FINAL REPORT OF THE PROJECT

MAPPING OF MANGROVES AND STUDIES OF SPECIES DIVERSITY AND OTHER MANGROVE CHARACTERISTICS IN MUMBAI METROPOLITAN REGION (MMR)

SUBMITTED TO

MMR ENVIRONMENT IMPROVEMENT SOCIETY (MMR-EIS) OF
THE MUMBAI METROPOLITAN REGION DEVELOPMENT AUTHORITY
(MMRDA)

SUBMITTED BY

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PROLOGUE

Wetlands – The transitional zones between permanently aquatic and terrestrial eco–systems, play a key role in maintaining the ecological balance by way of flood control, water purification, microclimatic regulation and as habitats if fish, birds and wildlife. Based on their contact with sea, they can be classified into 2 broad categories the coastal wetlands and the inland wetlands.

Mangroves are an important part of the coastal wetlands and comprise associations of hydrophytic trees, shrubs and plants growing in brackish to saline tidal waters along the tropical and subtropical coasts. Their utility in protection of the coasts from sea, as fish breeding grounds and as a pollution cleansing areas has made them an indispensable component of the coastal ecosystem that needs to be conserved for ensuring the environmental improvement along our coastal stretches.

The Mumbai Metropolitan Region (MMR) has been bestowed with large growth of mangrove vegetation that is noticed along inter tidal zones of estuaries and creeks in Manori, Thane, Dharamtar, Vasai – Virar regions. A total of 4787 ha of area is reported to have been covered by the mangroves in Greater Mumbai region (Garg *et al*, 1998) and is under constant threat of reclamation/destruction due to the developmental pressures this region experiences. Concerns about declining fish stocks, increasing industrial and domestic waste discharges in the marine waters along the Mumbai coast and heavy siltation in port areas (leading to higher expenditure on dredging operations) are but a few reasons why this vital component of our ecosystem needs to be monitored and saved from future onslaught. Understanding the current status and rate of changes occurring in the MMR mangrove spread is the foremost step in this direction.

Keeping the aforementioned facts in view, the Board of Governors of MMR-Environment Improvement Society (MMR-EIS) of the Mumbai Metropolitan Region Development Authority (MMRDA), Mumbai, in its meeting held on March 31, 1998, offered to Bombay Natural History Society and the Centre for Studies in Resources Engineering (CSRE) of Indian Institute of Technology (IIT), Mumbai, a research project entitled "Study of species diversity and other mangrove characteristics for entire Mumbai Metropolitan Region (MMR)

MMR-Environment Improvement society subsequently issued sanction of the said Project through a letter (No. TCP/ENV/SOC/685/98) dated July 01, 1998, along with the grants. This project is a joint venture of Bombay Natural History Society (BNHS) and the Centre for Studies in Resources Engineering (CSRE) of the Indian Institute of Technology Bombay and MMRDA.

Major objective of this Project was to integrate ecological and remote sensing data for studying coastal habitats, particularly mangrove ecosystems of Mumbai Metropolitan Region. The Project addressed following four major aspects such as:

1. study (field level) and mapping (based on satellite imageries) of the mangroves in 1997;
2. study the change in mangrove status between 1991 and 1997;
3. study species diversity and health status of mangroves located in MMR; and
4. organizing of the corresponding maps and database developed in a Geographic Information System (GIS)

This Report enumerates the observations by CSRE, IIT-Bombay and BNHS to understand the status of the mangroves around MMR and the changes that have occurred in the status in a span of about 6 years. *i.e.*, between the years 1991 and 1997. It is expected that this study will provide guidelines to MMR-Environment Improvement society in conserving and managing its pristine mangrove and other coastal habitats in years to come.

- Asad R. Rahmani
Director – BNHS, Mumbai

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1. BACKGROUND AND OBJECTIVES

1.1 Background:

Mumbai Metropolitan Region (MMR), spread over an area of about 4,355 sq. km, has a 167 km. long coastline. There are six major creeks in this region namely, Vasai, Manori, Malad, Mahim, Thane and Dharamtar, and nine major rivers namely, Tansa, Bhatsa, Barvi, Ulhas, Panvel, Gadi, Bhogeshwari, Vaitarna, Patalganga and Amba which, are under the influence of tidal water. They constitute the major coastal water system of the region.

Sandy beaches, exposed rocks, mud flats, marshes, mangroves and salt pans are found at several places along the coastline in MMR. The region does not have any designated wetlands of national importance, but its wetlands have rich ecological diversity. The wetlands have been traditionally used for production of salt, fisheries and for dumping of solid waste. Presence of large tracks of the coastal wetlands in the region covered with mangroves is of great ecological and environmental importance. It is noteworthy that the mangroves have reached a height of about 4 to 5 m. in most of the regions of MMR and upto 10 m. in a few places in Greater Mumbai besides other locations such as the banks of Ulhas, Patalganga rivers as also Vasai and Dharamtar creeks. Considering the vital role mangroves play in the coastal ecosystem, taking a stock of mangroves and monitoring their status, assumes a greater importance.

1.2 The project of MMR-EIS:

MMRDA setup the MMR-Environment Improvement Society (MMR-EIS) in 1996, with an initial corpus fund of Rs. 5.00 crores. Since then, the Society has been funding studies and projects that contribute to its objectives of achieving improvement of the environmental conditions in MMR.

The current Project entitled "Mapping **Study of species diversity and other mangrove characteristics of entire Mumbai Metropolitan Region**" was funded by the Society in the year 1997-98. The Project work comprised field surveys as well as interpretation of satellite imageries to prepare a GIS based information system which, was jointly carried out by the CSRE, IIT Mumbai and BNHS, Mumbai. The work of organizing the spatial data in digital form was done by MMRDA.

1.3 Objectives of the Project:

Principal components of this Project are:

1. study and mapping of the mangroves in 1997,
2. study the change in mangrove status between 1991 and 1997,
3. indentification of species diversity and health status of mangroves located in MMR and
4. organizing the corresponding maps and database in a Geographical Information System (GIS)

1.3.1 Scope of work:

The scope of work outlined through the TOR document, for each of the collaborating agencies, is reproduced below:

1.3.1.1. For IIT Bombay:

1. Prepare base maps for MMR excluding Brihan Mumbai, delineating mangrove area on 1:25,000 scale using IRS I-C FCC geo-coded data at 1:50,000 scale for development of spatial database on mangrove status using PC based GIS. For Brihan-Mumbai region, the Chief Hydrographer to the Govt. of India will prepare maps with mangrove delineation.
2. Conduct field visits for verifying the presence of mangroves and develop methods for interpreting the satellite images for delineation of mangroves as well as making photographic documentation of mangrove areas.

3. Compare changes in status of mangrove areas in 1997 with that of 1991 using data available with CRSE, IIT Bombay.

The MMRDA shall provide IRS IC panchromatic data and multi-spectral data (FCC) on 1:50,000 scale for 1997. For comparative analysis, the maps prepared by CSRE, IIT Bombay in 1991 and/or any other maps available should be used.

1.3.1.2 For BNHS:

1. Conduct based on the base maps of mangroves area prepared by IIT Bombay and the Chief Hydrographer to GOI, field surveys to check the species diversity and other characteristics of mangroves (such as height, density, canopy cover and health status) located in the entire MMR.
2. Compare changes in species diversity and other characteristics mentioned above between 1991 and 1997 using base maps and other information provided by IIT Bombay and Chief Hydrographer to GOI.
3. To conduct field visits as may be necessary for carrying out the tasks stated above and to prepare a photographic documentation of species diversity and other characteristics.

1.3.1.3. For MMRDA:

1. Digitalize mangrove maps for the MMR and for Brihan Mumbai and organize the digital data in GIS environment.
2. Prepare final maps at desired scale with statistics as an input to the final report.

For achieving the above objectives, basic spatial data in the form of maps prepared by CSRE, IIT Bombay (based on 1991 data) and by both, CSRE, IIT Bombay and BNHS, Mumbai (based on 1997 data) at 1:50,000 scale are utilized. In particular the following data was used.

1. Maps (1:50,000 scale) showing distribution of mangroves in 1997 (Geocoded FCCs from IRS-IC satellite imageries, April 1997 available with MMRDA);
2. Maps (1:50,000 scale) showing distribution of mangroves in 1991 (using Diapositive from SPOT satellite imageries, 1991 and a set of 1:25,000 scale 'CRZ Land-use Maps' prepared by CSRE, IIT Bombay); and
3. Maps at 1:50,000 scale showing change in status of mangroves between 1991 and 1997.

1.4. Additional inputs to the Terms of Reference:

1. Though the mapping of Brihan-Mumbai region was supposed to have been done by the Chief Hydrographer to the Govt. of India, mapping of this area including South Mumbai was completed by CSRE, IIT Bombay without asking for any additional budgetary provisions.
2. This was done to achieve continuity between the mapping procedures and accuracy all over Mumbai Metropolitan Region.

Methodology followed for achieving the above objectives is provided in the following Chapter.

2. METHODOLOGY OF WORK:

2.1 Mapping mangroves using remotely sensed data:

The spatial resolution and spectral bands in which the sensors collect the remotely sensed data are important parameters of coastal wetland study. Modern remote sensing technology provides various types of data products. Hardcopy images of these data products were converted into maps by manual image interpretation technique in this study. The region covering entire MMR was studied using the Indian Remote Sensing satellite (IRS IC) Geocoded False Colour Composite (FCC) images of 1997. Results from this study were then compared with those obtained from the French Satellite SPOT data (FCC) of 1991 for mapping the changes in the mangrove area.

The study area falls between Latitudes 18° 30′ and 19° 35′ as well as Longitudes 72° 40' and 73° 10′. The region is covered in following ten SOI (1:50,000 scale) Toposheets. They are 47-A/11, 47-A/14, 47-A/15, 47-A/16, 47-B/13, 47-B/14, 47-E/03, 47-E/04, 47-F/01 and 47-F/02.

Though the Brihan-Mumbai mapping was to be completed by Chief Hydrographer to GOI, work relating to mapping of this area (covering south Mumbai) was also undertaken by IIT Mumbai, on the request of MMR-EIS. This was done to achieve continuity between the mapping procedures as well as accuracy during the entire study.

2.1.1. Data Used:

Besides the field information, following data was used during the mapping exercise:

Geo-coded FCCs from IRS – IC satellite passes of Sept-Oct 1997 on 1:50,000 scale (Already procured and existing with MMRDA) 'CRZ Land-use maps' on 1:25,000 scale prepared by CSRE, IIT Mumbai, based on 1991 FCCs from SPOT satellite data (as dia-positives) and SOI Toposheets of 1970s on 1:50,000 scale.

2.1.2 Preparation of Maps:

The methodology followed during the study comprised following steps:

2.1.2.1 Mangrove status during 1997:

1. Preparation of Remote Sensing (Visual Interpretation) keys for identification of the classes to be mapped.
2. Interpretation of the classes viz., Mangroves (dense and sparse), in the study area, using the Geocoded FCCs data (on 1:50,000 scale) from IRS-IC data of September-October 1997.
3. Preparation of base maps on 1:50,000 scale using SOI Toposheets showing major roads, rail network and names of important places/towns.
4. Transferring the details of the information about the mangrove classes on the base maps. Instead of the initial plan of making maps on 1:25,000 scale, maps on 1:50,000 scale were found acceptable for the GIS exercise and were used for the purpose.
5. Limited field checks for verifying the map information and field photography
6. Enlarge the mangroves status maps on 1:25,000 scale if needed (this was done in few cases)

2.1.2.2. Remote Sensing Keys for identification of wetland classes:

The interpretation key necessary for identifying various coastal features was developed after observing these areas in the FFCs. The interpretation key for identification of the wetland classes to be mapped was prepared n the basis of the image characteristics such as shape, size, shadow, pattern, tone, texture, association and location as provided in Table 2.1.

On the basis of the characteristics mentioned in the Table, the wetland classes namely dense and sparse mangroves were identified. Further, the dense mangroves class in 1997 images was re-classified as dense mangroves with height above 3 metres and dense mangroves with height below 3 metres, based on the extensive field observations undertaken in the entire MMR.

Table 2.1: Interpretation keys for analysis of image characteristics with wetland type.

Coastal wetland type	Image Characteristics						
	Tone	Texture	Size	Shape	Shadow	Pattern	Association
Dense Mangroves	Pale Red	Smooth	Variable	Variable	Nil	Scattered	Along the coast and creeklets
Sparse Mangroves	Brownish	Smooth	Variable	Variable	Nil	Scattered	Along the coast and creeklets
Mud flats	Grey	Coarse	Variable	Variable	Nil	Scattered	Along the coast and creeklets
Salt pans	Bright White	Smooth	Uniform	Square/ rectangle	Nil	Contiguous	Along the creeklets

2.1.2.3. Changes in mangrove status during 1991 and 1997:

This exercise comprised comparison of the information on mangrove status from the maps made from 1991 and 1997 data and delineation of the changes, to obtain the change detection maps. This was achieved through physical superimposition of the two sets of maps (of 1991 and 1997), registering major roads and railway lines, as their locations remained same in both the maps and then delineating the changes.

Information on changes in mangrove cover was generated on 1:50,000 scale and was passed on to MMRDA for digitization and further enlargement (if needed). Various transformation in the change of mangrove cover patterns were defined based on extensive field checks using maps prepared based on 1991 and 1997 information.

The maps were prepared using the Geocoded IRS-IC FCC images (photographic prints) on 1:50,000 scales, already available with MMRDA. The locations of road/ rail links on 'Geocoded' images were not perfectly matching with those from the SOI Toposheets. As a result, the base map information obtained from the Toposheets was used in marking of major roads and rail links in the changed maps too.

Two sets of maps were prepared during this study, one depicting Mangroves status of 1997 and the other showing the changes that have occurred between 1991 and 1997. The quadrants covered in the maps were (a) 47/B/13 (SE-SW); (b) 47 B/14 (NE); (c) 47 F/1 (NW); (d) 47 A/15 (NW); (e) 47 A/15 (SE); (f) 47 A/16 (NE); (g) 47 F/1 (SW); (h) 47 A/16 (SE); (i) 47 A/14 (SE); (j) 47 A/14 (SW); (k) 47 E/4 (NW); (l) 47 B/13 (NE); (m) 47 A/15 (SW); (n) 47 F/2 (NW); (o)47 E/3 (SW); (p) 47 A/15 (NE); and (q) 47 E/4 (SW).

Both the sets of maps were handed over to the MMR-EIS to be handed over to the MMRDA (collaborator) for digitizing the maps and providing us with the class area statistics from the GIS.

2.2 Species diversity studies of mangroves in MMR:

Mangroves are constantly subjected to both rhythms of tides and seasons (shorter term) as well as changes of climate and sea level (longer term). Exposed breathing roots, support (stilt) roots and buttresses, salt excreting leaves and viviparous propagules are some of the several highly specialized and collectively well known adaptations of this group of plants. The habitat in which mangroves are observed is often referred to as mangrove forest and/or tidal forest. Mangroves stabilize shorelines and decrease coastal erosion by reducing the energy of waves and currents and by holding the bottom sediment in place with plant roots. They also act as windbreaks and protection from coastal storms, forming a cost-free, self repairing barrier.

2.2.1. Survey of mangrove flora in MMR:

During the Project period, coastal mangrove vegetation of Mumbai Metropolitan Region was studied for floral elements and their distribution along the coastal areas. This included a region which, broadly covered creeks and estuaries of three districts, namely Thane, Mumbai and Raigad, besides the islands of Elephanta and Butcher (now known as Jawahar Dweep).

Table 2.2: Categories for marking transformation in the change of mangrove cover patterns.

No.	Transformation in the change of mangrove cover pattern	Code
1	Sparse mangrove remained sparse mangrove (no change)	(ss)
2	Sparse mangrove changed to other (land-use) class	(so)
3	Sparse mangrove changed to dense mangrove	(sd)
4	Dense mangrove remained dense mangrove (no change)	(dd)
5	Dense mangrove changed to sparse mangrove	(ds)
6	Dense mangrove changed to other (land-use) class	(do)
7	Other (land-use) classes changed to sparse mangrove	(os)
8	Other (land-use) classes changed to dense mangrove	(od)

2.2.2. Structural studies of mangroves in MMR:

Detailed ecological studies (phyto-sociological studies) of coastal mangrove flora of entire MMR were initiated in various coastal regions. The purpose of these is to understand the composition of component species to the different types of vegetation of mangroves in MMR. The quantitative aspects of the vegetation such as the phyto-sociological characters of the plants of mangrove habitats are studied.

In order to express the dominance and ecological success of any species with a single value, the concept of importance value index is developed. This index utilises three characteristics, such as relative frequency, relative density and relative dominance. These values will be obtained at the end of ecological studies of MMR, by evaluating frequency, density and basal area for all the mangrove species growing in a unit area (quadrates) studied in the respective coastal regions. Species with higher Importance Value Index can be regarded as most successful species in that specific region.

Dispersion of plant species in a community (frequency), their numerical strength (density) and dominance can be studied, following the methods given by Misra (1968) and Pandeya *et al.* (1968).

2.2.2.1 Frequency:

Frequency indicates the number of sampling units in which the particular species occurs in the study area. In other words, it expresses the distribution of the species in the plant community. It is measured with the help of the following formula.

A	Frequency (%)	=	$\frac{\text{No. of sampling units in which species occurs}}{\text{Total no. of quadrats studied}} \times 100$

2.2.2.2. Density and Abundance:

The terms density and abundance represent the numerical strength of a species in a plant community. The density represents the number of individuals per unit area. The density and frequency considered together are of prime importance in determining the structure of community and have a variety of uses far beyond those of other quantitative values (Oosting, 1958). If abundance is considered along with frequency gives an idea about the distribution patterns of the species. These are calculated by the following formula:

B	Abundance	=	$\frac{\text{Total no. of individuals}}{\text{Total no. of quadrats in which the species occurs}}$

C	Density	=	$\frac{\text{Total number of individuals}}{\text{Total no. of quadrats studied}}$

2.2.2.3. Basal area:

Basal area refers to the ground actually penetrated by the stem and is seen when the leaves and stems clipped at the ground surface (Hanson and Churchill, 1961). It is one of the major characters determining the dominance of the species and the nature of the community. The basal area is measured either at 2.5 cm. above ground or at the ground level. The values obtained in the latter case are less flexible.

The measurement of the basal area at ground level was done with the help of measuring tape for each species in very quadrate and the basal area was calculated by using the formula: Basal area (cm^2)= πr^2 , where r (radius) is calculated after measurement o the perimeter (girth) of the stem at the ground level. The radius was calculated by the formula provided as follows:

Perimeter (girth) = 2π r, and $r = \frac{\text{Girth}}{2\pi}$

The radius can also be calculated as ½ (DBH).

2.2.2.4. Dominance:

Dominance is the relative prevalence or predominance of individuals of a species that results from their numbers and massiveness. Each species of the community can be assigned some degree of dominance according to the relative area or volume of the community that is occupied by it. It is also used to express the phenomenon of actual predominance in a community of the individuals of a species (Cain and Castro, 1959).

2.2.2.5. Importance Value Index:

A	Relative frequency	=	No. of occurrences of the species / No. of occurrences of all the species	x 100
B	Relative density	=	No. of individuals of the species / No. of individuals of all the species	x 100
C	Relative dominance	=	Total basal area of the species / Total basal area of all the species	x 100

In order to express the dominance and ecological success of any species, with a single value, the concept of importance value index has been developed. This index utilizes three characteristics, viz., relative frequency, relative density and relative dominance.

All the mentioned values can be obtained by evaluating frequency, density and basal area for all the species growing in the study area, using the equations, mentioned earlier.

The above three values are added to get the importance value index (IVI). It is calculated for all the species recorded in the quadrates in the study area.

2.2.3. Qualitative Assessment of mangroves of MMR:

The widely increasing pollution problems, extensive destruction and modification of marine habitats in the interests, called economic development and the prodigious over-exploitation of renewable resources are definite indications of our heading towards a point of no return in many areas of our country, without concerns for the future. Mangrove ecosystems are one of the glaring examples of the same.

Because of the conflict of uses in the coastal zone, coast-related island systems and surrounding habitats, many facets of the marine ecosystem and habitats of MMR are being increasingly tampered with activities such as reclamation for slum development, housing and recreation, dumping of untreated sewage as well as conversion of coastal habitats for agriculture.

A qualitative assessment of the stresses on mangrove habitats of MMR and problems in their preservation was done based on extensive field observations. This would provide an insight to planners and policy makers to sustainable preservation and development of mangrove habitats of MMR.

Results f the above studies are provided in the following Chapter.

3. OBSERVATIONS

3.1. Mapping of mangroves in MMR:

In order to get a fairly detailed view of the geographical distribution of mangroves in MMR, the data set was organized under eight major regions with further sub-regions. They are provided in Table 3.1.

Table 3.1.: Administrative boundaries (region and sub-regions) of MMR, used for highlighting mangrove distribution.

Category	Region	Sub-region
1.	Brihan-Mumbai	Island City(1.1), Western suburb(1.2), Eastern Suburb(1.3)
2.	Western region	Mira-Bhayander sub-region(2.1), Vasai-Navghar sub-region(2.2), Nallasopara sub-region(2.3), Virar sub-region(2.4), VVNA Coast sub-region(2.5), VVNA Rural sub-region(2.6), Outside VVNA sub-region(2.7)
3.	North-East region	TMC sub-region(3.1), KMC sub-region(3.2), Ulhasnagar sub-region(3.3), Ambernath sub-region(3.4), Badlapur sub-region(3.5), Bhiwandi sub-region(3.6), Bhiwandi Rural sub-region(3.7), South Kalyan Ulhas sub-region(3.8), North Kalyan Tehsil sub-region(3.9)
4.	Navi Mumbai	NMMC (excluding 15 villages)-(4.1), NMMC (including 15 villages)-(4.2), Panvel sub-region(4.3), Uran sub-region(4.4)
5.	Neral-Karjat region	Krjat sub-region(5.1), Khalapur sub region(5.2)
6.	Panvel-Uran region (outside Navi Mumbai)	Rasayani-Panvel sub-region(6.1), Rest Panvel sub-region(6.2), Kopta sub-region(6.3), Rest Uran sub-region(6.4), Karnala sub-region(6.5)
7.	Pen region	
8.	Alibag region	

The spatial data gathered during the Project period were computerized. For creating the digital version of the maps, a standard drafting software namely, AutoCAD is employed. The digitized maps were stored in different thematic layers for processing the data in a variety of ways. In order to analysis these spatial data along with the linked attribute data, GIS software namely; PC ARC/INFO was used.

3.1.1. Distribution of mangroves as per the Survey of India Toposheets (1968)

The area of about 350 sq. km. i.e. 8% of the total measured MMR area of 4236 sq. km. is mud flat which is a coastal wetland. In these Toposheets the mangroves are not separately identified and only marshy reeds in the mud flat area is shown near Mandwa in Alibag Tehsil and in Uttan in Mira-Bhayandar area.

3.1.2. Distribution of mangroves in 1991:

The area of about 95.43 sq. km., i.e. 2.25% of the MMR area was under mangroves in the year 1991. Mangrove categories, i.e. sparse and dense are identified by using the interpretation key for the satellite imageries. The distribution of mangroves is provided in **Table 3.2.**

It is seen from **Table 3.2** that out of the total mangrove cover of 95.43 sq. km., sparse mangroves comprise 68.11% and dense mangroves 31.89%. It can also be seen from that in 1991, the area under the mangrove in Greater Mumbai was 30.77 sq. km. which, formed the largest cover (area-wise) amongst all the Sub-regions of MMR. This was followed by 17.19 sq. km. in North-East region consisting of Thane, Kalyan, Bhiwandi, 15.50 sq. km. in Navi Mumbai, 10.98 sq. km. in Mira-Bhayandar and Vasai-Virar area in the Western region, 3.29 sq. km. in Alibag region, 2.64 sq. km. in Panvel-Uran region and 0.80 sq. km. in Pen region. A number of maps are prepared (kindly refer to **Sheets 1 to 7**) and are presented here to give a fair idea of the areas under mangroves in the region. The Sheet 1 shows the distribution of mangroves in the whole of MMR. The Sheet 2 – Alibag-Pen, Sheet 3 – Mumbai, Sheet 4 – Navi Mumbai, Sheet 5 – Thane, Sheet 6 – Kalyan-Bhiwandi and Sheet 7 – Vasai-Virar depict the distribution of mangroves in different locations in the MMR.

Table 3.2: Area wise (sq. km.) distribution of Mangroves in MMR (as on 1991)

Category	Region/Sub-region	Mangrove Type		Total area under Mangroves
		Sparse	Dense	
1.	**Brihan-Mumbai**	**16.67**	**14.10**	**30.77**
1.1	Island City	0.17	0.25	0.42
1.2	Western Suburbs	6.92	5.47	12.39
1.3	Eastern Suburbs	9.58	8.38	17.96
2.	**Western region**	**10.40**	**0.58**	**10.98**
2.1	Mira-Bhayander Sub-region	5.95	0.58	6.53
2.2	Vasi-Navghar Sub-region	2.65		2.65
2.3	Nallasopara Sub-region			
2.4	Virar Sub-region	0.65		0.65
2.5	VVNA Coast Sub-region	0.50		0.50
2.6	VVNA Rural Sub-region			
2.7	Outside VVNA Sub-region	0.65		0.65
3.	**North-East Region**	**8.67**	**8.52**	**17.19**
3.1	TMC Sub-region	3.90	6.09	17.19
3.2	KMC Sub-region	0.89		0.89
3.3	Ulhasnagar Sub-region			
3.4	Ambernath Sub-region			
3.5	Badlapur Sub-region			
3.6	Bhiwandi Sub-region	2.66	1.81	4.47
3.7	Bhiwandi Rural Sub-region	1.22	0.62	1.84
3.8	South Kalyan Ulhas Sub-region			
3.9	North Kalyan Tehsil Sub-region			
4.	**Navi Mumbai**	**13.24**	**2.26**	**15.50**
4.1	NMMC (excluding 15 villages)	2.76	1.37	4.13
4.2	NMMC (including 15 villages)			
4.3	Panvel Sub-region	4.76	0.83	5.59
4.4	Uran Sub-region	5.72	0.06	5.78
5.	**Neral-Karjat region**			
5.1	Karjat Sub-region			

Category	Region/Sub-region	Mangrove Type		Total area under Mangroves
		Sparse	Dense	
5.2	Khalapur Sub-region			
6.	**Panvel-Uran region (outside Navi Mumbai)**	**2.42**	**0.22**	**2.64**
6.1	Rasayani-Panvel Sub-region			
6.2	Rest Panvel Sub-region			
6.3	Kopta Sub-region	2.42	0.22	2.64
6.4	Rest Uran Sub-region			
6.5	Karnala Sub-region			
7.	**Pen region**	**0.66**	**0.14**	**0.80**
8.	**Alibag region**	**3.04**	**0.25**	**3.29**
9.	**Beyond LTL (Survey of India Toposheet)**	**9.90**	**4.36**	**14.26**
	Total Area	**65.00**	**30.43**	**95.43**
	Percentage Area	**68.11%**	**31.89%**	**100.00%**

It may be noted that the newly formed mangrove area of 14.26 sq. km. is beyond the Low Tide Line (LTL) shown in SOI Toposheets. This increase in sparse and dense mangroves is seen along the Thane Creek in the Eastern suburbs of Mumbai, along the banks of Ulhas River, particularly in Mira-Bhayandar and Naigaon, along the Panvel, Karanja and Dharamtar Creeks and near Rewas in Alibag Tehsil. The **Sheet 8** depicts the increase in mangroves beyond SOI Toposheet LTL line, along the Thane Creek and Ulhas River.

3.1.3. Distribution of mangroves in 1997:

An area of 231.11 sq. km. i.e. 5.34% of the MMR area is under the mangroves in the year 1997. Mangroves categories namely, sparse and dense above 3 metres and dense below 3 metres are identified using the satellite imageries with extensive field checks.

Area-wise distribution of mangroves in MMR (as on 1997) can be seen from **Table 3.3** on the pages that follow. It is seen from Table 3.3 that the share of the sparse mangroves is 41.81% and dense mangroves is 58.19% of the total area of 232.11 sq. km. under the mangroves.

It is seen that the area under mangroves is increased by 2.43 times between 1991 and 1997 period and the increase is noticed without exception in all the regions and sub-regions of the MMR.

Table 3.3: Area wise (sq. km.) distribution of Mangroves in MMR (as on 1997)

Category	Region/Sub-region	Mangrove Type				Total
		Sparse	Dense			
			Above 3 m	Below 3 m	Total	
1.	**Brihan-Mumbai**	**11.25**	**20.77**	**20.25**	**41.02**	**52.27**
1.1	Island City	00.84	00.55	00.24	00.79	01.63
1.2	Western Suburbs	05.89	06.61	14.11	20.72	26.61
1.3	Eastern Suburbs	04.52	13.61	05.90	19.51	24.03
2.	**Western region**	**13.68**	**07.48**	**14.88**	**22.36**	**36.04**
2.1	Mira-Bhayander Sub-region	03.08	05.35	03.89	09.24	12.32
2.2	Vasi-Navghar Sub-region	03.86	00.95	02.23	03.18	07.04
2.3	Nallasopara Sub-region	00.72				00.72
2.4	Virar Sub-region	00.66	00.23	05.36	05.59	06.25
2.5	VVNA Coast Sub-region	04.39	00.53	02.92	03.45	07.84
2.6	VVNA Rural Sub-region	00.81	00.17	00.14	00.31	01.12
2.7	Outside VVNA Sub-region	00.16	00.25	00.34	00.59	00.75
3.	**North-East Region**	**16.90**	**05.83**	**06.79**	**12.62**	**29.52**
3.1	TMC Sub-region	06.85	02.97	04.57	07.54	14.39
3.2	KMC Sub-region	00.86	00.13	00.11	00.24	01.10

Category	Region/Sub-region	Mangrove Type				Total
		Sparse	Dense			
			Above 3 m	Below 3 m	Total	
3.3	Ulhasnagar Sub-region					
3.4	Ambernath Sub-region					
3.5	Badlapur Sub-region					
3.6	Bhiwandi Sub-region	07.74	01.94	01.48	03.42	11.16
3.7	Bhiwandi Rural Sub-region	01.45	00.79	00.63	01.42	02.87
3.8	South Kalyan Ulhas Sub-region					
3.9	North Kalyan Tehsil Sub-region					
4.	**Navi Mumbai**	**31.50**	**07.51**	**10.77**	**18.28**	**49.78**
4.1	NMMC (excluding 15 villages)	07.85	04.19	02.31	06.50	14.35
4.2	NMMC (including 15 villages)					
4.3	Panvel Sub-region	15.76	00.84	04.53	05.37	21.13
4.4	Uran Sub-region	07.89	02.48	03.93	06.41	14.30
5.	**Neral-Karjat region**					
5.1	Karjat Sub-region					
5.2	Khalapur Sub-region					
6.	**Panvel-Uran region (outside Navi Mumbai)**	**05.07**	**02.10**	**00.70**	**02.80**	**07.87**
6.1	Rasayani-Panvel Sub-region					
6.2	Rest Panvel Sub-region					
6.3	Kopta Sub-region	04.55	02.10	00.46	02.56	07.11
6.4	Rest Uran Sub-region	00.11		00.24	00.24	00.35
6.5	Karnala Sub-region	00.41				00.41
7.	**Pen region**	**02.79**	**01.96**	**03.17**	**05.13**	**07.92**
8.	**Alibag region**	**07.93**	**01.52**	**07.56**	**09.08**	**17.01**

Category	Region/Sub-region	Mangrove Type				Total
		Sparse	Dense			
			Above 3 m	Below 3 m	Total	
9.	Beyond LTL (Survey of India Toposheet)	07.92	17.23	06.55	23.78	31.70
	Total Area	97.04	64.40	70.67	135.07	232.11
	Percentage Area	41.81%	27.75 %	30.45 %	58.19 %	100.00 %

It is also seen from **Table 3.3** that in the year 1997, the area under mangroves in Greater Mumbai was 52.27 sq. km., followed by 49.78 sq. km. in Navi Mumbai, 36.04 sq. km., in Mira-Bhayandar and Vasai-Virar area in Western region, 29.52 sq. km. in North East region consisting of Thane, Kalyan and Bhiwandi, 17.01 sq. km. in Alibag region, 7.92 sq. km. in Pen region and 7.87 sq. km. in Panvel-Uran region.

Further, it is seen from **Tabel 3.3** that in 1997 the total area under the dense mangroves was 135.07 sq. km. Out of that the area of 64.40 sq. km. is under the mangroves below 3 meters in height. This implies the existence of fairly good amount of area under the thick growth of mangroves (height exceeding 3 meters) in MMR.

The maps (kindly refer to Sheets 9 to 15) of the areas under mangroves in the region are appended here. The Sheet 9 shows the distribution of mangroves in the MMR, Sheet 10 – Alibag-Pen, Sheet 11 – Mumbai, Sheet 12 – Navi Mumbai, Sheet 13 – Thane, Sheet 14 – Kalyan-Bhiwandi and Sheet 15 – Vasai-Virar shows the distribution of mangroves in different parts of the MMR.

It may be noted that the newly formed mangrove area of 31.70 sq. km. is beyond the Low Tide Line (LTL) shown in the SOI Toposheets. The increase in mangroves between 1991 to 1997 is about 17.44 sq. km. This increase in sparse and dense mangroves is seen along the Thane Creek in Eastern suburbs, Malad and Manori Creeks in Western suburbs of Mumbai and along the Thane Creek from Airoli to

Belapur in Navi Mumbai, all along the banks of Ulhas River from Mira-Bhayandar to Dombivli, near JNPT at Nhava and Sheva in Uran Tehsil, Navi Mumbai along the Panvel, Karanja and Dharamtar Creeks, along the banks of Amba River in Alibag and Pen Tehsils.

The Sheet 16 shows the increase in mangroves beyong the SOI Toposheet LTL, along the Thane Creek and Ulhas River in 1997.

3.3. Changes in Mangroves Status from 1991 to 1997:

3.3.1. Qualitative Analysis:

During the extensive field studies to physically verify various land-uses of MMR as also patterns of mangrove cover, as seen in maps (for the year1997), certain areas showed significant changes. They included changes in land-uses in coastal stretches, conversion of mangrove areas for various purposes, the cumulative effect of which is marked in **Table 3.4.**

Table 3.4: Areas of significant changes in mangrove cover (detection of changes in mangrove patterns/cover of 1997 over 1991), based on qualitative observations during field/ physical verification.

No.	Area	Region-wise change (approximate estimate in percent) in mangrove patterns		
		Downstream	Intermediate	Upstream
01	**Vaitarna River estuary**			
	Northern Bank	Not applicable	Dense to Dense (05%)	Others to Sparse (60%)
	Southern Bank	Not applicable	Sparse to Sparse (05%)	Sparse to Others (20%)
02	**Vasai Creek/Ulhas River estuary**			
	Northern Bank	Others to Dense (05%)	Others to Sparse (15%)	Others to Sparse (60%)
		Sparse to Dense (05%)	Others to Dense (10%)	Sparse to Others (10%)
		Others to Sparse (40%)	Sparse to Dense (20%)	Sparse to Sparse (10%)

No.	Area	Region-wise change (approximate estimate in percent) in mangrove patterns		
		Downstream	**Intermediate**	**Upstream**
		Sparse to Others (10%)	Sparse to Others (05%)	Dense to Sparse (15%)
			Dense to Others (05%)	
			Sparse to Sparse (10%)	
	Southern Bank	Others to Sparse (%)	Others to Sparse (30%)	Others to Sparse (25%)
		Others to Dense (10%)	Others to Dense (05%)	Sparse to Others (10%)
		Sparse to Dense (05%)	Sparse to Others (05%)	Dense to Sparse (30%)
		Dense to Dense (05%)	Sparse to Sparse (20%)	Dense to Others (05%)
03	**Manori Creek**			
	Northern Bank	Others to Sparse (95%)	Others to Sparse (80%)	Others to Sparse (20%)
			Others to Dense (05%)	Others to Dense (05%)
			Sparse to Others (05%)	Sparse to Dense (30%)
				Sparse to Others (10%)
	Southern Bank	Others to Sparse (85%)	Others to Sparse (60%)	Others to Sparse (20%)
		Dense to Others (05%)	Others to Dense (20%)	Sparse to Dense (30%)
			Dense to Sparse (05%)	Dense to Dense (10%)
			Dense to Others (10%)	Sparse to Others (10%)
04	**Malad Creek**			
	Northern Bank	Others to Sparse (50%)	Others to Sparse (30%)	Others to Sparse (05%)
		Sparse to Dense (10%)	Others to Dense (05%)	Others to Dense (05%)

No.	Area	Region-wise change (approximate estimate in percent) in mangrove patterns		
		Downstream	**Intermediate**	**Upstream**
			Sparse to Dense (40%)	Dense to Others (60%)
			Dense to Sparse (05%)	
			Dense to Sparse (10%)	
	Southern Bank	Others to Dense (10%)	Others to Sparse (10%)	Dense to Others (70%)
		Sparse to Others (10%)	Sparse to Dense (10%)	
		Sparse to Dense (05%)	Dense to Sparse (55%)	
		Dense to Others (30%)		
05	**Mahim Creek/Mithi River estuary**			
		Dense to Others (70%)	Others to Sparse (10%)	Not applicable
			Others to Dense (10%)	
			Dense to Sparse (55%)	
06	**Thane Creek**			
	Eastern Bank	Others to Sparse (40%)	Others to Sparse (30%)	Others to Sparse (20%)
		Others to Denser (30%)	Others to Dense (05%)	Others to Dense (05%)
		Sparse to Others (10%)	Sparse to Dense (05%)	Dense to Dense (15%)
			Dense to Dense (10%)	Sparse to Others (05%)
			Sparse to Others (10%)	
	Western Bank	Others to Sparse (10%)	Others to Dense (10%)	Others to Sparse (10%)
		Sparse to Dense (30%)	Sparse to Dense (25%)	Others to Dense (10%)

No.	Area	Region-wise change (approximate estimate in percent) in mangrove patterns		
		Downstream	**Intermediate**	**Upstream**
		Dense to Dense (35%)	Dense to Dense (35%)	Sparse to Others (10%)
		Sparse to Others (10%)	Dense to Others (15%)	Dense to Others (15%)
07	**Panvel Creek**			
	Northern Bank	Others to Sparse (70%)	Others to Sparse (90%)	Others to Sparse (90%)
		Others to Dense (10%)		
	Southern Bank	Others to Sparse (80%)	Others to Sparse (75%)	Others to Sparse (90%)
		Sparse to Sparse (05%)	Sparse to Sparse (05%)	
		Sparse to Others (05%)	Sparse to Others (05%)	
08	**Nhave Creek**			
	Northern Bank	Others to Sparse (80%)	Others to Sparse (80%)	Others to Sparse (40%)
			Others to Dense (05%)	Sparse to Sparse (20%)
			Sparse to Dense (05%)	Sparse to Others (10%)
	Southern Bank	Not Significant	Sparse to Dense (50%)	Others to Sparse (40%)
			Dense to Dense (10%)	Sparse to Sparse (20%)
				Sparse to Others (10%)
09	**Uran**			
	Eastern Side	Others to Sparse (20%)	Not Applicable	Not Applicable
		Others to Dense (20%)		
		Sparse to Dense (20%)		