The present study is on ecology of mangroves which indicates more of the field work rather than laboratory based analytical work. The study includes Habitat Analysis as the only analytical part where samples were needed to be collected. Vegetation study is based on data collection and analysis.

2.1 Study Area

The study area is the coastal Maharashtra, which is situated along the central west coast of India. It lies between 15°44' to 20°08'N latitude. This coastal belt is known as 'Konkan'. It is a narrow strip of land which widens towards the northern region. North of Bombay it widens to more than 100Km. The length of entire coastal Maharashtra is about 720Km. The coastal Maharashtra has 5 districts viz. Thane, Bombay, Raigad, Ratnagiri and Sindhudurga. All these districts are
FIG. 1: COASTAL MAHARASHTRA
segmented by large number estuaries, creeks and backwater areas (Totally about 60). The estuarie are formed by the rivers having origin in the Sahyadri-Western Ghat ranges. These meet the Arabian Sea.

The study area has tropical wet and dry climatic conditions. Three district seasons are observed as, Monsoon (June to Mid October), Winter (Mid-October to February) and Summer (February to May). The maximum annual rainfall that occurs along the coast is 2,500mm, relative humidity between 60 and 80% and temperature varies from 20° to 35°C. The soil is of laterite type towards the South, while it is red, loamy towards North of the coast (Arunachalam, 1967).

Geomorphology Of Study Area

The entire coastal zone between 15°30' and 19° N latitudes falls in two lighological provinces. In the North of 16°30'N latitudes the coastal features have developed on basalt, part of the extensive trap and is between Malvan to Bombay, whereas South of 16°30'N has metamorphosed Dharwars overlying the crystalline base. Much of the Konkan, South of 18° is covered with laterites which have developed uniformly both over the trap as well as the metamorphic and crystalline rocks (Dixit, 1976).

The 'Konkan' i.e., present study area, though broadly part of the Deccan Plateau, falls in different
orographic province, separated from the plateau by the Sahyadrian scrap.

The littoral forms all along the west coast are not alike and they can broadly be recognised into three zones (Dixit, 1976) which are as follows.

1. Northern zone of north of Revadanda (18° 33'N) - It is characterised by a modified surface of marine plantation.

2. Central part between 16° to 18° 33'N - It is distinguished by lateritic plateau and cliffs and interspersed with beaches. For over 200Kms from North to South this coast is backed by a lateritic plateau with an average height of 200m ASL.

3. Southern part of South of 16° N latitude - It is represented by exhumed surface monadnock like hills and narrow coastal plain associated with estuaries.

The Estuaries And Deep Channels Of Study Area

Almost all the streams north of Manglore upto the Gulf of Camby are marked by drowned estuaries. The estuaries of Konkan are the drowned valleys (Wagle, 1982). The presence of laterite bed at the depth of 27 to 35m below the present sea level along the Goa (Feio, 1956), indicates the drowned valley.
Most basins in a Konkan have a narrow estuarine zone varying in width from 6.4 to 12.8Km. The estuaries in Konkan are very efficient and have no difficulty in disposing of water received from the catchments. The delta are absent in the Konkan estuaries. There are two factors for absence of delta and narrowing of basin in the estuarine zone. The first reason is that the estuaries and river valleys are very efficient as they are deep trenches sometimes as deep as 200m with valley sides sloping 15°, due to which the heaviest rains of monsoon are easily drained off. The second reason for no delta formation is that the catchment of Konkan rivers are not large (Dixit, 1976).

The district wise estuaries/creeks which were considered for floristic study with respect to mangrove, are presented in Table-12 and 13 along with the mangrove and associated species composition.

During present study more attention is given towards the estuaries of South-Western Maharashtra to cover the ecological aspects of mangroves. The estuaries Are, Kalabadevi and Bhatye were considered for studying water and soil parameters, in relation to mangrove communities. In addition to these estuaries, Ganapatipule, Girye-Padel, Kalawali and Kolamb estuaries were also selected for detailed phytosociological and some allied studies of mangroves.
The estuaries like Are, Kalabadevi, Bhatye, Girye-Padel and Kolamb-Kalawali which were thoroughly studied to understand ecological aspects of mangroves are being discussed in detail herewith.

1. Are Estuary

This estuary belongs to Ratnagiri district. It is located at 17° 5'N and 73° 27'E, about 7Kms away from the Ratnagiri city in the North. It is small estuary having length about 3Kms. It is formed by the rivers Kusum and Agni. Along both the banks, South and North, distantly placed, small villages are present. The villages are Are, Basani, Sadye, Dhameliwadi and Muslimwadi. These villages are small, hence human population is less and consequently the impact of sewage pollution is comparatively less in this estuary. The estuary was compartmented into 11 stations which are located along both the banks, from mouth to upstream (Fig. 2).

The Sites Of Are Estuary

I. Are Village West Stand

It is daily inundated site with swampy, deep muddy substratum. The village Are is located 500-600m away from this site. It has little sewage input.
II. Are Village S.alba Patch

It is shallow, flat basin like muddy area, daily inundated and located nearby the village. Between the vegetation and village boundary there is stream. The vegetation along village is less or absent. Along the village boundary there is a bund of stones. It is sheltered from the direct attack wind by vegetation in Are village. The stream flows with low velocity.

III. Are Village Middle Island

It is small island in the main stream. It faces direct attack of high energy tidal waves as well as strong wind. It is infront of open mouth region of estuary. The substratum is very deep muddy. It is daily inundated area.

IV. Are North Bank

It is big fringe vegetation patch directly infront of main stream as well as along the stream. The substratum along the stream is deep muddy while substratum towards landward side becomes shallow muddy. Except landward border the area is daily inundated. It has small shallow flat slightly raised area, along the north boarder (landward).
V. Sadye Village Boundry (West)

This is large area along the South bank of estuary. It shows gradient slope from stream towards landward side. It is traversed by small channels running from South-North direction. These channels are bordered by R.mucronata. This is the site which shows variation in inundations and nature of the substratum. The site is protected from both strong tidal waves and wind. Eastern, Streamline area at the site is shallow basin. The substratum is very deep muddy along the stream but gradually, towards land it becomes shallower and is almost dry at the border along the landward side.

VI. Sadye Village Boundry (East)

This is raised area in the eastern side while slightly shallow towards west side. The substratum is moist to dry and accompanied by big mounds of Crabs and other burrowing animals. The frequency of inundations is comparatively less and it is variable. Along the stream it is more while towards bank it is low. A small channel with sewage from village Sadye enters this site.

VII. Dhameliwadi Inner Island

It is small island in the main stream nearby the north border. The substratum is shallow to deep muddy. It is a daily inundated site. This stand is in the middle of the estuary.
VIII. Dhameliwadi Village Boundary

It is site along the north bank of the estuary, near the village Dhameliwade. Small channels are present in the area. It shows variation in inundations and nature of substratum. It is sheltered area.

IX. Upstream Island

It is site located in the far upstream region of estuary which shows variation in the nature of substratum. The part towards west and facing stream is muddy and daily inundated, the part along southern border of the island is raised and is frequently inundated. While part towards northern side is more raised and rarely inundated, substratum almost dry on most of the days of the month. The eastern side of the island is most sheltered area.

X. Muslimwadi Village Boundary

It is upstream part along the North bank of estuary. It has shallow muddy substratum. It is polluted region by the sewage input from Muslimwadi.

XI. Upstream Channel

It is in extreme upstream region. The site
is with deep channel. The substratum is not muddy, area though not inundated daily shows water logging in the ditches and channels. It receives sewage from village Kotawade in east side of the estuary.

2. Kalabadevi Estuary

This estuary is situated in the North of Ratnagiri about five kilometers distance. It is located at 17°0'N and 73°3'E. Length of estuary is about 4.80Km. The mouth of the estuary is broad while head (upstream) region is narrow (about 15m wide). Depth and spread of water, during high tides is variable. Along the bank of estuary 10 villages are located Kalabadevi, Kasarvelli, Sakhartar, Mhamurwadi, Powarwadi, Kelye, Margaon and Shil are from mouth to the upstream along the north bank while villages Patilwadi and Adi are located along the south bank.

The sites selected for water and soil analysis and also to study floristic composition and distribution of mangrove species are given below (Fig.3).

I. Kalabadevi

It is 500-700m away from mouth of estuary. It is the first site near to mouth. But it is located along the main stream and not facing directly rising high tidal water. It is shallow, sheltered stand and
dominated by *S. alba* vegetation. The substratum is shallow muddy, and inundated almost daily. The site receives sewage pollutants from village Kalabadevi. The site is good ground for harvesting the molluscs.

II. Sakhartar South Near Bridge

This site is near the bridge and located along the stream. It has gentle gradient slope from south to north. It is flooded by slowly rising tidal water. The substratum is deep muddy along the main stream but becomes shallow towards the southern border. The inundations available to this site are variable.

III. Sakhartar West

This site is all along the main stream and thickly populated village Sakhartar. All along the banks of this site human settlement is there, which adds large amounts of domestic sewage in this site. Along the village no mangrove vegetation is present, but *S. alba* seedlings are establishing in the eastern side, little away from the houses, located along the estuary. The substratum is muddy and contains large amount of organic matter.

IV. Sakhartar East

The part of this site is directly infront of
main stream which receives water with high speed and faces to the water waves and wind too, while the some portion of this site is along the stream and remaining portion is sheltered and along the bank towards land ward side. The depth of the substratum is variable, which is shallow to deep muddy. Area gets variable number of inundations.

V. South Bank - Powarwadi

It is the site along the south bank near village Powarwadi, facing the main stream the part of this site facing the stream receives water daily with energy tides, and is with deep muddy substratum. This part shows a characteristic species of such areas i.e., A.marina. While remaining portion is gently slopping land mass getting variable number of inundations.

VI. South Bank - Adi

It is slightly raised area. Most of the area gets less number of inundations. This site shows large mound and ditches towards landward side which is covered by species like E.agallocha and L.racemosa etc. The substratum is moist and not muddy.
VII. Mhamurwadi Islands

The main stream is little wider in this area and has 3 island. The waves are very strong and all the energy in the tides is almost bore by this site. The island show variation in the nature of substratum, it is muddy as well as gravelly. The areas within islands show variation in the inundation, substratum and wave energy. The mangrove vegetation of this site is diverse, but most of the space of islands facing the strong waves is occupied by the A.marina dwarf plants.

3. Bhatye Estuary

It is large estuary having length about 14.3Km in length and flows in east west direction. It is formed by river 'Kajavi' and its tributories. It is located at 16°58'N and 73°21'E. It is situated at the south of Ratnagiri city. It has many stands of the mangrove vegetation which occur along the banks, in shallow basin and as well as on islands in the estuary. The estuary is compartmented into 18 sites for phytosociological studies and some of the sites from these are considered for studying physico-chemical parameters of soil and water (Fig.4).
The sites of the Bhatye estuary are as follows

Mouth

It is the mouth of estuary where river meets sea. The site was selected to collect water and soil for studying physico-chemical parameters. Here substratum is sandy and no mangrove vegetation is present.

I. Rajiwade-Karla Island

It is island nearby the mouth. The western side of this island faces the tidal water flowing with high speed and energy tides. The substratum at this region is shallow muddy. The vegetation is of *A. marina* and plants have remained dwarf. The region of this island at north and east side is along the stream but with slow speed tidal water. There is no more movement of tidal waves, water slowly spread the area, hence the substratum is very deep muddy due to siltation. The area is protected from strong wind and waves. The southern part of island is along the main stream, but it is raised portion, getting flooded by slow rising tidal water. Substratum is shallow muddy with gravelly. The central part of the island is more elevated area. The different regions of island get different number of inundations.
II. Karla Village Boundary

It is the site along the north bank and village Karla. Part of this site towards west is shallow, flat, basin like area with deep muddy substratum. The whole of the area is polluted by sewage from thickly populated village Karla. It is daily inundated site.

III. Bhatye-Navanagar Village Boundary

It is the site along the south bank and has gentle gradient slope. It is intersected by few small channels and inundated daily. The villages Bhatye and Navanagar are along this site, so the sewage pollution is tremendous at this site. A part of this site towards east has been severly exploited and totally denuded by cutting the mangroves.

IV. Ambeshet

It is reclaimed area by Khar land development department by the construction of dyke having flapgets. The mangroves from this area were cut off but due to leakage in the dyke the tidal water enters the area hence few species of mangroves are observed at this site.
V. Juve

It is small area near the village Juve along north bank. Mangroves along the north boundary of village are being continuously exploited however, mangroves along the stream toward east side are maintained by the local people as protection from the floods during heavy monsoon days.

VI. Takala Island

It is big and raised island in the main stream. Depth of stream towards the west side is more than the depth of the stream along south border. It is daily inundated area with muddy substratum. Mangroves on this site are under human pressure and are regularly utilized by local inhabitants.

VII. Takala-Phansop Village Boundary

It is a narrow strip of mangrove vegetation along the South Bank. The substratum is shallow muddy. Area which is toward west side is regularly inundated while towards the east side the frequency of inundations is comparatively less. The substratum at east side is gravelly.
VIII. Juve-Chinchkheri Twin Island

It is very big island about 51 hectares in area. Due to this island the main stream is divided into two small streams along the north and south border of the island. The northern side of this island is well raised above the high tidal mark but it is gently slopping towards the south. The island has small channel passing from east to west direction. The substratum is deep muddy, shallow muddy and gravelly found at different sectors of this island. The island shows secondary mangrove vegetation.

IX. Juve Village Boundry (East)

It is the site at the east of Juve village. It is small mangrove area (1.4ha) once occupied by R.mucronata and S.alba, after cutting of these species, the secondary vegetation of A.coriculatum, C.tagal and A. ilicifolius is developed. The substratum is shallow muddy to moist. The inundations are variable.

X. Juve-Narayanmali Boundry

It is narrow strip of vegetation with deep muddy substratum along the north bank of vegetation. It is along the stream and daily inundated.
XI. Phansop Island

It is small island at summit of main stream of Kajavi and its tributary, near the village old Phansop. The part of the island facing the main stream receives water flowing with high speed. The part towards east side gets flooded by slow rising water. The substratum is deep muddy.

XII. Mangale-Vechurlewadi Village Boundry

It is the site along east boarder of the tributary of Bhatye estuary. The substratum at this site is variable, mostly it shallow muddy however along the bank soil remains more or less dry for many days due to less number of inundations. Towards the southern end, the substratum is gravelly and lack of true mangrove species. The number of inundations available at this site are comparatively less than the sites described earlier.

XIII. Chinchkheri East

It is along the south bank of main stream and towards east side and village Chinchkheri. Most of the area is reclaimed by constructing band. The part towards eastern side is along the channel which receives fresh water. The side along the main stream at this region is raised. It has gentle slope from north
(stream) to south (land). The substratum at the raised part is not swampy. Along the slope towards south substratum is muddy. This part is dominated by the R. apiculata.

XIV. Chinchkheri West

It is the site along the stream and band, towards west of the village Chinchkheri. It is daily inundated, deep muddy area.

XV. Narayanmali

It has narrow strip of mangrove vegetation along north region of the main stream near village Narayanmali. There is small basin just near the village Narayanmali having about 1ha in area and occupied by S. alba. The area is inundated regularly and has muddy substratum.

XVI. Nachane-Kajarghati-Village Boundry

It is long strip of scattered vegetation along the upstream north bank of main stream. The nature of substratum is variable and it is moist but not muddy. The big mounds are observed under the vegetation of A. officinalis, number of inundations available are less, but the water stagnacy is observed at many places.
There is shallow basin along the landward border which is flooded by narrow channel connected with main stream.

XVII. Pomendipar-Tembepul Boundary

Patch of scattered vegetation along the north bank towards extreme upstream. Inundations are very less and are of short duration.

XVIII. Kosabwadi

From Tembepul towards Hatis, the scattered vegetation of *A. officinalis* and *E. agallocha* is present. The inundations are very very less and substratum remains almost dry for many days within fortnight.

4. Girye-Padel Estuary

It is the estuary located near the Vijay Durga, which is one of the tahsils of district Sindhudurga. Vijaydurga creek is formed by the confluence of two estuaries viz. Kharepalan and Girye-Padel estuary. Out of these two estuaries, Girye-Padel estuary is considered for detailed phytosociological studies of mangroves.

Girye-Padel estuary is located at 16°30'N latitude and 73°18'E in the south of Ratnagiri. It is 14.5Km in length and extends from village Vijaydurga
upto village Padel in the upstream. It flows in south­west direction in the beginning and then in the east. From mouth upto village Anapur no mangrove vegetation is present in estuary while elaborative patches of mangrove vegetation are present from the village Anapur upto the village Padel in the upstream. The estuary is compartmented into following sites which are from mouth to upstream.

I. Anapur Village Boundry (North)

It is the site located along the west bank of the estuary. It is the site directly facing the strong tidal waves. It is also facing the strong wind. The substratum is very deep muddy. This site is daily inundated.

II. Anapur Village Boundry (South)

It is site near village Anapur. But this site is sheltered and protected from the onslaught of strong waves of water and wind. Substratum is deep muddy. Inundation frequency is high, almost daily inundated site. The site receives sewage from village Anapur.
III. Anapur Island

It is the island present at the region where Kharepatan and Girye-Padel estuaries meet. It shows variation in the nature of substratum. The inundations available are also variable i.e. some areas are daily inundated while others get comparatively less number of inundations. North side island faces strong waves and tidal water flowing with high speed, while southern part of island is sheltered.

IV. Girye West

It is almost sheltered site along the west bank of estuary near the village Girye, the substratum is deep muddy and some places it is gravelly muddy.

V. Girye East

It is along east bank. The vegetation from a narrow strip all along the stream. The middle portion of this site is infront of the direction of flow of water and receives energy waves. The area at north and south of this region is sheltered. The substratum is also muddy.

VI. Banderwadi

There is narrow strip of vegetation along the
stream. A part of this site is in front of direction stream while remaining portion is along the stream. Area daily inundated except the area along landward side. Substratum is shallow muddy.

VII. Hurshewadi South

It is also narrow strip of vegetation along the south bank of estuary near village Hurshewadi. Substratum is shallow muddy, inundations available are variable. The site is little polluted due to sewage from village.

VIII. Harshewadi North

The site is along the north bank of estuary. It is sheltered area. Inundations available are less. No sewage pollution is observed.

IX. Padel West

It is in the upstream of the estuary near village Padel. Near the south bank of this side there is small island. The substratum is shallow muddy or gravelly. Inundations frequency is less.

X. Padel East

It is at the end of estuary in the upstream.
Substratum is gravelly and soil remains dry for many days. Very less number of inundations are available.

5. Kolamb-Kalawali (Kalavali) Estuaries

Kolamb and Kalawali are the two estuaries located at the north of Malvan City. Kolamb estuary is located at 16° 4'N latitude and 73° 28'E and is about 1.9Km in length. Most of the areas from the upstream of this estuary are reclaimed. Kalawali estuary is located at 16° 6'N latitude and 73° 29'E. Its length upto village Kandalgao in the upstream, is about 8.5Km and upto Masura 9Km. The sites along these two estuaries are described together. The sites I, II, III and IV are the sites of Kolamb estuary, while site V, VI, VII, VIII and IX are of Kalawali estuary (Fig.6).

I. Kolamb Mouth

It is small raised area near the mouth of the estuary. Substratum is muddy.

II. Kolamb Bridge

It is site along the south bank of Kolamb estuary. Substratum is deep muddy. It is daily inundated area.
III. Kolamb North

It is the site along the north bank of the estuary. Inundations available are variable. Substratum is shallow to deep muddy.

IV. Revtal

It is reclaimed area by the construction of band, almost all mangroves species except A. officinalis are dried and died.

V. Talashi West

This is first site of Kalawali estuary. There is narrow strip of vegetation along the west bank. Substratum is shallow muddy and regularly inundated.

VI. Talashi East

It faces direct attack of strong water waves and wind. Substratum is deep muddy and the area is daily inundated.

VII. Tondvali

It is the site almost in the middle of estuary. The shallow basin like areas with muddy substratum are present near both the banks at this site.
VIII. Hadi

Site located near the village Hadi below the bridge scattered mangrove patches present along both the banks. Area is shallow and daily inundated. No pollution is seen.

IX. Kandalgaon North

It is the site along the tributary of Kalawali estuary. This site has area dissected by large number of small channels. The substratum is deep muddy. The site is sheltered except at the extreme north.

X. Kandalgaon South

It is at the extreme upstream of tributary of Kalawali estuary, near the village Kandalgaon. The substratum at some places is shallow muddy while at end, in upstream is moist or sometimes dry. This is extreme limit of tidal water rise. The inundations available are very less.

2.2 Surveying And Mapping

Bhatye, Kalabadevi and Are estuaries were surveyed with the help of Magnetic Compass, a 'Bearing Reader' and Pedometer. With the Bearing Reader, exact directions, different angles of turn in the estuary and
vegetational stands were recorded. While recording these observations the distance was measured with 'Pedometer'; 50m tape and also by calibrated steps. Recorded data was then put on the paper with proper scale. For the Girye-Padel, Kalawali and Kolamb estuaries the available geographical maps were used and vegetation was placed on the maps. But for others, maps were prepared by walking along the boundary lines of estuaries. During survey, the quadrats (10x10m and 20x20m), line and belt transects of different dimensions were placed in the vegetation so as to study species composition and their relative positions in the respective quadrats/transects. The collected data of the vegetation was then charted at the exact relative positions on the paper, drawing to the scale.

2.3 Habitat And Vegetation Analysis

2.3.1 Sampling

a) Water

Water samples were collected at depth of 50cm (Takahashi and Parsons, 1972) from the different sites in the Bhatye, Are and Kalabadevi estuaries. The samples were collected monthly.
b) Soil

The soil samples from different sites of Bhatye, Are and Kalabadevi estuaries were collected monthly (from 0-15cm zone). It was air dried and used for analysis. In addition, to obtain comparative data some estuaries were chosen. For this purpose the soil sample were collected from Are, Bhatye, Kalawali, Kolamb and Girye-Padel estuaries, in the month of May, 1991; and were air dried and used for analysis.

c) Fauna

During the survey and sample collections, all the possible, birds, fishes, molluscs and crustaceans were recorded. Many a times Mollusc and Crustacean samples were also collected from the fishermen on the site of collection. The samples were identified and were confirmed with the help of experts in Marine Biological Research Station, Ratnagiri. Identification of Birds was done with the help of 'A Pictorial Guide to the Birds of the Indian Subcontinent' by Ali and Ripley (1983).

d) Tidal Study

It was carried out using the Tide Table of Port.
The rise and fall of tidal water in the estuary was recorded with the help of a pole marked with scale. Each division on the pole was of the 25cm length which was painted with red and white paints alternately. The observations were taken hourly for 24 hours. Simultaneously, the spread of water was recorded with 50m tape and/or calibrated steps.

The number of inundations for different species were also counted. To do this, different sites from the Are, Bhatye and Kalabadevi estuaries were selected. The observations were taken for the period between neap tide and spring tide considering the days having maximum of high water levels and minimum of low water levels. For this purpose tidal time table for Ratnagiri coast was used.

2.3.2 Methods Of Analysis

A. Habitat Analysis

1. Water

The water samples were brought to laboratory and subjected to analysis for physico-chemical characteristics. Analysis was completed within 24 hours of collection.
Temperature

Water temperature along with air was recorded in the field by ordinary mercury thermometer of 0.50°C accuracy.

Electrical Conductivity

It was measured by using field conductivity meter (Naina N.D.C. 730) as mS/cm.

Hydrogen Ion Concentration (pH)

It was recorded using digital pH meter (Globol-DPN-501).

Chlorides

Chlorides were determined by Argento-metric method i.e., titrating water samples against silver nitrate using Potassium dichromate as an indicator.

Salinity

Calculated from chlorinity according to Knudsen (1901) using the formula -

\[ \text{Salinity } \% = [\text{Chlorinity } \% \times 1.805] + 0.03 \]
2. Soil

i) Physical Parameters

Soil texture (Granulometry) was found from 100gms of air dried soil. It was passed through metal sieves having pore size ranging from 25μm to 2057μm.

ii) Chemical Parameters

Aquaeous solution (1:5) was used to study of chemical parameters.

Electrical conductivity was determined using field conductivity meter (Naina N.D.C.-730 and Elico PE-133) and expressed as mS/cm. pH was found out on Digital pH meter (Global DPN-501 an Elico LI-10T). Argento-metric method was used for chlorides. Salinity was found out from chlorides.

B. Vegetation Analysis

A list of species composition of mangroves and associates was prepared for different estuaries. Number of individuals of a species per quadrat for stands in the Are, Bhatye, Kalabadevi, Girye-Padel, Kolamb and Kalawali estuaries were recorded. DBH (cbh) was recorded at a height of 1.37m from ground level.
Diameter of canopy was measured by recording spread of canopy on two sides of main hole, in a straight line. The number of pneumatophores and prop roots was recorded by placing quadrats of 1m at different locations taking into consideration the nature of substratum. Seedling population was recorded by placing belt transects as well as quadrats of 1m area.

Relevé lists of the plant species in mangrove communities were prepared for different stands and different estuaries according to the Zurich-Montpelier school as described in Colinvaux (1986).

The primary data recorded from sampling units on presence, height and cover of the mangrove plants was analysed for synthetic characters like density, abundance and frequency following standard phytosociological methods, mentioned in following pages.

Importance Value Index was calculated as the sum of Relative density, Relative frequency and Relative dominance (Pool et al, 1977).

The Simpson's index of species diversity was calculated as described in Williams (1987).

The Shannon-Wiener Information Theory Index, Simpson's Index (∑), Equitability (E), Community Dominance Index, Continuum or Stand Index and Similarity
Index was calculated as per the methods described in Krebs (1978) and Colinvaux (1986).

The formulae for above indices are given below in detail.

1. Simpson's Index Of Species Diversity - D
   (Williams, 1987).

\[ D = \frac{N(N-1)}{\sum n(n-1)} \]

Where,
- \( D \) = Diversity Index
- \( N \) = Total number of Plants
- \( n \) = Number of individuals per species
  = Sum of.

2. The Shannon-Wiener Information Theory Index or Shannon-Wiener Diversity Index (Krebs, 1978).

\[ H' = -\sum p_i \log_2 p_i \]

Where
- \( H' \) = Diversity Index or Information Theory Index
- \( p_i \) = is the proportion of total number of individuals in the ith species.
The results were obtained by using programme in Basic which is given below.

```
10 S=0
20 INPUT N
30 FOR I=1 TO N
40 INPUT P
50 L = LOG(P)
60 T=P*[LOG(P)/LOG(2)]
70 S=S+T
80 NEXT I
90 PRINT "SUM=", S
100 END
```

3. Simpson's Index Of Diversity = D

\[ D = 1 - \sum_{i=1}^{s} (p_i)^2 \]

4. The Simpson's Index (Colinvaux, 1986).

It is called a Dominance Index, which is inversely proportional to diversity hence can help judging the diversity also.

\[ \lambda = \sum p_i^2 \]

\[ = \sum (n_i/N)^2 \]

Where,

ni = Number of individuals of a specie.

N = Total number of individuals of all species.
5. Equitability (E)

The Relative evenness of the numerical importance of a species in a sample is equitability. It is found out as per Krebs (1978).

\[
E = \frac{H}{H_{\text{max}}}
\]

Where,

- \( H \) - Observed species diversity
- \( H_{\text{max}} \) - Maximum species diversity i.e. equal to \( \log S \), where \( S \) = Total number of species.

6. Community Dominance Index (CDI)

It is the percentage of abundance contributed by two most abundant species as given by McNaughton (1968) following Krebs (1978) is calculated.

\[
\text{CDI} = \left( \frac{Y_1 + Y_2}{Y} \right) \times 100
\]

Where,

- \( Y_1 \) = Abundance of most abundant species.
- \( Y_2 \) = Abundance of Second abundant species.
- \( Y \) = Total abundance for all species.

7. Continuum Index or Stand Index

This was calculated for different stands as per the method of Brown and Curtis (1952) as described in Colinvaux (1986).
Continuum Index or Stand Index
= \sum [(importance value) \times (climax adaptation number)]

The climax adaptation number is an arbitrary rank value and it was assigned to species as per the order of occurrence in the estuary along environmental gradient.

8. Complexity Index

Which is the multiple of number of species, density, basal area, height and factor 10 based on 0.1ha, was calculated as given by Holdridge (1967).

9. Association

The association between the mangrove species was calculated by using a simple statistical test with a 2x2 contingency table and \( X^2 \) (chi-square) equation as given in Krebs (1978).

The \( X^2 \) was calculated as per the formula

\[
X^2 = \frac{n(ad-bc)}{(a+b)(c+d)(a+c)(b+b)}
\]

Where,

- \( n \) = Total number of quadrats
- \( a \) = The number of quadrats containing both the species
- \( b \) = The number of quadrats with only one species
\[ c = \text{Number of quadrats with another species} \]
\[ d = \text{The number of quadrats with neither species.} \]

The programme in Basic given below, is used to obtain the results.

```
10 INPUT A, B, C, D
20 N=A+B+C+D
30 E=(A*D-B*C)*(A*D-B*C)
40 F=(N*E/[(A+B)*(C+D)*(A+C)*(B+D)])
50 PRINT "CHI="; F
60 END
```

10. Index Of Similarity

The Sorensen Index (1948) of similarity between two stands was calculated as follows

\[
\text{IS} = \frac{2C}{A + B}
\]

Where,

- \( A \) = total number of the species in stand(A)
- \( B \) = total number of the species in stand(B)
- \( C \) = Number of the species common to both stands.

The value of this index ranges from 0 to 1 i.e., no similarity to complete similarity.
11. Growth Correlations

Correlations between Height and Girth, Height and Canopy and Girth of mangrove species was studied by using co-efficient of correlation as defined by Pearson, which is as follows.

\[ r = \frac{\sum (x-\bar{x}) (y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2 \sum(y-\bar{y})^2}} \]

The programme used is given herewith.

```plaintext
05 A=0 : B=0 : C=0 : D=0 : E=0 : F=0 : G=0 : H=0 : J=0
10 INPUT N
20 FOR I = 1 TO N
30 INPUT X, Y, Z
40 A = A+X
50 B = B+Y
60 C = C+Z
70 D = D+X*X
80 E = E+Y*Y
90 F = F+Z*Z
91 G = G+X*Y
92 H = H+Y*Z
93 J = J+X*Z
95 NEXT I
96 P = (D-A*A/N) ^ .5
97 Q = (E-B*B/N) ^ .5
```
98  \[ R = \left( F - C \cdot C / N \right)^{0.5} \]
100  \[ K = \left( G - A \cdot B / N \right) / (P \cdot Q) \]
110  \[ L = \left( J - A \cdot C / N \right) / (P \cdot R) \]
120  \[ M = \left( H - B \cdot C / N \right) / (Q \cdot R) \]
130  PRINT "R12=", K, "R13=", L, "R23=", M
150  END

12. Stem Volume

It was obtained by multiplying the basal area by one half of the total height as suggested by Aksornkoae (1980). Same method has also been followed by Jagtap (1985).

13. Succession

Stages in the change of species occurrence and nature of substratum were observed and recorded. Records may be used and then occurrence or disappearance of species will give idea of succession.