



**BEFORE THE NATIONAL GREEN TRIBUNAL WESTERN
ZONE BENCH, PUNE
APPEAL NO. 59 OF 2026 (WZ)**

SAGARDEEP SIRSAIKAR

...Appellants

Versus

GCZMA & ORS

...Respondents

**ADDITIONAL AFFIDAVIT-IN-REPLY ON BEHALF OF
CAPTAIN OF PORTS I.E., RESPONDENT NO 2.**

I, Shri Octavio Antony Rodrigues, major of age, holding the post of Captain of Ports, Government of Goa, i.e., Respondent No 2 herein, having office at Captain of Ports Department, Dayanand Bandodkar Road, Panjim, Goa, do hereby make solemn affirmation and state as under:-

1. I say that I am holding the post of Captain of Ports. I say that I am filing the present affidavit based on the records available with my office and that I am competent to depose in this case.

A handwritten signature in black ink, appearing to be 'A. Rodrigues', located at the bottom of the page.



2. At the very outset, Respondent No 2 (“**Answering Respondent**”) denies all the averments, allegations and contentions raised by the Appellant *in toto*, save and what are matter(s) of record. Nothing stated in the present application shall be deemed to be admitted by the Answering Respondent unless specifically admitted hereinafter. I say that I am filing the present preliminary Additional Affidavit-in-Reply for only for the purpose bringing certain facts on record before this Hon’ble Tribunal. Nothing may be deemed to have been admitted for want of *traverse seriatim*.

3. I say that the Appellant, by way of the present proceedings, has challenged the NOC/Clearance dated 17.11.2025 granted by the Goa Coastal Zone Management Authority (GCZMA) for undertaking maintenance dredging at the mouth of River Chapora..

4. I say that the Chapora Port was declared as a Non-Minor Port as early as the year 1967, and fishing vessels have been operating in River Chapora since time immemorial. The



navigational channel at the river mouth is an established and historically used passage, which has been periodically dredged and maintained by the Captain of Ports from time to time to ensure safe navigation and adequate draft for fishing/sailing vessels etc. The maintenance dredging in question is not a new activity but forms part of routine upkeep of an existing navigational channel essential for maritime safety and continuity of fishing operations.

5. I say that on 08.02.2025, two fishing trawlers sustained significant damage after striking a sandbar at the mouth of the Chapora River while returning ashore. The incident posed a serious risk not only to property but also to human life. Fishing constitutes a primary source of livelihood for a large number of local Goans, and safe access through the navigational channel is therefore of critical importance. In view of the safety concerns arising from sedimentation and formation of sandbars at the mouth of the Chapora River, there was an urgent and compelling need to undertake maintenance dredging to restore navigability and prevent further accidents.



6. I say that the maintenance dredging work was undertaken pursuant to the said CRZ clearance and has since been completed. I say that a contractor was appointed through a tender process for execution of the maintenance dredging work at the mouth of River Chapora, measuring approximately 1000 meters in length, 50 meters in width, and 2.50 meters in depth, in accordance with the GCZMA NOC dated 17.11.2025. I say that vide letter dated 12.02.2026, the said contractor informed that the awarded work has been duly completed. I say that this has been completed to ensure a smooth and safe navigational channel. It is submitted that the works executed were limited strictly to maintenance dredging within the approved parameters and did not involve any expansion or alteration of the existing navigational alignment.

7. I say that the navigational channel where maintenance dredging was undertaken is located at a distance of more than 1000 meters from the turtle nesting sites at Morjim and Mandrem beaches. The Forest Department has earmarked an area extending



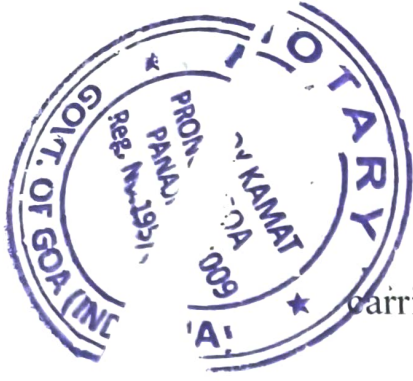
approximately 600 meters from Morjim Beach as a No-Take-Zone for conservation purposes. The maintenance dredging activities were carried out entirely outside the said No-Take-Zone and in compliance with applicable environmental safeguards.

A copy of Google Map screenshot of the subject site where the maintenance dredging activity took place is annexed hereto and marked as “Annexure A”

8. I say that the maintenance dredging activity was undertaken strictly within permissible area and did not extend into or disturb any notified turtle nesting habitats or ecologically sensitive nesting sites. The dredging operations were carefully planned and executed so as to maintain an appropriate balance between environmental conservation, navigational safety and the larger public interest served by ensuring the safe and uninterrupted movement of vessels.

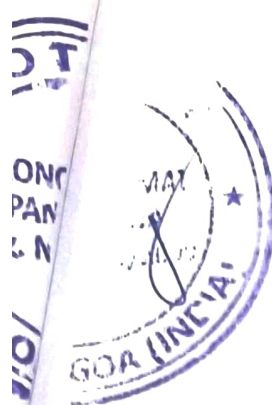
9. I say that, by way of abundant caution and in adherence to environmentally responsible practices, the dredging activity was





carried out using machinery, equipment, and vessels that were in proper working condition and fitted with appropriate noise suppression mechanisms to minimise noise emissions and any potential disturbance to the surrounding environment. All reasonable precautions were taken throughout the execution of the work to ensure that the activity did not adversely affect turtle nesting habitats or interfere with the nesting behaviour of marine turtles. The dredging operations were conducted under strict supervision, with due regard to environmental sensitivities, and every effort was made to ensure that the ecological integrity of the area remained protected while carrying out the essential maintenance dredging operations.

10. I say that the Answering Respondent has duly applied for and obtained the requisite No Objection Certificate/Clearance for undertaking maintenance dredging at the mouth of River Chapora in accordance with law and in due compliance with the provisions of the CRZ Notification, 2011. The maintenance dredging activity has been undertaken strictly in terms of the permissions granted by



the competent authorities and subject to the conditions imposed therein.

11. I say that, prior to the grant of the aforesaid permission, an "EIA/EMP and Modelling Studies for the Sand Mining Clusters in the Rivers of Goa – Chapora Estuary" was undertaken by CSIR – National Institute of Oceanography (hereinafter referred to as the "said Report"). The said Report was submitted before the Goa Coastal Zone Management Authority (GCZMA) as part of the process for obtaining the requisite clearance for the maintenance dredging activity. I say that the said Report contains a scientific assessment of the Chapora River ecosystem, identifies stretches where sand mining/dredging may be undertaken, and specifically demarcates ecologically sensitive stretches where such activities ought to be restricted. I say that the maintenance dredging undertaken by the Answering Respondent is confined to the permissible area and does not fall within any of the ecologically sensitive or restricted zones identified in the said Report. The dredging activity has, therefore, been carried out strictly in





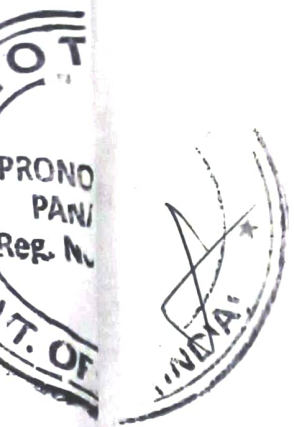
conformity with the recommendations contained in the said Report and without causing any disturbance to the environmentally sensitive areas identified therein.

Annexed hereto is a copy of the “EIA/EMP and modelling studies for the sand mining clusters in the rivers of Goa – Chapora Estuary” marked as “**Annexure B**”

12. I say that the Appellant has erroneously contended that the National Framework for Sediment Management issued by the Ministry of Jal Shakti prohibits the disposal of dredged material at sea. The said contention is wholly misconceived and contrary to the provisions of the said Framework. At no place does the National Framework for Sediment Management impose an absolute prohibition on the disposal of dredged material at sea.

13. I say that the Appellant has further contended that the National Framework for Sediment Management mandates the preparation of a Detailed Project Report (DPR) for maintenance dredging by a Technical Advisory Committee. The said contention





is factually and legally incorrect. I say that Clause 7.4 of the National Framework for Sediment Management expressly provides that a Detailed Project Report "may be" prepared by the Project Proponent. The use of the expression "may" clearly indicates that the provision is enabling and discretionary in nature and not mandatory. There is nothing in the said Framework which makes the preparation of a DPR a mandatory pre-condition for undertaking maintenance dredging activities in rivers. Consequently, the Appellant's reliance on the said Framework to contend that the maintenance dredging activity is vitiated for want of a DPR is entirely misplaced and devoid of merit.

14. I say that the National Framework for Sediment Management recognises that rivers and estuaries are dynamic systems where sediment deposition is a continuous natural process, resulting in the gradual accumulation of silt within navigation channels. Accordingly, the said Framework recommends that maintenance dredging be undertaken on a periodic basis, including annual maintenance dredging wherever warranted, so as to ensure

A handwritten signature in dark ink, appearing to be 'D. S.' or similar, located at the bottom center of the page.

the continued navigability of waterways, prevent excessive siltation and maintain the hydraulic efficiency of the river. I say that the maintenance dredging undertaken by the Answering Respondent is consistent with the objectives and recommendations of the said Framework and was carried out solely for the purpose of restoring and maintaining the navigable depth of the Chapora River, in the larger public interest, without altering the natural course or natural configuration of the river.

15. I say that what has been stated in Paras 1 to 14 are true to my own knowledge and/or are based on documents/records available with the Respondent and the contents of the same are true and correct and nothing material has been concealed herein.

Solemnly Affirm on Oath

Place: Panaji, Goa.

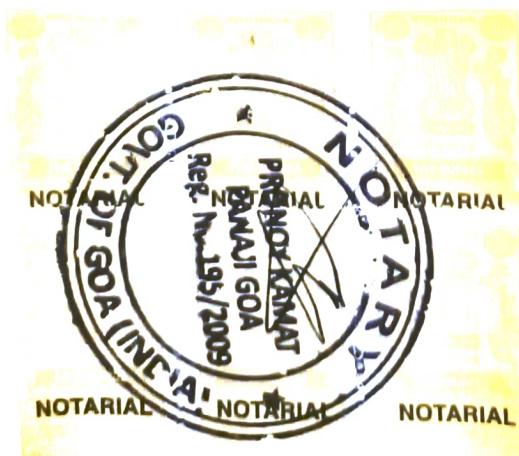
Date: 29.06.2026

Rodrigues

**DEPONENT
EXECUTED BEFORE ME**

Reg. No. 20161 Dt: 29/6/26

Identified by: *Kamat*



PRADYUMN KAMAT
NOTARY PUBLIC, TALUKA
STATE OF GOA, INDIA
Reg. No. 195/2009 Dated 10/7/2009
License Expires on 10/7/2029

Untitled Map

Write a description for your map.

Legend

- 1.03km
- chapora Dredging Site
- Fishing Jetty Chapora

chapora Dredging Site

1.03km

Burger Factory Morjim

Morjim Beach Goa

Morgim Beach

River Island

Chapora River

Fishing Jetty Chapora

Chapora Beach

Chapora Fort

DABHOL WADA

Darlings bar

Vagator Beach

800 m

Google Earth

Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Image © 2026 Airbus

Report on
EIA/EMP and modelling studies for the sand mining
clusters in the rivers of Goa

Report on Chapora Estuary

Submitted to:

Dr. Pradip Sarmokadam
Member Secretary
Goa State Biodiversity Board (GSBB)
C/o Department of Science, Technology and Environment,
Opp Saligao Seminary, Saligao, Bardez - Goa.
Tel: 0832-2407032 Fax: 0832-2407033
Email: goanbiodiversity@gmail.com

15th July 2020

Report submitted by:

	सीएसआईआर – राष्ट्रीयसमुद्रविज्ञानसंस्थान CSIR-NATIONAL INSTITUTE OF OCEANOGRAPHY (वैज्ञानिकतथाऔद्योगिकअनुसंधानपरिषद) (COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH) दोनापावला, गोवाभारत / DONA PAULA, GOA - 403004 India फ़ोन/Tel : 91(0)832-2450450/ 2450327 फैक्स /Fax: 91(0)832-2450602 इ-मेल/e-mail : spmg@nio.org http:// www.nio.org	
---	--	---

TABLE OF CONTENTS

List of Tables:	3
List of Figures	4
List of plates:	10
Executive Summary	11
Chapter 1- INTRODUCTION	14
Chapter 2-METHODOLOGY:	18
CHAPTER 3- PHYSICO-CHEMICAL AND BIOLOGICAL PARAMETERS:.....	23
CHAPTER 4: RESULT:	30
CHAPTER- 5 MODELLING- Climatology & Meteorology.....	97
Physical parameters	100
Instruments used	100
Deployed locations and parameters	100
Results	101
Currents	101
Water level.....	103
Chapter 6: NUMERICAL Modelling Studies	105
Assessment of mining.....	109
Hydrodynamic impact.....	110
Morphological impact	110
Results.....	110
Hydrodynamics modelling	111
Bed level changes	115
Chapter 7Anticipated impacts.....	120
CHAPTER 8 Mitigation Measure.....	144
Chapter 9Environmental conservation and management plan	149
9.9 Biodiversity conservation & management plan	163
Chapter 10 Environmental Monitoring plan.....	197
Recommendation:	207

LIST OF TABLES:

Table 2.1: Coordinates, depth and sediment texture of Chapora Estuary	20
Table 3.1: Threshold limits used for ecological status of AMBI and M-AMBI index.....	29
Table 4.1: Chemical parameters of Chapora Estuary	30
Table 4.1: Depth wise and spatial variation of phytoplankton abundance, composition in the Chapora Estuary.....	37
Table 4.2: Distribution of number of species, total abundance, species richness, evenness and diversity of phytoplankton in the Chapora Estuary.	41
Table 4.3: Depth wise and spatial variation of zooplankton abundance and composition in the Chapora Estuary.....	45
Table 4.4: Number of species (S), species diversity(H'), species richness (d) and evenness (J') in Chapora Estuary.....	47
Table 4.5: Total meiofaunal abundance (ind/10 cm ²) of Chapora Estuary (Central transect).	49
Table 4.6: Total meiofaunal abundance (ind/10 cm ²) of Chapora Estuary (Peripheral transect).	50
Table 4.7 : Nematoda:Copepoda ratio of Chapora Estuary(Central transect).....	52
Table 4.8 : Nematoda:Copepoda ratio of Chapora Estuary(Peripheral transect)	52
Table 4.9: Abundance (no/m ²) of macrofauna from Chapora Estuary(Central transect).....	62
Table 4.10: Abundance (no/m ²) of macrofauna from Chapora Estuary (Peripheral transect)	63
Table 4.11: Benthic Polychaete Amphipode(BPA) ratio of Chapora Estuary (Central transect)	74
Table 4.12: Benthic Polychaete Amphipode (BPA) ratio of Chapora Estuary (Peripheral transect)	75
Table 4.13: Fish diversity from Chapora Estuary.....	80

Table 4.14: List of Reptiles and Mammals recorded from Chapora Estuary.....	83
Table 4.15: List of Bird species spotted from Chapora Estuary.....	84
Table 4.16: LULC Chapora.....	91
Table 4.17: List of Seaweed/Grass found in Chapora Estuary.....	92
Table 4.18: Mangroves and associated species found in Chapora estuary.	95
Table 5.1 Soil classification in Chapora Estuary.....	99
Table 5.2 Table showing secondary data used in the study	99
The various instruments used for measuring different parameters are presented in Table 5.3.	100
Table 5.3 Instruments used for measuring different parameters	100
Table 5.4 Table showing instruments used and deployed locations.....	100
Table 5.5 Maximum and average value of Current speed at Chapora Location-1 CR1	102
Table 6.1: Maximum and minimum of current velocity components at different section for Case-1 and Case-2.....	114
Table 7.1: Depicting type of sensitivity, colour code, width and guidelines referred.	133
Table 9.1: Schemes for aquaculture in Goa (Source: Fishery department).....	170
Table. 10.1: Water quality monitoring parameters and schedule.	203

LIST OF FIGURES

Figure 1.1 Hydrographic Map of Goa. Insight zoom area of Chapora Estuary	17
Figure 4.1: Graph depicting TSM and TDS of Chapora Estuary	31
Figure 4.2: Spatial variations in (a) temperature ($^{\circ}\text{C}$), b salinity (psu) in the Chapora Estuary.(C1-river mouth and C15-upstream region)	32
Figure 4.3: Spatial variations (surface and bottom) in dissolved oxygen in the Chapora Estuary.(C1-river mouth and C15-upstream region)	33
Figure 4.4: Spatial variations in (a) nitrate (NO_3) , nitrite (NO_2) and phosphate (PO_4) and (b) silicate (SiO_4) in the Chapora Estuary.(C1-river mouth and C15-upstream region)	34
Figure 4.5: Spatial variations in Chlorophyll a ($\mu\text{g/L}$) in the Chapora Estuary.(C1-river mouth and C15-upstream region)	36
Figure 4.6: Spatial variations in total phytoplankton (Nos./L) and % contribution of diatoms and dinoflagellates in the Chapora Estuary.(C1-river mouth and C15-upstream region).....	40
Figure 4.7: Spatial variations in Meso-zooplankton abundance along middle portion of the in the Chapora Estuary.(C1-river mouth and C15-upstream region).....	42
Figure 4.8: Spatial variations in zooplankton abundance along the southern (right side of the river) bank of Chapora Estuary.(C3-near river mouth and C12-upstream region).....	43
Figure 4.9: Spatial variations in zooplankton abundance along the northern (left side of the river) bank of Chapora Estuary.(C1-river mouth and C15-upstream region)	43
Figure 4.10: Distribution of copepods ($\text{Ind}/100\text{m}^3$) from the River mouth (C1) to upstream (C15) regions of the Chapora Estuary.....	46
Figure 4.11: Station-wise meiofaunal abundance ($\text{ind}/10\text{ cm}^2$) from River Chapora (Central transect).	53
Figure 4.12: Percent composition of meiofaunal taxa from River Chapora (Central transect).	53

Figure 4.13: Station-wise meiofaunal abundance (ind/10 cm ²) from River Chapora (Peripheral transect).	54
Figure 4.14: Percent composition of meiofaunal taxa from River Chapora (Peripheral transect).	54
Figure 4.15: Station-wise Nematoda:Copepoda ratio from River Chapora (Central transect).	55
Figure 4.16 : Station-wise Nematoda:Copepoda ratio from River Chapora (Peripheral transect).	55
Figure 4.17: Total Living Foraminifera Number in Chapora Estuary	58
Figure 4.18: Total Dead Foraminifera Number in Chapora Estuary	58
Figure 4.19: Station-wise macrofaunal abundance (no/m ²) of the Chapora Estuary (Central transect).	67
Figure 4.20: Percent (%) composition of macrofaunal abundance of the Chapora Estuary (Central transect).	67
Figure 4.21: Percent (%) composition of Polychaeta of the Chapora Estuary (Central transect).	68
Figure 4.22: Station-wise macrofaunal abundance (no/m ²) of the Chapora Estuary (Peripheral transect).	68
Figure 4.23: Percent (%) composition of macrofaunal abundance of the Chapora Estuary (Peripheral transect).	69
Figure 4.24: Percent (%) composition of Polychaeta of the Chapora Estuary (Peripheral transect).	69
Figure 4.25: Station-wise Biomass (g/m ²) of the centre of the Chapora Estuary.	70
Figure 4.26: Station-wise Biomass (g/m ²) of the Chapora Estuary (Peripheral transect).	70
Figure 4.27: Station-wise diversity indices of Chapora Estuary (Central transect).	73

Figure 4.28: Station-wise diversity indices of Chapora Estuary (Peripheral transect).	73
Figure 4.29: Ecological quality status assessment through AMBI index along the sampling sites.....	76
.....	77
Figure 4.30: Ecological quality status assessment through M-AMBI index along the sampling sites.....	77
Figure 4.31: Ecological quality status assessment through BENTIX index along the sampling sites.....	77
Figure 4.32: Distribution of macrobenthic- Polychaetes based on the ecological sensitivity group assessed through BENTIX index along the sampling sites.	78
Figure 5.1. The monthly rainfall data at Pernem, North Goa from 2010-2019 (source IMD)	98
Figure 5.2. Soil map of Chapora basin, Goa (Source: NBSS&LUP)	98
Figure 5.3. Locations of current and water level measurements in Chapora Estuary	101
Figure 5.4. Variation of measured current speed and directions at CR1 during pre-monsoon 2020.....	102
Figure 5.5. Variation of measured current speed and directions at CR1 during monsoon, 2020.	103
Fig 5.6. Variation of water levels at Location-1 CR1	104
Fig 5.7. Variation of water levels at Location-2 CR2.....	104
Fig 5.8. Variation of water levels at Location-3 CR3.....	104
Figure 6.1. Model domain of the Chapora Estuary.....	106
Figure 6.2. Figure showing seven different sections (A-G) in the model domain.	107
Figure 6.3. Model domain for modified bathymetry increasing depth by 3 m at different sections (A-G).....	107

Figure 6.4a. Comparison between measured and modelled surface elevations and U&V component of current during pre-monsoon.	108
.....	108
Figure 6.4b. Comparison between measured and modelled surface elevations and U&V component of current during monsoon	108
Figure 6.5. Flow patterns and surface elevations during typical ebb and flood tide for Case-1.	111
.....	111
Figure 6.6 Comparison of U & V velocity at different sections between Case-1 and Case-2.	114
.....	114
Figure 6.7 Comparison of U & V velocity between Case-1 and Case-2 during February-April 2014 at section A.	115
Figure 6.8. showing the deposition/erosion at the Chapora estuary mouth. Top figure is Case-1 and bottom is Case-2	116
Figure 6.9. showing the deposition/erosion in the Chapora Part I.....	117
Figure 6.10. showing the deposition/erosion in the Chapora Part II	118
Figure 6.11. showing the deposition/erosion in the Chapora Part III	119
Figure 7.1: Depicting Mining Sensitive Zones for Chapora estuary (Zone I to IV).....	132
Figure 7.2: Shannon-Wieners and Simpsons Index depicted on the river stretches with encircled proposed sand extraction zones.	134
Figure 7.3: M-AMBI and BENTIX indices depicted on the river stretches with encircled proposed sand extraction zones.	135
Figure 7.4: Two sections of the rivers depicting areas highlighted in the subsequent Figure 7.5 for land use changes.	137
Figure 7.5: Areas depicting Land Use Land Cover along the Chapora Estuary.....	142
Figure 7.6: Erosion of banks in the upstream stretches of Chapora Estuary.....	143

Figure 9.1. Schematic diagram of management of sand mining	153
Figure 9.2. Diagram of channel cross sections showing	155
Figure 9.3. Diagram of channel cross sections showing	156
Figure 9.4: Exposed mangrove cutting and root buttresses of Chapora Estuary.....	160
Figure 9.5: Constriction of protective wall/embankment opposite Sal water treatment plant.	162
Figure 9.7. Schematic diagram depicts execution of management plan	190
Figure 9.8. Schematic diagram of development and functioning of team	193



LIST OF PLATES:

Plate 1: Study area - Chapora Estuary (A- Artisanal fishing in Chapora estuary; B- Mouth region showing exposed sand flat in the estuary; C- Tourism activity in middle stretches of the estuary; D- Upstream region of the estuary.) 22

Plate 2: A=Nematoda, B=Kinorhyncha, C=Polychaeta, D=Halacarida, E and F=Harpacticoida 56

Plate 3: Foraminifera species found in Chapora Estuary. 57

Plate 4: Macrofauna of Chapora Estuary A-*Prionospio pinnata*; B-*Heteromastus* sp.; C- *Glycera alba*; D- *Inemophrys inermis*; D-; E-Nemertea; F- Bivalvia 71

Plate 5: Fish species observed in Chapora estuary [A. Platycephalidae sp.; B.Tetradontidae; C. Total catch; D. Terapontidae] 79

Plate 6: Representative Seaweed and grass sample from Chapora Estuary. 93

Plate 7: Mangroves from Chapora estuary 96



EXECUTIVE SUMMARY

Chapora Estuary is one of the nine major rivers of Goa flowing from the east (Western Ghats) to the west (Arabian Sea) and is in the northern part of Goa. It is between the latitudes 15° 42' 42.3" and 15° 35' 53.1"N and longitudes 73° 51' 31.5" and 73° 42' 01.3"E. The present study was undertaken to study the following aspects of the Chapora estuary: Hydrodynamic modelling of flow dynamics; Numerical modelling of replenishment and recharge related aspects / issues of clusters - including dynamics of accretion and erosion; Hydrological study of the area under consideration; the diversity and abundance of phytoplankton, zooplankton and benthos in the study area; fish diversity; to evaluate the impact of sand extraction on the riverine ecology and biodiversity and to calculate the biodiversity index of the rivers.

The results of all the above aspects have been incorporated in the chapters of this report as baseline studies. The overall biological results suggest moderate to poor conditions considering the diversity indices. The overall survey also reveals that several parts of the estuary are impacted due to cumulative activities in the region. The lower reaches of the estuary show good growth of mangroves and the mangrove cover has doubled in couple of decades. Many riparian zones in the lower half of the Chapora have shown change in land use wherein paddy fields have been converted into saline marshlands and subsequently this area has proliferation of mangroves. The major reason for this is saline water intrusion due to tidal surges, flooding, and other anthropogenic activities such as sand extraction close to the banks as well as deterioration of embankment. The upper stretches of the river shows bank erosion and breaching of bunds, due to non-maintenance. Hence, the banks are vulnerable and may experience erosion in the future.

Considering the physical baseline parameters, modelling studies have been carried out. The Hydrodynamic Module is the basic computational component of the entire MIKE21 Flow Model FM modelling system. The MIKE 21 Flow Model FM is a modelling system based on a flexible mesh approach providing the hydrodynamic basis for the Sediment transport Module. The modelling system is based on the numerical solution of the two-dimensional shallow water equations i.e., depth-integrated incompressible Reynolds Averaged Navier-Stokes equations. The Sediment transport module calculates the resulting transport of non-cohesive materials based



on the flow conditions found in the hydrodynamic calculations. The model output consists of bed level changes, amongst other parameters. The comparisons of the current speed between Case 1 (present scenario) and Case 2 (scenario after mining) at each section A-G are also included. The comparisons of the bed level changes between Case 1 and Case 2 are presented in the morphology model results.

Following the results, all the anticipated impacts have been delineated along with the mitigation measures. A comprehensive Environmental Conservation & Management plan has been prepared covering all the aspects of sand extraction and its impacts. A monitoring plan also has been formulated to ensure that all the activities fall within the legal framework and the best practices in the industry. Following are the recommendations from the study:

- Considering the results of the baseline, Chapora estuary has been impacted by cumulative anthropogenic activities and natural riverine and coastal processes.
- These effects have changed the geo-morphology and bathymetry at many stretches of the river/estuary. Geomorphologic studies indicate, over the years sand extraction has caused many pits and deep gorges in the lease areas as well as outside the lease areas.
- The lower stretches of the estuary are influenced by higher salinity regime thus the adjacent banks have been protected by traditional embankments. These embankments allow the locals to carry out agriculture- predominantly paddy. These traditional embankments consistently face the problem of saline water intrusion and require continuous repair and maintenance, which has not been carried.
- Salinity intrusion has changed the land use, converting many paddy fields and riparian zones and mudflats into mangrove areas.
- The upper stretches of river banks have experienced bank erosion at many locations and many more areas are vulnerable and are prone to bank erosion.
- Based on the SSMG (2016) & Hon'ble NGT recommendations, certain areas in the stretches of the river have been demarcated where sand extraction from the river bed cannot be carried out. These sites identified as sensitivities include islands, bridges- piers, embankments, eroded and erosion prone banks, ecological sensitive areas viz; mangroves.



- In the Chapora estuary the bed level changes for the post-mining scenario are mostly around -0.15 m to 0.15 m. The changes in bed morphology in the post-mining scenario at different sections of the river are highly dynamic and patchy in nature.
- The difference between the pre- and post-monsoon seismic data did not show major significant changes in the depth across the Chapora river except in few regions where the local depositions are seen with a maximum depth difference of ~0.3-0.4 m. In few regions localized changes in the river bed morphology and spatial adjustment of sand bar are observed.
- No sand is available in upper stretches of the Chapora estuaries, which is non saline region of the estuary. While majority of sand deposits are in the salinity influenced areas.
- The stretches, which have low sensitivities, can be considered for sand extraction while following the national statutory and legal guidelines. While recommending the lease areas, the authority shall conduct a reconnaissance site survey and a consultative discussion with the stakeholders and accordingly work out areas that do not have conflict of interest.
- Once the lease areas are issued, the delineated “Environmental Conservation and Management Plan” needs implementation. The plan also describes the team/committee, which should be capable to address, execute and monitor all the aspects of the plan. Furthermore, the team/committee should appoint sub-teams, SHG’s, Village committees on requirement basis as per the plan.



CHAPTER 1- INTRODUCTION

1.1. Sand Mining Scenario in the State of Goa

Sand is available in three forms in the State of Goa. They are ordinary sand, silica sand and beach sand. Ordinary sand is brought by the river originating in general from Western Ghats and flows west and joins Arabian Sea. The process of weathering helps deposition of sand. Sand is collected mainly from the river Mandovi, Zuari, Terekhol Chapora and its tributaries. On upstream the sand is collected manually, screened and supplied directly. Where the water column is more the sand extraction is done with the help of canoes and bucket attached to bamboos. Sand is used in making concrete in construction activity.

The extraction of Sand is a traditional activity being carried out in Goa prior to Portuguese regime. The extraction was manually carried out and there are communities who are dependent on sand extraction for livelihood. Post Portuguese regime Goa, Daman and Diu Minor Minerals Extraction and Removal Rules, 1974 were in force and thereafter the Goa Minor Mineral Concession Rules, 1985 were notified. In the year 1979 various references are available in the Form of Application from traditional extractors, letters from cart owners, village Panchayat of Camurlim.

The extraction of sand from the rivers beds in Goa is governed by the Goa Minor Mineral Concession Rules, 1985 and permission were being granted on yearly basis. However after the CRZ Notification dated 6th January 2011, no permission for sand extraction was granted after 2011-2012 onwards as it was declared a non-permissible activity in CRZ. Subsequently some States including Karnataka requested to Ministry of Environment & Forests, Government of India for permission for removal of sand bars naturally formed in rivers by manual methods by traditional communities and an Office Memorandum dated 08/11/2011 of the Dy. Director, Ministry of Environment and Forest was issued which carved out an exception to the CRZ notification. In order to facilitate the grant of sand permits in Goa the State Government has constituted two District Committees under the Chairmanship of the respective District Collectors to deal with the grant of permit for extraction of sand. The said committees are notified in the Official Gazette Series II no. 37 dated 13th December, 2012. Based on studies conducted by the Committees certain zones/stretched were identified in Terekhol, Chapora, Mandovi, in North



Goa and Dudhsagar, Ragada, Kushavati, Ugvem, Zuari and Sal River in South Goa wherein manual extraction by traditional communities could be permitted. Prior Environment Clearance was obtained by the respective District Collectors vide 3-181-2010/STA-DIR/159 dated 01/10/2015, 3-181-2010/STA-DIR/158 dated 01/10/2015 and 3-181-2010/STA-DIR/184 dated 14/12/2015 from the Goa State Environment Impact Assessment Authority.. As per letter no. 39/8/13-MAG/DC-Sand-Ext-NG/9486 dated 04/12/2015 received from District Magistrate, North Goa it was formed that in its meeting held on 02/12/2015 it was unanimously decided that Directorate of Mines & Geology can issue the permission/permits for extraction of sand by local communities by traditional method. Similar decision was recorded in the meeting held on 11/12/2015 by District Magistrate, South Goa. 458 Sand permits were issued by the Directorate starting 2015 onwards For the year 2017-18, 333 permits were renewed for the period 1M October 2017 to 31st May 2018. As per one of the condition in the EC, Sand Extraction is banned from 1st June to 30th September due to monsoon, the sand permit holders for the year 2017-18 are being assessed for payment of royalty and non-filling of monthly returns which is a violation of Goa MMCR. Recovery is being carried and penalties imposed as per rules. On 3rd May 2018 a PIL Writ petition (14 of 2018) was filed in Hon'ble High Court of Bombay at Goa by Federation of Rainbow Warriors regarding Sand Extraction in Goa. Subsequently as per High Court Order dated 3rd October 2018 the learned Advocate General submitted that the State is in the process of examining various conditions and permits will be renewed/ granted after consideration of the same. However as per para 9 of the High Court Order dated 23rd October 2018 the Hon'ble Court has not passed any restraint order against issuance of permits. Further affidavit was filed by the State Environment Impact Assessment Authority (SEIAA) on 31/10/2018, wherein at para no. 4 of the Hon'ble High Court's order various lacunae's are pointed out and has made further observation. Subsequently a note is forwarded to the office of the Learned Advocate General for seeking extension of the time cited in the order of Hon'ble High Court dated 31 October 2018 for the State Government to take a decision on renewal of sand permits as well as seeking modification of the order as approved by the State Government. A MCA application is filled before Hon'ble High Court seeking a time frame of 8 weeks as Directorate of Environment is in process of finalizing the studies to be conducted as required under Sustainable Sand Mining management Guidelines 2016 and MOEFF notification no So. 141(E) and Directorate of Mines and Geology are working out modalities such stacking point of sand, installation of weigh bridges, etc.



Subsequently, In Order dated 4th April 2019, Eight weeks were granted to State Government to decide on renewal of sand permits. Directorate of Environment has decided to incorporate Environment Management Plan for individual cluster in order to capture all possible externalities before renewal of the permits. A proposal for Environmental Management plan is sent for cabinet approval. Hon'ble High Court gave its Judgment in PIL WP No. 14 of 2018 on 18th December 2019. The studies as far as sustainable sand mining as per guidelines of 2016 and MOEF Notification, the Environment Department accorded the work to NIO, Dona Paula. This report presents the EIA/EMP and modelling studies for the sand mining cluster in the Chapora estuary.

1.2 Chapora Estuary

Chapora Estuary is part of the nine major rivers flowing from the east (Western Ghats) to the west (Arabian Sea) in the north of Goa. It is located between the latitudes (15° 42' 42.3" and 15° 35' 53.1" N) and longitudes (73° 51' 31.5" and 73° 42' 01.3" E). The river originates from Sahyadri Mountains in Chandgad Taluka of Kolhapur District, Maharashtra, is known as Tilari River in the up-streams, and enters into Goa where it is popularly known as Chapora. The total flowing distance of the river is 32 km in the State of Goa. The total basin area of the Chapora Estuary is 255 Sq. km and average runoff of 588. 4 MCM (Million cubic meters). Sal, Kalana Virnoda and Parshe are the tributaries of the Chapora Estuary. The NGT / CPCB have declared this stretch of the river between Alorna Fort (Pernem Taluka) and Morjim as a polluted stretch.

Monitoring by GSPCB is carried out on a monthly basis throughout the year under National Water quality Monitoring Programme (NWMP) conducted by Central Pollution Control Board Programme. This stretch of the River Chapora between Morjim and Alorna fort (Pernem Taluka) is classified as SW II (for bathing, water sports and commercial fishing). Central Pollution Control Board (CPCB) has classified Chapora Estuary (Stretch from Morjim to Pernem 32 km) under Priority V, having BOD level range between 3.5 -5.2 mg/lit.

The saline stretch of the river is about 32 km in the State of Goa. Along the 32 km saline stretch of Chapora Estuary, Mangroves are observed in 90 hectares (2001) as per the NIO study of 2013 and the EIA study of NIO of 2018 mangrove forest observed in area of 220 hectares (2018) which indicates that the mangrove forest have doubled in the period of 20 years with the highest density at Camurlim and Tuem villages. Thus the overall forest cover shows increase but with the



replacement of terrestrial vegetation by mangrove forest (wherein the areas might be different). It was also observed during the physical survey that there are extensive coconut orchards /plantation along both the bank of the River.

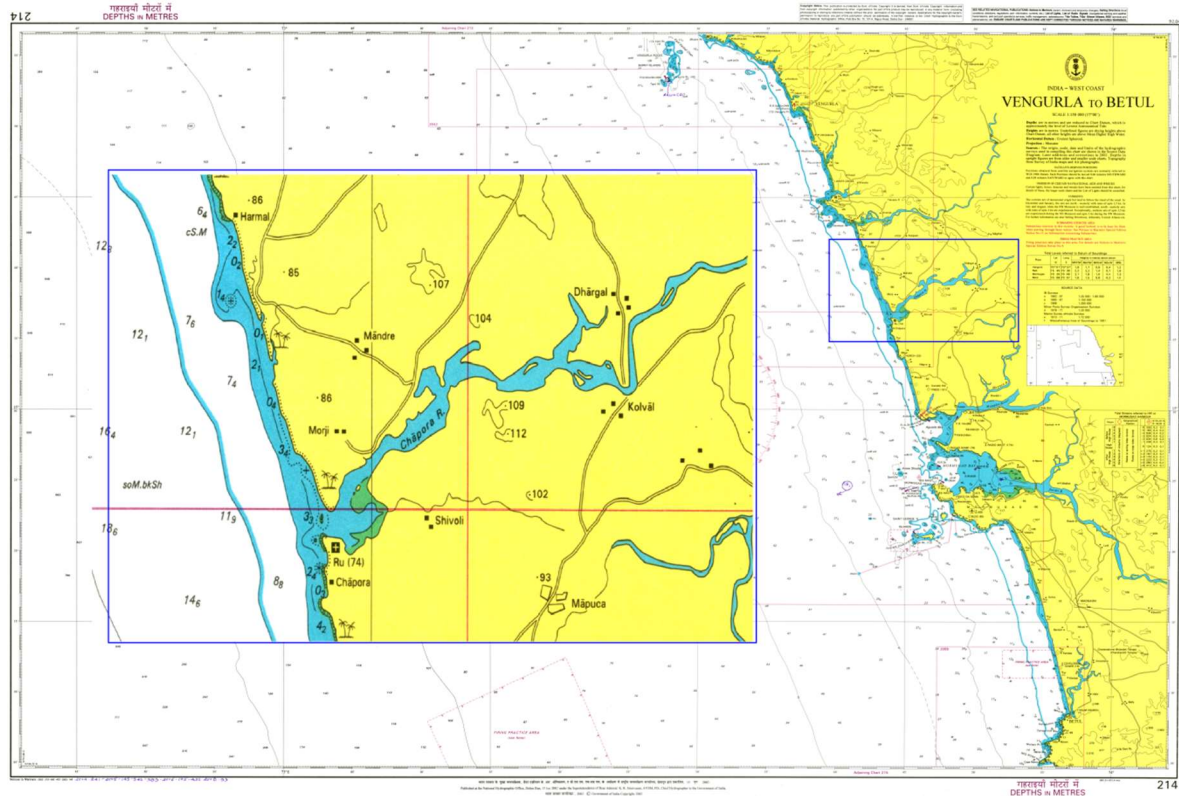


Figure 1.1 Hydrographic Map of Goa. Insight zoom area of Chapora Estuary



CHAPTER 2-METHODOLOGY:

2.1 Measurements of Physical Parameters

Currents: Current measurement was carried out at location CR1 (15°38'58.3" N; 73°50'05.4" E) near Colvale at Chapora Estuary during February-March, 2020 and September-October, 2020. The water depths at the measuring point were 8.5m and 9m at the time of pre-monsoon and monsoon deployment respectively. The Current meter was placed at mid-water depth.

Water level: Water levels were measured at three different locations. Water level was measured near Colvale (15°38'58.3" N; 73°50'05.4" E) (CR1) at Chapora Estuary during February-March, 2020. Water levels were measured at Colvale bridge (15°38'57"N; 73°50'11"E) (CR2) during March-April, September-October, 2020 and (15°36'31"N; 73°44'19"E) (CR3) Chapora jetty at Chapora Estuary for a month during March-April, 2020. Also, water level was measured at a location near Dumacem (15°41'22.9"N 73°54'46.6"E) during September-October, 2020.

River Discharge: The data obtained from secondary sources (Department of Water Resources, Government of Goa and Lina et al. (2018)).

Rainfall: Pernem is the nearest IMD observatory to the Chapora Estuary. Pernem rainfall station data is obtained from IMD. The average annual rainfall (2010-2019) over Pernem, North Goa, is about 3546 mm. The maximum precipitation occurs within June to September.

2.2 Sampling locations for water and sediment

Chapora Estuary was sampled in March 2020 (Figure 2.1). Total 15 locations were selected. Water and sediments were collected from central and peripheral region using standard instruments. Depth was approximately 8m at the central region. In this estuary, sandy silt was observed at central region and silty clay at the periphery of the region. Sampling stations were coded as CH A at the centre and CH B and C at the periphery (Table 2.1).

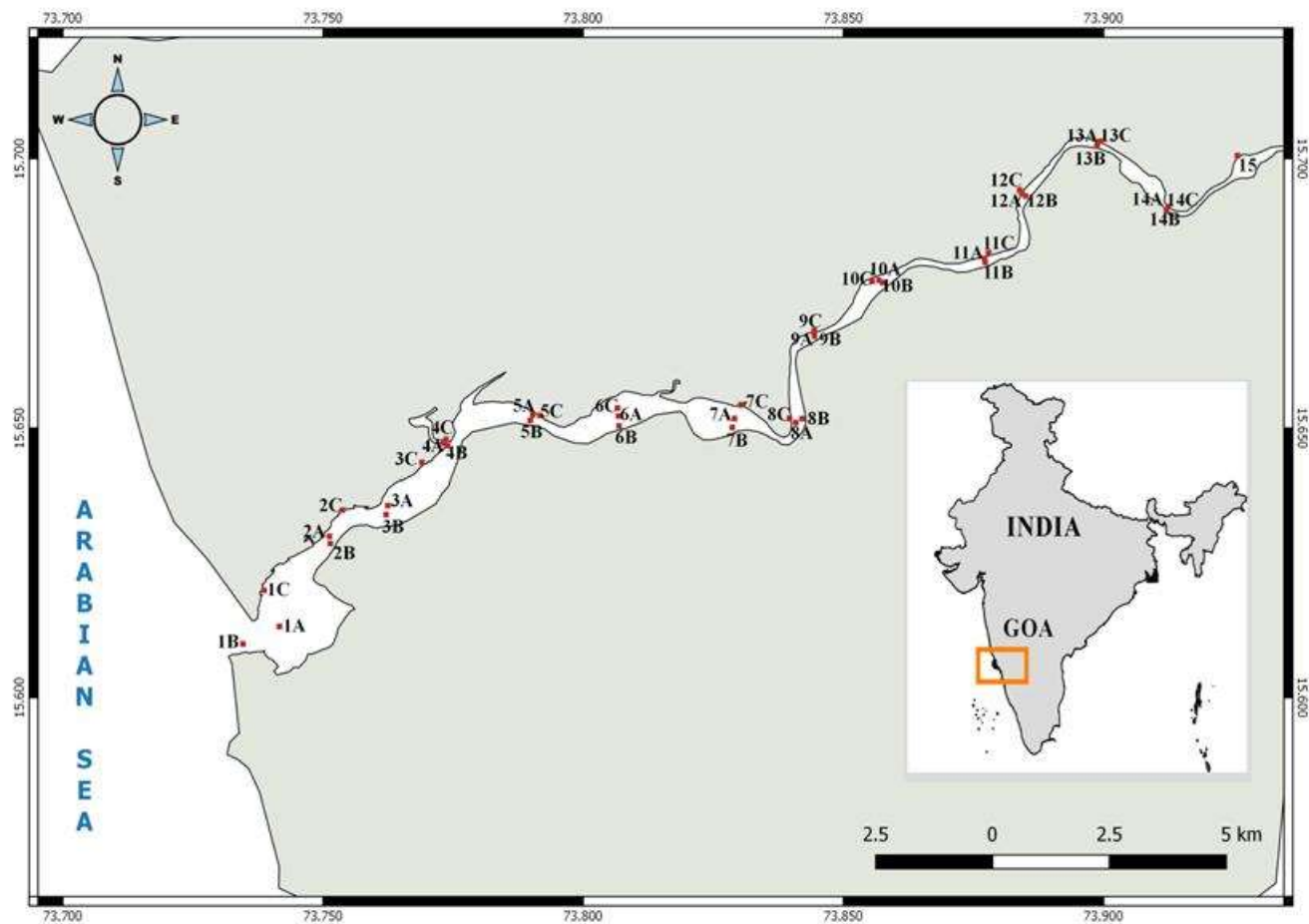


Figure 2.1: Map showing sampling stations of Chapora Estuary



Table 2.1: Coordinates, depth and sediment texture of Chapora Estuary				
Sampling station	Location		Depth (m)	Sediment texture
	Latitude (°N)	Longitude (°E)		
CH 01 A	15.60945	73.73512	6	Sand
CH 01 B	15.61268	73.74213	2	Sandy silt
CH 01 C	15.6194	73.73918	2	Silty sand
CH 02 A	15.62941	73.75174	4	Sandy
CH 02 B	15.62809	73.75191	2	Sandy
CH 02 C	15.63428	73.75425	2	Silty clay
CH 03 A	15.63541	73.76296	3	Silty sand
CH 03 B	15.63344	73.76263	0	Sandy silt
CH 03 C	15.64313	73.76951	0	Sandy silt
CH 04 A	15.64623	73.77446	8	Silty sand
CH 04 B	15.64741	73.77415	0	Silty clay
CH 04 C	15.64672	73.77374	0	Silty clay
CH 05 A	15.65193	73.79079	7	Sandy
CH 05 B	15.65089	73.79034	5	Sand
CH 05 C	15.65185	73.79217	0.5	Silt
CH 06 A	15.65176	73.8073	3	Sandy silt
CH 06 B	15.64941	73.8074	0.5	Clay
CH 06 C	15.65324	73.80711	1	Silt
CH 07 A	15.65128	73.82957	2	Clay silt
CH 07 B	15.64964	73.82914	0.5	Clay
CH 07 C	15.65382	73.83078	1	Clay
CH 08 A	15.65051	73.84137	4	Clay silt
CH 08 B	15.65125	73.84258	1.5	Clay
CH 08 C	15.65131	73.84017	6	Sandy



CH 09 A	15.66716	73.84493	8	Courser sand
CH 09 B	15.66655	73.84494	6	Clay silt
CH 09 C	15.66759	73.84491	6	Silty clay
CH 10 A	15.67693	73.85734	4	Sandy
CH 10 B	15.67673	73.85601	0	Silty
CH 10 C	15.6765	73.85805	0	Clayey silt
CH 11 A	15.68096	73.87763	6.5	Silty sand
CH 11 B	15.68206	73.87842	0	Silty clayey
CH 11 C	15.68028	73.87776	0	Silty clay
CH 12 A	15.69309	73.88482	8	Silty
CH 12 B	15.69369	73.88438	0	Silty clay
CH 12 C	15.6926	73.8855	0	Silty
CH 13 A	15.7025	73.89944	2.5	Gravel & pebbles
CH 13 B	15.70273	73.89989	3	Silty clay
CH 13 C	15.70273	73.89925	2	Silty clay
CH 14 A	15.67632	73.91286	2	Pebbles
CH 14 B	15.68989	73.91293	2	Silty clay
CH 14 C	15.69058	73.91263	2	Gravel sand
CH 15 A	15.70009	73.92625	1	Gravel & pebbles

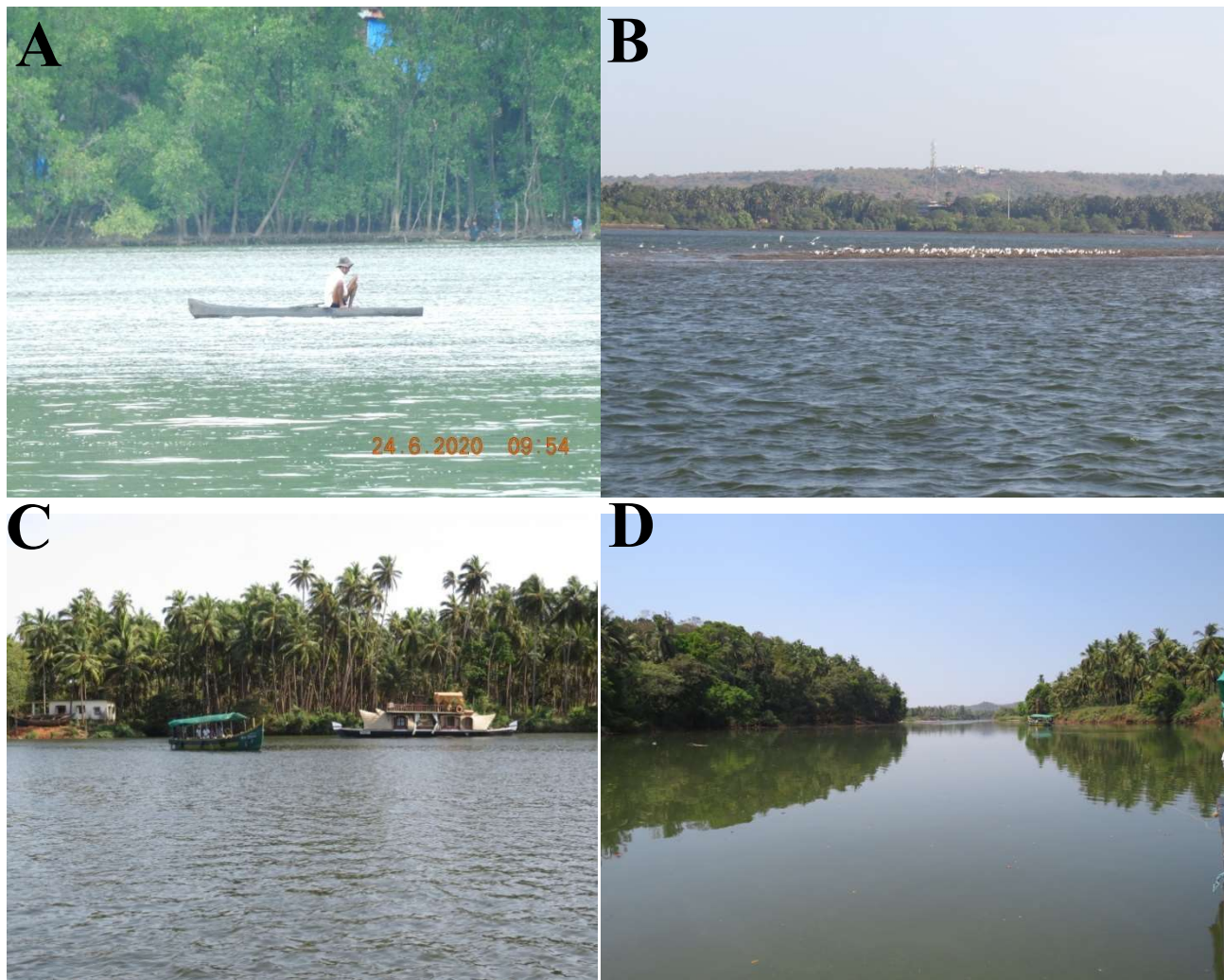


Plate 1: Study area - Chapora Estuary (A- Artisanal fishing in Chapora estuary; B- Mouth region showing exposed sand flat in the estuary; C- Tourism activity in middle stretches of the estuary; D- Upstream region of the estuary.)



CHAPTER 3- PHYSICO-CHEMICAL AND BIOLOGICAL PARAMETERS:

All sampling sites were sampled using trawler/boat/dinghy. Both biological and hydrological parameters were collected and processed following standard protocol. Hydrological parameters were addressed using standard sensors mounted onto a CTD. Sampling and processing procedure of biological parameters is briefly mentioned below (Figure 3.1).

3.1 Phytoplankton:

Sub-samples of water collected from different depths using Niskin sampler (1L) were fixed with 2% Lugol's iodine and preserved in 3% formaldehyde solution and stored in dark at room temperature until analysis. These samples were concentrated to 20ml using a siphoning tube (fitted with 10micron mesh). After settling and siphoning procedure, 1 ml of concentrated sample were taken in a Sedgwick-Rafter counting cell for enumeration and identification of phytoplankton to the genus/species level. The total number of phytoplankton cells present in a litre of water sample was calculated using appropriate formula.

The data for the phytoplankton analyzed using MS-Excel package. Excel is used for density and correction based on graphical representation. Attempts were made to estimate the natural variability of phytoplankton especially that of diatoms and dinoflagellates, in surface and bottom water.

3.2 Chlorophyll & Phaeophytin:

A known volume of water sample (1L) were used to measure the concentration of chl-a, and phaeophytin. Samples were filtered through Whatman GF/F (nominal pore size 0.7 μ m) under low vacuum. The chlorophyll pigments were extracted for 24 hours in 10ml of 90% acetone in the dark in a refrigerator. Samples were brought to room temperature and measured using a fluorometer.

3.3 Zooplankton:

Meso-zooplankton were collected with Heron Tranter Net (HT net) having mouth area 0.25 m² and mesh size 200 μ m towed horizontally just below the surface for a duration of ~1.5 knots. The



net were fitted with a calibrated flow meter to quantify the volume of water filtered. Zooplankton biomass was measured volumetrically after removing large detritus following which samples were preserved in 4% formaldehyde. In the laboratory, zooplankton samples were divided according to their density by using a Folsom splitter obtaining representative sub-sample containing not less than 300 individuals. The density of individuals were enumerated and identified (species/genus level) with the help of literature.

3.4 Meibenthos:

Sediment samples were collected from 45 sampling stations from Chapora Estuary. Sampling was carried out on a mechanized boat in March 2020 using an acrylic core of 4.5 cm in diameter. The sampling stations were represented as CHA, CHB, and CHC respectively. CHA stations were located at the centre of the river where there is extraction of sand and CHB and CHC at the periphery of the river where there are mangroves and other sensitive areas. Among all stations, 39 stations with duplicate sample had taken but in six samples (CH13A, CH14A, CH14C, CH15A, CH15B, and CH15C) were not collected due to hard substratum. All samples were preserved in 10% formalin mixed with rose-Bengal formalin solution and stored in polythene bags.

3.5 Foraminifera:

The top 2 cm of the sediments were scrapped from the river bed for foraminiferal studies. Half the sediment was immediately stained with ethanol rose-Bengal solution (2 g rose-Bengal in 1 L of 70% ethanol) to preserve living benthic foraminifera. Other half was stored in plastic containers. The stained sediments were processed for picking foraminifera. The volume of the sediment was measured and the wet sediments were poured on a 63 μ m size sieve. The sediments were gently washed and the material retained on the sieve (>63 μ m, coarse fraction or sand) was dried and stored in plastic containers. An appropriate aliquot of the coarse fraction was taken after coning and quartering. As the foraminiferal abundance was very low, a maximum of 1.5 g of the coarse fraction was taken to pick foraminifera. The coarse fraction taken for picking was weighed and all intact living and dead benthic foraminifera were picked.

3.6 Macro benthos:

A total of 45 stations were sampled for benthic study. The sampling stations were represented as CHA, CHB and CHC respectively. Sampling was carried out on a mechanised boat in March 2020



using a Van veen grab (0.0418m^2) for the central stations and metal Quadrant (0.0625 m^2) at the periphery of the river. All the sediment samples were washed through a $300\mu\text{m}$ nylon mesh in the field and then transferred to polythene bags and preserved in 10% formaldehyde containing Rose Bengal stain. CHA stations were located at the centre of the river where there is extraction of sand and CHB and CHC at the periphery of the river where there are mangroves and other sensitive areas. However, sediment samples were recovered only from 38 locations. Sediment could not be retrieved from station CH3A, CH5C, CH13A, CH14A and station CH15 due to hard/rocky substratum. The sand texture at central region was observed mainly sandy whereas as at the periphery it was more silty clayey. Details of the sampling locations are provided (Table 2.1).

Laboratory analysis:

In the laboratory, all samples of meiobenthos were sieved thoroughly on 0.3 mm to remove large fauna (macrofauna) and then 0.04 mm sized mesh sieve for smaller fauna (meiofauna). The fauna retained on 0.04 mm mesh were considered as meiofauna which was collected in beaker and preserved in 5% buffered formalin. The fauna was enumerated and identified up to the group level under the stereo-zoom microscope (Leica) using the guide Introduction to study of meiofauna (Robert P. Higgins et.al, 1988).

In the laboratory, all the sediment samples of macrobenthos were again washed on a $300\mu\text{m}$ sieve. All the fauna were sorted and preserved in plastic vials containing 5% formaldehyde. The fauna was enumerated and identified up to the family/genus level under the stereo microscope (Olympus SZX10). Faunal abundance was calculated as individual No/ m^2 . Polychaetes were identified to the highest taxonomic level using available identification keys (Fauvel, 1953; Fauchald, 1977; Day, 1967; <http://www.marinespecies.org/>). Abundance of other fauna such as Oligochaeta, Crustacean, Bivalvia, Gastropoda, Ophiuroidea, Platyhelminthes, Nemertea, Sipuncula, Nematoda, Hydroides, Phoronida, Chaetognatha, Fish juveniles were recorded group-wise. Station wise biomass (Wet weight) was done and expressed as g/m^2 .



Figure 3.1: Sample collection of Chapora Estuary

3.7 Diversity indices:

All the raw data was initially processed using Microsoft Excel. Further processing of the ecological data was done using the PRIMER (Plymouth Routine in Multivariate Ecological Research) software package (Clarke and Warwick, 1994) after square root transformation. The univariate as measures such as number of individuals or specimens (N), number of species (S), total abundance (A), Shannon- Wiener diversity index (H'), Margalef species richness (d), Pielou's evenness (J') and Simpson index ($1-\lambda'$) were calculated using log2 scale at each station (Clarke & Gorley, 2001).

2.10 Biotic indices:

Biotic indices are developed based on indicator species, used as a guide to the level of a particular abiotic factor. For example, the presence of certain invertebrate groups in aquatic ecosystem can be awarded a score that indicates the quality of the water. Such indices like the AZTI Marine Biotic Index (AMBI), Multivariate AMBI (M-AMBI), Bentix index are specialized case of a diversity



index generally considered an important means for assessment of water-pollution, and ecosystem stability.

3.7.1 AMBI index:

The AZTI Marine Biotic Index (AMBI) is software developed by AZTI-Tecnalia for assessing the quality of benthic macro-invertebrates assemblages by calculating the homonymous index. It was developed in order to establish the ecological quality of European coasts and estuaries. This index explores the response of soft-bottom communities to natural and man-induced changes in water quality, integrating long-term environmental conditions. AZTI Marine Biotic Index (AMBI) relies on the calculation of the biotic coefficient (BC), which is based in turn on the proportion of disturbance-sensitive taxa and is expressed on a continuous scale ranging from 0 (best status) to 6 (worst status). The AMBI approach follows a model (Glémarec & Hily, 1981; Grall & Glémarec, 1997) which categorises benthic invertebrates into five ecological groups (EGs), depending on their dominance along a gradient of organic enrichment and oxygen depletion. The software includes near 8.000 taxa from all seas, representative of the most important soft-bottom communities presents at estuarine and coastal systems, from the North Sea to the Mediterranean, North and South America, Asia, etc.

3.7.2 M-AMBI index:

M-AMBI ('Multivariate AMBI', Bald et al., 2005; Muxika et al., 2007) is a multimetric index for assessing the ecological quality status of marine and transitional waters. It is based on benthic macro invertebrates and integrates AMBI, a biotic index based on species sensitivity/tolerance, with diversity and richness, making it compliant with the European Water Framework Directive. It adopts a multivariate (trivariate) approach, integrating the response of three selected metrics, i.e. species richness, the Shannon diversity index (Shannon & Weaver, 1949) and the biotic index AMBI (Borja et al., 2000). The success of AMBI paved the way for the introduction of M-AMBI, which was subsequently incorporated into the regulations of several European countries. The M-AMBI algorithm integrates the metrics by means of factor analysis (FA).

3.7.3 BENTIX index:

The Bentix index (Simboura and Zenetos, 2002) is a marine biotic index based on the concept of indicator species and was developed for the purpose of the ecological status classification of the



marine environment using the macro invertebrates quality element. The index is designed for the assessment of the impact caused by general stress factors and does not discriminate among natural and anthropogenic disturbance. It has been tested successfully in a variety of Hellenic benthic ecosystems (Simboura and Zenetos, 2002) and in case areas subject to organic pollution such as the Athens or Saronikos gulf (Simboura et al., 2005), to oil spills accidents (Zenetos et al., 2004) and is currently tested in other Mediterranean areas within the framework of the EU Water Framework Directive intercalibration exercise (EC, 2003).

3.7.4 AMBI and M-AMBI index:

AMBI relies on the abundance-weighted average disturbance sensitivity of the macrobenthic species in a sample (Borja et al., 2000). Each species were distributed in five ecological groups (EG) as per their sensitivity to an increasing stress gradient as summarized by AZTI's classification (Grall and Glémarec 1997).

EG I: species sensitive to organic enrichment and present only under unpolluted conditions.

EG II: species indifferent to enrichment, present in low densities with non-significant variations.

EG III: species tolerant to high organic matter enrichment.

EG IV: second-order opportunistic species.

EG V: first-order opportunistic species, able to withstand high disturbance.

The index calculation was done by the software provided at AZTI's software, following the guidelines of Borja and Muxika (2005). The index generates a final score on a continuous scale from 1 to 6 (7 in azoic sediments) and the thresholds used to define benthic community health were <1.2 (undisturbed), 1.2–3.3 (slightly disturbed), 3.3–5 (moderately disturbed), 5–6 (heavily disturbed) and >6 (extremely disturbed) (Borja et al., 2000) which were then condensed to a high, good, moderate, poor and bad status respectively. The multivariate AMBI (M-AMBI) combines with AMBI values in a factor analysis multivariate approach (Table 2).



3.7.8 BENTIX Index (Simboura and Zenetos 2002):

BENTIX considers sensitive (GS) and tolerant (GT) taxa based on the reduction of five EG's (as per AMBI) to two EG's, i.e. EG-I, II as EG-I and EG-III,-IV,-V as EG-II for BENTIX. For BENTIX computation, a newly developed add-in BENTIX v.09 (beta version) software package was used.

Table 3.1: Threshold limits used for ecological status of AMBI and M-AMBI index		
	AMBI	M-AMBI
High	0.0-1.2	>0.77
Good	1.2-3.3	0.53-0.77
Moderate	3.3-5.0	0.35-0.53
Poor	5.0-6.0	0.20-0.38
Bad	6.0-7.0	<0.2

4. LULC map:

LISS IV data was used for the purpose of classification of Land use Land Cover for the study area. The LISS-4 (Linear Imaging Self-Scanning Sensor-4) multispectral high-resolution camera is the prime instrument of Resourcesat satellite series, with a spatial resolution of 5.8 m and a swath of 70 km.

The study area comprised of the sub scene (A) of path and row 96 and 62 respectively of the LISS IV data. The Red (Band 2, 0.62-0.68), Green (Band 3, 0.52-0.59) and Infrared Red (Band 4, 0.77-0.86) bands were used to prepare the false colour composite for the area.

The land use and land cover for an area of 500 meters around the Chapora Estuary was extracted from the imagery with the help of object oriented classification of the data where a group of pixels were identified as features with the help of factors such as Shape, Texture, Tone, and spatial relation between the surrounding pixels. All the LULC maps of Chapora Estuary were prepared by using ArcGIS.



CHAPTER 4: RESULT:

4.1 Physico-chemical parameters

Total 14 stations were sampled in Chapora Estuary. Salinity varied from 0.2 to 28.8psu. It showed high at station CH3A (28.8psu) and CH4A (28.3). pH range varies from 7.2 to 7.9. Total suspended matter (TSM) showed high at two stations i.e CH3A (16.3mg/L) and CH4A (16.3mg/L) and low at CH12A (4.3mg/L). Total dissolved solid (TDS) was high at CH3A (21.29ppt) and low at CH10A (4.6ppt) respectively (Table 4.1). TSM and TDS showed similar trend from station CH1A to CH14A (Figure 4.1).

Table 4.1: Chemical parameters of Chapora Estuary				
Stations	Salinity (psu)	pH	TSM (mg/L)	TDS (ppt)
CH1A	24.5	7.9	12.1	18.8
CH2A	23.9	7.8	12.4	18.35
CH3A	28.8	7.9	16.3	21.29
CH4A	28.3	7.9	16.3	19.8
CH5A	17.5	7.7	9.9	13.88
CH6A	15.1	7.6	8.3	12.1
CH7A	14.2	7.6	7.9	11.76
CH8A	13.0	7.6	6.7	10.18
CH9A	11.2	7.4	7.1	9.03
CH10A	5.6	7.2	5.2	4.6
CH11A	3.4	7.2	4.9	3.09
CH12A	2.0	7.2	4.3	1.91
CH13A	1.8	7.3	5.0	1.63
CH14A	0.2	7.2	9.5	10

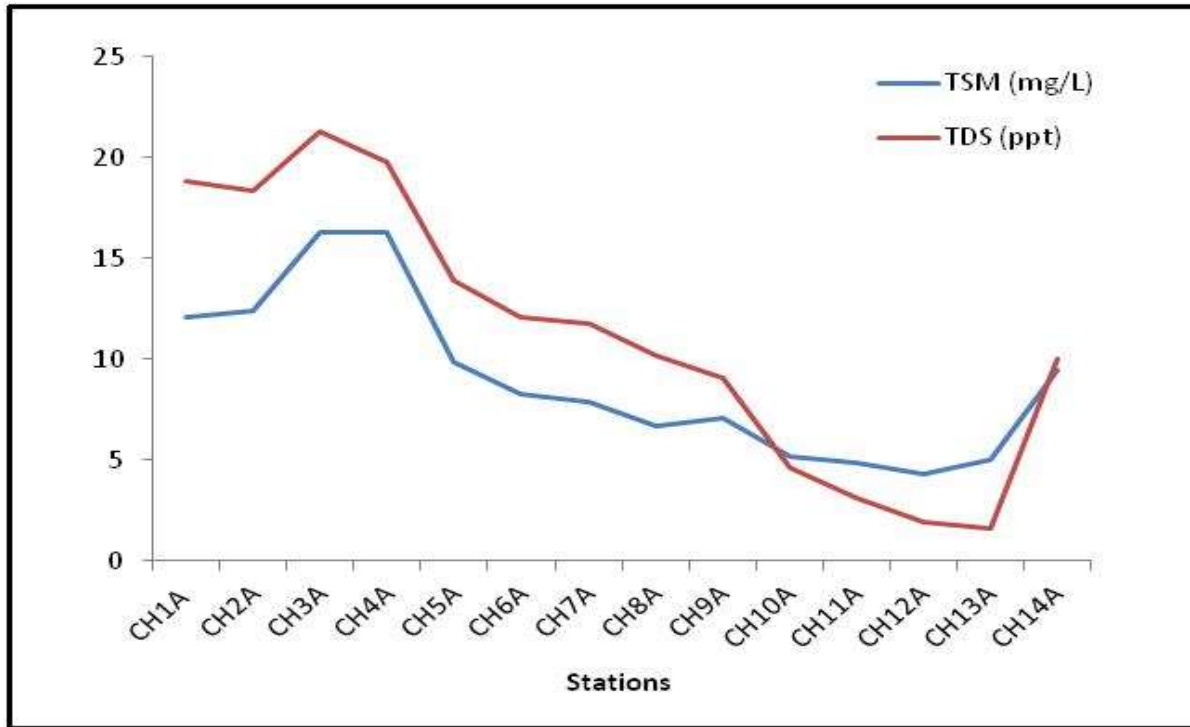


Figure 4.1: Graph depicting TSM and TDS of Chapora Estuary

4.2 Temperature and Salinity

The average depth of the Chapora Estuary was found to vary between 2 and 10m (avg. 5m). River being influenced by the tidal currents, hydrographic variations are thus known to vary accordingly, controlling the temperature and salinity variation, the high temperature during high water level. In general, salinity variations were much larger (0.7-32 PSU) than that of temperature (27.0°C- 29.5°C) (Figure 4.2). Though high saline was generally restricted to Zone-1 (st C1-C5), particularly below 2m water depth, influences of saltwater were found to penetrate even up to the station (C14; ~ 28kms inside). Beyond which river is mainly dominated by freshwater. This hydrographic feature characteristically divides the river into three zones, region under the influence of seawater (Zone 1; stn C1-C5), transitional zone (Zone 2; C6-C8/C9) and region influenced by the freshwater (Zone3; C10-C15)(Figure 4.2)

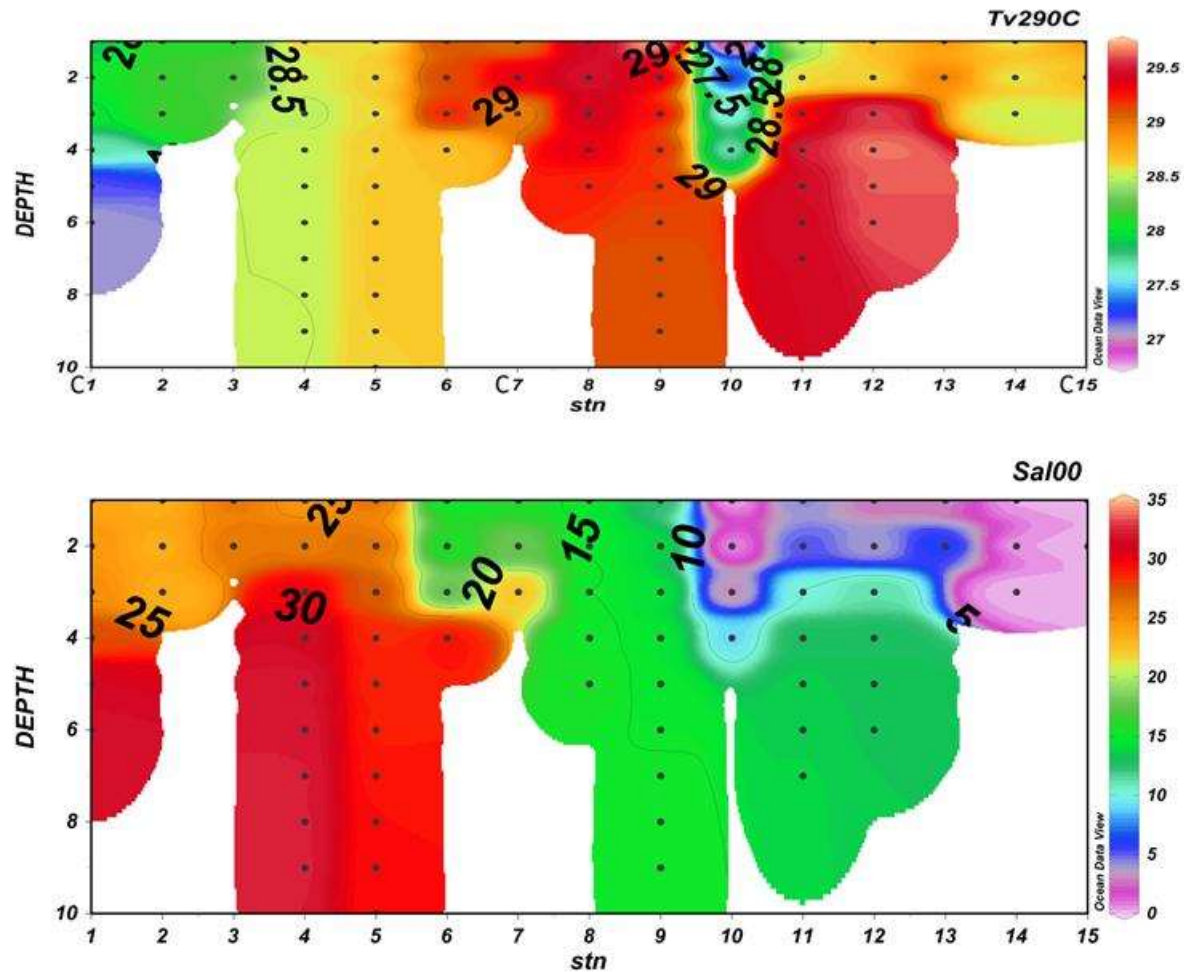


Figure 4.2: Spatial variations in (a) temperature (°C), b salinity (psu) in the Chapora Estuary.(C1-river mouth and C15-upstream region)

4.3 Dissolved Oxygen:

The study region to be well oxygenated (2.2-6.6 ml/L). However, spatially dissolved oxygen (DO, ml/L) (and nutrients, see below) found to decrease from mouth to the upstream region, especially at the subsurface, while DO showed an opposite, increasing trend at the surface (Fig.3). Low concentration (~2ml/L) observed at stn C12 has significant implications for nitrogen and carbon mediated by microbial processes (Fig. 4.3).

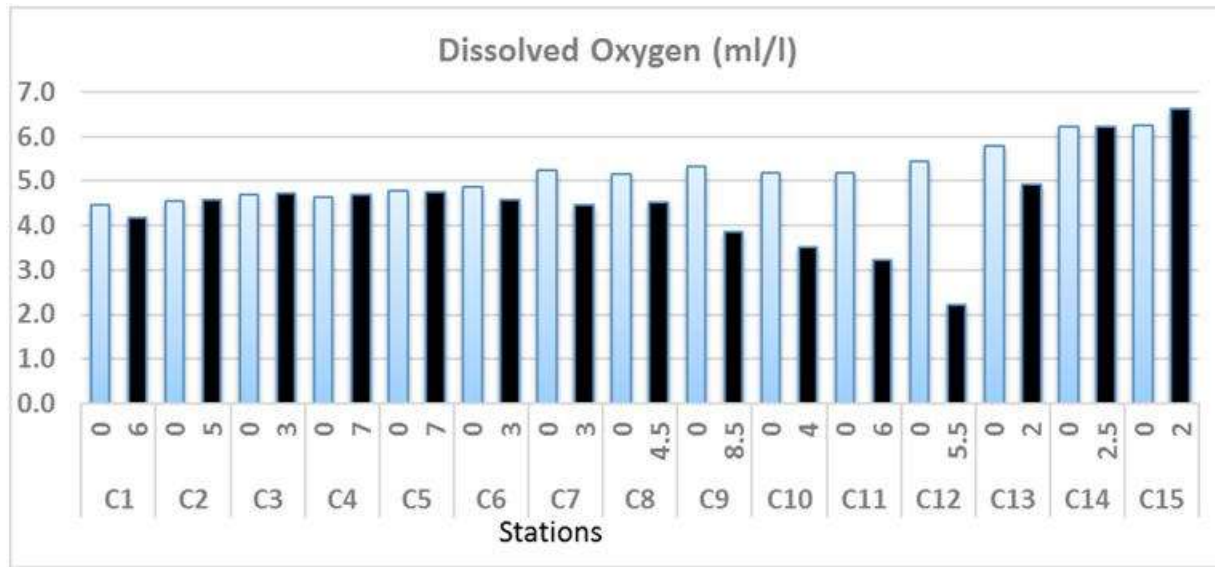


Figure 4.3: Spatial variations (surface and bottom) in dissolved oxygen in the Chapora Estuary.(C1-river mouth and C15-upstream region)

4.4 Nutrient concentration:

Phytoplankton needs nutrients to grow. They are like the fertilizers we add to land plants that are used to make proteins, nucleic acids, and other cell parts by the phytoplankton to survive and reproduce. The two most critical nutrients are nitrogen and phosphorous. In most cases, nitrogen runs out first, and the growth of phytoplankton stops.

Nutrient concentration in the Chapora Estuary estuary varied considerably from the mouth region to the upstream region. Nitrate (NO_3^-) was found to be very low ($0.03\text{--}0.5\mu\text{M}$) from mouth to mid-stream region and increased substantially further upstream to be the highest (Stn C15: $5.8\mu\text{M}$). Similarly, nitrite (NO_2^-) was very low ($0.02\text{--}0.23\mu\text{M}$) between the mouth and mid-stream region. But it attained maxima ($1.97\text{--}2.81\mu\text{M}$) just after stn C10 and then decreased further to $0.07\mu\text{M}$ near stn, C15. Contrary, phosphate (PO_4^{3-}) showed the opposite trend to nitrate. Highest PO_4^{3-} ($0.9\mu\text{M}$) was observed at the mouth region, which progressively decreased to $0.26\mu\text{M}$ in the mid-stream region and further to $0.06\mu\text{M}$ in the upstream region. Silicate (SiO_4^{4-}) showed a similar trend to NO_3^- . It increased from $27\mu\text{M}$ at the mouth region to $76\mu\text{M}$ in the mid-stream region and further to $112\mu\text{M}$ in the upstream region.

Rivers receive nutrients through run-off from terrestrial sources (agriculture fields, sewage discharge from human settlements), and benthic sources (underlying sediments). The above



nutrient concentrations and their trends are typically observed in the Goan rivers during the premonsoon season (February-May). Any massive resuspension of bottom sediments would significantly increase PO_4^{3-} and SiO_4^{4-} concentrations in the water column since sediment porewaters are extremely rich in these two nutrients. Consequently, it would distort the concentration gradient across the riverine length. But our observation neither showed any abnormally high concentration, not any irregular trend. Overall, all nutrients showed the expected levels and trends in the river well oxygenated (2.2-6.6 ml/L). However, spatially dissolved oxygen (DO, ml/L) (and nutrients, see below) found to decrease from mouth to the upstream region, especially at the subsurface, while DO showed an opposite, increasing trend at the surface (Figure 4.4). Low concentration (~ 2 ml/L) observed at stn C12 has significant implications for nitrogen and carbon mediated by microbial processes.

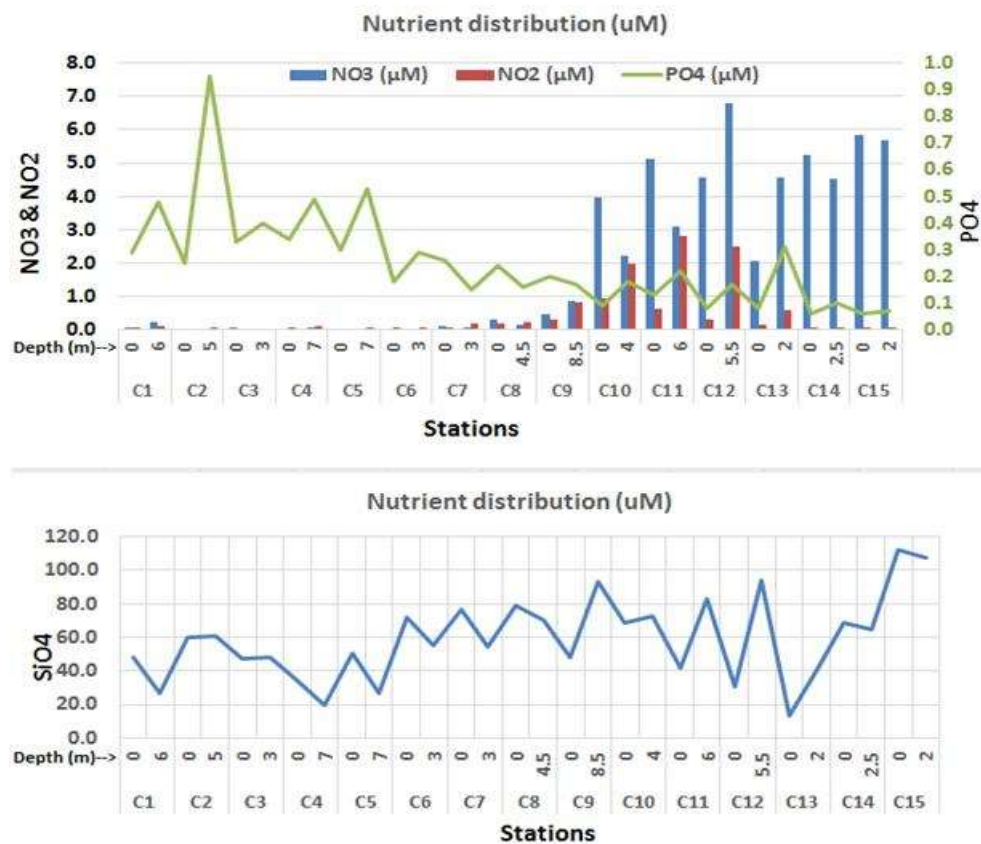


Figure 4.4: Spatial variations in (a) nitrate (NO_3), nitrite (NO_2) and phosphate (PO_4) and (b) silicate (SiO_4) in the Chapora Estuary.(C1-river mouth and C15-upstream region)

4.5 Biological parameters



Planktons are organisms that drift along with the water current. It constitutes both phytoplankton and zooplankton. Phytoplanktons are the primary producers of the aquatic environment and are an essential component of ecosystems functioning. Being the primary producers, they provide a range of ecosystem services from higher trophic levels to acting as a sink of CO₂. Various physico-chemical variables highly influence phytoplankton (and zooplankton, see below) abundance and composition. They are highly patchy both in space and time, reflecting the environmental status. Therefore, they are often accounted for in aquatic ecosystem management/mitigation processes.

4.5.1 Phytoplankton

Chlorophyll a: One of the most widely used proxies of phytoplankton (photosynthesizing microscopic organisms) biomass is the total chlorophyll-a concentration, which was measured following widely accepted fluorometric technique. Phytoplankton creates organic compounds that form the basis of oceanic/freshwater food web. Thus, phytoplankton pigment (chlorophyll a), together with the taxonomic composition of phytoplankton assemblages, was sampled from the entire stretch of the Chapora Estuary covering 15 sites along with mouth to the upstream. Since their production is governing minerals, nutrients such as nitrate, phosphate, and silicic acid were also simultaneously measured.

Phytoplankton biomass (Chl *a*; µg/L) also showed spatial variation that varied between 1.1 and 11.3 (avg. 3.4) with the highest concentration at the mid-stream region (Zone 2) particularly at stn C7. One of the upstream stations (stn C13) also recorded higher chlorophyll value at near bottom depth. (Figure 4.5).

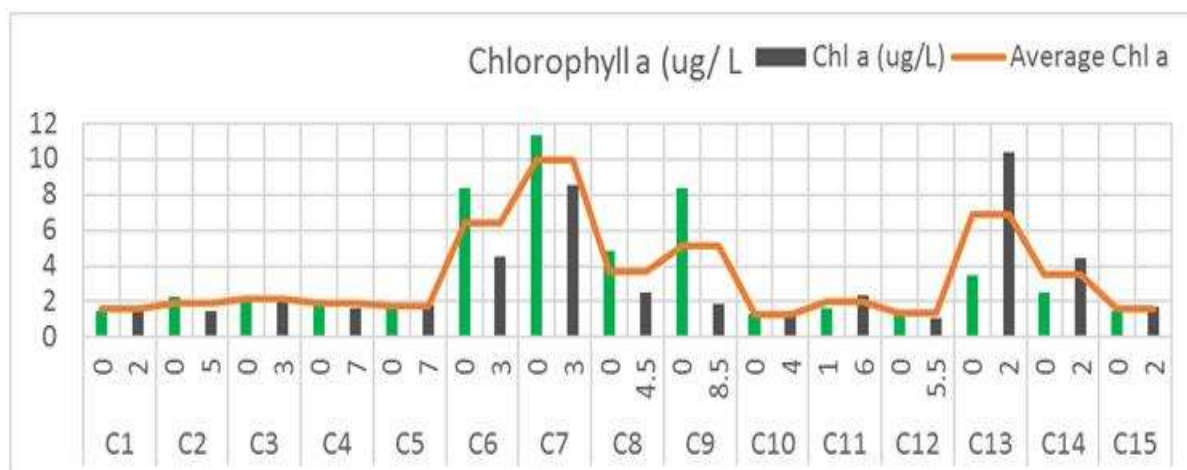


Figure 4.5: Spatial variations in Chlorophyll a (ug/L) in the Chapora Estuary.(C1-river mouth and C15-upstream region)

Species composition and abundance of phytoplankton

Phytoplankton composition and its numerical abundance studied from the Chapora estuary following microscopic technique (>10um in size) showed diverse forms. Phytoplankton represented by 94 genera were mainly comprised of diatoms (71 genera; centric: 35 & pennate: 36), while dinoflagellates were characterized by only 23 genera (Table 4.1).



Table 4.1: Depth wise and spatial variation of phytoplankton abundance, composition in the Chapora Estuary.

	Phytoplankton composition and abundance (Nos./L) [Surface (S) and Bottom (B)]																														
Stations	C1		C2		C3		C4		C5		C6		C7		C8		C9		C10		C11		C12		C13		C14		C15		
Depth	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	
DIATOM (Centric)																															
Agmenellum spp.																													0.60		
Aulacoseira spp.																			10.21	3.64	39.53	16.80	84.20	10.08	73.08	114.9	131.6	134.1	215.3	82.88	
Bacteriastrium spp.								0.18								0.78													0.31		
Bellerochea spp.	2.24	1.46	1.88	1.92	2.70	3.40				1.62	1.04	0.43	0.65																		
Cerataulina bicornis								0.54														6.56		8.16							
Cerataulina pelagica				0.48														0.48													
Cerataulina spp.			0.56				0.60	2.16	1.28	1.92	2.88	16.63	0.72	9.33						0.78		1.28									
Chaetoceros danicus	2.06	0.21		0.72					0.35	0.30	0.86	0.22						0.48													
Chaetoceros compressus							5.00	1.26																							
Chaetoceros decipiens	0.34	0.83		5.52	1.26	3.40			2.34	2.32	0.15										0.26		1.60								
Chaetoceros laevis					1.20		0.36	0.23	0.44	0.58	1.51					2.24	1.82					0.32									
Chaetoceros peruvianus				0.72							0.22																				
Chaetoceros subtilis		0.83	8.46	7.92	5.04	11.40			7.08	1.18	22.32	39.96	21.60	23.53	9.10	14.00	6.50	0.96	1.86	10.14	2.16	8.00									
Chaetoceros spp.	4.64	0.42	4.32					8.28			1.15																				
Corethron spp.					0.36						0.14																				
Cosmarium spp.																					1.30		7.00	0.72	1.80	2.08	6.72	3.90	8.74	9.24	
Coscinodiscus spp.				0.48	0.54	0.60		3.96	3.25	3.26		0.22		0.21	0.26	0.28				0.78				0.24							
Closterium spp														0.42					1.86	0.26	0.22	4.48		0.24							
Cyclotella spp.	4.64		5.45	0.96	1.62	0.80	0.20	2.34	0.81		0.14	1.08	0.24	0.85	1.04	2.80		0.24	0.70	3.90	0.65	5.92	2.00	4.32	0.72	1.04	0.56	0.90			
Dactyliosolen analarcticus											0.29																				
Dinobryon spp.																							0.80			0.52		1.20	0.31		
Ditylum spp.		0.21	1.13		0.18				0.35	0.59										0.26		0.32									
Euglena spp.																								0.40			0.26				
Gossleriella tropica	0.52																														
Guinardia delicatula																															
Guinardia flaccida					0.40				0.23			2.59					0.26														
Guinardia spp.			4.14	0.24		1.40	0.40	0.36	1.62	0.89					0.42	1.04	3.64	0.26			1.30										
Guinardia striata					0.18	1.40		0.72			1.15	6.05		0.42																	
Hemiaulus spp.			0.75	1.92	0.36				0.23	1.04	0.29	0.43																			
Leptocylindrus spp.			1.88		2.16	2.00	11.80	15.66	4.06	0.44	6.62	33.48		19.50	1.82	4.20	5.20	2.16	0.70	2.08											
Melosera granulata									10.09	3.40																					
melosera spp.				0.48				0.18																							
Odontella mobiliensis			1.32																												
Odontella sinensis					0.18																										
Odontella spp.	0.86			0.72	0.54	0.20		0.36		0.44	0.14				2.80																
Oocystis spp.																							0.20					0.30		0.28	
Oscillatoria																							0.20								
paralia Sulcata																				0.26											
Pediastrum spp.																													0.94	0.28	
Pseudoguinardia spp.						0.80		0.36																							
Rhizosolenia imbricata								0.18																							
Rhizosolenia pungens			4.70	1.92	6.66	0.80		0.36																							
Rhizosolenia setigera		1.66	5.64	9.60	8.10	6.20	1.00	0.90	2.55	1.48	5.04	7.99		7.42	1.56	7.84	6.50	0.72		4.42											
Rhizosolenia spp.																			0.23		3.68				0.26						
Scenedesmus spp.																			0.46				0.20	0.96		0.26	1.12			0.28	
Skeletonema spp.	9.98	1.66	9.78	20.40	1.80	6.00			3.25	3.40		11.88		3.39		5.60	5.46			2.34		2.08		1.20							
Staurastrum parastrum																				0.23											
Staurastrum Diacanthum																				1.16		0.22									
Staurastrum spp.														0.24						0.70		3.46	0.48	7.00		3.96	6.50	23.80	7.50	21.84	13.44
Stigonema spp.																														0.28	
Surirella busta											1.51																				
Surirella spp.				0.24	0.18				0.58	0.44		0.22		0.21	0.26	0.84	0.26				0.16		0.24								
Tetraedron spp.																										0.52		0.90	0.62	0.56	
Thalassiosira spp.		6.02	1.87	2.82	9.60	4.14	7.40	1.00	2.16	11.72	1.63	7.20	5.18	1.68	5.09	2.60	7.00	3.38	2.88		3.64	0.65				0.52					

[illegible]

Average phytoplankton abundance ($\times 10^3/\text{L}$) that varied within the water column from 61-235 (avg. 137 ± 61.9) showed spatial variation along the length of the estuary with higher population chiefly at the mid-stream region (Zone 2) and a few upstream locations of Zone-3 (stn. C13-C15) (Figure 8). Likewise, depth variation in its abundance was also noticed with higher abundances at the near bottom depth at most sampling sites. Amongst, diatoms were predominant forms of the phytoplankton community contributing $>50\%$ to its abundance compared to the dinoflagellates, which were relatively higher at the mid-stream region (Zone -2) (Figure 4.6).

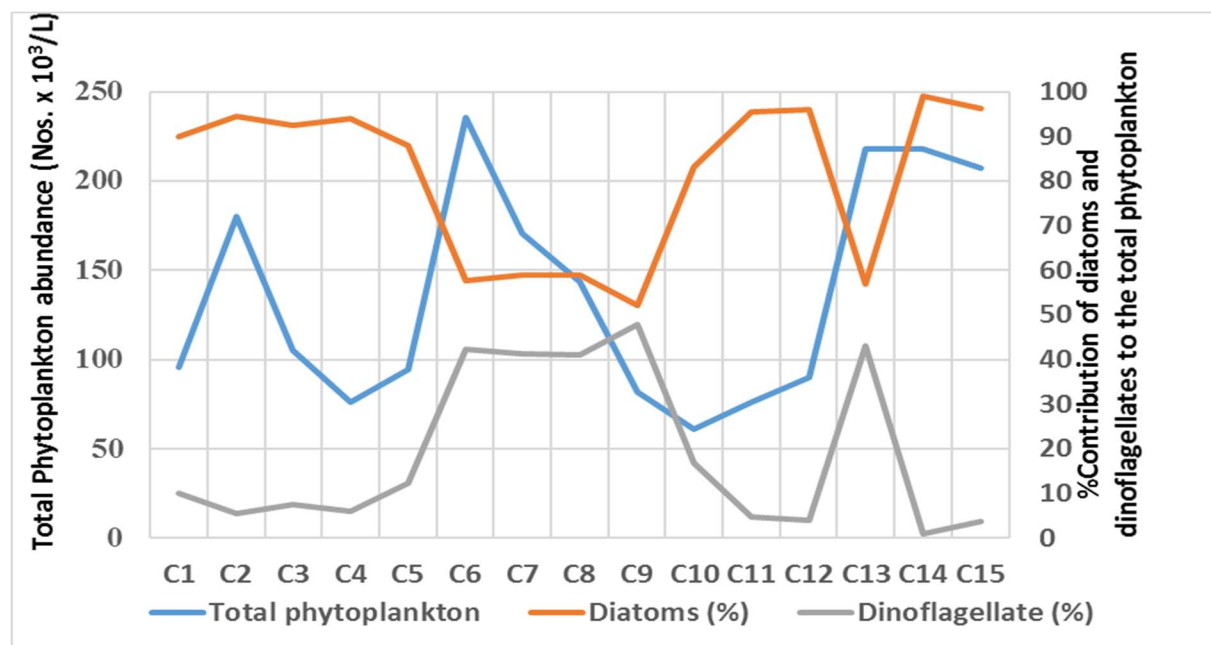


Figure 4.6: Spatial variations in total phytoplankton (Nos./L) and % contribution of diatoms and dinoflagellates in the Chapora Estuary.(C1-river mouth and C15-upstream region)

The most predominant species of the total phytoplankton were *Aulacoseira* Spp., *Chaetoceros Subtillis*, *Skeletonema* Spp., *Melosera Granulate*, *Leptocylindrus* Spp., *Cerataulina Bicornis* (Centric Diatom), *Nitzschia* Spp. *Pseudo-Nitzschia* Spp. *Micrasterias* Spp., *Cylindrothica* Spp., *Staurostrum* Spp., *Ceratoneis* Spp., *Tribonema* Spp. *Actinastrum* Spp. (Pennate Diatoms) While, Dinoflagellates were Represented By *Peridinium* Spp., *Oxyrrhis Marrina*, *Gymnodinium* Spp., And *Gyrodinium* Spp. Few Forms Present At Both Surface (S) And At The Near Bottom (B) Were *Aulacoseira* Spp., (S>B) *Chaetoceros Subtillis*, (S>B) *Cylindrothica* Spp. (S<B) *Nitzschia* Spp. (S<B) and *Navicula* Spp., (S>B) (Belong To Diatoms) and *Peridinium* Spp., (S>B) And *Oxyrrhis Marrina* (S>B) Of Dinoflagellates.

Phytoplankton diversity indices:

The phytoplankton diversity index across the length of the river and with respect to its surface and bottom depths are shown in Table 4.2. The total numbers of phytoplankton forms found to be not much varying between the bottom (18-49) and surface (16-47). However, species richness was more in the surface (ranging between 1.19 & 3.92) than bottom (1.44-3.79) similarly to evenness that ranged from 0.35-0.78 (surface) to 0.36-0.88 (bottom). High diversity index that



was relatively higher at the bottom (1.85-3.2) than the surface (0.98-3.02) depicted a decreasing trend across the length of the estuary, particularly in Zone-3 (beyond stn C9) (Table 4.2)

Table 4.2: Distribution of number of species, total abundance, species richness, evenness and diversity of phytoplankton in the Chapora Estuary.

Surface						Bottom					
Stations	S	N	d	J	H(log _e)	Stations	S	N	d	J	H(log _e)
C1	33	127108	2.72	0.76	2.66	C1	26	64480	2.26	0.64	2.08
C2	41	160552	3.34	0.73	2.71	C2	40	199680	3.20	0.64	2.36
C3	39	96840	3.31	0.72	2.66	C3	42	113200	3.52	0.79	2.94
C4	20	34000	1.82	0.71	2.12	C4	44	117720	3.68	0.80	3.04
C5	47	122960	3.93	0.79	3.03	C5	39	65564	3.43	0.88	3.23
C6	42	163584	3.42	0.76	2.84	C6	49	306936	3.80	0.77	3.00
C7	28	131040	2.29	0.68	2.27	C7	38	209880	3.02	0.77	2.80
C8	31	123500	2.56	0.70	2.39	C8	35	164080	2.83	0.83	2.94
C9	19	70460	1.61	0.71	2.09	C9	19	92640	1.57	0.61	1.79
C10	21	35496	1.91	0.80	2.42	C10	25	86060	2.11	0.75	2.42
C11	20	66096	1.71	0.55	1.66	C11	29	85920	2.46	0.81	2.72
C12	22	126000	1.79	0.47	1.46	C12	30	54000	2.66	0.77	2.60
C13	17	106560	1.38	0.48	1.35	C13	27	328900	2.05	0.36	1.18
C14	20	225400	1.54	0.53	1.59	C14	21	210000	1.63	0.47	1.42
C15	16	279864	1.20	0.36	0.99	C15	18	134120	1.44	0.48	1.40

S-Total no. of species; N-total no. of individuals; d-Richness; J- Evenness; H (log e) Diversity index (Shannon-Wiener diversity index).

4.5.2 Zooplankton

Zooplanktons are primary consumers or secondary producers. Hence they form an important link between the primary producers, phytoplankton and tertiary consumers like fishes. Also, they are important contributors and modifiers of the biogeochemical cycle. Thus, knowledge of their abundance and distribution is essential for understanding the ecological balance of any water bodies. In ecological studies, the study on zooplankton communities is essential because different species have different tolerance/adaptive levels to environmental variables, hydrographical conditions (pollutants), and response to changes in their diversity and abundance. Hence, they act as an indicator to monitor aquatic ecosystems (Gannon and Stemberger, 1978; Gajbhiye and Desai, 1981; Telkhade et al., 2008 and Davies et al., 2009).

Total abundance of zooplankton in Chapora Estuary: Present study revealed the spatial variation of zooplankton across the length (West-East direction) of the river dividing the Chapora Estuary broadly into three zones 1) zone -1: Near mouth region (stn C1-C5); Zone -2: Mid-stream region



(stn. C6-C8) and Zone -3: Upstream region (stn. C9-C15). The zooplankton abundance in the riverine region (stn: C9-C15) was much lower (minimum at stn C15; 1173 org./100m³) than the near mouth seaside region (stn. C1-C5) while midstream station (stn. C6-C8) depicted the highest abundance with a maximum at stn C7 (424200 org./100m³) (Figure 4.7). Spatial variability was also found to be significant, across the width of the river, north-south spatial variability depicted maximum in the middle region followed by southern bank of the river (see Figure 4.5 & 4.6) that also showed the variation from the river mouth to the upstream region (611649 Ind. /100 m³ at C3 [B] to 7565.5 Ind./100 m³ at C12 [B]).

These findings clearly classify the Chapora Estuary into three zones 1) Zone -1: Near mouth region (stn C1-C5); Zone -2: Mid-stream region (stn. C6-C8) and Zone -3: Upstream region (stn. C9-C15).

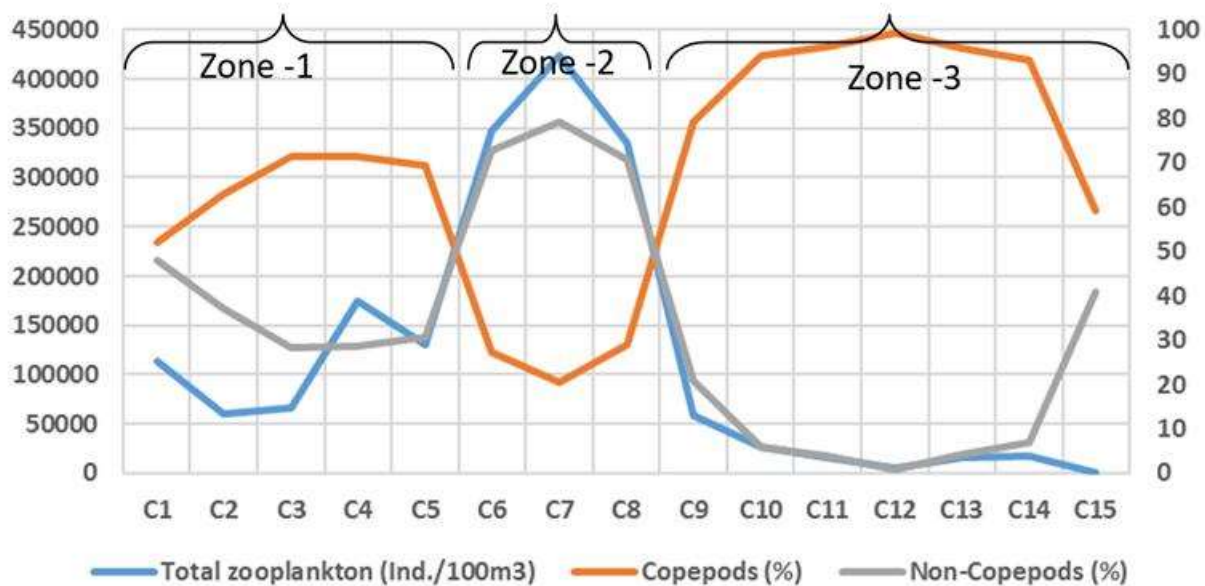


Figure 4.7: Spatial variations in Meso-zooplankton abundance along middle portion of the in the Chapora Estuary.(C1-river mouth and C15-upstream region)

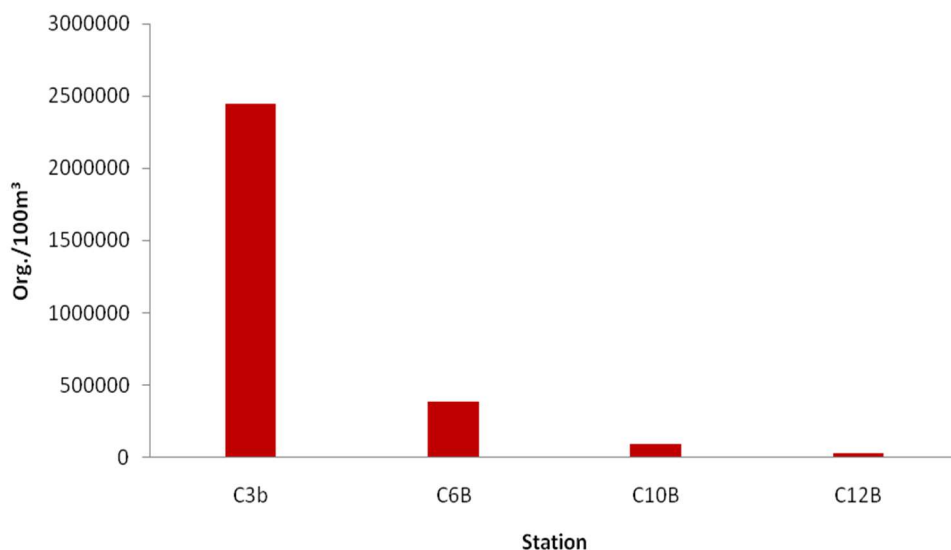


Figure 4.8: Spatial variations in zooplankton abundance along the southern (right side of the river) bank of Chapora Estuary.(C3-near river mouth and C12-upstream region)

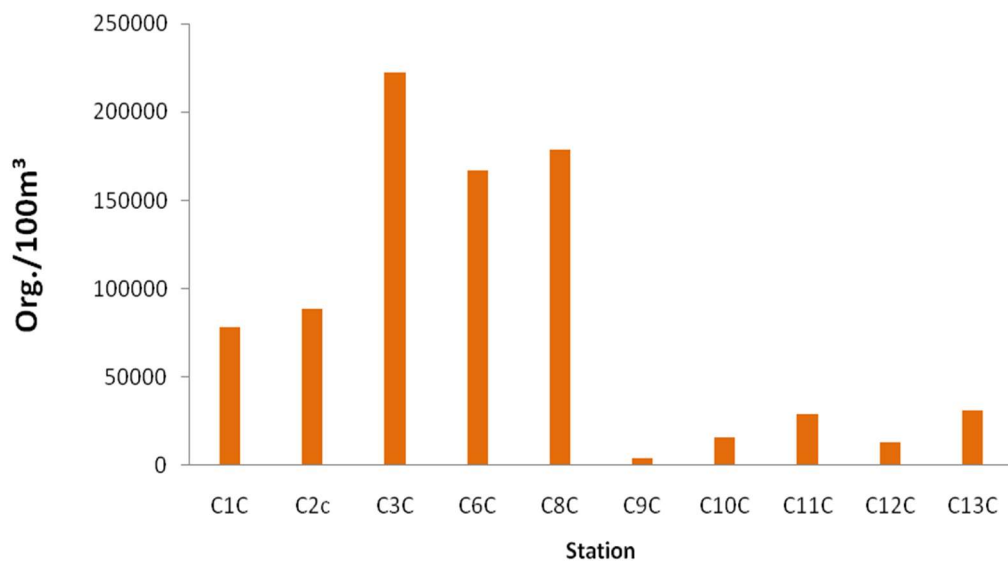


Figure 4.9: Spatial variations in zooplankton abundance along the northern (left side of the river) bank of Chapora Estuary.(C1-river mouth and C15-upstream region)

Distribution of taxonomic groups of zooplankton



Zooplankton community composition, which is broadly divided into two major categories, copepods, and non-copepods, showed spatial variability (Table 4.2). Copepod community dominates over non-copepod groups at Zone -1 (river mouth; 50-76%) and Zone-3 (upstream regions; above 92%) (Figure 4.8). Whereas in the midstream regions (Zone-2) the community was largely dominated by non-copepods. Overall, the percentage composition of copepod varied from 19.7 (C6B) – 98.5% (C12B).

Among non-copepod groups, Chaetognaths, Gastropods, Decapod larvae, and Fish larvae were found throughout the sampling area, whereas the distribution of Fish egg, Ostracod, Echinoderm larvae, Doliolum, Oekopleura are strictly confined to the river mouth. Some unidentified cladoceran were completely absent in the midstream, but present in the river mouth and upstream regions. Also, bivalves and barnacle nauplii were found in the river mouth and midstream region and completely absent in the upstream region. The presence of water mites in certain upstream stations indicated the poor quality of water.



Distribution of copepods

The taxonomic composition and abundance of copepods varied from the river mouth to upstream regions, including calanoida, cyclopoida, harpacticoida, and poicelostomatoida (nauplii and copepodite stages). Amongst, the calanoida dominates the copepod community (contributing >50%) throughout the study area particularly in the midstream and upstream regions (beyond station C6) while, at the near mouth region poicelostomatoida followed by cyclopoida and, harpacticoida were more predominant compared to their distribution in the upstream region (beyond stn C5; Figure 4.10).

The calanoid copepods such as *Crocalanus* sp., *Paracalanus* sp., and *Acartia* sp. were distributed all along the study area. the species such as *Centropages furcatus*, *Temora turbinata*, *Temora discaudata*, *tortanus* sp., *Subeucalanus* sp., *Nanocalanus minor*, *canthocalanus pauper* and *labidocera* sp., etc. were confined to the river mouth region. moreover, the *Pseudodiaptomus* sp was found in the river mouth and upstream regions.

interestingly, a tumor-like out-growth was seen on copepods of mid-streams and upstream (beyond c10(c10b and c10c) regions. the out-growth was noticed on species such as acrocalanus sp., paracalanus sp., acartia sp., and pseudodiaptomus sp. moreover, a similar tumor-like out-growth was reported as a vulnerability to the ecological food web from indian waters (jagadeesan, l., and jyothibabu, r. 2016).

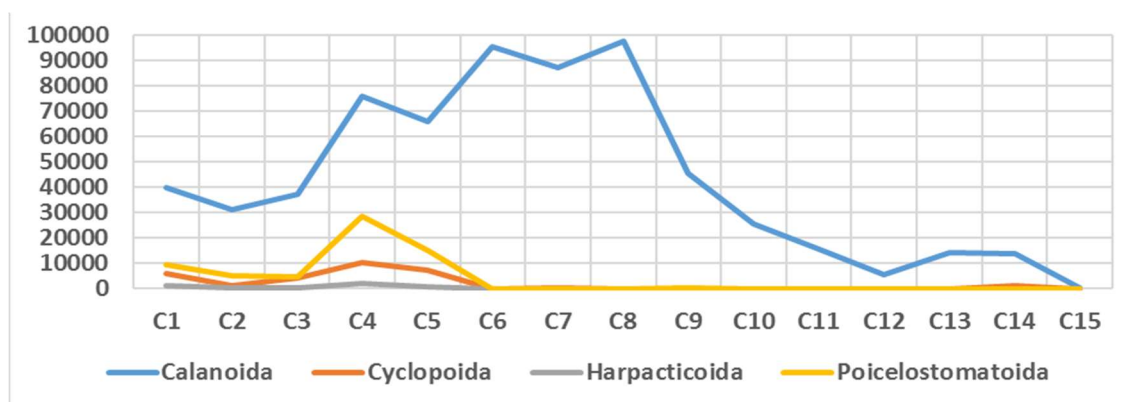


Figure 4.10: Distribution of copepods (Ind/100m³) from the River mouth (C1) to upstream (C15) regions of the Chapora Estuary.



Zooplankton Diversity Indices

Diversity indices are significant aids to characterize diversity, richness, and evenness of the species in the community (Magurran, 1988). The number of species (S) and the range of diversity indices (based on Shannon index) in the Chapora Estuary are given in Table 4.1. The number of species varied as 26-37 (river mouth), 11-12 (midstream), and 5-21 (upstream) depicting more species diversity (H') is more at river mouth followed by midstream region. Species evenness and richness are lower at midstream and upstream on comparing with river mouth.

Table 4.4: Number of species (S), species diversity(H'), species richness (d) and evenness (J') in Chapora Estuary.

Sample	S	H'	d	J'
River mouth (C1-C5)	26-37	4.39-4.79	3.43-4.74	0.89-0.94
	31.6±4	4.55±0.15	4.23±0.49	0.92±0.02
Midstream (C6-C8)	11-12	2.55-2.88	1.37-1.53	0.74-0.83
	11.33±0.58	2.71±0.16	1.44±0.08	0.77±0.05
Upstream (C9-C15)	5-21	1.57-3.35	0.84-3.52	0.68-0.98
	12.29±6.37	2.73±0.73	1.99±0.99	0.79±0.1

4.5.3 Meiobenthos

Central transect: The large variation of meiofaunal abundance was recorded from 15 stations (Table 4.5). Total 10 meiofaunal taxa were identified in the centre region of the river. From all the identified taxa, Harpacticoida was the most abundant group followed by Nematoda, Oligochaeta, Nemertea, Polychaeta, Turbellaria, Bivalvia, Gastropoda larvae, Naupli larvae, Amphipoda (Table 4.5). The highest meiofaunal abundance (424 ind/10cm²) was recorded at station CH3A and lowest (20 ind/10cm²) at station CH11A (Table 4.5). The percent composition of meiofaunal community showed that Harpacticoida (40.3%) was dominant among all other meiofaunal groups followed by Nematoda (36.7%), Oligochaeta (6.0%), Nemertea (4.2%), Polychaeta (3.9%), Turbellaria (3.3%), Bivalvia (2.9%), Gastropoda larvae (1.3%), Naupli larvae (0.9%), Amphipoda (0.5%) (Figure 4.11).



Peripheral transect: Total 13 taxa are identified in the periphery region of the a river from which Nematoda was abundant group followed by Harpacticoida, Polychaeta, Oligochaeta, Bivalvia, Tubellaria, Nemertea, Nauplilarvae, Gastropoda larvae, Amphipoda, Halacarida, Kinoryncha. The percent composition of meiofaunal community showed that Nematoda(60%), Harpacticoida(15%), Polychaeta(8.1%), Oligochaeta(5.3%), Bivalvia(4.2%), Tubellaria(3%), Nemertea(1.71%), Naupli larvae(1.15%), Gastropoda larvae(0.66%), Crustacean larvae(0.30%), Amphipoda(0.22%), Halacarida(0.16%), Kinoryncha(0.12%).

Conclusion:

The present analysis of distribution and abundance of meiobenthic community revealed that, due to the changes in pH and TSM (mg/L) the meiofaunal community also shows the variations. Our observation supports the reduced pH and TSM may have effect on meiofaunal abundance found to be decreased in peripheral region as compared to central region of the river. As suggested by Raffaelli and Mason (1981), the ratio of Nematoda Copepoda is <100 indicate impact of degrading the quality of the water. Through our analysis, we observed that in the central region of the river the ratio Nematoda- Copepoda was higher except station CH4A and CH11A (Table 4.8). While at the periphery region the Nematoda- Copepoda ratio lower values at station CH5C, CH13C, CH14B except station CH4A.

Table 4.5: Total meiofaunal abundance (ind/10 cm²) of Chapora Estuary (Central transect).

Taxa	CH1A	CH2A	CH3A	CH4A	CH5A	CH6A	CH7A	CH8A	CH9A	CH10A	CH11A	CH12A	Total	%
Nematoda	43	38	93	47	78	55	29	31	5	28	1	3	450	36.7
Polychaeta	13	10	1	10	3	1	0	4	1	3	3	0	48	3.9
Naupli larvae	0	0	0	0	9	1	0	0	0	1	0	0	11	0.9
Harpacticoida	13	5	289	0	104	50	5	5	4	14	3	1	495	40.3
Amphipoda	0	0	0	0	0	6	0	0	0	0	0	0	6	0.5
Bivalvia	1	0	4	4	0	0	15	9	0	3	0	0	35	2.9
Gastropoda larvae	1	0	0	4	0	5	4	0	1	1	1	0	16	1.3
Oligochaeta	1	0	5	5	1	26	1	5	5	4	6	13	74	6.0
Nemertea	24	13	8	4	0	0	0	0	1	2	0	0	51	4.2
Turbellaria	5	1	4	4	6	0	11	1	0	8	0	0	41	3.3
Total	101	67	404	77	201	146	65	55	16	64	13	16	1227	100.0

* Stations number CH13A, CH14A, CH15A was not collected due to hard substratum.

Table 4.6: Total meiofaunal abundance (ind/10 cm²) of Chapora Estuary (Peripheral transect).

Taxa	CH1B	CH1C	CH2B	CH2C	CH3B	CH3C	CH4B	CH4C	CH5B	CH5C	CH6B	CH6C	CH7B	CH7C	CH8B	CH8C	CH9B
Nematoda	97	826	31	131	84	210	122	167	4	35	23	13	11	4	0	15	6
Polychaeta	25	55	3	1	0	3	0	13	0	0	8	1	0	1	0	72	1
Naupli larvae	0	3	0	0	1	1	0	0	11	0	0	0	0	0	0	1	0
Harpacticoida	5	166	6	6	15	30	13	42	21	1	3	1	1	4	0	9	3
Amphipoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Halacarida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crustacean larvae	1	1	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
Kinorhyncha	0	0	1	0	0	3	0	0	0	0	0	0	0	1	0	0	0
Bivalvia	0	3	3	1	3	4	0	0	0	0	0	0	0	9	0	0	0
Gastropoda larvae	1	0	1	3	1	4	0	1	0	0	1	0	0	4	0	0	0
Oligochaeta	20	18	5	1	4	8	0	4	1	5	9	0	1	4	0	16	2
Nemertea	0	6	0	14	3	11	6	6	0	3	3	1	0	0	0	0	0
Turbellaria	5	9	0	5	20	29	4	0	0	1	0	1	0	1	0	1	0
Total	155	1086	49	162	135	302	145	233	38	45	45	17	14	26	0	115	11



Taxa	CH9B	CH9C	CH10B	CH10C	CH11B	CH11C	CH12B	CH12C	CH13B	CH13C	CH14B	Total	%
Nematoda	6	4	26	18	5	5	1	16	3	20	0	1878	60.0
Polychaeta	1	3	34	0	0	4	23	6	1	0	1	254	8.1
Naupli larvae	0	1	4	0	0	0	10	4	0	0	0	36	1.1
Harpacticoida	3	15	29	4	3	49	29	11	1	0	3	469	15.0
Amphipoda	0	0	5	0	0	2	0	0	0	0	0	7	0.2
Halacarida	0	0	0	0	0	5	0	0	0	0	0	5	0.2
Crustacean larvae	0	0	1	0	0	0	3	0	0	0	0	9	0.3
Kinoryncha	0	0	0	0	0	0	0	0	0	0	0	4	0.1
Bivalvia	0	10	20	0	0	8	5	63	1	5	0	133	4.2
Gastropoda larvae	0	1	1	1	0	2	0	0	0	0	0	21	0.7
Oligochaeta	2	9	8	3	20	2	20	0	1	4	1	165	5.3
Nemertea	0	0	0	0	0	0	0	1	0	0	0	53	1.7
Turbellaria	0	0	5	1	0	1	3	1	1	0	6	94	3.0
Total	11	42	133	26	28	77	93	103	8	29	11	3128	100.0

* Stations number CH14C, CH15B, CH15C was not collected due to hard substratum.



Table 4.7 : Nematoda: Copepoda ratio of Chapora Estuary (Central transect)

Taxa	CH1A	CH2A	CH3A	CH4A	CH5A	CH6A	CH7A	CH8A	CH9A	CH10A	CH11A	CH12A
Nematoda	68	60	148	74	124	88	46	50	8	44	1	4
Harpacticoida	20	8	460	0	166	80	8	8	6	23	5	2
Nematoda/copepoda ratio	3	8	0	0	1	1	6	6	1	2	0	2

Table 4.8 : Nematoda: Copepoda ratio of Chapora Estuary (Peripheral transect)

Taxa	CH1B	CH1C	CH2B	CH2C	CH3B	CH3C	CH4B	CH4C	CH5B	CH5C	CH6B	CH6C	CH7B	CH7C	CH8B	CH8C
Nematoda	154	1312	50	208	134	334	194	266	6	56	36	20	18	6	0	24
Harpacticoida	8	264	10	10	24	48	20	66	34	2	4	2	2	6	0	14
Nematoda: copepoda ratio	19.3	5.0	5.0	20.8	5.6	7.0	9.7	4.0	0.2	28.0	9.0	10.0	9.0	1.0	0.0	1.7

Table 4.8?: Continued..

Taxa	CH9B	CH9C	CH10B	CH10C	CH11B	CH11C	CH12B	CH12C	CH13B	CH13C	CH14B
Nematoda	10	6	42	28	8	8	2	26	4	32	0
Harpacticoida	4	24	46	6	4	78	46	18	2	0	4
Nematoda: copepoda ratio	2.5	0.3	0.9	4.7	2.0	0.1	0.0	1.4	2.0	0.0	0.0

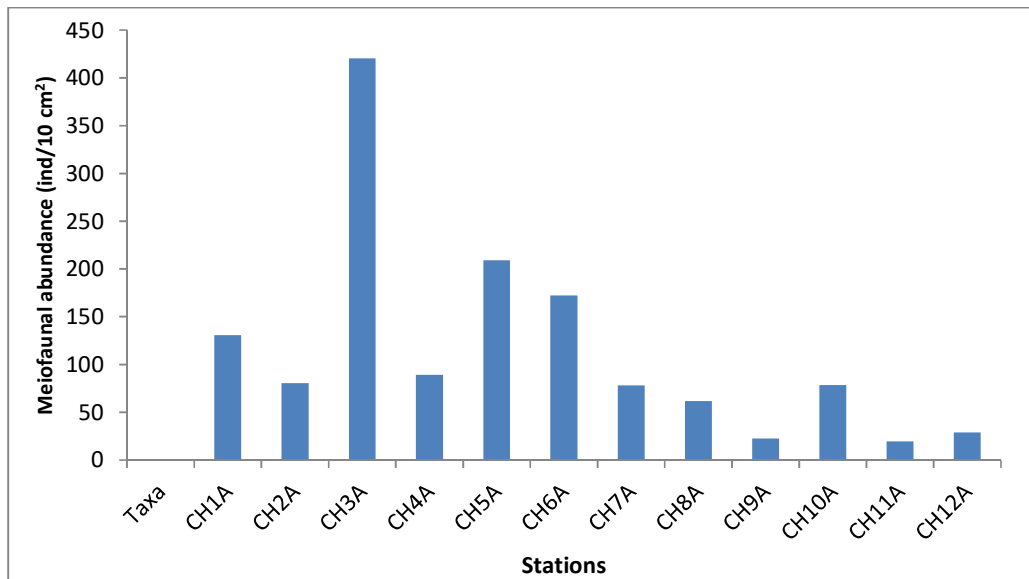


Figure 4.11: Station-wise meiofaunal abundance (ind/10 cm²) from River Chapora (Central transect).

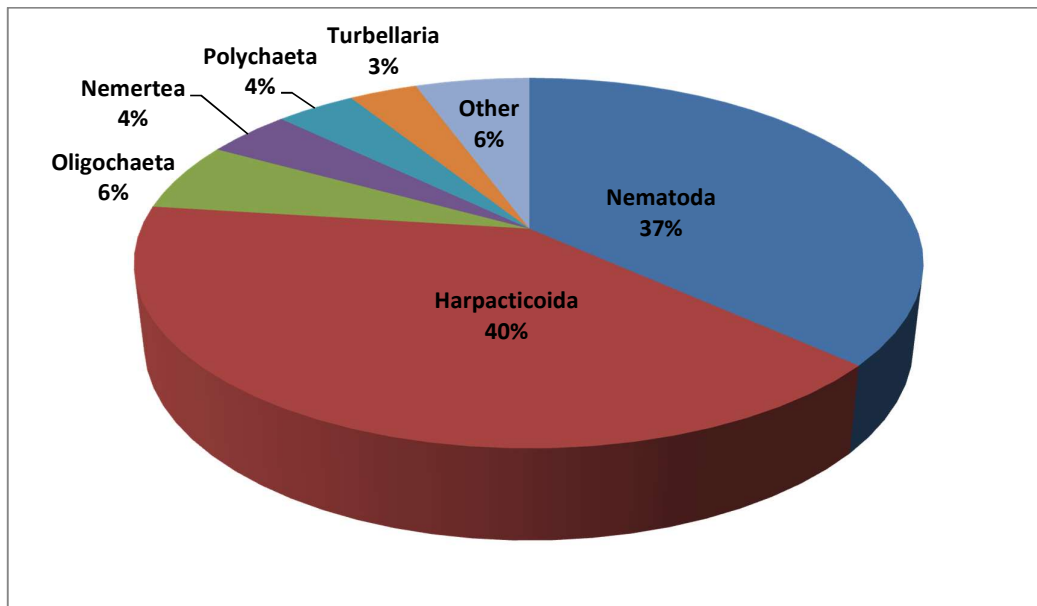


Figure 4.12: Percent composition of meiofaunal taxa from River Chapora (Central transect).

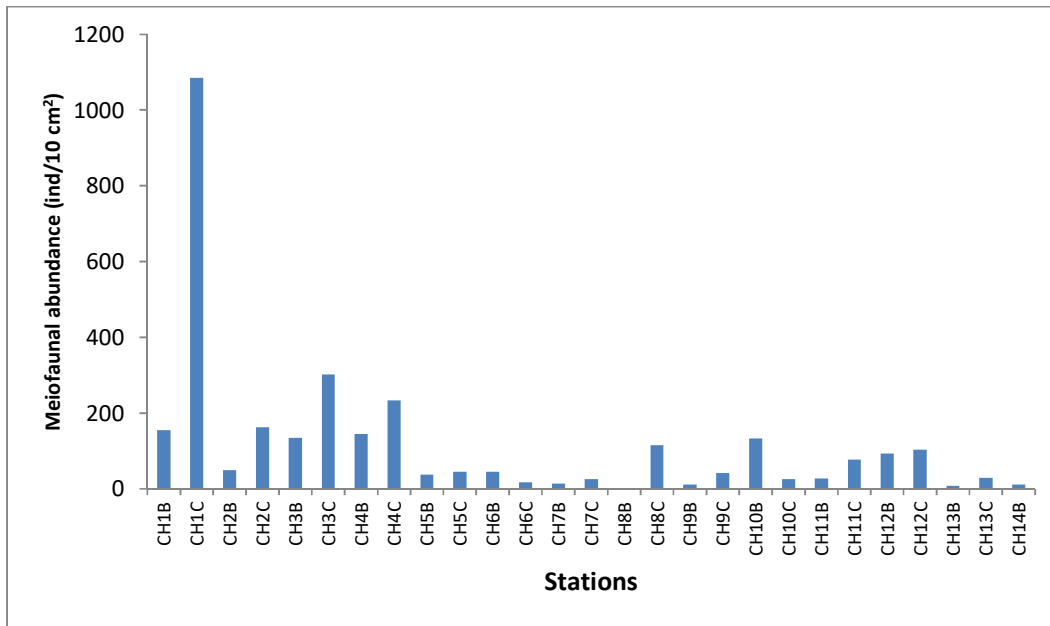


Figure 4.13: Station-wise meiofaunal abundance (ind/10 cm²) from River Chapora (Peripheral transect).

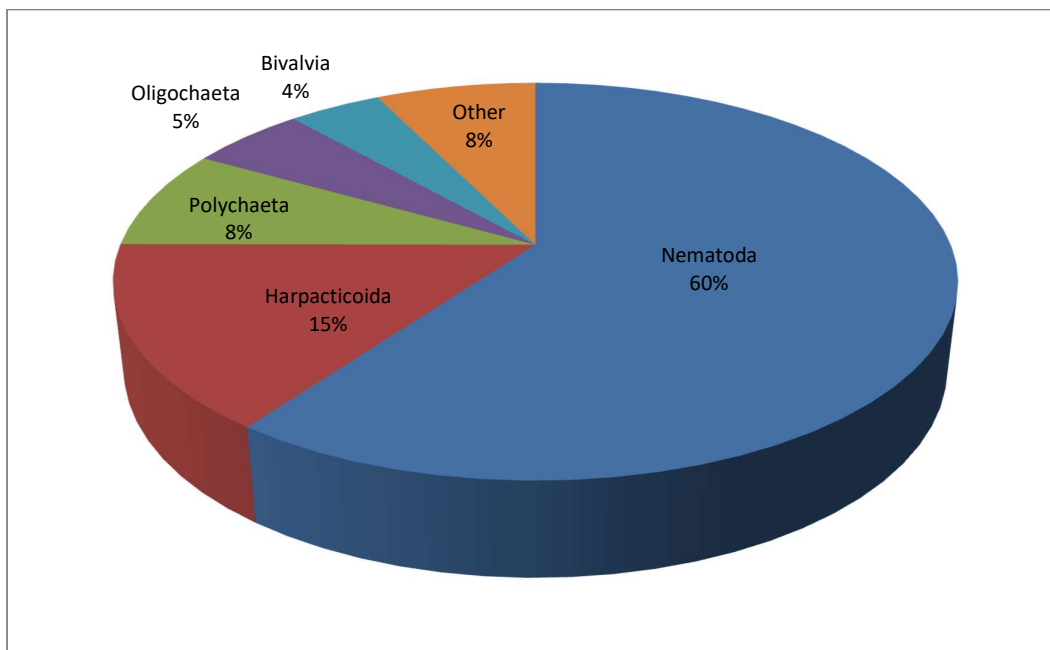


Figure 4.14: Percent composition of meiofaunal taxa from River Chapora (Peripheral transect).

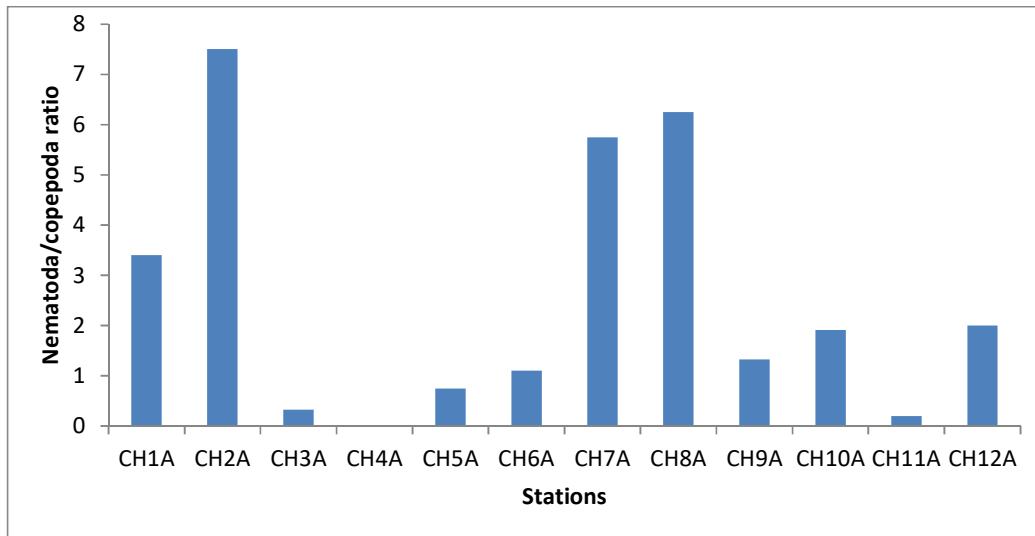


Figure 4.15: Station-wise Nematoda:Copepoda ratio from River Chapora (Central transect).

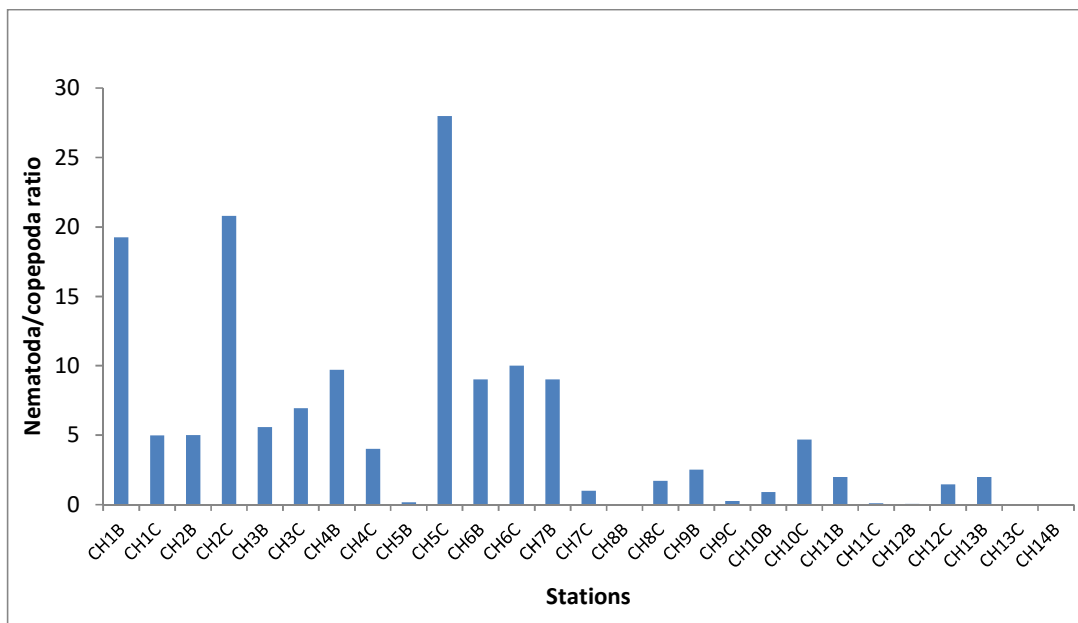


Figure 4.16 :Station-wise Nematoda:Copepoda ratio from River Chapora (Peripheral transect).

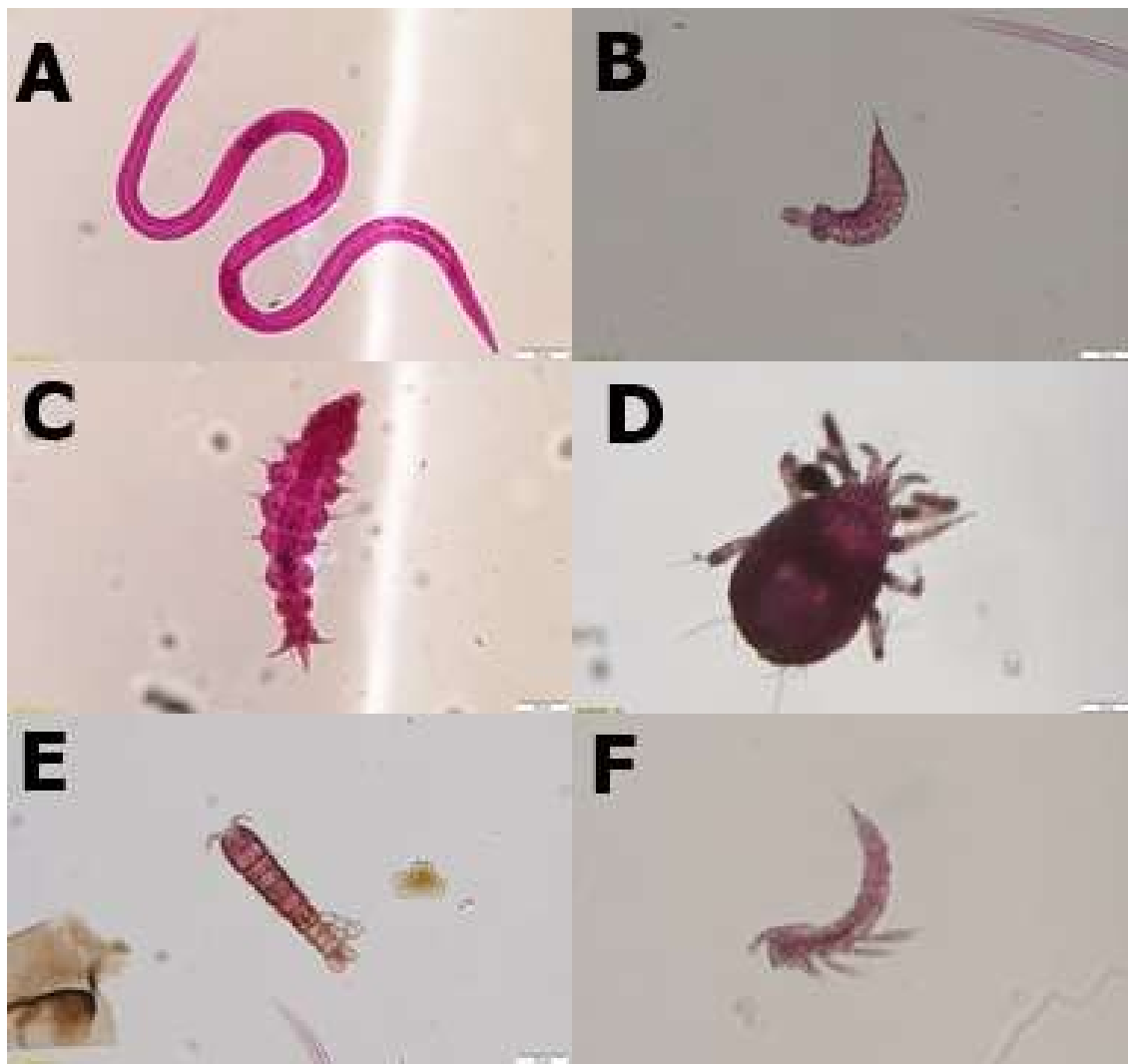


Plate 2: A=Nematoda, B=Kinoryncha, C=Polychaeta, D=Halacarida, E and F=Harpacticoida



4.5.4 Foraminifera

Living benthic foraminifera are rare in the middle of the river bed, whereas a substantial population is observed on the margin of the river. Living benthic foraminiferal population is very low in all the samples collected at station Ch1, at the confluence of the Chapora Estuary with the Arabian Sea. As benthic foraminifera have high sensitivity for low salinity thus their survival in the upper stretches of the river is rare.

The dead foraminiferal population is an order of magnitude higher than the living population. However, the dead foraminifera are also rare in the middle of the river bed, probably due to high flow velocities and hydrodynamic conditions.

The rare benthic foraminiferal presence in the middle of the river bed is attributed to the very coarse texture of the sediments. Such sediments are almost completely devoid of organic matter, the food for foraminifera. The sediments at the river margin have fine texture facilitating a better preservation of the organic matter. Benthic foraminifera thrive in such organic matter rich fine sediments. Analysis of foraminifera data is still in process as it is time consuming work.

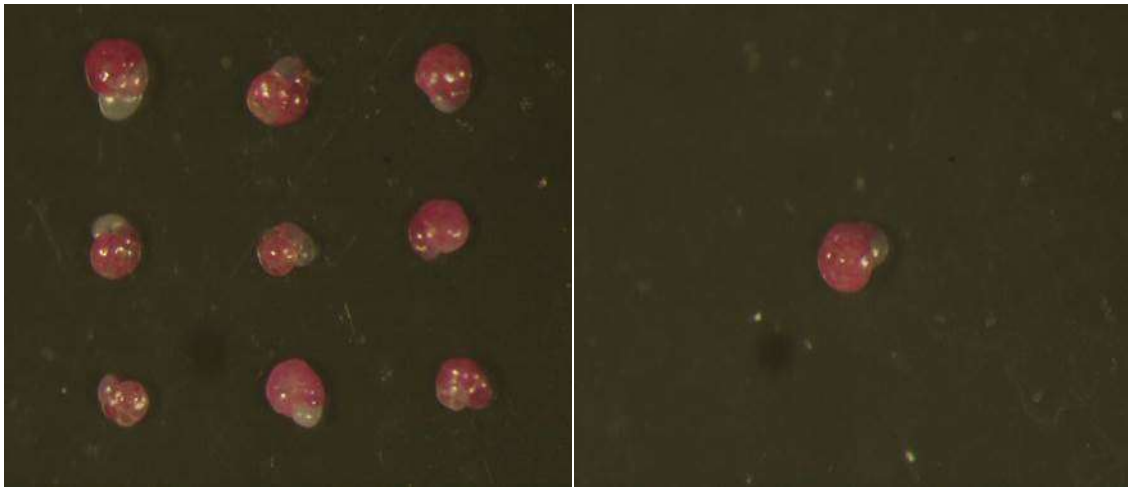


Plate 3: Foraminifera species found in Chapora Estuary.

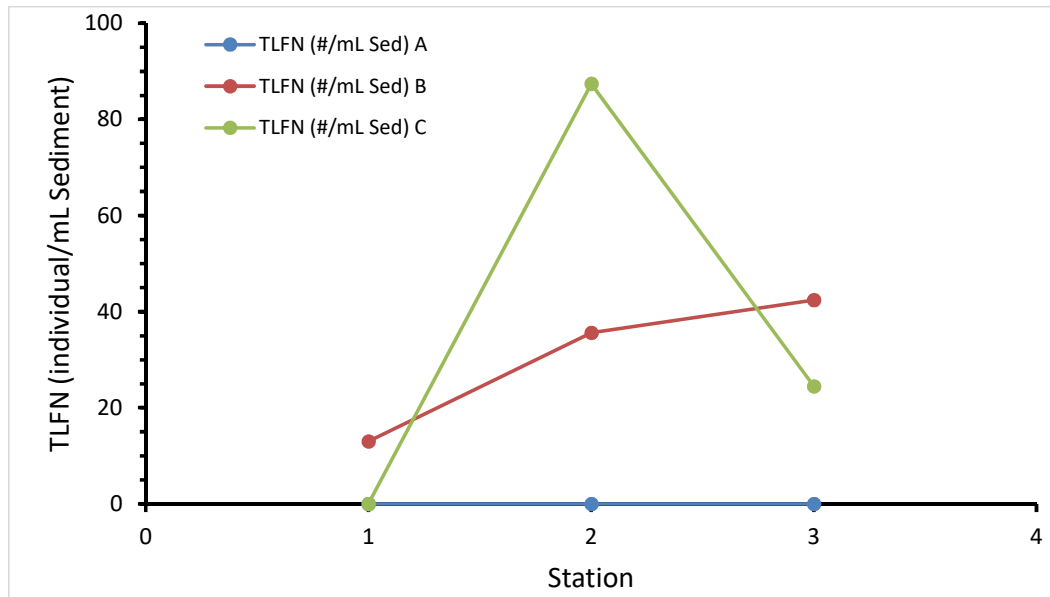


Figure 4.17: Total Living Foraminifera Number in Chapora Estuary

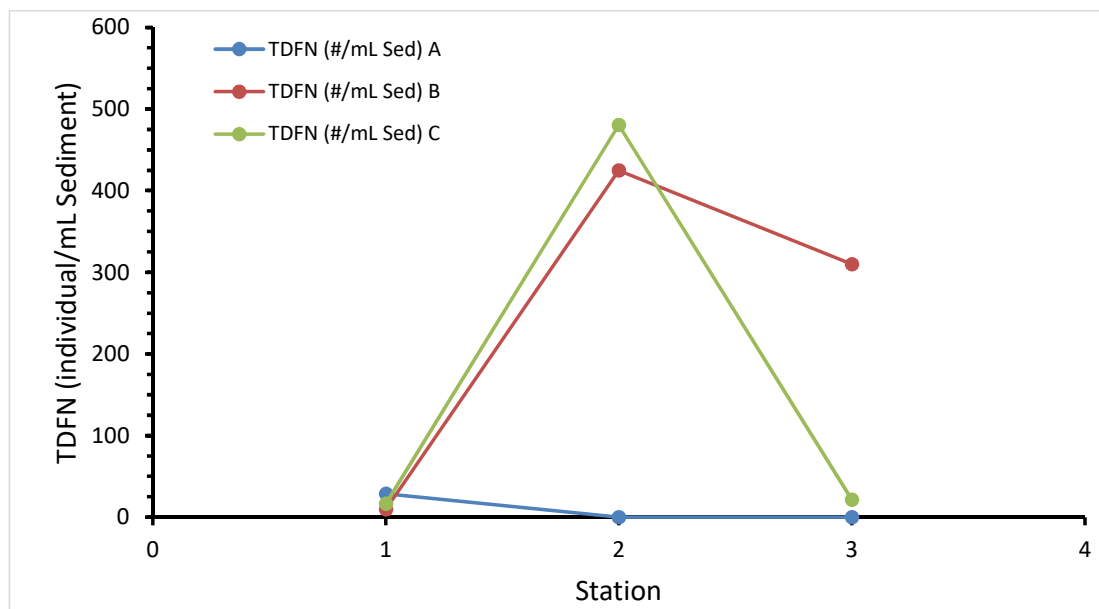


Figure 4.18: Total Dead Foraminifera Number in Chapora Estuary



4.5.5 Macrobenthos:

Central transect:

A total of 28 macro invertebrate taxa belonging to 10 phyla were identified from the central region of the river sample (CHA). Among all these groups, Polychaeta was the most dominant. Higher abundance of Polychaeta was found at station CH12A (3584no/m²) followed by CH8A (2556 no/m²). However, lower abundance found in CH 1A (24no/m²), (Table 4.9). In Polychaeta, *Prionospio pinnata* was the highly abundant species at station CH12A (3345no/m²), and lower abundance at station CH8A (1696 no/m²) and was absent at CH1A and CH1B stations. *Glycera alba* was the second dominant species with highest at CH8A (382no/m²) and lowest abundance found at CH1A, CH2A and CH12A with 24 no/m². Bivalvia were the second dominant taxa present at CH6A, CH7A, Ch8A, CH9A and CH12A. Other taxa like Nematoda, Sipunula, Crustacea, Gastropoda, Ophuroidea, Platyhelminthes, Trematoda, Oligochaeta and Phoronida were found less in abundance at all the stations (Table 4.9). The stations at the centre of mouth of river showed less in abundance due to continuous dredging may results loss of faunal abundance (Figure 4.19). Elias et.al, (2005) reported *Prionospio* spp. are the indicator species for organic enrichment, in areas sampled during summer.

The macrofaunal composition showed polychaetes was the highly abundant (86%) followed by Crustacea (4%) and Bivalvia (4%). The remaining 6% of the fauna was comprised by Nematoda, Sipuncula, Crustacea, Gastropoda, Ophuroidea, Platyhelminthes, Trematoda, Oligochaeta and Phoronida (Figure 4.20). Among Polychaeta, *Prionospio pinnata* showed high composition with 79%, followed by *Glycera alba* (10%), *Poecilochaetus* sp. (4%) and the remaining 7% represented by other Polychaeta which were found less in abundance at the central region of the River (Figure 4.21). Polychaetes are the most dominant group in the benthic communities and may provide the details of effect of pollutants on life history characteristics (Harlan Dean, 2008).

Peripheral transect: A total of 41 macro invertebrate taxa belonging to 13 phyla were identified from the sample from periphery region of the river (CHB & CHC). The macrofaunal abundance was high at CH11C (17120 no/m²) followed by CH10B (11328 no/m²) and CH 2B (11200 no/m²) whereas low abundance was observed at CH8B (48no/m²) station, respectively (Table 4.10)(Figure 4.22). From all these taxa, Polychaeta showed high abundance followed by Crustacea, Chironomidae larvae, Oligochaeta and Bivalvia. Among the Polychaeta, *Nereis*



sp. was found to be the most abundant polychaete with 30896no/m² from all the sampling stations. High abundance of *Nereis* sp. was found in CH11C (6928 no/m²) and CH12C (6384 no/m²) and less at station CH1B, CH3B, CH3C and CH8C. *Prionospio pinnata* was the second abundant species with 29136no/m² from all the samples. Station CH11C showed high abundance (7360 no/m²) followed by CH10B (3968 no/m²) and CH13C (3872 no/m²) and found less in abundance at CH1B (16 no/m²), respectively. The second dominant taxa was Crustacea, among which Amphipoda was the abundant group with 9376 no/m² from all the stations, herein at CH13C and CH10B Amphipoda abundance was found to be 3120 no/m², 2912 no/m². Chironomidae larvae (3824 no/m²) were also found upstream region of the river at the station CH10B to CH14B. Bivalvia (1344 no/m²) and Oligochaeta (3072no/m²) were also found along the periphery area of the river (Table 4.10). The upstream peripheral area of Chapora Estuary showed high diversity as compared to the downstream peripheral region.

The macrofaunal percent composition showed that Polychaeta (78%) were the most dominant taxa with followed by Crustacea (11%) and other groups represented by 11% (Figure 4.23). In Polychaetes, *Nereis* sp. (42%) was the most dominant species from all the stations followed by *Prionospio pinnata* (40%), *Heteromastus* sp. (13%) and the remaining 5% with the other Polychaetes which were found less in abundance (Figure 4.24). The periphery region of Chapora Estuary showed high macrofaunal diversity; this may be due to presence of mangroves area which is known to be rich in faunal diversity.

Biomass:

At the central region of the river, the macrofaunal biomass (wet weight) ranged from 0.02 to 66.53 g/m² with lowest values at station CH1A and CH4A. The highest values were recorded at station CH4A, which was contributed by Polychaeta species due to their larger size and abundance (Figure 4.25). The diversity was very less at the central region of the river may be because the sediment texture as it was mostly sandy in nature. Along the periphery of the river, the diversity was high at station CH2B with 26.83 g/m² and low at CH3C, CH5B and CH8B with 0.02g/m² at each station. The biomass was found to be higher at the upstream region of Chapora Estuary as well as the macrofaunal diversity (Figure 4.26).

Conclusion:



Based on the present data set, macrofaunal abundance was found to be higher at upstream of the Chapora Estuary as compared to downstream. The present analysis also found that the peripheral region of upstream was rich in macrofaunal diversity, which decreased gradually towards the downstream. The observed benthic polychaetes and crustacean which constitute a major food source for fishes and avifauna.



Table 4.9: Abundance (no/m2) of macrofauna from Chapora Estuary(Central transect)

Taxa	CH 1A	CH 2A	CH 4A	CH 5A	CH 6A	CH7A	CH8A	CH9A	CH10A	CH11A	CH12A	Sum	%
Nematoda	0	0	0	0	0	0	24	0	0	0	0	24	0.19
<i>Nereissp.</i>	0	0	24	0	0	0	24	0	0	24	0	72	0.59
<i>Heteromastussp.</i>	0	0	0	24	0	0	24	0	0	24	0	72	0.58
<i>Prionospio pinnata</i>	0	0	119	24	96	72	1696	1003	549	1505	3345	8409	68.48
<i>Polydora ciliata</i>	0	0	72	0	0	0	0	0	0	0	0	72	0.58
<i>Glycera alba</i>	24	24	119	143	119	72	382	119	0	0	24	1027	8.27
<i>Ancistrosyllis sp.</i>	0	0	24	0	0	0	0	0	0	0	0	24	0.19
<i>Lumbrineris sp.</i>	0	0	0	0	0	0	72	0	0	0	0	72	0.58
<i>Amphictene sp</i>	0	24	0	0	0	72	0	0	0	0	0	96	0.78
<i>Sabellaria sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0.00
<i>Poecilochaetus sp.</i>	0	406	0	0	0	0	0	0	0	0	0	406	3.31
<i>Inemophrys inermis</i>	0	0	48	0	0	24	0	0	0	0	0	72	0.58
<i>Aphrodite sp.</i>	0	0	24	0	0	0	0	0	0	0	0	24	0.19
<i>Orbinia sp.</i>	0	0	24	0	215	0	0	0	0	0	0	239	1.95
Echura	0	0	191	0	0	0	0	0	0	0	0	191	1.56
Amphipoda	0	0	48	0	48	0	96	0	0	0	24	215	1.75
Harpacticoida	0	0	0	0	24	0	0	0	0	0	0	24	0.19
Lucifera	0	0	0	24	0	0	0	0	0	0	0	24	0.19
Cumacea	0	0	0	0	215	0	24	0	0	0	0	239	1.95
Shrimp	0	0	0	24	0	0	0	0	24	0	0	48	0.39
Bivalvia	0	0	0	0	24	143	72	48	0	0	191	478	3.89
Naticidae	0	0	24	0	0	0	0	0	0	0	0	24	0.19
Trochidae	0	24	0	0	0	0	0	0	0	0	0	24	0.19
Ophiuroidea	0	0	24	0	0	0	0	0	0	0	0	24	0.19
Platyheminthes	0	0	0	0	24	0	0	0	0	0	0	24	0.19
Trematoda	0	0	72	0	0	0	0	0	0	0	0	72	0.58



Oligochaeta	0	24	0	0	0	24	0	24	72	0	0	143	1.17
Phoronida	0	0	0	0	0	0	143	0	0	0	0	143	1.17
Abundance (No/m²)	24	502	812	239	764	406	2556	1195	645	1553	3584	12279	100

*CH3A, CH13A, CH14A & CH15A station sample could not retrieve due to hard substratum.

Table 4.10: Abundance (no/m2) of macrofauna from Chapora Estuary (Peripheral transect)

Taxa	CH 1B	CH 1C	CH 2B	CH 2C	CH 3B	CH 3C	CH 4B	CH 4C	CH 5B	CH 6B	CH6C	CH7B	CH7C
Hydrozoa	16	0	0	0	0	0	0	0	0	0	0	0	0
Nematoda	0	0	0	0	0	0	0	0	352	0	0	16	0
<i>Nereis</i> sp.	16	0	1568	0	16	16	32	0	0	224	0	32	320
<i>Mediomastus</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Heteromastus</i> sp.	0	0	4512	336	416	16	32	128	0	3264	32	48	112
<i>Prionospio pinnata</i>	16	64	2144	32	0	0	416	48	0	208	112	32	544
<i>Polydora</i> sp.	0	0	0	0	0	0	0	0	0	0	0	16	0
<i>Glycera alba</i>	32	32	224	0	0	0	32	0	0	0	0	0	0
<i>Ancistrosyllis</i> sp.	0	0	864	16	0	0	224	0	0	16	0	0	0
<i>Lumbrineris</i> sp.	0	0	32	0	0	0	0	0	0	32	0	0	0
<i>Amphictene</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Sabellaria</i> sp.	0	0	0	0	0	0	0	0	0	16	0	0	0
<i>Poecilochaetus</i> sp.	0	0	64	0	0	0	0	0	32	0	0	0	0
<i>Paraonis</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Hydroides</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Inemophytis inermis</i>	0	32	112	0	0	0	0	0	0	0	0	0	0
<i>Hesion</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Chaetopterus</i> sp.	0	0	32	0	0	0	0	0	0	0	0	0	0
<i>Aphrodite</i> sp.	0	0	16	0	0	0	32	0	0	0	0	0	0



<i>Orbinia</i> sp.	272	16	0	0	0	0	320	0	0	0	0	0	0
<i>Maldanellasp.</i>	32	0	0	0	0	0	16	0	0	0	0	0	0
<i>Ophelia</i> sp.	80	0	0	0	0	0	48	0	0	0	0	0	0
Echuiira	0	0	0	0	0	0	32	0	0	0	0	0	0
Amphipoda	0	0	16	0	0	0	16	0	0	16	0	48	432
Isopoda	32	0	992	32	0	112	0	0	0	0	0	0	16
Harpacticoida	0	0	0	0	0	0	16	0	16	0	0	0	0
Lucifera	0	0	0	0	0	0	48	0	16	0	0	0	0
Cumacea	0	0	0	0	0	0	0	0	48	0	0	0	0
Tanaidacea	0	0	0	0	0	0	0	0	0	0	0	0	0
Shrimp	0	32	0	0	0	0	0	0	0	0	0	0	0
Brachyura	0	0	0	0	0	0	0	0	0	0	0	0	32
Decapoda	0	0	0	16	0	0	0	0	0	0	0	0	0
Bivalvia	16	0	368	16	16	16	64	32	32	0	0	16	0
Platyhemintthes	0	0	48	0	0	16	0	48	0	0	0	16	0
Planaria	0	0	0	0	0	0	0	0	0	0	0	0	0
Nemertea	80	16	176	32	0	0	32	0	0	0	0	16	32
Chironomidae larvae	96	0	0	0	0	0	0	0	0	0	0	0	0
Fish (Juveniles)	0	0	0	0	0	0	0	0	0	0	0	0	0
Lingulidae	0	0	32	32	0	0	0	0	0	0	0	0	0
Oligochaeta	0	0	0	0	0	48	80	1600	0	0	0	1136	0
Chaetognatha	0	0	0	0	0	0	16	0	0	0	0	0	0
Abundance (No/m ²)	688	192	11200	512	448	224	1456	1856	496	3776	144	1376	1488

*CH5C station had no fauna & CH15 A, CH15B and CH15C samplenot collected due to hard bottom.



(Contd.....): Abundance (no/m ²) of macrofauna from Chapora Estuary (Peripheral transect).																
Taxa	CH8B	CH8C	CH9B	CH9C	CH10B	CH10C	CH11B	CH11C	CH12B	CH12C	CH13B	CH13C	CH14B	CH 14C	Sum	%
Hydrozoa	0	0	0	0	0	0	0	0	0	0	0	32	0	0	48	0.05
Nematoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	368	0.39
<i>Nereis</i> sp.	0	16	0	0	3808	1200	4000	6928	864	6384	48	3056	1456	912	30896	32.65
<i>Mediomastus</i> sp.	0	0	0	0	16	0	0	0	0	0	0	0	0	0	16	0.02
<i>Heteromastus</i> sp.	0	0	16	48	0	0	0	0	0	0	0	0	0	1008	9968	10.53
<i>Prionospio pinnata</i>	0	480	800	672	3968	4112	288	7360	2512	704	448	3872	112	192	29136	30.79
<i>Polydoraciliata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0.02
<i>Glycera alba</i>	16	160	32	96	16	16	0	0	0	0	0	32	0	16	704	0.74
<i>Ancistrosyllis</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1120	1.18
<i>Lumbrineris</i> sp.	0	0	0	0	128	0	0	0	0	0	0	16	0	0	208	0.22
<i>Amphictene</i> sp.	0	96	0	64	0	0	0	0	0	0	0	0	0	0	160	0.17
<i>Sabellaria</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0.02
<i>Poecilochaetus</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	96	0.10
<i>Paraonis</i> sp.	0	0	0	0	0	0	0	16	0	0	0	0	0	0	16	0.02
<i>Hydroides</i> sp.	0	0	0	0	0	0	0	0	0	0	48	0	0	0	48	0.05
<i>Inemophytis inermis</i>	0	0	0	48	0	0	0	0	0	0	0	0	0	0	192	0.20
<i>Hesione</i> sp.	0	0	0	0	16	0	0	0	0	0	0	0	0	0	16	0.02
<i>Chaetopterus</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0.03
<i>Aphrodite</i> sp.	0	0	0	0	0	0	0	0	0	0	16	0	0	0	64	0.07
<i>Orbinia</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	608	0.64
<i>Maldanella</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	48	0.05
<i>Ophelia</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	128	0.14
<i>Echuiria</i>	0	0	0	0	0	0	0	0	0	0	16	0	0	48	96	0.10
Amphipoda	0	0	16	0	2912	16	16	1328	96	464	48	3120	720	112	9376	9.91
Isopoda	0	0	0	0	0	0	0	0	0	0	0	0	0	32	1216	1.28



Harpacticoida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0.03
Lucifera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	64	0.07
Cumacea	0	0	16	0	0	0	0	0	0	0	0	0	0	0	64	0.07
Tanaidacea	0	0	0	0	0	0	0	0	0	0	0	0	48	0	48	0.05
Shrimp	0	0	0	0	0	0	0	16	0	0	32	0	0	0	80	0.08
Brachyura	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0.03
Decapoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0.02
Bivalvia	32	80	0	192	64	0	16	176	0	64	64	48	0	32	1344	1.42
Platyhelminthes	0	0	0	0	0	0	0	0	0	0	0	0	32	16	176	0.19
Planaria	0	0	0	16	0	16	0	0	0	0	0	0	0	0	32	0.03
Nemertea	0	0	0	0	0	32	48	224	208	112	64	32	32	0	1136	1.20
Chironomidae larvae	0	0	0	0	400	0	192	1072	48	1184	16	736	80	0	3824	4.04
Fish (Juvniles)	0	0	0	16	0	0	0	0	0	0	0	32	0	0	48	0.05
Lingulidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	64	0.07
Oligochaeta	0	0	96	0	0	0	48	0	16	16	0	32	0	0	3072	3.25
Chaetognatha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0.02
Abundance (No/m ²)	48	832	976	1152	11328	5392	4608	17120	3744	8928	800	11008	2480	2368	94640	100.00

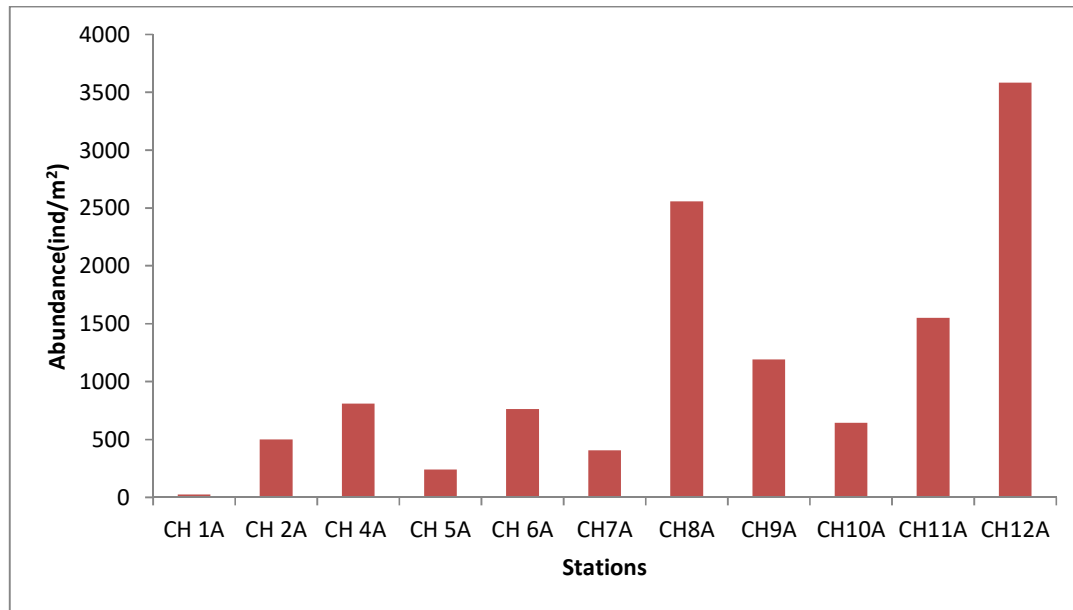


Figure 4.19: Station-wise macrofaunal abundance (no/m2) of the Chapora Estuary (Central transect).

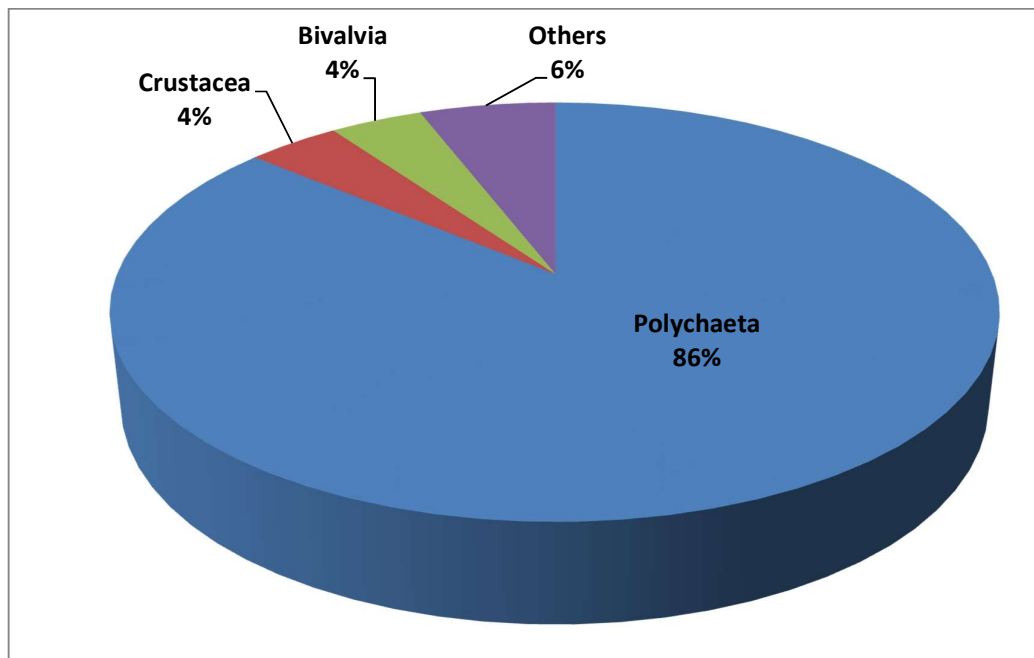


Figure 4.20: Percent (%) composition of macrofaunal abundance of the Chapora Estuary (Central transect).

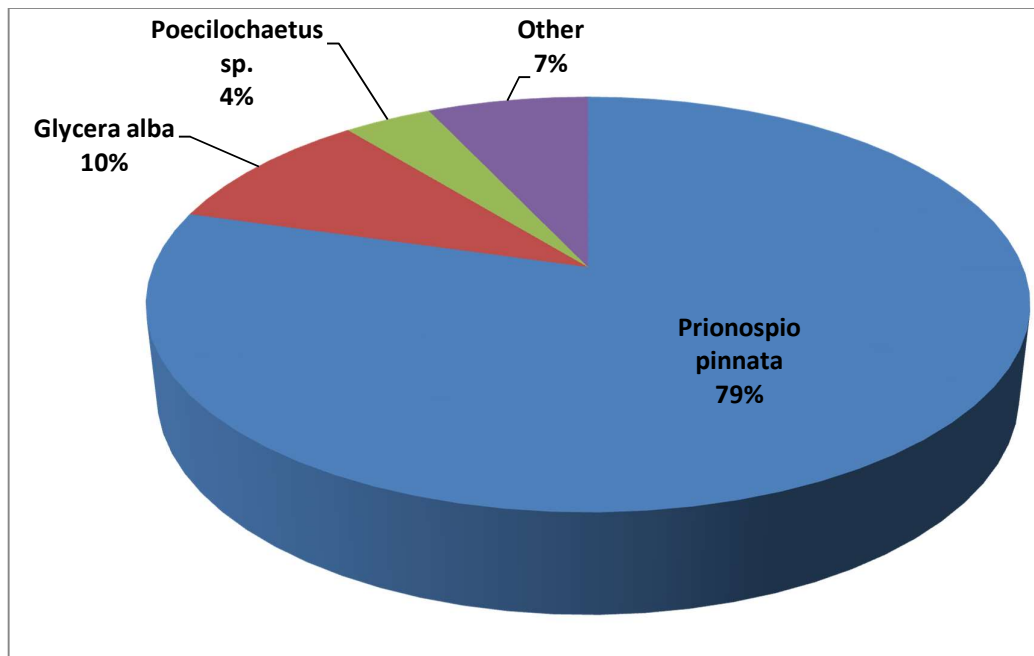


Figure 4.21: Percent (%) composition of Polychaeta of the Chapora Estuary (Central transect).

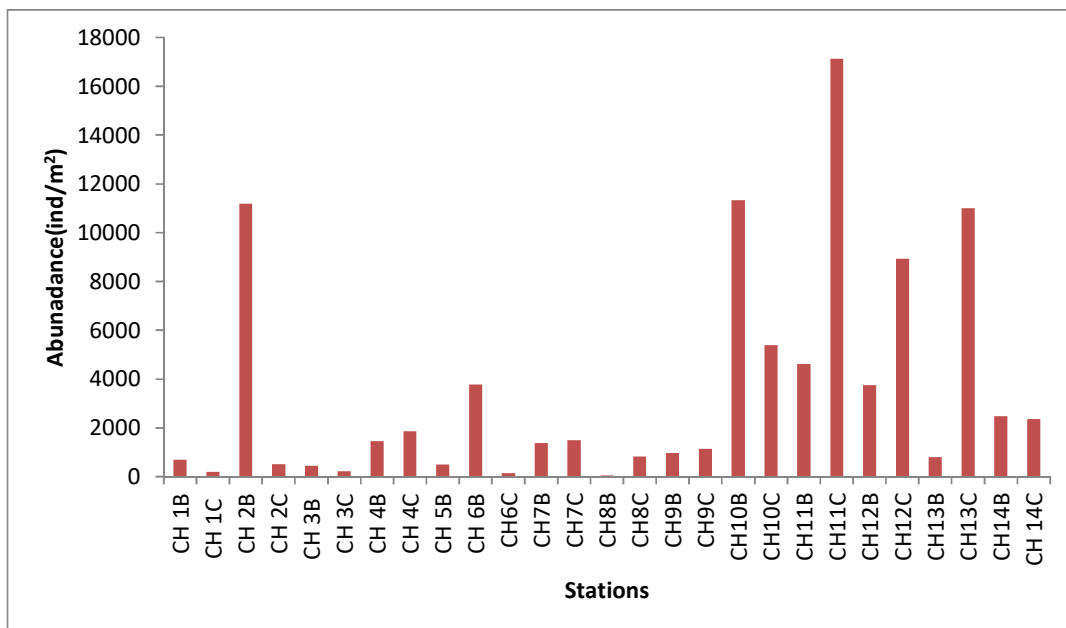


Figure 4.22: Station-wise macrofaunal abundance (no/m²) of the Chapora Estuary (Peripheral transect)..

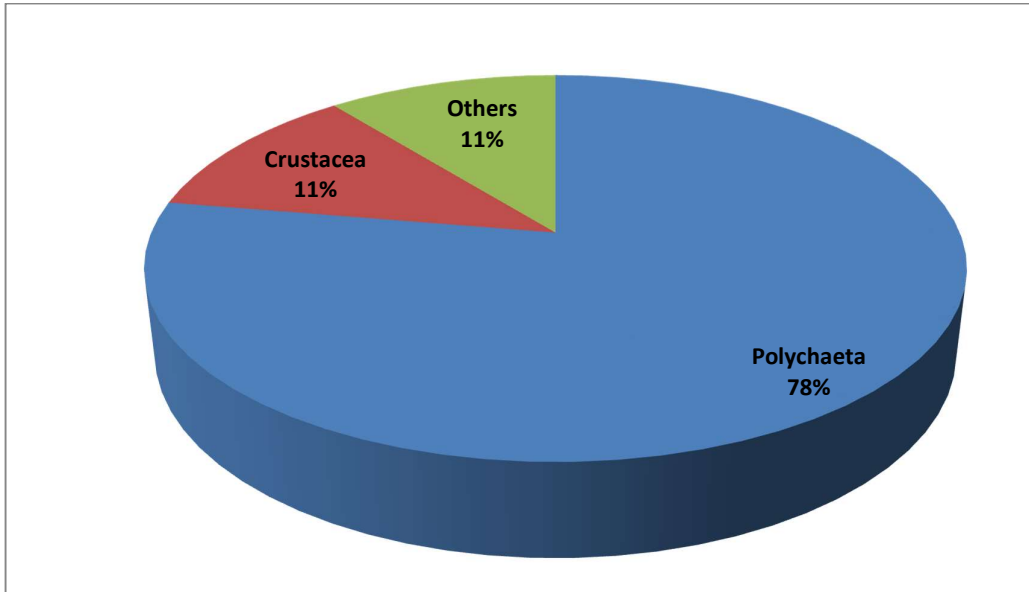


Figure 4.23: Percent (%) composition of macrofaunal abundance of the Chapora Estuary (Peripheral transect).

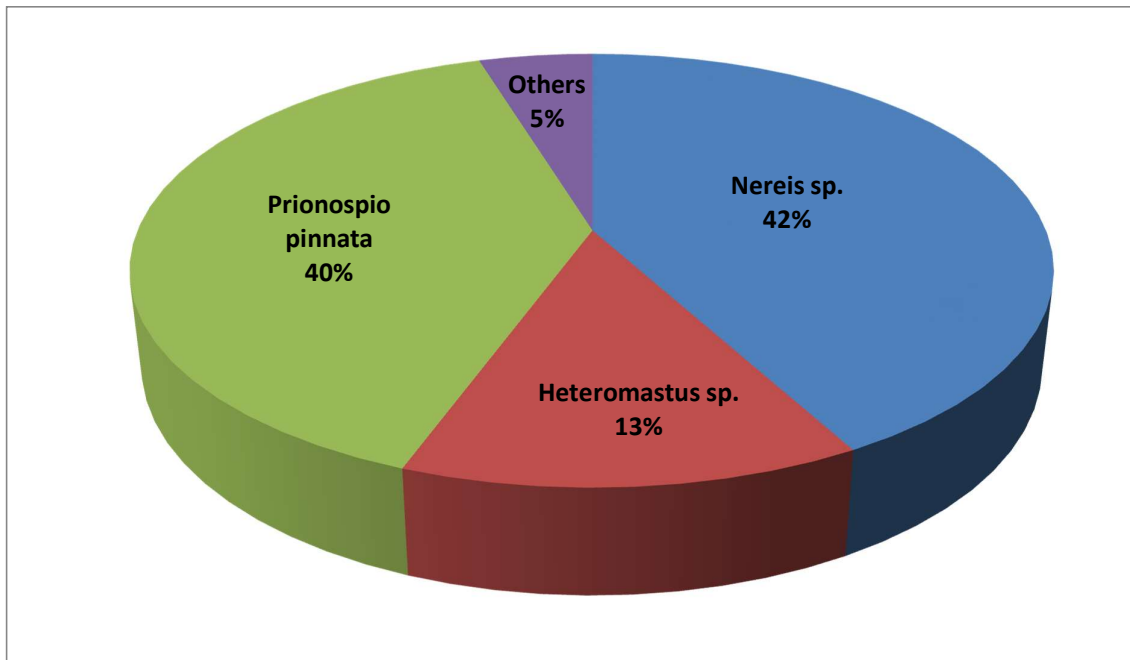


Figure 4.24: Percent (%) composition of Polychaeta of the Chapora Estuary (Peripheral transect).

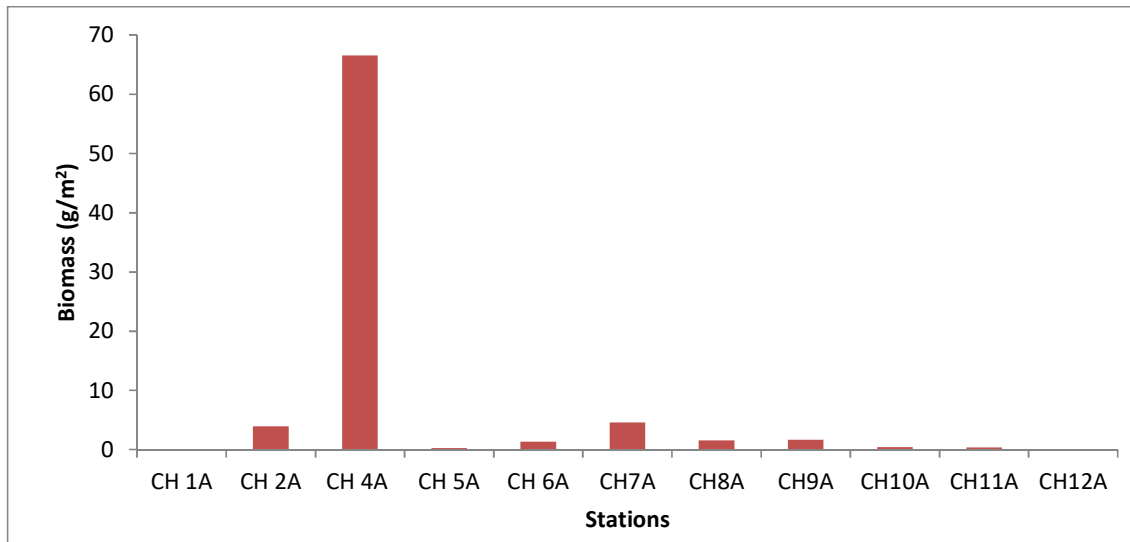


Figure 4.25: Station-wise Biomass (g/m²) of the centre of the Chapora Estuary.

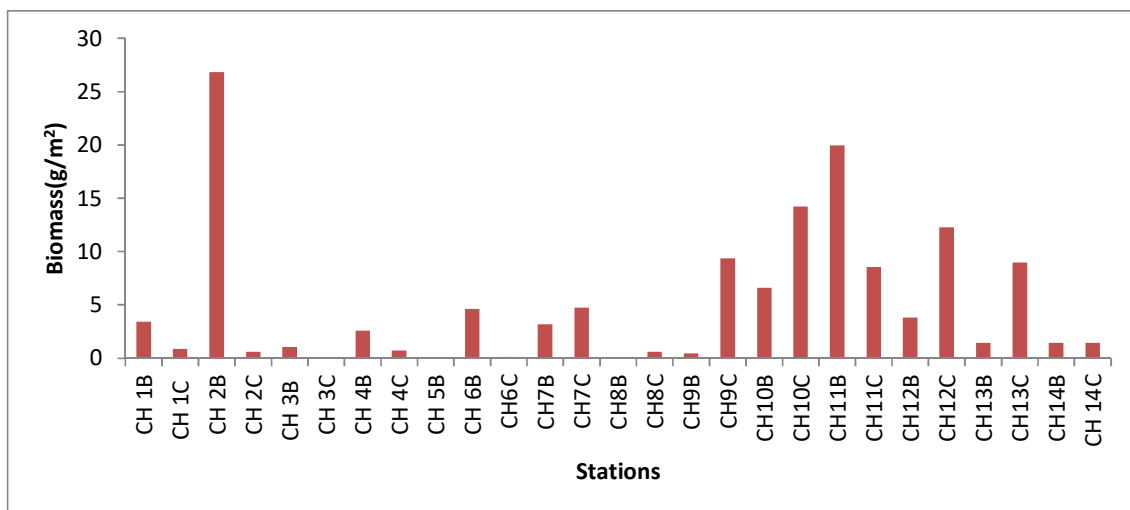


Figure 4.26: Station-wise Biomass (g/m²) of the Chapora Estuary (Peripheral transect).



Plate 4: Macrofauna of Chapora Estuary A-*Prionospio pinnata*; B-*Heteromastus* sp.; C-*Glycera alba*; D- *Inemophytys inermis*; D-; E-Nemertea; F- Bivalvia



4.5.6 Diversity indices

Diversity indices are the mathematical expression of the species diversity of a given community or area, which includes due allowance for the relative abundance of different species present.

Shannon-Wiener index of diversity:

Shannon-Wiener index of diversity (information index), a measure derived from information theories developed by Shannon & Wiener (1949), which is used by ecologists when a system contains too many individuals for each to be identified and examined. A small sample is used; the index is the ratio of the number of species to their importance values (e.g. biomass or productivity) within a trophic level or community. This normalizes the Shannon diversity index to a value between 0 and 1. The lower values indicate more diversity while higher values indicate less diversity. Specifically, an index value of 1 means all groups has the same frequency.

Simpson's Diversity Index:

Simpson's Diversity Index is a measure of diversity which takes into account the number of species present, as well as the relative abundance of each species. As species richness and evenness increase, so diversity increases. The value of Simpson's Diversity Index (D) ranges between 0 and 1, the greater the sample diversity.

The macrofaunal diversity was explained in terms of number of individuals or specimens (N), number of species (S), total abundance (A), Margalef species richness (d), Pielou's evenness (J') and Shannon index (H') and Simpson index ($1-\lambda$) using square root scale at each CHA stations (Clarke & Gorley, 2001). The number of species were maximum at station CH8A (119) and minimum at station CH1A (5). The species richness (d) was highest at CH4A ($d=2.6$) and lowest at CH1A ($d=0$). Evenness was recorded highest at CH4A, CH6A & CH7A ($J'=1$) and lowest at CH1A ($J'=0$). The Shannon index was highest at CH4A ($H'=2.5$) and lowest at CH1A ($H'=0$) adjacent mangrove area could be the reason for high diversity at CH4A whereas CH1A depicted low diversity as it is located at the mouth channel which explains the lower value as maintenance dredging takes place for swift movement of vessels (Figure 4.26). The number of species were found to be maximum at station CH11 (202) and minimum at station CH03 (31). The species richness (d) was highest at CH02 ($d=2.2$) and lowest at CH06 ($d=0.8$).



Evenness was recorded highest at CH01 ($J'=1$) and lowest at CH10 ($J'=0.7$). The Shannon index was highest at CH02 ($H'=2.2$) and lowest at CH06 ($H'=1$) (Figure 4.27). CH02 is situated near the mouth with healthy mangrove forest adjacent to it, which explains high diversity. While CH06 lies where sand mining used to be carried out earlier which is why it is found to be low in diversity.

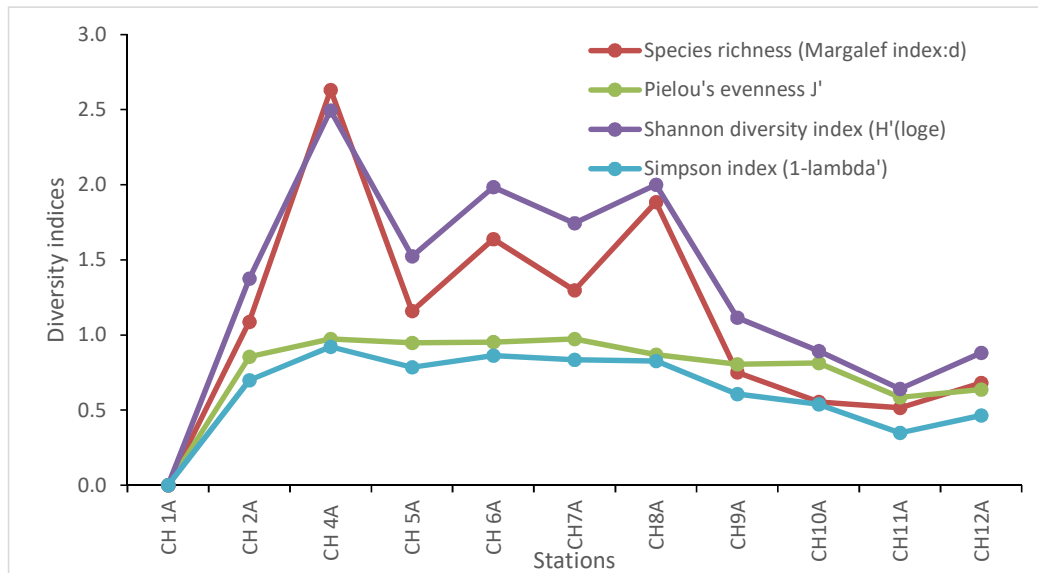


Figure 4.27: Station-wise diversity indices of Chapora Estuary (Central transect).

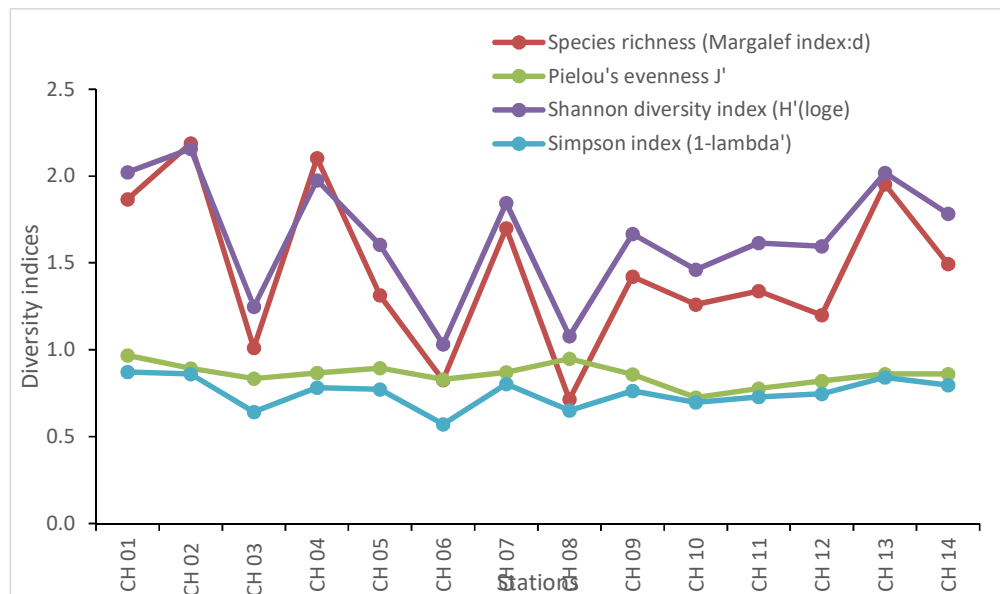


Figure 4.28: Station-wise diversity indices of Chapora Estuary (Peripheral transect).

Benthic Polychaeta: Amphipoda (BPA) Ratio:



To study the pollution status of the marine environment and to access the ecological quality status of the area, biotic indices like Benthic Polychaetes Amphipods Index (BPA) was done. This index was based on the ratio of sensitive amphipods to other fauna like annelids (polychaetes). The Benthic Polychaetes Amphipods Index (BPA) was determined by the lack of sensitive species among polychaetes from the study area. Amphipods are abundant fauna of the estuarine and marine soft-bottoms and they are sensitive to polluted sediments, they mainly disappear from benthic communities which is impacted by pollution and will reappear when the environmental condition recover (Ré *et al.*, 2009; de-la-Ossa-Carretero *et al.*, 2012).

The Benthic Polychaetes Amphipods ratio (BPA) index is given as:

$$BPA = \log_{10} [fp/(fa+ 1)+ 1]$$

Where *fp* was the polychaete frequency and *fa* is the amphipod frequency and +1 used to prevent a total absence of amphipods and the other +1 used to prevent a total absence of opportunistic polychaetes. This index corresponded to the total number of polychaetes (or annelids) and total number of amphipods divided by the overall abundance accounted in a station sample. Thresholds for establishing the Ecological Quality status by each index, the values ranged as 0.025-0.130 (Good status), 0.130-0.199 (moderate status), 0.199-0.255 (poor status).

At the centre region of Chapora Estuary, the BPA ratio ranged from 0.307 to 0.47. At station CH4A, CH5A, CH6A and CH7A, the BPA ratio ranged from 0.30-0.39 (Table 4.11). The stations CH1, CH2A, CH3A, and CH8 to CH12A showed high values of the polychaete/amphipod ratio where there was absence or low abundance of amphipods and high abundance of polychaetes. *P.pinnata* of the family Spionidae dominated in the centre area, which is an opportunistic polychaete species. At the periphery region, the BPA ratio ranged from 0.02 to 0.30 at Station CH5B and CH6C (Table 4.12). *Heteromastus* sp. and *P. Pinnata* of the family Capitellidae and Spionidae dominated which are the opportunistic polychaetes.

Table 4.11: Benthic Polychaete Amphipode(BPA) ratio of Chapora Estuary (Central transect)	
Stations	Polychaeta/Amphipoda ratio
CH 1A	0.477
CH 2A	0.449
CH 4A	0.307
CH 5A	0.398
CH 6A	0.314



CH 7A	0.338
CH 8A	0.422
CH 9A	0.459
CH 10A	0.432
CH 11A	0.473
CH 12A	0.458

Table 4.12: Benthic Polychaete Amphipode (BPA) ratio of Chapora Estuary (Peripheral transect)

Stations	Polychaeta/Amphipoda ratio
CH 1B	0.218
CH 1C	0.243
CH 2B	0.268
CH 2C	0.243
CH 3B	0.293
CH 3C	0.058
CH 4B	0.255
CH 4C	0.039
CH 5B	0.027
CH 6B	0.299
CH 6C	0.301
CH 7B	0.037
CH 7C	0.178
CH 8B	0.125
CH 8C	0.280
CH 9B	0.268
CH 9C	0.257
CH 10B	0.193
CH 10C	0.298
CH 11B	0.285
CH 11C	0.249
CH 12B	0.274
CH 12C	0.244
CH 13B	0.224
CH 13C	0.174
CH 14B	0.173
CH 14C	0.273



Biotic indices

Ecological quality status assessment carried out by AMBI analysis based on the benthic polychaete diversity and abundance. This index assigned the most of the sampling sites as slightly disturbed to moderately disturbed. Only sites CH1B, CH2A, and CH5B were found to be undisturbed based on the AMBI results. According to M-AMBI, most of the sampled sites were assigned to poor ecological quality status. Sites CH1B, CH1C, CH2B, CH7A were in good status. Sites CH2A, CH5A, CH6A-6B, CH7B, CH8C, CH9C, CH10B and CH14C were showed moderate status.

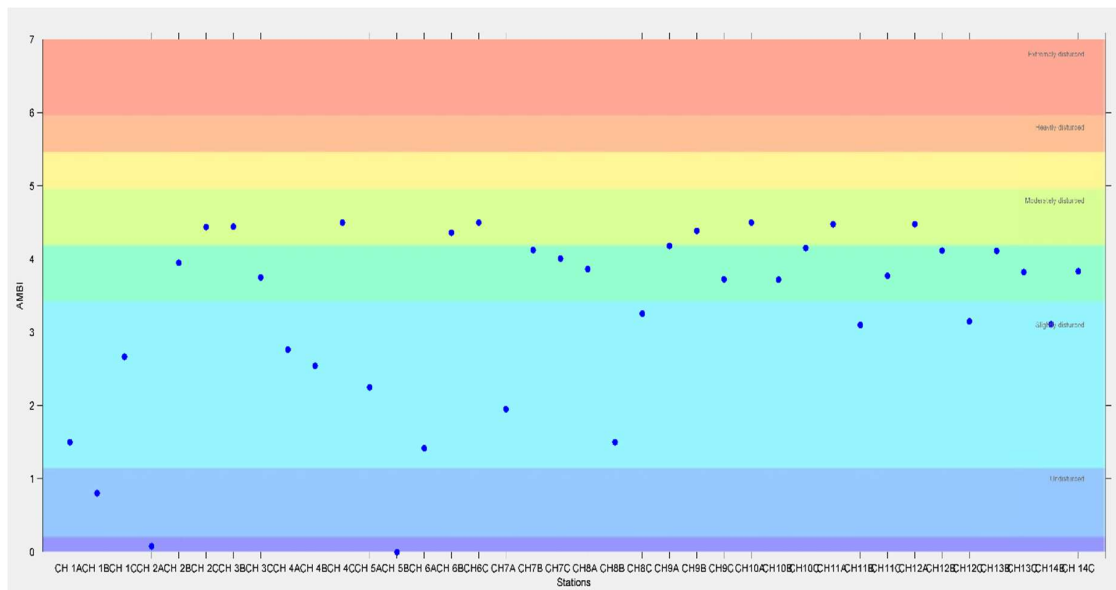


Figure 4.29: Ecological quality status assessment through AMBI index along the sampling sites.

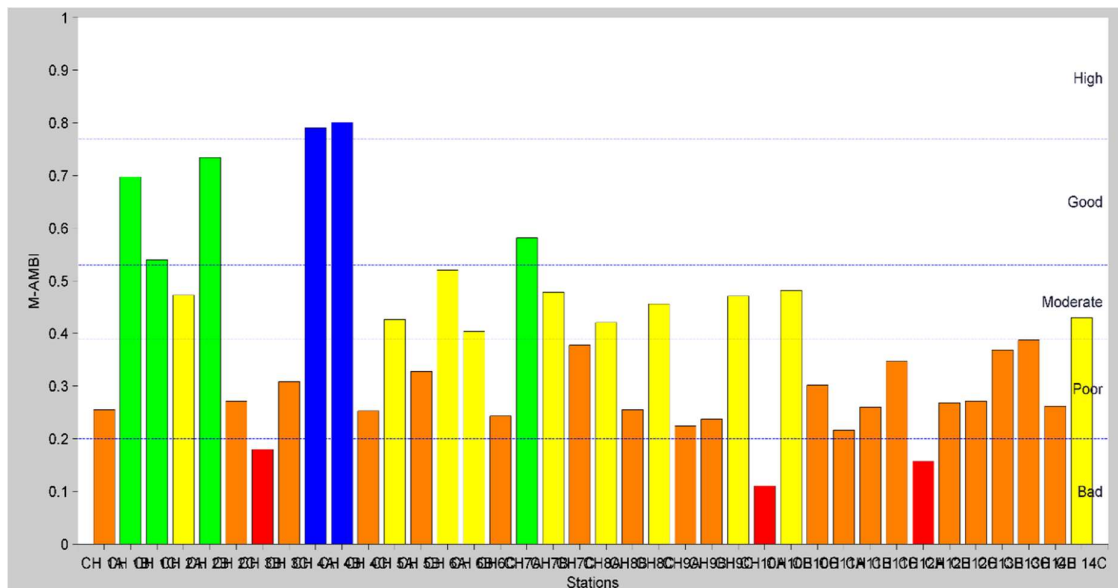


Figure 4.30: Ecological quality status assessment through M-AMBI index along the sampling sites.

BENTIX produced a poor status in most of the sites in the upper stretch of the Chapora Estuary, except the site CH14C, which displayed good ecological quality status. Sites in the lower stretch (CH1-CH7) of the Chapora Estuary showed high to good ecological quality status due high diversity and abundance in benthic fauna. Site CH8 A and CH8C found as moderate ecological quality. Additionally, sampled sites in the lower stretch of the river were found to harbour more ecological sensitive benthic organisms, whereas the upper stretch was mostly dominated by the stress tolerant benthic organisms.

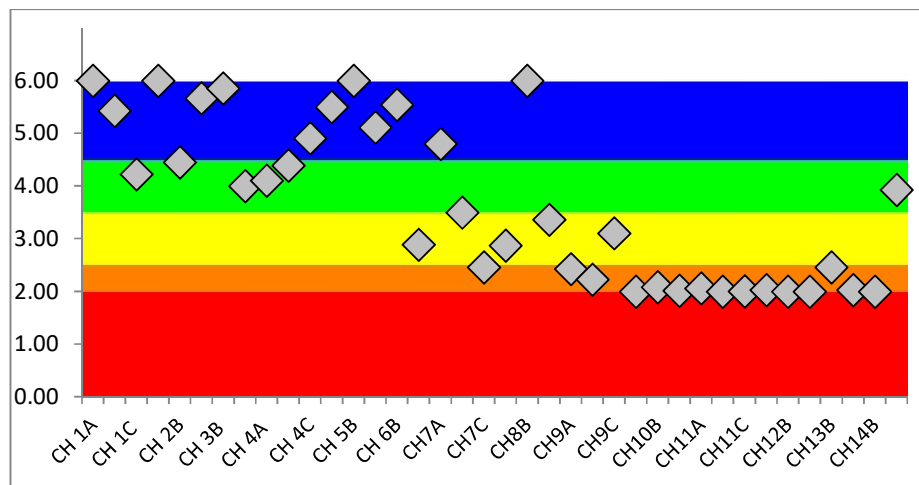


Figure 4.31: Ecological quality status assessment through BENTIX index along the sampling sites.

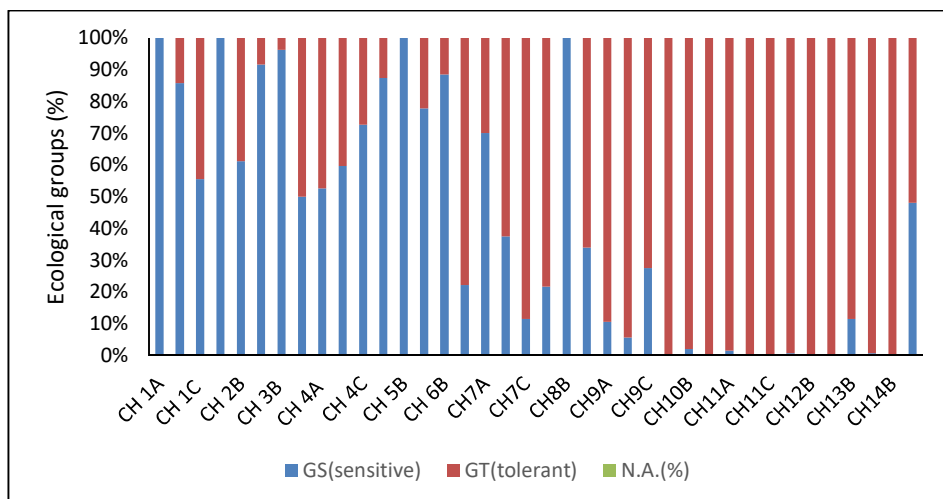


Figure 4.32: Distribution of macrobenthic- Polychaetes based on the ecological sensitivity group assessed through BENTIX index along the sampling sites.

4.5.7 Fishery:

Chapora is a fishing village which falls under the Village Panchayat of Anjuna-Assagao in Bardez taluka in North Goa district, Goa. The Chapora village is about 11 km from taluka headquarters at Mapusa and about 24 km from Panaji, the state capital. Coastal marine waters off Chapora and Chapora estuary is endowed with rich fishery resources and famous for fishing activities which are carried out through fibre reinforced plastic (FRP) outboard engines boats, trawlers and small size traditional dugout canoes. The secondary data for the fishes were collected from the locals and fishermen community around. Therefore, the secondary data reveals that commercially important fish varieties such as mackerels, sardines, catfish, sharks, seerfish, pomfrets, cuttlefish and prawns were found during trawling operations. The fishes found in this area represent marine, estuarine and backwater species. Fishing is mainly carried out with the help of mechanized and non-mechanized or traditional crafts in various parts of Goa. The methods of fishing in Chapora Estuary are of mainly by cast-nets, gill nets, stake nets, hook and line, shore seine (Rampani), purse seine, trawler, and free diving for the collection of clams, oysters and green mussels. Skate fishing is a common traditional fishing method used in the river creeks. It is pursued throughout the year, except the time of high tides during the monsoons. This type of fishing mainly depends upon the ebb and flow of tides and current of water, which differs from day to day. Secondary data of fishes is listed in the table. The shell fishery is common fishing practice used by the local people. Bivalve clams, *Meritrix casta* and *Paphia malbarica* were commonly found in the river. These clams were found throughout the year with variable quantities depending on season. Local



fishermen use to depend on these clams for their livelihood. These clams are collected and harvested by hand picking and hand operated scoop net or with the help of a small hand held digging sick. Locals use canoe to collect these clams from deeper waters. Other species found in this area are *Perna viridis*, *Polymesoda erosa* and *Villorita cyprinoides*. Oyster collection is one of the fishing practices carried out in the river by the local people. List of clams, oysters and mussels is given in table 4.13. Most common fish species found in estuarine and brackish water are *Etroplussuratensis*, *Mugilcephalus*, *Chanoschanos*, *Latescalcarifer* along with species of Red snapper, mud skippers and common shrimps found in this estuary include *Penaeusindicus*, *P. merguensis*, *P. monodon* etc (Source:, NIO 2017; Table 4.13). In the recent times, the clam fishery has almost collapsed in the estuary and according to local sources the overall fishery yield has reduced drastically.

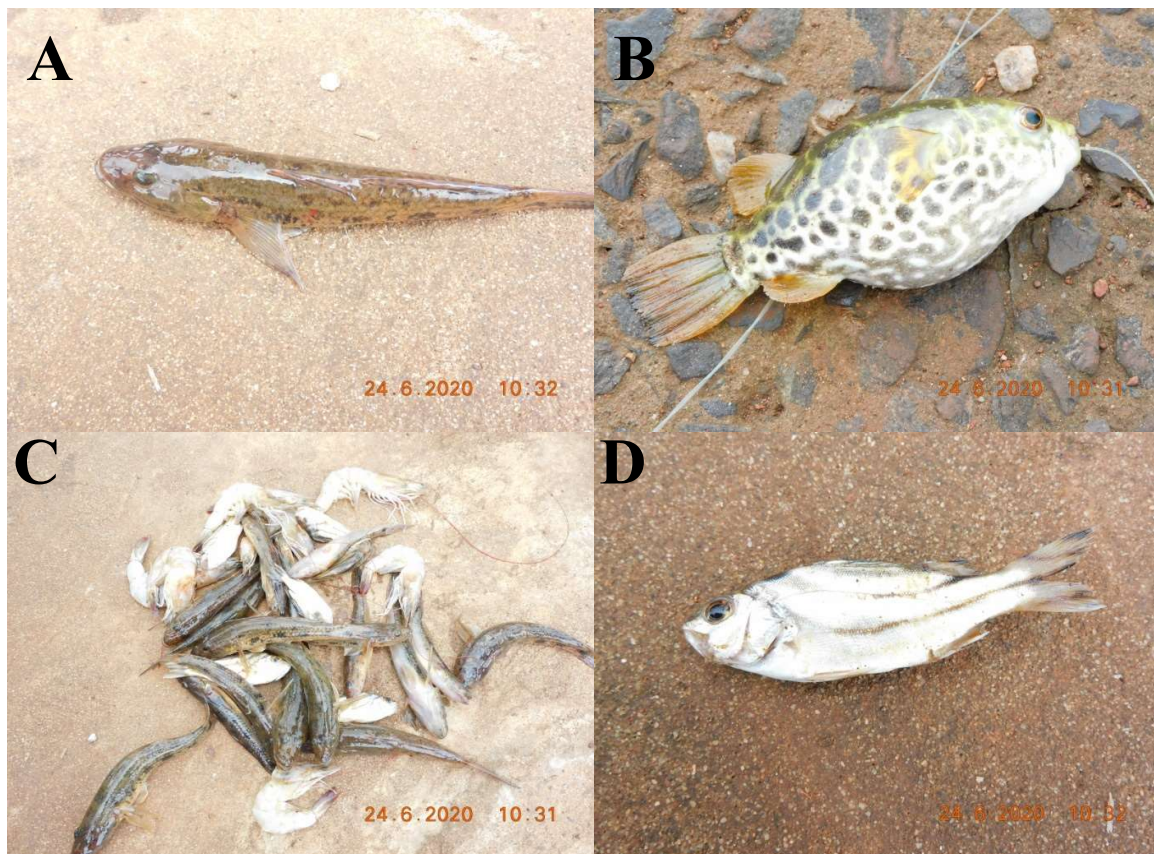


Plate 5: Fish species observed in Chapora estuary [A. Platycephalidae sp.; B.Tetradontidae; C. Total catch; D. Terapontidae]



Table 4.13: Fish diversity from Chapora Estuary

Families	Species	Common name	Vernacular name	Habitat class
Congridae	<i>Bathy congrusnasicus</i>	Eel	Vam	Demersal
Chirocentridae	<i>Chirocentrusdorab</i>	Wolf herring	Karli	Pelagic
Engraulidae	<i>Stolophorusindicus</i>	Indian anchovy	Dindvus	Pelagic
	<i>Thryssamalabarica</i>	Malabar thryssa	Khavali	Pelagic
Pristigasteridae	<i>Opisthopterustardoore</i>	Tardoore	Kateri	Pelagic
Ariidae	<i>Arius jella</i>	Blackfin Sea catfish	Sangot	Demersal
Clupeidae	<i>Sardinellafimbriata</i>	Fringscale sardine	Pedi	Pelagic
Synodontidae	<i>Sauridatumbil</i>	Lizard fish	Bokalav	Demersal
Platycephalidae	<i>Eurycephaluscarbunculus</i>	Papilose flathead	-	Demersal
		Flat headed fish		Demersal
Ambassidae	<i>Ambassisgymnocephalus</i>	Bald glassy	Burato	Pelagic
Nemipteridae	<i>Nemipterus japonicas</i>	Japanese threadfin bream	Rano	Demersal
Lutjanidae	<i>Lutjanuscampechanus</i>	Red snapper	Tamoshi	Pelagic
Mugilidae	<i>Mugilsp</i>	Mullet	Shevto	Pelagic
Serranidae		Grouper	Palu	Pelagic
Cichlidae	<i>Etroplussuratensis</i>	Pearl spot	Kalunder	Benthopelagic
Terapontidae	<i>Teraponjarbua</i>	Tiger perch		Pelagic
Tetraodontidae		Puffer fish		Pelagic
Gerridae	<i>Gerresfilamentosus</i>	Silver biddy	Shetuk	Demersal
Latidae	<i>Latescalcarifer</i>	Giant sea perch	Chonak	Demersal
Sillaginidae	<i>Sillagosihama</i>	Silver whiting	Muddoshi	Demersal
Sciaenidae	<i>Johniuscarouna</i>	Caroun croaker	Dhodiya	Demersal
Leiognathidae	<i>Otolithesruber</i>	Tiger toothed croaker	Dhodiya	Demersal



	<i>Secutorinsidiator</i>	Pugnose pony fish	Kapi	Demersal
Carangidae	<i>Secutorruconius</i>	Deep pugnose pony fish	Kapi	Demersal
	<i>Alepeskleinii</i>	Razorbellyscad	-	Pelagic
Polynemidae	<i>Caranxsp</i>		-	Pelagic
	<i>Polydactylusplebeius</i>	Stripped threadfin	Ravas	Pelagic
Trichiuridae	<i>Trichiuruslepturus</i>	Ribbon fish	Baye	Pelagic
Stromatidae	<i>Rastrelligerkanagurata</i>	Indian mackerel	Bangdo	Pelagic
	<i>Pampuschinensis</i>	Chinese pomfret	Surungati	BenthoPelagic
Lactariidae	<i>Lactariuslactarius</i>	White fish	Saudale	Pelagic
Solidae	<i>Synapturaalbomaculata</i>	Kaup's sole fish	Lepo	Demersal
Cynoglossidae		Flounder	lepo	Demersal
	<i>Cynoglossusarel</i>	Sole fish	Lepo	Demersal
Penaeidae	<i>C. macrostomus</i>	Malabar tongue sole	Lepo	Demersal
	<i>Penaeusmonodon</i>	Tiger shrimp	Vaghi	Demersal
Portunidae	<i>Fenneropenaeusmerguensis</i>	Banana prawn	Safedsungata	Demersal
	<i>Metapenaeusaffinis</i>	Jinga shrimp	Sungat	Demersal
	<i>Metapenaeusdobsonii</i>	Kadal shrimp	Sungat	Demersal
	<i>Meapeaneusmonoceros</i>	Speckled shrimp	Sungat	Demersal
	<i>Scylla serrata</i>	Mud crab	Kurlo	Demersal
Calappidae	<i>Portunussanguinolentus</i>	Three spot swimming crab	Tin doyanchikurli	Demersal
	<i>Portunuspelagicus</i>	Blue swimming crab	Padyachikurli	Demersal
	<i>Charybdis feriatus</i>	Crucifix crab	Khrusachikurli	Demersal
	<i>Matutalunaris</i>	Moon crab	Bhamburte	Demersal
Squillidae	<i>Calappalophos</i>	Box crab	-	
	<i>Oratosquillaquinquedentata</i>	Mantis shrimp	Luchi	Demersal



Diogenidae	<i>Pagurus sp.</i>	Hermit crab	-	Demersal
Ocupodidae		Fiddler crab		Demersal
Loliginidae	<i>Loligoduvauceli (Juv.)</i>	Indian squid	Manki	Demersal
Sepiidae	<i>Sepia sp. (Juv.)</i>	Cuttle fish	Bebo	Demersal
Naticidae	<i>Naticatigrina</i>	Tiger moon shell	Congo	Demersal
Cyrenidae	<i>Villoritacyprinoides</i>	Black clams	Khube	Benthic
Veneridae	<i>Polymesoda erosa</i>	Mud clam	Khube	Benthic
	<i>Meretrix meretrix</i>	Asiatic hard clam	Tissryo	Benthic
Ostreidae	<i>Meretrix casta</i>	Backwater hard clam	Tissryo	Benthic
	<i>Paphia malabarica</i>	Venus clams	Khube	Benthic
	<i>Paphia textilis</i>	Venus clams	Khube	Benthic
	<i>Crassostrea madrasensis</i>	Oyster	Kalva	Benthic
Mytilidae	<i>Crassostrea gigas</i>	Oyster	Kalva	Benthic
	<i>Saccostrea</i>	Oyster	Kalva	Benthic
	<i>Perna viridis</i>	Asian green mussel	Shenanyo	Benthic
Melongenidae	<i>Hemifusus pugilinus</i>	Sea snail	-	Demersal
Turritellidae	<i>Turritella acutangula</i>	Screw shell	Congali	Demersal
Rostellariidae	<i>Tibia curta</i>	Indian tibia	Congali	Demersal
Burside	<i>Bufonaria rana</i>	Frog shell	-	Demersal
Muricidae	<i>Murex aduncospinosus</i>	Spine murex	-	Demersal
Babyloniidae	<i>Babylonia spirata</i>	Whelks	-	Demersal
Conidae	<i>Conus sp.</i>	Cone shell	-	Demersal
Astropectinidae	<i>Astropecten indicus</i>	Star fish	-	Demersal
Rhizostomatidae	<i>Rhopilema spp.</i>	Jelly fish	Zar	Pelagic

4.5.8 Reptiles & Mammals:

Reptiles, such as estuarine crocodiles *Crocodylus palustris*, snakes, monitor lizards, turtles are found in Chapora Estuary. Morjim beach on the north of Chapora Bay is a protected site for Turtle nesting mainly the Olive Ridley sea turtles (*Lepidochelys olivacea*). Every year number of turtles visits this beach for breeding during October and hatchling emerges in March-April every year. Morjim was the first site in Goa where sea turtle conservation was started by the Forest Department in 1997. Mammals are mainly represented by Otters, jackals, flying fox,



wild cats and wild boar. These mammals visit mangroves for shelter, breeding or feeding on molluscs, crabs, fishes and other crustaceans (Table 4.14).

Table 4.14: List of Reptiles and Mammals recorded from Chapora Estuary

Sr. no.	Common name	Scientific name	IUCN status	Wildlife Protection Act (1972)
1	Smooth-coated otter	<i>Lutrogale perspicillata</i>	Vulnerable	Schedule II
2	Mugger crocodile	<i>Crocodylus palustris</i>	Vulnerable	Schedule I
3	Indian grey mongoose	<i>Herpestes edwardsi</i>	Least concern	Schedule II
4	Indian flapshell turtle	<i>Lissemys punctata punctata</i>	Least concern	Schedule I
5	Flying fox	<i>Pteropus medius</i>	Least concern	Schedule IV
6	Indian rock python	<i>Python molurus</i>	Near threatened	Schedule I
7	Golden jackal	<i>Canis aureus</i>	Least concern	Schedule II
8	Wild boar	<i>Sus scrofa</i>	Least concern	Schedule III

4.5.8 Avifauna:

Birds are the prominent part of the mangrove ecosystem and they are often present in large numbers. Many bird species make extensive use of mangroves for roosting, feeding and breeding. The mud flats, marshes provide abundant food to these birds in the form of small molluscs, crustaceans, worms, insects etc. Bird species such as kingfishers, Plovers, large Herons, Storks, Egret etc. were found feeding in the mangrove mudflats. It is common site for birds perched on mangroves for roosting or some waiting for an opportunity to catch a fish when they surface in the water. Besides mangroves many shore birds like Gulls were observed on sand bars at the mouth of the river for feeding purposes. Chapora Estuary also hosts a variety of migratory birds such as Painted stork, Heuglins gull, Caspian gull during the winter months. Large numbers of birds were seen during low tides. Eroded vertical banks of the upper stretches of the banks have burrow nests mostly by kingfishers and bee-eaters. List of birds found in Chapora estuary are given in table 4.15. (Ref: NIO Report, 2017 & <http://www.realbirder.com/Goa%20-%20Morjim%20Beach.htm>).



Table 4.15: List of Bird species spotted from Chapora Estuary

Sr.No.	Common name	Scientific name	IUCN status	Wildlife Protection Act 1972
1	Indian Cormorant	<i>Phalacrocorax fuscicollis</i>	Least Concern	Schedule IV
2	Lesser Cormorant	<i>Microcarbo niger</i>	Least Concern	Schedule IV
3	Red-wattled lapwing	<i>Vanellus indicus</i>	Least Concern	Schedule IV
4	black headed oriole	<i>Oriolus larvatus</i>	Least Concern	Schedule IV
5	Stock billed kingfisher	<i>Pelargopsis capensis</i>	Least Concern	Schedule IV
6	White breasted kingfisher	<i>Halcyon smyrnensis</i>	Least Concern	Schedule IV
7	Common kingfisher	<i>Alcedo atthis</i>	Least Concern	Schedule IV
8	Small green bee eater	<i>Merops orientalis</i>	Least Concern	Schedule IV
9	Painted stork	<i>Mycteria leucocephala</i>	Near Threatened	Schedule IV
10	White ibis	<i>Threskiornis melanocephalus</i>	Near Threatened	Schedule IV
11	Glossy ibis	<i>Plegadis falcinellus</i>	Least Concern	Schedule IV
12	Intermediate Egret	<i>Ardea intermedia</i>	Least Concern	Schedule IV
13	White breasted waterhen	<i>Amaurornis phoenicurus</i>	Least Concern	Schedule IV
14	Brahminy kite	<i>Haliastur indicus</i>	Least Concern	Schedule IV
15	White browed wagtail	<i>Motacilla maderaspatensis</i>	Least Concern	Schedule IV
16	House crow	<i>Corvus splendens</i>	Least Concern	Schedule V
17	Sand Plover	<i>Charadrius sp.</i>	Least Concern	Schedule IV
18	Bay-backed Shrike	<i>Lanius vittatus</i>	Least Concern	Schedule IV
19	Common Quail	<i>Coturnix coturnix</i>	Least Concern	Schedule IV
20	Ruddy Turnstone	<i>Arenaria interpres</i>	Least Concern	Schedule IV
21	Asian Koel	<i>Eudynamys scolopaceus</i>	Least Concern	Schedule IV
22	Common Sandpipers	<i>Actitis hypoleucos</i>	Least Concern	Schedule IV
23	Caspian Gull	<i>Larus cachinnas</i>	Least Concern	Schedule IV
24	Heuglin's Gull	<i>Larus heuglini</i>	Least Concern	Schedule IV
25	Steppe Gull	<i>Larus (heuglini) barabensis</i>	Least Concern	Schedule IV
26	Pallas's Gull	<i>Ichthyaeetus ichthyaeetus</i>	Least Concern	Schedule IV
27	Brown headed Gull	<i>Chroicocephalus brunnicephalus</i>	Least Concern	Schedule IV
28	Black headed Gull	<i>Chroicocephalus ridibundus</i>	Least Concern	Schedule IV
29	Gull-billed tern	<i>Gelochelidon nilotica</i>	Least Concern	Schedule IV
30	Greater Crested Tern	<i>Thalasseus bergii</i>	Least Concern	Schedule IV



31	White bellied Sea Eagle	<i>Haliaeetus leucogaster</i>	Least Concern	Schedule I
32	Osprey	<i>Pandion haliaetus</i>	Least Concern	Schedule I
33	Lesser whistling duck	<i>Dendrocygna javanica</i>	Least Concern	Schedule IV
34	Plain prinia	<i>Prinia inornata</i>	Least Concern	Schedule IV
35	Snipe	<i>Scolopacidae</i>	Least Concern	Schedule IV
36	Terek sandpiper	<i>Xenus cinereus</i>	Least Concern	Schedule IV
37	Little Egret	<i>Egretta garzetta</i>	Least Concern	Schedule IV
38	Western Reef-egret	<i>Egretta gularis</i>	Least Concern	Schedule IV
39	Great Egret	<i>Ardea alba</i>	Least Concern	Schedule IV
40	Eastern Cattle Egret	<i>Bubulcus ibis coromandus</i>	Least Concern	Schedule IV
41	Indian Pond-heron	<i>Ardeola grayii</i>	Least Concern	Schedule IV
42	Black-crowned Night-heron	<i>Nycticorax nycticorax</i>	Least Concern	Schedule IV
43	Black-shouldered kite	<i>Elanus caeruleus</i>	Least Concern	Schedule IV
44	Black kite	<i>Milvus migrans</i>	Least Concern	Schedule IV
45	Common Kestrel	<i>Falco tinnunculus</i>	Least Concern	Schedule IV
46	Kentish plover	<i>Charadrius alexandrinus</i>	Least Concern	Schedule IV
47	Lesser Sand Plover	<i>Charadrius mongolus</i>	Least Concern	Schedule IV
48	Greater Sand Plover	<i>Charadrius leschenaultii</i>	Least Concern	Schedule IV
49	Caspian Sand Plover	<i>Charadrius asiaticus</i>	Least Concern	Schedule IV
50	Common Redshank	<i>Tringa totanus</i>	Least Concern	Schedule IV
51	Common Greenshank	<i>Tringa nebularia</i>	Least Concern	Schedule IV
52	Common Sandpiper	<i>Actitis hypoleucos</i>	Least Concern	Schedule IV
53	Ruddy Turnstone	<i>Arenaria interpres</i>	Least Concern	Schedule IV
54	Slender-billed Gull	<i>Larus genei</i>	Least Concern	Schedule IV
55	Gull-billed Tern	<i>Sterna nilotica</i>	Least Concern	Schedule IV
56	Lesser Crested Tern	<i>Thalasseus bengalensis</i>	Least Concern	Schedule IV
57	Sandwich Tern	<i>Thalasseus sandvicensis</i>	Least Concern	Schedule IV
58	Plum-headed Parakeet	<i>Psittacula cyanocephala</i>	Least Concern	Schedule IV
59	Southern (Greater) Coucal	<i>Centropus sinensis parroti</i>	Least Concern	Schedule IV
60	Spotted Owlet	<i>Athene brama</i>	Least Concern	Schedule IV
61	Black-capped Kingfisher	<i>Halcyon pileata</i>	Least Concern	Schedule IV
62	Indian Roller	<i>Coracias benghalensis</i>	Least Concern	Schedule IV
63	Malabar Lark	<i>Galerida malabarica</i>	Least Concern	Schedule IV
64	Eurasian Swallow	<i>Hirundo rustica</i>	Least Concern	Schedule IV



65	Wire-tailed Swallow	<i>Hirundo smithii</i>	Least Concern	Schedule IV
66	Red-rumped Swallow	<i>Hirundo daurica rufula</i>	Least Concern	Schedule IV
67	Richard's Pipit	<i>Anthus richardi</i>	Least Concern	Schedule IV
68	Paddy field Pipit	<i>Anthus rufulus</i>	Least Concern	Schedule IV
69	Common Iora	<i>Aegithina tiphia</i>	Least Concern	Schedule IV
70	Pied Bushchat	<i>Saxicola caprata</i>	Least Concern	Schedule IV
71	Grey-breasted Prinia	<i>Prinia hodgsonii</i>	Least Concern	Schedule IV
72	Clamorous Reed-warbler	<i>Acrocephalus stentoreus</i>	Least Concern	Schedule IV
73	Common Tailorbird	<i>Orthotomus sutorius</i>	Least Concern	Schedule IV
74	Asian Brown Flycatcher	<i>Muscicapa dauurica</i>	Least Concern	Schedule IV
75	Black-lored Tit	<i>Parus xanthogenys</i>	Least Concern	Schedule IV
76	Long-tailed Shrike	<i>Lanius schach</i>	Least Concern	Schedule IV
77	Brahminy Starling	<i>Sturnus pagodarum</i>	Least Concern	Schedule IV
78	Rosy Starling	<i>Sturnus roseus</i>	Least Concern	Schedule IV
79	Common Myna	<i>Acridotheres tristis</i>	Least Concern	Schedule IV

4.5.9 Riparian Vegetation:

A riparian zone is the interface between land and water bodies, including streams, rivers, lakes and estuarine marine shores. Riparian zones can therefore be considered as a transitional belt between terrestrial and aquatic ecosystems and are distinguished by gradients in biophysical conditions, ecological processes and biota (National Research Council, U.S, 2002).

A riparian zone is often a habitat for rare species and it is also a breeding ground for aquatic fauna such as fish and invertebrates (Naiman *et al.*, 2005). Loss of riparian vegetation can decrease the amount of suitable habitat for riparian and aquatic fauna such as fish and invertebrates, thereby reducing stream productivity and fish carrying capacity (Karen, M. & Karen, S., 1998). Riparian vegetation has many critical functions; it provides resistance to flowing water as well as to runoff during floods. The vegetation provides protective cover which helps to absorb the forces exerted by flowing water (Watson & Basher, 2006). Riparian plant canopies intercept, store and evaporate a portion of precipitation and have an important role in influencing stream temperature and the health of aquatic species (National Research Council, U.S., 2002).



A considerable change in riparian zone of the river is evident. . Increased urbanisation, especially in the coastal areas and river fronts is visible as well as many areas having increased accessibility by roads. Apart from expansion of villages and increase in urban areas, forest area has reduced and vegetation cover changes are evident as many natural habitats are converted to orchards and plantation. In the upstream half of the river, the vegetation and plantations are unsuccessful in protecting the banks from erosion. In the stretches of the river wherever there are soft muddy and silty banks, erosion has taken away a part of land while taking with it the riparian vegetation as well and leaving behind vertical banks. These vertical banks remain vulnerable to erosion and it is extremely important to protection these banks urgently.

Downstream part of the river has more saline influenced waters with higher salinity compared to upper stretches. Thus most of the areas have been protected by embankments traditionally. These embankments require constant repair and maintenance, as the terrestrial part of it is used for paddy cultivation and building houses. In the downstream areas, many parts of the riparian zone have been intruded by salinity and now converted to saline marsh lands, mudflats or mangroves. This is one of the most significant land use changes noted for this river. The present land use of the riparian zone of the River is shown in Figure 4.33.

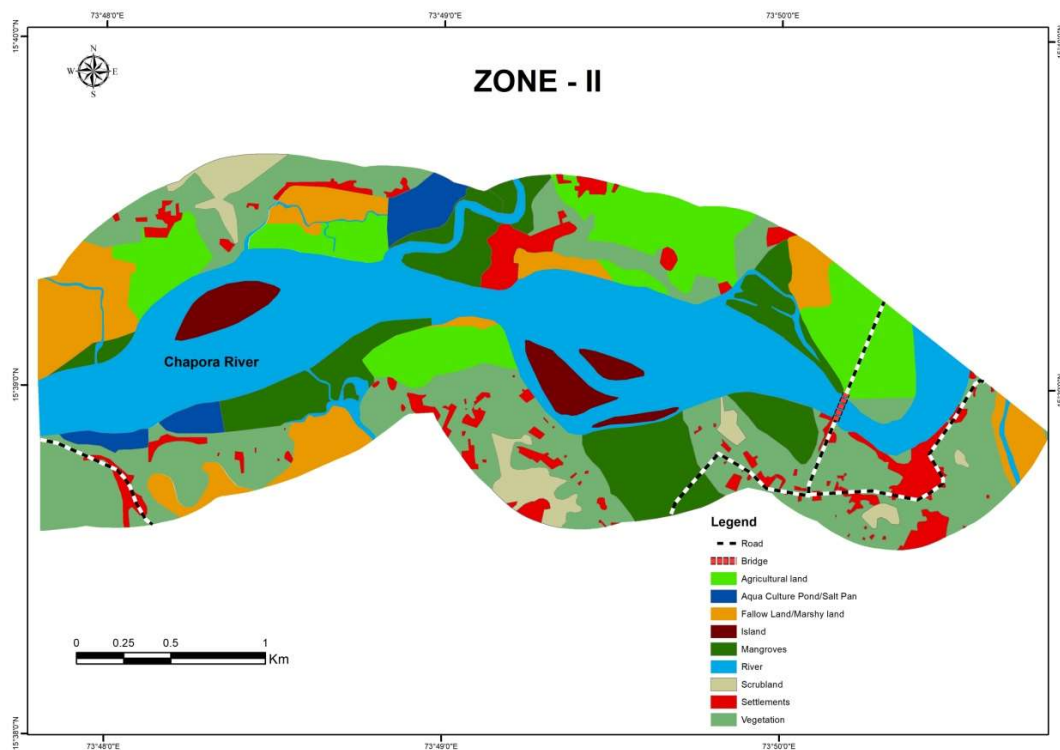
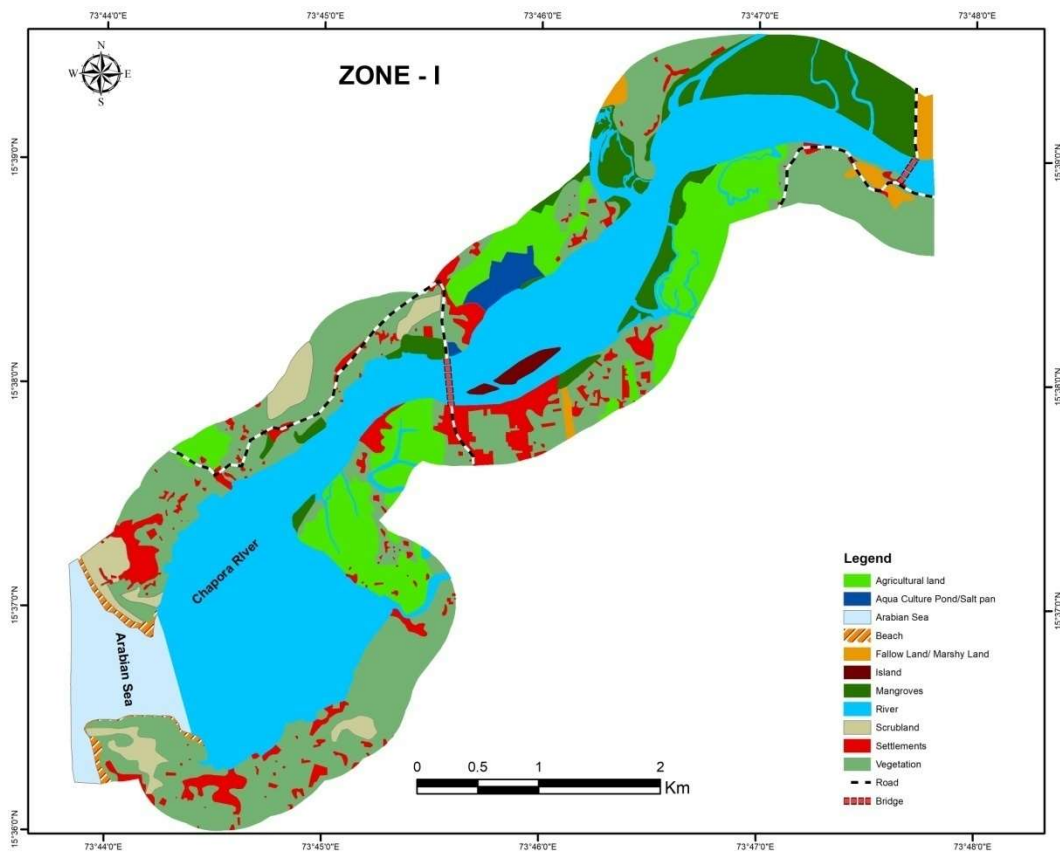
The riparian vegetation along the banks of the river in the upstream stretches consist of typical tropical deciduous species typical to this region and the department of forest categorises this region under open forest (<https://fsi.nic.in/isfr19/vol2/isfr-2019-vol-ii-go.pdf>). The area is predominantly planted with *Cocos nucifera* and mostly represented by species of *Terminalia* spp., *Ficus* spp., *Syzygium cumini*, *Careya arborea*, *Mangifera india*, *Anacardium occidentale*, *Xylia xylocarpa*, *Caesalpinia* spp., *Bauhinia* spp. and *Bombax ceiba* along with several species of bamboos, shrubs, herbs and grasses.

The river bank in the upstream areas (with mostly narrow mudflats) have grasses such as *Cyprus* sp./ *Typha* sp. (Plate 5) which have ability to resist some salinity. Although grasses are known to offer protection from erosion, these grasses may not be able to resist strong current which is visible from the eroded bank stretches in the upstream regions which have also uprooted larger trees (mostly coconut palms).



There are few notable species which have invaded this region and may pose threat to the native vegetation in the long run. Some of the plants were *Chromolaena odorata*, *Cassia tora*, *Ageratina adenophora*, *Triumfetta rhomboidea* and *Acacia farnesiana* (<https://fsi.nic.in/isfr19/vol2/isfr-2019-vol-ii-go.pdf>).

The Chapora estuary has an area of 16.63 square kilometres. Agricultural land makes up 12.9%, Aquaculture Pond/Salt pans are 0.9%, Fallow land 2.89%, Islands 1.3%, Mangroves 6.5%, Scrubland 4.5%, Settlements 6.7%, Vegetation 35.5% and water body 0.01%. (Table 4.16). Mangroves have invaded agricultural land resulting in increase in cover of mangroves and hence have to be managed.



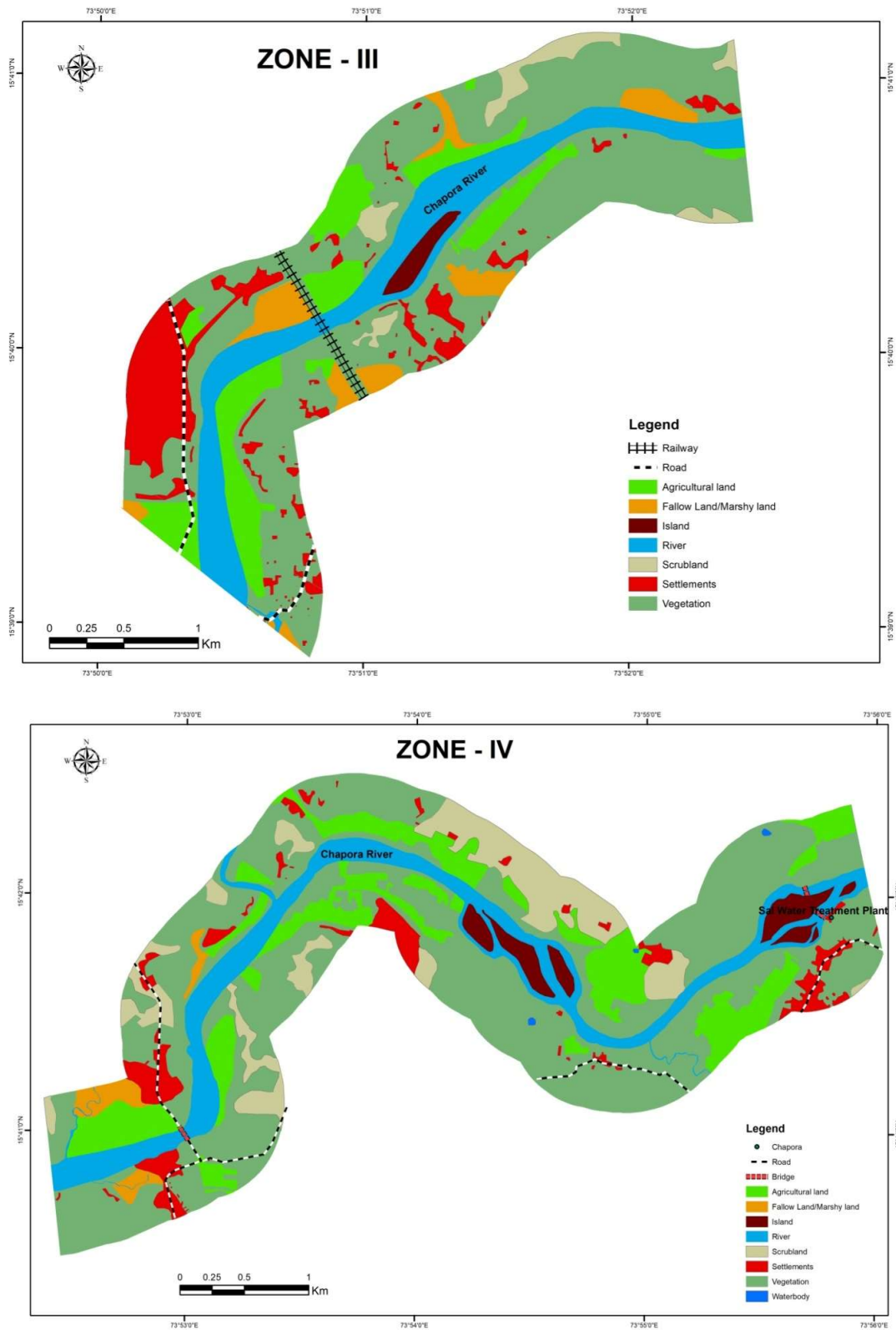


Figure 4.33: LULC Map of Chapora Estuary (Divided in 4 zones, image used LISS-IV, December 2019)



Table 4.16: LULC Chapora			
Sl:No:	LULC Class	Area in Square Kilometers	Percentage Area
1	Agricultural land	7.49	12.9
2	Aqua Culture Pond/Salt Pans	0.49	0.9
3	Fallow land	1.67	2.89
4	Island	0.77	1.3
5	Mangroves	3.75	6.5
6	River(Chapora)	16.63	28.8
7	Scrubland	2.55	4.5
8	Settlements	3.85	6.7
9	Vegetation	20.51	35.5
10	Waterbody	0.008	0.01
Total		57.718	100



4.5.10 Seaweeds & Grass (Halo tolerant):

Seaweeds or macroalgae are the marine algae which found either on marine or brackish environments. Depend on their pigments they are classified into three types; Red Algae (Rhodophyta), Brown Algae (Phaeophyta) and Green Algae (Chlorophyta). Most commonly they inhabit the littoral zone preferably rocky shores as they are attached to the substratum. Some species of seaweeds are edible and are commercially important as they are cultivated for food, medicine, fertilizer and are considered as one of the potential source of bioethanol. Some of the examples are: *Ulva* sp., *Sargassum* sp., *Padina* sp., *Caulerpa* sp. Common species of sea weeds was found in the mouth of the estuary, as these species inhabit pools in the littoral zone typically with clayey, silty and sandy sediment. A typical grass was found along the periphery of the river (Table 4.17).

Table 4.17: List of Seaweed/Grass found in Chapora Estuary	
Sl. No.	Seaweeds/Grass (Halo tolerant)
1	<i>Padina</i> sp.
2	<i>Dictyota</i> sp.
3	<i>Cyperus</i> sp



Plate 6: Representative Seaweed and grass sample from Chapora Estuary.

4.5.11 Sand Dune Vegetation:

Sand dunes are a mount, hilly or ridge of sand formed mainly by Aeolian action that lies behind the beach affected by tides. They are formed over many years when windblown sand is trapped by beach grass or other stationary objects. Dune grasses anchor the dunes with their roots, holding them temporarily in place, while their leaves trap sand promoting dune expansion. Without vegetation, wind and waves regularly change the form and location of dunes. Sand dunes provide sand storage and supply for adjacent beaches. They also protect inland areas from storm surges, hurricanes, floodwater, and wind and wave action that can damage property.

Sand dunes arrest blowing sand, deflect wind upwards, assist in the retention of fresh water and protect the hinterland from attack by waves, cyclones and storm surges and thus obstruct the ingress of saline marine water into the hinterland, and thus protecting the inland low lying



areas and terrestrial ecosystem from strong wave actions and tide surges. Dune vegetation helps in dune stability however, is vulnerable to even slightest interference due to its fragility. Moreover, sandy stretches including dune vegetation contain many species of specific flora (and fauna).

Sand dunes, especially if covered by dune vegetation which acts as sand binders, preclude loose sand from advancing inland on the coastal zone, thus menacing coastal populations and structures.

Sand dunes support an array of organisms by providing nesting habitat for coastal bird species including migratory birds. Sand dunes are also habitat for coastal halophilic vegetation. Increased tourism foot traffic, and removal of plant species can cause destruction of dunes and erosion. Sand dunes are of various sizes, shapes and the size depends on two factors, namely, physical and biotic factor. The physical factors are the speed of wind, the prevailing wind directions, wave regime, the amount of sand available, the size of the sand, the sand supply from the beach and offshore bars whereas the biotic factor are plant succession and grazing pressure.

Below the Chapora fort, and especially at Vagator, low sand dunes are common over a limited stretch.

The coastal stretch is thickly vegetated by coconut trees. At Morjim, a long strip which terminates at the mouth of river Chapora is marked by rows of sand dunes with dune vegetation, being more pronounced in the southern part. The Morjim area which has been protected from anthropogenic disturbances is one of beaches used as nesting site by Olive Ridley's Turtle. But in recent times, increase in tourism, beach huts and shacks have occupied many parts of this pristine habitat and has resulted in drastic reduction of dune vegetation. These dunes have very patchy distribution of *Ipomea* sp. and *Vitex* sp. followed by large trees (eg: Coconut) in the hind dune region. Thus it is imperative to conserve sand dunes and development has to be regulated.



4.5.12 Mangrove:

India has 4827 km of mangrove cover out of which only 23% is present on West Coast of India. Altogether, 69 species of mangroves belonging to 25 families and 43 genera have been reported from Indian Coast. On the West Coast, rich mangrove habitat can be observed along Gujarat Coast in Gulf of Kutch and Gulf of Khambat which is approximately 80% of total mangrove cover of West Coast and 23% that of India. Reported 370 km of mangrove cover in Gujarat which is now increased in last two decades due to declaration of Marine National Park in Gulf of Kutch in 1983. Though mangrove cover is more in Gujarat state (1058 km), species diversity is limited to nine species; on the other hand, species diversity is more in Maharashtra, Goa, Karnataka and Kerala state. Mangroves show various specialized root structures for support, oxygen supply and sediment accumulation. Some of the mangroves like *Kandelia candel* adapt buttresses root system which not only helps in balancing but also cover wide area for long distance transport of water, nutrients and metabolites. A total of eleven mangrove species and four mangrove associates have been recorded from the Chapora estuary (Table 4.18).

From the historic images (Google Earth) it can be noted that mangrove vegetation has increased over the years. The mudflats and paddy fields have been established by new grown mangrove forest and many areas are in progression of converting into mangrove habitat. It can be noted that the dominance of mangroves has been a major change in land use in Chapora estuaries' downstream stretch. There can be several reasons for this change of land use viz; non-maintenance of embankments, extreme weather events, tidal surges, flooding, sand mining and dredging activity.

Table 4.18: Mangroves and associated species found in Chapora estuary.		
Sr. No.	True mangrove species	Mangrove associate species
1	<i>Avicennia marina</i>	<i>Clerodendrum inerme</i>
2	<i>Avicennia officinalis</i>	<i>Derris heterophylla</i>
3	<i>Rhizophora mucronata</i>	<i>Porteraciacoreata</i>
4	<i>Kandelia candel</i>	<i>Calophyllum inophyllum</i>
5	<i>Sonneratiacaseolaris</i>	<i>Acrostichum aureum</i>
6	<i>Sonneratia alba</i>	
7	<i>Ceripostagal</i>	
8	<i>Brugieracylindrica</i>	



9	<i>Aegicerascorniculata</i>	
10	<i>Acanthus ilicifolius</i>	
11	<i>Excoecariaagallocha</i>	

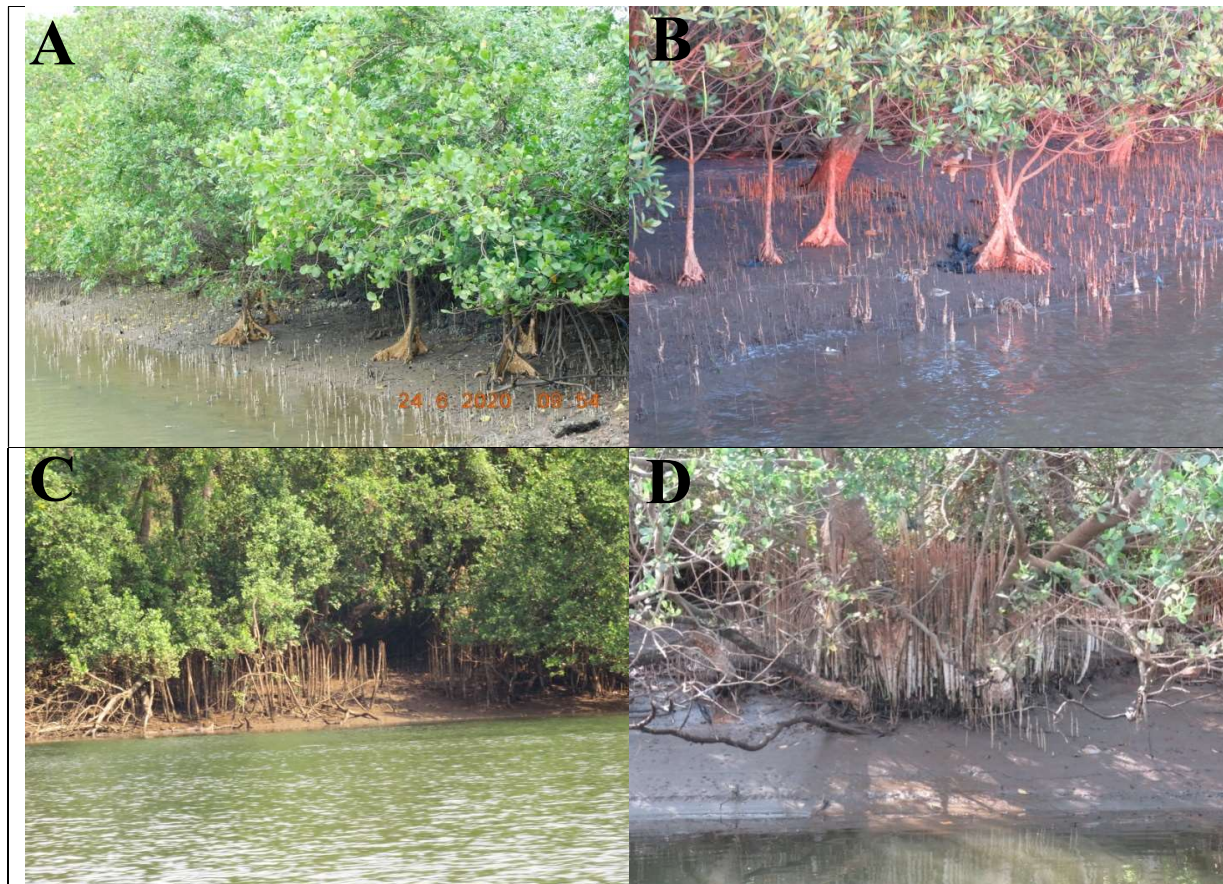


Plate 7: Mangroves from Chapora estuary



CHAPTER- 5 MODELLING- CLIMATOLOGY & METEOROLOGY

The meteorological data is important to understand the meteorological and climatic conditions of the study area for the evaluation of impacts of the proposed project. Historical data on meteorological parameters also plays an important role in identifying the synoptic meteorological regime of the region.

Climate: Climatic conditions in the district are strongly influenced by its geographical conditions. The district falls under the 'Assured and High Rainfall zone'. The climate is generally humid, oppressive weather in the hot months and high humidity throughout the year. The winter season is from December to February, followed by summer from March to May. June to September is the south-west monsoon, while, October and November constitute the post-monsoon season. December is the coldest month with mean daily maximum temperature at 32.7 °C and the mean daily minimum temperature at 18.7 °C. April is the hottest month. The relative humidity during the south-west monsoon is very high (86 to 90%). The relative humidity during winter and summer months is also >57%.

Winds: Winds are very strong and blow from west or south-west during the monsoon season. During October-December, the winds are generally moderate and blow from directions between north-east and south-west. In the three months from January to March the winds continue to be moderate and are predominantly from directions between south-west and northwest. Sometimes associated with cyclonic storms in the Arabian Sea in the post-monsoon months and to a lesser extent in May, the region experiences powerful winds, occasionally reaching gale force with widespread heavy rain.

River Discharge: The data obtained from secondary source shows that during Dry season (October–May), monthly freshwater input was less than 8 m³/s.

Rainfall: Pernem rainfall station data is obtained from IMD. Pernem is located near the Chapora Estuary. The average annual rainfall (2010-2019) over Pernem, North Goa, is about 3546 mm. The maximum precipitation occurs within June- September. The monthly rainfall data at Pernem, North Goa, is presented in Figure 5.1.



Table 5.1 Soil classification in Chapora Estuary

Types	Area(sq.km)	Soil Texture
A	120	Sandy, sandy loam
B	63.34	Silt, gravel
C	1.96	Sandy clay loam
D	2.37	Clay loam, silty clay loam, sandy clay.

Table 5.2 Table showing secondary data used in the study

Type of data	Availability	Source
Soil map	YES	ICAR National Bureau of Soil Survey and Land Use Planning (NBSS&LUP)
Rainfall	YES	India Meteorological Department (IMD)
Land use/ Land cover map	YES	LISS IV 5.8m
River discharge Time series data	Secondary source	Department of Water Resources, Government of Goa and Lina et al. (2018)
River bathymetry	YES	Captain of Ports Department, Government of Goa



Physical parameters

This chapter comprises of the physical measurements carried out at Chapora Estuary, Goa, during February-April 2020 and September-October 2020. The current and water level measurements were carried.

Instruments used

The various instruments used for measuring different parameters are presented in Table 5.3.

Table 5.3 Instruments used for measuring different parameters

Parameter	Equipment used
Currents	Aanderaa RCM9
Water level	SBE 26plus Seagauge WTR / Seaguard WLR

Deployed locations and parameters

The deployment locations (Figure 5.3) and duration are as given in Table 5.4

Table 5.4 Table showing instruments used and deployed locations

Location	Location-1 (CR1) Chapora Estuary	Location-2 (CR2) Chapora Estuary	Location-3 (CR3) Chapora Estuary	Dumacem Chapora Estuary
Latitude	15°38'58.3" N	15°38'57"N	15°36'31"N	15°41'22.9"N
Longitude	73°50'05.4" E	73°50'11"E	73°44'19"E	73°54'46.6"E
Duration	04 Feb. 2020 till 05 Mar. 2020 and 12 Sep. 2020 till 11 Oct. 2020	12 Mar. 2020 till 13 April 2020 and 12 Sep. 2020 till 11 Oct. 2020	09 March. 2020 till 16April. 2020	12 Sep. 2020 till 11 Oct. 2020

RCM-9	YES	NO	NO	NO
SBE 26plus Seagauge WTR / Seaguard WLR	YES (20 Feb. 2020 till 05 Mar. 2020 and 12 Sep. 2020 till 11 Oct. 2020)	YES	YES	YES



Figure 5.3. Locations of current and water level measurements in Chapora Estuary

Results

The results of the current and water level measurements carried out in the study region are presented in this section.

Currents

Current measurement was carried out at location CR1 (15°38'58.3" N; 73°50'05.4" E) near Colvale at Chapora Estuary during February-March, 2020 and September-October, 2020. The water depths at measuring point were 8.5m and 9m at the time of pre monsoon and monsoon deployment respectively. The Current meter was placed at mid-water depth. The measured current speed and direction during pre-monsoon and monsoon, are shown in Figure 5.4 and Figure 5.5. From the Figures, it is observed that during pre-monsoon, the maximum current speed was 0.38 m/s, and the current is mainly towards South East (SE)



and North West (NW) at the measuring location. However, during monsoon, maximum current speed was 0.78 m/s.

Table 5.5 Maximum and average value of Current speed at Chapora Location-1 CR1

Current Parameter	Maximum	Average
Current Speed (m/s) (Pre-monsoon)	0.38	0.11
Current Speed (m/s) (Monsoon)	0.78	0.21

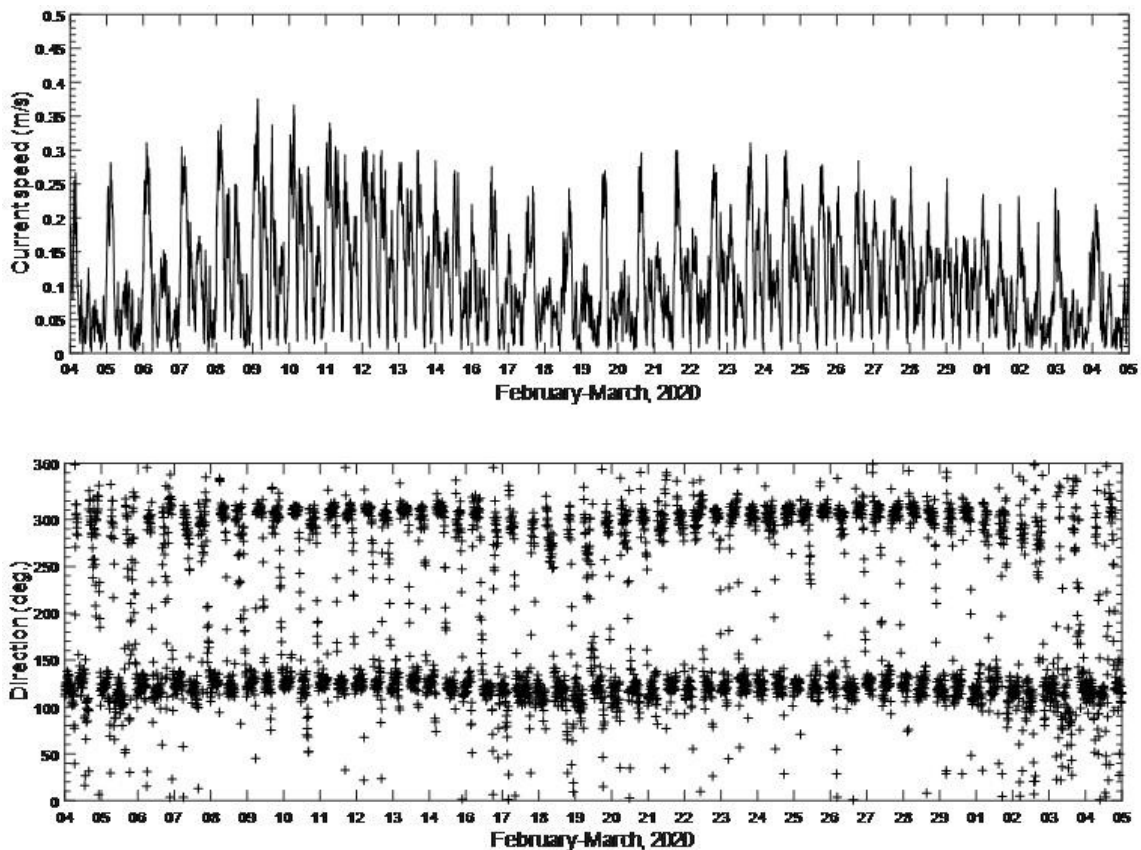


Figure 5.4. Variation of measured current speed and directions at CR1 during pre-monsoon 2020.

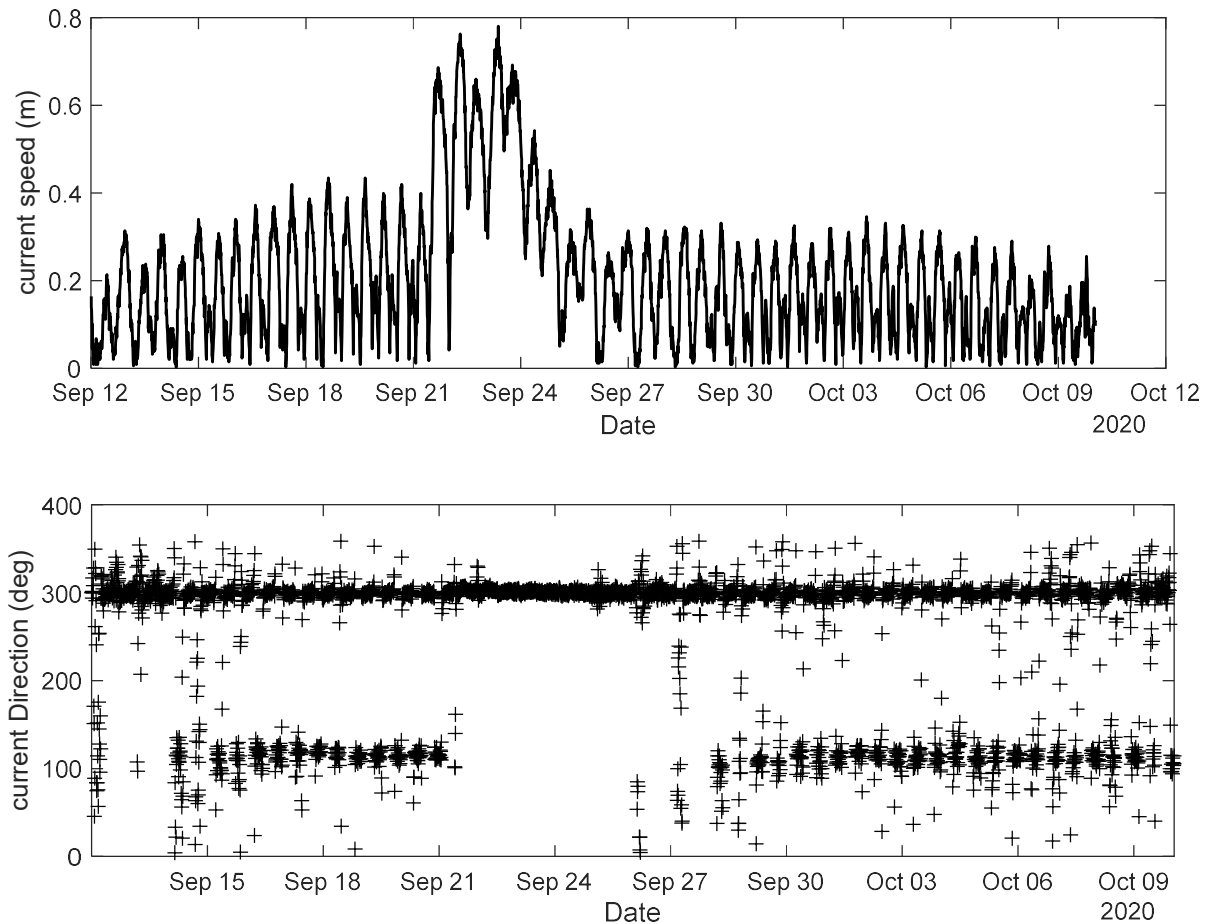


Figure 5.5. Variation of measured current speed and directions at CR1 during monsoon, 2020.

Water level

Water levels were measured at three different locations. Water level was measured near Colvale ($15^{\circ}38'58.3''$ N; $73^{\circ}50'05.4''$ E) (CR1) at Chapora Estuary for 15 days during February-March, 2020. Water levels were measured at Colvale bridge ($15^{\circ}38'57''$ N; $73^{\circ}50'11''$ E) (CR2) and ($15^{\circ}36'31''$ N; $73^{\circ}44'19''$ E) (CR3) Chapora jetty at Chapora Estuary for a month during March-April, 2020. The water level ranges are about 1.84m, 2.32m and 2.45m at CR1, CR2 and CR3 respectively during the pre-monsoon measurement period. The measured water level variations at CR1 during monsoon period, is shown in the next chapter.

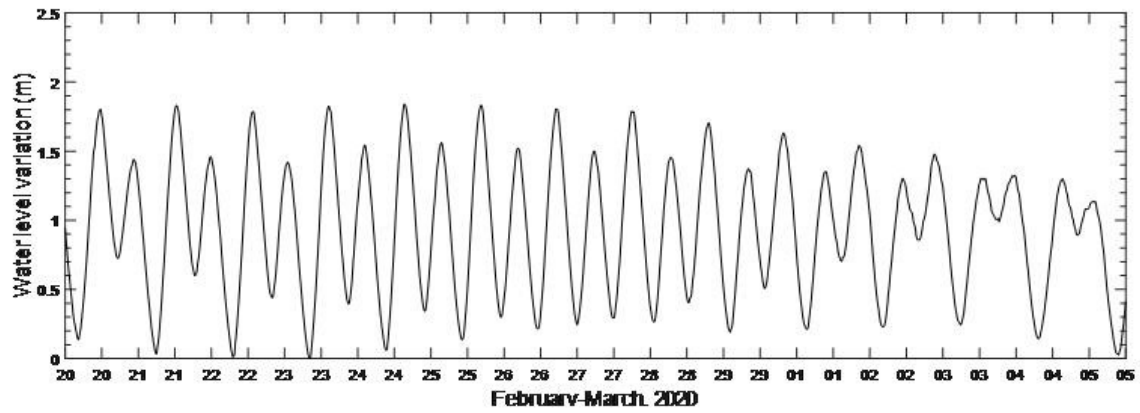


Fig 5.6. Variation of water levels at Location-1 CR1

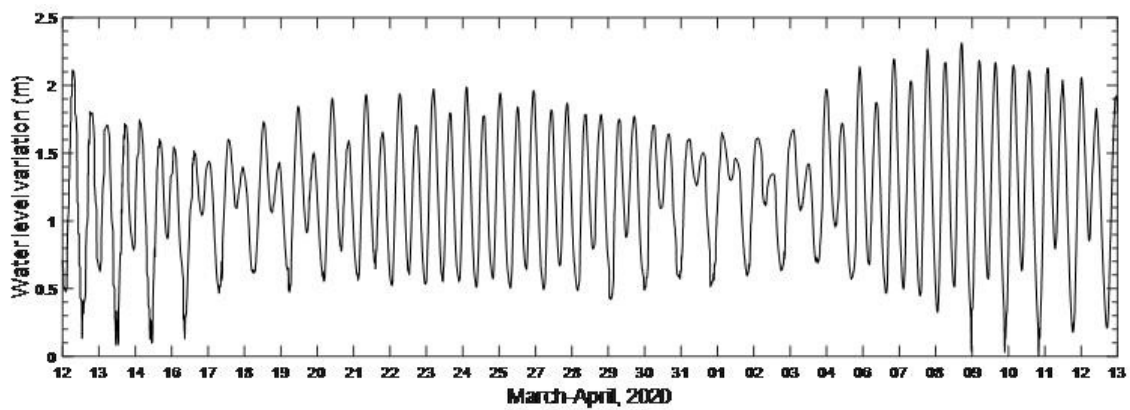


Figure. 3.1.

Fig 5.7. Variation of water levels at Location-2 CR2.

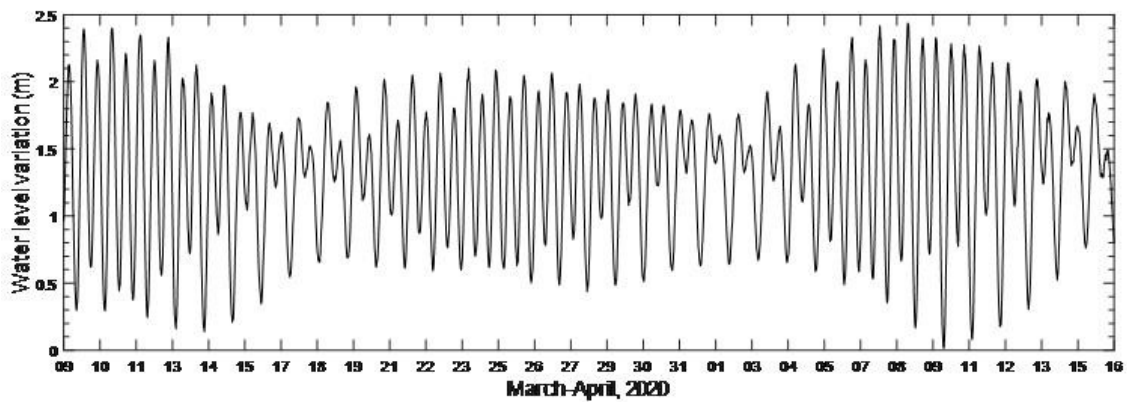


Figure. 3.2.

Fig 5.8. Variation of water levels at Location-3 CR3.



CHAPTER 6: NUMERICAL MODELLING STUDIES

Introduction

In order to simulate the coupled hydrodynamics and morphology in the study region, a state of the art numerical modelling software suite (MIKE by DHI) is used. The flow model FM comprising of flow model, and sediment transport model is used to study the hydrodynamics and morphology impact in the region due to different mining pit scenario. All these models take feedback from each other as well as provide inputs to each other. The sediment transport models also utilise the flow parameters from the hydrodynamics model. In this manner, the coupled model provides output of modified flow, and changes in the bed morphology in the study region.

Coupled model

The MIKE 21 flow model FM is used in this study which dynamically couples the flow and sediment transport calculations. Full feedback of bed level changes on flow calculations is included in this formulation. Wave has negligible effect on the flow dynamics and morphology changes inside the river. Hence, wave is not considered in the present simulations. However, the morphology changes due to wave with the coupled model at Chapora Estuary mouth can be found in NIO report 2017. The flow model FM is mostly used for investigating the morphological evolution of the near shore bathymetry due to the impact of engineering works (coastal structures, mining, dredging works etc.) and also to study the morphological evolution of tidal inlets and rivers. It is most suitable for medium-term morphological investigations (several weeks to months) over a limited study area. The computational effort can become quite large for long-term simulations, or for larger areas. The different models used in the flow model FM are briefly described below.

Hydrodynamic model

The Hydrodynamic Module is the basic computational component of the entire MIKE21 Flow Model FM modelling system. The MIKE 21 Flow Model FM is a modelling system based on a flexible mesh approach providing the hydrodynamic basis for the Sediment transport Module.



The modelling system is based on the numerical solution of the two-dimensional shallow water equations i.e., depth-integrated incompressible Reynolds Averaged Navier-Stokes equations. Thus, the model consists of continuity, momentum, temperature, salinity and density equations. In the horizontal domain both Cartesian and spherical coordinates can be used. The spatial discretization of the basic equations is performed using a cell-centred finite volume method wherein the spatial domain is discretized by subdivision of the continuum into non-overlapping element/cells. An unstructured grid comprising of triangles or quadrilateral element is used in the horizontal plane. An approximate Riemann solver is used for computation of the convective fluxes, which makes it possible for MIKE21 FM model to handle discontinuous solutions. For the time integration an explicit scheme is used. Coriolis term, eddy viscosity using Smagoransky formulation and bed friction are included in the model. For more details of the MIKE 21 FM module and its validation, the scientific manual can be referred.

The model domain used in this study is shown in Figure 6.1. This model domain was further used for all simulations. In this study, a sand mining case scenario is studied by modifying existing bathymetry. The model domain for sand mining case is shown in Figure 6.2.

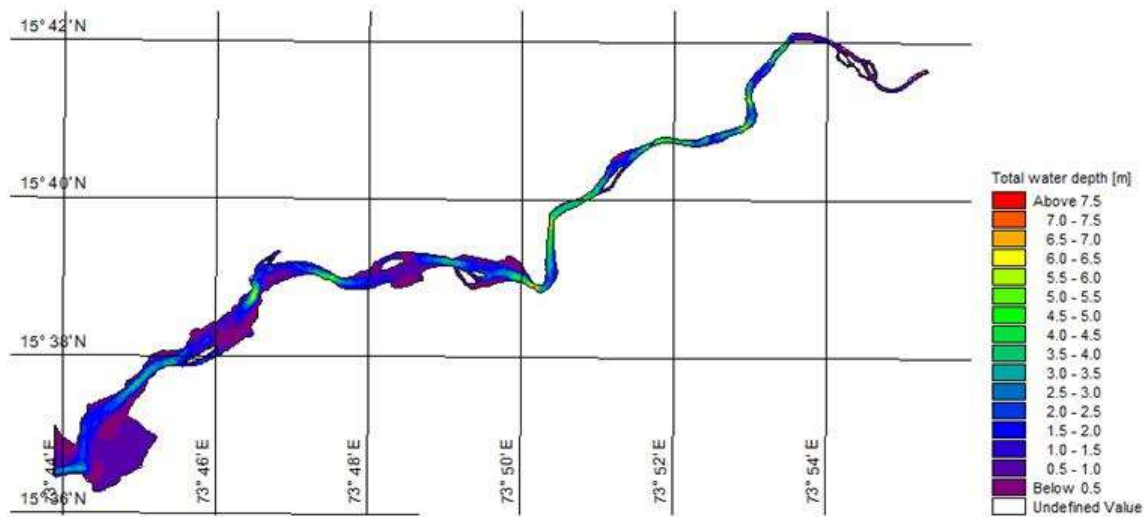


Figure 6.1. Model domain of the Chapora Estuary

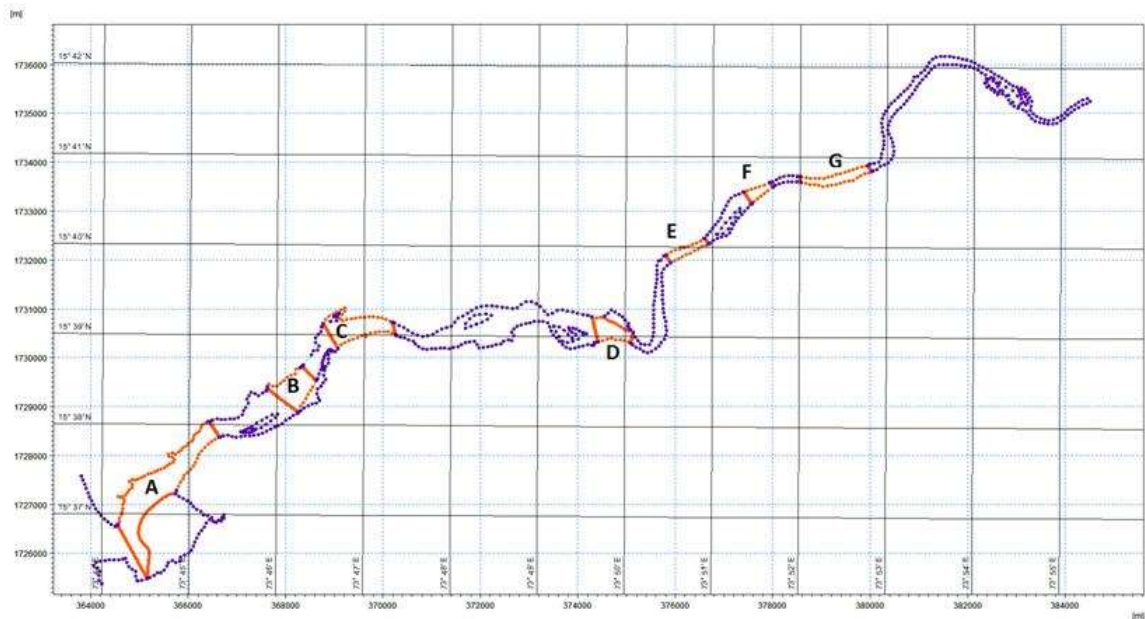


Figure 6.2. Figure showing seven different sections (A-G) in the model domain.

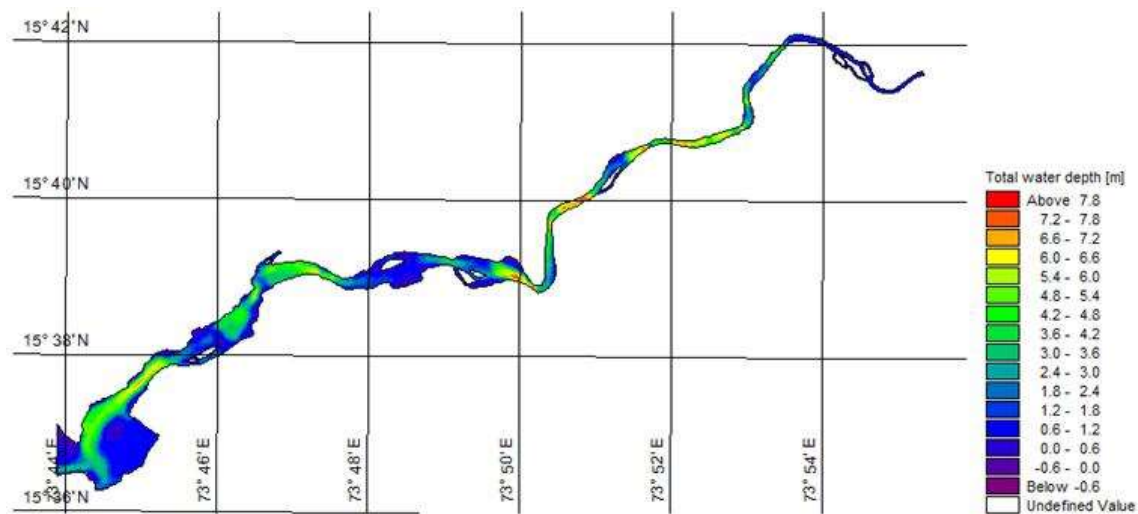


Figure 6.3. Model domain for modified bathymetry increasing depth by 3 m at different sections (A-G)

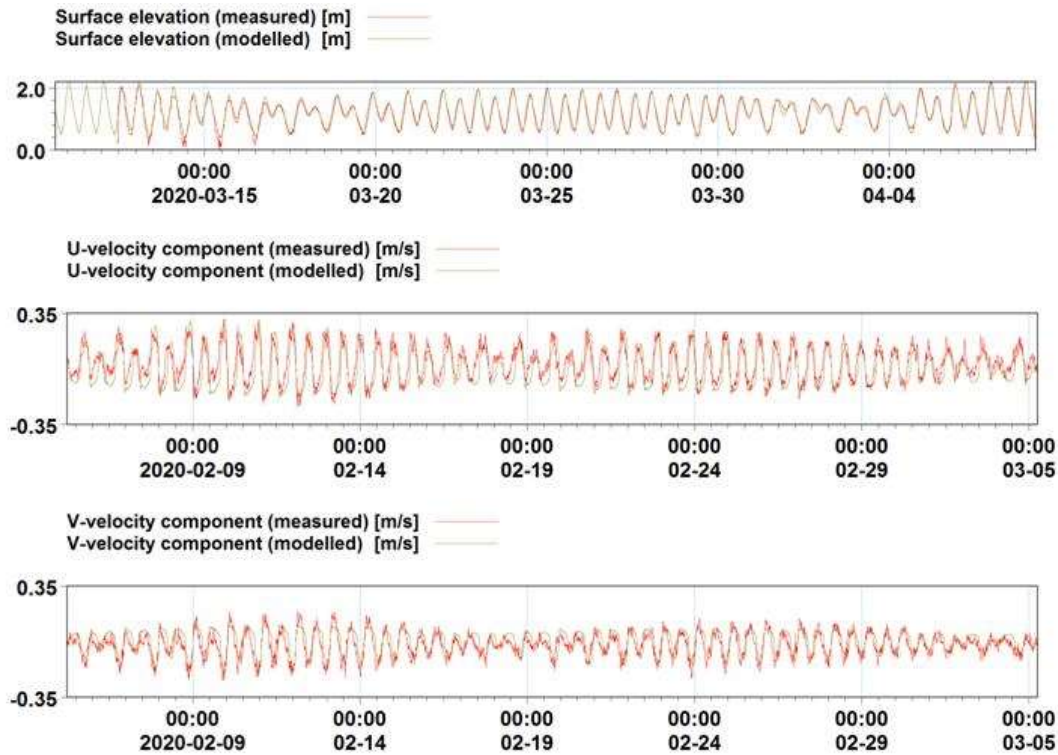
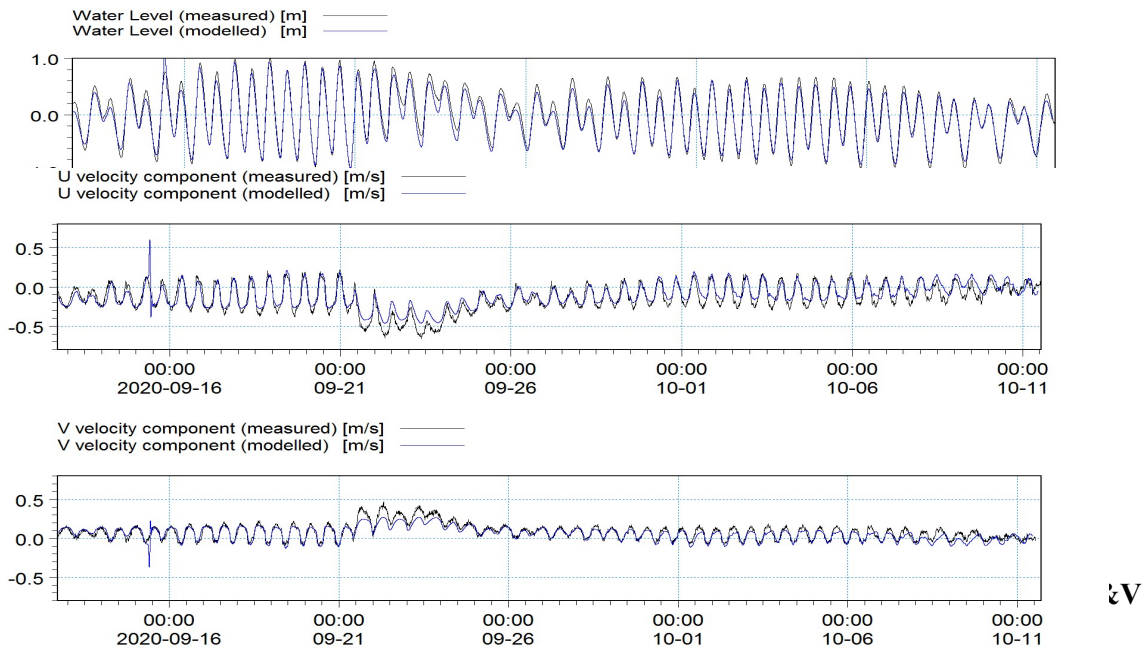


Figure 6.4a. Comparison between measured and modelled surface elevations and U&V component of current during pre-monsoon.



A comparison between the model derived and measured surface elevations, currents have been carried out at location #1 (CR1), and the comparisons are shown in Figure 6.4. It is



observed that the surface elevations and currents are well predicted by the model during both pre-monsoon and monsoon period, 2020.

Sediment transport model

The sediment transport module calculates the resulting transport of non-cohesive materials based on the flow conditions found in the hydrodynamic calculations. The model output consists of bed level changes, amongst other parameters. In this study, the current formulation of sediment transport is considered with the flow model providing the currents.

Methodology

The main inputs considered to the numerical model are river topography, river discharge and water level. The Chapora Estuary's bathymetry chart received from Captain of Ports, Govt. of Goa, is in Everest 1956 datum and has 14 parts. The map was digitized for the numerical modelling purposes keeping the datum unchanged. The base case scenario (Case-1) is with bathymetry provided by Captain of Ports, Govt. of Goa. The second scenario (Case-2) is the modified bathymetry by deepening 3m uniformly at 7 locations (A-G), as in Figure 2.2, of Chapora Estuary.

The numerical model described in the previous sections is setup for various scenarios initially to ascertain the validity of the model for the study region. In order to test the validity of the model, purely tidal forcing is given to the model during non-monsoon. However, during monsoon, measured water level data at the upstream model boundary of Chapora estuary, is given to the model and the hydrodynamic results are compared in Figure 6.4.

In this study, the effects of the deepening of the river at A-G sections on the hydrodynamics and morphology are studied by comparing with the base case scenario. The Case-1 (base case) scenario model therefore provides a basis for comparison with the modified bathymetry model simulations. However, it is important to simulate the model for the full year to understand the dynamics of the sediment transport. In this study, after testing the validity of the model (Figure 6.4), the numerical model is simulated for Jan-Dec 2014 based on availability of fresh water input data (source: Water Resources Department, Goa) of Chapora estuary. The model results of each of these scenarios are presented in following sections.

Assessment of mining



Based on the modelling of the hydrodynamics or flow conditions of the region, possible impacts due to the Case-2 scenario of this work are reported in terms of (i) changes in flow or hydrodynamics impact, and (ii) bed level change or morphological impact. The difference between the base case (Case-1) and modified bathymetry case (Case-2) are studied to ascertain the changes in flow patterns and bed morphology changes. The variations of current speed and bed level changes for each of the scenarios are also compared for each section A-G, in the study region.

Hydrodynamic impact

Any change in existing bathymetry, results in changes in the local hydrodynamics till such time equilibrium is attained. Till then the local hydrodynamics would be in dynamic mode adjusting to the new and changing conditions. The extent of change in the hydrodynamics can be ascertained through comparison of flow conditions between the base case (Case-1) and modified bathymetry case (Case-2). In this study, the hydrodynamic impact assessment is carried out through numerical modelling of flow conditions. This is ascertained by studying the differences between the validated model results for the base case and the modified bathymetry case.

Morphological impact

The activity of sand mining would modify the local bottom topography which in turn changes the local hydrodynamics. The impact of the change in bottom topography is studied through numerical modelling of the bed level changes. Modelling the morphology changes using the sediment transport model provides the bed level changes. The changes in the bed morphology for the base case, as well as the modified bathymetry scenario, are carried out.

Results

The numerical model study results are presented in the following sections. The flow patterns in the study region for the Case 1 and Case 2 are presented in the hydrodynamic model results. The comparisons of the current speed during pre-monsoon, 2020 between Case 1 and Case 2 at each section A-G are presented. However, the comparisons of the bed level changes between Case 1 and Case 2 for the full year 2014, are presented in the morphology model results.



Hydrodynamics modelling

Hydrodynamic model validation is carried out with the measured currents and water levels in the study region. The comparison of water levels, u-component and v-component of currents are presented in Figure 6.4. The model simulated water levels, and the tidal current flow components well for both the east-west and north-south components. The flow vector patterns with surface elevation during the typical ebb and flood tides are shown in Figure 6.5.

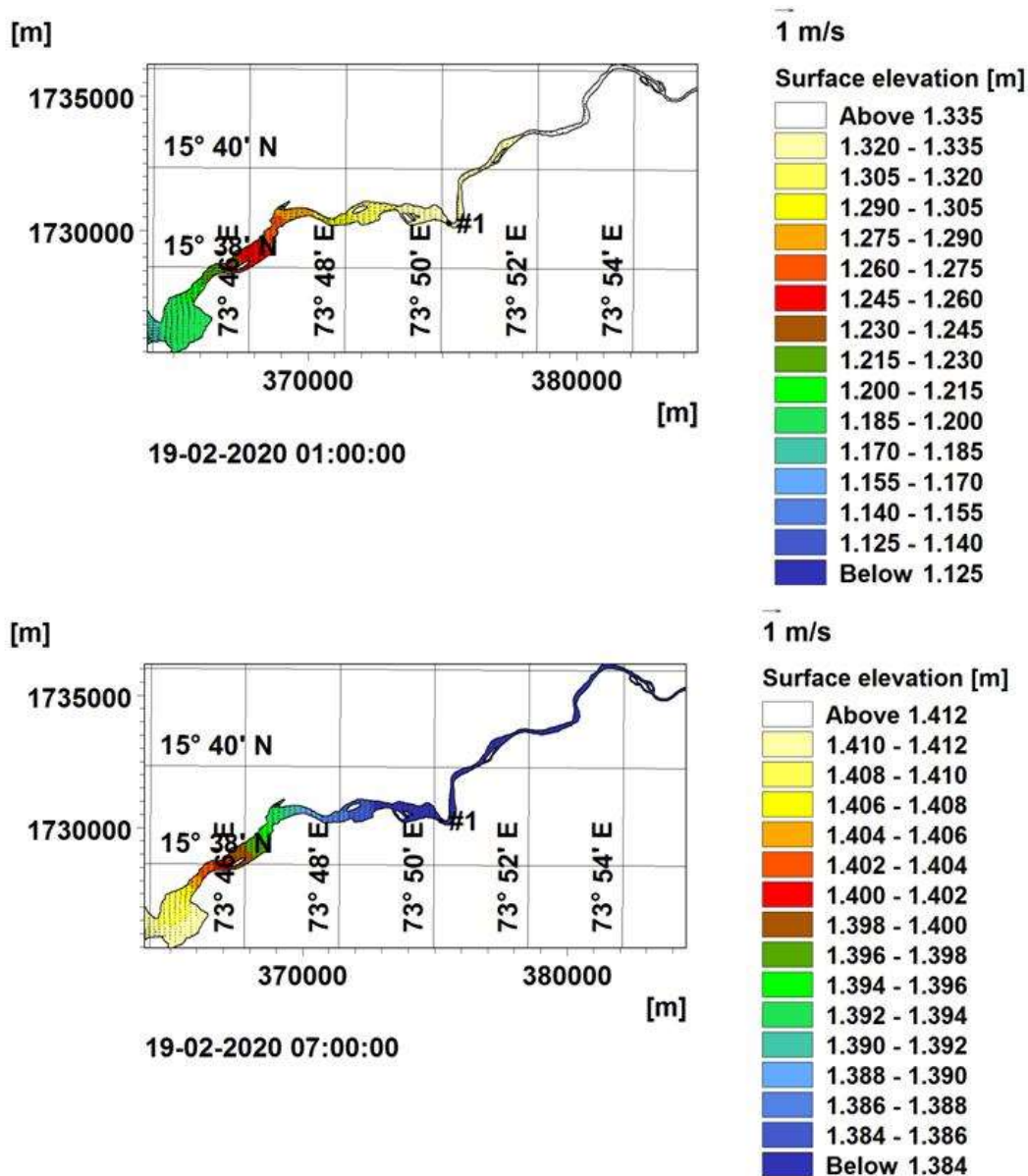
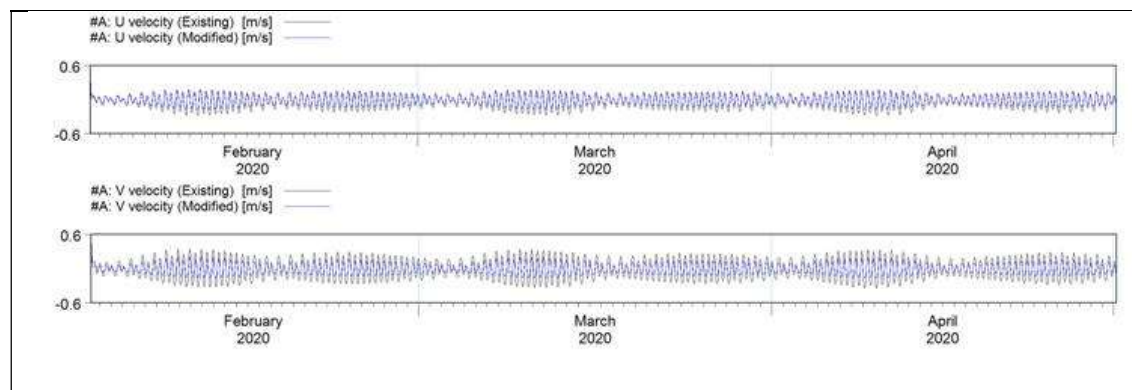


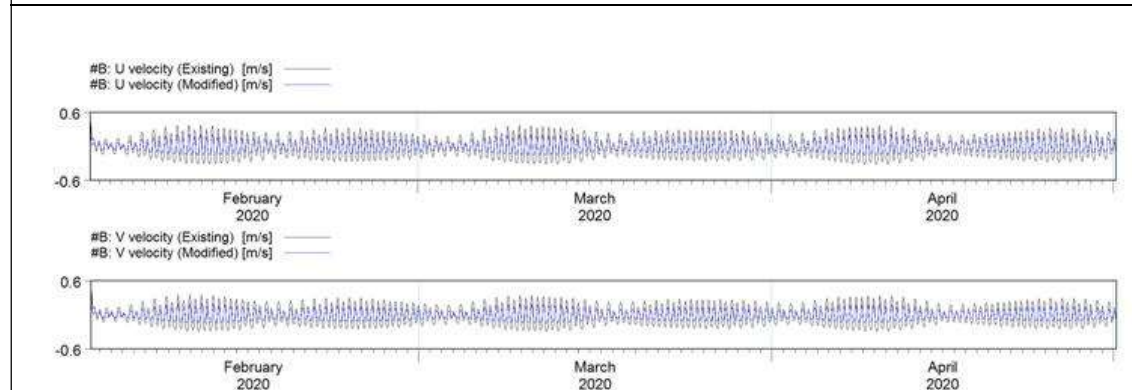
Figure 6.5. Flow patterns and surface elevations during typical ebb and flood tide for Case-1.



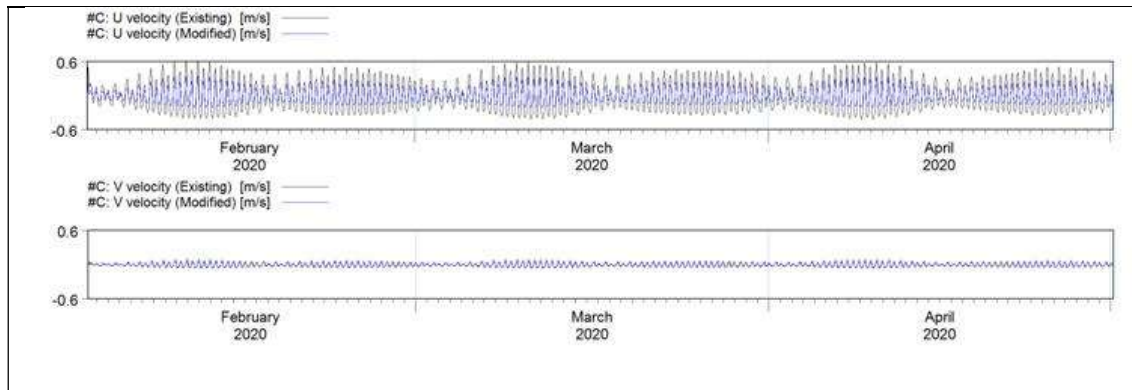
A comparison of current speeds between the Case-1 (base case) and Case-2 (Modified bathymetry case) is carried out. A total of 7 points covering the seven sections A to G as in Figure 6.2 are considered for comparing the currents. The comparison Figures are presented in Figure 6.6. The maximum current speeds observed are in the range of 0.26 to 0.63 m/s for Case-1, while maximum current speeds lie in the range of 0.16 to 0.35 m/s for the Case-2 at the different sections A-G with the flow direction changing with the tide. The reduction in current speeds at these sections is mainly due to the change in the water depths. The maximum and minimum current speed with u and v components for Case-1 and 2 are shown in Table 6.1.



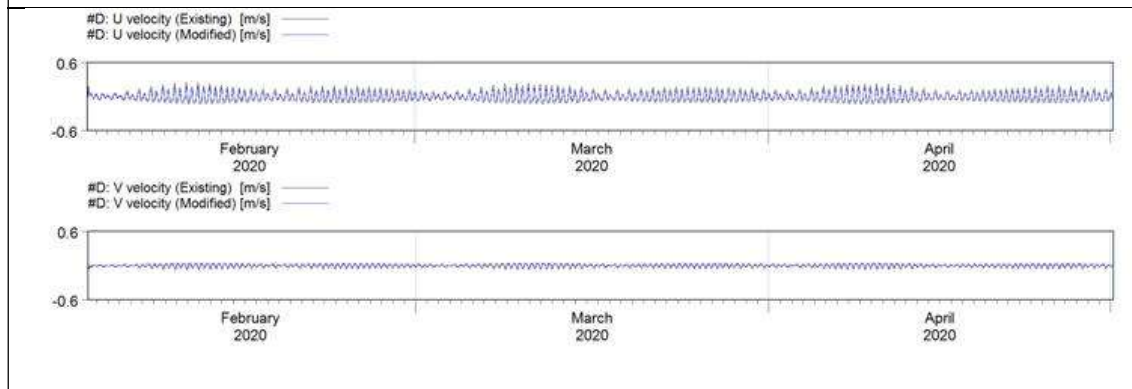
Comparison between existing and modified current U & V component at section A



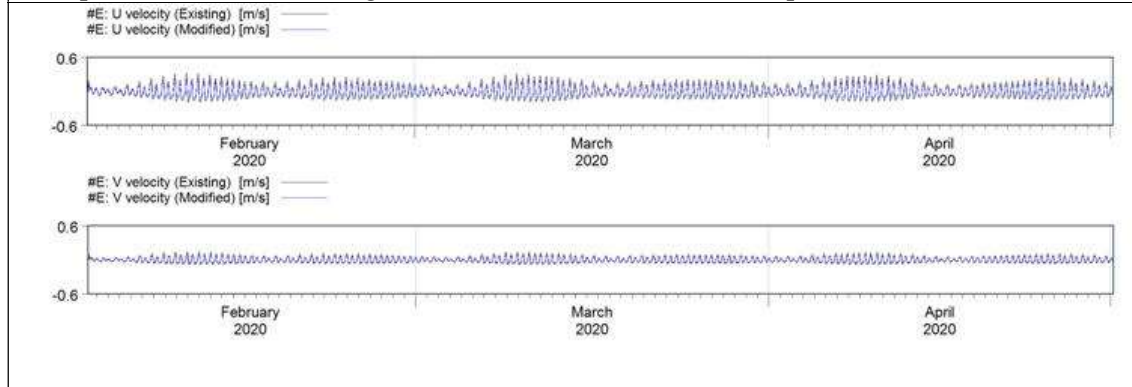
Comparison between existing and modified current U & V component at section B



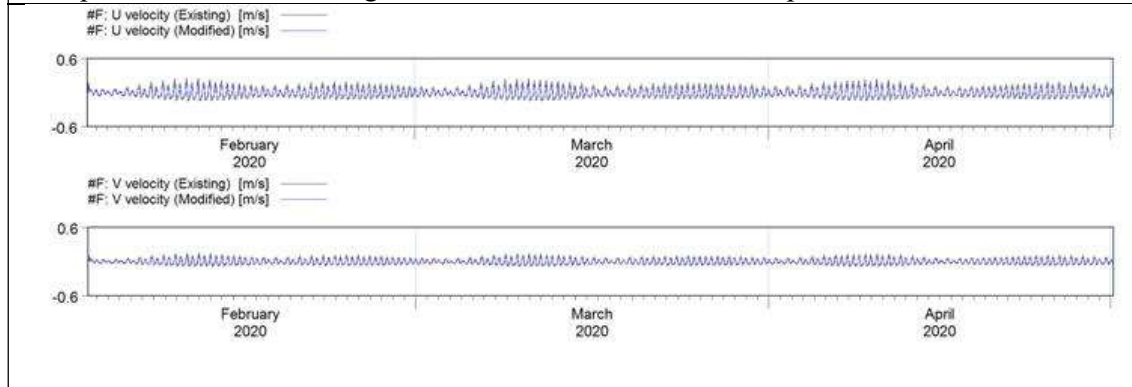
Comparison between existing and modified current U & V component at section C



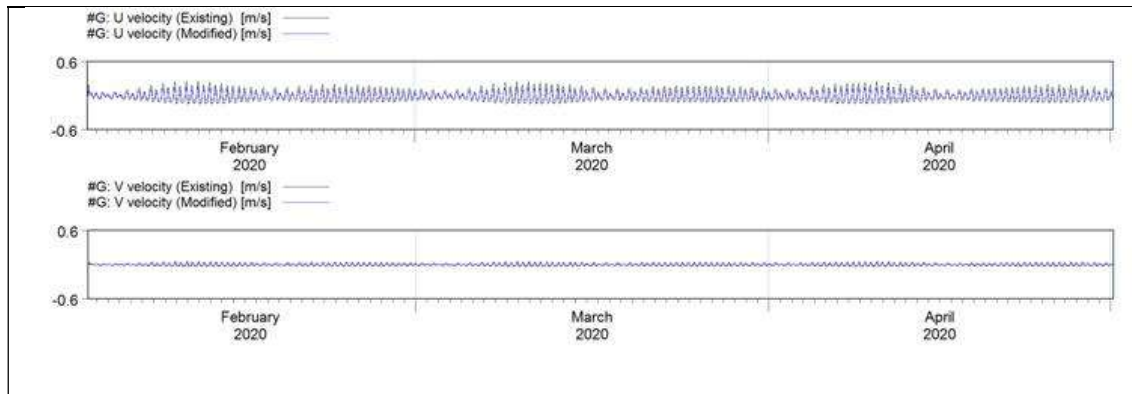
Comparison between existing and modified current U & V component at section D



Comparison between existing and modified current U & V component at section E



Comparison between existing and modified current U & V component at section F



Comparison between existing and modified current U & V component at section G

Figure 6.6 Comparison of U & V velocity at different sections between Case-1 and Case-2.

In Figure 6.7, the comparison of U and V velocity between Case-1 and Case-2 during February-April 2014 at section A are presented. The maximum current speeds observed for Case-1 is higher than Case-2 at section A. The similar phenomenon is observed for Figure 6.6. The reduction in current speed due to uniform deepening of the original bathymetry, is observed irrespective of year.

Table 6.1: Maximum and minimum of current velocity components at different section for Case-1 and Case-2

Section	U-component				V-component				Speed	
	Case-1		Case-2		Case-1		Case-2		Case-1	Case-2
	Min (m/s)	Max (m/s)	Min (m/s)	Max (m/s)	Min (m/s)	Max (m/s)	Min (m/s)	Max (m/s)	Max (m/s)	
A	-0.28	0.30	-0.17	0.24	-0.34	0.44	-0.17	0.23	0.54	0.33
B	-0.32	0.42	-0.16	0.22	-0.29	0.41	-0.14	0.20	0.59	0.29
C	-0.41	0.62	-0.21	0.35	-0.06	0.10	-0.04	0.06	0.63	0.35
D	-0.12	0.25	-0.08	0.17	-0.07	0.04	-0.05	0.03	0.26	0.18
E	-0.19	0.32	-0.13	0.24	-0.09	0.15	-0.06	0.11	0.36	0.26
F	-0.15	0.26	-0.10	0.18	-0.09	0.15	-0.06	0.10	0.30	0.21
G	-0.15	0.25	-0.08	0.15	-0.03	0.06	-0.02	0.04	0.26	0.16

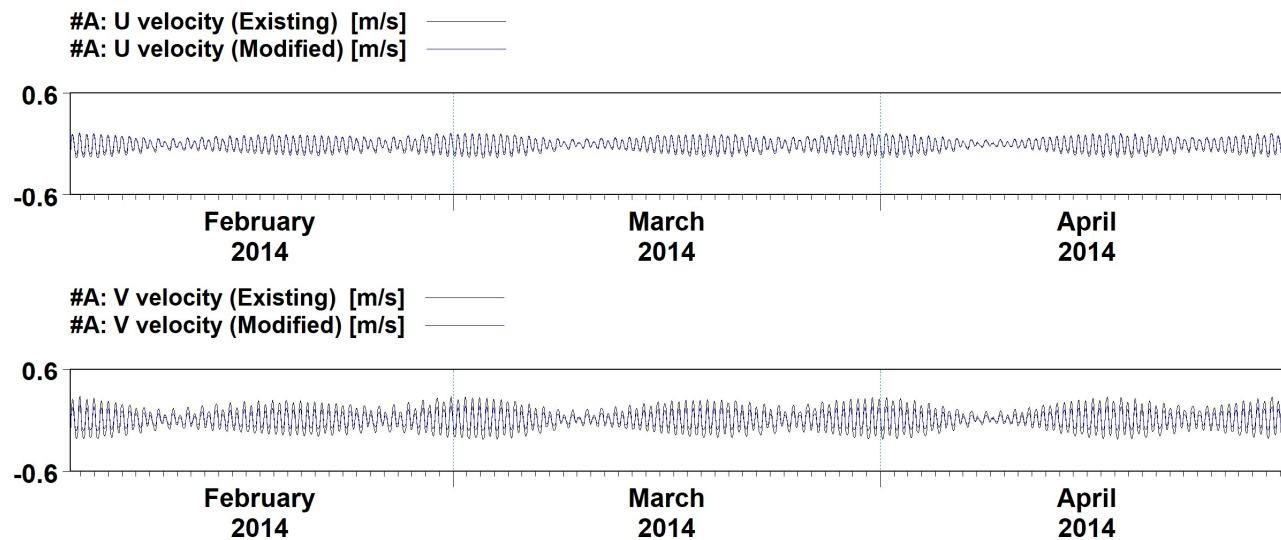


Figure 6.7 Comparison of U & V velocity between Case-1 and Case-2 during February-April 2014 at section A.

Bed level changes

The change in the bed level from the sediment transport model simulations provides accretion/erosion in the study region for the simulation period. This study is carried out assuming that the mined channel is stable and the flow dynamics are stabilized. In Figure 6.8, It is observed that high sediment deposition occurs at the mouth of Chapora estuary. For the sake of clarity, the Chapora Estuary is divided into three different parts based on the locations of sections A-G, and the comparisons of bed level changes between the between the Case-1 and Case-2 models are shown in Figure 6.9-6.11. The changes in bed morphology at different sections of the river are highly dynamic and patchy in nature. In Figure 6.9, it is observed that for Case-2, erosion occurs at the location between sections A and B at Chapora Part I. Figure 6.10 reveals that the accretion happens in section D in Case-2. It is observed that the locations around the northern side of the isolated island between sections C and D is eroded more for Case-2 than Case-1 at Chapora Part II. In Figure 6.11, more sediment accretion is observed at sections F and G than Case-1 at Chapora Part III whilst more intense erosion observed at the island between section E and F for case-2 than Case-1. It is important to note that localized bed level changes may happen due to abrupt change in the bed morphology.

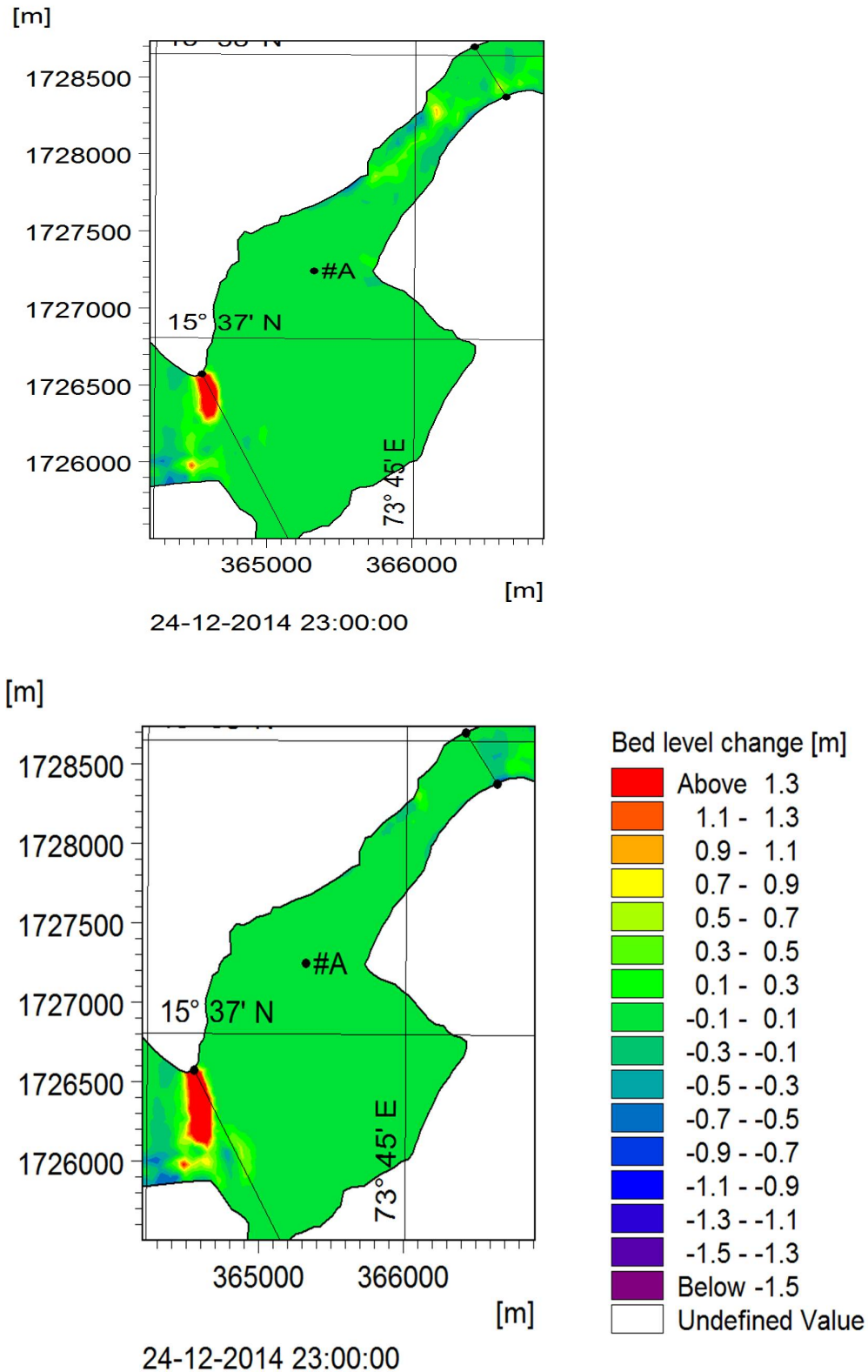
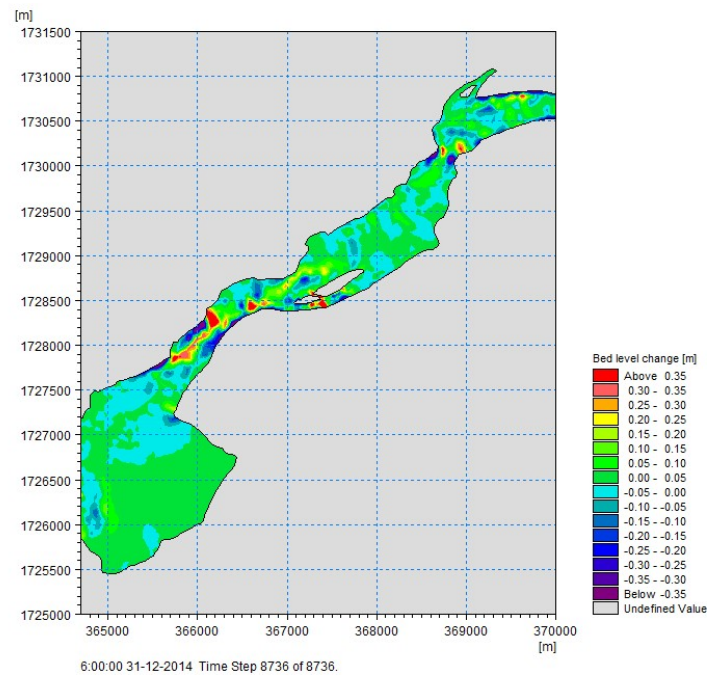


Figure 6.8. showing the deposition/erosion at the Chapora estuary mouth. Top figure is Case-1 and bottom is Case-2



Base Case Scenario (Case-1) for Chapora Part I



Modified Bathymetry Scenario (Case-2) for Chapora Part I

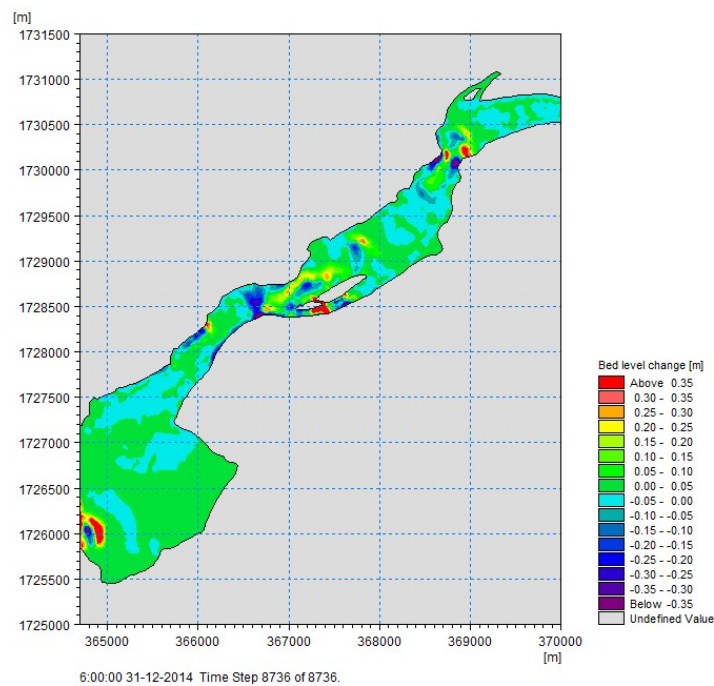
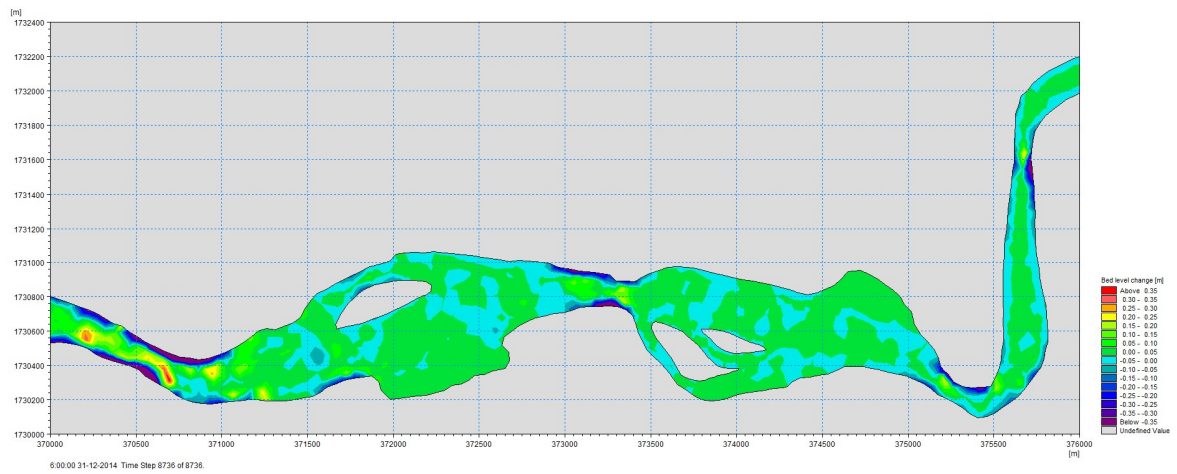


Figure 6.9.showing the deposition/erosion in the Chapora Part I



Base Case Scenario (Case-1) for Chapora Part II



Modified Bathymetry Scenario (Case-2) for Chapora Part II

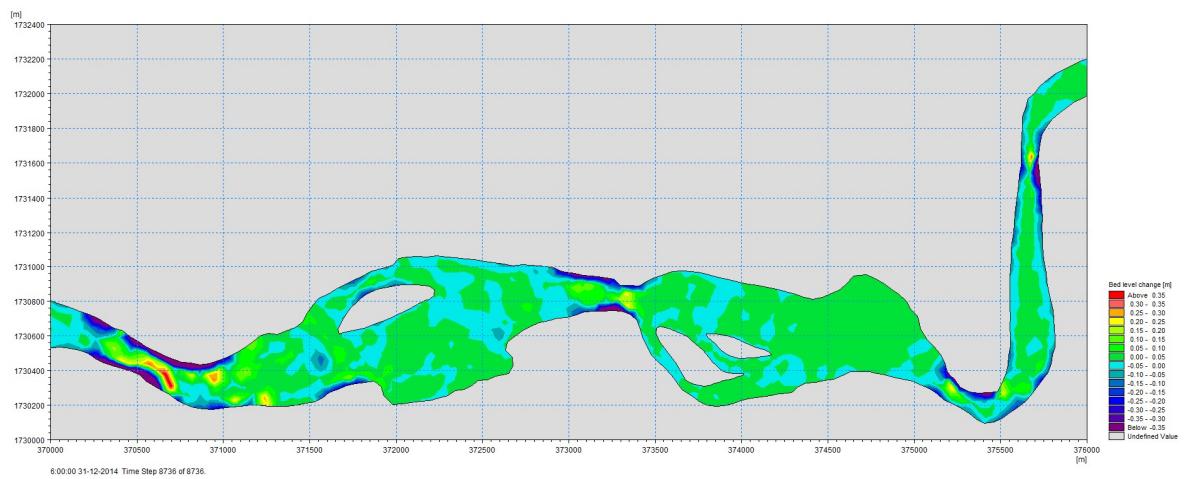
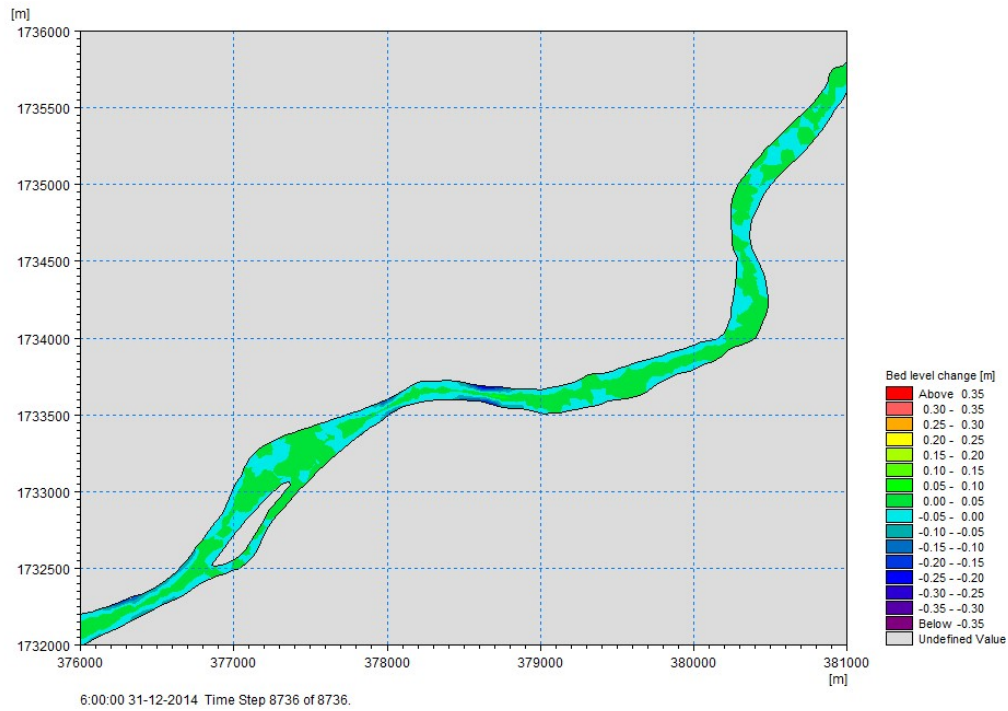


Figure 6.10.showing the deposition/erosion in the Chapora Part II



Base Case Scenario (Case-1) for Chapora Part III



Modified Bathymetry Scenario (Case-2) for Chapora Part III

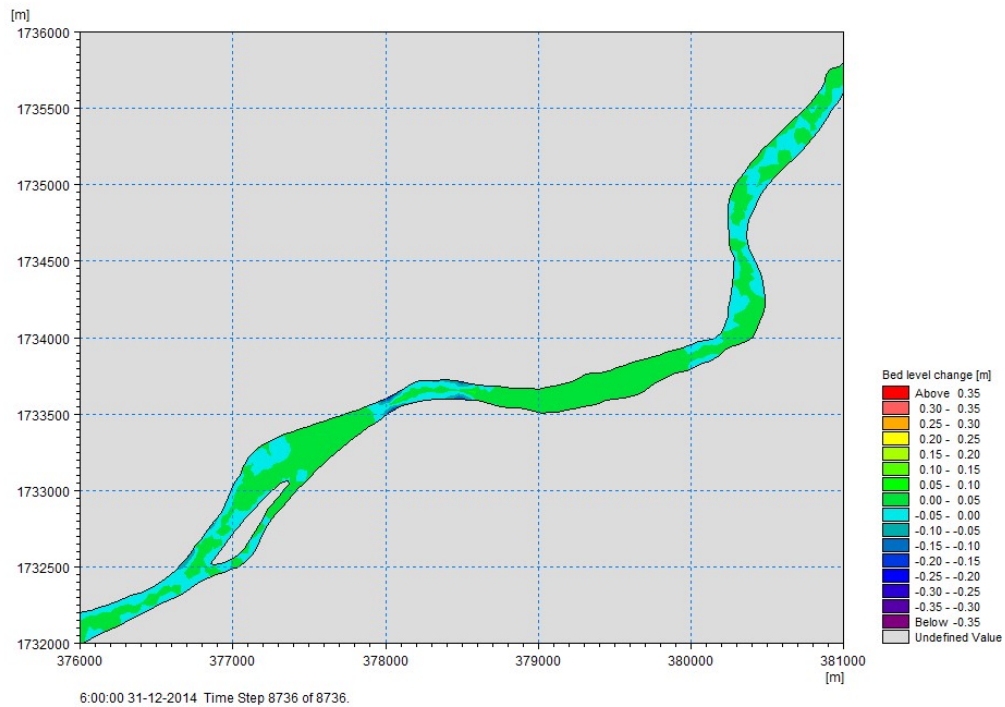


Figure 6.11. showing the deposition/erosion in the Chapora Part III



CHAPTER 7 ANTICIPATED IMPACTS

The primary function of an environmental impact assessment study is to predict and quantify potential impacts, and assess & evaluate the magnitude. Environmental impacts could be positive or negative, direct or indirect, local or regional and also reversible or irreversible. For each identified environmental impact, the associated risk is assessed based on its likelihood and significance.

Sand has become a very important mineral for our society due to its many uses. It can be used for making concrete, filling roads, building sites, brick-making, making glass, sandpapers, reclamations etc. The role of sand is very vital with regards to the protection of the coastal environment. It acts as a buffer against strong tidal waves and storm surges by reducing their impacts as they reach the shoreline. Sand is also a habitat for crustacean species and other related marine organisms. Individuals and private companies are increasingly demanding sand for construction purposes and this has placed immense pressure on sand resources. It is a practice that is becoming an environmental issue as the demand for sand increases in industry and construction.

Environmental Management Plan is a guiding document for environmental impacts associated with the proposed projects. It is a guiding document for management of good environmental condition on the site & surrounding of the proposed sand mine.

A scientific assessment of these impacts those are likely to influence the existing environmental scenario is needed. This could also facilitate in formulating a suitable environmental management plan depicting all mitigation measures. It can help in implementing the project in an eco-friendly manner. The project activities influencing the following environmental attributes have been studied and their impacts on the following attributes have been assessed.

The proposed project is to study impact of sand mining on the health of the Chapora Estuary. The projects seeks to understand the geomorphology, bathymetry, sand budget and flow dynamic of the river and the impact of sand mining on environment and biodiversity of the river. The EIA seeks to ensure that the potential negatives impacts arising from sand mining are mitigated or minimised whilst at the same time maximising on the positive impacts. The potential impacts of the project have been identified through literature review and site-



specific baseline. A variety of technical studies and investigations were also conducted. These include geo-morphological, modelling, physico-chemical and ecological studies.

7.1 Prediction & Assessment of impacts

In the state of Goa, the sand extraction activity is carried out in the estuarine areas of the river as the sand is mostly available in this region due to the topography and river hydrodynamics. In Goa the sand extraction activity has slowly increased over the year and is mostly carried out by traditional manual methods. There are no earlier studies on the estimates of sand available and the quantities and rates of replenishments. Therefore the exact impacts due to long term sand mining are difficult to assess. Therefore the present section deals with impacts that can be anticipated considering the baseline conditions prevailing at present.

Developmental projects such as sand mining have an impact on their surrounding environment. These impacts beneficial or harmful depend on the effect it brings about in the status of air, land, water, natural systems, ecology, socio-cultural, lifestyles and economics.

Depending on the improvement or the deterioration it brings about in the status of air, water, land, ecology, natural systems, socio-cultural life styles and economics of the local population. The impacts are assessed for their importance based on the nature of activities and environmental screening.

Marine organisms are known for their adaptive nature to the environmental changes though they possess certain tolerance capacity. Crossing these tolerance limits could give rise to serious impact on their existence which will ultimately result in ecological damage to the environment. The extent to which the baseline conditions can be altered by sand mining needs to be thoroughly analysed, and adequate mitigation measures need to be adopted so as to minimise the damage, if any to environment. Impacts to biological resources from physical and chemical environmental alterations are associated with sand mining activities. Major classes of alteration include suspended sediments, sedimentation, chemical release, flow patterns, topography. The biological impacts of marine sediments extraction are the disturbance and removal of benthic epifauna and infauna and alteration of the substratum upon which the colonization depends. This in turn affect its stability as a fish or shellfish food habitat where the remnant substrate is identical to the surficial sediment, disturbance is



unlikely to be permanent and the extraction area will be re-colonized, although the time scale will vary depending on the nature and location of the deposit.

Sand mining is the physical activity in the proposed project and it is known and increased sand mining has an adverse impact on the biodiversity by disturbing the biological community structure. Furthermore sand mining activities potentially affect not only the site itself but also the surrounding areas. The major impact of sand mining will be habitat destruction due to dislodging of sediment. The important parameters that influence the impacts are the scale of sand mining, its extent and duration.

Based on the present study and using available information, following anticipated impacts to the environment in the study area of the estuarine system have been identified. This needs to be further examined considering the monsoon flow conditions.

7.1.1 Anticipated impact on Physical environment

- Large-scale extraction for over a long period of time extraction of streambed materials, mining below the existing stream bed and the alteration of channel-bed form and shape may lead to several impacts such as erosion of channel bed and banks, increase in channel slope, and change in channel morphology.
- Undercutting and collapse of river banks
- Loss of adjacent land and/or structures
- Upstream erosion as a result of an increase in channel slope and changes in flow velocity.
- Formation of deep pits in the channel bed produce slower flow velocities and lower flow energies, causing sediments transported from upstream to deposit at deepened area.
- Deficient water (hungry water) can have a very high erosive effect on the river banks.
- Downstream triggering bank erosion and damages to engineering structures.

7.1.2 Anticipated impact on traffic

- Mining contractor will use the same main roads to transport product out of the study area and through road networks. This will result in an increase in the number of trucks utilizing the road.



- Traffic congestion may occur due to narrow width of road and damage to roads due to plying of heavy vehicles further disturbing local well-being and increasing the maintenance cost.

7.1.3 Anticipated impact on Air Environment

- Dust will be generated from loading, screening and transportation operations. This dust becomes air borne and gets carried away to surrounding areas.
- The impact on air is mainly localized in nature as the dust particles are not carried to longer distances due to larger size.
- Combined impact of air borne dust from the mining lease areas will definitely give a relatively larger picture of fugitive dust emission in the area.
- Collection and lifting of minerals will be done manually without any blasting. Therefore the dust generated is insignificant as compared to mining process of other hard minerals like the process of drilling, blasting, mechanized loading etc.

7.1.4 Anticipated impact on Water environment

- Sand mining activities will have an impact on the river's water quality. Impacts include increased short-term turbidity at the mining site due to re-suspension of sediment, and dumping of excess mining materials, oil spills or leakage from transportation vehicles and washing of vehicles in the river.
- Suspended solids may adversely affect water towards downstream and aquatic ecosystems. The impact is particularly significant if water toward downstream of the site are abstracting water for domestic and irrigation purposes etc.
- Excessive mining will reduce the thickness of the natural filter materials (sediments) through which the groundwater is recharged. The pollutants due to mining, such as washing of mining materials, wastes disposal, diesel and vehicular oil lubricants and other human activities may pollute the groundwater.

7.1.5 Plume generation

- At the proposed sites of River Chapora, a turbid plume would eventuate as material is released to the water column during sand mining operations.
- Increased turbidity results in decreased primary productivity in the water column.



- Sand mining activity may change the nutrient regime of the water column and may result in increased pollutant.
- The turbidity plume generated may have localized dispersal due to tidal action and riverine flux, thus the overall anticipated impact shall be localized and not of chronic nature.
- The size of plume will depend on the scale and periodicity of the mining activity.

7.1.6 Anticipated impact on pelagic environment

- The increased turbidity may lead to decrease in dissolved oxygen (DO) in the water column during sand mining operations.
- Increase in suspended sediment loads and turbidity level due to sand mining may have adverse impacts on marine producers and consumers by reducing euphotic zone of water column.
- This increased load not only limits light penetration in water temporarily but may also affect filter feeding organisms such as zooplankton and bivalves.
- Reduced DO can cause the loss of micro-eukaryotic biomass, decrease aerobic bacterial community.
- Loss or reduction of bacteria means remineralisation of matter will be significantly slower affecting the invertebrate grazers, predators and fish community.
- Nutrients such as phosphate released from the bottom churning of the sediments during sand mining may increase surface phytoplankton blooms that may clog membranes of filter feeding zooplankton and larval fish.

7.1.7 Anticipated impact on planktons

- Sand mining causes suspension of sediments in the water column during the extraction. The increase in turbidity would decrease light penetration and reduce photosynthesis, thereby causing changes in phytoplankton community structure and the food web. Many bottom dwelling pinnate phytoplankton and zooplankton groups such as bivalves could be impacted or translocated. The suspended solids would also release excessive material such as nitrates during mining. This could lead to blooms of dinoflagellates. Since the activity does not involve long distance vessel movement, the chances of new/exotic/weed/invasive species to be introduced would be negligible.



- One of the main concerns of sand mining is the suspension of fine sediments into water column, causing short term increase in turbidity. This increased turbidity has short-lived effect on phytoplankton, which are light dependent, these are generally negligible and temporary.

7.1.8 Anticipated impact on Fishery

- Common fish found in Chapora Estuary are *Etroplus suratensis*, *Mugil cephalus*, *Sillagosihama*, *Lates calcarifer* but the overall fishery yield from the river is very low. Thus the sand extraction may have deleterious effects on the already depleted fish population (Based on secondary information from the native stakeholders)
- Disturbance during sand mining activities may limit the ability of such areas to function as a nursery area, and/or feeding ground for aquatic fauna.
- Physiological stress to marine fish and commercially important species by creation of higher sediment loads in the water column.
- Increased bioaccumulation of contaminants in commercially important species.
- Reduction in habitat due to loss of benthic primary producer habitat.
- Change in fish catch may occur due to proposed activity. Based on the secondary information (local stakeholders) the sand extraction activity is ongoing for several years and the fish and shellfish quantities have also reduced over the years. The interdependence of these two activities is difficult to assess as cumulative activities and impacts require historic trend dataset.
- Increased turbidity and organic matter may change the microbial water quality at nearby recreational sites and may also affect the fish fauna. May lead to increase in the population of undesirable species such as viruses and parasites.

7.1.9 Anticipated impact on benthic environment

- During sand mining operations, the removal of material from the seabed also removes organisms living on and in sediments which are collectively termed as 'Benthos'.
- Initial reduction in abundance, species diversity, benthic biomass as well as recovery of the lost biota varies with scale and duration of disturbance, local hydrodynamics,



and associated transport processes and lacks similarity to the habitat that existed prior to sand mining.

- Sand mining results in complete removal of surface biota at mining sites.
- Excessive and unplanned riverbed sand mining results in the destruction of aquatic and terrestrial habitat through large changes in the channel morphology.
- Disturbance of the upper layers of the seabed causes short term re-suspension of sediments, re-mineralization of nutrients and contaminants and re-sorting of sediment particles. Direct removal damages, displaces or kills a portion of benthic flora and fauna. It also causes a short term attraction of carrion consumers. It leads to alteration of habitat structure (e.g. removal of sand, flattening of wave forms, and removal of structures required by some organisms).
- Increased suspended sediment due to sand mining can affect the filter feeding organisms such as shellfishes by clogging and damaging their feeding and breathing physiology.
- Sand mining may lead to patchy distribution of organisms between mined and adjacent non-mined areas.
- Adult fish are likely to move away or avoid areas of sand mining sites, unless food supplies are increased as result of increase in organic matter.
- Fauna was comprised of polychaetes & crustacean which constitute a major food source for benthic feeding fishes; these showed low population in the central regions of the river and thus lowered secondary benthic productivity.

7.1.10 Impact on riparian areas

- Sand-and-gravel mining in stream channels can damage public and private property. Channel incision caused by sand/gravel mining can undermine bridge piers and expose buried pipelines and other infrastructure.
- Excavation of a mining pit in the active channel lowers the stream bed, creating a nick point that locally steepens channel slope and increases flow energy.
- Excessive and unplanned riverbed sand mining results in the destruction of aquatic and terrestrial habitat through large changes in the channel morphology. Impacts include bed degradation, bed coarsening, and channel instability. This in turn can



cause erosion of banks, embankments along fields leading to salt water intrusion and loss of land.

7.1.11 Anticipated impact on mangrove

- Mangroves are crucial habitats as they act as feeding and breeding grounds for many organisms. These are also an important site for crab fisheries. Mangroves could be affected by sustained inundation of pneumatophores and declining water quality which may lead to their death.
- In downstream areas sand mining may lead to damage to embankments which cause saline water intrusion into fields this leads to abandonment of fields which are colonized by mangroves (already damage due to breach of bunds), and bunds hence have to be restored in the traditional method.
- Damage to mangroves can also affect species (eg: *Meretrix* spp., *Polymesoda* spp., oysters and clams) that depend on mangroves for resources.
- However the overall impacts to mangrove in the study area are not of concern as mangrove cover has shown steady increase in-turn showing indications of large scale increasing its expanse in to other land use areas.

7.1.12 Impact on mudflats

- Sand mining can cause increased scour, erosion and increase steepening of slopes thereby removing the mudflat habitat.
- Create a disturbed benthic community and possibly reduce the number and diversity of benthic species and affects larval recruitment negatively.

7.1.13 Anticipated impact on sandflats

- In-stream mining lowers the stream bottom, which may lead to bank erosion. Depletion of sand in the streambed and along coastal areas causing deepening of rivers and estuaries, and the enlargement of river mouths and coastal inlets.
- Epifaunal and large in-faunal organisms will be most affected by sand mining. Crab and lobster spawning areas occur where sand banks meet rocky areas. It can cause extinction of commercially important species dependent on sand flats for eg: *Paphia* spp.



- Cumulative impacts will include undercutting and collapse of river banks, loss of adjacent land and/or structures, upstream erosion and uprooting of as a result of an increase in channel slope and changes in flow velocity. In the downstream region there is channel widening and deepening, undermining of engineering structures, dwindling of riverine habitats, damage to protective structure such as bunds leading to salt water intrusions into paddy field.

7.1.14 Others

- The most likely adverse impact will be of cumulative nature and it will be hard to discern from the singular impact of any new or old activity in the given location and period.
- There are crocodile and smooth coated otters found in the river which are protected under schedule I and II respectively by the Indian Wildlife Protection Act, 1972. Other mammals such as Otters, jackals, flying fox, wild cats, wild boar etc. visit mangroves for shelter, breeding or feeding. Primate species such as macaques and langurs can face increased threats. These animals can face increased threats and can be harmed in man-animal conflicts.
- Olive Ridley's turtle protected under schedule I of Wildlife protection Act, 1972 nesting sites could be affected due to sand extraction around the mouth of the estuary in large scale.
- Chapora Estuary has a good diversity and abundance of avifauna. Birds gather on the sand bars at mouth of River Chapora for feeding. Several migratory birds visit these rivers during winter and use it as an important feeding ground. These are most sensitive to any sort of disturbance such as noise, use of mechanized vessels, change in turbidity, productivity or change in water quality. The disturbance by sand mining may affect foraging behavior of birds, mainly aquatic birds. These birds are likely to move away from such areas.
- Occurrence of unintended events such as vehicle collision, accidents, fire, fuel leaks and other inadvertent events may occur mainly due to lack of coordination, casual approach, un-managed activity and associated activities (e.g.: fishing) and no timely communication within and between stakeholders involved in nearby



areas. These events may also result in environmental disaster if there are no precautions taken.

7.1.15 Positive anticipated impacts

- Sand mining can help the economy directly by generating employment for extraction of sand and income from sale of sand.
- Maintenance of channel for the movement of fishing vessels is carried out by the state authority. Same areas can be excavated which can serve dual purpose and reduce expenses.

7.2 Mining Sensitive Areas:

Estuaries are most dynamic and complex ecosystems known around the globe. They are made up of a wide range of different habitats, which exist in an ever changing mosaic structure. Typical habitats that make up an estuary include sand banks, mudflats, mangroves, salt marshes, sand flats, and at their coastal edge sand dunes, small islands sandy beaches etc. They are prime importance for wildlife especially migrating and breeding birds and major values in terms of their rich natural resources (nursery grounds and commercially important fish). In addition they also offer a wide range of ecosystem services such as shoreline stabilization, nutrient regulation, carbon sequestration, detoxification of polluted water and supply of food and energy resources.

To preserve and protect these habitats areas have been demarcated based on importance and in accordance with Sustainable Sand Mining and Management Guideline 2016. The entire region is divided into four different zones. Zone –I (Figure 7.1 and Legends as per Table 7.1) is located at the mouth region, it ends at Camurlim village jurisdiction. The area consists of sensitive regions viz; Turtle nesting site, embankment to protect paddy fields, sand flat, Mangroves, riverside urban areas and bridge. Shallow sand flats provide feeding habitat to a lot of migrating and local birds while Morjim is well known Olive Ridley's turtle nesting site, if sand is excavated from zone-I(Figure 7.1) it is predicted to impact shoreline, change in geomorphology, beach profile and grain size of sandy beach, which will potentially have adverse impact on turtle nesting grounds. Further a bridge is present connecting Siolim and Morjim; mining might damage this structure, stability or strength of the bridge. As per SSMMG, 2016, to avoid structural damage to any bridge, an area upto 500 m on both the sides of bridge is



restricted for mining. East to the bridge an Island (North of Oxel village) vegetated with mangroves, and considering the Hon'ble NGT order (28/2015 (WZ) an area of 1000m (upstream and downstream) has to be restricted for mining. Based on the baseline geo-morphology and bathymetry, the profiles reveal deeper excavated areas that may pose threat to the constructed structures.

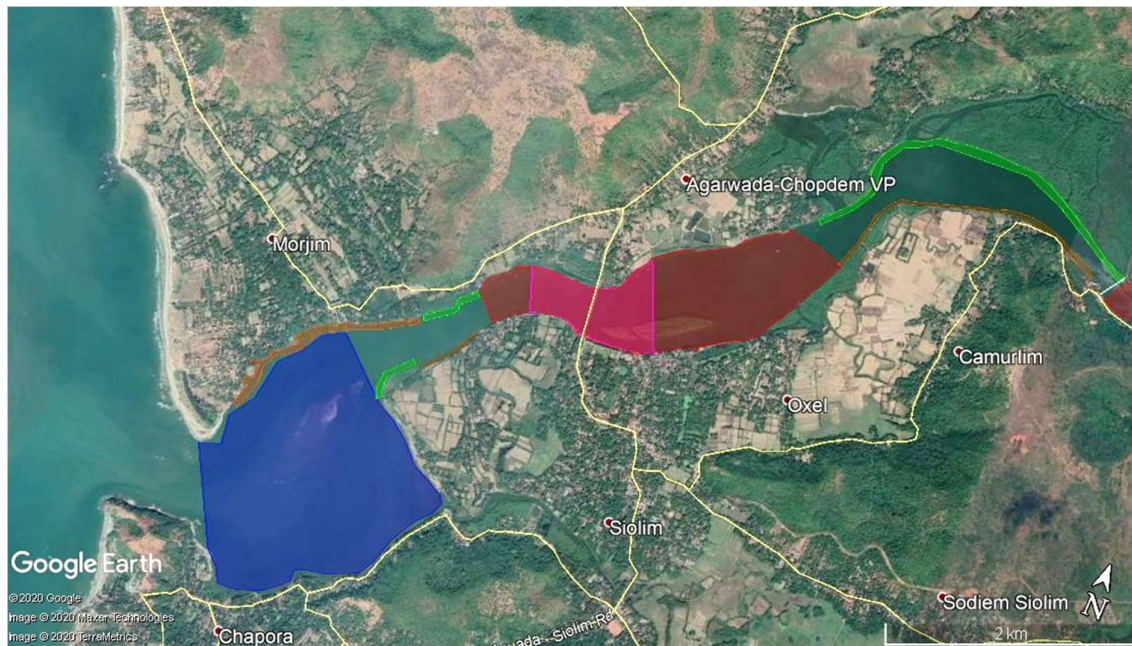
An embankment exists to protect salt water intrusion as well as to secure paddy field on Siolim side. Opposite to this embankment lies mangrove forest, as per SSMMG (2016), a 50m wide area from ecologically sensitive areas (such as mangroves) and 25m from the embankments are to be avoided for mining.

Next zone is considered from Oxel to Revora which consists of two adjacent islands towards west end, bridge and meandering towards east. Here the order of Hon'able NGT order (28/2015 (WZ) has been followed for excluding an area of 1000m upstream and downstreams of Juem de Tuem Island is applied to all the islands of this river as all the islands are equally important and vulnerable due to changes in geo-morphology and erosion pertaining to mining activity. Thus 1000m upstream and downstream areas from these islands are to be restricted for sand mining. Meandering bends are to be avoided as these may have major geo-morphological changes such as accretion which may lead to deposition and erosion at the upper/lower reaches pertaining to sand extraction. Mudflats and mangroves are also to be avoided as these serve as habitat, breeding ground and nursery for myriad of marine organisms. A flyover bridge is also present at the meandering point where an area of 500 m on both the sides is restricted for mining. Zone III (Figure 9.1) falls between Revora to Nadora, it consists of an Island and bridge towards north while a meander and National highway running parallel to the river. Therefore 100m from any National Highway is exempted from mining activity (SSMMG 2016). Further east of the National Highway a meander is encountered where 200m area on either sides is restricted. On the eastward side there is an Island and bridge which are restricted as well 1000m and 500m on either side respectively. Last zone has three main features viz Bridge, Meander and islands and thus as per SSMMG (2016), these zones are restricted as well from mining activities Zone IV (Figure 9.1).

The figure 7.2 and 7.3 shows the benthic biodiversity indices overlapped on the proposed areas of sand extraction. The upstream stretches indicate low values of indices for A-Ambi



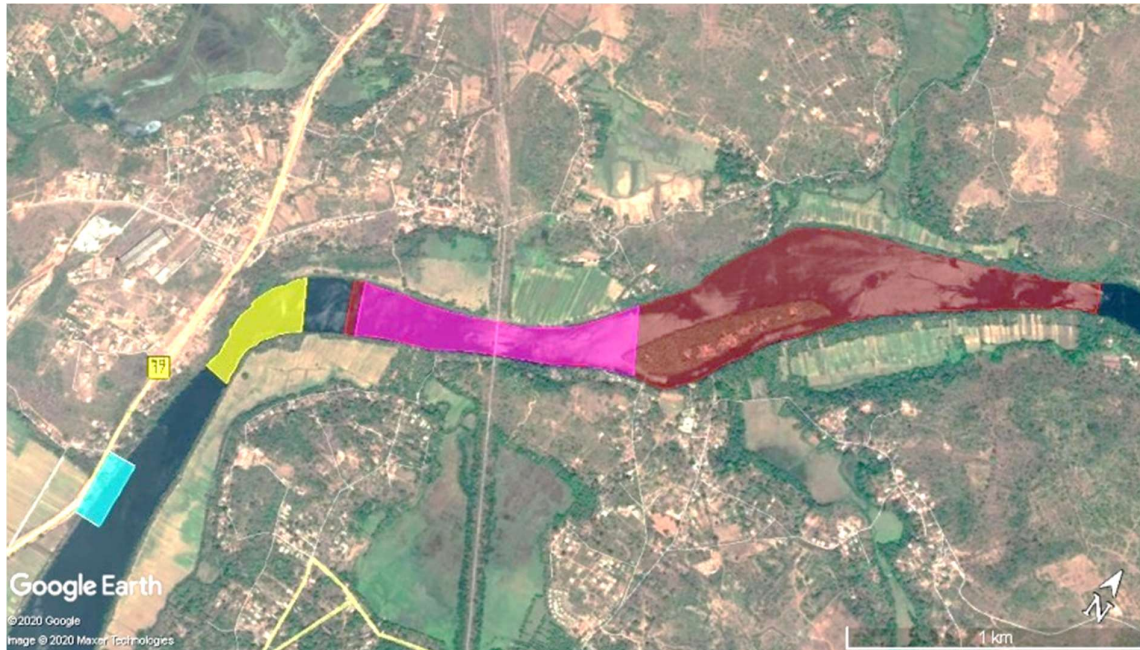
and Bentix therefore the impact of sand extraction will be minimum on the benthic biota but Shannon-Wiener's and Simpson's Index shows high values. While the stretch between Camurlim- Chopdem has higher indices (Figure 7.2) which indicates sand extraction will have higher impacts on the benthic biodiversity.



Zone-I



Zone-II



Zone-III



Zone-IV

Figure 7.1: Depicting Mining Sensitive Zones for Chapora estuary (Zone I to IV).



Table 7.1: Depicting type of sensitivity, colour code, width and guidelines referred.

Colour	Sensitive Areas	Width	Guideline
	Mangrove	50 m	Sustainable Sand Mining Management Guideline 2016
	Embankment (Saline Intrusion)	25 m	Sustainable Sand Mining Management Guideline 2016
	Bridges	500 m up-streams & down-streams	Sustainable Sand Mining Management Guideline 2016
	Islands	1000 m up-streams & down-streams	Sustainable Sand Mining Management Guideline 2016/ National Green Tribunal.
	National Highways	100 m	Sustainable Sand Mining Management Guideline 2016
	Meandering	200 m Up-strems& down-streams	Sustainable Sand Mining Management Guideline 2016
	Ecologically Sensitive	-	Sustainable Sand Mining Management Guideline 2016
	Urban Habitat	50 m	Sustainable Sand Mining Management Guideline 2016

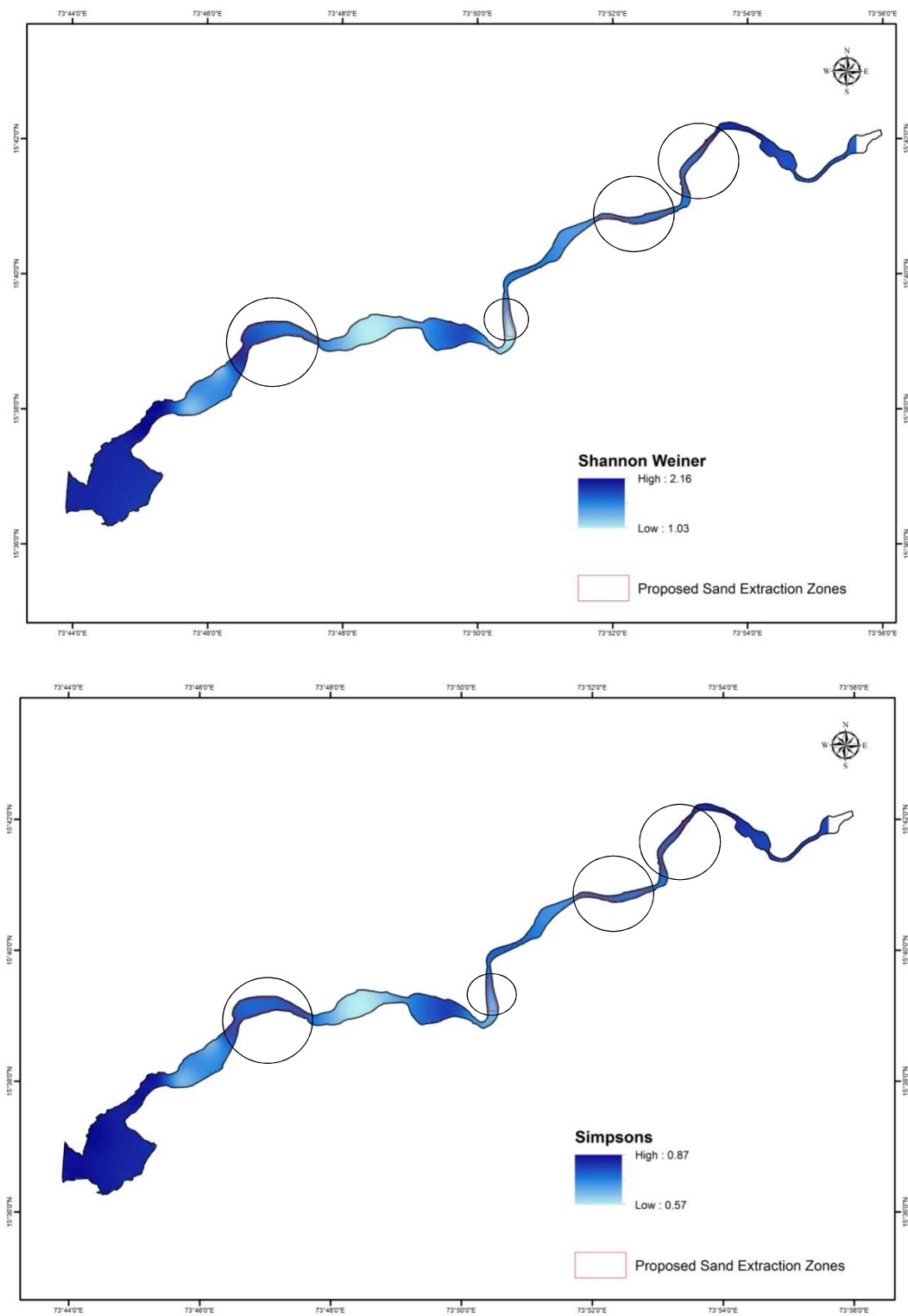


Figure 7.2: Shannon-Wieners and Simpsons Index depicted on the river stretches with encircled proposed sand extraction zones.

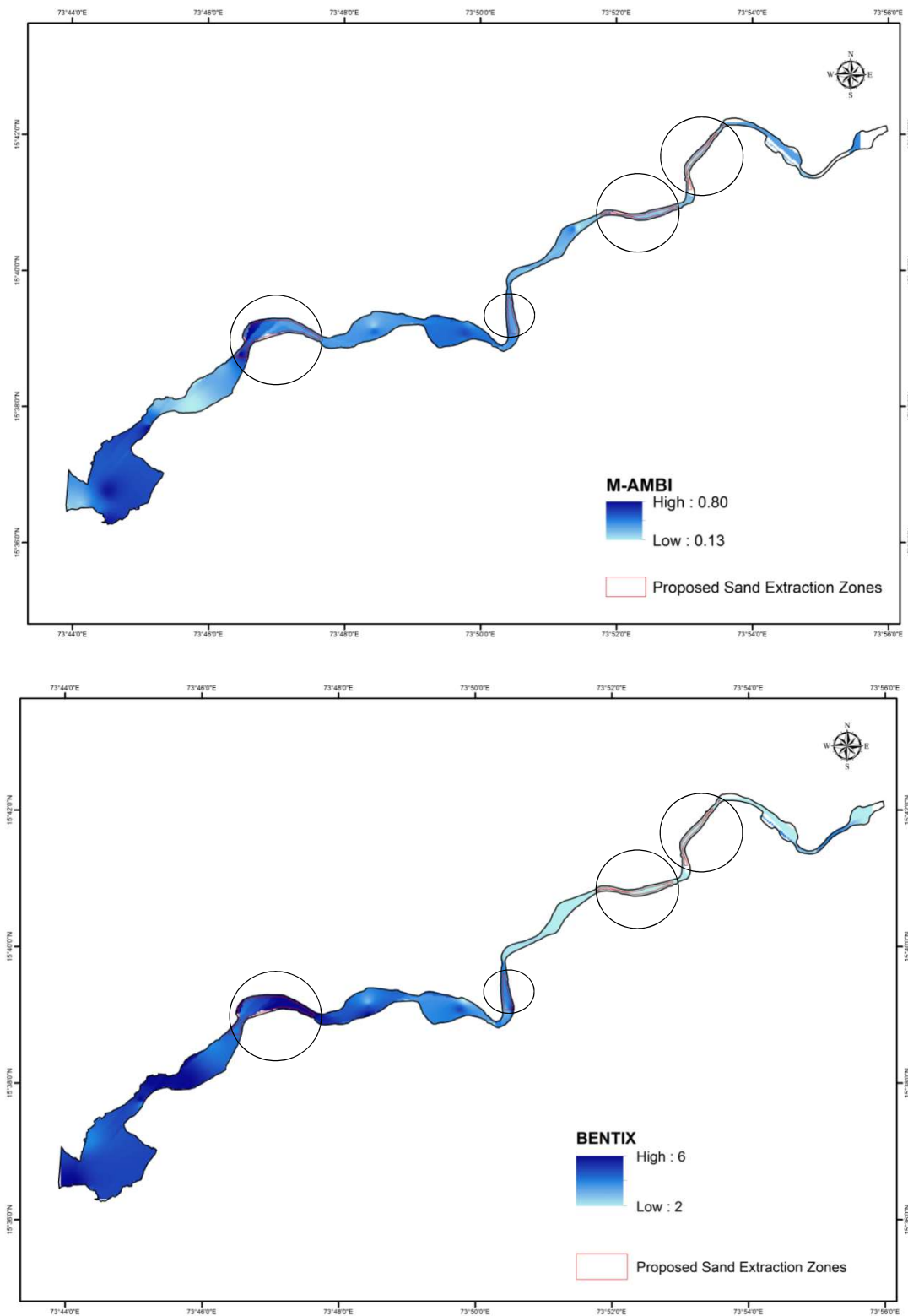


Figure 7.3: M-AMBI and BENTIX indices depicted on the river stretches with encircled proposed sand extraction zones.



7.3 Cumulative Impacts:

In the present study Land Use Land Change cover was observed by mapping the project area by comparing present scenario with year 2003. Several areas were noted and maps were prepared accordingly along the entire stretch of Chapora estuary. Total sixteen regions are identified and depicted based on land use change. For all the regions two maps were created, representing current scenario and other depicting 2003 scenario. These maps have been numbered 1-16.

First region lies near the mouth area of estuary, in the year 2003 the region showed minimal mangrove cover whereas now it shows a significant increase in the mangrove. Similarly in the next region notable increase of mangroves on the island can be seen. Earlier aquaculture ponds/salt pans were in use near the bridge (Siolim-Morjim) area, but now it has been taken over by mangroves. There has been change in Pernem area as well; the land used for agriculture earlier has now become fallow land. This could be the result of salt water intrusion due and simultaneous increase in mangrove cover, as clearly visible in the sporadic distribution of mangrove has grown into a thicket now which depicts a possible shift of mangrove region landward side. In the mid region of estuary, significance increase in saline areas is clearly visible. The areas once utilised for paddy cultivation, now have turned barren and fallow due to a single saline water surge or recurrent high tide water brining in salinity. This intrusion of saline water could be due to lack of maintenance of already existing embankments, breach in embankments, eroding mudflats or shift in mangrove area to landward side as well as excavation of sand. In the upper reaches of the estuary cumulative impacts on the banks is visible wherein banks have been eroded taking away the riparian vegetation (Fig: 7.4). It is to be noted that in spite of good vegetation cover like tall grasses, shrubs and large trees (mostly coconut palm) the chunk of land is eroded, leaving a cross sectional vertical wall of the soft sandy silty bank sediment (Figure 7.6).

From the comparison of historic land use it is clearly visible that land once used for paddy cultivation has been converted into waste/marshy land due to saline intrusion (Figure 7.5). Apart from the major areas depicted in the Figure 7.51A-B to 16A-B there are several small land parcels that have been either intruded by saline water or are eroded due to strong monsoon currents.

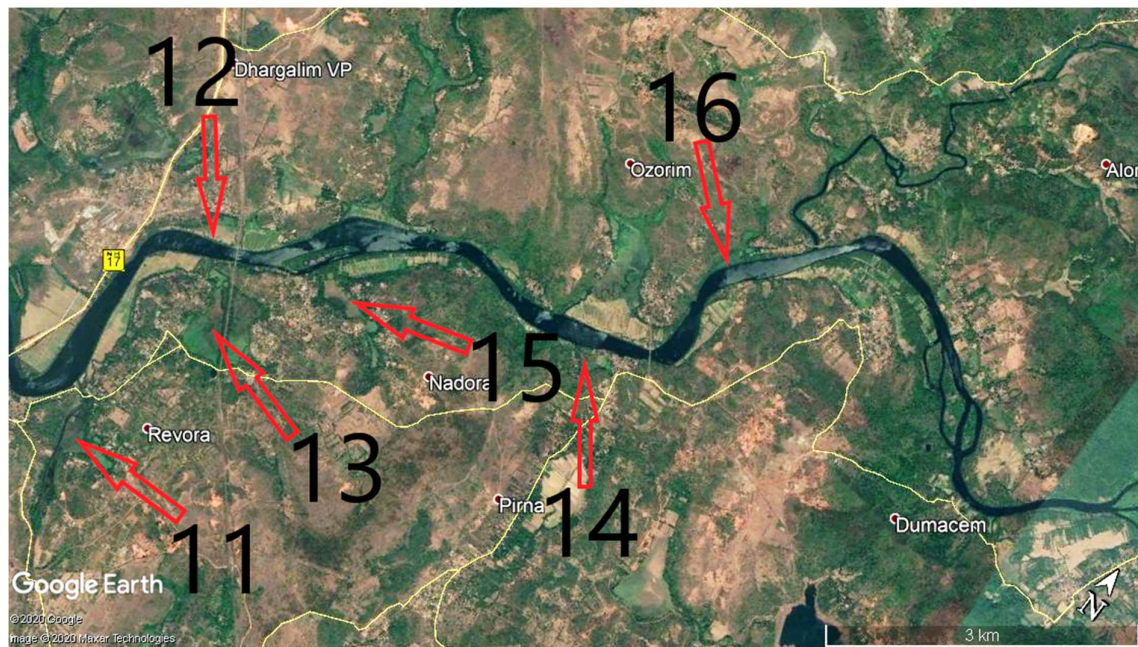
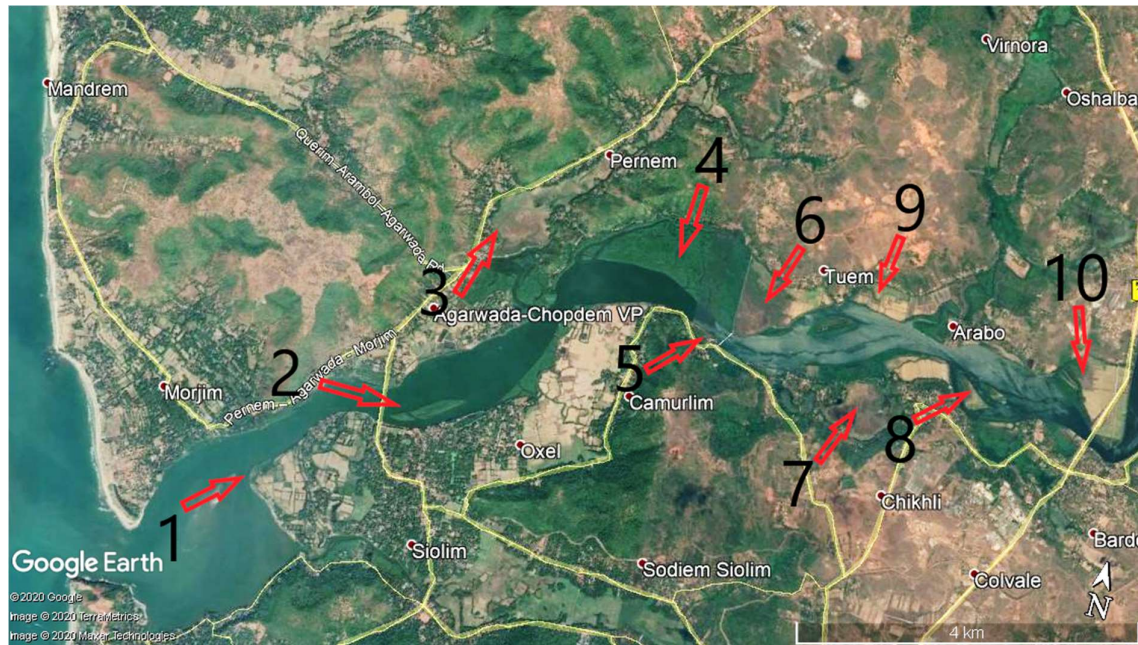
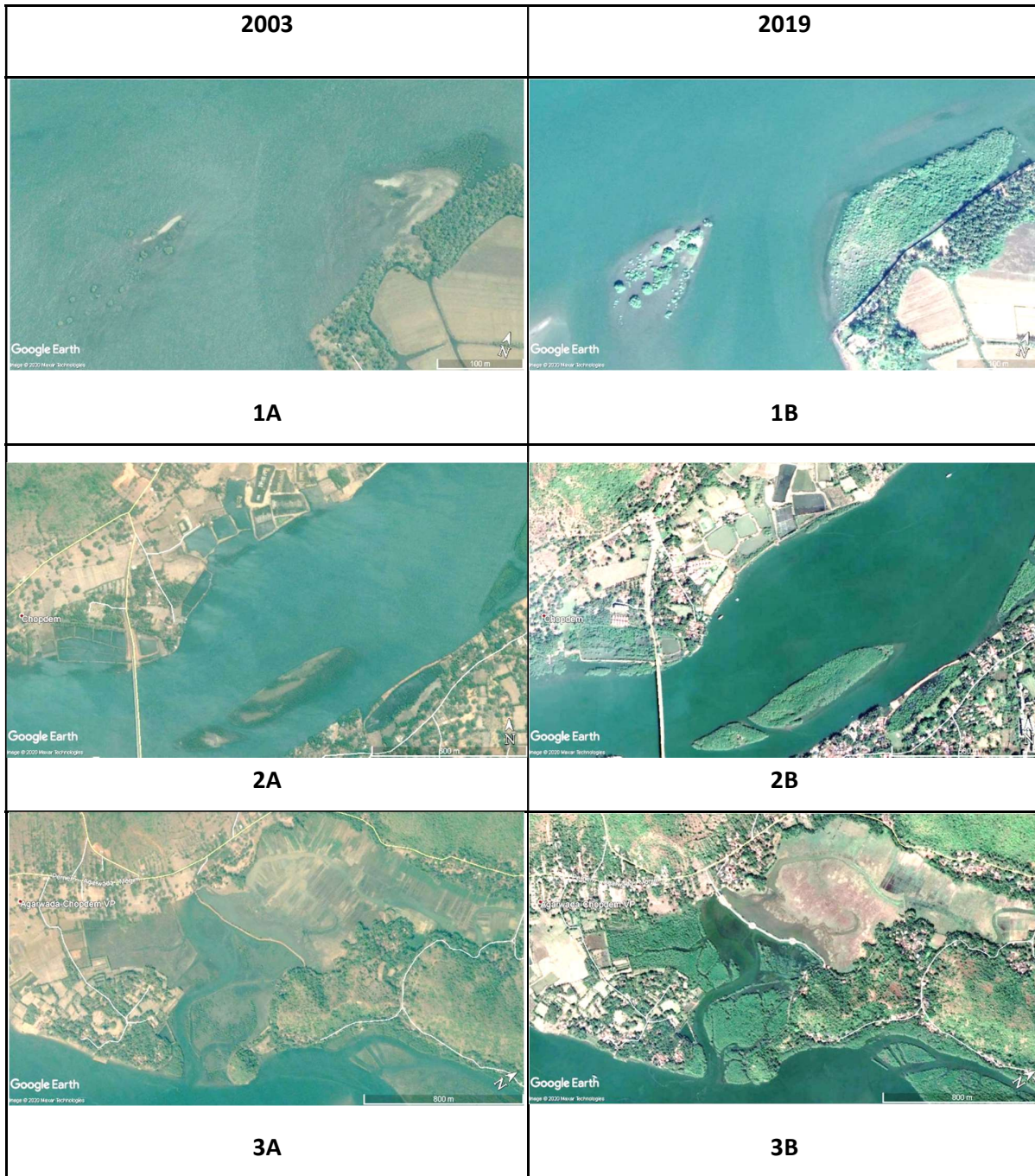
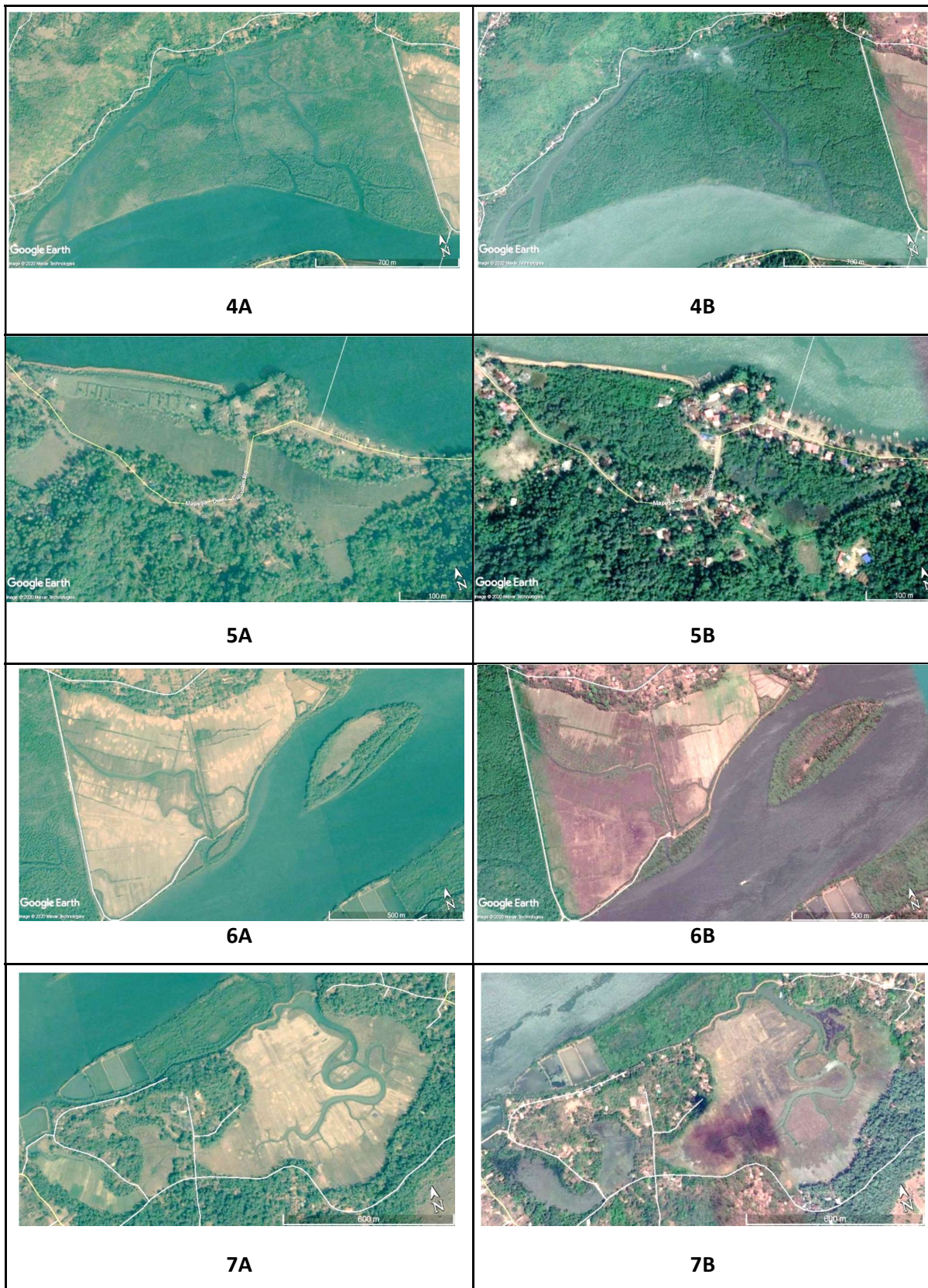
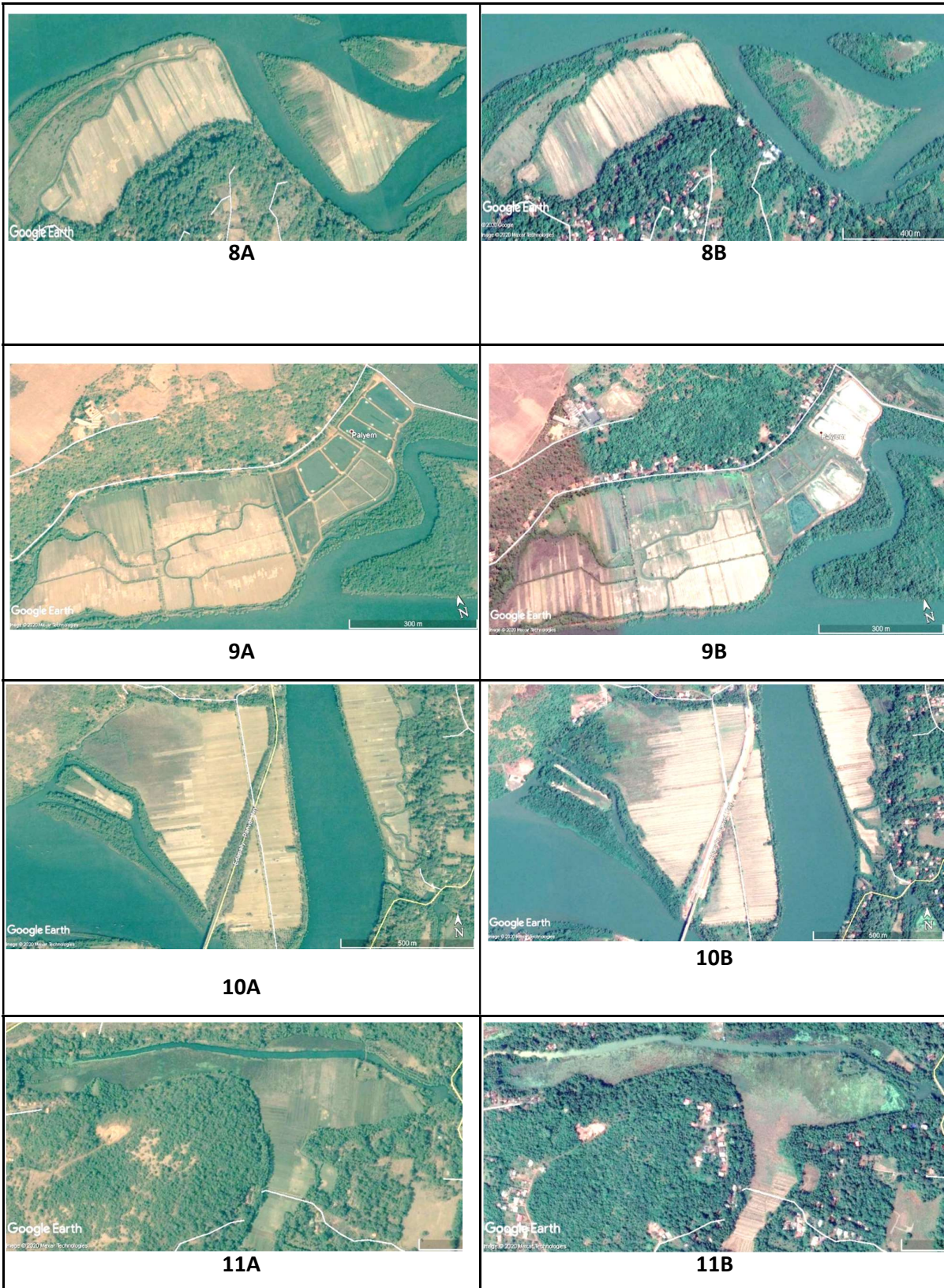


Figure 7.4: Two sections of the rivers depicting areas highlighted in the subsequent Figure 7.5 for land use changes.









12A



12B



13A



13B



14A



14B



Figure 7.5: Areas depicting Land Use Land Cover along the Chapora Estuary.

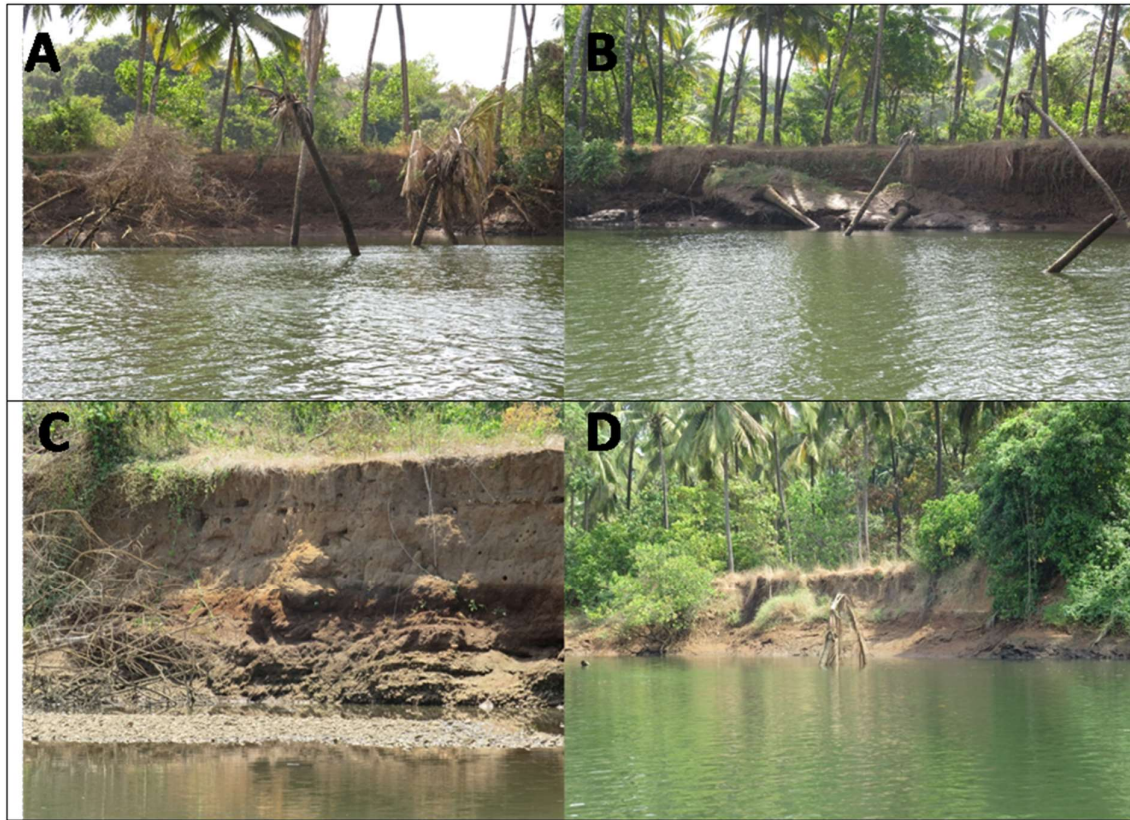


Figure 7.6: Erosion of banks in the upstream stretches of Chapora Estuary.



CHAPTER 8 MITIGATION MEASURE

The aim of the mitigation guidelines to ensure that the sand mining is carried out in an environmentally sustainable and socially responsible way, improve the effectiveness of monitoring of mining and transportation of mined out material, conservation of river equilibrium and its ecosystem health, no obstruction of the river flow, water transport and restoring the riparian rights and in-stream habitats, to prevent river pollution and water quality deterioration. The extraction of sand and gravel from the river bodies has to be regulated and done with the adoption of required environmental safeguards. Mapping of the sand resources at the district level, identification of appropriate sites for extraction, appraisal of the extraction process, putting in place the required environmental safeguards and rigorous monitoring of the volume of extracted material is required to ensure the sustainability of the entire process. In broader sense, the impacts of sand mining can be reduced or avoided and mitigating it may only imply replenishment (which may happen over a course of time during which the magnitude and expanse of impacts might change thus making it difficult to comprehend).

8.1 Protection of river embankment

Site-specific evaluation is needed to evaluate each proposed operation to minimize disturbance and maximize the stability of the channel. In downstream areas, sand mining can lead to damage of bunds, which causes saline water intrusion into fields, leads to abandonment of fields. Mining lease should be preferably granted for those locations which have the least possibility of an impact on the environment and nearby habitation. Demarcation of the mining area with pillars and geo-referencing should be done before the start of mining to ensure that sand extraction is going on only within the permitted area. The permanent boundary pillars need to be erected after the identification of an area for deposition of mined sand outside the river bank at a safe location. The distance between boundary pillars on each side of the bank shall not be more than 100 m.

Sand and gravel shall not be allowed to be extracted where erosion may occur, such as at the concave bank. Sand and gravel shall not be extracted up to a distance of 1 kilometer (1 km) from major bridges and highways on both sides, or five times (5x) of the span (x) of a



bridge/public civil structure (including water intake points) on up-stream side and ten times (10x) the span of such bridge on the down-stream side, subjected to a minimum of 250 meters on the upstream side and 500 meters on the downstream side as per the guidelines issued by National Green Tribunal. The borrow area should preferably be located on the riverside of the proposed embankment because they get silted over time. For low embankment, less than 6 m in height, the borrow area should not be selected within 25 m from the toe/heel of the embankment. In the case of the higher embankment, the distance should not be less than 50 m. In order to obviate the development of flow parallels to the embankment, crossbars of width eight times the depth of borrow pits spaced 50 to 60-meter center-to-center should be left in the borrow pits.

River bed sand mining shall be restricted within the central 3/4th width of the river/rivulet or 7.5 meters (inward) from river banks but up to 10% of the width of the river. The mining area must be demarcated at a minimum distance of at least 50 m away from the river embankment on either side. The boundaries of the quarries may be fixed concerning the existing survey marks from the survey fields adjacent to the river. Sand quarrying lease area shall be demarcated on the ground with pucca stone or concrete pillars to show the present natural bed level, and the depth of mining allowed. The zone of river bed mining shall ensure that the objective to minimize the effects of riverbank erosion and consequential channel migration are achieved to the extent possible. In general, the area for removal of minerals shall not exceed 60% of the mine lease area, and the scientific report shall adequately support any deviation or relaxation in this regard.

8.2 Annual replenishment of sand

It is necessary to ascertain the rate of sand replenishment in the river bed. A regular replenishment study needs to be carried out to keep a balance between deposition and extraction. Replenishment would need to occur before subsequent extraction could take place. The concept of annual replenishment accounts for the episodic nature of sediment transport. For example, during monsoon, high stream flows result in a high contribution of sediment from hill slopes and tributaries, and during the dry periods, low stream flow led in little sediment supply. The use of monitoring data is essential in measuring when actual replenishment occurs.



The use of the concept of annual replenishment protects long-term channel stability as well as aquatic and riparian habitat by extracting a sustainable volume of sand. Sand mining must not be done on one site, but in alternating sites, to reduce over-extraction, which damages the environment beyond rehabilitation.

According to best practices, the distance between any two sand mining clusters should not be less than 2.5 km to reduce the cluster formation. Mining lease should be defined in such a way that the total area of the mining leases in a cluster should not be more than 10 Ha. After every year, a mandatory audit of the quantity extracted and quantity permitted along with the replenishment rate.

8.3 Maintenance of flood capacity

Flood capacity in the river should be maintained in areas where there are significant flood hazards to existing structures or infrastructure. Sand and gravel could be extracted from the downstream of the sand bar at river bends. Retaining the upstream one to two-thirds of the bar and riparian vegetation is accepted as a method to promote channel stability. Mining depth should be restricted to 3 meters, and distance from the bank should be $\frac{1}{4}$ th of river width and should not be less than 7.5 meters.

8.4 Seasonal ban on sand mining activity

There shall be no river bed mining operation allowed in the monsoon period. The period as defined by IMD Nagpur for each state shall be adhered to. The cumulative riverine impact of all mining activity should be reviewed on an annual basis to minimize long-term impacts and inequities in permits between adjacent mining operations.

8.5 Limiting sediment impact

Minimize activities that release fine sediment to the river. No washing, crushing, screening, stockpiling, or plant operations should occur at or below the streams "average high-water elevation," or the dominant discharge. These and similar activities have the potential to release fine sediments into the stream, providing habitat conditions harmful to local fish.

8.6 Prevention and mitigation of pollution

Proper entry and exit points for the movement of loading vehicles in and out of the sand mining sites shall be carefully located, taking into consideration the habitations/settlements



in the area. Construction of separate gravel roads for tipper trucks to reduce traffic congestion, accidents, as well as noise and air pollution, maybe consider. All the vehicles should be serviced regularly according to the existing Govt. guidelines to minimize noise and air pollution. The transportation route so selected should be verified by the Goa Government for its carrying capacity. Movement of heavy vehicles from public roads to pit sand, gravel, and river sand collection points need access roads. To prevent air pollution due to the dust during sand mining operations and safeguard the workforce in the sand mining and depot site, constant water sprinkling on the pathways and dust prone areas may be conducted. The sand loaded vehicles are to be covered with a tarpaulin before moving out of the quarries/depots. Plantation needs to be done with the consultation of the state forest department beside the sand transportation road to curtail the dust pollution.

The air and water quality should to be checked periodically to ensure that no pollution is caused due to sand transport operations. Safety gadgets such as earplugs, goggles, respiratory devices, luminescent vests may be provided to the workers at the sand mining site. First aid kit with all essentials shall be kept ready at all quarry/depot sites, in case of any emergency. Independent environmental audits need to be carried out at least once in a year for each mining site by reputed third party entity and report of such audit be placed in the public domain.

8.7 Protection and management of groundwater

To monitor the groundwater level during sand extraction operations, a network of existing wells may be established around the sand mining area, and new piezometers must be installed at all sand mining sites. The monitoring of groundwater quality in the vicinity (one Km radius from the sand mining site) shall be carried out once in two months. If, at any stage, it is observed that the groundwater table is getting depleted due to the mining activity, necessary corrective measures shall be carried out, which may include immediate stopping of the mining operation.

GSPCB has been monitoring water quality for Chapora and has not found significant change in water quality (Action Plan Report on River Chapora, 2019) wherein sand extraction was an on-going activity thus representing cumulative results. The report delineates several activities



for the rejuvenation of Chapora River and considering these proposed actions, the management aspects in this report have been proposed.

8.8 Soil management

Sand mining can cause weakening of soil in adjacent areas, which can lead to erosion of river banks. Sand mining destabilizes soil structure, river banks and often leaves isolated islands of trees; the subsequent flow will erode the banks and islands. Construction of soil conservation structures like river embankments/bundhs, extensive plantation drive, and mitigation of afforestation are some of the prerequisites to reduce soil erosion. Mangroves around the Chapora estuary are crucial habitats that serve as feeding and breeding ground to many ecologically and economically organisms like oysters and clams, crab, fishes. Mangroves also protect the river embankment and an excellent source of carbon sequestration. Hence, ultimate care needs to be taken to protect the mangrove habitat.

Soil salinity is a major global issue owing to its adverse impact on agricultural productivity and sustainability. It should be noted that no single approach can deliver a complete solution to fix/reclaim the soil salinity problem. Soil salinity undermines the resource by decreasing soil quality and can jeopardize the integrity of soil's self-regulatory capacity. Therefore, regular salinity mapping of the river bank may assist in taking necessary and timely actions to tackle the increased soil salinity and to avoid a further spread of soil salinity to a new area. Different methods, such as physical (levelling, salt scraping, tillage, subsoiling, and sanding); chemical (use of soil amendments such as elements, acids, gypsum to rectify soil sodicity problems and to improve soil health); hydrological (irrigation systems: Surface, flood, basin, drip, sprinkler, subsurface irrigation, leaching, and drainage), and biological (biosaline agriculture: Salt tolerant crops, and a serial biological concentration approach), may be employed to manage and prevent soil salinization.

8.9 Alternative resource generation

Promotion of manufactured sand, artificial sand, and alternative technologies in construction materials and processes are also required for reducing the dependence and demand on naturally occurring sand and gravel. Reusing and recycling of building material to reduce demand for river sand, pit sand, and gravel.



CHAPTER 9 ENVIRONMENTAL CONSERVATION AND MANAGEMENT PLAN

9.1 Background

Under the Environmental Impact Assessment notification of 2006 issued by the Ministry of Environment, Forests and Climate Change (MoEFCC), Govt. of India, which forms the legal basis for environmental impact assessment of development projects in India, mining of minerals with a lease area of less than 5 hectares did not require prior environmental impact assessment (EIA), until 2012 when the Supreme Court of India ruled that EIAs were mandatory for minor minerals, irrespective of the lease area. Pursuant to this, the MoEFCC, in response to the increase in the EIA applications requiring scrutiny devolved the process of environmental clearance to the district level. This included amending the EIA Notification of 2006 to create District-level authorities for screening and evaluating EIAs for mining of minor minerals, including sand. Since this directive was enacted, the National Green Tribunal and other courts have issued repeated directives to halt illegal sand mining, based on the environmental impacts arising from the activity. These have included a 2015 National Green Tribunal directive to ban sand mining in Madhya Pradesh during the monsoon, but the ban was lifted within a month (SANDRP, 2016). In 2016, the Union Ministry of Mines (Ministry of Mines, India, 2016) released a press release addressing the administrative responsibilities associated with legal and illegal sand mining in rivers, stating that:

- Sand mining is regulated at the state level under powers granted by the Mines and Minerals (Development and Regulation) Act, 1957 (MMDR Act).
- States can grant mineral concessions for minor minerals and enact regulations to control these activities.
- The same Act empowers state governments to frame rules to prevent illegal mining, transportation and storage of mineral sands, and therefore the control of illegal activities is under the legislative and administrative jurisdiction of the state governments.

9.2 Legal requirements

As per the provisions of the EIA Notification issued on 14th September 2006 and subsequent amendments till date:



All projects and activities are broadly categorized in to two categories – Category A and Category B. Category ‘A’ in the Schedule requires prior environmental clearance from the MoEFCC and Category ‘B’ in the Schedule, from the State/Union Territory Environment Impact Assessment Authority (SEIAA). An application seeking prior environmental clearance in all cases shall be made in the prescribed Form –I along with the pre-feasibility project report. “Scoping” refers to the process by which the Expert Appraisal Committee in the case of Category ‘A’ projects or activities, and State Level Expert Appraisal Committee in the case of Category ‘B1’ projects or activities, determine detailed and comprehensive Terms of Reference (TOR) for the preparation of an Environment Impact Assessment (EIA) Report in respect of the project or activity for which prior environmental clearance is sought. However, after the introduction of standard TOR for each sector amendment of EIA notification the issued on 10th April, 2016 it was stated that “Standard TOR developed by the Ministry in consultation with the sector specific Expert Appraisal Committees shall be the deemed approved TOR for the projects or activities. These standards TOR shall enable the Project Proponent to commence preparation of an Environment Impact Assessment Report after successful online submission and registration of the application. All Category ‘A’ and Category B1 projects or activities shall undertake Public Consultation. But now as per Gazette notification amendment S.O. 3977(E) dated on 14.08.2018 issued by the MoEFCC of India, the Public consultation are not required for B2 Sub-category under B category project.

Acts and legislations applicable for sand mining leases

- The Mines Act 1952
- The Mines and Mineral (development and Regulation) Act 1957
- Mines Rules 1955
- Mineral Concession Rules 1960
- Mineral Conservation and Development Rules 1988
- The Environment (Protection) Act, 1986
- EIA Notification (and amendments) 2006
- Wildlife Protection Act, 1972
- The Forest (Conservation) Act, 1980
- Water (Prevention and Control of Pollution) Act (and subsequent amendments) 1974



- The Water (Prevention & Control of Pollution) Rules 1975, Cess Act 1977 & Cess Rules 1978.
- Air (Prevention and Control of Pollution) Act (and subsequent amendments) 1981
- Solid Waste Management Rules, 2016
- CRZ notification 2019

9.3 Mining plan

A mining plan has to be prepared by each lease owner and accordingly the state/district level committee may issue the permits. The basic information required in the mining plan is given below which has to be prepared as per the guidelines of EIA Notification (2006).

- Location & Basic Information of the Mining Lease Area (quantities Haulage and Surface Transport Plan.
- Brief layout of mine working & layout mine faces.
- Demarcation of Mining Lease Area.
- Mining methodology (Should include tools and machinery used, energy requirement, water, manpower, waste [solid, liquid & air emissions]).
- Yearly schedule of sand mining.
- Facilities and amenities for workers (Porta-cabins, toilets, fuel, health check-up as per Mines Rule 1955).
- Compensatory plantation and CSR activities.

Sustainable Sand Mining Management Guidelines, (2016) and Enforcement & Monitoring Guidelines for Sand Mining (2020) by MoEFCC are being followed for formulating this management and subsequent monitoring plan. Sustainable sand mining guidelines in India have been developed by the Ministry of Environment Forest and Climate Change (MoEFCC, 2016). The guidelines are based on the premise that sand extraction from rivers is required for construction, but it is also required for maintaining river health. The Guidelines recommend the following process be followed and included:

- a) Identification of areas of deposition where mining can be allowed; and identification of areas of erosion and proximity to infrastructural structures and installations where mining should be prohibited. Use of satellite imagery for identifying areas of sand deposit and quantity is done.



- b) Calculation of annual rate of replenishment and allowing time for replenishment after mining in area.
- c) Identifying ways of scientific and systematic mining.
- d) Identifying measures for protection of environment and ecology.
- e) Determining measures for protection of bank erosion.
- f) A bench mark (BM) with respect to mean sea level (MSL) should be made essential to in mining channel reaches (MCR). Below which no mining shall be allowed.
- g) Identifying steps for conservation of mineral.
- h) Permanent gauging facilities (for discharge and sediment both) should be made compulsory for the sites having excessive mining in consultation with Central Water Commission or any competent State Agency.
- i) Implementing safeguards for checking illegal and indiscrete mining.

Sand extraction from riverbanks and river channels areas causes local disruptions which can be anticipated and prevented through appropriate studies. After various environmental problems of river sand mining in various physiographic zones, an EIA was carried out to suggest appropriate Environmental Management Plan (EMP) for regulating the mining activities on a sustainable basis. The river environments in all the three physiographic zones such as highlands, midlands and lowlands are deteriorated drastically due to illicit scooping of sand even from prohibited areas close to bridges and water intake structures. Hence, an attempt has been made to analyse the environmental impacts caused by river sand mining to identify and address the key environmental issues that results in from the activity. The main intention of the effort is to mitigate the negative impacts and enhance the positive ones.

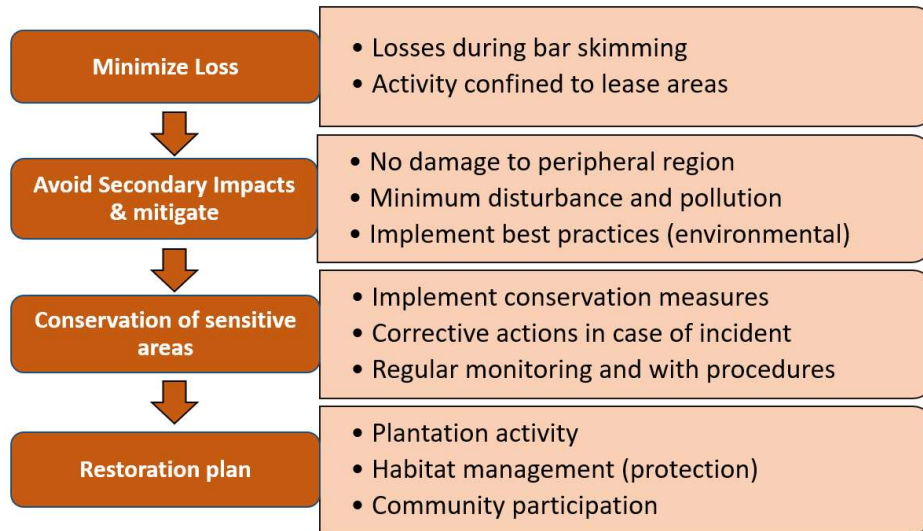


Figure 9.1. Schematic diagram of management of sand mining

9.4 Strategy for the management plan

Following requirements are suggested for defining a mechanism for monitoring of mining activities which will help in identification of mining which is operating either illegally or are violating the regulatory provisions. All precaution shall be taken to ensure that the water stream flows unhindered and process of natural river meandering doesn't get affected due to mining activity. Survey shall be carried out for identifying the stretches having habitation of freshwater turtles or turtle nesting zones. Similarly, stretches shall be identified for other species of significant importance to the river ecosystem. Such stretch with adequate buffer distance shall be declared as no-mining zone and no mining shall be permitted. The regulatory authority as defined for granting Environmental Clearance, while considering the application of issuance of ToR and/or EC for the adjacent block (to non-mining zone) of mining shall take due precaution and impose requisite conditions to safeguard the interest of such species of importance.

District administration shall provide detailed information on its website about the sand mines in its district for public information, with an objective to extend all information in public domain so that the citizens are aware of the mining activities and can also report to the district administration on any deviation observed. Appropriate feedback and its redressal mechanism shall also be made operational. The details shall include, but not limited to, lease area, geo-coordinates of lease area and mineable area, transport routes, permitted capacity, regulatory



conditions for operation including mining, environmental and social commitments etc. (Figure 9.1).

9.5 Management plans:

a) River bed mining recommendations

Permit mining volume based on measured annual replenishment in the first year following adoption of the management plan, a volume equal to the estimated annual replenishment could be extracted from the reach of channel. Replenishment (up to the elevation of the selected channel configuration) would need to occur before subsequent extraction could take place. The concept of annual replenishment accounts for the episodic nature of sediment transport. For example, during wet periods with high stream flows, and a high contribution of sediment from hill slopes and tributaries, monitoring data would show that sand and gravel bars are replenished quickly. During drought periods with low stream flow, and little sediment supply or transport, monitoring data would likely show that bars were replenished at a slower rate.

The use of monitoring data is essential in measuring when actual replenishment occurs. The use of the concept of annual replenishment protects long-term channel stability as well as aquatic and riparian habitat by extracting a volume sustainable by watershed processes.

B) Establish an absolute elevation below which no extraction may occur (minimum enveloped level or redline)

The absolute elevation below which no mining could occur or “redline” would be surveyed on a site-specific basis in order to avoid impacts to structures such as bridges and to avoid vegetation impacts associated with down-cutting due to excessive removal of sediment. An extraction site can be determined after setting the deposition level at 1 m above natural channel thalweg elevation, as determined by the survey approved by mine plan approving authority.

c) Limit river bed extraction methods to bar skimming

If mining is limited to the downstream end of the bar with a riparian buffer on both the channel and hill slope (or floodplain) side, bar skimming would minimise impacts. Other methods such as excavation of trenches or pools in the low flow channel lower the local base

level, and maximizes upstream (head cutting and incision) and downstream (widening and braiding) impacts.

d) Extraction of sand/ gravel from the downstream portion of the bar

Retaining the upstream one to two thirds of the bar and riparian vegetation while excavating from the downstream one to two third of the bar is accepted as a method to promote channel stability and protect the narrow width of the low flow channel necessary for aquatic life. Sand and gravel would be re-deposited in the excavated downstream one to two thirds of the bar (or downstream of the widest point of the bar) where an eddy would form during sediment transporting flows. In contrast, if excavation occurs on the entire bar after removing existing riparian vegetation, there is a greater potential for widening and braiding of the low flow channel.

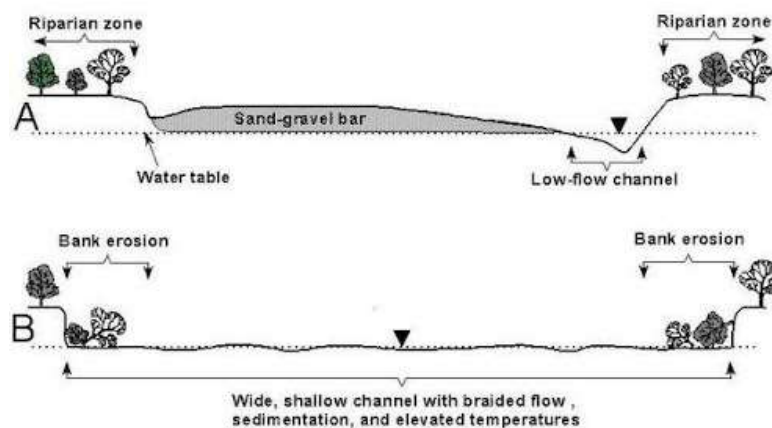


Figure 9.2. Diagram of channel cross sections showing

9.2.a typical sand-gravel bar in relation to the low-flow channel, riparian zone and water table, and (B) the wide shallow channel that results from unrestricted mining and that is characterized by bank erosion, braided flow, sedimentation, and increased water temperatures. (Source: http://threeissues.sdsu.edu/three_issues_sandminingfacts01.html).

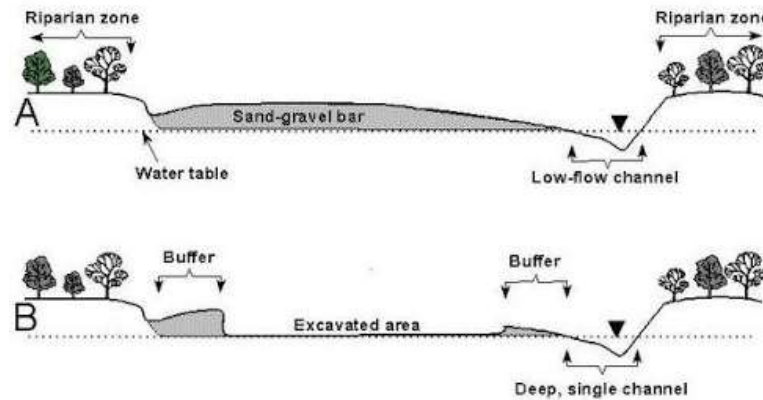


Figure 9.3. Diagram of channel cross sections showing

9.3(A) a typical sand-gravel bar in relation to the low-flow channel, riparian zone and water table, and (B) the protected deep, single channel and channel banks when mining is restricted within a buffer of designated width and above the water table. (Source: http://threeissues.sdsu.edu/three_issues_sandminingfacts01.html).

e) Concentrate activities to minimise disturbance

River bed extraction activities should be concentrated or localised to a few bars rather than spread out over many bars. This localisation of extraction will minimise the area of disturbance of upstream and downstream effects. Skimming decreases habitat and species diversity – these effects should not be expanded over a large portion of the area.

f) Review cumulative effects of sand and gravel extraction

The cumulative impact of all mining proposals should be reviewed on an annual basis to determine if cumulative riverine effects or effects to the estuary are likely.

g) Maintain flood capacity

Flood capacity in the river should be maintained in areas where there are significant flood hazards to existing structures or infrastructure.

h) Establish a long-term monitoring program

Monitoring of changes in bed elevation and channel morphology, and aquatic and riparian habitat upstream and downstream of the extraction would identify any impacts of sand and gravel extraction to biological resources. Long-term data collected over a period of decades as sand and gravel extraction will provide data to be used in determining trends.



l) Minimise activities that release fine sediment to the river

No washing, crushing, screening, stockpiling, or plant operations should occur at or below the streams average high water elevation, or the dominant discharge. These and similar activities have the potential to release fine sediments into the stream, providing habitat conditions harmful to local fish.

j) Retain vegetation buffer at edge of water and against river bank

Riparian vegetation performs several functions essential to the proper maintenance of geomorphic and biological processes in rivers. It shields river banks and bars from erosion. Additionally, riparian vegetation, including roots and downed trees, serves as cover for fish, provides food source, works as a filter against sediment inputs, and aids in nutrient cycling. More broadly, the riparian zone is necessary to the integrity of the ecosystem providing habitat for invertebrates, birds and other wildlife (Figure 11.2 & Figure 11. 3).

k) Seasonal ban in sand mining

The River bed mining should only be allowed during the dry season. No River bed mining should be permitted during rainy season.

l) An annual status and trends report

This report should review permitted extraction quantities in light of results of the monitoring program, or as improved estimates of replenishment become available. The report should document changes in bed elevation, channel morphology, and aquatic and riparian habitat. The report should also include a record of extraction volumes permitted, and excavation location. Finally, recommendations for reclamation, if needed should be documented.

m) Prevention and management of illegal mining

Prevention and mitigation to illegal mining can be achieved through close monitoring, cancellation of mining license of violators, imposing heavy penalties including long-term jail for mining on sensitive areas, and confiscation of mining machinery and vehicles. Department of Mines, law and order authorities need to restrict some areas for example, riverbanks, near schools, clinics, or residential areas. Only miners with licenses should be allowed into mining areas and stop illegal miners through tight security; additionally, 24x7 security to be employed to apprehend illegal miners daily. Night surveillance by night-vision drones may be employed



to control illegal mining incidents. The committees formed to guard and monitor mining should control and restrict the number of truckloads per day. The districts/state sharing the boundary shall constitute the combined task force for monitoring of mined materials, mining activity.

n) Management of infrastructure

Temporary access roads or Katcha roads shall be formed between the banks of the river and the mining area with locally available bio-degradable materials such as sugarcane waste, hay, etc. The preliminary works such as the construction of temporary sheds, bio-toilets, drilling of bore wells, waste management facilities need to be developed before mining operations. CCTV cameras need to be installed at the entry and exit points. Cameras may be installed at all quarries/depots to monitor illegality if any is taking place. All such points should have 24X7 CCTV coverage of the footage of which should be made available to the district administration. The entry/exit points should have boom barriers which will record the vehicles entering and exiting the plot to reduce unrecorded dispatch.

o) Management of pollution

Proper entry and exit points for the movement of loading vehicles in and out of the sand mining sites shall be carefully located, taking into consideration the habitations/settlements in the area. Construction of separate gravel roads for tipper trucks to reduce traffic congestion, accidents, as well as noise and air pollution, maybe consider. All the vehicles should be serviced regularly to fulfil the existing legal framework to minimize noise and air pollution. The transportation route so selected should be verified by the Goa Government for its carrying capacity. Movement of heavy vehicles from public roads to pit sand, gravel, and river sand collection points need access roads. To prevent air pollution due to the dust during sand mining operations and safeguard the workforce in the sand mining and depot site, constant water sprinkling on the pathways and dust prone areas may be conducted. The sand loaded vehicles are to be covered with a tarpaulin before moving out of the quarries/depots. Plantation needs to be done with the consultation of the state forest department beside the sand transportation road to curtail the dust pollution.

The air and water quality may be checked periodically to ensure that no pollution is caused due to sand quarrying operations. Safety gadgets such as earplugs, goggles, respiratory



devices, luminescent vests may be provided to the workers at the sand quarry site. First aid kit with all essentials shall be kept ready at all quarry/depot site, in case of any emergency. Independent labour camp and environmental and its need to be carried out at least once in a year for each mining site by reputed third party entity and report of such audit be placed in the public domain.

9.6 Development of green belts and Nursery

This helps in prevention of dust and screening noise, maintaining ecological balance, increasing aesthetic value, plantation to be carried out on both sides of the roads/river, saplings will be planted with recommended interval. Channel erosion often occurs on riverbanks with no or minimum vegetation cover; hence, plantation is prerequisite to improvement of river banks.

- Development of nursery can help in providing sapling for the region. It is recommended to cultivate nursery (for grasses, palms and other native tree including mangrove species) that are helpful in river bank protection and erosion control.
- A plantation plan developed by a plant ecologist familiar with the flora of the river for areas (in consultation with the Forest Dept.).
- River bank should be stabilized by means of compaction and then planting with vegetation.
- Any access routes without vegetation, especially if they are not beneficial to the local community should be ploughed and replanted with native species.
- Plantation along the riverbanks with no or minimal vegetation need to be conducted, irrespective of signs of erosion or not (ensure that species selected are indigenous).

9.7 Mangrove management and conservation

In Chapora, the mangroves are well represented in the lower stretches of the river. Most of the mangroves are well grown and there has been a steady growth in the mangrove cover along this river. As shown in the (Figure 9.4 A&B) many mangrove trees have developed buttresses, which is the sign of loose soft sediment and/or low nutrient regimes. There are

also indications of mangrove cutting (Figure 9.4 C&D) in some parts of the estuary. Considering these threats, it is essential to protect the mangroves areas that are degraded and which are vulnerable in terms of direct and indirect impacts.

There is no requirement of mangrove plantation in the study area but management of the existing mangrove vegetation is essential. The areas which are intruded by saline water need protection and the mudflats need to be maintained. Areas with newly recruited mangrove saplings can be blocked by restricting the tidal influx so that land use change can be avoided (from paddy fields to mangrove).

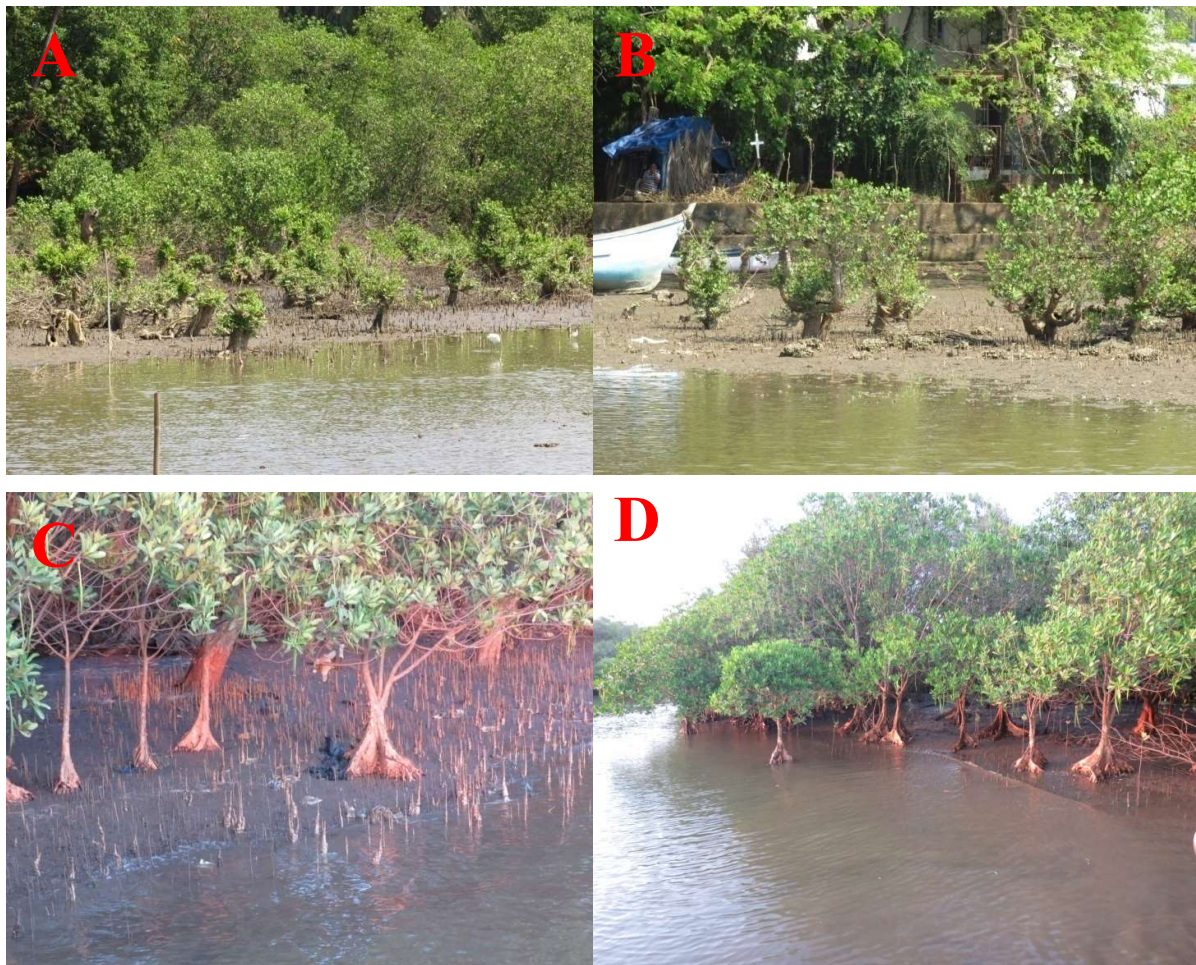


Figure 9.4: Exposed mangrove cutting and root buttresses of Chapora Estuary.



9.8 Embankment protection and restoration

This river is comparatively small and traditionally managed by construction of embankments so that floodplain can be used for paddy cultivation. The region is also represented by coconut plantation. Embankments have been constructed mostly by mud, silt and soil with protection of laterite bricks/boulders as lining between the estuarine river and land. Regular maintenance of embankments is an essential activity and failure to maintain results in saline water intrusion towards the landward side and turns the paddy fields into saline marshy areas rendering them uncultivable fallow lands.

- One saline surge can destroy the paddy fields and render them fallow lands as well as it can damage the houses; thus, it is imperative to protect the riverbank sensitivities constantly. In recent times there are few stretches of the river where construction of concrete embankments is completed.
- The areas adjacent to the river with paddy field and villages/ houses will require safeguarding from saline intrusion and flooding. Bunds have to be made with traditional means and should ensure maintenance. The authorities may also consider new methods that are innovative and sustainable for protection of bunds, restrict erosion and arrest saline intrusion.
- Some of the areas do not have embankments (mostly in the upstream areas of the river) and eroding banks area visible phenomenon (Figure 11.2). Such areas require protection, as these areas have soft sedimentary strata that can be easily washed away by stronger riverine currents.
- The vulnerable (soft sediment bank walls of the river) areas should be protected and no sand extraction shall be permissible in these regions.
- In the down-streams of the river (Figure 11.5), embankments are regularly maintained to protect the paddy field, funds and team for maintaining these embanks is essential.



Figure 9.5: Constriction of protective wall/embankment opposite Sal water treatment plant.

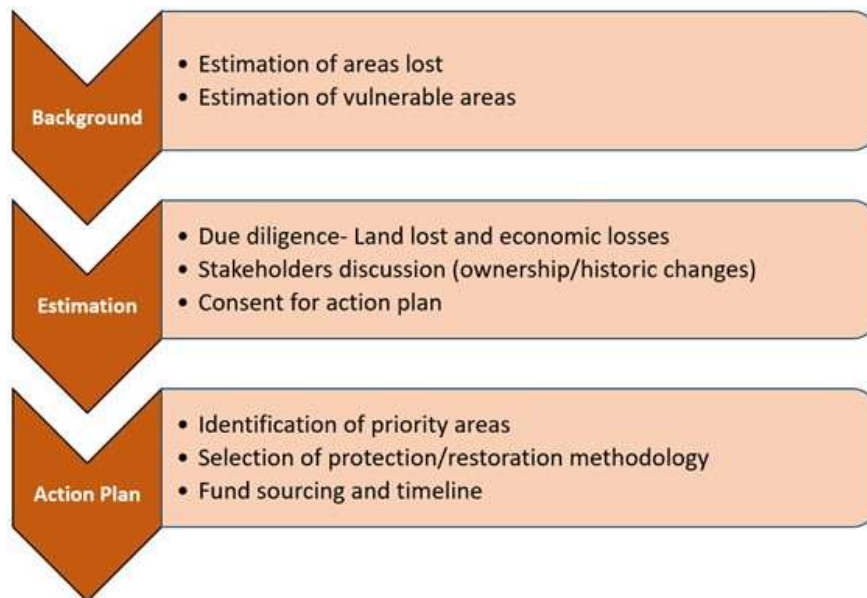


Figure 9.6: Schematic diagram of river bank protection and restoration plan



9.9 Biodiversity conservation & management plan

Several habitats in the study area are important habitats for several species of conservation importance. It is important to protect not only the species but the resources and habitats on which they are dependent. No doubt the proposed activities are deleterious to the ecosystem, no matter how sustainable we make it. Thus to compensate the negative impacts, proactive conservation efforts have to be undertaken to minimize the impacts and to further enhance biodiversity, improve conservation and add ecosystem services.

Being an area of edible natural resources, necessary protection should be provided to promote the traditional fishing by public consultations and if necessary through environmental protections.

Objectives

- To minimize direct and indirect disturbance to marine flora and fauna other than within the immediate works areas.
- To ensure turbid plumes from the works and re-suspension of material from the disposal site do not impact the long term ecological values and integrity of the adjacent benthic assemblages and important faunal groups.
- To reduce the impacts to the intertidal sensitive habitats to the maximum extent possible.

9.9.1 Conservation plan for fauna

The estuarine region is a known habitat (based on secondary information) for Otters, Crocodiles, marine turtles (Olive Ridley's) and Dolphins. Sea turtles are seen in the open waters and occasionally in the estuarine areas whereas crocodiles are found near the mangrove forests and inland marshy areas. The otters inhabit the mangrove areas and frequent the river banks and sub-tidal estuarine waters for foraging. These species require minimal human disturbance therefore they thrive well if given protection and their habitat is well conserved. Several birds visit the river and adjoining habitats for foraging as well as nesting. There are few species that are long distant migrants (especially waders) as well as local migrants. Mangroves and banks of the rivers are used as nesting sites by several species.

Following measures have to be followed to ensure the conservation of marine fauna and their habitat:



- An on-site expert (observer) has to be deployed for periodic monitoring of the important species in the entire stretch of the river which is being carried out in the region and the same activity can be extended to the proposed areas
- Vessel movement has to be regulated. Vessel movement has to be immediately halted at the sighting of any marine mammals/reptile in the active working zone. The excavation of sand as well has to halt until the animal leaves the area.
- Monitoring and conservation initiatives at Morjim beach by the State Forest Department are to be assisted and added measures and actions for conservation of Turtle nesting sites are to be supported.
- Management of marine litter, garbage and plastic is one of the important aspects with respect to each active mining zone.
- Noise levels, air pollution and sewage discharge has to be kept at minimum and have to be within limits as prescribed by laws.
- Capture, trade or killing of any scheduled species has to be reported and accordingly non-conformance action has to be initiated by the team/committee.

9.9.2 Conservation & natural resource utilization

The estuarine region and river bed harbour important benthic faunal and floral diversity. In order to conserve these habitats, they are needed to be monitored regularly as they are dynamic habitat and are constantly exposed to anthropogenic pressures. Hence proper management plan for solid waste and oil pollution is needed to be followed and precautionary measures for any incident should be in place. The entire hard substratum within the study area is a good site for the growth of green mussel (*P. viridis*) and oyster (*Crassostrea madrasensis* and *C. gigas*). However, in the recent times (information based on interaction with local stakeholders) due to various reasons, the annual stock of edible mussels showed great fluctuations and the population in recent times have decline drastically. Shellfish in the study area are exploited due to its high price as a food source. Due to frequent localized extraction, and no scope of growth, shellfish size has decreased over the years and at many places, there population has been replaced by other species. Restoration and sustainable use of such species helps in good ecological and economic gains. Several species of clams of commercial importance occur in the study area. These clams mostly inhabit the mudflats/sandflats and preferably collected during the low tide. Species of *Paphia*



malabarica, *Paphia textile*, *Meretrix meretrix*, *Meretrix astata*, *Villorita ceprenoides*, *Anadra* sp. And *Polymesoda erosa* are found in the mudflats, sand flats and mangrove sediments in the study area. According to local artisanal fisherman, these species have shown a drastic reduction in the population and their revival is very important. The team/committee appointed for this plan can further carry out these activities and should make village level teams for monitoring and implementation of all the activities. Following practices have to be followed for sustainable utilization of these resources:

- Harvest of the natural population requires regulation and regular restoration. It is necessary to block certain areas as no harvest zone, so as to ensure their population to replenish. Integrated sustainable aquaculture as given below (sub-sections of this plan) is to be implemented to harvest and rejuvenate these ecologically and economically important species.
- Quota system should be implemented by each village so that depletion of natural stock can be avoided.
- Cleaning programs, by participatory approach for sustainable resource utilization from mudflats, a rocky shore is essential.
- There should be size restriction for each species wherein, care should be taken to harvest natural populations so that they attained reproductive size.
- The empty shells after extraction of edible flesh should be placed back in the same habitat as they serve as recruitment substratum for new spat. The cues from the dead shells attract larvae for settlement that aids in avoiding succession for establishment of another species as well.
- Conservation of habitat for the above mentioned commercially important species will also aid in conserving other species that are not commercially important but are ecologically very vital for sustenance of healthy and functional ecosystem.

9.9.3 Community participation

The existing mangrove management strategy is a combination of conservation through statutory compliance, community awareness and sustainable utilisation of natural resources through cooperative management. In 1952, Government of India (GoI) formulated National Forest Policy, which classified Indian forests into four classes, viz. i) Protected forests, ii) National forests, iii) Village forests and iv) Tree lands. Forest Conservation Act of 1980



encourages reasonable use of natural forest resources while National Forest Policy of 1988 invites community participation for the regeneration and management of forest through Joint Forest Management (JFM) program. This gives rights to local inhabitants to exploit forest resources to some extent like collection of fuel wood, fodder, fish, shrimp, honey and wax and thus provided mutual benefit to community and forest department. Presently, almost all mangrove habitats of India enjoy legal protection under Wildlife Protection Act of 1972 and Forest Conservation Act of 1980. Gadgil (2002) lists the following 6 factors as important considerations in a participatory assessment program;

- Motivating local people to revive and build on their traditional conservation practices;
- Establishing a positive relationship between local communities and government agencies;
- Identifying and establishing a system of positive incentives for local communities to adopt conservation management;
- Enhancing elements of good governance such as efficiency, participation and transparency;
- Incorporating local information into the formal system of scientific knowledge so as to make it richer and more immediately relevant; and
- Ensuring that folk knowledge of conservation management and sustainable resource use is preserved and at the same time giving recognition to the validity of such knowledge.

Based on the above concepts it is imperative to carry out the conservation, restoration and monitoring with community participation. Local village committee/ Biodiversity Management Committees (BMC already exist) to carry out the responsibilities of the restoration and conservation plan. These committees adhere to the people's biodiversity register (PBRs) and can form self-help groups (SHGs). A technical team of experts is usually attached for the smooth working and guidance from subject experts. These procedures will help to develop responsibility and equitable sharing of resources as well as conservation of the area (Goa State Biodiversity Board [GSBB] carries out these responsibilities regularly for the entire state).

Below mentioned techniques and methods are can be mostly financed by several available governmental schemes. There are several schemes which provide training, start- up grant and



technical guidance to carry out sustainable integrated fishery and cultivation. The schemes are fully or partially funded, wherein the role of technical team and experts is important to bridge the gap between the involved stakeholders. The financial support in case of a prerequisite can be taken up by the respective project proponent as part of their CSR.

9.10 Floodplain management (saline marshlands)

The areas with saline intrusion have been converted to saline marshlands followed by mangroves and many areas are at different stages of progression towards these habitats. If these areas are unattended, not maintained or taken care of, they will be ultimately succeeded by mangroves. Once mangroves are established, the spread to adjoining areas is usual as they tend to accumulate more sediment and concurrently the embankments are penetrated by salinity due to natural deterioration of embankments. There are various reasons for the deterioration of embankments such as sea level rise, high tide surges, other extreme events and floods. Overall, over the time to come, if protections by embankments are penetrated by saline water more floodplain areas will be dominated by salinity.

Considering the present status of this river and the adjoining land use in the floodplain areas there is already intrusion of salinity, and it is important to manage these areas (depicted in Fig.9.5). Restoration of bunds should be undertaken on priority basis along with management and maintenance of sluice gates. Following activities are proposed for sustainable use of existing lands;

- There are developed varieties of saline resistant rice species. Such species can be recommended for cultivation in areas of saline intrusion.
- Various state level schemes and subsidies are available for carrying out the paddy cultivation which can be tapped via the committee members of this plan.
- Traditionally, paddy cultivation has been a community activity and the same can be extended to manage the saline marshland and its cultivation.
- Village level SHGs, BMCs, Farmer's group can be formed/ a sub-committee including members of concern state government officials and technical expertise as well for the smooth running of the schemes.

These areas which do not have mangroves can be utilized for sustainable aquaculture practices.



9.11 Development of sustainable integrated aquaculture

Several options are suitable for the rivers in Goa which have estuarine region with mangroves and mudflats, thus the suggestions given below are added after consultation with State Fisheries Dept., Goa and ICAR, Old Goa.

Integrated aquaculture is a technique of sustainable aquaculture which includes raising fish with combination of rice, pigs, and ducks as well as poultry which helps in rising family income. Since animal waste make good fertilizer it can save upto approximately 60 percent of the cost of fish farming which goes for feed. This technique includes different types of farming: paddy cum fish farming, composite culture and polyculture. Several species are available that give good economic gains and if a compatible mix species culture can be carried it reduces the risk of losses. The team for the plan can suggest the combination of species and the methods accordingly considering the site, locations, area, tidal regime, physico-chemical parameters and economics.

The important estuarine fish species caught are *Mugil cephalus*, *Osteomugil cunnesius*, *Etroplus suratensis*, *Lates calcarifer*, *Chanos chanos*, *Leptomelanosoma indicum*, *Eleutheronema tetradactylum*, *Eubleekeria splendens*, *E. thoracata*, *N. blochii*, *Sillago sihama*, *Nematalosanus*, *Ilisha toil*, *Escualosathoracata*, *Leiognathusbrevirostris*, *Thryssamystax*, *Alepeskleinii*, *Tenualosailisha*, *Harpadonnehereus*, *Pamapama*, *Setipinnasp*, *Coiliadussumieri*, *Msytusgulio* etc. The major penaeid species caught in the estuary are *Fenneropenaesmerguiensis*, *F. indicus*, *Marsupenaeusjaponicus*, *Metapenaeusaffinis*, *M. brevicornis*, *M. dobsonii*, *Penaeussemisulcatus*, *M. monoceros* and *Parapenaeopsisstylifera*. The major crab resources are *Scylla serrata*, *S. tranquebarica*, *Portunuspelagicus*, *P. sanguinolentus*, *Charybdis feriatus*, *C. natator* and *C. lucifera*. The mollusks such as clams (*Villoritacyprinoides*, *Paphiamalabarica*, *Polymesodasp.*, *Tegillarcagranosa*, *Marcia opima*, *Meretrixmeretriand* *M. casta*) oysters (*Crassostreamadrasensis* and *Saccostreacucullata*) and mussels (*Pernaviridis* and *Pernaindica*) are also harvested from the estuarine habitats. From the available statistics, the approximate fish production from the east coast and west coast estuaries are 30,000 and 20,000 tonnes respectively. However, there is always a scope revising, reclassifying, and adding the estuarine systems in order to formulate an estuarine monitoring network along the Indian coast. Therefore, we would be able to understand the



major gaps in the fisheries data of estuaries, which would enable us to focus on these ecosystems to explore its diversity, fish biomass, and landing patterns.

Development of shrimp farming from a traditional activity to a highly commercial farming enterprise in a span of about one decade has been one of the most spectacular achievements of aquaculture in India. The government of India enacted the Coastal Aquaculture Authority Act, 2005, enabling the establishment of the Coastal Aquaculture Authority for enforcing proper regulatory measures for sustainable eco-friendly aquaculture. The Act encompasses all forms of aquaculture to be practiced in saline or brackish water in the coastal areas.

The brackish water aquaculture can also further go ahead with the means of diversification of species used in the farming practices. Seabass, *Lates calcarifer* is a fast growing, high valued carnivorous fish ideal for Indian conditions. The technologies are available for seed production and grow out culture. However, the demand for seed needs to be met through the development of more hatcheries along the coastal states. The total area under seabass farming is 2500 ha with a total production of 5000 tonnes. At present 30, 000 farmers are employed in this farming practice and project a huge potential for the future. The other candidate species for the brackishwater aquaculture are Milkfish (*Chanos chanos*), Pearlsport (*Etroplussuratensis*), Mud crab (*Scylla serrata*), and Grey mullet (*Mugil cephalus*), Red snapper (*Lutjanus argentimaculatus*), and Silver pompano (*Trachinotus blochii*) etc.

Apart from the species diversification, the diversification of aquaculture systems is essential to provide access to a large number of farmers to support their livelihood through brackishwater aquaculture. Cage culture of finfish in brackish waters provides a great opportunity for farmers with access to open waters to adopt aquaculture as a livelihood option. However, the availability of the quality seed and feed are the major hurdles that need to be addressed through indigenous seed production systems to address the demand.

Goa state encompasses huge potential for fishery activities with a coastline of 105 km, continental shelf area of 10 million ha, estuarine area of 13,157 ha (covering 8 estuaries), brackishwater area of 3500 ha, Khazan land of 18,000 ha, 555 km length of rivers, 100 ha freshwater ponds, 3250 ha of reservoirs and mine reject pits of 200 ha. The fish production of state currently stands as 1.05 lakh tonnes of which 1 lakh comes from marine and 5000 comes from inland fisheries (95% from estuarine and brackishwater resources). On the other hand, inland fish production is gradually decreasing and there is ample scope for coastal



aquaculture for further improvement in production on account of greater demand. The estuarine area of Goa is not utilised for development of coastal aquaculture. There are several culture systems that can be practiced in the estuaries of Goa, which has higher productivity and abundant natural seed resources. The government of Goa has introduced various schemes to encourage development of aquaculture in the state (Table 9.1).

Table 9.1: Schemes for aquaculture in Goa (Source: Fishery department)

1.	Financial Assistance to Brackish Water Aquaculture Pond	A. <u>Financial Assistance for Construction and Renovation of Farms</u> 25% subsidy limited to Rs.2.00 lakh per ha of which Rs.45, 000/- per ha will be the Central Share. Up to 2 ha after 5 years. B. <u>Financial Assistance for purchase of farming equipments:</u> 50% subsidy limited to Rs.1.00 lakh per ha. Up to 2 ha after 5 years. C. <u>Financial Assistance for purchase of feed:</u> 25% subsidy of the cost of feed limited to Rs. 30000/- per crop per ha for 2 crops in a yr. Eligible every year.
2.	Financial Assistance for setting up of Crab farming Unit in Goa	A. <u>Financial Assistance for setting up of the crab culture unit:</u> 25% of the actually cost limited to Rs.1,50,000/- per ha. Farmer will be eligible to 2 ha. B. <u>Financial Assistance for purchase of seed and feed:</u> 50% of the actual cost limited to Rs.75, 000/- ha. Limited to 2ha per yr.



3.	Financial Assistance to Freshwater Aquaculture farm	A. <u>Financial Assistance for Construction and Renovation of Farm:</u> 25% subsidy limited to Rs. 2.00Lakh per ha. Eligible every after 5 yr. B. <u>Financial Assistance for purchase of seed and feed:</u> 25% subsidy limited to Rs.50,000/- per ha. Limited to 2 ha. Eligible on seed and feed once in every year. C. <u>Financial Assistance for purchase of Farm Equipments:</u> 50% limited to Rs. 60,000/- per ha. Eligible after every 5 years.
4.	Financial Assistance to Mussel Culture and Oyster Farming in Goa	A. <u>Setting up of unit in estuarine waters:</u> 50% subsidy limited to Rs.25,000 per unit, maximum for 2 units. Each unit in the estuarine water will be of size 4 mtrs X 4 mtrs. B. <u>Setting up of unit in open sea</u> 50% limited to Rs.40,000 per unit, max for 2 units. Each unit in the open sea will be of size 6 mtrs X 6 mtrs.
5.	Financial Assistance for setting up of Ornamental Fish Unit in Goa	A. For setting up of Breeding unit-50% of the actual cost limited to Rs.1, 50,000/-. B. For setting up of Rearing unit-50% of the actual cost limited to Rs.1, 50,000/-. C. For setting up of Rearing unit and Breeding unit- 50% of the actual cost limited to Rs.2,50,000/-.



Following are some of the known aquaculture species that are well suitable for considering as small scale business model.

9.11.1. Paddy cum fish farming (freshwater)

This system explained here produces mix species of fishes with paddy. Process of culture starts from growing two crops of paddy; the one which is tall variety and the other is high yielding variety in wet season and dry season respectively with single crop of fish. In freshwater, Rohu (*Labeorohita*), Catla (*Catla catla*), Mrigal (*Cirrhinus cirrhosis*), and fast growing species like Silver carp (*Hypophthalmichthys molitrix*), Grass carp (*Ctenopharyngodon idella*) and Common carp (*Cyprinu scarpio*) were used as pelagic, mid pelagic and benthic fishes. Prawns also grow well on paddy fish culture plots. Optimum stocking density that is usually practiced in case of carps is 6,000- 20,000 number of seeds per hectare.

Selection of site: Water holding capacity of selected plot should be good enough. Clay-loamy soils are suitable for paddy- fish culture. Low laying area with high rainfall is suitable for culture. Either side of the central line dug deep to act as main supply or drain canal. Each plot is bordered with bundhs with 0.3m height and 0.3m width. Dike or bundh is provided by inlet and outlet made up of bamboo shoots. These are placed in the middle and fitted with screens to avoid entry of predators as well as escape of cultured fishes.

Culture of paddy-fish together: Generally this technique is practiced in moderate or low paddy fields where water source exists for 4-5 months naturally. Carps or other fishes like Tilapia are cultivated along with the rice.

Fish culture after harvesting rice: In this technique, fishes are stoked after the harvesting of rice crops. This will provide 6-7 months of rearing fishes.

11.11.2. Oyster culture

Some Oysters are edible and its culture is widely practicing in India. Four species are commercially cultivated in India. They are: *Crassostrea madrasensis*, *Crassostrea gryphoides*, *Crassostrea rivularis*, *Saccostrea cuculata*.

Site selection: Site must have good water quality, open sea from strong wave action and salinity range should be 25-31ppt. Avoid sites prone to toxic algal bloom.

Seed production: Seed requirement for culture is met either from wild or from hatcheries.



Spat fall prediction: Gonadal maturity stage helps in spat fall prediction. When 70% of female are with ripe gonad spat collectors used to collect the spat. If they are placed much earlier or after the spat, fall they get silted or fouled and make them unsuitable for spat settlement.

Intensive culture: Containerized production of oysters is referred in intensive culture. Containerized production includes floats, bags, rafts, long line system, racks etc. for predator protection. This system has to face impacts from storms, fouling organisms etc. Therefore, selection of site should be based on water quality, wave action and predation level. This type of culture is more expensive as it requires more labour for gear and product maintenance.

Extensive culture: This culture refers to spat on shell or clutched production. Oyster larvae from hatchery are set on clean oyster shell and planted directly on the bottom and grow out in clusters. This method is not expensive as the other one but in this methods mortality rates are higher as there is very less maintenance.

Feeding: Oysters feed on algae especially *Isochrysisgalbana* and *Chaetocero* ssp.

Farming methods: Seed oysters could be grown either on bottom or off bottom culture methods. Rate of production depends on culture methods. Bottom should be firm and free from predators and silting. There are different types of culture methods: Rack and Tray Method, Stake Method and Rack and String Method.

Rack and tray method: The young oysters are scrapped from the tiles and transferred to box type cages and covered with synthetic twine. After two months of rearing by suspending cages from racks, the grown oysters are transferred to rectangular trays. 20 trays each of 200 oysters are reared on rack and at the end of the year oysters attain length from 78mm-105mm. The approximate production rate in this method of culture is 120t/ha/year.

Stake method: Stake is a support used to keep spat on spat collector above bottom. It may be Casuarina or eucalyptus pole of 1.50m. To protect spat from predation pole can be covered with piece of fabric. Production rate may be 20t/ha/year.

Rack and string method: A string can hold six shells valves holding 80-100 spats and the strings are enclosed in a bag. These suspended from racks should keep in calm and good water movement site. After 2 months of rearing the bags are removed and the oysters are transferred to oyster farm. In this method the production rate is 80t/ha/year.



Threats: Pest and predators can cause considerable damage. Common predators are barnacles, serpulids, anemones, sponges and gastropods.

Harvesting: Harvesting season depends on spawning season which is March-April and August-September. Harvested oysters go through depuration which is cleaning and reducing the bacterial load on shellfish and shucking which is the process of removing meat from depurated oysters. Meats of the oysters are edible and shells are used in spar settling and manufacturing of calcium, lime etc.

11.11.3. Mussel culture

India has a long history of mussel farming that dates back to the 13th century. They are considered as popularly eaten and delicious food by the people of West Cost. The main producers are India, China, Korea, Spain, France, New Zealand and Netherlands. Three different types of mussels are cultivated in India. They are: *Perna viridis* (Blue green mussel), *Mytilus edulis* (Blue mussel), *Modiolusmetacalfie* (Brown mussel).

Site selection: Estuarine areas which are free from strong wave actions may be selected. Clear water with high plankton production is ideal for mussels. Depth of culture should be 2m and salinity should be 30-35 ppt. and should be free from industrial pollution.

Seed collection: Healthy seeds from natural habitat are collected. Seeds are healthier if they are from submerged tidal area. Size of the seed should be 20-25mm. Nylon rope or coir rope is used for seeding. Cotton cloth or cheap net is used to cover seeds on the rope. After placing the rope over the seed, the net is tightly stitched in such a way that seeds spread uniformly around the rope.

Culture methods: There are 3 main types of culture methods in mussels.

A. Deep Water Culture

- Raft Culture
- Long Line Culture

B. Intertidal and Shallow Water Culture

- Rack Culture
 - Hanging Method
 - Stake Method
 - Tray Method



- Buochot Method
- Wigwarm Method

C. Bottom Culture

Raft culture: The depth of the site may vary from 5-10m and rafts measured 5×5m or 8×8m. Teakwood, Casuarina and bamboo shoots are used to make poles in raft construction. Empty oil drums are used as floats. Seeds of 2.6-2.8mm length are seeded on coir or rope. Depending on the depth length of the rope varies. Ropes are spaced 0.6-1m apart. Average growth rate is 9-11mm/month and can be harvest in 5-6 months. Production rate in this type of culture is high.

Long line culture: Long lines are long ropes anchored at each end supported by plastic barrels. Depth may be 10-15m. It can withstand severe climatic conditions. The rope is 60 m long with 20-24m thickness anchored at both the ends with 150kg concrete and barrels are fixed at 3m intervals. A long line unit of 60×60m rope can accommodate 12 horizontal ropes and 900-1000 seeded ropes. The production rate was 15.32kg/net bag/5 months.

Rack culture: Fixed structures are constructed in the waters at the depth of 3 m. Bamboo or Casuarina pole are driven at the bottom at 1-2m interval. Wooden frame built on ropes used to suspend seeded bags. Once the mussel seeds are placed the netting is wrapped and both the ends are stitched with cotton twines. In about six months mussels reach around 65-77mm length. The production rate is approximately 33.5kg/net bag/5 months.

Hanging method: Nylon ropes are threaded with coco fibres supported by empty oyster shells to collect spat. Piece of stone is attached at the end of the rope to prevent surface floating.

Stake method: Bamboo pole of 4-6 m length are staked at the bottom at the depth of 3 m. collected spats are allowed to grow for 6 months until they reach marketable size. Around 2000-3000 seeds are attached to 1 m stake below low water level.

Tray culture: Tray culture is limited to detached clusters of mussels. Bamboo or metal trays are used. They are either hang between pole of hanging or stake methods.

Bouchot culture: They are also called Pole Culture. Poles which are used are big branches of oak tree around 4-6 m which are staked 0.7m apart on soft, muddy bottom of intertidal zones. Mussel seeds are collected on coco fibers and are attached to oak branches in spiral fashion



until they grow marketable size. Production was 14kg/pole of 15.7mm average length mussels.

Bottom culture: This method is widely practiced all over the world. Mussels are grown directly on the bottom. Firm bottom is required with adequate tidal flow with silt deposition and provide sufficient oxygen. If the natural ground is unsatisfactory then those seeds can be transferred to private farming ground. Natural conditions control quality and quantity of food as well as water flow. This type of culture requires minimum investment however it is prone to heavy predation such as oyster drills, crabs, starfish etc.

Harvesting: Harvesting takes place after 6 months and meats as well as shells are used in various fields.

9.11.4. Clam culture

Clams, as a general term, can be used to describe any bivalve mollusc species which buries itself in the sediment. There are numerous commercially important clam species which are cultivated in India. Some of the species are given below: *Villoritacyprinoides*, *Paphiamalabarica*, *Meritrixcasta*, and *Anadaragranosa*.

Site selection: Intertidal and sub-littoral locations are best. They are buried in the substrate. Their survival is better in sand or gravel substrates but it is possible to grow them in muddy areas too. Salinity should generally be above 25 ‰.

Cultural techniques: Their stocking density should be approximately 400 to 500 seed at 8mm shell length. Manual methods can be used for small-scale cultivation but mechanisation is needed for laying mesh and harvesting as scale of production is increased. Seed are available from commercial hatcheries at a range of sizes from 4 to 30 mm shell length. Clams are usually grown in plots under lengths of netting to protect them from predators. The edges of the netting should be buried in the substrate down to 10 cm and kept in place with rope stapled round the edges with metal hooks every 0.5 m pushed through the mesh into the substrate. It will be necessary to change the netting at least once during culture period increasing the mesh size since the clams will take around 3 years to grow to a harvest size. Clams can also be grown in oyster bags sunk into the sand in rectangular plots and staked into place leaving about 2.5 cm protruding above the sand.

Harvesting: Harvesting takes place when they reach marketable size.



9.11.5. Seabass culture

Pond culture of Asian Seabass (*Latescal carifer*) is one of the commercially important finfish. This variety is much-in-demand with huge export potential. Small and marginal farmers can adopt this method of culture as it is cost-effective manner. This is a euryhaline fish, growing rapidly up to 3-5 kg within a growing period of 2-3 years in both freshwater and brackish water environments. It is a voracious carnivorous fish; juveniles are omnivorous, feeding mainly on crustaceans and other small fishes. It attains maturity at the age of 3-4 years at a length and weight range of 60 to 70 cm and 2.5 to 4.0 kg respectively.

Nursery: The main purpose of the nursery is to culture the fry from hatchery to juvenile size. During nursing period, the juveniles can be graded into different size groups and stocked in separate grow-out ponds. Nursing the fry in concrete tanks is not recommended as accumulation of excess feed on the bottom of the tank cannot be avoided. Such accumulation can cause bacterial disease.

Nursery pond: Nursery pond size ranges from 500 to 2000 m² and water depth should be 50–80 cm. The pond has separate inlet and outlet gates which facilitate water exchange. Pond bottom should be flat and sloping towards the drainage gate.

Stocking: Stocking of 1 kg fish biomass/m³ is recommended for a 100 tonne of water.

Culture methods:

- Cage Culture
- Traditional Culture

Cage Culture: Seabass culture can be done in more organized manner as a large scale activity in cages. The size of the cage may be 50 m (5 x 5 x 2 m) with mesh size depending upon the size of the fish to be stocked. In cage culture, both floating and stationary net cages are used.

Traditional culture: In ponds, juveniles of various sizes collected from estuarine areas are introduced and fed with the trash fishes like tilapia, shrimps and prawns. These ponds receive water from adjoining brackish water or freshwater canals or from monsoon flood. Harvesting is done after 6-8 months of culture. Production can go up to 2 ton/ha/7-8 months.

Pond culture: The two-week nursery reared fingerlings are ideal for pond culture. Pond can have concrete walls and a soft bottom with water depth of up to 2 m and salinity of 5-10 ppt.



Seabass culture in ponds can be carried out either by monoculture or by polyculture method. Monoculture is that type of culture where a single species of animal is produced and Polyculture is method which involves incorporation of a species of forage fish with the main species in the pond. The choice of forage fish will depend on its ability to reproduce continuously in quantity sufficient to sustain the growth of seabass throughout the culture period. The forage fish must be such a species that could make use of natural food produced in the pond and does not compete with the main species in terms of feeding habit such as *Oreochromis mossambicus*, *Oreochromis niloticus*, etc.

Pond preparation: The pond is at first dried, tilled, levelled and manured with raw cow dung @ 1000 kg/ha. If required, lime is added @ 50-200 kg/ha to maintain soil pH above 7. Sea water/fresh water is then filled to a depth of 60-70cm in the pond. When the pond water becomes light green in colour indicating sufficient development of algae in the pond, forage fishes are introduced.

Feeding: The fish feed methods has to be carried out as per the following. In the first method, the fish are fed exclusively with chopped trash fish and in the other; the food is made available in the pond in the form of forage fish like Tilapia (*Oreochromis mossambicus*). Pelletized feed can also be given.

Harvesting: Harvesting is done with the help of seine-netting the pond or by draining. After harvesting they are usually transported live in tanks by truck.

9.11. 6. Shrimp culture

Shrimp is one of the most traded seafood commodities, and aquaculture of shrimp is considered to be one of the success stories of modern aquaculture. Shrimp farming generated millions of employments, and provides foreign exchange to developing countries. Modern practices with growth on scientific basis using hatchery produced seeds, formulated feeds water management methods have been initiated over the last 20 years. Although growth of shrimp aquaculture is remarkable, the sector has been facing several issues such as viral diseases, issues in marketing, and poor farm level performances. For optimum utilization of the resources and increased production, productivity and returns to the farmer, improvement in the existing technology is necessary. Such improvements should aim at the following:

- a) Improved farm design – for operational ease



- b) Optimum soil and water condition
- c) Removal of pests and predators
- d) Qualitative and quantitative aspects for stocking shrimp larvae
- e) Supplementary feeding
- f) Soil and water quality management
- g) Monitoring of growth and health
- h) Improved methods of harvesting post-harvest management

According to Brackish Water Fish Farmers Development Agencies (BFDA), the topography of Goa is ideally suited for prawn farming, as the seawater is regulated only on the basis of high and low tides and the flooding of water is almost negligible. The BFDA also claims that Goa has good tidal amplitude as well as spring-tides which facilitate natural flushing. Moreover, there are no turbulences or fast currents. Coastal Aquaculture Authority (CAA) guidelines were formed to ensure orderly and sustainable development of shrimp aquaculture in the country. The guidelines are intended to lead to environmentally responsible and socially acceptable coastal aquaculture and also enhance the positive contributions that shrimp farming and other forms of aquaculture can make to socio-economic benefits, livelihood security and poverty alleviation in the coastal areas.

Stocking: The most suitable species for culture in India are the Indian white prawn *Penaeus indicus*, White leg shrimp *P. vannamei* and tiger prawn *P. monodon*. Apart from these candidate species other commercially important species such as *Metapenaeus*, *M. monoceros*, *M. brevicornis*, *P. semisulcatus* and *P. merguensis* are also potential species that can be grown in India.

Site selection

Selection for a suitable site is a critical activity and must be carefully determined before establishing of a shrimp farm. Site evaluation is not only undertaken to determine if a site is suitable for shrimp farming. It is also valuable in determining what modifications are needed concerning layout, engineering, and management practices to make shrimp farming possible at a given site. Factors involved during site selection are topography and climatic condition, infrastructure, accessibility, electricity, security, availability of labor and other factors, water



supply, soil conditions. Besides these, the environmental and socio-economic aspects covering social, economic and legal issues are important parameters to be considered while finalizing the site for setting up a shrimp farm.

Pond design and construction: Shrimp pond should be designed according to the characteristics of the selected site and the culture system. There is no unique design, but optimum and functional farm layout plan and design should be based on the physical and economic conditions prevailing in the locality.

Culture systems: There are three types of shrimp culture being practiced in most countries.

Traditional/extensive cultures: Extensive Freshwater Prawn Culture extensive culture means rearing in ponds (but also in other impoundments such as reservoirs, irrigation ponds and rice fields), which produce less than 500 kg/ha/yr of freshwater prawns. They are stocked, often from wild sources, with PL or juveniles at 1-4/m². There is no control of water quality; the growth or mortality of the prawns is not normally monitored; supplemental feeding is not normally supplied; and organic fertilisation is rarely applied.

Semi-intensive culture: Semi-intensive systems involve stocking PL or juvenile freshwater prawns (usually from hatcheries) at 4-20/m² in ponds, and result in a range of productivity of more than 500 kg/ha/year and less than that defined as intensive in this box. Fertilisation is used and a balanced feed ration is supplied. Predators and competitors are controlled and water quality, prawn health and growth rate are monitored. This form of culture is the most common.

Intensive culture: The ponds are usually of 0.5-1 ha in size and are designed to keep the water at 1.5-2.0 m deep. A reservoir of at least 30 % of the pond area is usually required. High stocking density of 25-60 PL/m² with feeding rate of 4-6 times daily and strong aeration is maintained.

Open system: This system requires a high supply of good quality water because it needs water, exchange of more than 20% of the total pond volume at one time, in order to reduce pond wastes and the density of the plankton. Seed can be stocked up to 60 PL/m² and will grow to 25-35 grams within 120 days.

Re-circulation system: In order to avoid deterioration of the environmental conditions, several advanced and company run farms have adopted the re-circulation system to minimize



contact with poor quality water from outside the farm. Farms must devote 40-50 % of the area for the construction of water storage/reservoir, sedimentation pond, and treatment pond and drainage canals. Stocking density for this system generally varies between 30-50 PL/m² and the culture period is between 110-130 days.

Minimal water exchange system: To reduce contact with the water from outside the farm, the minimal water exchange system or closed pond system is practiced in some countries, particularly in Thailand. The system involves filling up the pond with cleaned seawater, treating it with chemicals to eradicate predators and competitors. Then the shrimps are stocked up to 30 PL/m² and cultured for a period of less than 100 days to attain the average weight of 10-20 gm.

Ponds: Pond preparation is an essential part of culture practices during which the metabolite load and contaminants (chemical and biological) in the soil from the previous culture cycle is removed through tilling, ploughing and drying. During pond preparation, the pests and predators are removed and pH and nutrient levels in the water and soil are brought to optimal concentrations through application of lime, organic manures and inorganic fertilisers.

Water quality and its management: The quality of the water available in the site has a strong influence on the success of the shrimp farm. Water quality parameters like pH, salinity, dissolved oxygen (DO) and the presence of toxicants/ pollutants should be ascertained. The water source should be free from any industrial/ agricultural pollution. The presence of contaminants and their levels should be considered in the light of the tolerance and also sub-lethal effects on the species to be cultured.

Seed selection and stocking: Seed quality has a direct relationship with the survival and growth of the cultured shrimps and the stocking density has a strong bearing on the level of waste generated in the pond. Only healthy and pathogen-free seed from registered hatcheries should be used for stocking. Before stocking the seeds must be acclimatized to prevailing conditions of temperature, salinity and pH conditions in the pond by gradual mixing. In areas with very low salinity, salinity adjustments are to be made over a period of 4 –5 days and hence should be done at the hatchery itself.

Feed and feed management: Using good quality feed in reasonable quantities, water and soil quality in ponds remains in optimum conditions. This reduces stress on shrimp, there is less



likelihood of disease, and they convert feed more efficiently to improve the feed conversion ratio and minimize feed costs.

Health management of shrimps: The health management approach includes reduced stocking of disease free seed, better handling, maintenance of good pond environment, and optimal feed management to reduce the stress and prevent most infectious and non-infectious diseases. Disease should be diagnosed immediately with the help of trained pathologists/ microbiologists. Treatment should be undertaken only when a specific disease has been diagnosed and it is known that this disease is treatable.

Harvest and post-harvest: Successful harvesting can be achieved if the shrimp can be harvested in good condition within a short period of time. The harvesting technique should not damage or excessively contaminate the shrimp with waste. Rapid harvesting will reduce the risk of bacterial contamination and the shrimp will still be fresh when reaching the processor.

Methods of harvesting: Harvesting can be done by completely draining the pond either by gravity or through pumping and hand picking or trapping.

The water drained out for harvesting should be pumped into the waste stabilization ponds and kept for a few days for settlement before releasing into the open water. Icing should be done immediately after harvest.

9.11.7. Mud crab culture

Among the marine edible crustaceans, crabs are one of the most important shellfish by virtue of its delicacy, demand and price. Since 1987, live mud crabs (*Scylla* spp.) are exported to an extent of 1500 tons annually, valued at Rs. 30 crores. Most of the commercially important crabs belonged to the family Portunidae and they can be recognized by the presence of flattened last pair of legs, which help them in swimming in the columnar waters. Species belonging to genera *Scylla*, *Portunus* and *Charybdis* which grow to 0.2 to 2.3 kg are considered as commercially important portunid crabs as they are utilized for both local consumption and export trade.

Mud crabs stand first in the context of both capture and culture fisheries due to their larger size, great demand and higher price. Mud crab is one of the components in the traditional fish/shrimp farming system of Indian and Southeast Asian countries. Due to their great



demand, monoculture of mud crabs is being practiced in most of the Southeast Asian countries. These mud crabs have a remarkable habit of remaining alive after capture for considerable time, say 5 to 8 days. There are only two species of mud crabs *Scylla serrata* and *Scylla tranquebarica* occurring in most of the Indian brackish water areas and inshore seas. They usually grow to a maximum size of 0.7 kg in case of *Scylla serrata*.

Though both the species co-exist in the same habitat, they differ in habits. The larger species remains buried under sand or mud. While the smaller species makes a deep burrow either at the bottom of estuary or in earthen bunds of canals/ponds. This differential habits make them more abundance in specified habitats. For example, the larger species is more abundant in the open inshore seas backwaters and coastal lakes, while the smaller species is more in number in mangrove areas.

The size-frequency studies indicated that male and female of mud crabs grew at rate of 9 and 10 mm in CW per month respectively. *Scylla serrata* attains a size of 0.7kg. In an experimental field culture the early juvenile mud crabs (15 to 60 mm in CW (Carapace width)/3 to 20 g in total weight-TW) grew at a rate of 7 to 12 mm/3 to 13 g per month, while juvenile crabs (61 to 80 mm/25 to 70 g) exhibited a monthly growth of 1 to 12 mm/145 to 97 g. In the sub-adult and adult stages, the monthly growth worked out to 8 to 10 mm/100 to 130 g.

Mud-crab farming involves the following steps nursery rearing, soft-shell crab rearing, grow-out culture and fattening. Nursery rearing involves the rearing of megalopa (0.003 g)/crablets (0.03 g) to juveniles in two phases, namely, up to 3 g (in hapas) and 3 g to 25 g (in nursery ponds). Soft shell crab rearing includes the stocking of juvenile crabs (50 to 100 g of *S. serrata*) individually in small plastic cage till they moult. Grow-out culture refers to farming of nursery grown juveniles of about 25 g (seed crabs of *S. serrata*) for a period of 3-6 months to produce marketable size crabs. During this growth period, the crabs undergo several moults (shedding of old skeleton).

Fattening refers to the holding of marketable sized crabs for about 3 to 4 weeks time, during which period, the stocked crabs gain weight. The live mud crab export from India has started in 1987-88 and exported mostly to south east Asian countries. The live crabs are packed in perforated carton boxes lined with thermocole sheets and air-lifted. In order to conserve and protect the natural stock from overexploitation and to meet the ever increasing demand for local consumption and export trade, mud crab farming with hatchery produced seed will be



the best option and as such collection of wild juvenile crab for farming/fattening needs to be discouraged.

In Goa due to low yields from salt-tolerant local varieties of paddy seeds like Korgutt and Azgo, Khazan fields in Goa are generally neglected by farmers. In order to provide farmers with alternative source of income, crab aquaculture can be taken up by these farmers. Goa has about 18,000 hectare of Khazan fields and there is huge opportunity for farmers to harness this to their benefit.

Site Selection: The mandatory guidelines enlisted for shrimp culture for the selection of sites for coastal farms should be strictly adhered to in the site selection for mud crab pond construction. In addition to the guide lines, there are other parameters should be addressed such as physiochemical condition, water quality, flow rate and temperature should be, appropriate for the species concerned. Other factors that must be considered for site selection are weather, shelter, depth and substrate.

Criteria for pen culture in mangrove areas: Mangrove areas should have sufficient supply of marine or brackish water throughout the year. Water depth at high tide should range between 0.3 to 1.0 m. Salinity should be ranging from 10 to 35 ppt and temperature between 25 and 30°C. The site must be free from big waves and pollution, protected from environmental hazards such as big waves and floods and secure from vandals and poachers.

Pond preparation: Pond preparation strategies generally employed in shrimp aquaculture can also be adopted in mud crab aquaculture. However, it is generally believed that meticulous and stringent pond preparation is not required. The installations like net fencing, earthen mounts should be considered. Pond should be drained and kept dry for 1 week to kill pests.

Nursery rearing: Nursery rearing in mud crabs is carried out in two stages as nursery phase - 1 and nursery phase - 2. During first phase, hatchery produced megalopa, which are very small in size are reared with maximum care to attain a size of about 3 g. These 3g sized crablets are further reared in second phase to attain a size of about 25 g

Transport and stocking: Crab juveniles are relatively easy to transport by using cane basket, carton lined with moist sea weeds or mangrove leaves. Chelae are tied to prevent fighting among crabs. Stocking should be done with individuals having intact appendages, and without



injury, further seeds should of uniform size. Different sizes leads to cannibalism. Stocking density has a major effect on crab growth, survival and production, and it is generally ranged between 0.5 and 3 crabs per square meter.

Nutrition and feeding: In grow out culture management, locally available cheap protein sources (trash fish, molluscs) at the rate of 8-10%W of biomass can be given. The crabs can be fed a mixed diet of 25% fish by catch (trash fish) and 75% fresh flesh of mollusc or crustacean.

Harvest and post-harvest: Culture period is generally 3 to 6 months and is dominated mainly by the size at stocking and the preference and demand, existing in the market. For *Scylla serrata*, culture duration will be 120 days with an initial size of 25 g and harvestable size of 200-300 g if the stocking density will be 1 crab per square meter. To obtain larger sizes (400-500 g), culture period can be extended to further 3 months. Partial harvest can be made with baited lift nets and bamboo cages. To have a total and complete harvest, crabs are to be handpicked after completely draining the culture pond. Crabs should be tied immediately after their capture in order to curb their movement and to avoid the fighting among them. The tied-up crabs are to be initially washed with fresh sea water and subsequently sent for local marketing after packing them in bamboo baskets.

9.11.8. Milkfish (*Chanos chanos*) culture

Semi-intensive pond farming of Milkfish fingerlings of 7-15 cm size can be stocked @ 8000-10,000/ha and formulated grow-out feed can be applied. Periodical manuring can be done to facilitate the growth of phytoplankton, as food item for the cultured fish. In 5 to 8 months, this fish can attain 0.5 to 0.6 kg body weight and a production of 3 to 4 t ha⁻¹ can be obtained. Milk fish can also be raised in cages and however, this method is not commonly adopted.

11.11.9. Pearlsport fish culture

Pearlsport, *Etroplus suratensis* (locally known as “Kalundhar”) is another important candidate species for culture in ponds, cages and tanks. Polyculture of pearlsport with other brackishwater fish species like milkfish, grey mullet or liza species is commonly practiced. Monoculture of pearl spot is commonly practiced in low volume cages. More recently, cage culture (2 to 4 m³ for 7 to 9 months) is commonly practiced by small scale farmers in estuarine



waters and feeding can be carried out using locally prepared feed, agro waste and kitchen discards.

9.11.10. Grey Mullet (*Mugil cephalus*) culture

Grey mullet, *M. cephalus* (locally known as “shevto”) can be culture in monoculture or polyculture with other brackish water species (Pearlspot and milk fish and other mullets such as like *Liza tade*, *L. parsia*) for about 8 months. Size of species stocked is more than 50 to 60 g, with a stocking density of 6000 to 8000 no. ha⁻¹. A total production of 2 to 3 t ha⁻¹ can be expected from the system. Feeding is carried out by supplementary feeding and fertilisation of the pond.

9.11.11. Red snapperculture

Mangrove Red snapper (locally knows as “Tamso”) can be cultured both in the pond and cages. Cage culture of *L. argentimaculatus* is being practiced in Karnataka and Maharashtra by stocking the wild collected seed in the cages/ponds either by monoculture or polyculture methods.

9.11.12. Ornamental fishculture

There are also some important ornamental fishes from the estuarine areas which can be promoted for domestic and international markets. Major species are silver-moony, *Monodactylus argenteus*, and orange chromide, *Etroplus maculatus*. At present, scarcity of seeds in adequate quantity is creating burden on the wild stock and increasing the price in the ornamental industry. Seed production technology is being standardised by various research institutes such ICAR-CIBA, that offer scope for development of the culture fisheries for these ornamental fish.

9.11.13. Seaweed farming

Seaweed is marine algal species that functions as renewable source of food, energy, bio-chemicals and medicines. It provides a valuable source of raw material for industries like health food, medicines, pharmaceuticals, textiles, fertilizers and animal feed. One of the most important uses of seaweed is for the production of agar, alginates & carrageenan. In India, currently sea weed farming is practiced in Mandapam, especially for the extraction of carrageenan and also to use as a bio-fertiliser. The cultivation of *Kappaphycus alvarezii* and



other commercial seaweed are grown by the fishing community in Tamil Nadu specifically in Ramanathapuram, Thoothukudi, Pudukottai and Thanjavur region. Seaweed is grown in three different ways. One of the most popular in India is using the Single Rope Floating Raft (SRFR) method (Cair Rope & Nylon Rope). This involves building of tethered rafts and spreading them out in the sea. After around 45 days, the seaweed is harvested, dried and carrageenan is extracted from it. The second method is using a Fixed Bottom Long Line method (Cair Rope & Nylon Rope). And the third is the less practiced, and however, offer wide scope as a component of the Integrated Multi Trophic Aquaculture (IMTA) method. The input costs for sea weed farming are almost nil and from a single raft, the dried seaweed earns up to Rs. 86,000 annually.

9.11.14. Integrated Multi-Trophic Aquaculture (IMTA)

Coastal brackish water systems face challenges of waste water management, which can be addressed through culture of species in multi-trophic levels a model Integrated Multi-Trophic Aquaculture can include combination of fish, seaweed and shellfish culture systems. Successful culture trials of Milkfish culture with other species like Shrimp (*P. monodon*), Tilapia (*Oreochromis niloticus*) and red seaweed (*Gracilaria* spp.) has been investigated and offer scope for the future prospects in this sector.

9.12. Development of eco-tourism

Ecotourism is now defined as “responsible travel to natural areas that conserves the environment, sustains the well-being of the local people, and involves interpretation and education. Ecotourism is catering for holiday makers in the natural environment without damaging it or disturbing habitats. It is a form of tourism involving visiting fragile, pristine, and relatively undisturbed natural areas, intended as a low-impact and often small scale alternative to standard commercial mass tourism. It means responsible travel to natural areas, conserving the environment, and improving the well-being of the local people. The origins of the term ‘ecotourism’ are not entirely clear, one of the first to use it appears to have been Hetzer (1965), who identified four ‘pillars’ or principles of responsible tourism: minimizing environmental impacts, respecting host cultures, maximizing the benefits to local people, and maximizing tourist satisfaction. The major objectives of eco-tourism are as follows:



- Build environmental and cultural awareness and respect.
- Provide positive experiences for both visitors and hosts.
- Provide direct financial benefits for conservation.
- Generate financial benefits for both local people and private industry.
- Design, construct and operate low-impact facilities.
- Recognize the rights and spiritual beliefs of the native community and work in partnership with them to create empowerment.

Ecotourism in Goa: Goa is gifted with abundant natural beauty as it a part of the Western Ghats. Goa is rich with over 1512 documented species of plants, over 48 genera of animals, over 275 genera of birds, over 48 genera of animals and over 60 genera of reptiles along with very rich marine biodiversity.

The river Chapora has a good potential for development of ecotourism activities. These activities can not only help in employment generation it helps in the development of villages along the river. Historic sites along river include Chapora fort, Alorna fort, as well as many religious places. Chapora Estuary also has a good diversity of birds hence bird watching tours, mangrove walks could be conducted. Water sports such as kayaking, river cruises in smaller boats. Nature trails can also be promoted. Recreational fishing could also be developed. Spice garden plantations and picnic spots can also be developed. Cycling tourism, photography tourism, meditation and rejuvenation tourism, cultural tourism can also be developed.

The above tourism activities should employ people from the local communities, as it helps in the regions development. These activities should be sustainable and waste generation should be minimised by reuse, reduce and recycling materials. The government on its part to incentivize ecotourism should provide schemes and funding to interested people as well as training courses in various fields such as culture, language, management, identification of flora and fauna etc.

Guidelines to be adopted for sustainable ecotourism suggested by some experts specifically for Goa are as follows:



1. The management plan areas proposed for eco-tourism should be prepared through professional ecotourism experts and in consultation with the local community as well as other stakeholders.
2. To avoid conflicts, inclusive and integrated planning should be adopted.
3. The architectural programme for eco-tourism centers should include controlled access points and cabins, roads, self-guided nature trails. Transportation options, interpretive signs, observation towers, adequate but unpretentious lodging and dining facilities, water docks, garbage disposal facility etc.
4. Structures creating visual pollution, unaesthetic values and non-compatible architecture should be controlled.
5. Exclude development in geologically unstable zones and define development and buffer zones after proper environmental impact assessment. For example, on beaches Coastal Regulation Zone (CRZ) regulations must be followed.
6. Establish standards, building codes and other regulations.
7. Specify environmental, physical and social carrying capacities to limit development activities.
8. Ensure continuous monitoring of adverse effect of tourism activities and initiate suitable corrective measures.
9. Recognize and award quality labels to eco-tourism operators.
10. Provide visitor information and interpretation services covering particularly i) what to see ii) how to see iii) how to behave.
11. Prepare and widely distribute codes of conduct to all visitors.
12. Launch training programmes on eco-tourism to tourism administration planner's operators and general public.

9.13. Development of team and funds for the plan

For management, monitoring and smooth running of the entire plan which will be spread across the river-scape, a well-coordinated team is essential. As there are several activities involved pertaining to sand mining and environmental conservation it is imperative to have a multi-disciplinary team to undertake activities as well as co-ordination between various stakeholders.



Stakes of all the interest groups is essential thus the team should have the representation of each group, community and related agencies, which also ensures discussion to reach consensus and transparency. This generic structure allows freedom to each of the bodies to discuss within themselves as well as with other bodies and decide the responsible team member. Given below is the structure of the team to be appointed after a consultative meeting (Figure 9.7).

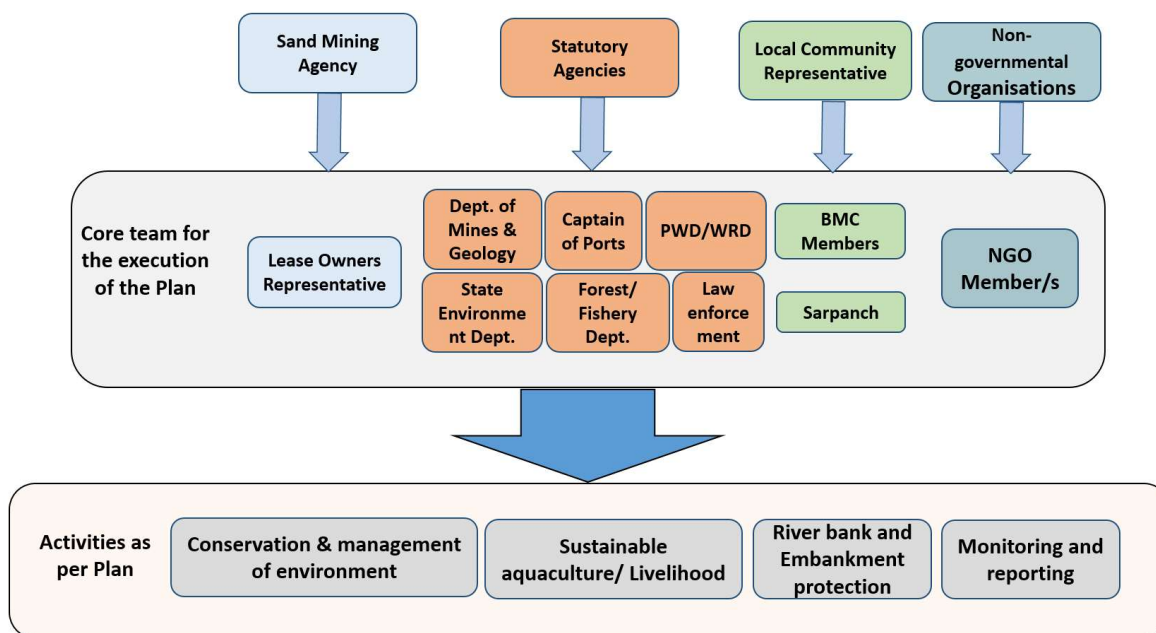


Figure 9.7. Schematic diagram depicts execution of management plan

11.13.1 Funds for the plan

A mechanism has to be formulated to impose minimum burden on the government for mitigating the impacts. Considering this perspective, as per the guideline provided by MoEFCC, the funds to carry out the activities to mitigate the impacts of sand mining, environmental safeguard and restoration need to be acquired from the lease holding agencies. A share of proportionate amount has to be assigned to carry out the aforementioned activities of the plan as part of CSR/CER.

Funds also have to be deviated towards sustainable aquaculture practices and eco-tourism, for which initial seed money can be provided from a corpus fund to bind with government schemes and subsidies. At the initial stage the interest group can also contribute for the small scale businesses in which they would like to participate.



11.13.2 Role and responsibility of the team

The plan gives freedom to discuss and decide the roles and responsibilities of each of the member as well as the rights to the team to appoint additional team members as felt necessary. Following are the responsibilities of the team:

- Monitor all the sand mining lease holder's activities and compliances.
- Carry out conservation activities and promote eco-tourism.
- As the expanse of the river spans across many villages with changing land use and activities, the team may appoint sub-teams to properly execute each activity. The sub-teams can be made or committees can be formed or SHGs can be formulated depending on the interests of the stakeholders and interest groups.
- Implement, supervise, monitor and take corrective actions for sustainable livelihood schemes as deemed fit considering the environmental conditions, available land, local expertise and willingness.
- The team has to monitor the activities of the sub-teams or the groups formed and weigh the achievement of work undertaken, suggest corrective measures and way forward for undertaken activity or projects.
- The team members (representatives of statutory agencies) shall help the activities by extending the available schemes and subsidies to the required stakeholders so as to support environmental conservation, sustainability and livelihood.
- Instruct actions to stop any environmental degradation (e.g.: tree cutting, garbage dumping, species decline/loss, embankment damage, saline intrusion etc).
- Carry out training for capacity building and to promote sustainable livelihood practices.
- The team is required to maintain all the records, handle complaints, incident and conformance and keep its record.

9.13.3 Corrective action/contingency plan

Any unlawful activity or failure to meet the performance criteria shall be recorded as a non-conformance incident and be reported. In the event of any incident, the team has to take immediate actions, document the incident, and report it to statutory authorities. This has to



be followed by remedial actions as directed by the Dept. of Mine and Geology and Environment Department (eg: GSPCB/GSBB).

9.13.4 Documentation and record keeping

Efficient and accurate record-keeping is essential for the application of a plan. Following necessary aspects are to be considered for record keeping and documentation-the DPR & Management plan, list of important areas (in terms mine lease, ecological sensitivities etc.) and details of priority areas for action. According to the size of the lease and areas/expanse of each lease area, the team needs to formulate and document a manual for their own working which shall include: critical limit determination, analysis, procedures -e.g. standard operating procedures, corrective action procedure, work instructions, monitoring activities, deviations and associated corrective actions, verification procedures performed, modification to the plan, training undertaken, periodic records, visual inspection reports, team meeting records, processing records.

11.13.5 Complaint handling procedures

Every complaint is different but the steps for dealing with them should be the same. As well as having a complaint policy, comes under best practices which will have a procedure handling protocol prepared by the team. A complaint handling procedure ensures complaints are dealt with the same way every time (**Figure 9.8**).

9.13.6 Incident and non-conformance reporting

Non Conformance report which is work done without approval of any concerned documents/not related to the standards (Construction Standards/Contract specification). Especially some works are not followed by the standards and specifications. Non-conformance report shows the exact possible error due to not following or deviate the procedure, while corrective action shows that, how the process or method will follow the right procedure. There is a formalized way of reporting environmental incidents i.e. uncontrolled events that have or could have had an impact on the environment, such as chemical/ oil spills; contamination of land, flora or fauna; damage to listed structures/building/embankments etc.

The objectives of the procedure are to:



- Ensure all relevant contractors are made aware of environmental incidents/ violation of lease granted and its handling procedure. Complaints can be forwarded to the appointed committee or to the office of Mamlatdar/ Dy. Collector/ Police. The complaint can be given manually or by electronic means to be devised by the committee.
- Ensure site workers and stakeholders understand the immediate environmental incident reporting requirements.
- Ensure all concerned stakeholders understand reporting timeframes, including statutory requirements.
- Ensure incidents are reported to enable monitoring, sharing of lessons learnt and response to emerging environmental incident trends.
- Comply with statutory obligations to report certain environmental incidents to regulators and other relevant government agencies for further action.

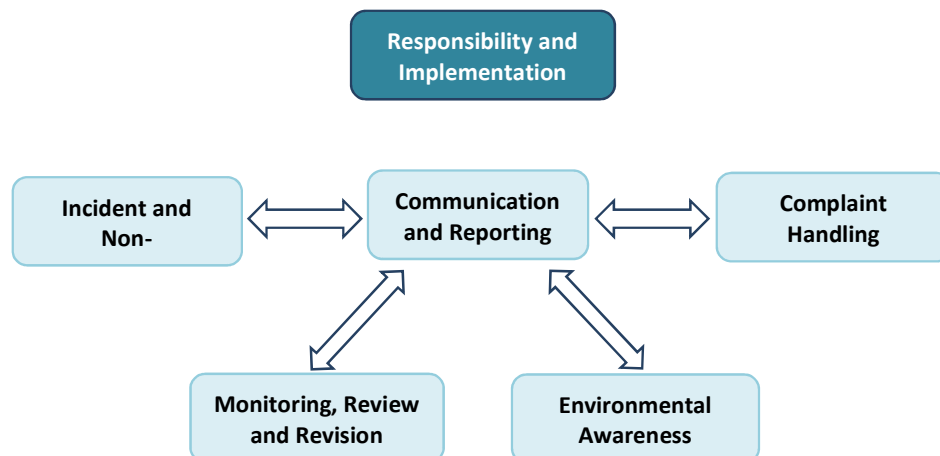


Figure 9.8. Schematic diagram of development and functioning of team

9.13.7 Attempts to deal with the illegal trade (WWF, 2018)

The Directorate of Mines & Geology, the Coastal Police, the Captain of Ports and the District Magistrate, North Goa, shall ensure maintenance of regular vigil in the area. As suggested by Honourable NGT, CCTV camera installation is essential at important location that have been leased as well as other critical areas vulnerable for mining need to be monitored. Wherever the monitoring shows that the guidelines and legality is not followed or violated, actions shall be taken as directed by the Honourable NGT order date 12/12/2019 (No: 28/2015 (WZ)).



Numerous approaches have been adopted by District, State and the Central Government to attempt to curb the illegal mining and the associated environmental, ecological and social impacts, including:

- Development of sustainable sand mining guidelines. The guidelines provide detailed information and recommendations on how to extract sand sustainably, but they are non-binding.
- Completion of sediment audits to identify sustainable sediment extraction limits. This approach was applied to Kerala in 2015 and resulted in the banning of sand mining from six rivers with severe restrictions placed on others.

The establishment of a complaint cell to receive and investigate complaints regarding sand mining. Legal authorities have been instructed to conduct raids, seize vehicles that engage in the illegal activity and take custody of illegally mined sand for subsequent sale at government rates, and to provide armed police to provide protection for revenue squads (Jha, 2013).9.13.8 Alternatives to river sand mining (WWF, 2018)

Alternative sources to river sand have been identified and adopted by most western countries, and similar shifts in developing countries could reduce pressure on the resource. However, without improved governance changing the primary sources of construction materials is difficult as alternatives are likely to cost more due to additional handling, processing and transport costs. Any increase in the cost of 'legal' sand as compared to illegally derived river sand drive an increase in illegal activities. Alternative sources and substitutes for sand in concrete is an area of active research. A literature review found the following examples.

9.13.9 Recycling of concrete for use as road bases (Smith, 2018)

Development of bacteria and fungi that can produce calcium carbonate can be used to repair existing concrete structures, increasing their lifespan. This may be particularly useful when applied to the huge highway systems of the world that are requiring repair or replacement (Smith, 2018). Replacement of sand with other materials should focus on the recycling of waste materials. It is notable that a web search of this topic returned many recent articles by Indian researchers, all of which highlight the need to identify replacement materials to



diminish sand mining and its related environmental impacts. Examples (not all from India) include:

- Backfilling of mining voids using fly ash composites in place of river sand in India due to a decrease in the availability of river sand. Finding an alternative use for fly ash is also desirable as it would reduce landfill (Mishra & Karanamk, 2006).
- Use of walnut shell and PET-fibres as a replacement for aggregate in lightweight shotcrete suitable for roadway or mine supports (Cheng, et al., 2017).
- Use of fly ash and polypropylene or steel fibers to produce high quality concrete (Raut & Deo, 2017).
- Use of rubber tyres and copper slag as aggregate in concrete (Blessen, et al., 2012).
- Replacing aggregate with recycled concrete sand in masonry and mortar design for indoor use (Fernandex-Ledesma et al., 2016).
- The use of residual materials such as kaolinitic waste, sewage sludge, schist fines and wasted glass to create light weight granules suitable for light concretes, road engineering and waste water treatment (Kanari et al., 2016).
- The use of crushed oil palm shell as a replacement for aggregated in concrete. Investigations have found that replacement rates of between 50% and 75% can be used to produce a lightweight concrete for use in non-load bearing structures, and structural concrete can be created at replacement rates of about 25% (Muthusamy et al., 2013).
- The replacement of river sand with manufactured (crushed) sand. Manufactured sand is a by-product of the production of coarse aggregate and has historically been used for road bases and land fill. Replacement of river sand with manufactured sand at a rate of 75% was found to produce concrete with properties suitable for use as high performance concrete (Prasanna et al., 2017).
- Replacement of river sand with crushed waste stone, dust and polish slurry generated by the production of dimension stone (stone quarried and cut to specific sizes or shapes, e.g. ornamental stone). Replacement of 100% of river sand in concrete by 85% stone waste and 15% slurry waste resulted in a very high-quality concrete product (Rana et al., 2017).



- Use of iron-ore tailings to replace sand in concrete. The inclusion of the tailings reduced the workability of concrete, but all other strength modulus of elasticity data was consistently higher than conventional replacement at all levels of replacement (25% to 100%). The use of tailings is recommended to minimise environmental problems, cost and natural resource depletion (Shettima et al., 2016). Note, this approach would not be suitable for tailings containing sulfides.



CHAPTER 10 ENVIRONMENTAL MONITORING PLAN

Environmental monitoring program includes periodic analysis of air, soil, noise and water, flora and fauna. Environmental monitoring should be conducted on regular basis to assess the pollution level in the mining lease area as well in the surrounding areas. Therefore, regular monitoring program of the environmental parameters is essential to take into account the changes in the environment.

Mining of sand and all the activities listed out in the conservation and management plan require periodic monitoring. Considering the activities and the monitoring results the team may decide to suggest additional management strategies to be implemented as appropriate. Competent outsourced certified organization/laboratory (eg: GSPCB) should be appointed to conduct the monitoring parameters wherever there are samples involved.

10.1 Mining activity monitoring:

1. Daily quantity of sand to be extracted from each lease should be based on the quantity given in the permit/ EC conditions.
2. De-casting from river beds should be monitored on a regular basis to keep a track of excavated quantity.
3. Every years, a mandatory audit of the quantity extracted and quantity permitted along with the replenishment rate should be carried out.
4. Depth should be up to 3.0m from the existing riverbed level and not less than one meter from the water level of the River channel.
5. Peizometer and eco-sounder (for depth measurement) should be used by each lease holder and daily records of these measurements should be made available to the monitoring team.
6. Monitoring team should ensure that sand mining activity in Monsoon season and during night time is not carried out.

10.2. Sand Transport Monitoring:

1. Mandatory e-pass/ e-permit should be made available at each lease area for transportation of any sand by an GPS enabled vehicle with the provision of entering the vehicle number of the vehicle carrying sand and expected delivery address and customer name/ mobile number.



2. Documents should be made available for stockyards/ stockiest of sand. In the case of nomination based (controlled pricing) business model, the margin of private stockiest should be capped over a fixed percentage of notified prices.
3. At the stockyard, the stock supervisor should verify the authenticity of payment receipt before issuing the transit pass. The loading of sand should be monitored electronically and all transporting vehicles should pass through an electronically monitored weighbridge.
4. To make transportation monitoring effective and useful, all the sand carrying vehicles (tractors/ trucks) should be registered with the department and GPS equipment should be installed in all the sand carrying vehicles.
5. There shall be one entry and exit point provided for trucks/vehicles. The said entry point should have facilities as mentioned above. In case, it is necessary to have more than one entry/exit points, all such points shall have checkpoints with facilities as mentioned above. All other possible ways of entry/exit should be closed using barriers like compound, trench, etc. All provisions shall be made to not make it possible for any vehicle to enter or exit without entry into the computerized system.
6. The Project proponent has to enter the destination, distance between plot and destination, vehicle number etc in the system. After scanning, unique bar code number, invoice date time and validity date-time are generated by the software which gets printed individually on each TP. Validity of TP is calculated based on the distance between plot and destination. After validity time is over the TP stands invalid.
7. Weighbridges with CCTV should be installed at all the stockyards, active reaches to ascertain the exact quantity of sand being transported in the vehicle. Check posts with CCTV cameras should be established near all major consumption centers to check if all the transporting vehicles are carrying a valid transport permit.
8. The transport permit generated should contain advanced security features so that one permit cannot be re-used by generating photocopies of the permit.
9. It is necessary to prevent any truck/vehicle from transporting sand out of the identified plot bypassing the strong IT enabled system. Therefore, at each of the sand plot, the following additional measures should be taken.
10. All such points should have 24X7 CCTV coverage, the footage should be made available online to the district administration. In cases, where sufficient internet bandwidth is



not available, it may be deposited with the district administration on a weekly basis. If possible, the entry/exit points should have boom barriers which will record the vehicles entering and exiting the plot.

10.3 Surveillance & monitoring:

11. Constantly monitor mining with drones and if possible night surveillance of mining activity through night- vision drones.
12. Project Proponent must ensure that CCTV camera, Personal Computer (PC) or laptop, Internet Connection, Power Back up, access control of mine lease site; and arrangement for weight or approximation of weight of mined out material on basis of volume of the trailer of vehicle used at mine lease site are made available for monitoring.
13. Even after all the regulatory procedure and policy being in place, there are instances where illegal mining is taking place. The monitoring agencies can monitor the sites remotely by using Unmanned Artificial Vehicles (UAVs)/Drone which are now a viable option. The drone can also be used for reserves estimation, quantity estimation, land use monitoring. Other options for the monitoring team may also be made available for possible use of IT/Satellite/Drone technology for effective monitoring of sand mining.
14. The officials involved in monitoring should be provided with mobile application and/or bar code scanners using which the TP can be checked anywhere on road. As soon as the bar or QR code on TP gets scanned through using the mobile application and/or scanner or vehicle number is entered into the application or sent by SMS to a predefined number, all details of TP such as plot details, vehicle details, validity time, etc. should be fetched from the server. This means if anything is re-written on TP and attempt is made to reuse the same, it can be traced immediately. Various reports can be generated using the system showing daily lifting reports and user performance report. This way the vehicles carrying sand can be tracked from source to destination.
15. The facility to fetch details using mobile app, website and SMS may be made available to the general public as well. If the citizen finds that the vehicle doesn't have such a permit, as ascertained from mobile app or website or SMS, he should alert local authorities, who shall then take further action as per the law.



16. Land contamination (by diesel, oil etc.) due to movement of site vehicles: Vendors of state pollution control board will be contracted for collection of hazardous waste (used oil) & oil spill kit will be provided with each vehicle used for transport. Monitoring team will ensure the log books are updated and accordingly check any signs of violation, accidents, spillage etc.
17. Monitoring wells should be established adjacent to each excavation area to record changes in ground water levels. Measurements should be taken monthly. This should help analyse surface water and ground water interaction around the lease area as well as for monitor the salinity intrusion into freshwater bodies.
18. River mining from outside shall not affect rivers; no mining shall be permitted in an area up to a width of 25m from the active edge of embankments.
19. A monitoring report should review permitted extraction quantities in light of results of the monitoring program, or as improved estimates of replenishment becomes available. The report should document changes in bed elevation, channel morphology, and aquatic and riparian habitat. The report should also include a record of extraction volumes permitted, and excavation location. Finally, recommendations for reclamation, if needed should be documented.
20. Sand mining has to be monitored as per The Mines Act 1952 and The Mines and Mineral (development and Regulation) Act 1957, Mines Act 1952, Mines rules 1955, Mineral Concession Rule 1960, Mineral Conservation and Development Rules 1988.

10.4. Air quality Monitoring

As per the EIA Notification (2006) and subsequent amendments, Air Environment is one of the pollution sources from mining sector which needs to be categorically addressed. Measuring and understanding air pollution provides a sound scientific basis for its management and control. If concentration of pollutant is higher than threshold limit values are observed, the source of fugitive emissions will be identified and necessary measures will be taken. If the levels are high, suitable measures as detailed in Environment Management Plan will be taken. The criteria for pollutants measured are Particulate Matter 10 (PM₁₀), Particulate Matter 2.5 (PM_{2.5}), Sulphur dioxide (SO₂), Oxides of Nitrogen (NO_x), and Carbon Monoxide (CO) concentration in downwind direction considering predominant wind direction, at the source and a distance of 500 meters from the following dust generating



sources shall be measured. Air pollution has to be monitored as per Air (Prevention and Control of Pollution) Act (and subsequent amendments) 1981. The air pollution impacts from the present baseline activities are of low nature as the sand extraction is from water therefore minimum dust emission. Hence emission from transportation and fugitive emission are to be taken care off using best practices in the industry.

10.5. Water Quality monitoring plan

Enforcing environmental monitoring. Plan is the responsibility of the assigned team and the major objective is to follow the best practices and legislative provisions for the prevention of environmental degradation. Thus the main actions would be:

- Pooling and communicate the results of the environmental monitoring.
- Proposing mitigation measures based on the results of the monitoring.
- Introducing environmental education programme among the workers and the villagers.

Mines can affect surface runoff and groundwater quality through contamination with dissolved and suspended materials. Mines can de-water groundwater aquifers some distance from shafts or open pits, which can make nearby wells or groundwater bores run dry or saline. Monitoring should inspect the water against the release of chemically or radiologically contaminated water. The sample collection, procedures for sample preservation and methods of analysis are followed as per Standard Methods. Monitoring of water samples will be done at a frequency of once in each season as per CPCB Guidelines for waste water: and Ground water (BIS-10500:2012). Water quality has to be monitored as per the law of Water (Prevention and Control of Pollution) Act (and subsequent amendments) 1974 and the water (Prevention and Control of Pollution) Rules 1975, Cess Act 1977 & Cess Rules 1978. GSPCB carries out regular monitoring of river water quality, same can be extended to the proposed stretches of the river with added parameters to fulfil the legality.

10.6 Solid waste management

Solid waste management is one of the most acute environment issues. Site clearance and tidiness is very much needed to have less visual impact of mining. Dumping of waste shall be



done in earmarked places as approved in Mining Plan. Thus, team/operator can monitor the bin and waste receptacles at the site, storage, segregation and its lawful disposal to a registered vendor. Monitoring has to be carried for each lease area and area of operation follows the Solid Waste Management Rules 2016. Monitoring team should ensure a record/log will be maintained for general and regulated waste disposal. The log shall record the type of waste, and the point and date of disposal.

10.7. Marine Environmental Monitoring

Water quality monitoring is an important aspect which needs to be monitored. A water quality monitoring system is required to signal, control or predict changes or trends of changes in the quality of a particular water body, so that curative or preventive measures can be taken to restore and maintain ecological balance in the water body. Project team should collect water parameters to check the physico-chemical parameters. Along with the parameters, the project team has to collect sediment sample to check the benthic faunal diversity. The monitoring has to be done as per The Environment (Protection) Act, 1986 and EIA Notification (and amendments) 2006.

Water quality is the main cause for the damage to marine environment and can be monitored by conducting training / awareness programs once a year for all the relevant staff/stakeholders.

The project teams also have to identify floral diversity like native and invasive species along the estuarine and riparian region of the estuary. The station locations identified in the baseline are to be monitored every six months (covering pre- and post- monsoon season) as given in table 10.2.



Table. 10.1: Water quality monitoring parameters and schedule.

Sr. No	Cluster	Parameters measured	Locations	Operation Phase
1	Sea Water	Temperature, Salinity, DO, BOD, OC, Nutrients	14 locations	Once every six months
2	Sediment	Texture, Grain Size, OC	14 locations	Once every six months
3	Plankton & Benthos	Phytoplankton, Zooplankton, Meio & Macro- fauna	14 locations	Once every six months
4	Flora & Mega fauna	Seaweeds, Marine mammals, reptiles & avifauna	Identified habitats in the study area	Once every six months
5	Sensitive habitats	Mudflats, Mangroves, Sand flats and Rocky shores	Identified habitats in the study area	Once every six months
6	Fisheries	Benthic & Demersal fish species & intertidal shellfish.	One bottom trawl & intertidal survey	Once every Six months

10.8 Embankments management and protection:

Embankments are the oldest known forms of flood protection works and have been used extensively for this purpose. They serve to prevent inundation, when the stream spills over its natural section, and safeguard lands, villages and other properties against damages. The embankment needs to be monitored as per the Environment (Protection) Act, 1986, CRZ notification, 2019.



- These embankments should be monitored on monthly basis and care must be taken to ensure the proper condition of the embankments. Damaged during the mining activity may leave many riparian zones vulnerable as they are known to protect from floods and soil erosion.
- Other areas should be monitored where there is no protection and it requires embankment construction.
- Saline intrusion in the adjoining areas should be monitored.
- Any repair work and construction of embankments should be monitored and recorded in site visit reports.

10.9 Monitoring of conservation plans:

Conservation of ecosystem is the most neglected aspect of any developmental project or mining activity as such. The present area is rich in biodiversity and requires serious conservation efforts. Otters, crocodiles, turtles play an important role in maintaining riverine ecosystem. As this ecosystem provides promising habitat for these species but it might be a difficult task for their survival because of sand mining, iron ore mining, dynamite fishing etc. Construction along the banks of river like embankments, check dams cause negative impact on their habitat. Cutting and lopping of trees along the banks, should be also be monitored. Mass public awareness campaign should be undertaken to educate people, especially fishermen inhabiting closer to estuarine habitats about the ecological role of the important species and their habitats which ultimately provides goods and services to the human society. All the aspects given in the conservation have to monitor to note the status of species, their habitat and actions to be taken for their improvement and enhancement. Conservation of the ecosystem has to be monitored as per Wild life Protection Act, 1972, Forest (Conservation) Act 1980

10.10 Monitoring of Plantation Plan:

Mining activities will not cause any harm to riparian vegetation cover as the working will not extend beyond the offset left against the banks. Plantation should be followed along the bank of river and along road sides of approach roads. While selecting plant species preference will be given for planting native species of the area and shall have soil binding capacity. The state forest department will supply saplings to surrounding villagers for green belt development in their villages and encourage the plantation by means of social forestry. Green belt



development as per the scheduled plan will be reviewed every year plantation records will be maintained for period of plantation, area under plantation, length of avenue plantation, type of species density of planted area and survival rate. Monitoring of Plantation needs to be monitored as per Environment (Protection) Act, 1986

- The implementation for development of green belt will be of paramount importance as it will not only add up as an aesthetic feature, but also act as a pollution sink.
- The species to be grown in the area should be dust tolerant and fast growing species so that permanent green belt is created.
- To stabilize the river bank erosion the plants having good growth will be planted along the river bank.
- Apart from the green belt and aesthetic plantation for elimination fugitive of emission and noise control, all other plantation efforts shall be decided and executed with the assistance and co-operation of the local community.

10.11 Integrated Aquaculture and eco-tourism

The discharge of nutrients, sediment, BOD, bacteria, and pathogens into estuarine waters is one of the problem which impacts the aquaculture and to be covered by existing programs. Land based facilities can be regulated under the existing waste discharge laws and regulations. The impacts are site specific and controllable with any other source of water to estuaries.

- The site of the aquaculture should give more important to the conservation; such importance can be maintained by monitoring the norms to be followed as per national guidelines and best practices in aquaculture.
- Aquaculture farms should not pose a significant threat to the surrounding environment. The potential impact of the aquaculture must be understood and an accurate assessment made to monitor the water quality changes.
- The feed is a primary cause of direct and indirect pollution of water resources used for aquaculture. Therefore, the assessment of feeds should be considered as important practices and monitored frequently.
- Land based facilities can be regulated under the existing waste discharge laws and regulations. The impacts are site specific and controllable with any other source of water



to estuaries. Potential problems exist where water quality standards either do not exist for some pollutants (eg: Nitrate or phosphate in estuarine waters).

- The eco-tourism activities planned and carried out should be monitored, for their impacts (negative and positive).
- It should be monitored that the native community gets maximum benefit from the eco-tourism schemes.
- It is to be monitored that the eco-tourism activities should be non-polluting and should be carried out using indigenous material.
- The number of tourists/foot fall should have a cap every season and the activities also should have upper limit considering the carrying capacity of the region/habitat/area.



RECOMMENDATION:

Sand mining is one of the most sensitive subjects in India as well as other parts of the world. It has been the issue of social conflict, environmental sustainability and administrative issues. 'Sand Mining' has been one of the most revenue generating business as direct extraction of natural resources does not require much investment or skillset or purchases of raw material for production. It has to be considered as limited natural resource with a limited ability to be replenished over long term duration. But the impacts of sand mining have been deleterious and sustainability of sand mining is always difficult. Being the most important commodity, sand is required for construction and thus the holistic development and urbanization.

The Chapora River in the State of Goa is a small river which opens up in the Arabian Sea. The present status of the river has been detailed out in this report. Considering the on-going activities including sand mining, site sensitivities, national guidelines, international best practices and concerns raised by local community as well as directions by Hon'ble NGT, following are the recommendations:

- Considering the results of the baseline, Chapora estuary has been impacted by cumulative anthropogenic activities and natural riverine and coastal processes.
- These effects have changed the geo-morphology and bathymetry at many stretches of the river/estuary. Over the years sand extraction has caused many pits and deep gorges in the lease areas as well as outside the lease areas.
- The lower stretches of the estuary are influenced by higher salinity regime thus the adjacent banks have been protected by traditional embankments. These embankments allow the locals to carry out agriculture- predominantly paddy. These traditional embankments consistently face the problem of saline water intrusion and require continuous repair and maintenance. There are several reason for the damage of embankments viz; high tidal surges, subsidence of land, removal of sand/sediment from the river bed, non-maintenance of embankments and flooding due to upstream water flow.
- The salinity intrusion has also changed the land use, converting many paddy fields and riparian zones and mudflats into mangrove areas.
- The upper stretches of river banks have experienced bank erosion at many locations and many more areas are vulnerable and prone to bank erosion.



- Based on the baseline data and the prevailing site conditions (cumulative impacts herein) sand extraction at unregulated rates or in the sensitive area will have negative impacts on the environment. Therefore minimum areas recommended by SSMG (2016) & Hon'able NGT are to be followed. Accordingly, certain areas in the stretches of the river have been demarcated where sand extraction from the river bed requires restrictions.
- The difference between the pre- and post-monsoon seismic data did not show major significant changes in the depth across the Chapora river except in few regions where the local depositions are seen with a maximum depth difference of ~0.3-0.4 m. In few regions localized changes in the river bed morphology and spatial adjustment of sand bar are observed.
- In the Chapora river the bed level changes for the post-mining scenario are mostly around -0.15 m to 0.15 m. The changes in bed morphology in the post-mining scenario at different sections of the river are highly dynamic and patchy in nature. Considering the stretches which have low sensitivities, can be considered for sand extraction while following the national statutory and legal guidelines. While recommending the lease areas the authority shall conduct a reconnaissance site survey and a consultative discussion with the stakeholders and accordingly work out areas that do not have conflict of interest.
- The sand extraction has to be conducted by traditional (manual) method only. No mechanized boats or machinery to be operated. The activity shall be restricted to the available areas (given the Fig 7.1) only and the depth of extraction should not exceed 3m from the existing baseline profiles.
- Once the lease areas are issued, the delineated "Environmental Conservation and Management Plan" needs implementation. The plan also describes the team/committee which should be capable to address, execute and monitor all the aspects of the plan. Furthermore the team/committee should appoint sub-teams, SHG's, Village committees on requirement basis as per the plan.



References

1. Higgins, R. P., & Thiel, H. (1988). *Introduction to the study of meiofauna*. Smithsonian Institution Press.
2. Fauvel, P. (1953). The Fauna of India including Pakistan, Ceylon, Burma and Malaya. Annelida Polychaeta. *Indian Press, Allahabad*, 12, 507.
3. Fauchald, K. (1977). The polychaete worms. Definitions and keys to the orders, families and genera. *Natural History Museum of Los Angeles County, Science Series*.
4. Day, J. H. (1967). A monograph on the Polychaeta of Southern Africa. *British Museum of Natural History, Publication*, (656), 1-878.
5. Clarke, K. R., & Warwick, R. M. (1994). Similarity-based testing for community pattern: the two-way layout with no replication. *Marine Biology*, 118(1), 167-176.
6. Clarke, K. R., Somerfield, P. J., & Gorley, R. N. (2008). Testing of null hypotheses in exploratory community analyses: similarity profiles and biota-environment linkage. *Journal of experimental marine biology and ecology*, 366(1-2), 56-69.
7. Borja, A., Muxika, I., & Franco, J. (2003). The application of a Marine Biotic Index to different impact sources affecting soft-bottom benthic communities along European coasts. *Marine Pollution Bulletin*, 46(7), 835-845.
8. Grall, J., & Glémarec, M. (1997). Using biotic indices to estimate macrobenthic community perturbations in the Bay of Brest. *Estuarine, Coastal and Shelf Science*, 44, 43-53.
9. Bald, J., Borja, A., Muxika, I., Franco, J., & Valencia, V. (2005). Assessing reference conditions and physico-chemical status according to the European Water Framework Directive: a case-study from the Basque Country (Northern Spain). *Marine Pollution Bulletin*, 50(12), 1508-1522.
10. Muxika, I., Borja, A., & Bald, J. (2007). Using historical data, expert judgement and multivariate analysis in assessing reference conditions and benthic ecological status, according to the European Water Framework Directive. *Marine pollution bulletin*, 55(1-6), 16-29.
11. Shannon, C. E., & Weaver, W. (1949). *The Mathematical Theory of Communication*, by CE Shannon (and Recent Contributions to the Mathematical Theory of Communication), W. Weaver. University of Illinois Press.
12. Borja, R. I., Regueiro, R. A., & Lai, T. Y. (2000). FE modeling of strain localization in soft rock. *Journal of Geotechnical and Geoenvironmental Engineering*, 126(4), 335-343.
13. Simboura, N., & Zenetos, A. (2002). Benthic indicators to use in ecological quality classification of Mediterranean soft bottom marine ecosystems, including a new biotic index. *Mediterranean Marine Science*, 3(2), 77-111.
14. Simboura, N., Panayotidis, P., & Papathanassiou, E. (2005). A synthesis of the biological quality elements for the implementation of the European Water Framework Directive in the Mediterranean ecoregion: the case of Saronikos Gulf. *Ecological indicators*, 5(3), 253-266.



15. Zenetos, A., Hatzianestis, J., Lantzouni, M., Simbouna, M., Sklivagou, E., & Arvanitakis, G. (2004). The Eurobulker oil spill: mid-term changes of some ecosystem indicators. *Marine Pollution Bulletin*, 48(1-2), 122-131.
16. Rayner, N. A. A., Parker, D. E., Horton, E. B., Folland, C. K., Alexander, L. V., Rowell, D. P., ... & Kaplan, A. (2003). Global analyses of sea surface temperature, sea ice, and night marine air temperature since the late nineteenth century. *Journal of Geophysical Research: Atmospheres*, 108(D14).
17. Gannon, J. E., & Stemberger, R. S. (1978). Zooplankton (especially crustaceans and rotifers) as indicators of water quality. *Transactions of the American Microscopical Society*, 16-35.
18. Gajbhiye, S. N., & Desai, B. N. (1981). Zooplankton variability in polluted and unpolluted waters off Bombay. *Mahasagar*, 14(3), 173-182.
19. Telkhade, P. M., Dahegaonkar, N. R., Zade, S. B., & Lonkar, A. N. (2008). Quantitative analysis of phytoplankton and zooplankton of Masala lake, Masala, Distt. Chandrapur, Maharashtra. *Environment Conservation Journal*, 9(1-2), 37-40.
20. Mauch, M., Cannam, C., Davies, M., Dixon, S., Harte, C., Kolozali, S., ...& Sandler, M. (2009). OMRAS2 metadata project 2009. In *Proc. of 10th International Conference on Music Information Retrieval* (p. 1).
21. Jyothibabu, R., Jagadeesan, L., & Lallu, K. R. (2016). Copepod carcasses in a tropical estuary during different hydrographical settings. *Environmental monitoring and assessment*, 188(10), 559.
22. Magurran, A. E. (1988). *Ecological diversity and its measurement*. Princeton university press.
23. Alioli, S., Nason, P., Oleari, C., & Re, E. (2009). NLO single-top production matched with shower in POWHEG: s-and t-channel contributions. *Journal of High Energy Physics*, 2009(09), 111.
24. De-la-Ossa-Carretero, J. A., Del-Pilar-Ruso, Y., Giménez-Casaldueiro, F., Sánchez-Lizaso, J. L., & Dauvin, J. C. (2012). Sensitivity of amphipods to sewage pollution. *Estuarine, Coastal and Shelf Science*, 96, 129-138.
25. Naiman, R. J., Bechtold, J. S., Drake, D. C., Latterell, J. J., O'keefe, T. C., & Balian, E. V. (2005). Origins, patterns, and importance of heterogeneity in riparian systems. In *Ecosystem function in heterogeneous landscapes* (pp. 279-309). Springer, New York, NY.
26. Watson, A. J., & Basher, L. R. (2006). Stream bank erosion: a review of processes of bank failure, measurement and assessment techniques, and modelling approaches. *A report prepared for stakeholders of the Motueka Integrated Catchment Management Programme and the Raglan Fine Sediment Study*. Landcare Research, Hamilton, New Zealand.
27. <http://www.realbirder.com/Goa%20-%20Morjim%20Beach.htm>
28. <https://fsi.nic.in/isfr19/vol2/isfr-2019-vol-ii-go.pdf>



29. National Research Council. (2002). *Scientific research in education*. Committee on Scientific Principles for Education Research. Shavelson, R.J., and Towne, L., Editors. Center for Education. Division of Behavioral and Social Sciences and Education. Washington, DC: National Academy Press.
30. Naiman, R. J., Bechtold, J. S., Drake, D. C., Latterell, J. J., O'keefe, T. C., & Balian, E. V. (2005). Origins, patterns, and importance of heterogeneity in riparian systems. In *Ecosystem function in heterogeneous landscapes* (pp. 279-309). Springer, New York, NY.
31. Sathish, K., Blessen, S. T., & Alex, C. (2012). An Experimental Study of the Properties of Glass Fiber Reinforced Geopolymer Concrete. *International Journal of Engineering Research and Applications*, 2(6), 722-726.
32. Fernández-Ledesma, E., Jiménez, J. R., Ayuso, J., Corinaldesi, V., & Iglesias-Godino, F. J. (2016). A proposal for the maximum use of recycled concrete sand in masonry mortar design. *Materiales de Construcción*, 66(321), 075.
33. Taha, Y., Benzaazoua, M., Mansori, M., Yvon, J., Kanari, N., & Hakkou, R. (2016). Manufacturing of ceramic products using calamine hydrometallurgical processing wastes. *Journal of Cleaner Production*, 127, 500-510.
34. Rana, A., Kalla, P., Verma, H. K., & Mohnot, J. K. (2016). Recycling of dimensional stone waste in concrete: A review. *Journal of cleaner production*, 135, 312-331.
35. Shettima, A. U., Hussin, M. W., Ahmad, Y., & Mirza, J. (2016). Evaluation of iron ore tailings as replacement for fine aggregate in concrete. *Construction and Building Materials*, 120, 72-79.