FINAL Report

Studying Mangrove Crab, Shrimps, Prawns and Oysters Farming Potential in the MMR Mangroves: Economic Sustainability for Ecosystem Maintenance

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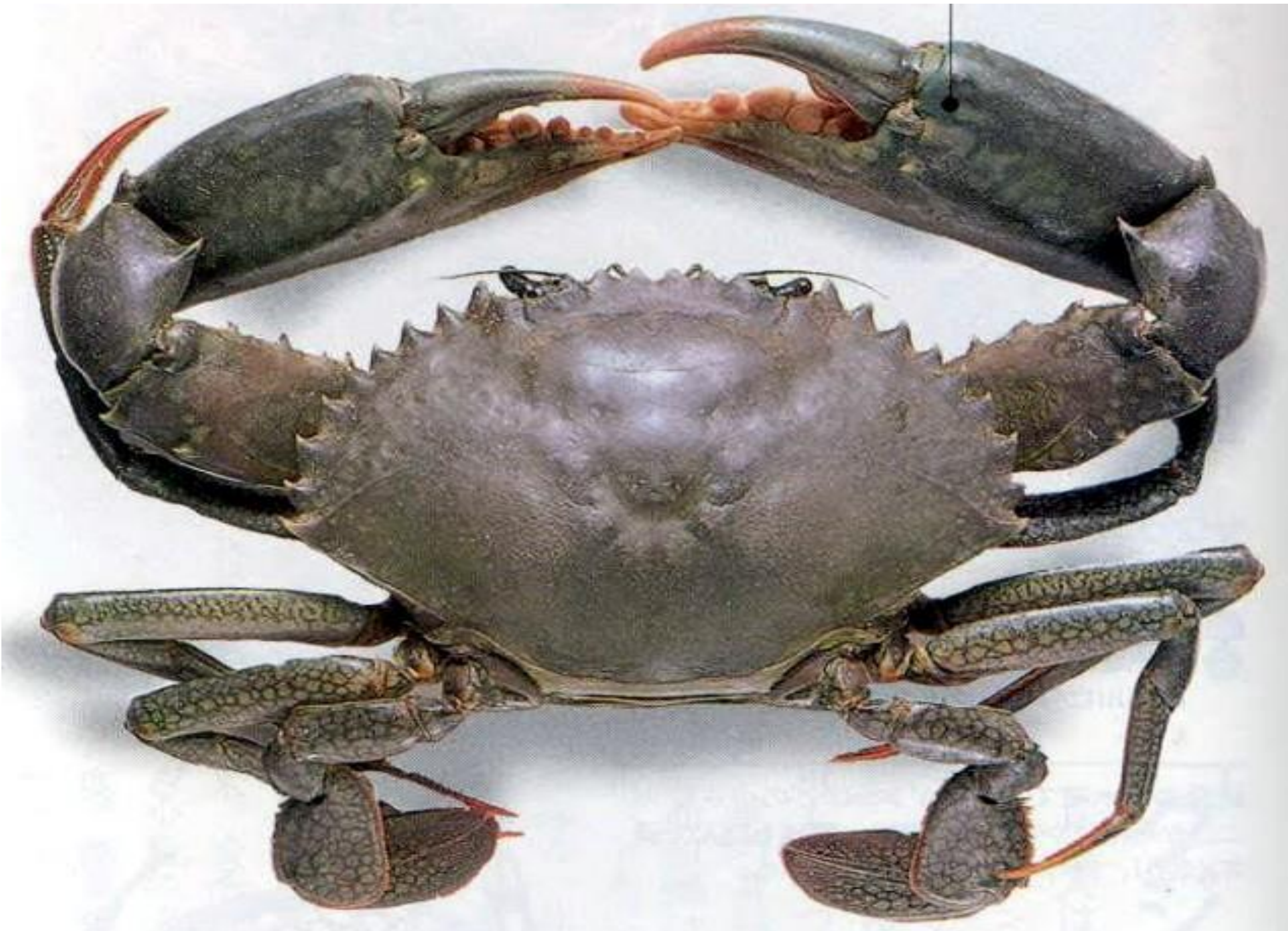
Submitted to

MMR Environment Improvement Society (MMR-EIS) of the Mumbai Metropolitan Region Development Authority (MMRDA)



List of Acronyms, Figures, and Tables

Chapter 1

Background

1.1 Scope of Work and Timeline

The following scope was fixed prior to the commencement of the study, with the ultimate objective of creating a feasible case study of co-existence of economic development and environment conservation.

- Secondary data collection - Complete
- Water and sediment sampling and analysis of the selected locations for season 1 - Complete
- Biodiversity survey of the selected locations for season 1 – Complete
- Socio-economic survey of the selected location for season 1 –Complete
- Water and sediment sampling and analysis of the selected locations for season 2 - Complete
- Biodiversity survey of the selected locations for season 2 – Complete
- Socio-economic survey of the selected location for season 2 – Partially Complete

Also completed – Visit to Mangrove Crab Aquaculture Pen –Vengurla, Sindhudurg

Training for Oyster Aquaculture from UNDP – Mochemad, Sindhudurg

Timeline – 3 months (Phase I) + 2 months (Phase II)

1.2 Study area Details

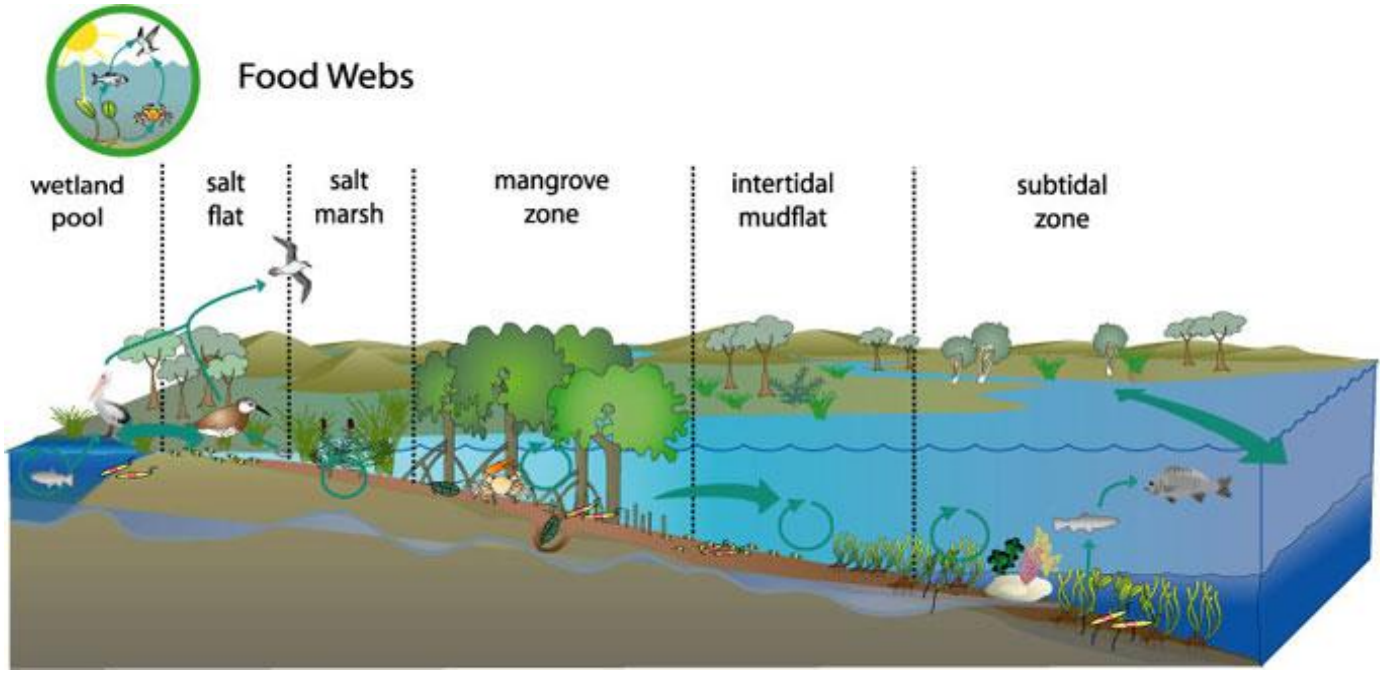
Mangrove crab farming potential in the MMR(Mumbai Metropolitan Region). The MMR extends over an area of 4,355 km^2 covering Mumbai, Thane and part of Raigad districts.

Figure 1: Mumbai Metropolitan Region

1.3 Mangrove Ecosystem: An Introduction

Saline water, freshwater, and land meet at mangrove ecosystems. They are among the most productive and complex ecosystems on the planet.They are absolutely vital for the safety ofcoastal areas. Mangroves are indeed the "protectors of shore-line" as by being present at the land-water interface they act as natural warriers to storms and tsunamis. They, therefore, prevent severe losses to life and property along the estuarine and coastal areas.

In coastal areas, mangroves play a diverse role ashydrophytic trees, vines, ferns shrubs and plants growing in brackish to saline tidal water along the tropical and subtropical coast. Mangroves are native species to tropical and subtropical regions with approximately 70 identified species worldwide. They have ability to grow where no other trees can, thereby making significant contributors that benefit the coastal ecology. India covers about 4,628 sq km areas of Mangroves of which 0.14 % of the country’s total geographical area as per 2013 census.



Mangrove ecosystems represent natural capital capable of producing a wide range of products and resources for coastal environments and their related communities with society as a whole. In these value is determinedby the markets through exchange and quantified in terms of price. Many of the wild species such as Fishes, Shellfishes, Avian, Reptilian, Mammalian and Planktonic diversity are supported by Nusery provided in Mangroves.Also, commercial fish and crustaceansare supported by mangrove ecosystems, sustaining the local abundance of fish and shellfish populations.The coastal water quality is maintained by Mangroves with the help of nutrientretention and cycling, and rhizofiltration of pollutants,preventing their seaward flow.

Mangrove conservation and management cannot be a one-time activity – it has to be a continuous exercise. This, in turn, implies that there must be a continuous financial activity that must be linked with the ecosystem conservation and management activity so that the entire project becomes sustainable.The broad term “aquaculture” refers to the breeding, rearing, and harvesting of animals and plants in all types of water environments including ponds, rivers, lakes, and the ocean.

The species found in brackish water includemangrovecrabs, shrimps, prawns, oysters, mussels, clams, mullet fish, cobia fish etc., which can be aqua-cultured to protect the existing mangroves on one hand and enhance the value of mangroves by enhanced supply of seafood.

One such activity can be the aquaculture of economically significant brackish water fauna. A few positive impacts of aquaculture on biodiversity are:

- cultured seafood can reduce pressure on overexploited wild stocks
- stocked organisms may enhance depleted stocks

Mangrove protection by aqua-culturists is a win-win situation. It is possible to have sustainable aquaculture farms and sustainable mangrove ecosystem in the same vicinity through enlightened management methods and dedication by the aqua-culturists towards environmental stewardship.

Chapter 2

Literature Review

2.1 Literature Review

In Google Scholar, keywords such as ‘sustainable aquaculture,’ ‘mangrove crab aquaculture,’ ‘mud crab aquaculture,’ ‘prawn aquaculture,’ ‘shrimp aquaculture,’ ‘oyster aquaculture,’ ‘mangrove and mangrove crab,’ ‘prawn farming and mangrove,’ ‘shrimp farming and mangrove,’ and ‘oyster aquaculture and mangrove’ were searched for. Relevant publications from peer-reviewed journals were downloaded and analyzed.

In Table 1 below, we have provided a detailed analysis of published literature on the basis of which marine and brackish water species aquaculture is recommended for concurrent mangrove ecosystem maintenance.

Table 1: Literature Review

S.No.	Citation	Major Finding
1.	Alongi, D. M. (2002). Present state and future of the world's mangrove forests. *Environmental conservation*, *29*(03), 331-349.	Estimating benthic biodiversity is very important for prevention of mangrove exploitation from aquaculture
2.	Rönnbäck, P. (1999). The ecological basis for economic value of seafood production supported by mangrove ecosystems. *Ecological Economics*,*29*(2), 235-252.	The life-support functions of mangrove ecosystems set the framework for sustainable aquaculture
3.	Kaloo, F. J., Hood, A., & Obwogi, J. (2015). Financial Effects of Depletion of Mangrove Forest on the Performance of Micro Finance Community Based Organizations-The Case Studyof Wajomvu Community in Kenyan Coast.	Mangrove depletion has strongly negative economic effects; sustainable economic and ecological benefits will come through proper mangrove management
4.	Boyd, C. E., & Clay, J. W. (1998). Shrimp aquaculture and the environment. Scientific American, 278(6), 58-65.	Shrimp farming is responsible for mangrove loss
5.	Primavera, J. H. (2005). Mangroves, fishponds, and the quest for sustainability. *Science*, *310*(5745), 57-59.	
6.	Barraclough, S. L., & Finger-Stich, A. (1996). *Some ecological and social implications of commercial shrimp farming in Asia*. UNRISD.	
7.	Primavera, J. H. (1997). Socio-economic impacts of shrimp culture.*Aquaculture research*, *28*(10), 815-827.	
8.	Martinez-Alier, J. (2001). Ecological conflicts and valuation: mangroves versus shrimps in the late 1990s. *Environment and planning C: Government and Policy*, *19*(5), 713-728.	
9.	Gujja, B., & Finger-Stich, A. (1996). What Price Prawn?: Shrimp Aquaculture's Impact in Asia. *Environment: Science and Policy for Sustainable Development*, *38*(7), 12-39.	
10.	Gunawardena, M., & Rowan, J. S. (2005). Economic valuation of a mangrove ecosystem threatened by shrimp aquaculture in Sri Lanka.*Environmental Management*, *36*(4), 535-550.	

Table 2: Contd.

S.No.	Citation	Major Finding
11.	Stokstad, E. (2010). Down on the shrimp farm. *Science*, *328*(5985), 1504-1505.	Acid sulphate soils in mangroves reduces shrimp yields
12.	Johnston, Danielle, et al. "Shrimp yields and harvest characteristics of mixed shrimp–mangrove forestry farms in southern Vietnam: factors affecting production." *Aquaculture* 188.3 (2000): 263-284.	
13.	Primavera, J. H., Binas, J. B., Samonte-Tan, G. P., Lebata, M. J. J., Alava, V. R., Walton, M., & LeVay, L. (2010). Mud crab pen culture: replacement of fish feed requirement and impacts on mangrove community structure.*Aquaculture Research*, *41*(8), 1211-1220.	Mangrove Crab aquaculture in pens minimizes negative impact on mangrove ecosystem
14.	Mwaluma, J. (2002). Pen culture of the mud crab Scylla serrata in Mtwapa mangrove system, Kenya. *Western Indian Ocean Journal of Marine Science*,*1*(2), 127-133.	
15.	Triño, Avelino T., and Eduard M. Rodriguez. "Pen culture of mud crab Scylla serrata in tidal flats reforested with mangrove trees." *Aquaculture* 211.1 (2002): 125-134.	Aquasilviculture of mangroves and mangrove crabs is economically and environmentally feasible
16.	Bagarinao, T. U., & Primavera, J. H. (2005). Code of practice for sustainable use of mangrove ecosystems for. *Ecosystems*, *9*, 1-4.	Mangrove Crab fattening or grow-out in pens, polyculture with fish, and oyster rafts are advisable within mangroves. Seaweed longlines also do not harm the mangrove ecosystem. This study also highlights that mangrove ecosystems are harmed by shrimp farming

Hence, from the literature review, it emerges that **<u>prawn and shrimp aquaculture have not been recommended</u>** for mangrove ecosystem – mangrove crab and oyster culture have been advised through pen and raft culture methods, respectively.

It must be noted here that **<u>a supreme court order has forbidden setting up of prawn and shrimp aquaculture</u>** farms in and around the mangroves because of their negative impact on the mangrove ecosystem. We have incorporated this report as **Annexure I**.

During our recent discussion with other mangrove crab aquaculturists, the following issues were raised against mangrove crab aquaculture –

a. Year-on-year purchase of crablings from RGCA is a cost burden, and there is loss of crablets' lives during the transport. Hence, efforts should be taken to ensure maximum survival of crablets by reducing the transportation time, perhaps through the setting up of a regional breeding center, if feasible.

b. The feed given to the mangrove crab is not exactly trash fish, but actual trawler fishing may be carried out for this purpose – this is environmentally unsustainable. To combat this, strong awareness drives on negative environmental impacts, and research on low-cost alternatives will be given high priority.

2.2 Key species - Mangrove crabs

Crabs requiring mangrove for the completion of their life cycles and exist among mangroves, and are ecologically significant in several ways.

As for this project, we had considered Mangrove Crab/Mangrove Crab/Black crab (*Scylla serrata*) because of its commercial importance and high association with Mangroves. To take out commercial output from *Scylla serrata* one has conserve mangrove first.

The species of our interest is *Scylla serrata* commonly called as Mud Crab/ Mangrove Crab/ Black Crab is spread across Africa, Asia and Australia, and are of economicn importance.Shell colour can vary from deep, mottled green to very dark black brown. In aquaculture, this species is of high demand and price, high flesh content, and rapid growth. Also they can tolerate high levels of nitrite and ammonia. They play crucial role as an most limiting factor in closed aquaculture systems.

Life Cycle Details

Mangrovecrabs (*Scylla serrata*) are economically significant seafood species that essentially require mangrove and estuarine ecosystems for survival (**Figures 2**).

Figure 3: Mangrove Crab (*Scylla serrata*)

Details of the mangrove crab life cycle have been depicted in **Figure 4**.

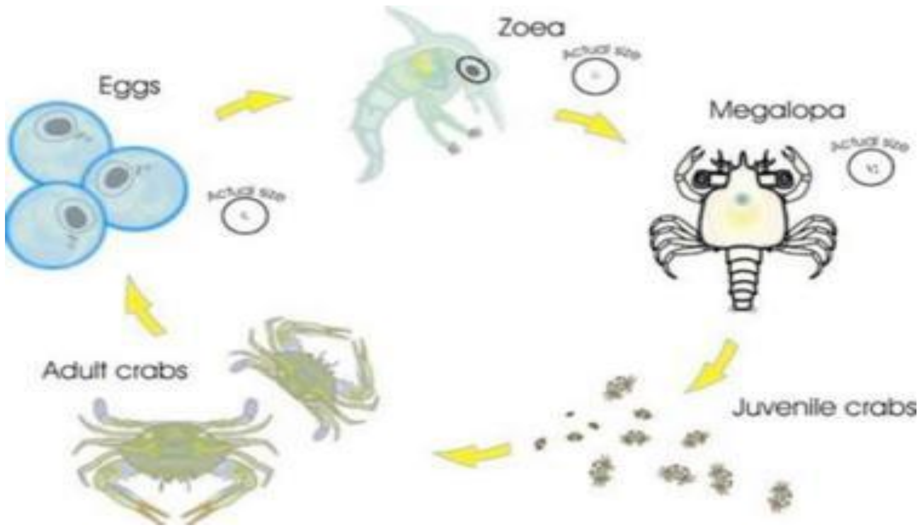


Figure 4: Mangrove Crab Life Cycle

Compared to Prawn and Shrimp, Mangrove crabs are steadierwith climatic changes and physico-chemical parameters. In Prawns and Shrimps very high stocking densities require high control over pond/tank management practices and are high-risk strategies, Growth rate is also slow. Also,prawns and shrimps have less resistance power towards diseases and viral infections compared to mangrove crabs.

In a clear example of over-harvesting damaging environmental as well as economic interests, aquaculture returns have either levelled off or actually declined in the Philippines.(Garcia 2000. Indonesia's mangrove-destructive tambak farming is of particular concern as the communities surrounding this area depend on the many ecosystem services provided by mangroves. Indonesian Governmenthas been attempting to stop tambak farming and restore the Tanjung Panjang's mangrovesbut it continues to be a challenge(Corbin, J., 2013). Brackish water pond culture has been a major factor in mangrove loss in Southeast Asia, and hence, it is necessary to support eco-friendly technologies likemangrove crab *Scylla serrata* culture in mangrove pens are required (Jurgenne 2009).The species of Mangrove crabs is strongly associated to mangrove, there is no harm in saying that Mangrove crabs are bio-indicators of healthy mangrove ecosystems. Aquaculture of mangrove crabs will indirectly support conservation strategy of mangroves.

Mangrove crabs can be a potential financially profitable source of export and earning foreign exchange, as perthe Marine Products Export Development Authority (MPEDA), which has already initiatedmangrove crab aquacuturein the Sindhudurg district in Maharasthra involving local fishermen.

Mangrove crabs, raised in mangroves along the coast, have a good demand in Japan, Thailand, China and other countries.

An adult mangrove crab weighs around a kg and fetches around INR 300 to 400 in local markets. Male crabsare larger than female ones.In countries abroad, the costcan be aroundINR 1,000 and above in the international market.

Figure 6: Mangrove Crab Aquaculture Pen

2.3 Oyster Aquaculture

Oysters are highly esteemed seafood and considered a delicacy in the USA, Europe, Japan and elsewhere. Even in India, demand for oyster is on the rise. It is one of the most widely and traditionally cultivated species worldwide. Even in the 1st Century BC, the Romans developed simple methods of collecting oyster seeds and growing them for food. The Japanese developed ‘Habitat culture technique,’ i.e., culture in nets fixed to bamboo poles during the 17th century, and at the turn of the 20th century they evolved off-bottom culture, especially hanging methods.

Oysters are filter feeders, hence they puify water. Also, they help remove nitrogen by accelerating denitrification. In addition, they improve water clarity.Oysters naturally grow in brackish water. Three methods of oyster cultivation are commonly used. In each case, oysters are cultivated to the size of "spat," which is the point in their life cycle at which they attach themselves to a substrate. The substrate is known as a "cultch" (Myer 1948).

Oyster aquaculture can become a financially beneficial project, especially when undertaken by women, yielding up to INR 32000 per annum. Currently, oysters are being sold at INR 2-5/piece. Also, as per CMFRI, there is relatively higher demand than supply for oysters.

Shape, size, color and other shell characteristics, anatomical features and breeding habits are the criteria on which oyster classification is based. *Crassostrea madrasensis* isthe chief species recorded in India. It tolerates a wide variation in salinity and inhabits backwaters, creeks, bays and lagoons and occurs from the intertidal region up to 17m depth. Other cultured species are *Crassostrea gryphoides, Crassostrea rivularis,* and *Saccostrea cucullata.*

Food and Feeding Habits

The food consists of organic detritus and phytoplankton such as diatoms and nanoplankton. The food particles are entrapped in the mucus of the gills and are passed in the water currents towards the mouth by the rapid beating gill cilia (fine hairs). The four labial palps sort the food before it enters the mouth. The unwanted food particles are rejected as pseudofeces.

Reproduction

In the genus *Crassostrea*sexes are separate, with external fertlization. Temperature, food availability and salinity are important factorsaffecting gonad maturation. An adult female of size 80-90mm can produce 10 to 15 million eggs at a time.

Farming Methods

<u>Rack Method</u>

It is also called the Ren Method. Racks can be 1-2.5m deep and come in several variations. For instance, the single beam rack has posts driven into the estuary bottom, across the tops of which a beam has been attached. Another variant is the crossbeam rack which consists of a cross bar placed atop single posts and two long beams attached to the ends of the cross beams.

Figure 7: Oyster Aquaculture - Setting up the Ren

Figure 8: Local Ratnagiri Women Displaying Harvested Oysters

Farm Management

It is vital that the farm is monitored at regular intervals, especially the ren structure, high mortality rates can occur if the rens fall down.Also, crabs, fishes, starfishes, polychaetes and gastropods are the predators of oysters while barnacles are the foulers that compete for the food with the oysters.

Post Harvest Processes

Depuration

Oysters being filter feeders tend to accumulate microorganisms in their body. Of particular concern are the common pathogenic species like *Vibrio, Salmonella* and *Escherichia*. Through the process of depuration, the oysters are cleansed off the pollutant load they may be carrying. For this, oysters are kept under clean flowing seawater for 24 hours so that their contaminants are expelled. At the end, the oysters are kept in 3 ppm chlorinated seawater for an hour, and then rinsed again in filtered seawater before transport/storage/direct marketing.

Transport and Storage

Oyster kept under moist and cool conditions can survive for many days, though it is best they reach the consumer within 1-3 days.Wet gunny bags are suitable for oyster transport.

Figure 9: Oyster Aquaculture - Local Sindhudurg Women at Work

The principles by Global Aquaculture Alliance (GAA) mangrove code are:

1] Construction of new farms or expansion of existing farms should not alter the mangrove ecosystem.

2] The farms should be operated in such a manner to prevent damage to mangrove

3] A monitoring program should be in place to verify mangroves are not damaged, but are rather conserved.

4] The abandoned farms, if any, should be replanted by mangroves.

http://gaalliance.org/

Chapter 3

Methods

3.1 Biodiversity

A. Biotic diversity (Flora and Faunna) were studied.Various types of flora and fauna studies were made during monitoring the place. Amongst flora, Mangrove diversity was studied with the help of line transects and quadrant method with Associate plants, Trees, Shurbs, Climbers and Grasses nearby in the vicinity of the area.

(A) The Faunal studied were made by various sub methods.The Sampling of Phytoplankton, Zooplankton and Benthic organisms were collected(A,B.C).

- *Sediment Sampling for Benthic Invertebrates*:- A plastic scoop was used to sample the benthic invertebrates using USEPA protocol (LG406). Briefly, the sediment sample scooped out from a 1 sq m area was mixed with water till a slurry-like consistency was achieved. This was followed by sample concentration, i.e., filtration through a 500µm mesh. The residue was fixed with 4% (v/v) formalin (final volume of formalin 5-10% v/v of sample). For identification, the fixed benthic organisms were viewed under the 20X lens of a stereo microscope.

- *Sampling for Phytoplankton*:- It has been demonstrated that wide-mouthed, bottle-type samplers are more efficient for phytoplankton sampling (Kuparinen et al. 2009). Hence, instead of a rosette sampler, a large bottle type sampler was used; rest of the sampling protocol was as per USEPA LG400. Briefly, samples were collected till the euphotic depth, which can be defined as the depth to which photosynthesisoccurs in an aquatic ecosystem. A Secchi disk was used to calculate the euphotic depth. The limit of visibility is approximately the region of transmission of 5% sunlight (Reid, 1961). The euphotic zone is usually three times the Secchi Disk depth (Welch, 1948). Samples were mixed and preserved with Lugol's iodine (final concentration 1% v/v) and viewed under the 40X lens in a compound microscope.

- *Sampling for Zooplankton*:- Zooplankton was sampled, concentrated and stained as per NIO Field Manual (2004), using a zooplankton net (75µm). The net was dipped slowly in water and raised. It was rinsed thoroughly and the sample was concentrated. It was fixed first with 4-5% formalin (1 part formalin and 9 parts sample). Few drops of Rose Bengal solution was used for sample staining. Zooplankton were viewed under a 20X lens in a stereo microscope.

- *Avian diversity, Mammals and Herpetofunal diversity* with other Macro faunal diversity were carried out by the Visual Encounter Method.

3.2 Water Sampling and Analysis

The parameters measured and the significance of each has been described in Table 2:

Table 2: Water Quality Parameters

Sr. No.	Water Quality Parameter	Significance	Measurement Method
1	Temperature	Temperature is a very significant water quality parameter with profound impacts on other water quality parameters and, most importantly, aquatic life. Fish are rather sensitive to water temperature and a change of even 1-3 degrees C in water temperature can disrupt their pattern. Temperature of water is affected strongly by the color of water, temperature of effluents entering the water body, depth of water and amount of shade provided by nearby vegetation.	Field thermometer
2	pH	The pH scale varies from 0-7, with neutral solutions having balanced concentration of H^+ and OH^- ions.	pH strips; Hand-held meter
3	Dissolved Oxygen	Dissolved oxygen (DO) is oxygen that is dissolved in water.It comes into water through photosynthesis of aquatic plants and algae and also through natural or artifical tumbling/mixing of water.If water is too warm, there may not be enough oxygen in it. Oxygen levels can also be reduced through agricultural run-off rich in nitrates and phosphates.	Chemical titration; Hand-held meter
4	Salinity	Salinity is the saltiness or dissolved salt content of a body of water. It is an important parameter affecting the biological processes within water. Importantly, it helps decide the mangrove species that will exist along a brackish water body.	Hand-held meter
5	Alkalinity	Alkalinity is a total measure of the substances in water that have "acid-neutralizing" ability. Alkalinity is important for fish and aquatic life because it protects or buffers against pH changes. The main sources of natural alkalinity are rocks, rich in carbonate, bicarbonate, and hydroxide compounds. Borates, silicates, and phosphates also contribute to alkalinity.	Chemical titration

Table 2 Contd.

6	Total Suspended Solids	The most frequent causes of high TSS are plankton and soil erosion from logging, mining, and dredging operations and also the inputs from sewage and industrial operations. Large amounts of suspended matter may clog the gills of fish and kill them directly.	Gravimetry
7	Chloride	Chloride, in the form of the Cl– ion, is one of the major inorganic anions. Dissociation of saltslike NaCl and $CaCl_2$, and is an important parameter in tidally-influenced water bodies.	Chemical titration
8	Calcium-Magnesium Hardness	Hardness is a measure of the quantity of divalent ions (usually Ca^{2+} and Mg^{2+})	Chemical titration
9	Heavy MetalsCu, Ni, Cd, Zn, Hg, Cr, Fe, Pb, Mn, Al, Co, Ba		Atomic Absorption Spectrophotometry

For social survey, we followed the method of convenience sampling, which as the name suggests consists of interviewing/surveying easy-to-reach people. It is a non-probability sampling method (Farrokhi and Mahmoudi-Hamidabad, 2012). It is highly suitable for our particular case considering that our target population is not readily available for questioning and the entire nature of the exercise depended on the voluntary nature of the interviewee. We accompanied convenience sampling with observations of the site.

3.3 Sites Visited

The details of the sites visited have been provided below in Figures 9-10(a-m).

Figure 9: Sites Visited in the MMR

Figure 10a: Dombivali

Figure 10b: Thane (beyond the railway station, Thane east)

Figure 10 c: Bhandup (near the pumping station)

Figure 10d: Vasai (near the jetty)

Figure 10e: Gorai (near Gorai jetty)

Figure 10f: Uttan

Figure 10g: Bandra (near Sion-Bandra link road)

Figure 10h: Diva Airoli

Figure 10i: Vashi (near Mr. Subhash Sutar's residence)

Figure 10j: Ghansoli (near the jetty, Sector 15)

Figure 10k: Mankhurd

Figure 10l: Uran

Figure 10m: Alibaug (near Revas jetty)

Chapter 4

Results, Discussion and Conclusion

4.1 Biodiversity

Table 3: Mangrove Species Richness

Locations	Species				
	Avicennia marina	*Avicennia officinalis*	*Sonneratia alba*	*Acanthus ilicifolius*	*Salvadora persica*
Gorai	Y	Y	Y	Y	Y
Uttan	Y			Y	Y
Vasai	Y		Y	Y	
Thane	Y		Y	Y	Y
Bhandup	Y		Y	Y	Y
Ghansoli	Y		Y	Y	Y
Mankhurd	Y		Y	Y	Y
Alibaug	Y	Y	Y	Y	Y
Uran	Y	Y			
Dombivali	Y	Y	Y	Y	Y

From species richness point of view, Gorai, Alibaug and Dombivali showed the presence of 5 mangrove species. Thane, Bhandup, Ghansoli, and Mankhurd had 4 species while Uttan and Vasai showed the presence of 3 species. Uran had only 2 species.

The avian species richness table has been appended as Supplementary Table 1. The sites of Bhandup, Alibaug and Vasai showed the highest avian species richness with 64, 55 and 54 species sighted. Mankhurd and Uttan had the lowest count with 11 and 15 species only. In Uran, Thane and Dombivali, 49, 47 and 42 bird species were sighted.

In the second season (monsoon), relatively fewer birds (32 species) were sighted. Alibag and Bhandup had the highest sighting (20 and 19 each) while Mankhurd and Uttan had the lowest (4 each).

The phytoplankton, zooplankton and benthic diversity has been provided in Supplementary Tables 2, 3 and 4. The sites of Alibaug, Uran, Bhandup and Diva Airoli largest number of phytoplankton species were reported, while Gorai, Dombivali and Uttan had the lowest species richness. *Skeletonema*, *Oscillatoria* and *Nitzschia* were the most common species.56 phytoplankton species were observed

In terms of zooplankton as well, Alibaug, Uran and Vasai showed high diversity while Dombivali and Gorai showed poor diversity. Benthic diversity was also high in Uran and Alibaug.

Good correlation was observed between phytoplankton diversity and water quality, as may be observed from the table below:

Station	**Indicator**
Dombivali	Presence of *Nitzchia* indicate polluted water
Thane	Presence of *Nitzchia & Euglena* (pollution indicator)as well as *Synedra & Pinnularia* (indicators of clean water)indicates slightly polluted waters
Bhandup	Presence of *Nitzchia (*pollution indicator)as well as *Synedra* (indicators of clean water)indicates slightly polluted waters
Airoli	Presence of *Nitzchia & Euglena* indicate polluted waters ; co-presence of *Synedra & Cyclotella* indicates slightly polluted waters
Ghansoli	Presence of *Oscillatoria, Thalassiosira* indicate organic pollution
Mankhurd	Presence of *Nitzchia* indicates polluted waters
Vashi	Presence of *Nitzchia* indicates polluted waters
Vasai	Presence of *Ankistrodesmus* &*Navicula* indicate clean water
Gorai	Presence of *Nitzchia* indicates polluted waters
Uttan	Presence of *Nitzchia* indicates polluted waters
Uran	Presence of *Nitzchia* indicates polluted waters
Alibaug	Presence of *Navicula* indicates clean water

N.B. The detailed references of phytoplankton as indicators has been provided in Supplementary Tables 16

4.2 Water Quality

Table 4a: Water Quality Parameters – Season I (Post-monsoon, Dec 2015-Jan 2016)

SITES	Color & Odor	pH	D.O. (mg/L)	Salinity (g/L)	Hardness (mg/L)	Alkalinity (mg/L)	Suspended Solids (mg/L)	Oil & Grease (mg/L)	Floating Matter
Ghansoli	**ND**	**7.7**	**5.1**	11	7272	40	13	ND	ND
Bhandup	**ND**	**7.5**	**6**	18	10909	48	20	ND	ND
Airoli Diva	**ND**	**7.2**	**6**	21	6363	60	14	ND	ND
Vashi	ND	7.9	3.1	23	7000	40	35	ND	ND
Mankhurd	ND	7.1	4	11	7000	30	15	ND	ND
Thane	ND	7.8	4	17	6800	44	20	ND	ND
Vasai	ND	8.1	4	15	7300	48	20	ND	ND
Gorai	ND	8	0.4	13	11000	44	21	ND	ND
Uttan	ND	7.9	2.4	12	12500	44	17	ND	ND
Uran	ND	7.8	4	23	10000	44	20	ND	ND
Alibag	ND	7.5	4	21	11000	40	11	ND	ND
Dombivali	ND	7.1	1.6	21	4000	40	18	ND	ND
MPCB Coastal Water Standards (SW I)	No noticeable color or offensive odor	6.5-8.5	5mg/L				None from sewage or industrial waste origin	0.1 mg/L	Nothing obnoxious or detrimental for use purpose
Mud Crab Aquaculture - A Practical Manual		7.5-9.0	>5mg/L	10-25g/L	>2000mg/L	>80mg/L			

Table 4b: Water Quality Parameters – Season II (Monsoon, Aug 2016-Sept 2016)

SITES	Color & Odor	pH	D.O. (mg/L)	Salinity (g/L)	Hardness (mg/L)	Alkalinity (mg/L)	Suspended Solids (mg/L)	Oil & Grease (mg/L)	Floating Matter
Ghansoli	**ND**	**7.2**	**4.4**	8	5000	40	35	ND	ND
Bhandup	**ND**	**7.3**	**5.4**	12	8600	38	30	ND	ND
Airoli Diva	**ND**	**7.1**	**5**	14	5400	50	20	ND	ND
Vashi	ND	7.1	4.3	12	5600	30	50	ND	ND
Mankhurd	ND	7.2	3.2	6	6200	30	25	ND	ND
Thane	ND	7	4.4	11	5780	50	39	ND	ND
Vasai	ND	7.3	4.1	12	6555	50	35	ND	ND
Gorai	ND	7.4	1.0	7	8000	45	45	ND	ND
Uttan	ND	7.3	3.4	6	8000	50	29	ND	ND
Uran	ND	7.3	5	12	7000	50	40	ND	ND
Alibag	ND	7	3	11	8000	50	25	ND	ND
Dombivali	ND	7.2	2.5	11	7000	45	41	ND	ND
MPCB Coastal Water Standards (SW I)	No noticeable color or offensive odor	6.5-8.5	5mg/L				None from sewage or industrial waste origin	0.1 mg/L	Nothing obnoxious or detrimental for use purpose
Mud Crab Aquaculture - A Practical Manual		7.5-9.0	>5mg/L	10-25g/L	>2000mg/L	>80mg/L			

Table 5: Heavy Metal in Water

Location/Heavy Metal	Cd	Cr	Cu	Fe	Mn
Uran	ND	**ND**	0.0797	3.6943	0.4549
Alibag (Rewas)	ND	**ND**	0.0713	1.7996	ND
Ghansoli	ND	**ND**	0.0506	1.5490	ND
Mankhurd	ND	**ND**	0.0757	1.9039	ND
Thane	ND	**ND**	0.0567	2.5986	ND
Saatpul (Dombivali)	ND	**ND**	0.0545	3.6562	ND
Gorai	ND	**ND**	0.0640	4.1164	ND
Vasai	ND	**ND**	0.0372	0.3480	ND
Uttan	ND	**ND**	0.0422	1.4698	ND
LIMITS **MPCB Coastal Water Standards (SW I)**	0.1mg/L				
Govindasamy and Azariah (1999)			0.092-0.240 mg/l		
Armstrong (1957)				Up to 3mg/L	

**All units in ppm*

As evident from the Tables above, heavy metals were either not detected, or were not present in significant quantities.

Water quality was within the range, in both the seasons, as far as the pH was concerned, but Dissolved Oxygen was low in all sites except Ghansoli, Bhandup, Alibaug and Uran. Hardness of each site was as required by the mangrove crab, though alkalinity was low in all the sites.

4.3 Sediment Quality

Table 6: Heavy Metal in Sediment

Location/Heavy Metal	As	Cd	Cr	Cu	Fe	Hg	Mn	Pb	V	Zn
Uran	ND	ND	94.0	8.04	65783.0	ND	915.0	ND	93.0	69.0
Alibag	0.25	ND	80.00	103.0	67298.0	ND	878.38	3.12	130.0	74.0
Ghansoli	ND	ND	111.00	**128.25**	82597.0	ND	1510.0	4.0	97.0	149.25
Mankhurd	1.83	0.41	50.02*	47.19	18765.4	ND	600.71	5.38	46.43	54.47
Thane	2.23	0.57	65.14	59.46	16824.1	ND	384.31	5.99	53.0	79.90
Dombivali	0.82	0.33	48.39*	40.24	20708.5	ND	285.14	4.61	39.73	54.08
Gorai	3.40	0.43	62.04	62.10	16950.2	ND	449.38	11.86	51.82	66.99
Vasai	6.83	0.52	45.62*	86.04	16883.3	ND	435.35	13.97	63.5	98.94
Uttan	3.21	0.47	60.86	51.10	17760.4	ND	537.33	4.61	61.95	57.68
LIMITS Canadian Sediment Quality Guidelines (for marine)	7.24-41.6	0.7-4.2	52.3-160.0	18.7-108.0		0.13-0.07		30.2-112.0		124.0-271.0

All Units in ppm

Compared to the Canadian Sediment Quality Guidelines, all heavy metals (except Fe, Mn and V for which no standards were found), all the MMR sites were safe but for Ghansoli, that showed higher content of Copper.

4.4 Social Interaction

Table 7: Social Interaction

Sites	Social Interaction	Contact
Ghansoli	Dilip Patil	9867906464
Bhandup pumping station	Koli samaj members	
Airoli Diva	Police	
Vashi	Subhash Sutar	9322737670
Mankhurd	Koli samaj members	
Thane	Kubal Sir	
Bhandup	Mr Stalin Vanshakti	7303293087
Vasai	Jayram Phatak	9322195381
Gorai	Koli samaj members	
Uttan	Saltpan worker	
Uran	Awra koli samaj members	
Alibaug	Mr. Patil	
Dombivali	Koli samaj members	

Figure 11: Social Interaction at Uttan

The very basics of social interaction were carried out. While in many sites, the locals interacted with did not share their contact numbers and name, in a few cases, the contacted lead appeared interested enough to do so. At the Diva Airoli site, we could not interact with locals.

In the second phase of the study, the social interaction was taken to a higher scale at the following locations:

- Alibaug
- Ghansoli
- Vasai
- Gorai – Gorai Machhimar Sanstha
- Thane

Herein, we held meetings with the members of the local *koli samaj/machhimar sanstha* etc., except in the case of Alibaug where we could not find a formal association but a loose cluster of 11 families. We approached each association with a questionnaire, and ended up having a focus group study with their representatives. The questionnaire inquired of them

a. their current mangrove crab harvesting practices,
b. the threats they were perceiving to the mangrove ecosystem around them
c. their current levels of ecological literacy
d. their willingness to attend our awareness sessions
e. their willingness to keep the mangroves safe and clean

The unfilled questionnaire has been appended as **Annexure II**. Basic demographic data was obtained from the Central Marine Fishery Research Institute (CMFRI), Mumbai Research Centre, who conduct year-on-year socio-economic survey of the local fishermen communities as part of their routine studies. **Annexure III** includes the entire publication.

In Table 8 below, details of the interaction have been provided:

Table 8: Details of the Second Round of Socio-economic Studies

Site	Name of Organization	Contact Person/Details	Remarks
Ghansoli	Mariaayi Machhimar Sahakari Sanstha (has 13 villages' – Ghansoli-Vashi – fishermen as members)	Dilip Patil/9867906464 Mr. Harish Rajaram Sutar (Head)	Extremely willing to getting trained/voluntarily shared information of threats of sewage discharge in their waters and complained of reducing fish catch/ecological literacy high/willing to take up cleanliness and safety of the mangroves
Thane	No organization; residents of a local	Unwilling to share name/number	They do not harvest mangrove crab and are not interested in learning the rearing of the

	housing society of *kolis* that they were unwilling to reveal the name of		same
Gorai	Sagardip Fishermen Society	Manori Peter/9930152528	Unwilling to work with mangrove crabs, as they had once attempted it before (privately) and failed. Not very co-operative
Vasai	Versova Fishermen Society	Dilip Mathak /9765590858 and 9168067171	Willing to be trained; willing to take care of mangroves; ecological literacy average
Alibaug	No organization; a loose cluster of 11 families	Vishwas Shantaram Mhatre/8698453148 Prahlad Patil/8554871346 Shantaram Mhatre/8888342001	Willing to be trained; willing to take care of mangroves; ecological literacy good

Figure 12: Second-level interaction at Ghansoli

Figure 13: Second-level interaction at Alibaug

We are planning to hold awareness sessions with fishermen of Vasai, Ghansoli and Alibaug to gain further insights into the social structure as well as making our objectives and activities clearer to the villagers. The awareness session materials (sourced from MPEDA and the Mangrove cell) have been provided as **Annexure IV**.

4.5 Discussion: Most Suitable Site Rating System

In the present study, we have attempted to create a simple Yes/No 0/1 type binary rating system based on locally relevant parameters.5 Factors were selected – Mangroves Under Threat, Biodiversity, Social Acceptance, Proximity to Source of Pollution and Physical & Legal Feasibility. Under each factor, 4 variables were named. The same have been defined in **Table 9**.

Table 9: Site Rating Scale

Mangrove Under Threat*	Biodiversity	Social Acceptance	Proximity to Source of Pollution	Physical and Legal Feasibility
Open defecation	*Richness of mangrove diversity*	*Willingness to get trained by us*	*Presence of industry/slum/both/any other pollution source*	*Government Permissions*
Over harvesting	*Richness of crab/oyster diversity*	*Willingness to protect mangroves*	*Water quality*	*Accessibility by road/boat*
Criminal activities like corpse disposal/illegal brewing/sand mining	*Richness of aquatic diversity (fish, aquatic birds, phytoplankton, benthos & zooplankton)*	*Annual income of target group*	*Sediment quality*	*Proximity to market*
Cutting of trees	*Richness of Bird Biodiversity in entire mangrove patch*	*Education level of target group*	*Solid waste content*	*Density of mangroves*

The fundamentals of formulating the factors and variables have been derived from the work of Buitrago et al. (2005).

4.6 Conclusions and Future Outlook

Based on the above discussion, the sites of Alibaug and Goraiwere selected for further establishment of the mangrove crab and oyster aquaculture.

The arguments in the favor of Alibaug –

- Conducive social atmosphere
- Healthy biodiversity
- Good water and sediment quality
- Easy accessibility (through ferry route) with Mumbai

The arguments in the favor of Gorai –

- Fair to medium biodiversity
- Poor water and sediment quality – an attribute that requires further investigation of sources and their control
- Easy accessibility
- Perceived threats to the ecosystem, which need to be ascertained

Challenges in Gorai –

We need to conduct awareness workshops with the Gorai target group so as to make them more conducive to the idea.

In the second phase of this project, we have the following objectives:

1. Holding at least two workshops (and more, if deemed necessary) with the target groups identified in Phase I
2. Crab meat quality testing from the two target areas
3. Obtaining relevant permissions
4. Getting the target group fishermen trained with the co-operation of MPEDA
5. Setting up the mangrove crab aquaculture pen and initiation of operations
6. Hand-holding and trouble-shooting help till one harvest has been made

Supplementary Tables

Table No	Table Title
1	Avian Species Richness
2	Phytoplankton
3	Zooplankton
4	Benthic Organisms
5	Site Rating Scale: Dombivali
6	Site Rating Scale:Thane
7	Site Rating Scale:Bhandup
8	Site Rating Scale: Diva Gaothan (Airoli)
9	Site Rating Scale: Ghansoli
10	Site Rating Scale: Mankhurd
11	Site Rating Scale: Vasai
12	Site Rating Scale: Gorai
13	Site Rating Scale: Uttan
14	Site Rating Scale: Uran
15	Site Rating Scale: Alibaug
16	References of phytoplantons as indicators
17	Secondary data
18	Secondary data on water quality of MMR region

Supplementary Table 1: Avian Species Richness (Black ticks indicate Winter report; red ticks indicate Monsoon report)

Sr no.	Avian species	Dombivali	Thane	Bhandup	Airoli	Ghansoli	Mankhurd	Vasai	Gorai	Uttan	Uran	Alibaug
1	Osprey											✔
2	Black kite	✔ ✔ (red)	✔ ✔ (red)	✔	✔ ✔ (red)	✔ ✔ (red)	✔	✔ ✔ (red)	✔ (red)	✔ (red)	✔ (red)	✔ ✔ (red)
3	Oriental honey buzzard										✔	✔
4	Brahminy Kite	✔	✔	✔ ✔ (red)	✔ (red)			✔	✔		✔	✔
5	Eurasian Marsh Harrier	✔		✔ ✔ (red)		✔ (red)		✔ ✔ (red)	✔ (red)		✔	✔
6	White bellied sea eagle										✔	✔ ✔ (red)
7	Greater spotted eagle										✔	✔ (red)
8	Shikra	✔ (red)		✔ ✔ (red)	✔ (red)		✔ (red)		✔ (red)			
9	Cattle egret	✔ ✔ (red)	✔ ✔ (red)	✔ ✔ (red)	✔ ✔ (red)	✔ ✔ (red)	✔ ✔ (red)	✔ ✔ (red)	✔ ✔ (red)	✔ ✔ (red)	✔ ✔ (red)	✔ ✔ (red)
10	Greater egret		✔	✔		✔	✔		✔			✔
11	Little egret				✔	✔					✔	
12	Western reef Egret		✔	✔				✔	✔		✔	
13	Intermediate egret	✔			✔			✔				
14	Grey heron			✔				✔	✔	✔		✔
15	Purple heron			✔		✔		✔				✔ ✔ (red)
16	Indian pond heron	✔ ✔ (red)	✔ ✔ (red)	✔ ✔ (red)	✔ (red)	✔ ✔ (red)		✔ ✔ (red)	✔ ✔ (red)	✔	✔	✔
17	Little heron	✔		✔		✔ ✔ (red)		✔				✔
18	Black Crowned Night Heron			✔	✔ (red)						✔	
19	Greater Flamingo			✔	✔			✔				
20	Lesser Flamingo		✔		✔				✔		✔	✔
21	Little Cormorant	✔	✔	✔ ✔ (red)				✔			✔ (red)	✔
22	Indian Cormorant				✔			✔			✔	✔ (red)
23	Glossy Ibis			✔						✔		
24	Oriental white ibis	✔	✔	✔				✔		✔		✔
25	Eurasian spoonbill											✔
26	Painted Stork	✔		✔								
27	Asian openbill stork	✔		✔				✔				
28	Woolly Neck Stork			✔								
29	Rosy Starling	✔	✔	✔				✔		✔		✔

Supplementary Table 1 Contd.

Sr no.	Avian species	Dombivali	Thane	Bhandup	Airoli	Ghansoli	Mankhurd	Vasai	Gorai	Uttan	Uran	Alibaug
30	Asian Pied starling	✔	✔	✔		✔		✔				✔
31	Common Myna	✔✔	✔	✔	✔	✔	✔		✔		✔	✔✔
32	Brahminy Starling		✔	✔		✔					✔	
33	Dusky Martine			✔	✔	✔					✔	
34	Barn Swallow		✔			✔						
35	Wire Tailed Swallow	✔	✔	✔			✔					✔✔
36	Red Rumped swallow			✔✔		✔		✔			✔	
37	Red Whiskered Bulbul	✔	✔	✔		✔		✔		✔	✔	✔
38	Red Vented Bulbul	✔		✔	✔✔			✔	✔			✔✔
39	White Eared Bulbul	✔	✔✔	✔		✔		✔			✔	✔✔
40	Gray Wagtail			✔				✔	✔			✔
41	Citrine Wagtail	✔	✔					✔	✔	✔	✔	
42	Yellow Wagtail		✔	✔							✔	✔✔
43	Paddyfield Pipit	✔	✔	✔		✔		✔	✔	✔	✔	
44	Baya Weaver			✔✔					✔		✔	✔
46	House Sparow	✔✔	✔	✔✔	✔		✔	✔		✔	✔✔	✔✔
48	Scaly Breasted Munia		✔	✔✔					✔		✔	
49	Red Avadavat			✔								
50	Ashy Prinia	✔✔	✔	✔✔	✔			✔	✔		✔	✔
51	Plain Prinia		✔	✔							✔	
52	Blyth's Reed Warbler		✔	✔								✔
53	Clamorous Reed Warbler			✔								
54	Common Tailor Bird	✔✔	✔	✔✔				✔	✔	✔	✔	✔✔
55	Crimson-backed sunbird											✔
56	Purple rumped sunbird			✔				✔				✔

Supplementary Table 1 Contd.

Sr no.	Avian species	Dombivali	Thane	Bhandup	Airoli	Ghansoli	Mankhurd	Vasai	Gorai	Uttan	Uran	Alibaug
57	Purple Sunbird			✔							✔	
58	Lesser Whistling Duck	✔	✔	✔				✔			✔	✔
59	Garganey	✔		✔							✔	✔
60	Copper Smith Barbet	✔	✔	✔				✔				✔
61	Common Hoopoe		✔					✔			✔	✔
62	Indian Roller	✔						✔✔			✔	✔
63	Common Kingfisher	✔	✔	✔	✔	✔		✔	✔		✔	✔
64	White Breasted Kingfisher	✔	✔✔	✔				✔✔	✔		✔	✔
65	Green Bea Eater			✔				✔			✔	
66	Blue Tailed Bee Eater	✔	✔					✔				
67	Common Hawk Cuckoo		✔								✔	✔
68	Asian Koel	✔	✔					✔			✔	
69	Greater Coucal	✔	✔	✔				✔			✔	
70	Alexandrine Parakeet		✔	✔				✔	✔		✔	✔✔
71	Rose Ringed Parakeet			✔	✔	✔		✔				✔
72	Rock Pigeon	✔✔	✔✔	✔✔	✔✔	✔✔	✔	✔✔	✔✔	✔✔	✔✔	✔✔
73	Laughing Dove							✔				
74	Spotted Dove			✔								✔
75	White Breasted waterhen		✔✔	✔✔	✔	✔		✔	✔		✔	✔
78	Common Sand Piper	✔	✔	✔✔	✔	✔			✔		✔✔	✔✔
79	Wood Sandpiper	✔	✔		✔			✔	✔		✔	✔
80	Lesser Sand plover			✔	✔							✔
81	Red Wattled lapwing	✔		✔				✔				
82	Pallas's Gull		✔		✔						✔	✔
83	Brown Headed Gull							✔				✔

SupplementaryTable 1 Contd.

Sr no.	Avian species	Dombivali	Thane	Bhandup	Airoli	Ghansoli	Mankhurd	Vasai	Gorai	Uttan	Uran	Alibaug
84	Black Headed Gull		✔	✔			✔	✔			✔	✔
85	Heuglin's Gull				✔		✔					
86	Slender Billed Gull						✔				✔	✔
87	Long Tailed Shrike	✔	✔	✔		✔		✔		✔		
88	House Crow	✔✔	✔✔	✔✔	✔✔	✔✔	✔✔	✔✔	✔✔	✔✔	✔✔	✔✔
89	Large billed Crow		✔					✔				✔
90	White throated fantail	✔		✔				✔				
91	Black Drongo	✔	✔✔	✔✔	✔	✔✔		✔✔			✔	✔
92	Oriental Magpie robin	✔	✔✔	✔✔		✔		✔	✔	✔	✔	✔
93	Gull Billed Tern				✔						✔	✔
94	Caspian Tern	✔									✔	✔
96	Whiskered Tern	✔					✔				✔	
98	House Swift			✔				✔				✔

SupplementaryTable 2: Phytoplankton

Taxon	Dombivali	Thane	Bhandup	Diva-Airoli	Ghansoli	Mankhurd	Vashi	Vasai	Gorai	Uttan	Uran	Alibaug
Nitzschia	✓	✓	✓	✓		✓	✓		✓	✓	✓	
Thalassiosira	✓		✓	✓	✓	✓				✓		
Skeletonema	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓
Cyclotella	✓		✓	✓		✓				✓	✓	✓
Peridinium	✓			✓			✓	✓				✓
Melosira			✓		✓						✓	✓
Volvox					✓							
Spirulina		✓			✓				✓	✓	✓	
Actinostrum			✓	✓	✓							
Oscillatoria			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Pediastrum					✓							
Fragilaria			✓		✓							✓
Scenedesmus		✓		✓	✓			✓				
Zygnema				✓	✓							
Cosinodiscus			✓	✓			✓	✓		✓	✓	✓
Pleurosigma		✓	✓	✓		✓						✓
Gyrosigma			✓	✓			✓	✓				✓
Leptocylindrus			✓	✓			✓	✓			✓	✓
Synedra		✓	✓	✓								
Cymbella			✓	✓			✓	✓				
Euglena		✓		✓								
Biddulphia			✓	✓		✓			✓		✓	✓
Anabaena				✓				✓				
Planktonella				✓								✓
Gloeothece				✓					✓			
Phaeocystis						✓		✓			✓	
Thalassiothrix						✓	✓				✓	✓
Rhizosolenia						✓	✓	✓				✓

Supplementary Table 2 Contd.

Taxon	Dombivali	Thane	Bhandup	Diva-Airoli	Ghansoli	Mankhurd	Vashi	Vasai	Gorai	Uttan	Uran	Alibaug
Hernidiscus			✓									
Prorocentrum			✓								✓	✓
Denticula			✓									
Bacteriastrum			✓								✓	✓
Surirella			✓								✓	✓
Chaetoceros			✓									✓
Triceratium			✓								✓	✓
Nodularia		✓									✓	✓
Dinophysis		✓										
Pondoria		✓										
Chlorogonium		✓										
Pinnularia		✓										
Tropidoneis		✓										
Navicula								✓		✓		✓
Ankistrodesmus								✓				
Eucampia								✓			✓	
Rhabdonema									✓		✓	
Gonyaulax												
Denti?											✓	
Amphora											✓	✓
Camphylodiscus											✓	
Ditylum											✓	
Ceratium												✓
Trichodesmium												✓
Dictyota												✓
Hemidiscus												✓
Cocclithus												✓
Thalassionema												✓

Supplementary Table 3: Zooplankton

Taxon	Dombivali	Thane	Bhandup	Diva-Airoli	Ghansoli	Mankhurd	Vashi	Vasai	Gorai	Uttan	Uran	Alibaug
Insect larva	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Rotifera				✓	✓			✓		✓	✓	✓
Fish egg			✓		✓			✓	✓	✓		✓
Fish larva		✓				✓	✓	✓	✓	✓	✓	✓
Chironomus larva					✓							
Copepod		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Decapoda		✓	✓	✓			✓	✓			✓	✓
Amphipoda		✓	✓								✓	✓
Gastropoda				✓		✓		✓			✓	✓
Cladocera												✓
Lucifer species												✓
Ctenophora												✓
Crustacean egg												✓

Supplementary Table 4: Benthic Organisms

Taxon	Dombivali	Thane	Bhandup	Diva-Airoli	Ghansoli	Mankhurd	Vashi	Vasai	Gorai	Uttan	Uran	Alibaug
Oligochaeta	✓				✓			✓		✓		
Insect larva	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
Fish larva		✓										✓
Gastropoda		✓		✓	✓	✓	✓	✓			✓	✓
Polychaeta		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Bivalves					✓	✓	✓	✓			✓	✓
Fish egg				✓		✓					✓	
Ostracod		✓		✓								✓
Crustacean egg						✓						
Amphipods							✓					
Pelecypods								✓				✓
Oreasteridae												✓

Supplementary Table 5: Site Rating Scale: Dombivali

Dombivali										
	Mangrove Under Threat		**Biodiversity**		**Social Acceptance**		**Proximity to Source of Pollution**		**Physical and Legal Feasibility**	
1	*Open defecation*	**N**	*Richness of mangrove diversity*	**Y**	*Willingness to get trained by us*	**N**	*Presence of industry/slum/both/any other pollution source*	**Y**	*Government Permissions*	**N**
2	*Over harvesting*	**N**	*Richness of crab/oyster diversity*	**N**	*Willingness to protect mangroves*	**N**	*Water quality*	N	*Accessibility by road/boat*	**Y**
3	*Criminal activities like corpse disposal/illegal brewing/sand mining*	**Y**	*Richness of aquatic diversity (fish, aquatic birds, phytoplankton, benthos & zooplankton)*	**N**	*Annual income of target group*	**Not ascertained**	*Sediment quality*	Y	*Proximity to market*	**N**
4	*Cutting of trees*	**Y**	*Richness of Bird Biodiversity in entire mangrove patch*	**Y**	*Education level of target group*	**Not ascertained**	*Solid waste content*	N	*Density of mangroves*	**Y**

Supplementary Table 6: Site Rating Scale: Thane

Thane										
	Mangrove Under Threat		**Biodiversity**		**Social Acceptance**		**Proximity to Source of Pollution**		**Physical and Legal Feasibility**	
1	Open defecation	**Y**	Richness of mangrove diversity	**Y**	Willingness to get trained by us	**Y**	Presence of industry/slum/both/any other pollution source	**Y**	Government Permissions	**To be ascertained**
2	Over harvesting	**Y**	Richness of crab/oyster diversity	**Y**	Willingness to protect mangroves	**Y**	Water quality	**N**	Accessibility by road/boat	**Y**
3	Criminal activities like corpse disposal/illegal brewing/sand mining	**Y**	Richness of aquatic diversity (fish, aquatic birds, phytoplankton, benthos & zooplankton)	**N**	Annual income of target group	**Not ascertained**	Sediment quality	**Y**	Proximity to market	**Y**
4	Cutting of trees	**Y**	Richness of Bird Biodiversity in entire mangrove patch	**Y**	Education level of target group	**Not ascertained**	Solid waste content	**N**	Density of mangroves	**Y**

Supplementary Table 7: Site Rating Scale: Bhandup

Bhandup										
	Mangrove Under Threat		**Biodiversity**		**Social Acceptance**		**Proximity to Source of Pollution**		**Physical and Legal Feasibility**	
1	*Open defecation*	**N**	*Richness of mangrove diversity*	**Y**	*Willingness to get trained by us*	**Y**	*Presence of industry/slum/both/any other pollution source*	**N**	*Government Permissions*	**Y**
2	*Over harvesting*	**N**	*Richness of crab/oyster diversity*	**Y**	*Willingness to protect mangroves*	**Y**	*Water quality*	Y	*Accessibility by road/boat*	**Y**
3	*Criminal activities like corpse disposal/illegal brewing/sand mining*	**Y**	*Richness of aquatic diversity (fish, aquatic birds, phytoplankton, benthos & zooplankton)*	**Y**	*Annual income of target group*	**Medium**	*Sediment quality*	Y	*Proximity to market*	**Y**
4	*Cutting of trees*	**N**	*Richness of Bird Biodiversity in entire mangrove patch*	**Y**	*Education level of target group*	**Medium**	*Solid waste content*	N	*Density of mangroves*	**Y**

Supplementary Table 8 Site Rating Scale: Diva Gaothan (Airoli)

Diva Gaothan (Airoli)										
	Mangrove Under Threat		**Biodiversity**		**Social Acceptance**		**Proximity to Source of Pollution**		**Physical and Legal Feasibility**	
1	*Open defecation*	**N**	*Richness of mangrove diversity*	**Y**	*Willingness to get trained by us*	**N**	*Presence of industry/slum/both/any other pollution source*	**Y**	*Government Permissions*	**N**
2	*Over harvesting*	**N**	*Richness of crab/oyster diversity*	**Y**	*Willingness to protect mangroves*	**N**	*Water quality*	--	*Accessibility by road/boat*	**N**
3	*Criminal activities like corpse disposal/illegal brewing/sand mining*	**Y**	*Richness of aquatic diversity (fish, aquatic birds, phytoplankton, benthos & zooplankton)*	**Y**	*Annual income of target group*	**Not ascertained**	*Sediment quality*	--	*Proximity to market*	**N**
4	*Cutting of trees*	**Y**	*Richness of Bird Biodiversity in entire mangrove patch*	**Y**	*Education level of target group*	**Not ascertained**	*Solid waste content*	**N**	*Density of mangroves*	Y

Supplementary Table 9: Site Rating Scale: Ghansoli

Ghansoli										
	Mangrove Under Threat		**Biodiversity**		**Social Acceptance**		**Proximity to Source of Pollution**		**Physical and Legal Feasibility**	
1	*Open defecation*	**N**	*Richness of mangrove diversity*	**Y**	*Willingness to get trained by us*	**Y**	*Presence of industry/slum/both/any other pollution source*	**N**	*Government Permissions*	**To be ascertained**
2	*Over harvesting*	**N**	*Richness of crab/oyster diversity*	**Y**	*Willingness to protect mangroves*	**Y**	*Water quality*	**Y**	*Accessibility by road/boat*	**Y**
3	*Criminal activities like corpse disposal/illegal brewing/sand mining*	**N**	*Richness of aquatic diversity (fish, aquatic birds, phytoplankton, benthos & zooplankton)*	**Y**	*Annual income of target group*	**Medium**	*Sediment quality*	**N**	*Proximity to market*	**Y**
4	*Cutting of trees*	**Y**	*Richness of Bird Biodiversity in entire mangrove patch*	**Y**	*Education level of target group*	**Medium**	*Solid waste content*	**N**	*Density of mangroves*	**Y**

Supplementary Table 10: Site Rating Scale: Mankhurd

	Mankhurd									
	Mangrove Under Threat		**Biodiversity**		**Social Acceptance**		**Proximity to Source of Pollution**		**Physical and Legal Feasibility**	
1	*Open defecation*	**N**	*Richness of mangrove diversity*	**Y**	*Willingness to get trained by us*	**N**	*Presence of industry/slum/both/any other pollution source*	N	*Government Permissions*	**N**
2	*Over harvesting*	**N**	*Richness of crab/oyster diversity*	**Y**	*Willingness to protect mangroves*	**N**	*Water quality*	N	*Accessibility by road/boat*	**Y**
3	*Criminal activities like corpse disposal/illegal brewing/sand mining*	**N**	*Richness of aquatic diversity (fish, aquatic birds, phytoplankton, benthos & zooplankton)*	**N**	*Annual income of target group*	**Not ascertained**	*Sediment quality*	Y	*Proximity to market*	**N**
4	*Cutting of trees*	**N**	*Richness of Bird Biodiversity in entire mangrove patch*	**Y**	*Education level of target group*	**Not ascertained**	*Solid waste content*	**N**	*Density of mangroves*	Yet to be ascertained

Supplementary Table 11: Site Rating Scale: Vasai

Vasai										
	Mangrove Under Threat		**Biodiversity**		**Social Acceptance**		**Proximity to Source of Pollution**		**Physical and Legal Feasibility**	
1	*Open defecation*	**Y**	*Richness of mangrove diversity*	**Y**	*Willingness to get trained by us*	**Y**	*Presence of industry/slum/both/any other pollution source*	**N**	*Government Permissions*	**N**
2	*Over harvesting*	**N**	*Richness of crab/oyster diversity*	**Y**	*Willingness to protect mangroves*	**Y**	*Water quality*	N	*Accessibility by road/boat*	**Y**
3	*Criminal activities like corpse disposal/illegal brewing/sand mining*	**Y**	*Richness of aquatic diversity (fish, aquatic birds, phytoplankton, benthos & zooplankton)*	**Y**	*Annual income of target group*	**Medium**	*Sediment quality*	Y	*Proximity to market*	**Y**
4	*Cutting of trees*	**Y**	*Richness of Bird Biodiversity in entire mangrove patch*	**Y**	*Education level of target group*	**Medium**	*Solid waste content*	N	*Density of mangroves*	**Y**

Supplementary Table 12: Site Rating Scale: Gorai

Gorai										
	Mangrove Under Threat		**Biodiversity**		**Social Acceptance**		**Proximity to Source of Pollution**		**Physical and Legal Feasibility**	
1	*Open defecation*	**Y**	*Richness of mangrove diversity*	**Y**	*Willingness to get trained by us*	**N**	*Presence of industry/slum/both/any other pollution source*	**N**	**To be ascertained**	**Y**
2	*Over harvesting*	**N**	*Richness of crab/oyster diversity*	**Y**	*Willingness to protect mangroves*	**Y**	*Water quality*	N	*Accessibility by road/boat*	**Y**
3	*Criminal activities like corpse disposal/illegal brewing/sand mining*	**N**	*Richness of aquatic diversity (fish, aquatic birds, phytoplankton, benthos & zooplankton)*	**Low**	*Annual income of target group*	**Medium**	*Sediment quality*	Y	*Proximity to market*	**Y**
4	*Cutting of trees*	**N**	*Richness of Bird Biodiversity in entire mangrove patch*	**Y**	*Education level of target group*	**Medium**	*Solid waste content*	N	*Density of mangroves*	**Y**

Supplementary Table 13: Site Rating Scale: Uttan

Uttan										
	Mangrove Under Threat		**Biodiversity**		**Social Acceptance**		**Proximity to Source of Pollution**		**Physical and Legal Feasibility**	
1	*Open defecation*	**Y**	*Richness of mangrove diversity*	**N**	*Willingness to get trained by us*	**Y**	*Presence of industry/slum/both/any other pollution source*	**Y**	*Government Permissions*	**N**
2	*Over harvesting*	**Y**	*Richness of crab/oyster diversity*	**N**	*Willingness to protect mangroves*	**Y**	*Water quality*	**N**	*Accessibility by road/boat*	**Y**
3	*Criminal activities like corpse disposal/illegal brewing/sand mining*	**Y**	*Richness of aquatic diversity (fish, aquatic birds, phytoplankton, benthos & zooplankton)*	**N**	*Annual income of target group*	**Not ascertained**	*Sediment quality*	**Y**	*Proximity to market*	**Y**
4	*Cutting of trees*	**Y**	*Richness of Bird Biodiversity in entire mangrove patch*	**N**	*Education level of target group*	**Not ascertained**	*Solid waste content*	**N**	*Density of mangroves*	**Y**

Supplementary Table 14: Site Rating Scale: Uran

Uran										
	Mangrove Under Threat		**Biodiversity**		**Social Acceptance**		**Proximity to Source of Pollution**		**Physical and Legal Feasibility**	
1	*Open defecation*	**N**	*Richness of mangrove diversity*	**N**	*Willingness to get trained by us*	**Y**	*Presence of industry/slum/both/any other pollution source*	**N**	*Government Permissions*	**To be ascertained**
2	*Over harvesting*	**N**	*Richness of crab/oyster diversity*	**Y**	*Willingness to protect mangroves*	**Y**	*Water quality*	**Y**	*Accessibility by road/boat*	**Y**
3	*Criminal activities like corpse disposal/illegal brewing/sand mining*	**N**	*Richness of aquatic diversity (fish, aquatic birds, phytoplankton, benthos & zooplankton)*	**Y**	*Annual income of target group*	**Medium**	*Sediment quality*	**Y**	*Proximity to market*	**Y**
4	*Cutting of trees*	**N**	*Richness of Bird Biodiversity in entire mangrove patch*	**Y**	*Education level of target group*	**Medium**	*Solid waste content*	**N**	*Density of mangroves*	**Y**

Supplementary Table 15: Site Rating Scale: Alibaug

Alibaug										
	Mangrove Under Threat		**Biodiversity**		**Social Acceptance**		**Proximity to Source of Pollution**		**Physical and Legal Feasibility**	
1	*Open defecation*	**N**	*Richness of mangrove diversity*	**Y**	*Willingness to get trained by us*	**Y**	*Presence of industry/slum/both/any other pollution source*	**N**	*Government Permissions*	**To be ascertained**
2	*Over harvesting*	**N**	*Richness of crab/oyster diversity*	**Y**	*Willingness to protect mangroves*	**Y**	*Water quality*	**Y**	*Accessibility by road/boat*	**Y**
3	*Criminal activities like corpse disposal/illegal brewing/sand mining*	**N**	*Richness of aquatic diversity (fish, aquatic birds, phytoplankton, benthos & zooplankton)*	**N**	*Annual income of target group*	**Low**	*Sediment quality*	**Y**	*Proximity to market*	**Y**
4	*Cutting of trees*	**N**	*Richness of Bird Biodiversity in entire mangrove patch*	**Y**	*Education level of target group*	**Low**	*Solid waste content*	**N**	*Density of mangroves*	**Y**

Supplementary Table 16: References of phytoplanktons as indicators

Sr. no.	Taxon	Citation	Water quality
1	*Nitzschia*	(Baruah 2016, and reference therein, Kelly and Whitton 1995)	Pollution indicator
2	*Thalassiosira*	Xivanand N. Verlecar, Somshekhar R. Desai, Anupam Sarkar And S. G. Dalal, 1998	Indicator of polluted water
3	*Skeletonema*	Andres Jaanus and et. al, 2009	Indicator of water with high concentration of inorganic compounds and nitrogen
4	*Cyclotella*	(Baruah 2016, and references there in)	Indicator of clean water
5	*Peridinium*	Palmer M.C., 1977.	Dominate in nutrient rich waters
6	*Melosira*	American Public Health Association, Washington, D.C., 1989.	Indicator of clean water
7	*Spirulina*	Tahir Atici, 2016	Indicator of Fresh water
8	*Oscillatoria*	(Baruah 2016, and references therein, Singh 2013)	Indicator of pollution
9	*Pediastrum*	Peera pornpisal, Y., Suphan, S., Ngearnpat, N. et al. Biologia (2008)	Indicator of fresh water
10	*Fragilaria*	H. van Dam & A. Mertens, 1993	Indicator of polluted water
11	*Scenedesmus*	Nandan and Aher (2005)	Found in organically polluted waters
12	*Zygnema*	Tahir Atici, 2016	Indicator of freshwater
13	*Cosinodiscus*	I.C. Onyema,2016	Indicator of marine water
14	*Pleurosigma*	I.C. Onyema,2016	Indicator of high nutritional level
15	*Gyrosigma*	Robert A short,1978	Indicator of freshwater
16	*Leptocylindrus*	Xivanand N. Verlecar, Somshekhar R. Desai, Anupam Sarkar And S. G. Dalal, 1998	Indicator of polluted water
17	*Synedra*	(Baruah 2016, and references there in)	Indicator of clean water
18	*Cymbella*	Tahir Atici, 2016	Indicator of freshwater
19	*Euglena*	(Baruah 2016, and references there in)	Indicator of polluted water
20	*Anabaena*	(Baruah 2016, and references there in)	Indicator of polluted water
21	*Phaeocystis*	C. Lancelot and et. al., 1963	Indicator of polluted water
22	*Rhizosolenia*	Xivanand N. Verlecar, Somshekhar R. Desai, Anupam Sarkar And S. G. Dalal, 1998	Indicator of polluted water
23	*Prorocentrum*	(Cynthia Heil and et. Al, 2005)	Indicator of polluting water
24	*Surirella*	Malebo D. Matlala,2010	Indicator of polluted water

25	*Chaetoceros*	Xivanand N. Verlecar, Somshekhar R. Desai, Anupam Sarkar And S. G. Dalal, 1998	Indicator of polluted water
26	*Dinophysis*	Subrat naik,2009	Indicator of pollution
27	*Chlorogonium*	Soler, A., Saez, J., Llorens, M., Martinez, I., Torrella, F., & Berna, L. M. (1991).	Indicator of pollution
28	*Pinnularia*	(Baruah 2016, and references there in)	Indicator of clean water
29	*Navicula*	(Baruah 2016, and references there in)	Indicator of clean water
30	*Ankistrodesmus*	(Baruah 2016, and references there in)	Indicator of clean water
31	*Amphora*	I.C. Onyema,2016	Indicator of poor water quality
32	*Trichodesmium*	Subrat naik,2009	Indicator of polluted water
33	*Hemidiscus*	I.C. Onyema, 2016	Indicator of brackish water
34	*Thalassionema*	Abhishek Mukherjee, Subhajit Das, Sabyasachi Chakraborty and Tarun Kumar De, 2015	Mangroves Impoverished water

Table 17: Secondary data

Flora		
Sr. No.	**Year and Citation**	**Findings**
1	Passenger Water Transport System- Bandra to Borivali- EIA report	*Avicennia* sp. were found along Gorai creek
Fauna:		
Sr. No.	**Year and Citation**	**Findings**
1	Pawar, P. R. (2012). Species diversity of birds in mangroves of Uran (Raigad), Navi Mumbai, Maharashtra, West coast of India. *Journal of Experimental Sciences*, *2*(10).	A total of 56 species of birds representing 11 orders, 29 families and 46 genera were recorded from the mangroves of Uran coast.
2	Prefesibility report- Mumbai coastal road project.	List of various fauna, avifauna, mammals, reptiles is provided.
Phytoplankton-Zooplankton-Benthos:		
Sr. no.	**Year and Citation**	**Findings**
1	JiyalalRam, M. J., Ram, A., Rokade, M. A., Karangutkar, S. H., Yengal, B., Dalvi,	*Thalassiosira gravid* and *Skeletonema costatum* were majorly observed in marine environment.

	S., & Gajbhiye, S. N. (2013). Phytoplankton dynamic responses to oil spill in Mumbai Harbour.	
2	Passenger Water Transport System-Bandra to Borivali- EIA report	Distribution of various phytoplanktons, zooplanktons and benthos along Bandra, Juhu, Versova creek, Gorai creek, Marve creek,
3	Shahi, N., Godhe, A., Mallik, S. K., Härnström, K., & Nayak, B. B. (2015). The relationship between variation of phytoplankton species composition and physico-chemical parameters in northern coastal waters of Mumbai, India.	A total of 230 taxa were recorded from both sites. Phytoplankton were dominated by diatoms (131 taxa)followed by dinoflagellates (82 taxa) and marine flagellates (17 taxa).
4	Schuytema, G. S., Nebeker, A. V., & Stutzman, T. W. (1997). Salinity tolerance of Daphnia magna and potential use for estuarine sediment toxicity tests. *Archives of environmental contamination and toxicology*, *33*(2), 194-198. Latta, L. C., Weider, L. J., Colbourne, J. K., & Pfrender, M. E. (2012). The evolution of salinity tolerance in Daphnia: a functional genomics approach. *Ecology Letters*, *15*(8), 794-802.	Salinity tolerance of *Daphnia*

5.	Gaonkar, C.A., V. Krishnamurthy, and A.C. Anil (2010). Changes in the abundance and composition of zooplankton from the ports of Mumbai, India. Environ Monit Assess. 168:179–194	Copepod species such as Canthocalanus sp., Paracalanus arabiensis, Cosmocalanus sp., Euterpina acutifrons, Nannocalanus minor and Tortanus sp. not reported in the earlier studies were observed during their investigation.
6.	Biju, A., & Panampunnayil, S. U. (2010). Mysids (Crustacea) from the salt pans of Mumbai, India, with a description of a new species. *Marine Biology Research*, *6*(6), 556-569.	In Bhayander salt pan the mysids *Mesopodopsis orientalis* and *Indomysis nybini*
7	Markande, A. R., Mikaelyan, A., Nayak, B. B., Patel, K. D., Vachharajani, N. B., Vennila, A., & Purushothaman, C. S. (2014). Analysis of midgut bacterial community structure of Neanthes chilkaensis from polluted mudflats of Gorai, Mumbai, India. *Advances in Microbiology*, *4*(13), 906.	Neanthes chilkaensis inhabits in gorai region
9	Jayalakshmy, K. V. (2013). Ecology and Distribution of Copepods from the Salt Pan Ecosystems of Mumbai, West Coast of India. *Journal of Marine Biology & Oceanography*.	*Fabrea salina*, *Pseudodiaptomus pankajus*, *Acartia sarojus, Bestiolina similis, Acartia southwelli, Oithona sp., O. similis, O. hebes* and *Mesochra* sp. were observed in Bhayander region

10	Stephen, R., Jayalakshmy, K. V., Nair, V. R., Gajbhiye, S. N., & Jacob, B. (2014). Deterioration in the biodiversity of copepods in sewage laiden creeks of Mumbai coast, west coast of India: A statistical approach.	*Acartia spinicauda, Paracalanus aculeatus, Acrocalanus* sp., *Centropages tenuiremis, Tortanus forcipatus, Acartia spinicauda, Tortanus forcipatus, Bestiolina similis, Pseudodiaptomus bowmani, Canthocalanus pauper* and *Bestiolina similis* were found in Versova and mahim creek
11	Gajbhiye, S. N., Nair, V. R., & Desai, B. N. (1984). Diurnal variation of zooplankton in Malad creek, Bombay.	*Acartia spinicauda, Acrocalamus similis, A. gracilis, Euchaeta concinna, Eucalanus subcrassus and Paracalanus crassirostris, P. aculeatus, Canthocalanus pauper, Acrocalanus inermis, A. monachus, Labidocera pectinata, Acartia pacifica, A. plumosa, A. centura, Acartia* sp. were found in malad creek.
12	Mandal, S., & Harkantra, S. N. (2013). Changes in the soft-bottom macrobenthic diversity and community structure from the ports of Mumbai, India. *Environmental monitoring and assessment*, *185*(1), 653-672.	*P. pinnata, Cossura coasta, N. indica , N. glandicincta, Cirriformia chrysoderma, Goniadopsis longicirrata, Dendronereides heteropoda, Nephtys polybranchia, Kinbergonuphis investigatoris* were found near Mumbai port.
13	Ingole, B. S., Gaonkar, U. V., Deshmukh, A., Mukherjee, I., Sivadas, S. K., & Gophane, A. (2014). Macrobenthic community structure of coastal Arabian Sea during the Fall intermonsoon.	*Coscinodiscus* sp., *Thalassiosira* sp., larval forms of polychaete and fish, *Paraprionospio pinnata* were observed in the region of west coast.

Supplementary table 18: Secondary data on water quality of MMR region

Sr. no.	Citation	Findings
1	Vijay, R., Khobragade, P. J., Sohony, R. A., Kumar, R., & Wate, S. R. (2014). Hydrodynamic and water quality simulation of Thane creek, Mumbai: an impact of sewage discharges.	Hydrodynamic and water quality simulations of Thane Creek confirms the impact of sewage discharges on creek water quality.
2	Mishra, S., Bhalke, S., Saradhi, I. V., Suseela, B., Tripathi, R. M., Pandit, G. G., & Puranik, V. D. (2007). Trace metals and organometals in selected marine species and preliminary risk assessment to human beings in Thane Creek area, Mumbai. *Chemosphere*, *69*(6), 972-978.	Trace metals and organometals were estimated in different types of marine organisms (fish, bivalve, crab and prawn) collected from the Trans-Thane Creek area, Mumbai.
3	Pawar, P. R. (2013). Monitoring of impact of anthropogenic inputs on water quality of mangrove ecosystem of Uran, Navi Mumbai, west coast of India. *Marine pollution bulletin*, *75*(1), 291-300.	Water quality from mangroves of Uran is deteriorating due to industrial pollution. High concentration of O- PO_4 NO_3 –N and silicates are found in higher concentration
4	Gupta, I., Salunkhe, A., Rohra, N., & Kumar, R. (2013). Chemometrics data analysis of marine water quality in Maharashtra, west coast of India.	Uttan creek, Ulhas creek and Vashi creek are moderately polluted.
5	Singare, P. U., Trivedi, M. P., & Mishra, R. M. (2011). Assessing the physico-chemical parameters of sediment ecosystem of Vasai creek at Mumbai, India. *Marine Science*, *1*(1), 22-29.	Vasai creek is polluted due to increase in industrialization

6	Singare, P. U., Trivedi, M. P., & Ravindra, M. (2012). Sediment heavy metal contaminants in Vasai Creek of Mumbai: pollution impacts. *American Journal of Chemistry*, *2*(3), 171-180.	The results of the study indicates that the concentration level of most of the toxic heavy metals like Al, As, Cd, Cr, Hg, Ni, Pb, Sr and Mn for the assessment year 2010-11 were higher than that obtained for the year 2009-10 by the factor of 1.0 to 2.5 µg/g. I

Case study:

Sr. No.	Citation	Findings
1	Binh, C. T., Phillips, M. J., & Demaine, H. (1997). Integrated shrimp-mangrove farming systems in the Mekong delta of Vietnam. *Aquaculture Research*, *28*(8), 599-610.	An economic analysis, based solely on the economic returns from shrimp culture showed that the farming systems with a mangrove coverage of 30-50% of the pond area gave the highest annual economic returns. The results demonstrate a better economic return to farmers who maintain mangroves in their farming systems.
2	Primavera, J. (2006). Overcoming the impacts of aquaculture on the coastal zone. *Ocean & Coastal Management*, *49*(9), 531-545.	Recommendation for protection of mangroves includes Holistic Integrated Coastal Zone Management based on stakeholder needs, mechanisms for conflict resolution, assimilative capacity of the environment, protection of community resources, and rehabilitation of degraded habitats, to improvements in the aquaculture sector pertaining to management of feed, water, and effluents.
3	Rönnbäck, P. (1999). The ecological basis for economic value of seafood production supported by mangrove ecosystems. *Ecological Economics*, *29*(2), 235-252.	The life-support functions of mangrove ecosystems also set the framework for sustainable aquaculture in these environments. Estimates of the annual market value of capture fisheries supported by mangroves ranges from US$750 to 16 750 per hectare, which illustrates the potential support value of mangroves. The value of mangroves in seafood production would further increase by additional research on subsistence fisheries, biophysical support to other ecosystems, and the mechanisms which sustain aquaculture production.

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Alongi, D. M. (2002). Present state and future of the world's mangrove forests. *Environmental conservation*, *29*(03), 331-349.

Armstrong, F. A. J. (1957). The iron content of sea water. *Journal of the Marine Biological Association of the United Kingdom*, *36*(03), 509-517.

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