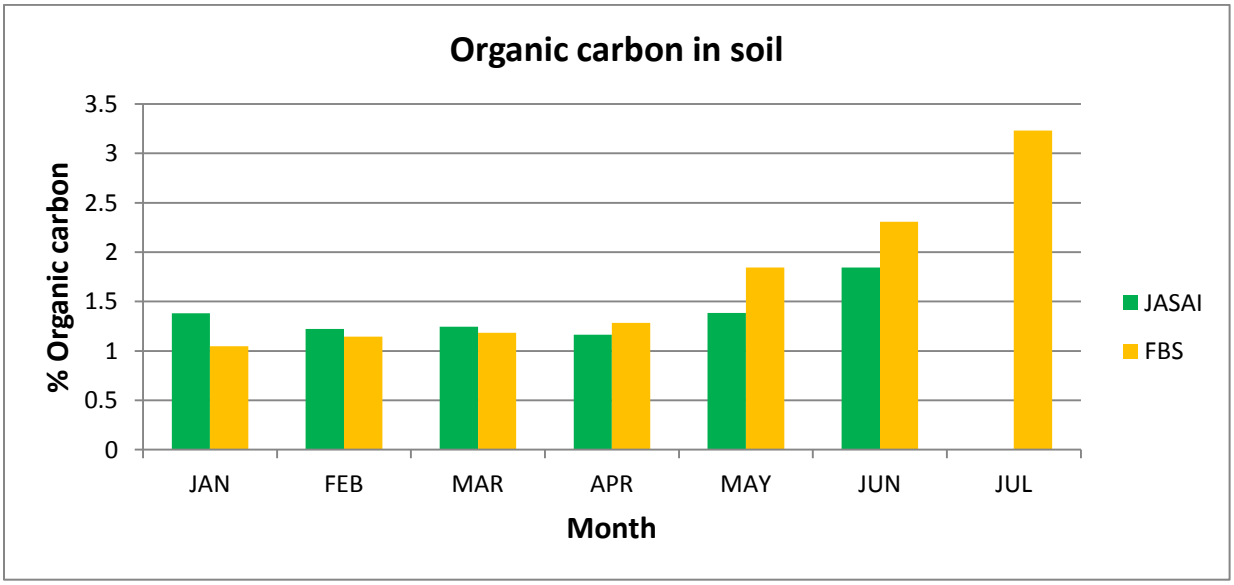
According to Dyer(1972), salinity pattern in an estuary throws light on many a physical processes and biological processes taking place in an estuary. Chloride is a major salt influencing salinity and hence estimation of chloride gives a fair idea of the salinity in an ecosystem.




Graph showing monthly variation in chlorides in soil at both the study areas.

At Jasai wetland maximum chloride concentration was 3.677 %, minimum chloride concentration was 1.988 % and average chloride concentration was 2.912 %. At Flamingo Bird Sanctuary maximum chloride concentration was 3.429 %, minimum chloride concentration was 0.575 % and average chloride concentration was 2.464%.

**Organic carbon:**



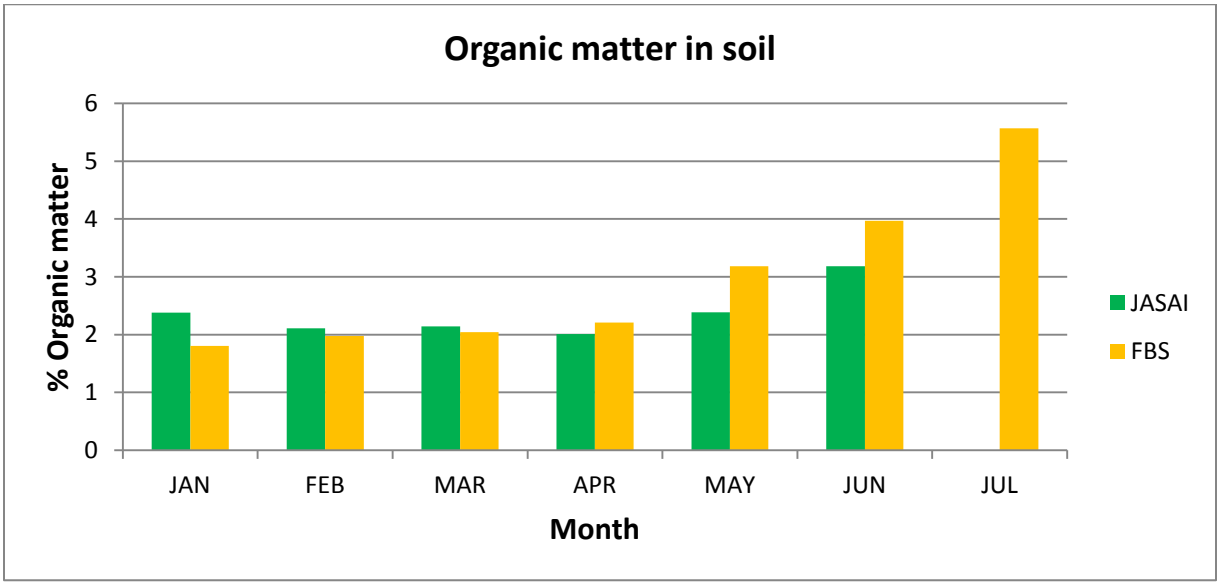

Graph showing monthly variation of organic carbon in soil at both the study areas.

Maximum organic carbon concentration was 1.846%, minimum organic carbon concentration was 1.165 % and average organic carbon concentration was 1.374% at

Jasai wetland. At Flamingo Bird Sanctuary maximum organic carbon concentration was 3.23%, minimum organic carbon concentration was 1.047 % and average organic carbon concentration was 1.720%

**Organic matter:**

Estuaries receive inputs of organic matter originating in the surrounding watershed and delivered by river or produced in surrounding habitats and tidal flats & marine derived organic matter from the adjacent coastal ocean (Canuel *et al.*, 1995).According to Ansari& Parulekar (1998), autochthonous sources like phytoplankton, benthic algae & vascular plants also form the organic matter. Industrial and municipal discharge may be important in some estuaries as well, although each of these sources may contribute substantially to the input of organic matter. Study of organic matter is necessary, as it is well known that substrate organic matter represents a food source for deposit feeding organisms (Mare, 1942).

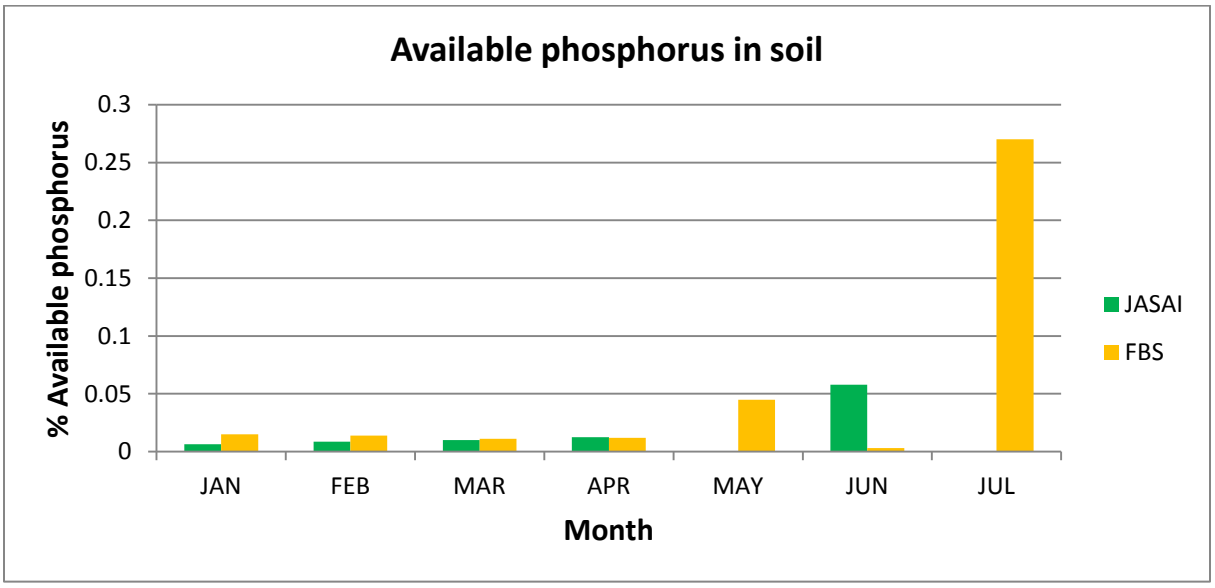



Graph showing monthly variation in organic matter in soil at both the study areas.

Maximum organic matter concentration was 3.182%, minimum organic matter concentration was 2.007% and average organic matter concentration was 2.3678% at Jasai wetland. At Flamingo Bird Sanctuary maximum organic matter concentration was 5.568%, minimum organic matter concentration was 1.803% and average organic matter concentration was 2.964%

**Available phosphorus:**

Phosphorus is available mainly in three different types inorganic phosphorus, organic phosphorus and particulate phosphorus. In the water body decaying vegetation and processes like mineralization makes phosphorus available for aquatic organisms. This available phosphorus is an important nutrient like other nutrients. The increase in the amount of Phosphorus may lead to the eutrophication which can harm the biodiversity of benthic fauna resulted to the loss of wader diversity hence the estimation of Available Phosphorus is necessary in order to understand the wader foraging and diversity more specifically.




Graph showing monthly variation in available phosphorus in soil at both the study areas.

During study period estimated maximum available phosphorus concentration was 0.0065%, minimum available phosphorus concentration was 0.058% and average available phosphorus concentration was 0.0191% at Jasai wetland. At Flamingo Bird Sanctuary maximum available phosphorus concentration was 0.27%, minimum available phosphorus concentration was 0.003% and average available phosphorus concentration was 0.0529%.

**Sediment texture:**

The diversity and abundance of benthic organism is influenced by sediment texture of coastal ecosystems like creek or backwater. Hence any disturbance to the soft sediment can damage the existing fauna and render the habitat available for new colonization and succession of species (Sanders et al., 1980; Quadros 2001).

Sediment texture analysis was done monthly at both the study areas. Results are as follows:

| LOCATION | MONTH | SOIL TEXTURE |
|---|---|---|
| JASAI | JANUARY | SANDY CLAY |
| JASAI | FEBRUARY | SANDY CLAY |
| JASAI | MARCH | SANDY CLAY |
| JASAI | APRIL | SANDY CLAY |
| JASAI | MAY | SANDY CLAY |
| JASAI | JUNE | SANDY CLAY |
| FBS | JANUARY | CLAYEY FINE SILT |
| FBS | FEBRUARY | CLAYEY FINE SILT |
| FBS | MARCH | FINE SILTY CLAY |
| FBS | APRIL | CLAYEY FINE SILT |
| FBS | MAY | CLAYEY FINE SILT |
| FBS | JUNE | CLAYEY FINE SILT |
| FBS | JULY | CLAYEY FINE SILT |

## 3.4 BIOLOGICAL PARAMETERS:

**Phytoplankton Diversity:**

Phytoplankton are photosynthesizing microscopic organisms that inhabit the upper sunlit layer of almost all oceans and fresh water bodies on Earth. The quality and quantity of phytoplankton is good indicator of water quality. Phytoplankton account for about half of all photosynthetic activity on Earth. They are agents for "primary production," the creation of organic compounds from carbon dioxide dissolved in the water, a process that sustains the aquatic food web**.**

According to Badsi, Rajesh *et al.*, Ananthan *et al.*, Tiwari and Chauhan, Tas and Gonulol and Saravanakumar *et al.*, phytoplanktonic organisms are one of the initial biological components from which the energy is transferred to higher organisms through food chain. The density and the diversity of phytoplankton are biological indicators for evaluating water quality and the degree of eutrophication. (Badsi, P. Ponmanickam et al and T. R. Shashi Shekhar *et al.*)

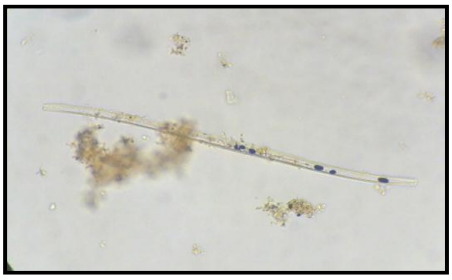
In the present study Phytoplankton samples were collected monthly from both the study sites. In Flamingo bird sanctuary the phytoplankton sample is collected at 19°8'54.50"N 72°59'0.32"E and in the Jasai wetland phytoplankton sample is collected at 18°55'38.75"N 73°0'57.40"E. Water samples were collected in 500 ml wide mouth white coloured bottles. Lugol's iodine was added in each sample immediately after collection by proper agitating the sample for thorough mixing. Samples were analyzed in the laboratory on compound light microscope. Standard keys were used for identification.

The most important groups of phytoplankton include diatoms, cyanobacteria, dinoflagellates, and groups of algae. Phytoplanktons are crucially dependent on minerals such as nitrate, phosphate or silicic acid. Phytoplankton rapidly responds to the changes in the environmental conditions. Their presence or absence from the community indicates changes in physico-chemical environment. There are studies stating that the diatoms like *Nitzschia sp.*, *Chlorella sp., Oscillatoria sp.* can be used as an indicator of organic pollution.

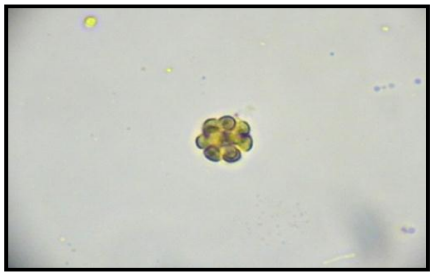
Following are the phytoplankton species observed while analyzing the samples from both the study.

**Phytoplankton sp. observed in waters of FBS, Thane creek:**

***Cocconies sp.***

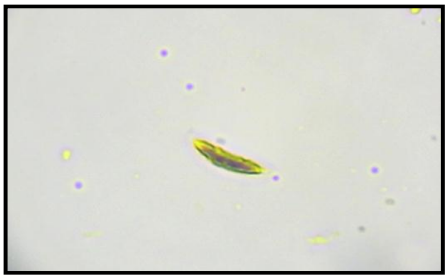


***Gyrosigma sp.***



***Coelastrum sp.***

***Melosira sp.***

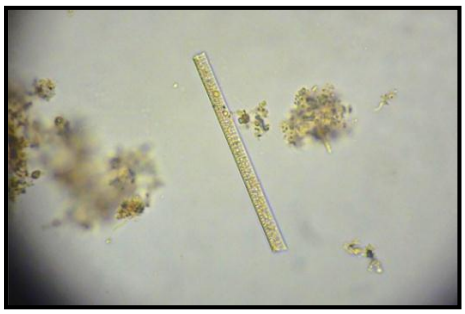


***Cymbella sp.***

***nitzschia sp.***

***Euglena sp.***

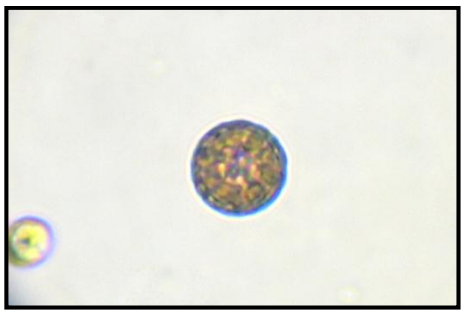
***Odontella sp.***



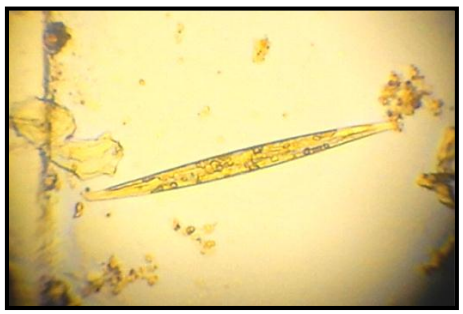
***Oscillatoria sp.***

***Rhizosolenia sp.***

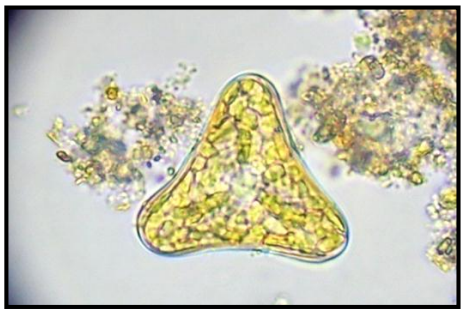
***Phacus sp.***



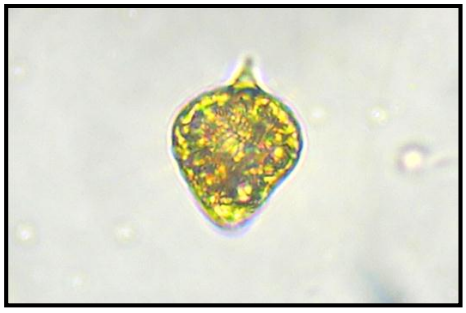
***Thalassiosira sp.***



***Pleurosigma sp.***

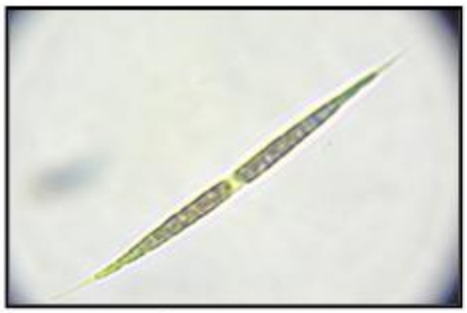


***Trigonium sp.***

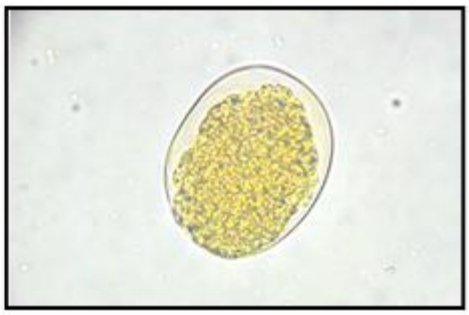


***Prorocentrum sp.***

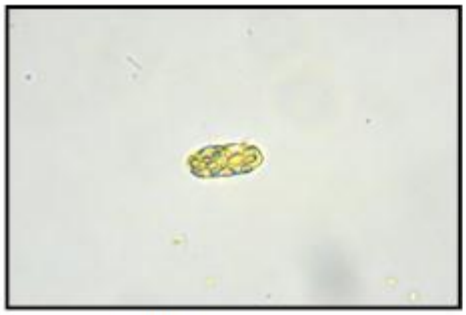
***Skeletonema sp.***



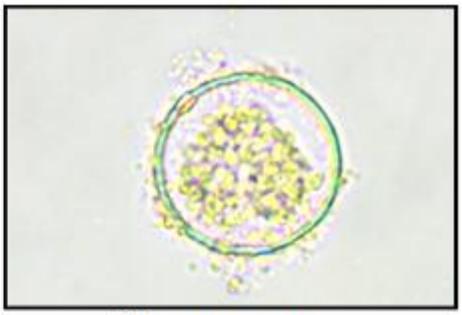
*Closterium sp.*



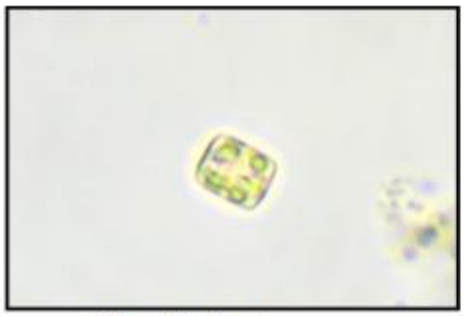
***Coscinodiscus sp.***



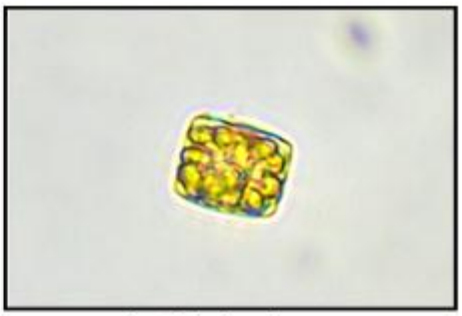
***Diatom sp.***



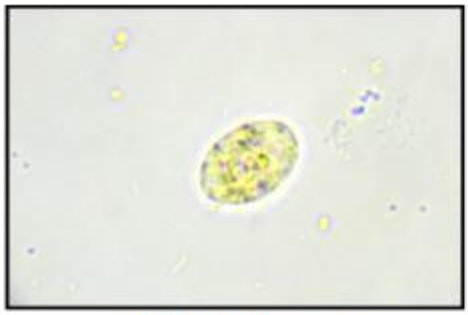
***Gleocapsa sp.***



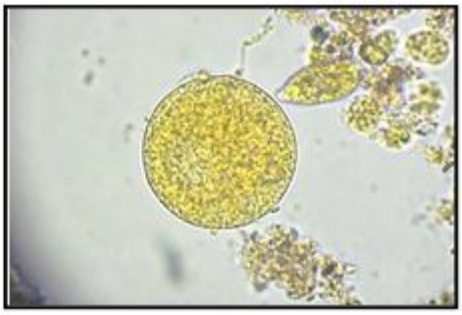
***Thallisiosira sp.***



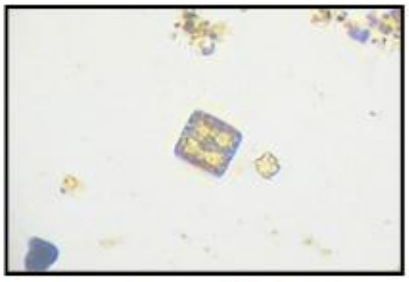
***Thallisiosira sp.***



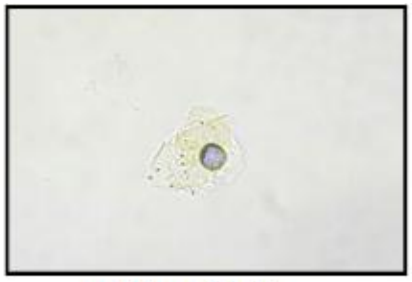
***Amphidium sp.***



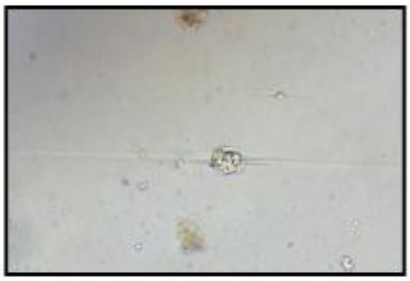
***Coscinodiscus sp.***



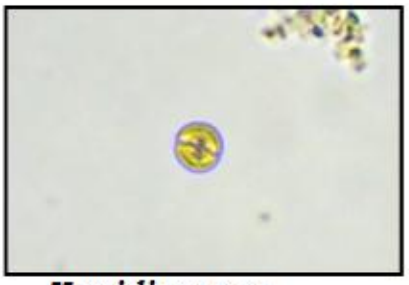
*Coscionodiscus sp.*



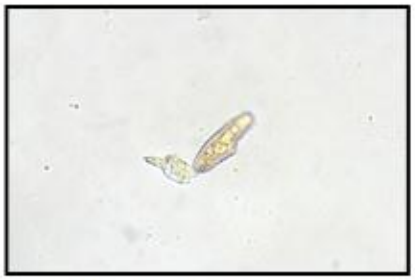
*Unidentified*



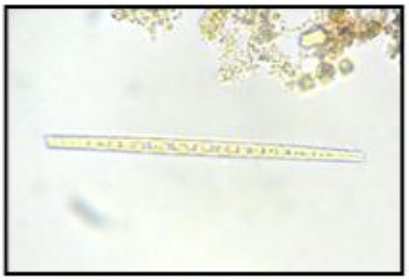
*Chaetoceros sp.*



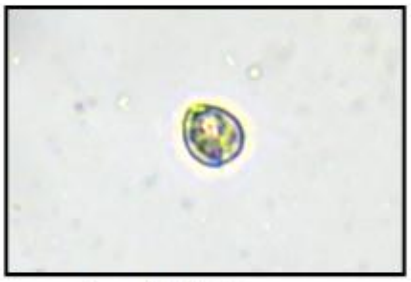
*Hemidiscus sp.*



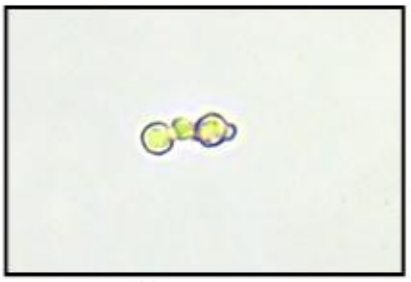
*Unidentified*



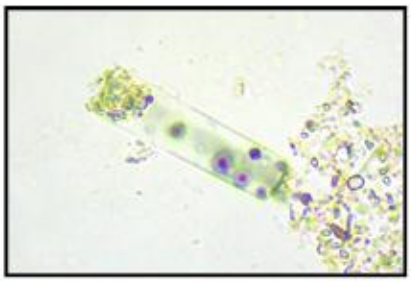
*Thalasionema sp.*



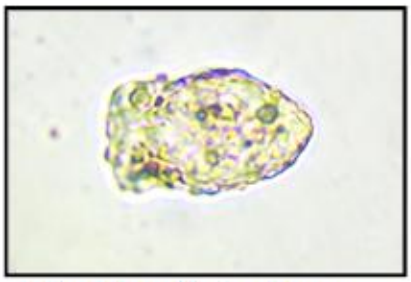
*Amphidinium sp.*



*Radiococcus sp.*

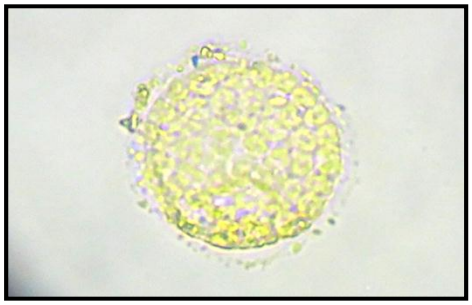


*Leptocylindrus sp.*

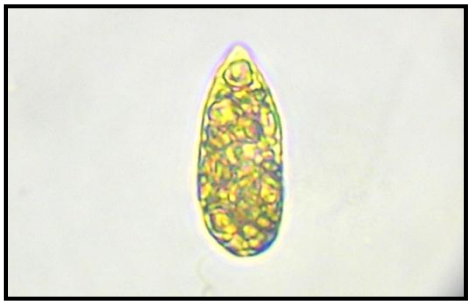


*Dinoflagellate alagra*

**Phytoplankton sp. observed in waters of Jasai wetland, Uran:**



***Aphanocapsa sp.***

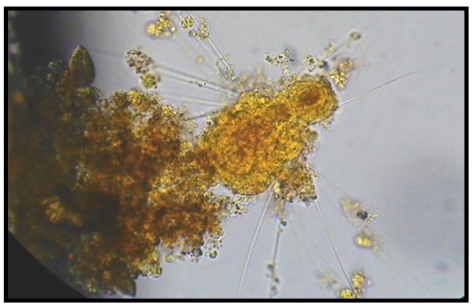


***Euglena sp.***

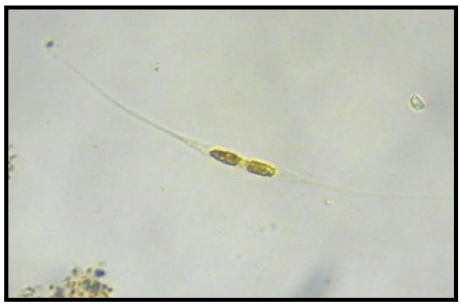
***Cymbella sp.***

***Navicula sp.***

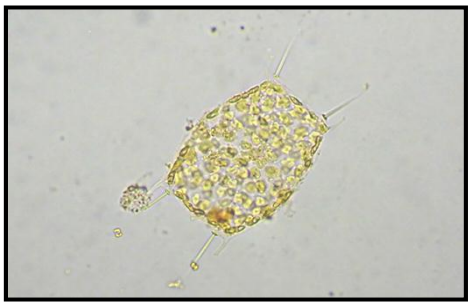
***Gyrosigma sp.***



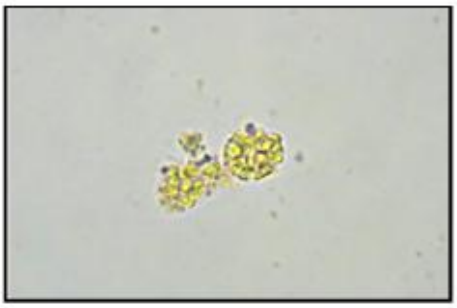
***Mallomonas sp.***



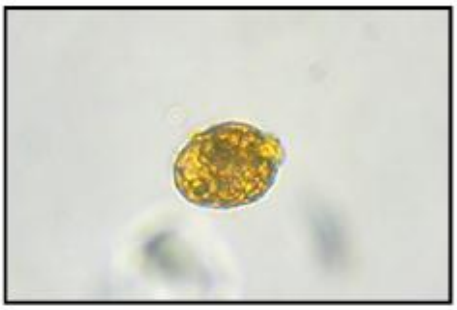
***Nitzschia sp.***



***Odontella sp.***

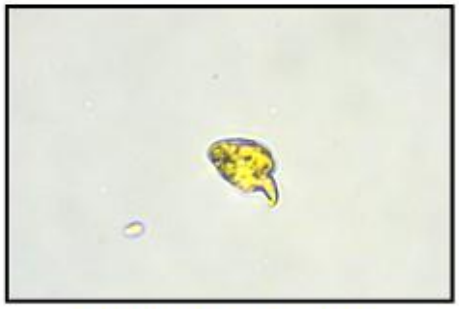


*Pandorina sp.*

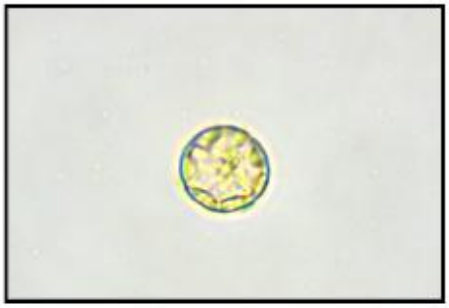


*Prorocentrum sp.*

*Rhizosolenia sp.*

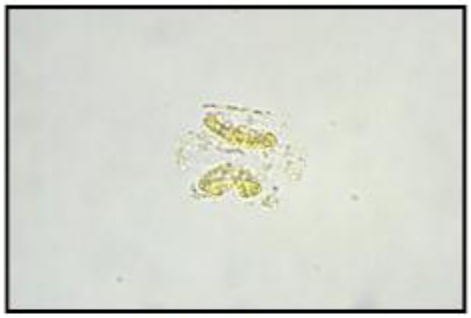


***Chloroplast broken***

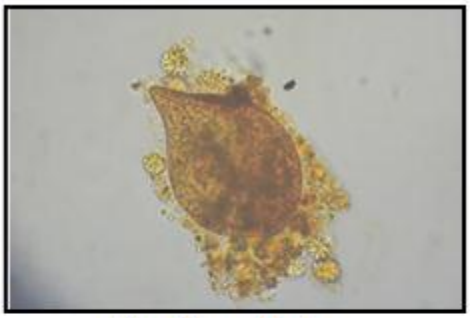


*Thalassiosira sp.*

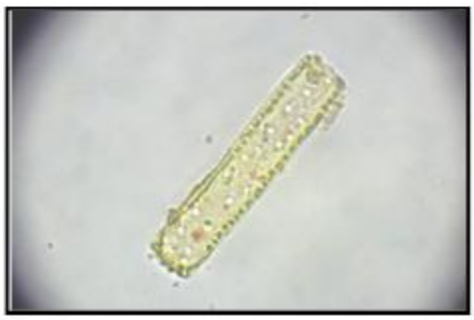
***Coscinodiscus sp.***



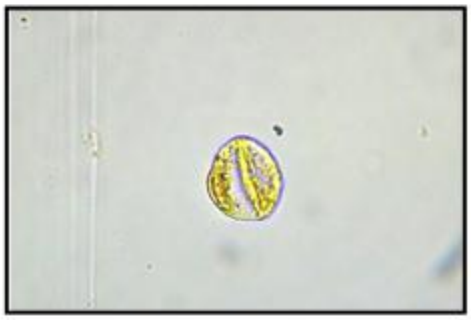
*Chloroplast*



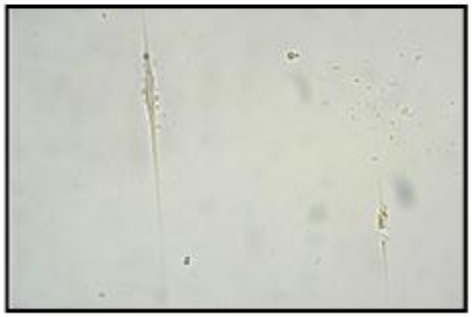
*Dinoflagellate*



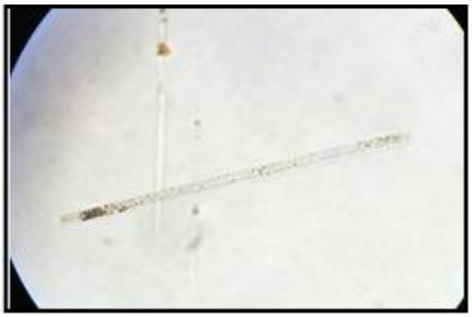
*Coscinodiscus sp.*



*Surivella sp.*



*Nitzschia sp.*



*Thalasiothrix sp.*

**Benthos Diversity:**

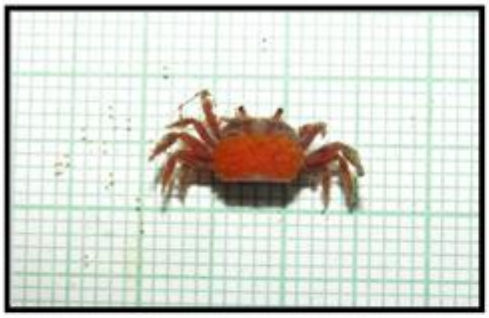
Benthic macro-invertebrate species are differentially sensitive to many biotic and abiotic factors in their environment (Mandaville 2002). Relative abundance and diversity of their community have commonly been used as an indicator of the condition of an aquatic system (Mandaville 2002; Azrina *et al.*2005). Benthos populations depend on the condition of the environment such as water quality, organic matter content, soil texture, sediment particles and the ability to construct permanent burrows in the substratum (Dahanayaka and Wijeyaratne 2006).

Coastal areas are often characterized by high benthic invertebrate production, and often support complex food webs, especially in estuaries and lagoons. Waders like Gulls, Terns and other shore birds regularly use coastal habitats as feeding ground. The term 'shorebird' refers to birds which have any activity such as resting, feeding or nesting within the shore system (Baird *et al.*, 1985). Many of these shore bird species obtain a substantial proportion of their daily energy requirements by predating benthic fauna.

During study period Benthos samples were collected monthly from both the study sites. At Flamingo bird sanctuary benthic samples were collected at 19° 8'54.50"N 72°59'0.32"Eand at Jasai wetland Benthos samples were collected at 18°55'38.75"N 73°0'57.40"E.Samples were collected in polythene bag by using handheld grab and immediately preserved in 10% formalin solution. Samples were analyzed under microscope in the laboratory and identified using standard keys.

Following are the benthic organisms found at broth the study locations while analyzing the samples.

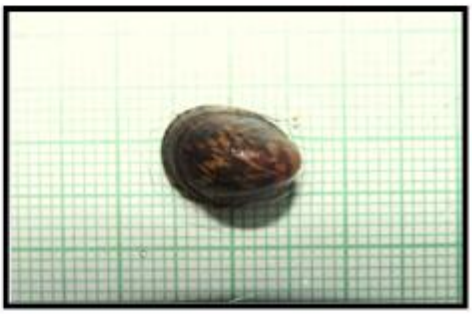
Benthic organisms found in waters of FBS, Thane creek



*Illyoplax gangetica*

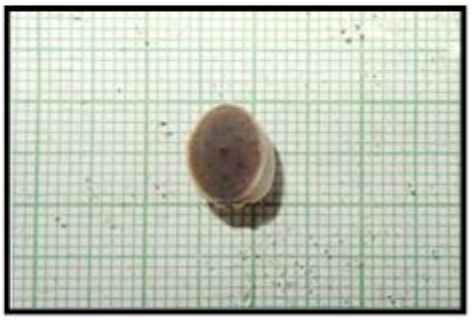
*Assaminea bervicula*

***Cerithium sp.***

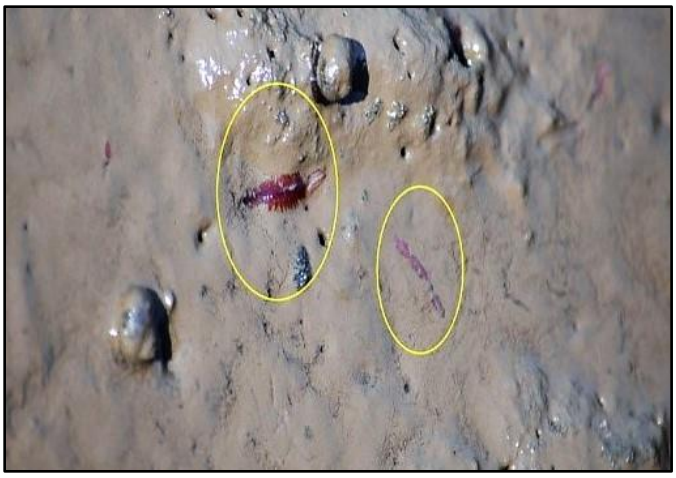


*Nerita sp.*

***Salinator burmana***

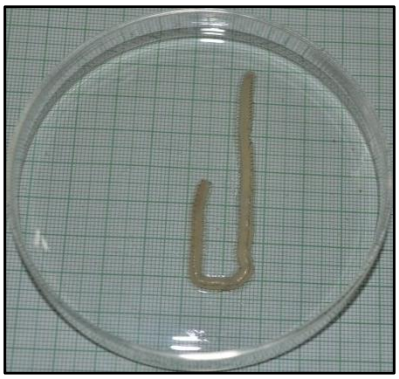


*Onchidium sp.*



Polychaete

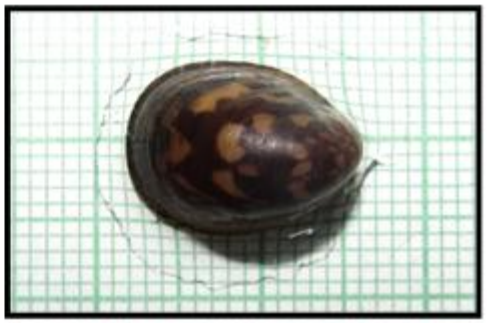
*Nereis species*



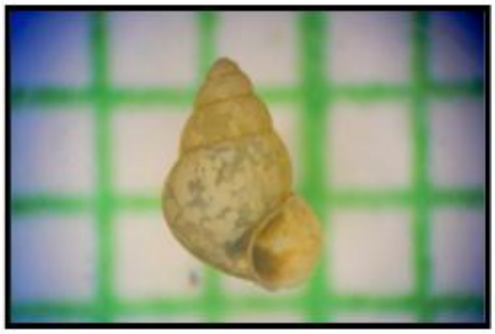
Unidentified polychaete

Benthic organisms found in waters of Jasai wetland , Uran:

*Cerethidea sp.*

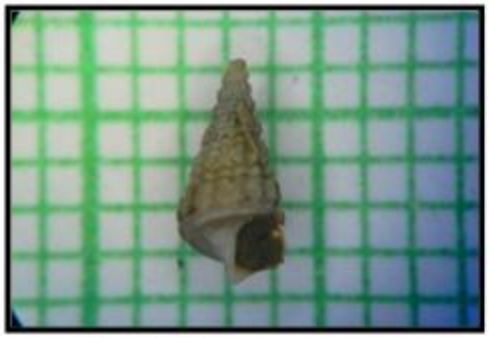


*Nerita sp.*

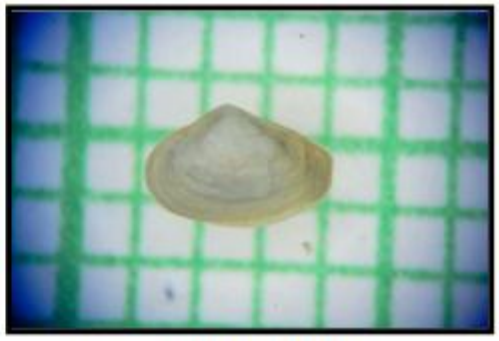


*Assaminea bervicula*

***Haminea sp.***

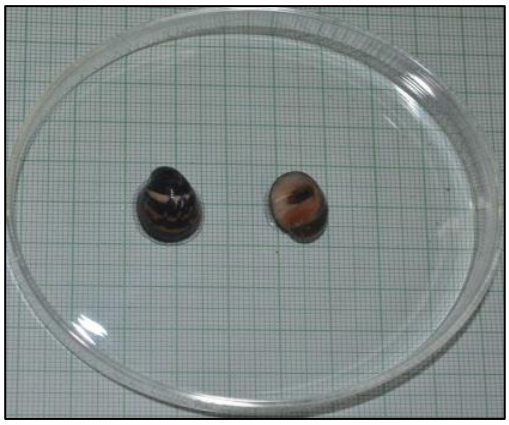


***Cerithidea sp.***



***Unidentified bivalve***

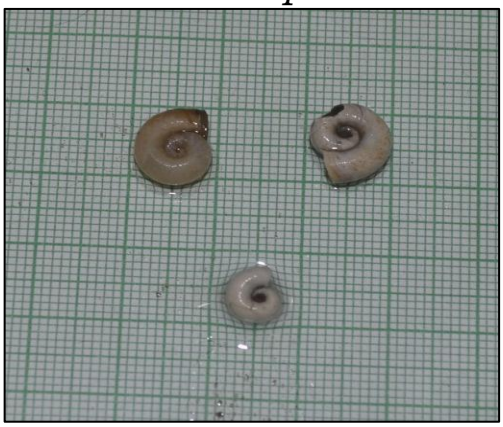
**DIVERSITY OF MACRO-BENTHOS FOUND IN THE WETLANDS OF JASAI, URAN**



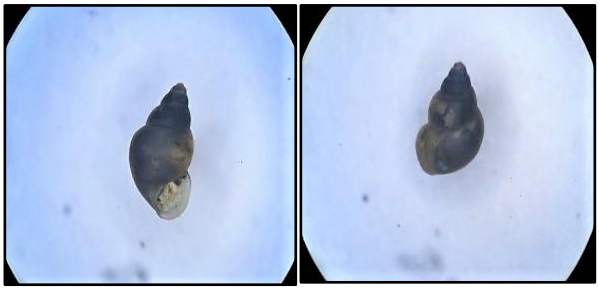
*Nerita sp.*

*Pila sp.*

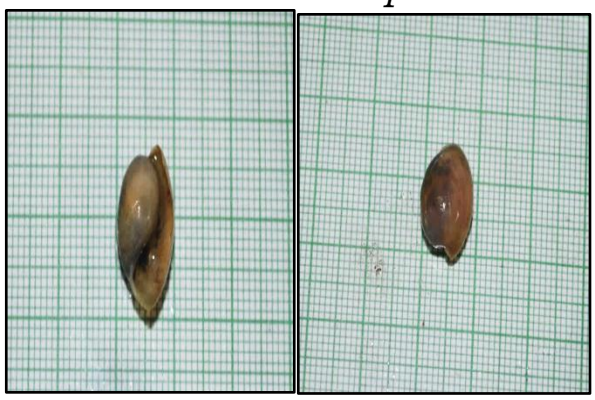
*Cerithidopsilla sp.*



*Pearsonia sp.*



*Glessula sp.*



*Haminea sp.*

**Fish diversity: General information on wetland fishes**

Wetlands serve as important feeding grounds for waders and waterbirds. These wetlands, whether inland or coastal, are abode to variety of plankton species, algae, fishes and a number of macro benthic organisms which are fed upon by varied species of birds. The diversity of different bird species that visit a wetland could indicate health of the habitat as well as the diversity of aquatic species. Bird migration is regular seasonal movement, between breeding and wintering grounds. Many species of bird migrate to escape extreme climatic conditions and for feeding purpose. Generally, these migratory species choose their feeding grounds depending on the availability and diversity of the preferred food items. Also various other factors like anthropogenic disturbances and safety of roosting sites affect their preferences for the feeding grounds.

In the present study, fish diversity was also recorded. Most of the wader species from families Ciconiidae, Laridae, Ardeidae, Threskiornithidae and Phalacrocorcidae prefer fish as one of the food sources. In Flamingo Bird Sanctuary total 6 different species of fishes were recorded while studying foraging behavior and in Jasai wetlands 4 species were found.

**Fish diversity at:**

| No. | FBS | Jasai |
|---|---|---|
| 1 | *Megalops cyprinoides* | *Mugil cephalus* |
| 2 | *Mugil sp.* | *Oreochromis mossambicus* |
| 3 | *Sciana sp.* | *Aplocheilus lineatus* |
| 4 | *Boleophthalmus sp.* | *Mystus sp.* |
| 5 | *Arius sp.* | |
| 6 | *Penaeus sp* | |

**a) Flamingo Bird Sanctuary**

*Megalops cyprinoides*

*Mugil sp.*

*Sciana sp.*

*Boleophthalmus sp.*

*Arius sp.*

*Penaeus sp.*

## b) Jasai wetland

*Mugil cephalus*

*Oreochromis mossambicus*

*Aplocheilus lineatus*

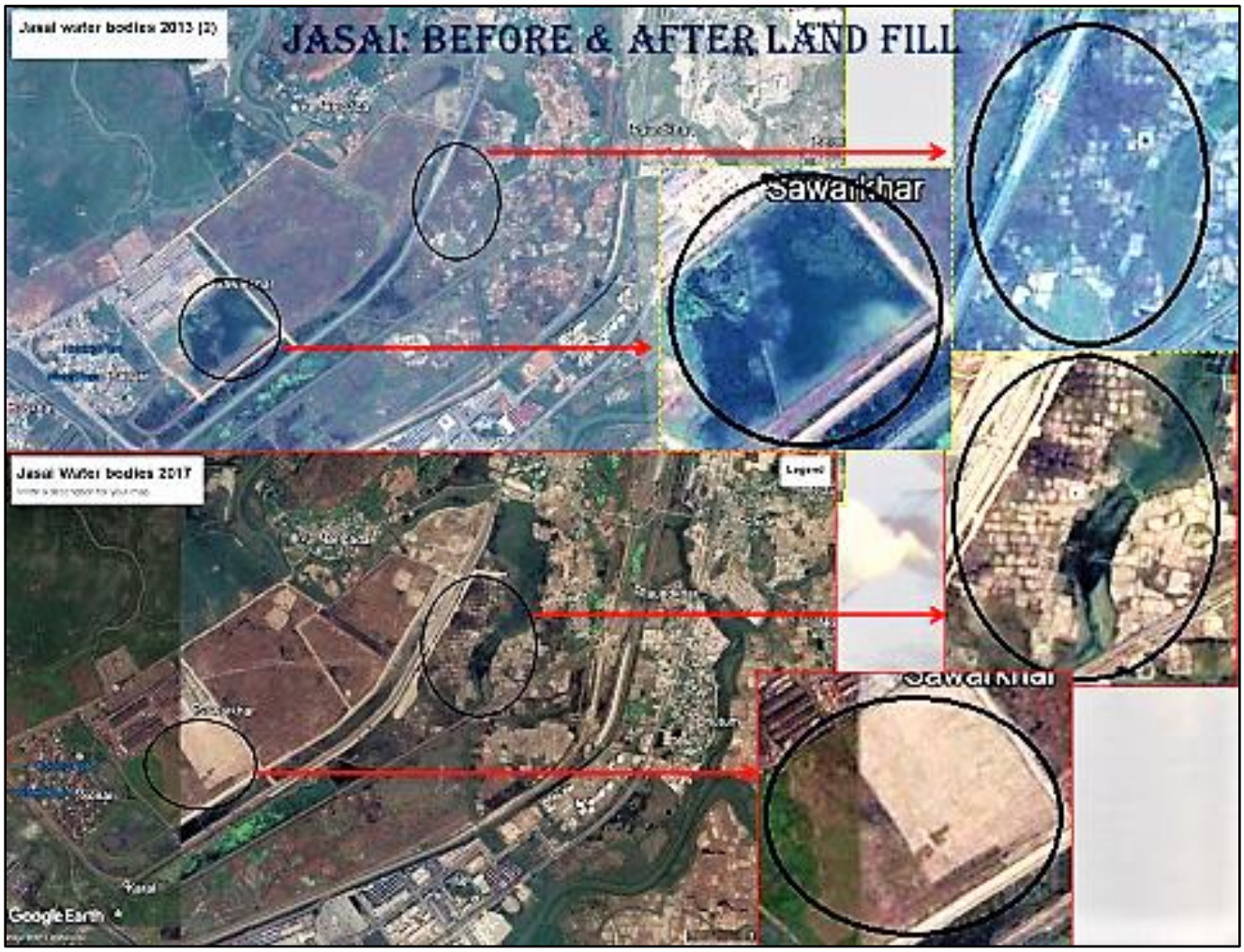
*Oreochromis mossambicus*

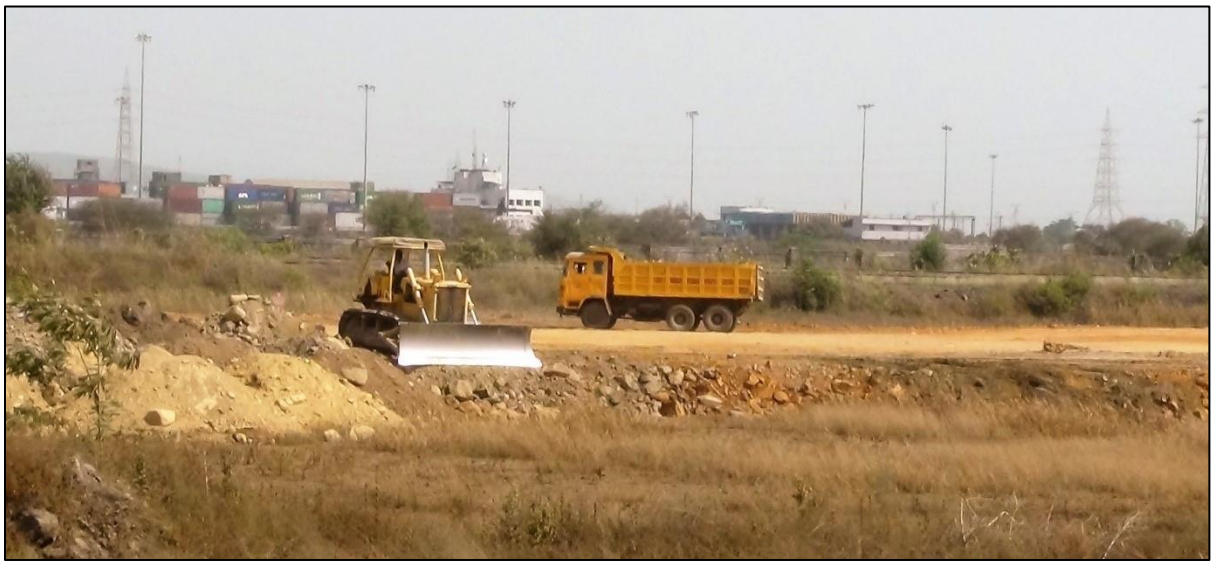
*Oreochromis mossambicus*

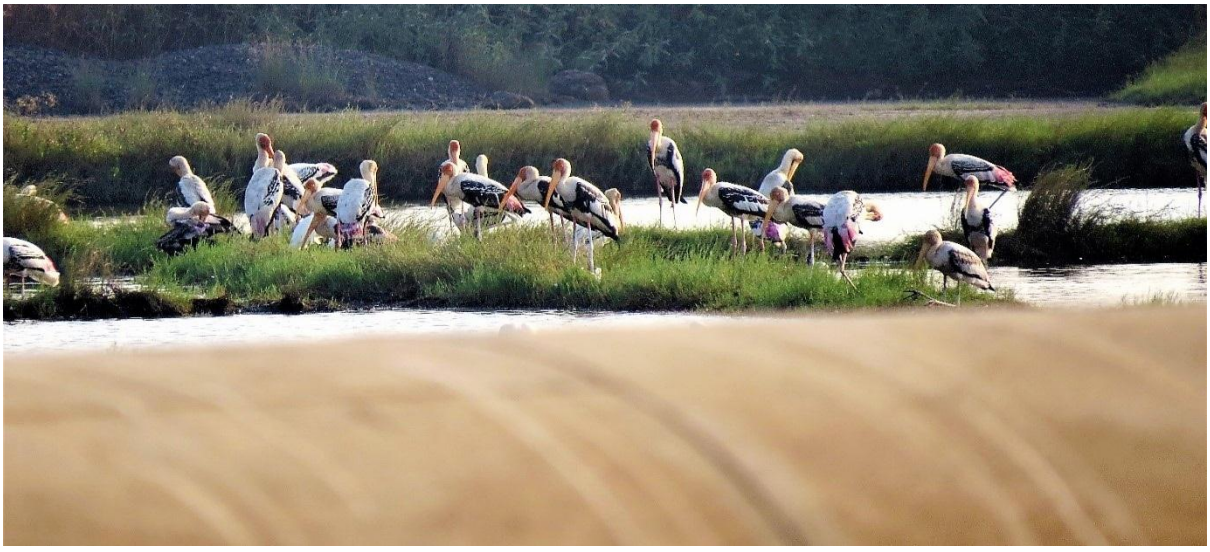
*Mystus sp.*

**3.5ANTHROPOGENIC ACTIVITIES CAUSING THREAT TO THE BIRD DIVERSITY:**

**Anthropogenic activities causing threat to the bird diversity.Jasai wetland, Uran**







In Jasai, wetland land fill activity is probably the main threat to the birds especially waders which forage on mudflats. As the Jasai wetland area is rapidly undergoing construction activity mudflats are vanishing leading to decrease in the diversity and number of waders. Eurasian Spoonbill, Ruddy Shelduck and Painted Stork were observed in Jasai wetland area from the year 2014 specifically in January and February months. Till 2016 the number was good but this year in January and February 2017 they were less in number as compared to earlier years' observations. As land fill was observed to be actively going on during the sampling period in Jasai wetland area, that may be the most justifiable reason for the decline in diversity.

**Plastic waste causing threat to the bird diversity.**
**FBS of Thane creek.**

In FBS of Thane creek plastic and industrial effluents are the major threats to the bird diversity. There are many places in FBS where plastics were seen on mudflats and hanging on mangrove during low tide. Sudden stinking smell was sensed in the creek water as nearby companies directly releasing effluents directly into the creek water.

## 3.6 DISCUSSION:

### Species diversity of the wader community:

In Jasai wetland, Uran during January 2017 to June 2017 total 34 species of waders were documented. Minimum two visits per month were undertaken for bird count and bird behavioural observation. From these 34 bird species Black-tailed Godwit, Curlew Sandpiper, Black-headed Ibis, Painted Stork and Lesser Flamingo were the Near Threatened species according to IUCN red list. Greater Flamingo, Indian Shag, Great Egret and Black-winged Stilt were more common birds. Black tailed Godwits were seen in large numbers during January and February, as it is migratory bird they were rarely seen in subsequent months. We have recorded and seen the activities of Painted Stork, Eurasian Spoonbill and Ruddy Shelduck from year 2014 particularly in months of January and February in Jasai, but in January 2017 and February 2017 their numbers were very less, this can be attributed to rapid landfill activity undergoing in the area at the time of sampling. Similarly, there was a patch of marshy area at one end of Jasai wetland where Ruddy Shelduck, Asian Openbill, Purple Swamphen and White-breasted Waterhen were recorded since 2014.that patch is now totally reclaimed into land.

In FBS, Thane creek during January 2017 to June 2017 total 46 species of waders was recorded. Minimum two visits per month were made for bird count and bird behavioural observation. From the 46 species recorded Black-tailed Godwit, Curlew Sandpiper, Eurasian Curlew, Painted Stork, Lesser Flamingo and Black-headed Ibis are near threatened birds according to IUCN red list. Lesser Flamingos were found in more number followed by Greater Flamingos. Their number was found far more than any other bird species in FBS. Other than Flamingos Black-tailed Godwit, Black- winged Stilt, Curlew Sandpiper, Whiskered Tern, Brown-headed Gull and Slender bill Gull were seen in good numbers. Common Shelduck was the rare bird cited in FBS; only two were recorded during January 2017.

**Population abundance of the waders:**

From the 34 species of waders documented at Jasai wetland Charadriiformes and Pelecaniformes were dominant containing 16 and 9 species respectively. Birds in the Charadriiformes were from Scolopacidae, Laridae, Recurvirostridae, Sternidae, Charadriidae and Jacanidae families. Scolopacidae showed more diversity than other families. Birds in the Pelecaniformes were from Threskiornithidae and Ardeidae with larger number of species belonging to Ardeidae family.

From the 46 species of waders documented in FBS of Thane creek Charadriiformes and Pelecaniformes were dominant containing 23 and 9 species respectively. Birds in the Charadriiformes were from Scolopacidae, Laridae, Recurvirostridae, Sternidae, Charadriidae families. Scolopacidae showed more diversity of species than other families. Birds in the Pelecaniformes were from Threskiornithidae and Ardeidae, with more number of species belonging to Ardeidae family.

After several visits to Jasai wetland and by taking total bird count several times, the average total count of species of waders showed that, Black winged stilt 16 percent, Greater Flamingo 14 percent, Indian Shag 13 percent and Lesser Flamingo 10 percent to the total population. Rest all wader species showed less contribution to total count.

In FBS, Thane creek also average total count of species of waders showed that Lesser Flamingo 48 percent and Greater flamingo 15 percent to the total population. Rest all wader species showed less contribution to total count.

Jaccard index showed that there was 60 percent similarity in the wader species between Jasai wetland and FBS, Thane creek.

Simpson Index of Diversity for Jasai wetland was 0.91686 and for FBS, Thane creek it was 0.73785. As Lesser and Greater Flamingo dominated in the total

count at FBS Jasai wetland showing the more diversity as compare to FBS, Thane creek.

Pielou's Evenness Index foe Jasai wetland was 0.81299 and for FBS, Thane creek it was 0.56142. It states that individuals from Jasai wetland are more evenly distributed among species as compare to FBS, Thane creek.

**Foraging behavior study of waders:**

Black winged Stilt, Black-tailed Godwit, Lesser Flamingo and Greater Flamingo were found appropriate for focal sampling in FBS of Thane creek; as these birds were good in number so they were chosen for foraging behavior study in FBS of Thane creek. In Jasai wetland Black winged Stilt, Greater Flamingo, Indian shag and Great Egret were found appropriate for focal animal sampling.

Frequency rates of events like paces, scanning, trial probing and pecking are compared with events like swishing and picking. As Flamingos are filter feeder there mode of feeding is different from other wader species. Flamingos were seen either scanning or in pause event when they were roosting. Flamingo feed on phytoplankton therefore the analysis were done for phytoplankton showed 34 species of phytoplankton in FBS, Thane creek and 24 species in Jasai wetland. *Odontella sp.* and *Phacus sp.* were common in FBS, Thane creek and *Aphanocapsa sp.*, *Odontella sp.* and *Euglena sp.* were common at Jasai wetland.

In Indian Shag, they are seen diving in water and mostly catch fish. They are observed while fishing or in pause event most of the time.

Birds like Black tailed Godwit and Black winged Stilts were found ideal for comparing the foraging events. These birds aremostly seen feeding on benthic organisms like molluscan gastropod and bivalves, Crustacean decapod and polychaet worms. Benthos analysis was also done revealed that *Illyoplax gangetica, Assaminea brevicula* were common species followed by *Cerethidea*

*sp.*, *Nerita sp.* and *Onchidium sp.* in FBS, Thane creek and *Cerethidea sp.* and *Nerita sp.* were more common in Jasai wetland.

Study revealed that there was disturbance in foraging when waders were in active feeding mode they were picking the food normally with respect to pace rate and scanning. As such, there is no comparative difference seen in the foraging of waders in Jasai wetland and also in FBS, Thane creek.

In FBS, Thane creek there is activity seen causing bird to be threatened and fly. Fishing boats sometimes pass very close to the birds yet the birds do not fly as they might have got used to the sound of the boats but tourist boats were found to be disturbing the waders due to their sound and speed. In Jasai, land fill activity was going on during study period but as birds usually forage far inside the water the disturbance does not seem to affect their foraging activity. Foraging in roadside area was not significant as the birds were getting disturbed by vehicular activity. It can be hence considered that though there is no short term impact of the surrounding disturbance but long term exposure to such disturbances will certainly affect the behavior of waders.

**Anthropogenic activities causing threat to the bird diversity:**

Physio – chemical parameters of water and soil were analyzed during study period. Analysis of soil texture and soil pH showed that it is sandy clay with pH 7.5 in Jasai wetland and clay with fine silt with pH 8.5 in FBS, Thane creek. Other parameters like percentage chloride, percentage organic carbon, percentage organic matter and percentage available phosphorus did not show any significant variation. As study period was late winter, summer and early monsoon phases variations in water temperature and water pH were observed.

In Jasai wetland, land fill activity is probably the main threat to the birds especially waders which forage on mudflats. As the Jasai wetland area is rapidly undergoing construction activity mudflats are vanishing resulting in decline in the diversity and number of wader.

In FBS of Thane creek plastic and industrial effluents are the major threats to the bird diversity. There are many places in FBS where plastics were seen on mudflats and hanging on mangrove during low tide. Obnoxious stench was sensed at the creek water as, nearby companies release untreated effluents into the creek water.

# Chapter 4

# BIBLIOGRAPHY

**A. Saravanakumar, J. Sesh Serebiah, G. A. Thivakaran, and M. Rajkumar 2007:** "Benthic macrofaunal assemblage in the arid zone mangroves of gulf of Kachchh-Gujarat," Journal of Ocean University of China, vol. 6, no. 3, pp. 303–309, 2007.

**A. Tiwari and S. V. S. Chauhan 2006:** "Seasonal phytoplanktonic diversity of Kitham lake, Agra," Journal of Environmental Biology, vol. 27, no. 1, pp. 35–38, 2006.

**Akshay Nachane, Amit Patil, Shashank More, Prachi Salunke and Madhavi Indap.2014**. "A baseline study of habitat and abundance of lesser flamingo (*Phoeniconaias minor*) in Sewri mudflats, Mumbai, India". Proceedings of the National Conference on Modern Trends in Zoological Research

**Anirudhan, T.S. and P.N.K. Nambissan, 1990**"Distribution pattern of salinity and silicon andtheir interrelationship in Cochin backwaters". Indian Journal of Marine Sciences. Vol.-19 (June): 137-139.

**Ansari, Z.A. and A.H. Parulekar,1998**"Community structure of meiobenthos from a tropical estuary". Indian Journal of Marine Sciences27 : 362 – 366.

**Ansari, Z.A., C.L.Rodrigues, A.Chatterji and A.H.Parulekar,1982**"Distribution of Meiobenthos and Macrobenthos at the mouth of some rivers of the east coast of India". Indian Journal of Marine Sciences11: 341 – 343

**Asad R. Rahmani 2013:** Baseline survey of birds at proposed Navi Mumbai International Airport(NMIA) area". Trimonthly report April-June 2013 by BNHS, Mumbai.

**Azrina, M.Z., C.K. Yap, A.R. Ismail, A. Ismail and S.G. Tan2005**."Anthropogenic impacts on the distribution and biodiversity of benthic macroinvertebrates and water quality of the Langat River, Peninsular Malaysia". Ecotoxicology and Environmental Safety 64 (3): 337-347.

**B. Tas and A. Gonulol 2007:** "An ecologic and taxonomic study on phytoplankton of a shallow lake, Turkey," Journal of Environmental Biology, vol. 28, no. 2, pp. 439–445, 2007.

**Bachelet, Guy, 1990.**"The choice of a sieving mesh size in the quantitative assessment of marine macrobenthos: a necessary compromise between aims and constrains". Marine environmental Research30: 21 – 35.

**Baird, D., P.R. Evans, H. Milne and M.W. Pienkowski1985:**"Utilization by shorebirds of benthic invertebrate production in intertidal areas". Oceanogr. Mar. Biol. Ann. Rev., 23: 573-597.

**Bibby, C. J., Burgess, N. D., & D. A. Hill2012**: *Bird Census Techniques*. Academic Press.

**Caunel, E.A., J.E.Cloern, D.B. Ringelberg. J.B. Guckert and G.H. Rau1995**:"Molecular and isotopic tracers used to examine sources of organic matter and its incorporation in to the food webs of San Francisco bay". Limnology and Oceanography 40 (1) : 67 – 81.

**Cowardin, L.M., V. Carter V., F.C. Golet, E.T. LaRoe1979:**"Classification of Wetlands and Deepwater Habitats of the United States". U.S. Fish and Wildlife Service Report No. FWS/OBS/-79/31.Washington, D.C.

**Dahanayaka, D.D.G.L. and M.J.S. Wijeyaratne2006**:"Diversity of macrobenthic community in the Negambo estuary, Sri Lanka with reference to environmental conditions". Sri Lanka Journal of Aquatic Sciences 11: 43-61.

**Edgar, G.J. and C. Shaw1995**:"The production and tropic ecology of shallow-water fish assemblages in Southern Australia". II. Diets of fishes and tropic relationships between fishes and benthos at Western Port, Victoria. J. Exp. Mar. Biol. Ecol. 194:83-106.

**G. Ananthan, P. Sampathkumar, P. Soundarapandian, and L. Kannan 2004:** "Observations on environmental characteristics of Ariyankuppam estuary and Verampattinam coast of Pondicherry," Journal of Aquatic Biology, vol. 19, pp. 67–72, 2004.

**H. Badsi, H. Oulad Ali, M. Loudiki, and A. Aamiri 2012:** "Phytoplankton diversity and community composition along the salinity gradient of the massa estuary," American Journal of Human Ecology, vol. 1, no. 2, pp. 58–64, 2012.

**Hemambika B., Julffia Begam A., Kirubhanandhini. , Babu S., Mahendiran M. & Goldin Quadros2015**: "Diversity of birds from the urban wetlands of Coimbatore, Tamilnadu, India". 1, 2 ISBN no. 978-81-909551-8-8.

**K. M. Rajesh, G. Gowda, and R. M. Mridula 2002:** "Primary productivity of the brackishwater impoundments along Nethravathi estuary, Mangalore in relation to some physico-chemical parameters," Fishery Technology, vol. 39, no. 2, pp. 85–87, 2002.

**Kiceniuk, J.W. and U.P. Williams, 1987:**"Sediment hydrocarbon contamination at the side of the Baie Verte, New Foundland, oil spill - resulting a four year study". Marine Pollution Bulletin18 (6): 270 – 274.

**Levinton, J.S.1982:**"Marine Ecology" published by Prentice Hall Inc. Englewood, Cliffs NewJersey, 07632.

**Lodh, N.1990:**"Ecological studies on plankton from near shore waters of Bombay".Ph.D. Thesis University of Bombay.

**Mandaville, S. M.2002**:"Benthic Macroinvertebrates in Freshwaters – Taxa Tolerance Values, Metrics, and Protocols". Soil and Water Conservation Society of Metro Halifax.

**Mare, M.F.1942:**"A study of a marine benthic community with special reference to microorganisms". Journal of Marine Biological Association 25 : 517 – 554.

**Nasnolkar, C.M., P.V. Shirodkar and S.Y.S. Singbal.1996:**"Studies on organic carbon, nitrogen and phosphorus in the sediments of Mandovi estuary, Goa". Indian Journal of Marine Sciences25 (2) : 120 – 124.

**P. Ponmanickam, T. Rajagopal, M. K. Rajan, S. Achiraman, and K. Palanivelu 2007:** "Assessment of drinking water quality of Vembakottai reservoir, Virudhunagar district, Tamil Nadu," Journal of Experimental Zoology, vol. 10, no. 2, pp. 485–488, 2007.

**Pearson, T.H. and R. Rosenberg, 1978**:"Macrobenthic succession in relation to organic enrichment and pollution of the marine environment". Oceanography and Marine Biology Annual Review**.** 16: 229 – 311.

**R. Manikannan, S. Asokan, A. Mohamed Samsoor Ali.2012:**"Abundance and Factors Affecting Population Characteristics of Waders (Charadriiformes) in Great Vedaranyam Swamp of Point Calimere Wildlife Sanctuary, South-east Coast of India". International Journal of Ecosystem; 2(1): 6-14. doi: 10.5923/j.ije.20120201.02

**T. R. Shashi Shekhar, B. R. Kiran, E. T. Puttaiah, Y. Shivaraj, and K. M. Mahadevan 2008:** "Phytoplankton as index of water quality with reference to industrial pollution," Journal of Environmental Biology, vol. 29, no. 2, pp. 233–236, 2008.