NATIONAL CENTRE FOR
SUSTAINABLE COASTAL MANAGEMENT
Ministry of Environment and Forests, Government of India

ANNUAL REPORT
2014 - 2015

Published by
National Centre for Sustainable Coastal Management
Ministry of Environment, Forests and Climate Change
Anna University Campus, Chennai

Citation
NCSCM Annual Report 2015. National Centre for Sustainable Coastal Management, Ministry of Environment, Forests and Climate Change. Chennai, p232.

Design and Print
Majix Design, Chennai

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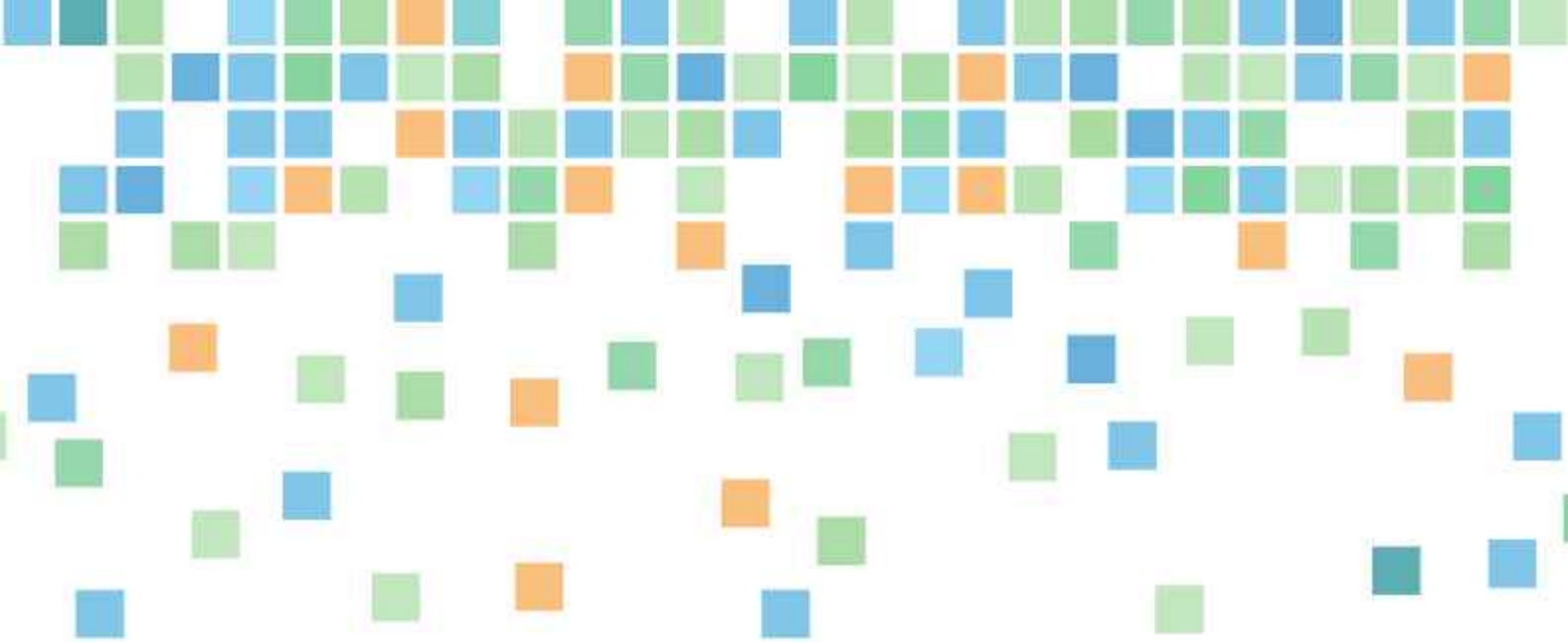


Preface

Complex and diverse types of natural processes that occur on the coastal zone bring in physical, chemical, and biological changes to the fragile coastlines. Human activities in the coastal zone add yet another dimension affecting changes to our coastlines. Considering the growing need for sustainability of the coast, the Ministry of Environment and Forests (MoEF), Government of India established the National Centre for Sustainable Coastal Zone Management (NCSCM) in February 2011 to be a world class institution for sustainable coastal management witha strong research and knowledge base.

NCSCM, MoEF identified research institutes in each of the Coastal State/UTs under the "Anna University Declaration" to enable representative coastal universities and institutions function in a Consortium mode. NCSCM has an advanced and multi-disciplinary research agenda, spanning physical, chemical, biological, social and economic disciplines through field surveys and extensive remote sensing and GIS applications. NCSCM has for the first time mapped the entire coastline of India to assess the shoreline change and to enhance the country's preparedness to coastal hazards. The MoEF has evolved the concept of preparing the Integrated Coastal Zone Management (ICZM) Plan for the Country's coastline for which NCSCM is providing the Guidelines to the Coastal States! UTs. NCSCM is also undertaking the delineation of Coastal Sediment Cells and mapping of Ecologically Sensitive Areas, with emphasis on traditional knowledge.

I wish to thank the Hon'ble Union Minister of Environment and Forest and Climate Change and the High Power Research Steering Committee for setting high standards of research goals for NCSCM. I would like to thank Secretary E&F for the continued support and guidance on the research programmes. The support provided by the Vice Chancellor, Anna University & Chairman, Governing Council, the Registrar and all the members of the Governing Council is greatly acknowledged. The immense support of National Project Director and Shri Tapas Paul, Task Team Leader, World Bank are gratefully acknowledged. The activities and periodic updates are available at the NCSCM website www.ncscm.res.in

National Centre for Sustainable Coastal Management (NCSCM) is established as an autonomous institution, with an aim to become a world-class institution for coastal and marine area management with adequate human resources, facilities and assured long-term funding. It would promote integrated and sustainable management of coastal and marine areas in India and advice the Union and State Governments and other associated stakeholder(s) on policy, and scientific matters related to Integrated Coastal Zone Management (ICZM). The Centre is established within the Anna University Campus, Chennai. Fourteen institutions have formed a consortium with NCSCM, with Anna University Chennai as the Hub. The Centre will become a centre for excellence within India on coastal research, management.

NCSCM would guide and coordinate the implementation of ICZM approaches leading to enhanced conservation of coastal resources and sustainable development along the coast of India through applied and futuristic research. The centre would develop a central repository of information and knowledge on ICZM practices in India and elsewhere. The centre will partner with national and similar international institutes to share knowledge in protection, conservation and management of the coastal areas. Further, NCSCM would promote technically sound and practical management approaches to ICZM. The outputs from research at NCSCM would aid in the better protection, conservation, rehabilitation, management and policy design of the coast.

High Powered Research Steering Committee (HPSC)

- Union Minister for Environment and Forests [Ex-Officio Chairperson]
- Prof. M.S. Swaminathan, Former Member of Parliament (Rajya Sabha) [Expert Member]
- Dr. K. Kasturirangan, Former Member, Planning Commission [Expert Member]
- Dr. K. Radhakrishnan, Chairman, ISRO, Bangalore [Expert Member]
- Secretary, Ministry of Environment, Forests and Climate Change (MoEF&CC) [Ex-Officio Member]
- Vice Chancellor, Anna University, Chennai [Ex-Officio Member]
- Adviser, Impact Assessment Division, MoEF&CC [Ex-Officio Member]
- Director, National Centre for Sustainable Coastal Management, MoEF&CC, Chennai [Ex-Officio Member]
- National Project Director, SICOM, MoEF&CC [Ex-Officio Member-Secretary]

Governing Council (GC)

- Vice Chancellor, Anna University, Chennai [Ex-Officio Chairperson]
- Secretary/ Additional Secretary, MoEF [Ex-Officio Member]
- Dr. K. Kasturirangan, Member, Planning Commission [Expert Member]
- Dr. Shailesh Nayak, Secretary, MoES [Expert Member]
- Dr. K. Radhakrishnan, Chairman, ISRO [HPSC Representative]
- Director, National Remote Sensing Centre, Department of Space [Ex-Officio Member]
- Chairman, CPCB [Ex-Officio Member]
- Registrar, Anna University, Chennai [Ex-Officio Member]
- National Project Director, SICOM, MoEF [Ex-Officio Member]
- Adviser (E&F), Planning Commission [Ex-Officio Member]
- Director, NIO, Goa [Ex-Officio Member]
- Surveyor General of India, Survey of India, Dehradun [Ex-Officio Member]
- Director, NIOT, Chennai [Ex-Officio Member]
- Director, NLSIU, Bangalore [Ex-Officio Member]
- Director, Centre for Climate Change & Adaptation Research, Anna University, Chennai [Ex-Officio Member]
- Director General (Fisheries), ICAR, New Delhi [Ex-Officio Member]
- Prof. A. Jayaraman, National Atmospheric Research Laboratory, Tirupati [Expert Member]
- Prof. G.M. Samuel Knight, Professor of Civil Engineering, Anna University, Chennai [Expert Member]
- Prof. M. Sekar, Dean, College of Engineering Guindy, Anna University, Chennai [Expert Member]
- Director, NCSCM [Ex-Officio Member-Secretary]

Vision

"Promote sustainable coasts through increased partnerships, conservation practices, scientific research and knowledge management for the benefit and wellbeing of current and future generations"

Goals

NCSCM has the following primary goals:

- To become a world class institution for sustainable coastal management with a strong research and knowledge base
- Create a Consortium of Institutions in India to strengthen capacity in multi-disciplinary research related to coastal management

Objectives:

A. Strive to become and remain a World-class knowledge institution pertaining to understanding coastal zones and coastal processes, and pertaining to integrated planning and management of coastal and marine areas

B. Promote integrated and sustainable management of the coastal and marine areas in India for the benefit and wellbeing of the traditional coastal and island communities

C. Advice the Union and State Governments and other associated stakeholder(s) on policy, and scientific matters related to ICZM

Mission & Role

environment for livelihood security, sustainable development and hazard risk management by enhancing:

- **Knowledge**
- **Research and Advisory Support**
- **Partnerships and network**
- **Coastal Community interface**

Administration of the institute rests

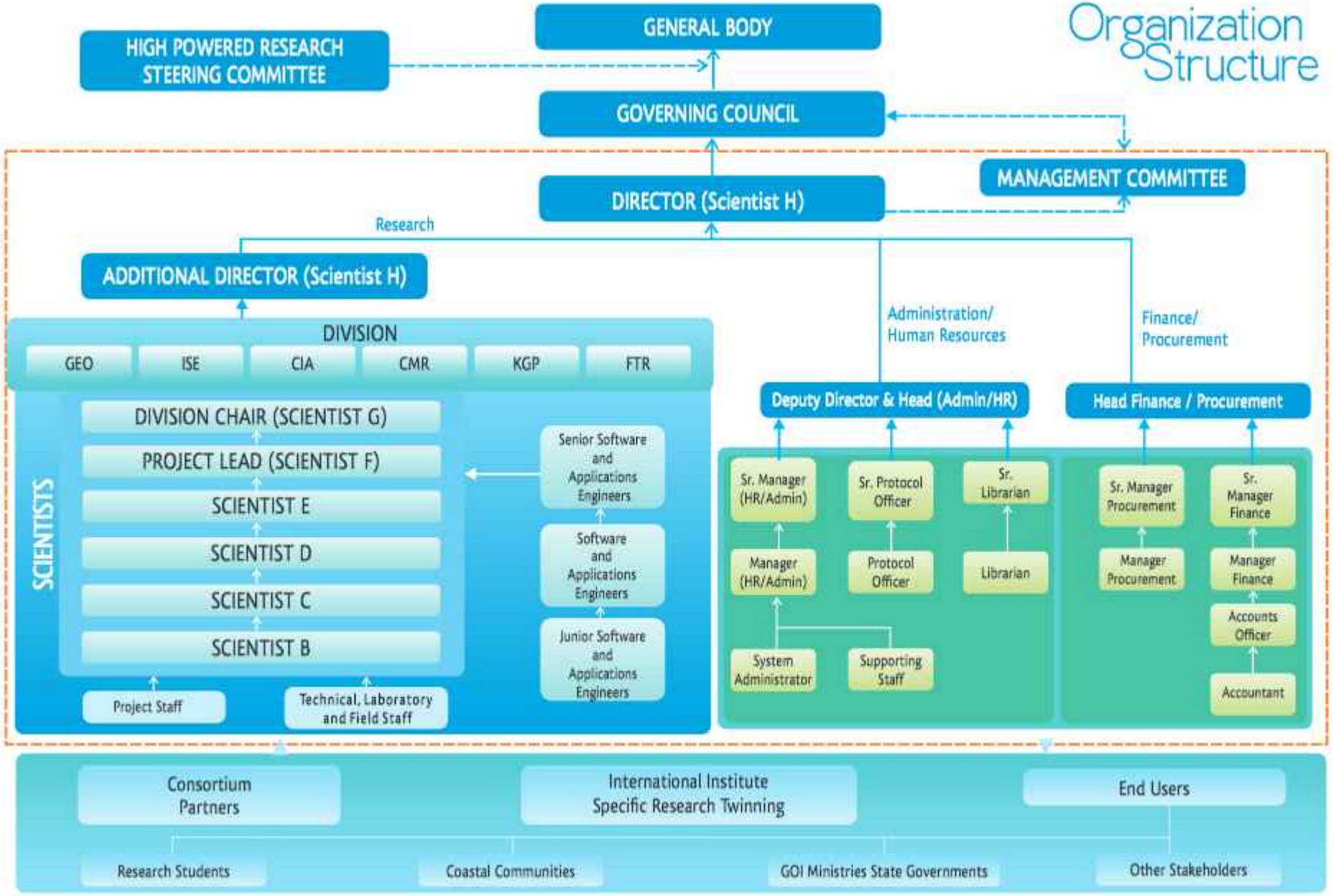
Organization Structure

with the Director, who receives support from both research divisions and administration. The High Powered Research Steering Committee (HPSC), the Governing Council (GC) and the Managing Committee (MC) review and monitor the research programmes and facilitate to identify new research thrust areas for the Institute.

To accomplish the mandate, the research activities are organized under seven divisions namely:

- Geospatial Sciences (GEO) Division
- Integrated Social Sciences & Economics (ISE) Division
- Coastal Environmental Impact Assessment (CIA) Division
- Conservation of Coastal and Marine Resources (CMR) Division
- Knowledge, Governance & Policy (KGP) Division
- Futuristic Research (FTR) Division
- Integrated Island Management (IIM) Unit of FTR Division

Organization Structure



NPMU Research Programme

NCSCM undertakes advanced CRZ 2011 and Climate Change related research and promotes integrated and sustainable management of coastal and marine areas in India. It advices the Union and State Governments and other associated stakeholder(s) on policy, and scientific matters related to ICZM. The Centre is developing partnership with National and similar international institutions to share knowledge in protection, conservation and management of the coastal areas. Further, the centre is promoting technically sound and practical management approaches to ICZM. The Centre is executing three major National Projects such as i) Delineation of coastal sediment cells ii) High resolution erosion mapping along with the Survey of India as a part of delineating the Hazard Line and iii) Mapping of Ecologically Sensitive Areas.

NCSCM has undertaken the task of mapping the ecologically sensitive areas along the entire coast of India as required under CRZ 2011 notification.


GEO

Geospatial Sciences

The objective of the GEO Division is to provide scientific decision support system to promote sustainable use of coastal resources by employing state-of-art Geographic Information Systems (GIS) and field surveys. The major groups under GEO division are: (i) Land Survey (ii) Hydrographic Survey (iii) Cartography (iv) Digital Photogrammetry, Digital Image Processing and ALTM Laboratory and (v) GIS Work Centre and Data Warehousing.

Delineation of sediment cells is envisaged to identify and demarcate the Indian coast into various sediment cells on the basis of the sediment movement along the coast. Demarcation of sediment cells is based on key criteria which are explained in detail in the sections below. These sediment cells are essential to understand the coastal sediment budget and stability of the coast. The outcome of the research study can be used as a key factor in Integrated Coastal Zone Management Plan. A detailed report of the research study is given below.

Delineation of Sediment Cells for the East & West Coast of India

Delineation of sediment cells is envisaged to identify and demarcate the Indian coast into various sediment cells on the basis of the sediment movement along the coast. Demarcation of sediment cells is based on key criteria which are explained in detail in the sections below. These sediment cells are essential to understand the coastal sediment budget and stability of the coast. The outcome of the research study can be used as a key factor in Integrated Coastal Zone Management Plan. A detailed report of the research study is given below.

Coastal erosion is one of the critical issues owing to various developmental activities along the coast. Apart from natural conditions, increased human activities along the coast has reflected in dynamic shifing of shoreline positions. Hence an understanding and proper application of short-term (decadal changes) and long-term (> 30 years) shoreline changes are identified as critical components for effective shoreline management. With this objective, High resolution erosion mapping project is undertaken to determine the state of the nation's coast and to map the extent of erosion/ accretion along the entire mainland coast of India from 1975– 2010 (35 years) and to extrapolate the erosion/ accretion data for the next 100 years. This research study will help in identifying the critically eroding areas that need coastal protection measures and proper planning on utilization of the coast. The outcome of the study is the horizontal displacement of the coast (Erosion extent) is being used as one of the two primary factors (Erosion and flood extent on the coast) to determine the Hazard line for the Indian coast.

There is increasing pressure on the coastal zone from numerous user groups utilizing various coastal resources. Consequently, comprehensive planning is required in order to ensure a balanced development taking into account all demands and restrictions. In India, a number of developmental activities are being carried out along the coast (such as construction or expansion of ports and harbours/ power plants/ tourism development/ desalination plants etc.). Coastal structures constructed as part of these activities have been found to affect sediment transport. The sediment budget and the transport rates, chiefly governed by the coastal processes prevalent in the area play vital roles in determining the stability of the coast. Hence there is a need to understand coastal sediment budgets and their inter-relationship with coastal management schemes. As the sediment budget and processes vary from one coastal area to another, there is a need to demarcate coastal areas based on these properties. For this purpose, the concept of sediment cell is to be adopted and the entire coast of India needs to be divided into a series of coastal sediment cells.

A coastal sediment cell can be defined as length of the coastline and associated near-shore areas where movement of sediments is largely self-contained. Each cell contains a complete cycle of sedimentation including sources, transport paths and sinks. The sediment cells thus identified are categorized as primary cell, sub-cell and management units based on certain unique key criteria for each type. The criteria for delineating the sediment cells are given below. The outcome of the study can be used as a key factor in Integrated Coastal Zone management plan especially to deal with shoreline changes by preparing the Shoreline Management Plans.

Delineation of sediment cells for entire mainland of India was done by studying the coastal geomorphology, coastal land use/ land cover, coastal & marine habitats, coastal processes such as wave/wind/current, littoral drift pattern, sediment budget and near shore bathymetry, decadal shoreline changes and coastal structures. Based on the above mentioned criteria, the coastal sediment cells have been classified into three categories namely, i) Primary Cells ii) Sub Cells and iii) Management Units.

The major criteria for delineation include coastal geomorphology, source of sediments, stores of sediments, interface of rocky-sandy-muddy coast for delineating primary cells. Based on the above criteria; the Indian coast has been delineated into 27 Primary Cells with 10 cells on the West Coast as shown in Fig. 1 and 17 cells on the East Coast as shown in Fig. 2.

Methodology for Delineation of Sub Cells

Sub cells divide the Primary Cells into smaller units, which exhibit similar sediment transport characteristics and are bounded by features around which sediment bypass is small during normal conditions, although there may be considerable bypass during extreme events. The sediment within a sub cell may get interrupted by major and minor morphological features along the shore, alignment of the coast, littoral drift nature of the coast, major man-made structures, erosion /accretion rates along the coast on a decadal scenario and tidal inlets/ river mouths along the coast.

Accordingly, delineation of sub-cells has been based on the following criteria: man-made littoral barriers, alignment of the coast, tidal inlets/river mouths, erosion /accretion along the coast and littoral drift pattern. Based on the above criteria, the 10 primary cells in the west coast are further delineated into 21 sub cells as shown in Fig. 8. Similarly the 17 primary cells of the east coast are further delineated into 38 sub cells as shown in Fig. 7.

On the basis of the criteria such as geomorphology (Fig. 5), sediment sources (Fig. 6), stores of sediment (Fig. 7) and interface of rocky-sandy-muddy coast (Fig. 8), 27 Primary Cells (PC) boundaries have been identified for the Indian mainland. Each PC boundary satisfies the criteria stated above for the sediments to remain within the sediment cell with minimum or negligible leakage to the adjacent cells even under extreme coastal hazard conditions. A few examples of PCs delineated based on each criteria are given in Fig. 3 to Fig. 6

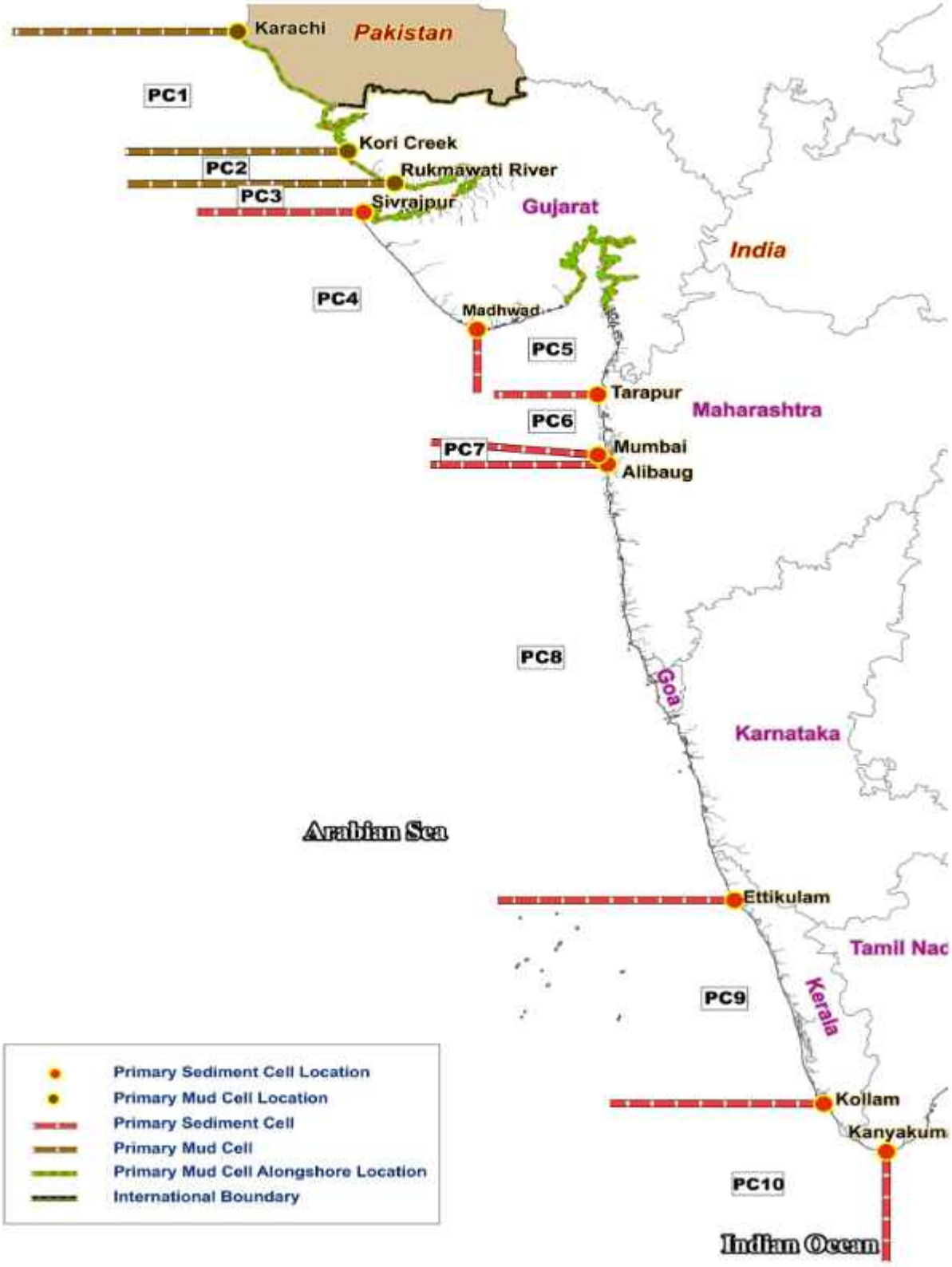


Fig. 1. Primary Sediment cells along the West Coast of India

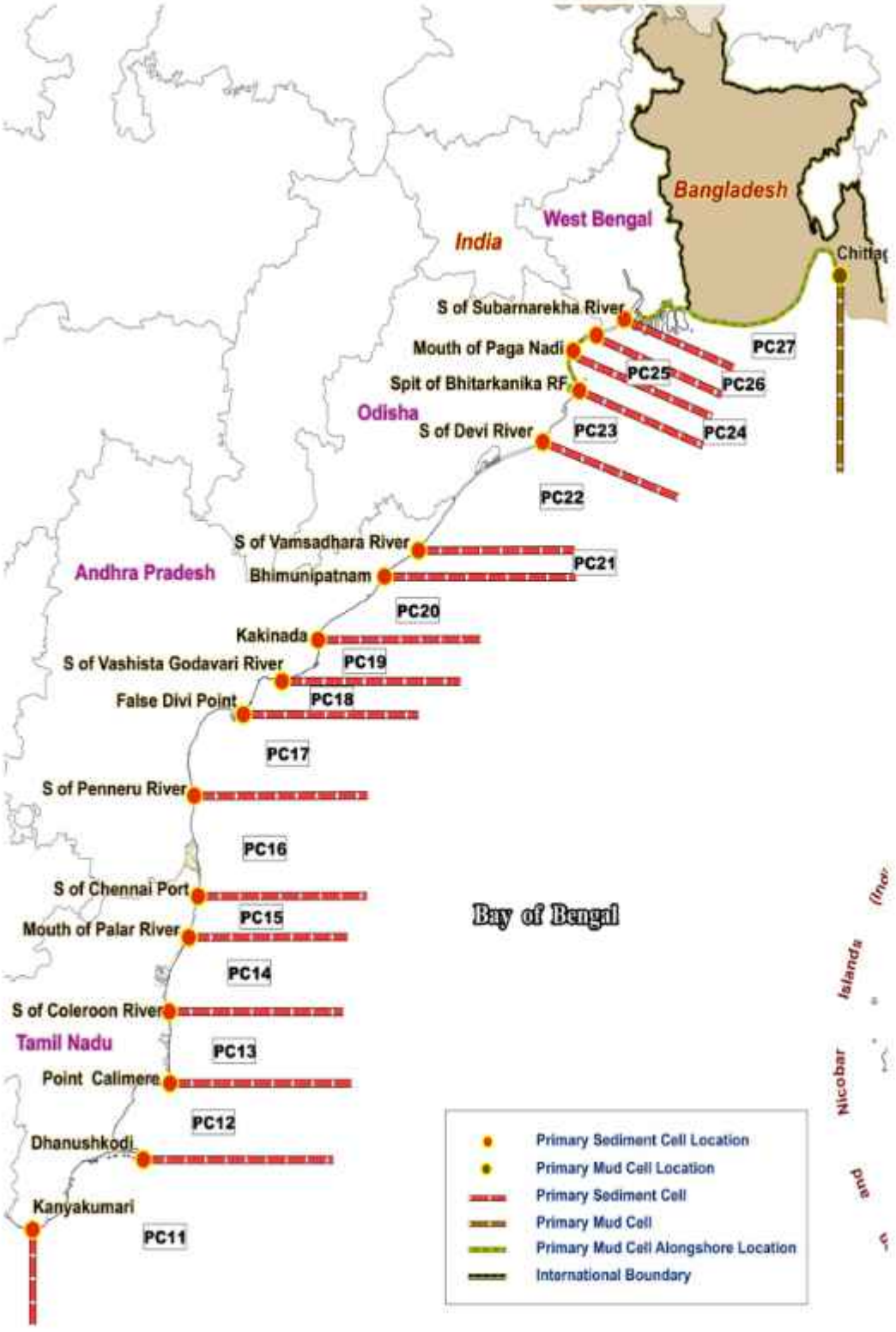


Fig. 2. Primary Sediment cells along the East Coast of India

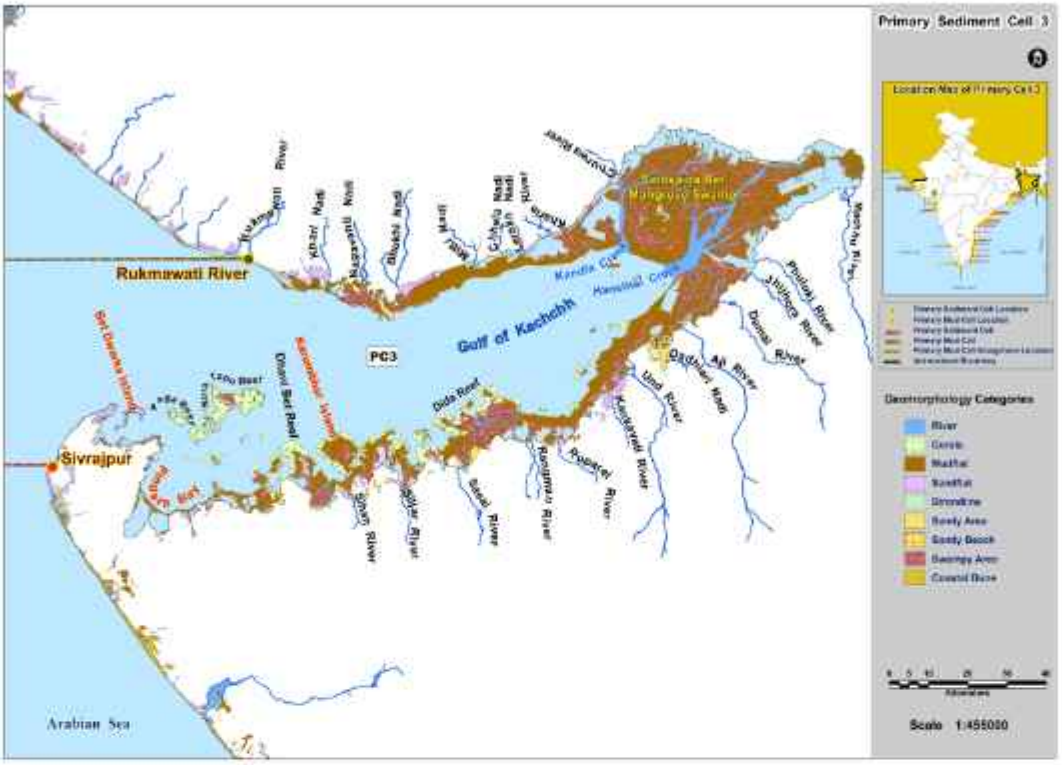


Fig. 3. Primary Cell delineated based on coastal geomorphology

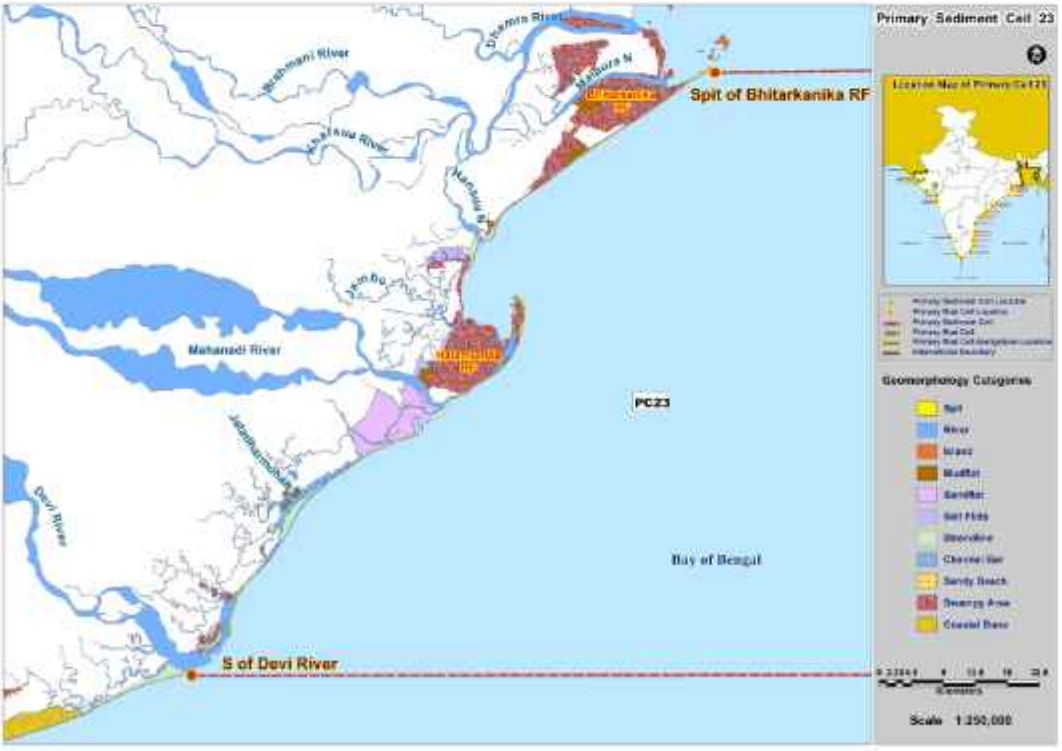


Fig. 4. Primary Cell delineated based on source of sediments

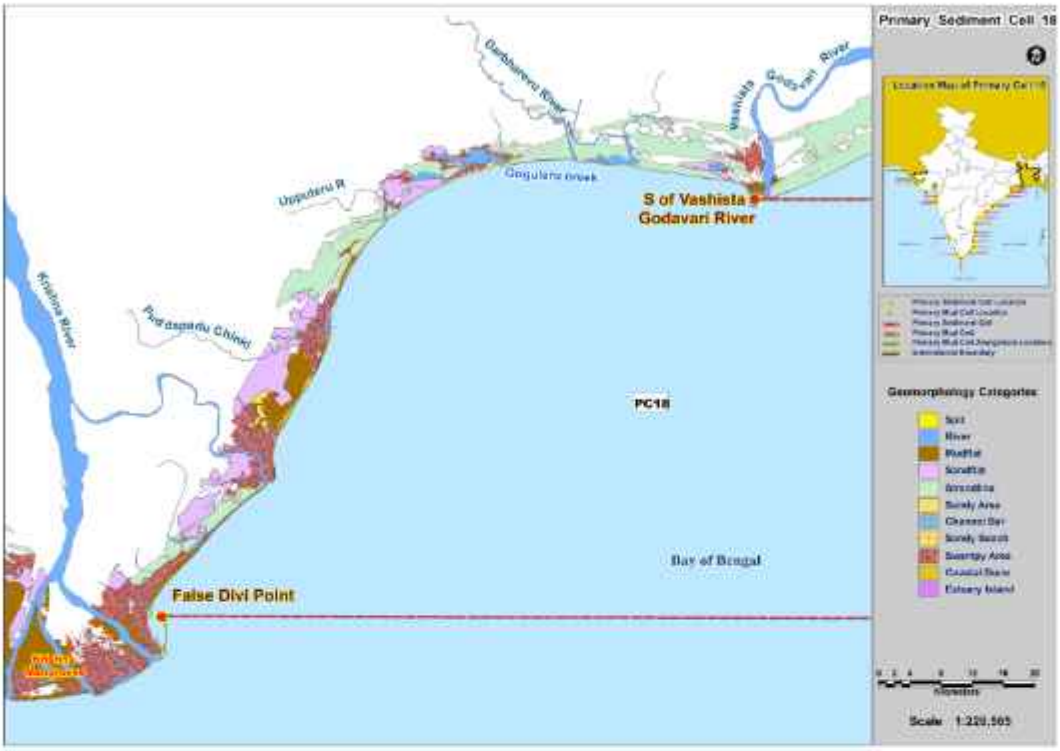


Fig. 5. Primary Cell delineated based primarily on stores of sediment

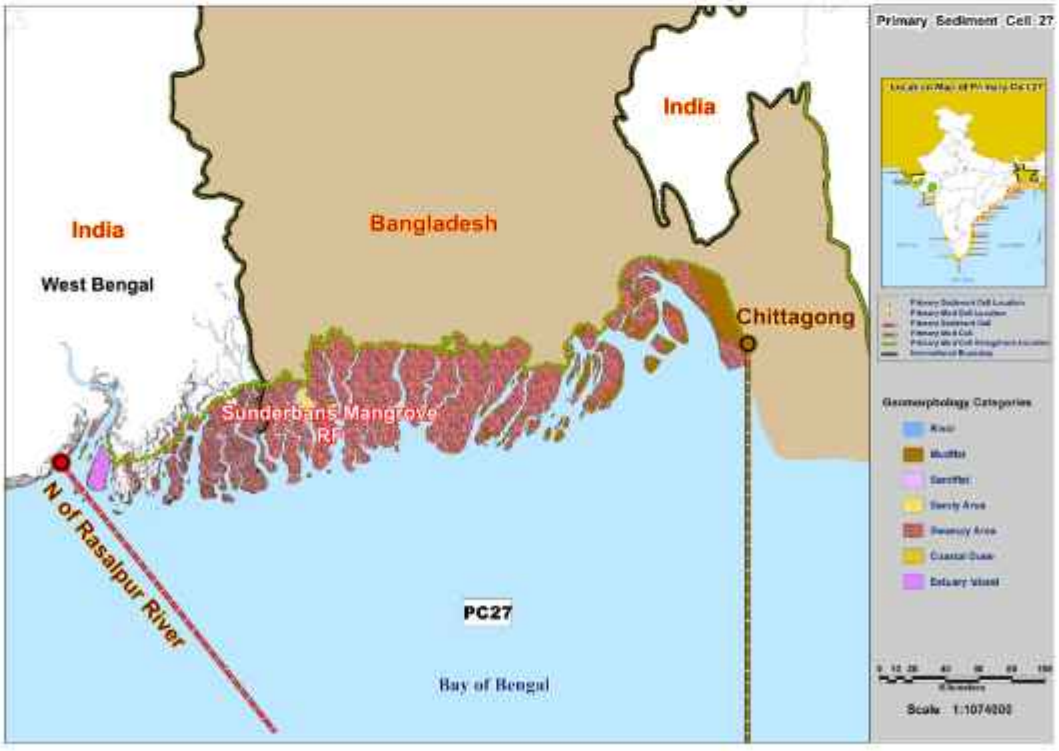


Fig. 6. Primary cell delineated based on sandy-muddy interface

Fig. 8. Sediment Sub cells along the West coast of India

Fig. 9. Sediment Sub cells along the East coast of India

The major criteria, namely, man-made littoral barriers (Figs. 10a & b), coastal alignments (Figs. 11a & b), tidal inlets (Fig.12), coastal erosion/accretion (Fig. 13) and littoral drift pattern (Fig. 14) were used for the delineation of the sub cells.

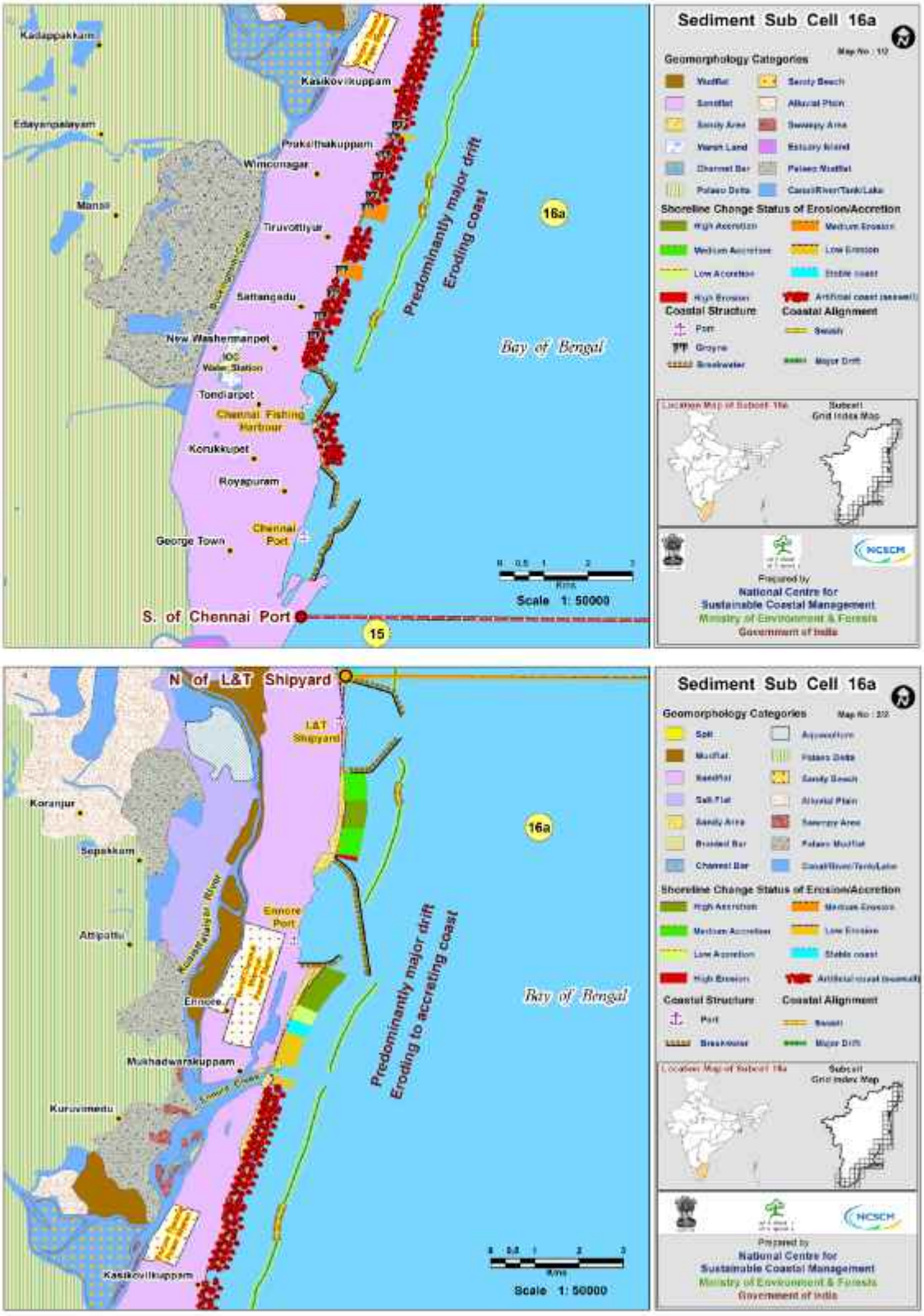


Fig. 10 a & b: Delinea tion of Sub cells based on man-made barriers

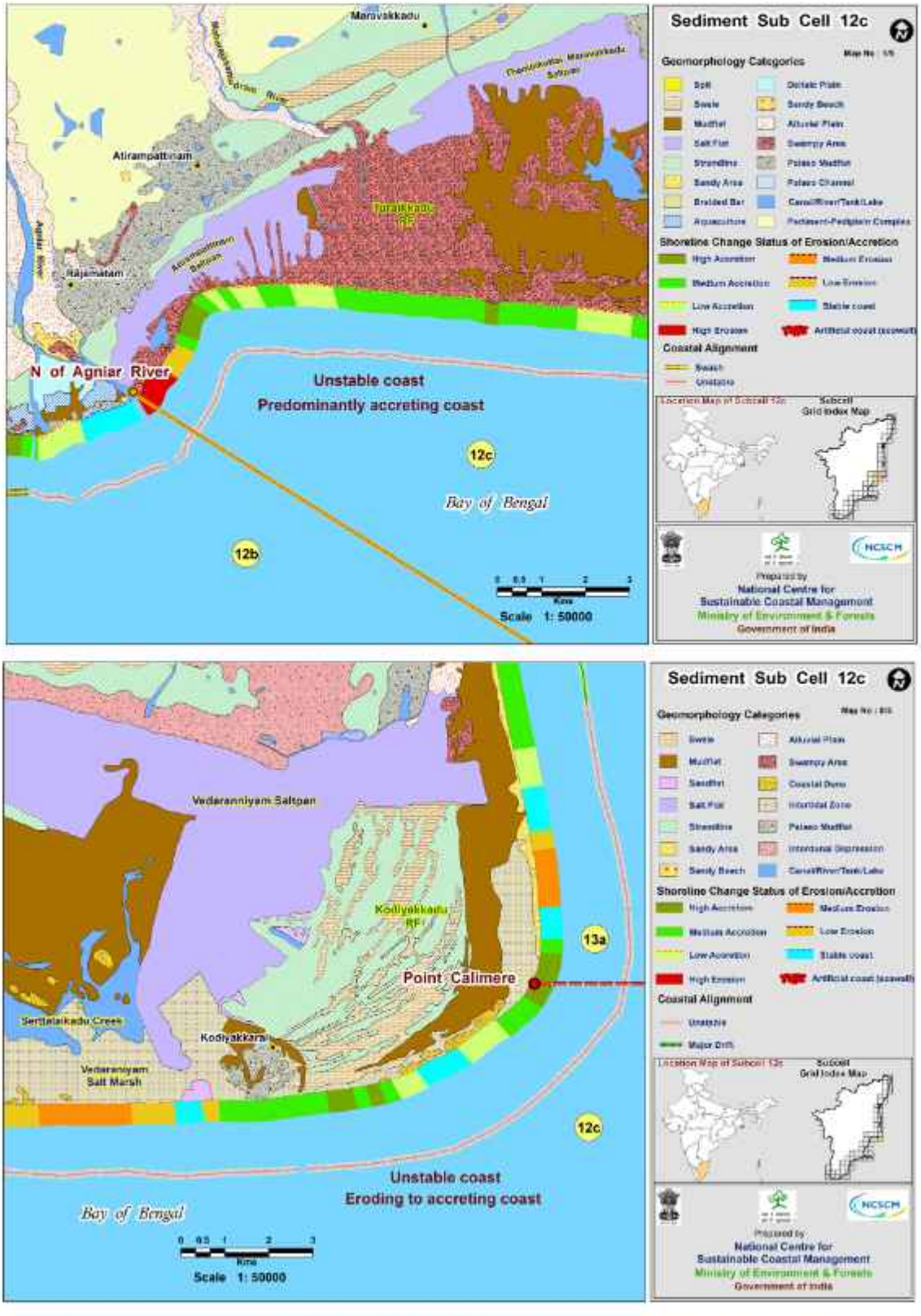


Fig. 11 a & b: Delineation of sub cell on the basis of change in coastal alignment

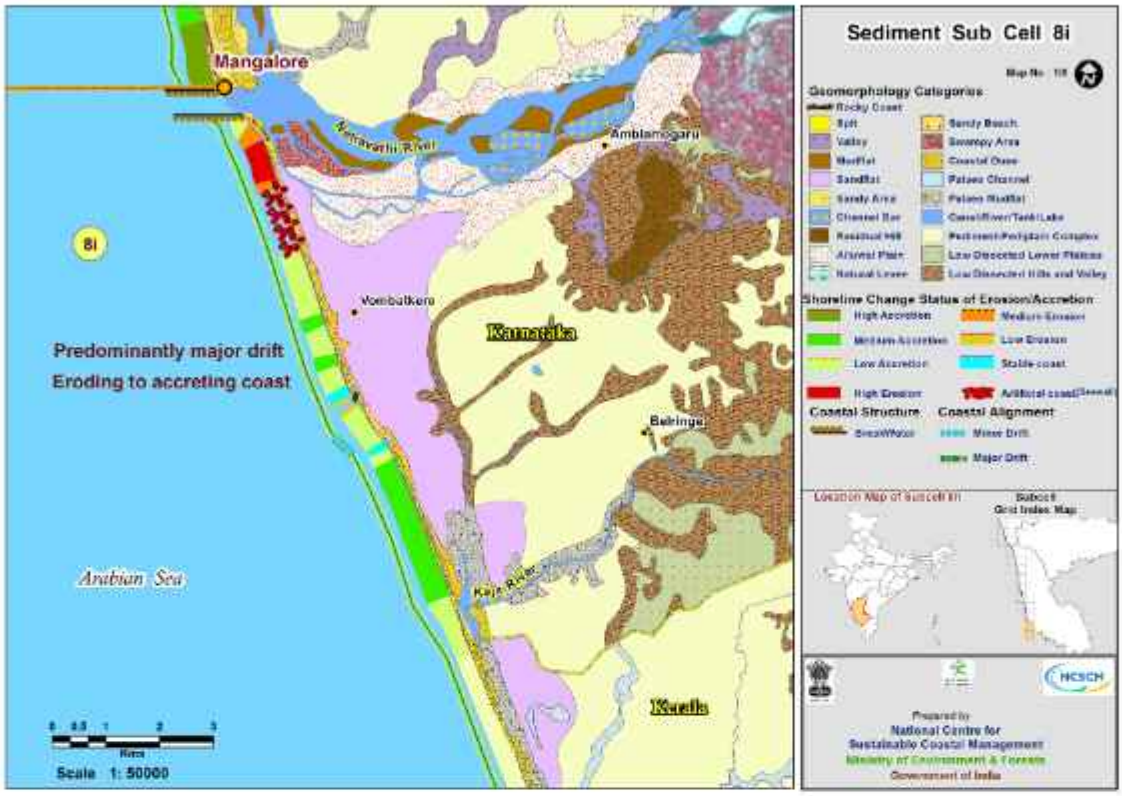


Fig. 12. Delineation of sub-cells on the basis of influence of tidal inlets

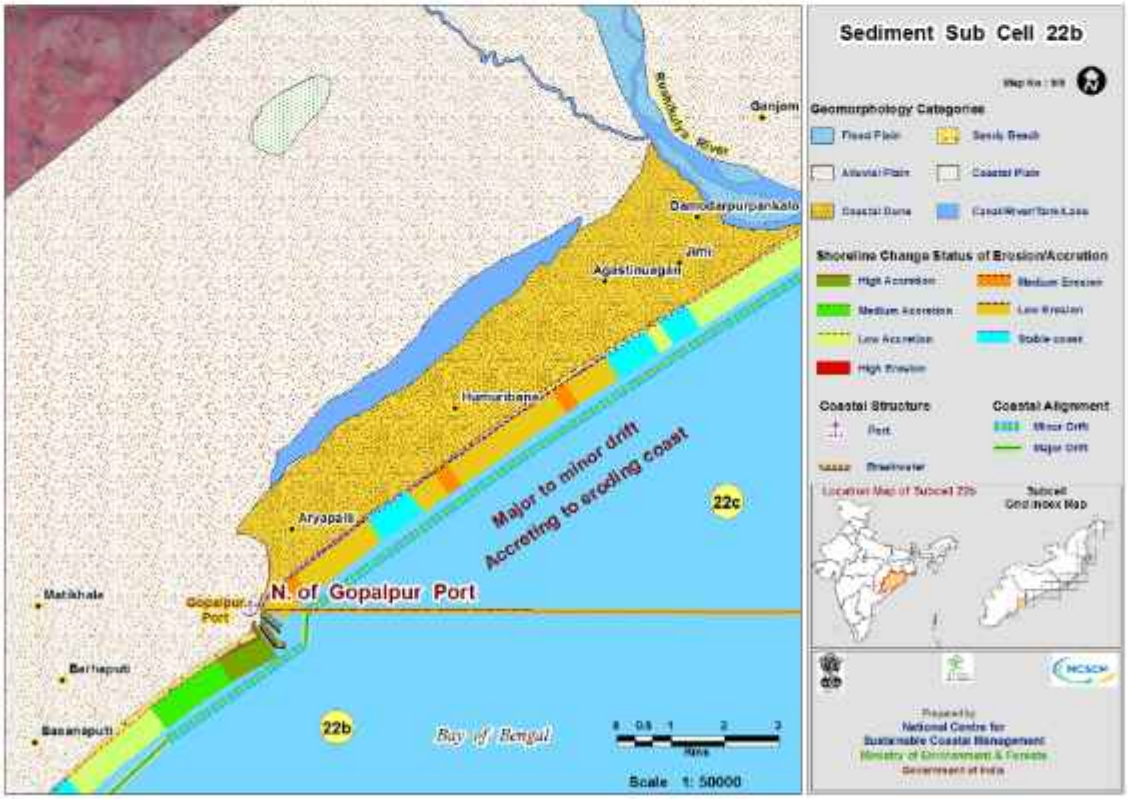


Fig. 13. Delineation of sub-cells based on shoreline change

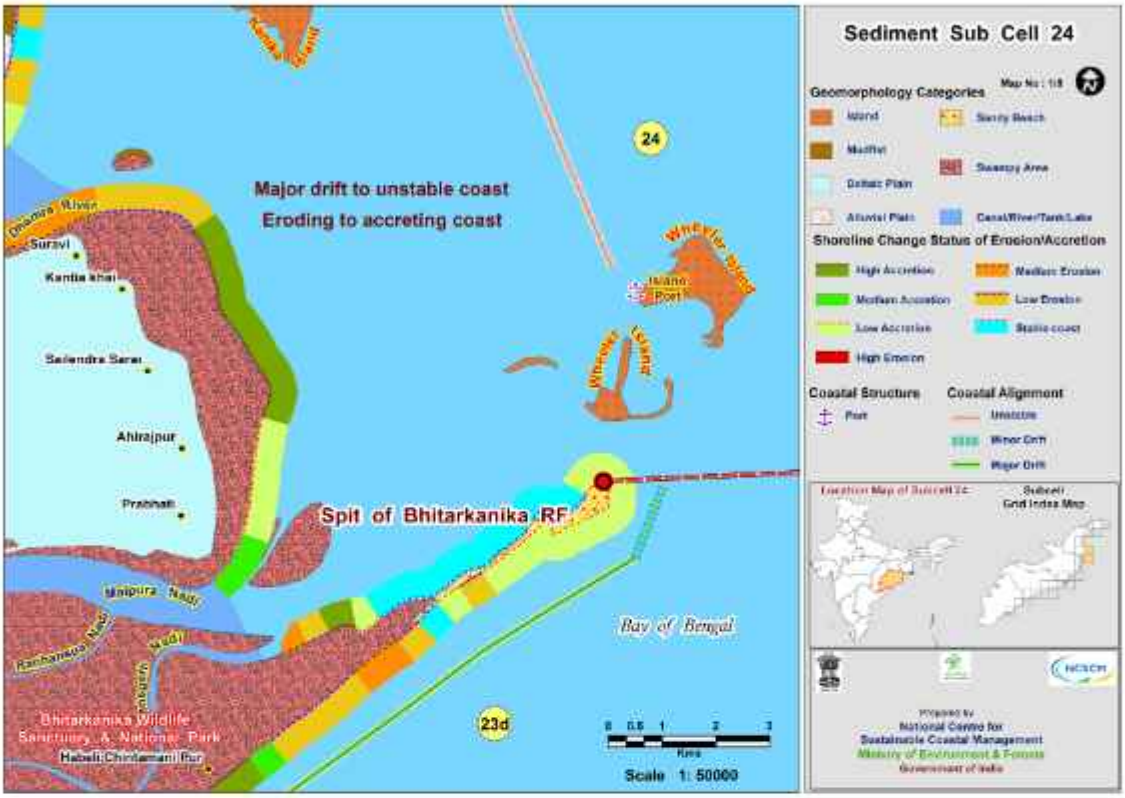


Fig. 14. Delineation of sub-cell on the basis of littoral drift

The primary aim of this research study is to determine the state of the nation's coast and to map the extent of erosion/ accretion along the entire mainland coast of India from 1975 – 2010 (35 years) and to extrapolate the erosion/ accretion data for the next 100 years

High Resolution Erosion/ Accretion Mapping for the Coast of India

India has 7,500 km coastline (~5,400 km on the main land) and about 250 million people are living within 50 km distance from the shore. India's mainland coastal stretch of 5,422 km has undergone tremendous changes due to varying natural and human induced coastal activities. Apart from these factors, the shorelines are constantly oscillating in response to winds, waves, tides, currents, sediment supply and changes in relative sea level. These cyclic and non-cyclic processes change the position of the shoreline over a variety of time scales, from the daily and seasonal interaction of winds and waves, to changes in sea level over thousands of years. Furthermore, shoreline changes are not constant through time and frequently reverse in sign, i.e. accretion to erosion, and vice versa. The changing shoreline due to natural causes with additional human influences on coastal processes makes it imperative to determine whether the long or short term rates of change reflect the current shoreline dynamics

This analysis is complicated in areas that exhibit trend reversals (erosion to accretion, and vice versa), or where human activities, such as revetment construction, have affected sediment sources and altered shoreline processes.

The primary aim of this research study is to determine the state of the nation's coast and to map the extent of erosion/accretion along the entire mainland coast of India from 1975 – 2010 (35 years) and to extrapolate the erosion/ accretion data for the next 100 years (Fig. 17).

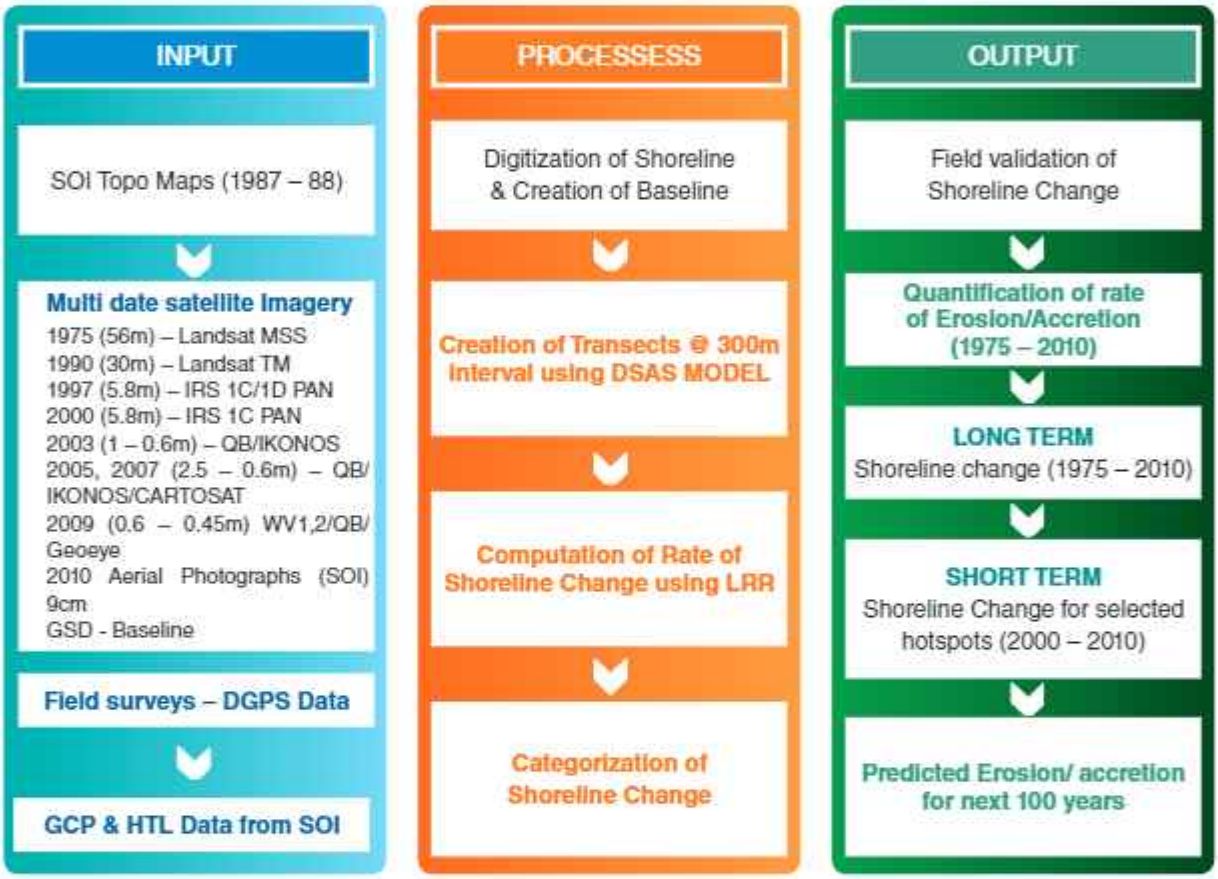
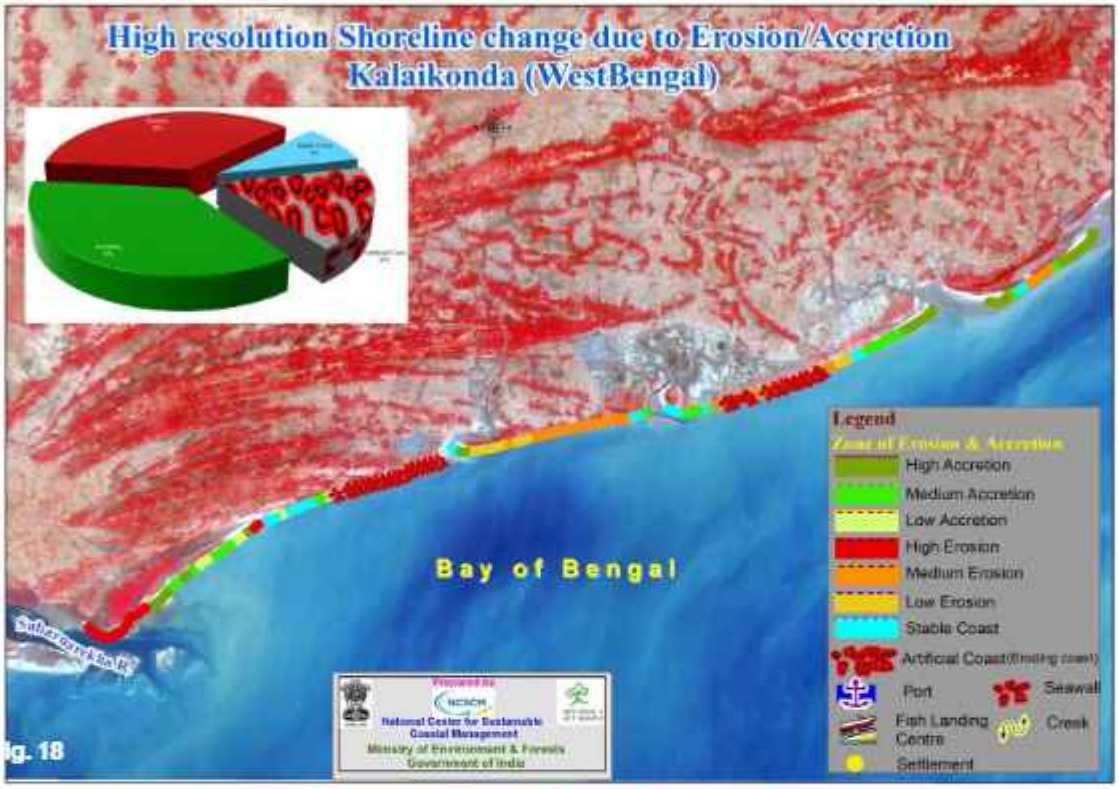
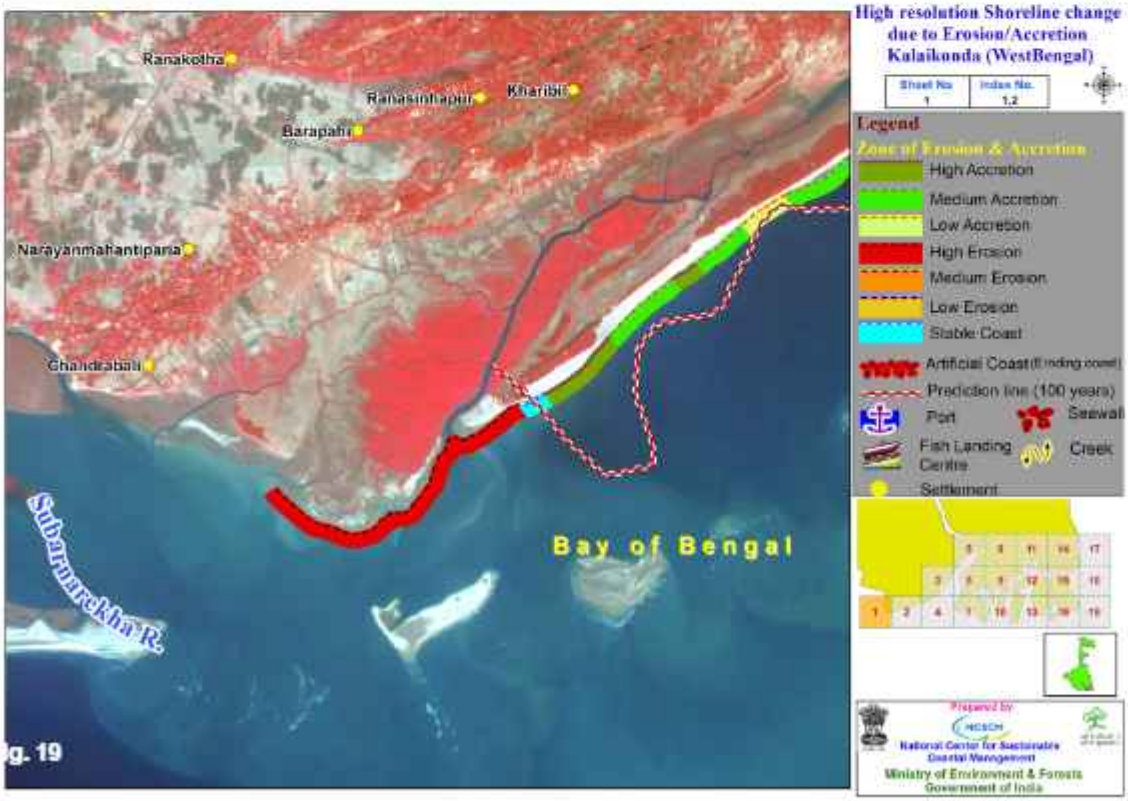


Fig. 17. Methodology for High Erosion Line Mapping

High Resolution Erosion / Accretion status and 100 years predicted Erosion Line for Dighalo in West Bengal is shown below in Figs. 18 through 23.



g. 18



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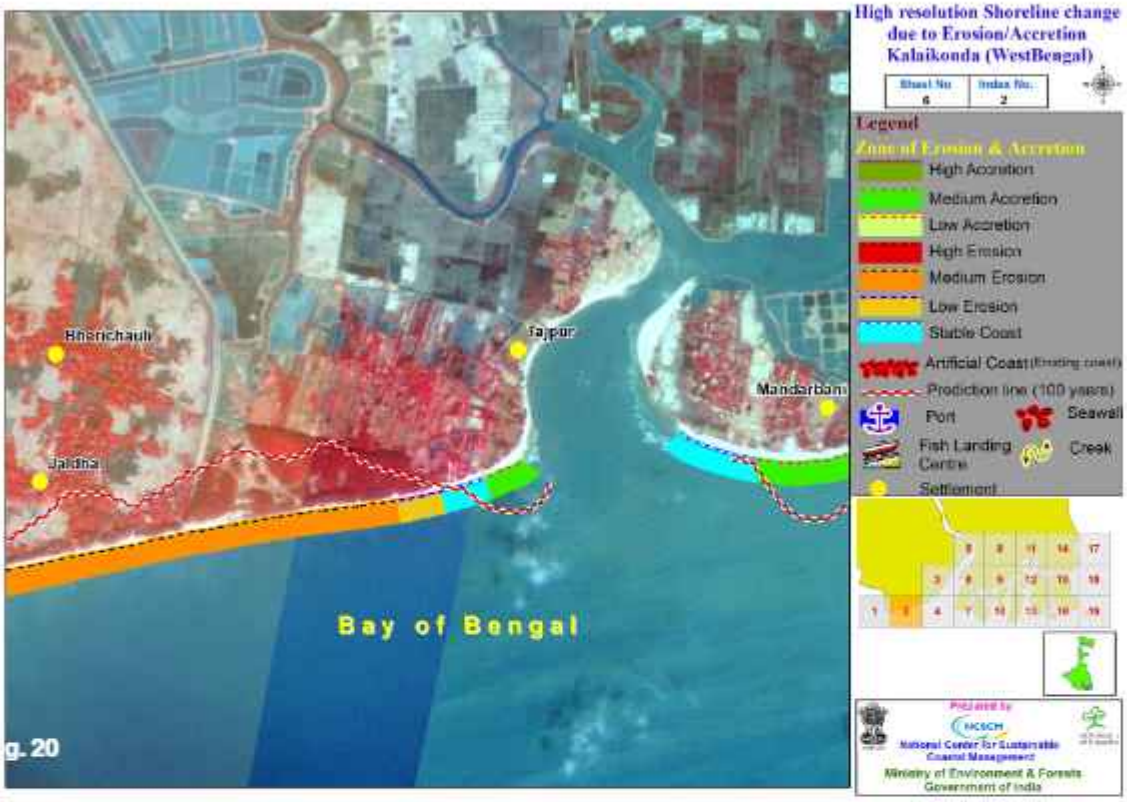
Bhenchauli
Tajpur
Mandarbani
Jaldha
Bay of Bengal
High resolution Shoreline change due to Erosion/Accretion Kalaikonda (WestBengal)
Legend
High Accretion
Medium Accretion
Low Accretion
High Erosion
Medium Erosion
Low Erosion
Stable Coast
Port
Seawall
Fish Landing Centre
Creek
Settlement
Ministry of Environment & Forests
Government of India

g. 20


Dera
Tajpur
Silampur
Mandaroani
Bay of Bengal
High resolution Shoreline change due to Erosion/Accretion Kalaikonda (WestBengal)
Legend
High Accretion
Medium Accretion
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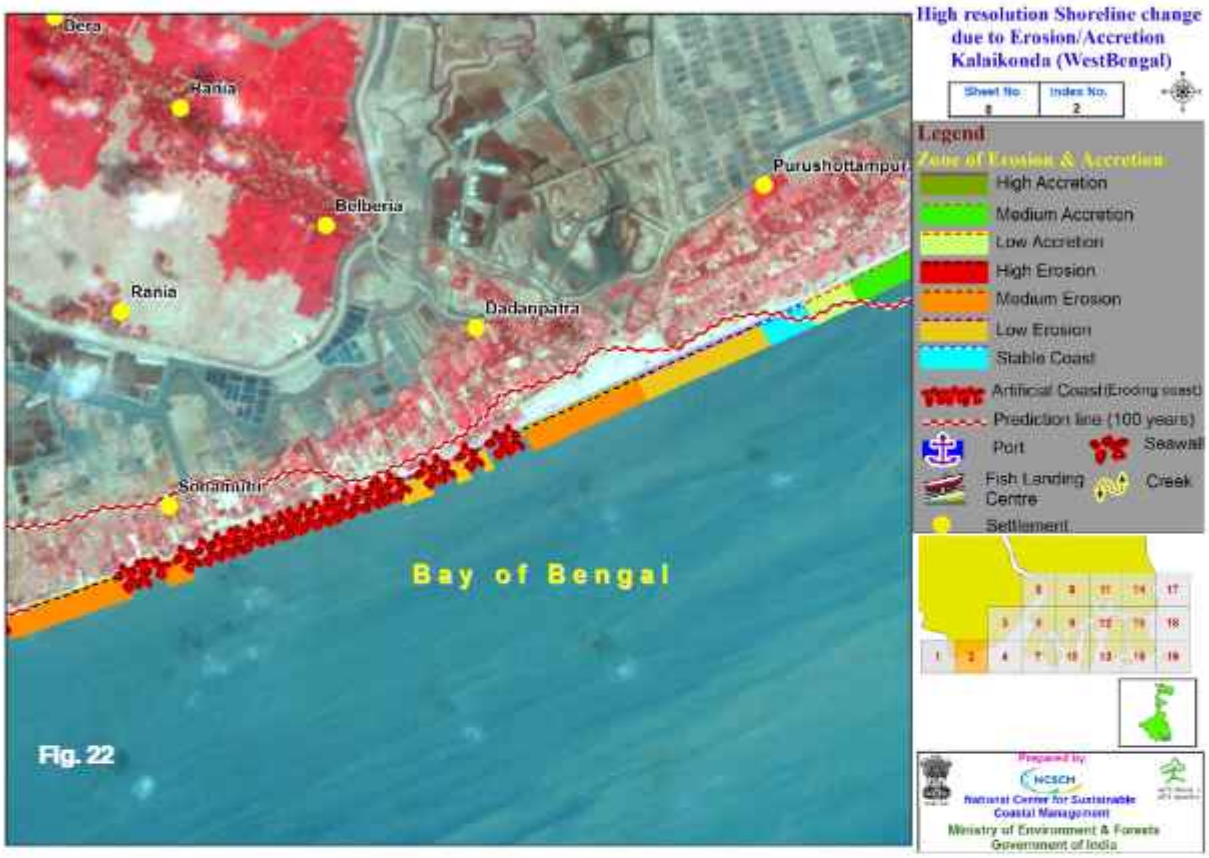


Fig. 22

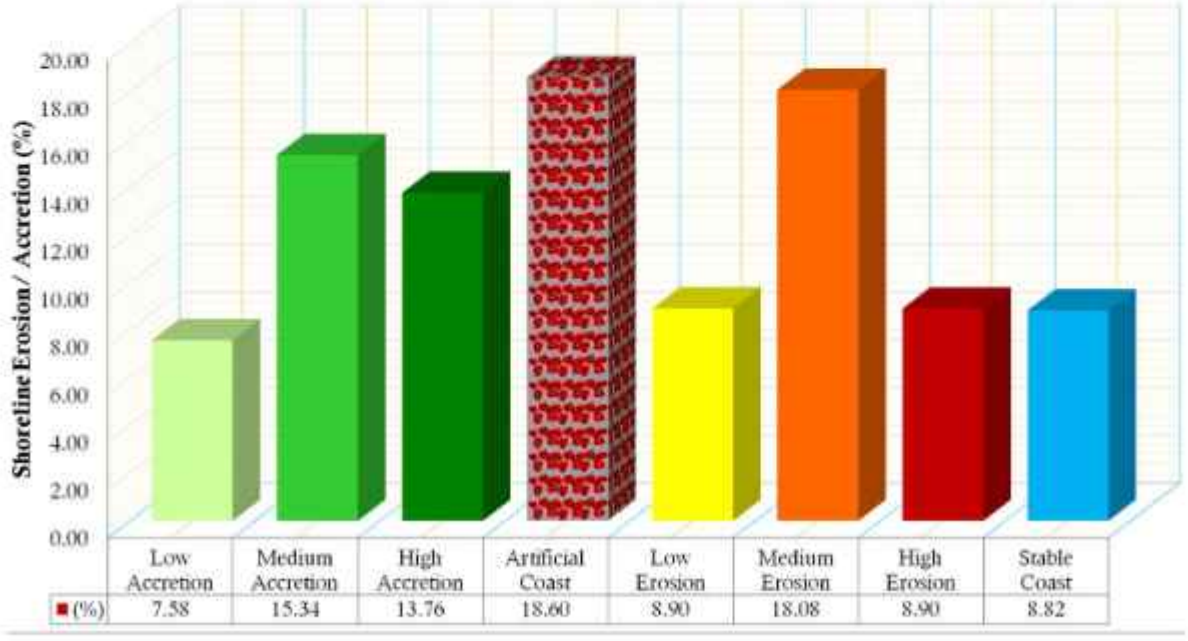


Fig. 23. Shoreline change status for the Dighalo coast - West Bengal


CMR

Coastal ESAs contribute to maintaining the integrity of the coast and the life on the coast and in the sea as they are the habitats for vast coastal biodiversity representing different levels in the food chain. They provide various ecosystem services, which provide livelihood avenues to millions of coastal community directly and indirectly. Coastal ecosystems such as mangroves and coral reefs aid in controlling coastal erosion and shoreline change and also serve as the natural defence against the fury of oceans.

Delineation and Mapping of Ecologically Sensitive Areas and Critically Vulnerable Coastal Areas along the Coast of India

India has large coastal wetlands which cover an area of over 40,230 km2 along its coastline measuring over 8000 km. The coast line is jotted with different sensitive ecosystems like coral reefs, mangroves, tidal mudflats, estuaries, lagoons, marshes and vegetated wetlands. The coastal ecologically sensitive areas are home to a vast biodiversity. For example, coral reefs constitute less than 1% of the ocean floor but support over 25% of the marine biodiversity. Coastal ESAs contribute to maintaining the integrity of the coast and the life on the coast and in the sea as they are the habitats for vast coastal biodiversity representing different levels in the food chain. They provide various ecosystem services, which provide livelihood avenues to millions of coastal community directly and indirectly. Coastal ecosystems such as mangroves and coral reefs aid in controlling coastal erosion and shoreline change and also serve as the natural defence against the fury of oceans.

The Indian government has classified the areas requiring special consideration into protected areas (eg. National parks, sanctuaries) and conservation areas (eg. biosphere reserve, tiger reserve) using appropriate legal instruments (Wildlife Protection Act, 1972; Environment Protection Act, 1986). The marine protected areas (MPAs) account for only 5.81% of the total surface area and about 5% of the total protected areas (PAs) of the country. The Coastal Regulation Zone (CRZ) 2011 notification, issued under the Environment Protection Act, 1986 provides for delineating the ecologically sensitive areas under CRZ I and thus expand the areas under conservation. NCSCM has undertaken the task of mapping the coastal ecologically sensitive areas (ESA).
A detailed research action plan with the breakup of work packages and framework of tasks for this NPMU project has been prepared. Seven work packages (WPs) are planned as listed below with specific tasks under each work package.

1. Mapping CRZ I Area
2. Mapping the Boundaries of Protected Areas
3. Development of criteria and guidelines for delineation of ESAs and CVCAs; Guidelines for IMPs
4. Identification of ESAs (highly sensitive and sensitive areas) and CVCAs
5. Stakeholder consultation and review
6. Delineation of ESAs (highly sensitive and sensitive areas) and CVCAs
7. Development of Knowledge System on ESAs/CVCAs

A series of expert consultations were held during 08-21 Oct 2013 in order to develop the criteria for primary screening of the ESAs listed in CRZ 2011 notification. 55 experts representing 42 institutions/ agencies participated in the three expert consultations. The criteria developed were deliberated among the officials of SICOM and Secretary, MoEF, GoI. These consultations helped in firming up the approach for ESA mapping.

The GIS-based maps for the ecosystems/habitats listed as CRZ I areas in the CRZ 2011 notification are pre-requisites to initiate the works. NCSCM has taken necessary steps for acquiring the maps of mangroves, coral reefs, salt marshes and mudflats prepared by Space Application Centre, Ahmadabad under the National Wetland Inventory and Assessment project supported by Ministry of Environment and Forests.

As per the CRZ 2011 notification, areas or structures of archaeological importance and heritage sites are among those listed under CRZ I. As the coastal archaeological sites are regulated according to the provisions of Ancient Historical Monuments and Archaeological Sites and Remains (Declaration of National Importance) Act, 1951/1958, special focus would be accorded to the underwater archeological sites for which boundaries are not demarcated. The study would be undertaken in collaboration with the Central and State archeological departments.

NCSCM has undertaken the task of preparing the maps of coastal dunes and seagrasses as comprehensive national level maps are not available for these ecosystems (Fig. 1). Similarly, for some of the habitats listed in the CRZ 2011 notification like turtle and bird nesting sites, it is not possible to develop maps based on remote sensing techniques and NCSCM will coordinate developing boundary maps for such habitats by involving state forest departments and expert agencies.

As per the CRZ 2011 notification, marine protected areas (MPAs) are part of CRZ I. The boundaries of MPAs would be obtained from the Wild life Institute of India, Dehradun and overlaid on the ecosystem maps. The outer most boundary of ecosystem and/or the MPA would be delineated on GIS so as to prepare the CRZ I boundary map.

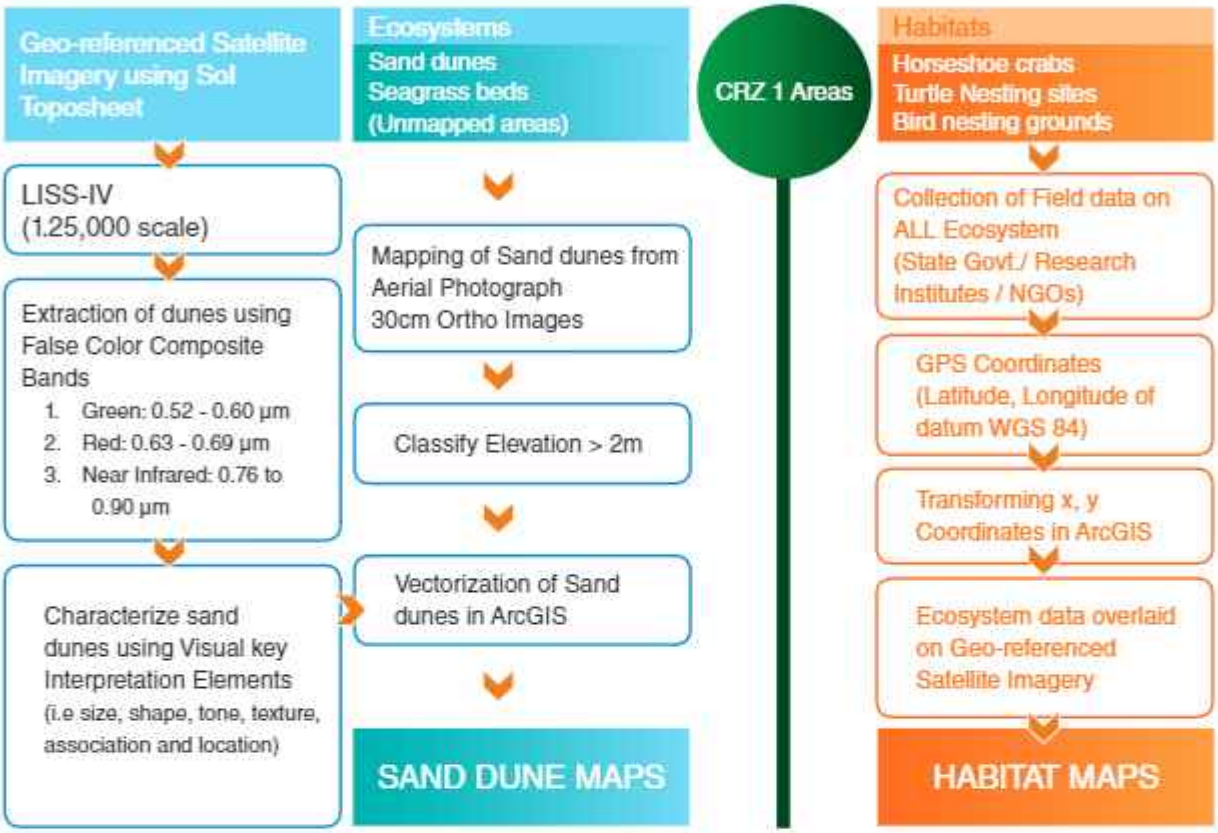
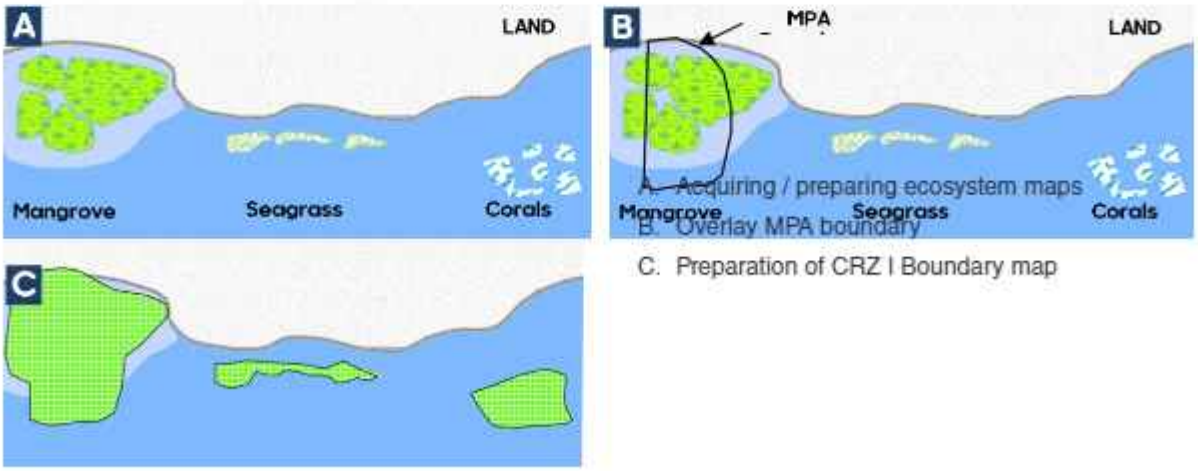


Fig. 1. Framework for mapping coastal ecosystems and habitats



A. Acquiring / preparing ecosystem maps
B. Overlay MPA boundary
C. Preparation of CRZ I Boundary map

Fig. 2. Illustration for preparation of CRZ I boundary maps

Subsequently, the conservation value of the ecologically sensitive areas located outside the Protected Areas will be assessed in order to identify the "highly sensitive areas", for which management plans would be prepared. These could eventually be notified with specific regulatory provisions for conservation. The conservation value of ecosystems would be compared within the bio-geographic zones/ coastal sediment cells as demarcated by NCSCM which are geo-morphological boundaries of sediment movement. Lastly, ESAs on which the local community have a significant dependence would be demarcated as Critically Vulnerable Coastal Areas (CVCA) and guidelines for Integrated Management Plans will be prepared. The threshold values for the conservation values and dependence values would be determined in consultation with the stakeholders so as to accommodate the location-specific ecological and social concerns.

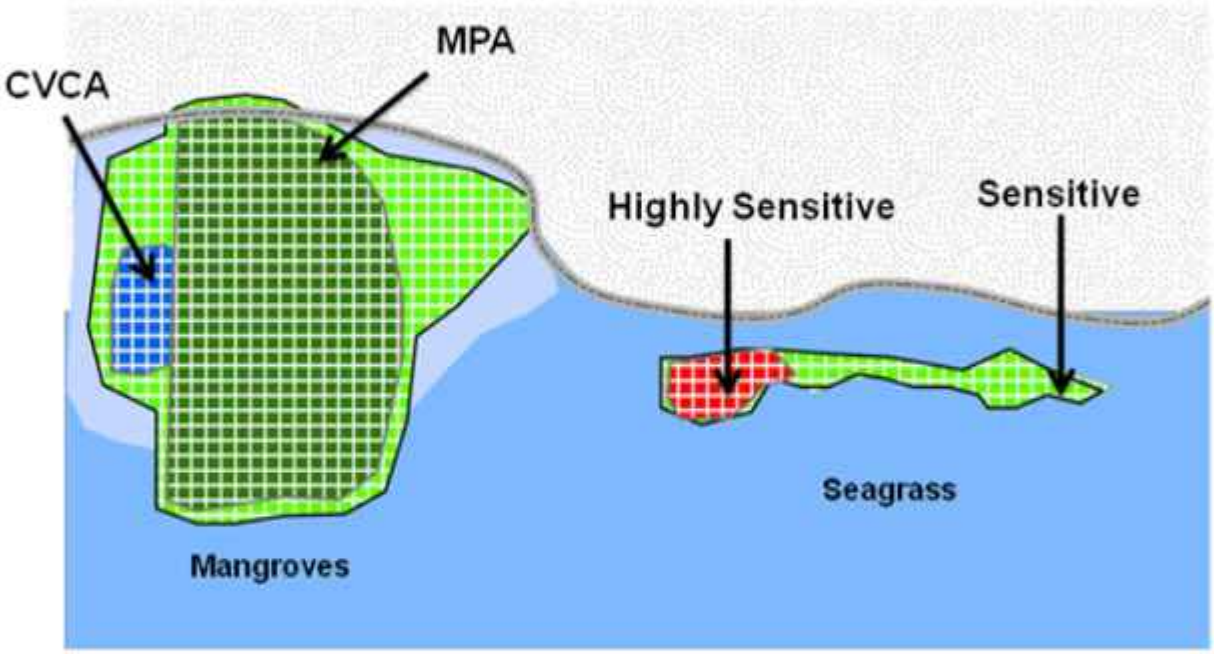


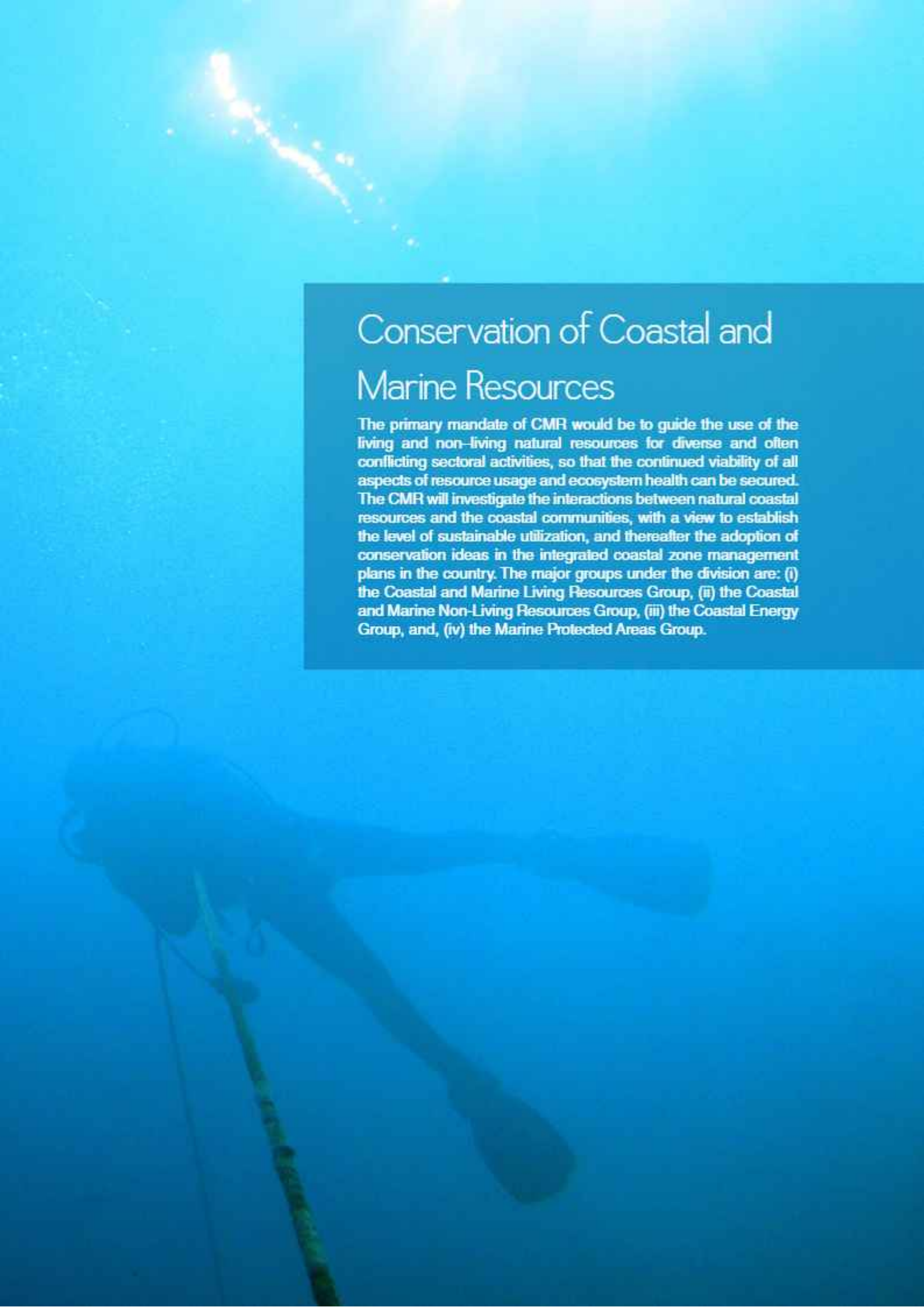
Fig. 3. An illustrative ESA map

It is planned to organize consultations with ecologists and sociologists to develop the framework for the assessment of conservation and dependence value and also to develop guidelines for the integrated management plans. The final ESA map prepared under this study would show the boundaries of highly sensitive areas, sensitive areas and the CVCAs, which would be managed by the community as per the integrated management plans.

In-house Research Studies

NCSCM undertakes multi-disciplinary research for furthering the technical and scientific knowledge-base on ICZM approved by the High Power Research Steering Committee (HPSC) of the Centre. The research studies cover all facets of the coastal issues ranging from geo-spatial through biological, environmental to social aspects. The salient outcome of the research studies undertaken by different research divisions of the Centre are provided in the following section.

CMR



Conservation of Coastal and Marine Resources

The primary mandate of CMR would be to guide the use of the living and non–living natural resources for diverse and often conflicting sectoral activities, so that the continued viability of all aspects of resource usage and ecosystem health can be secured. The CMR will investigate the interactions between natural coastal resources and the coastal communities, with a view to establish the level of sustainable utilization, and thereafter the adoption of conservation ideas in the integrated coastal zone management plans in the country. The major groups under the division are: (i) the Coastal and Marine Living Resources Group, (ii) the Coastal and Marine Non-Living Resources Group, (iii) the Coastal Energy Group, and, (iv) the Marine Protected Areas Group.

Coastal and Marine Biodiversity Integrated Network (CoMBINe) is being developed as a national repository for coastal and marine biodiversity comprising of macro plants (Seagrass, Mangroves, Seaweeds) and animals (Porifera to Chordata) inhabiting the coastal regulation zone (I to IV) as defined in CRZ 2011 notification. CoMBINe integrates an innovative schema for character-based identification of organisms by re-engineering conventional taxonomy.

Development of Coastal and Marine Biodiversity Integration Network (CoMBINe)

The Coastal and Marine Biodiversity Integration Network (CoMBINe) is a unique coastal and marine biodiversity web portal that combines multiple databases and brings on to a platform that allows searching the huge wealth of information from multiple, independent, heterogeneous datasets about Indian coastal and marine flora and fauna, housed in biological repositories. The database would include all macro plants (seagrass, mangroves, seaweeds) and animals (Phylum Porifera to Chordata) inhabiting the coastal regulation zone (I to IV) as defined in CRZ 2011 notification. A national level scoping consultation was conducted on 28th June, 2013 in which the architecture and roadmap for CoMBINe were firmed up. The CoMBINe architecture would provide for integrating the biodiversity databases scattered among several institutes and local bodies with incompatible data types.

CoMBINe database architecture has been built as per international codes so as to share data between national and international sites. The primary purpose is to create a common language for sharing biodiversity data that is complementary and reuses metadata standards from exsisting domains wherever possible.

CoMBINe has two major components (i) developing and sustaining a web portal to serve as a national repository for the coastal biodiversity and (ii) developing and operationalizing an innovative schema for character-based field identification through re-engineering conventional taxonomy.

Developing and sustaining CoMBINe Web portal

CoMBINe uses the Darwin Core 2.0 metadata standard. Darwin Core is a standard for sharing data about biodiversity, which has a relatively long history of community development and is deployed widely. Fundamentally, Darwin Core is a set of terms having clearly defined semantics. The terms are organized into nine categories (often referred to as "classes"), six of which cover broad aspects (event, location, geological context, occurrence, taxon, and identification) of the biodiversity domain. The remaining categories cover relationships to other resources, measurements and generic information about records.

CoMBINe dataset is an extension of Darwin core and has a special customization to adopt to the Indian Biodiversity practices (taxonomy/specimen centric) and to the global practices of storing information of ocean species covering all major areas of biodiversity data.

Table 1. Darwin Core Database Schema

Record-Level Terms	Dublin Core terms, institutions, collections, nature of data record	
Occurrence	Evidence of species in nature, observers, behavior, associate media, references	
Event	Sampling protocols and methods, date, time, field notes	
Location	Geography, locality descriptions, spatial data	
Identification	Linkage between Taxon and Occurrence	
Taxon	Scientific names, vernacular names, names usage, taxon concepts, and the relationships between them	
Geological context	Geologic time, chrono-stratigraphy, biostratigraphy, lithostratigraphy	Simple Darwin core(Flat)
Resource Relationship	Explicit relationships between identified resources	
Measurement or Fact	Measurements, facts, characteristics, assertions, references	Generic Darwin core (Relational)

System Landscape

CoMBINe is built on Darwin Core 2.0 metadata standard along with Simple Object Access Protocol (SOAP), which is a request and response message format for communication between data provider, portal engine, and applications, by linking the metadata and the existing databases already available in different organizations. The adoption of SOAP enables data sharing between GBIF, OBIS, FishNet, MaNIS, HerpNET, PaleoPortal and other international databases.

CoMBINe utilizes Open Cloud configuration. This architecture enables the web servers to utilize the Cloud Block Storage for extra disk space. Cloud Load Balancers are also used in multiple levels of the application, balancing not only web workloads but application workloads as well.

Application Server Architecture

CoMBINe Application Server Architecture is a comprehensive design of the entire system, including all its sub-components and external applications interfaces (Fig. 1). The architecture is designed in a way to access the application through a Web browser or a specialized user agent. The browser creates HTTP requests for specific URLs that map to resources on a Web server. The server renders and returns HTML pages to the client, which the browser would display. CoMBINe is designed keeping in mind the overall objective of integration, scalability and interoperability within the system, as well as with external systems.

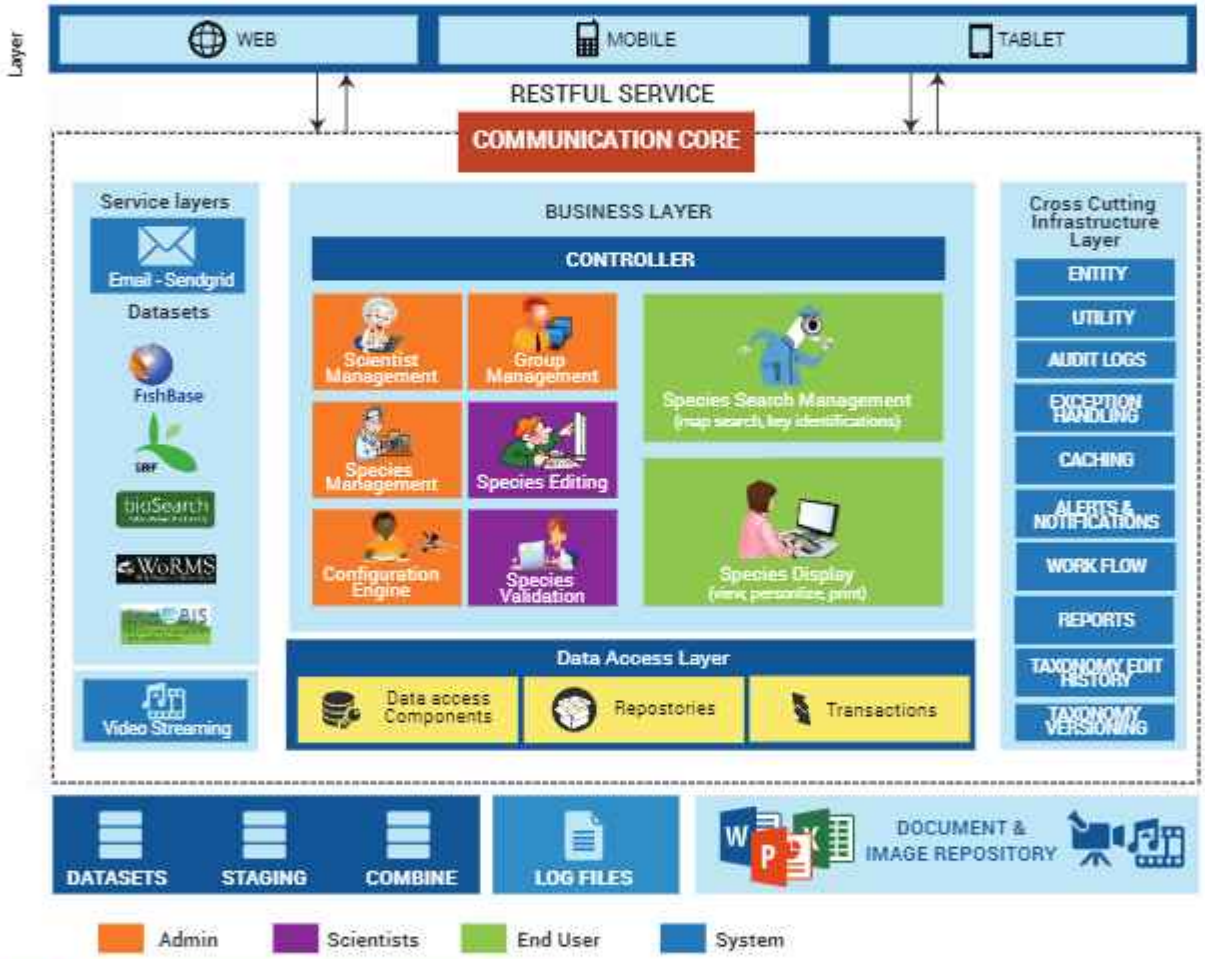


Fig. 1. CoMBINe Application Server Architecture

The core of a Web application is its server-side logic. The application can contain several distinct layers. The typical example is a three-layered architecture comprised of presentation, business, and data layers. The web application architecture with common components grouped by different areas of concern is illustrated in Fig. 2.

CoMBINe was designed with the goal of minimizing the complexity by separating tasks into different areas of concern to design a secure, high performance application.

Web Application

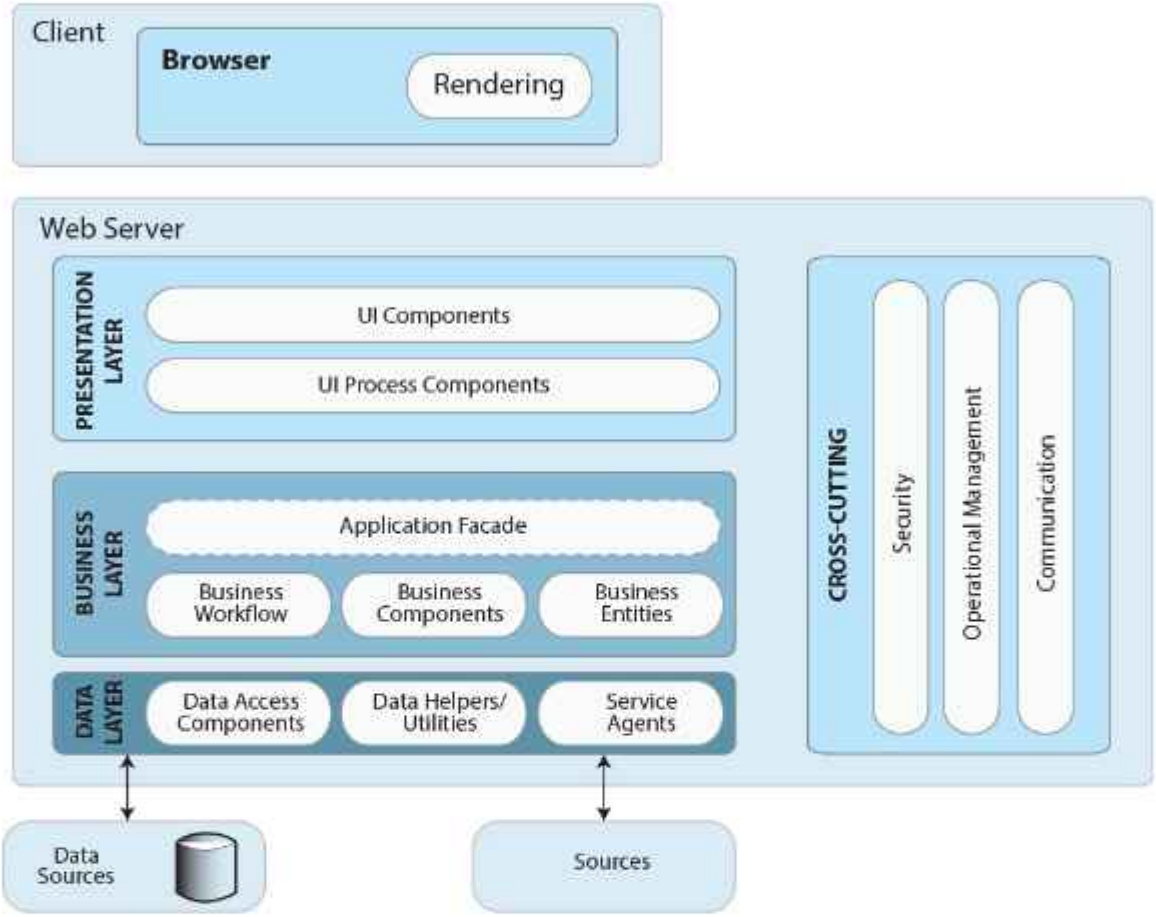


Fig. 2. System landscape of CoMBINe

A complete and comprehensive database is designed with 62 fields covering taxonomy, anatomy, biology, conservation, molecular, spatial, spectral and others. The DiGIR protocol will allow more precise data searches because it is designed to reduce information overload and extract common characteristics from all data sources in different formats. As a first step, information pertaining to organisms inhabiting the coastal and marine environment are being gathered from existing databases, species records, publications and other secondary sources and stored in CoMBINe staging database, which currently has over 72,000 records.

Developing a character–based field identification schema

The salient steps involved in building the CoMBINe data is summarized in Fig. 3. While significant works have been done on the coastal biodiversity in India, comprehensive national checklist of species is not readily available. Effort is underway to compile the checklists for all groups from various sources.

The "character/image based field identification" feature aims at taking the biodiversity information to and create interest among all the stakeholders, irrespective basic understanding on taxonomy, through re-engineering conventional taxonomy, thus bridging the knowledge-divide.

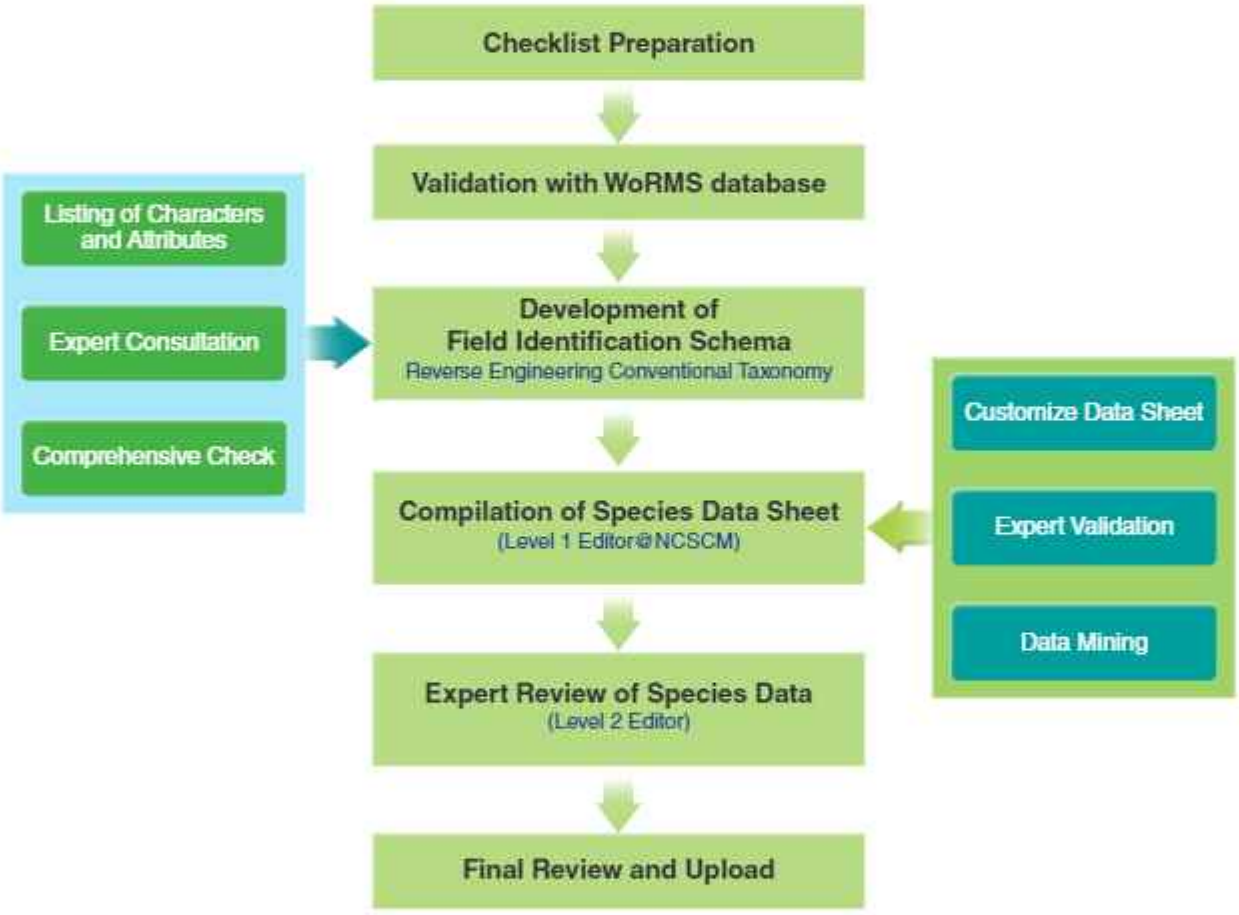


Fig. 3. Steps involved in building CoMBINe

The coastal and marine organisms are grouped into 20+ groups based on broad morphological features and for each such group, which would include different classes across phyla, key identification characters and attributes are being developed. Table 2 summarizes the current status with respect to different taxonomic groups. The screen-shots of the users and editor's page in the w eb portal are provided in Fig. 4 & 5.

It is envisaged that the CoMBINe portal, the first Indian biodiversity portal to be built as per International codes, would emerge as the national repository for coastal and marine biodiversity. Steps have been taken for developing the mobile portal of CoMBINe so as to integrate people and knowledge in real-time. Further, CoMBiNe would help in identifying taxonomic and biological data gaps so as to steer focused research on coastal and marine biodiversity.

Table 2. Status of various tasks under CoMBINe against targeted taxonomic groups.

Kingdom : PLANTAE						
Group / Taxa	Check list targets		Progress Status			
	Venkataraman et al., (2005)*	Biosearch**	Checklist preparation$	Species data sheet	Field identification schema	Expert Review
Seaweeds						
Rhodophyta	434	634	434	✓	IP	◊
Phaeophyta	191	-	191	✓	IP	◊
Chlorophyta	216	374	216	✓	IP	◊
Xanthophyta	3	-	3	✓	IP	◊
Seagrass	14	206 **	14	✓	✓	✓
Mangroves	39		42	✓	✓	✓

Kingdom : ANIMALIA						
Group / Taxa	Check list targets		Progress Status			
	Venkataraman et al., (2005)*	Biosearch**	Checklist preparation$	Species data sheet	Field identification schema	Expert Review
Porifera	486	485	501	IP	∞	∞
Cnidaria						
Hydrozoa	212	1295	◊	◊	◊	◊
Scyphozoa	25		◊	◊	◊	◊
Cubazoa	5		◊	◊	◊	◊
Anthozoa	600		850	IP	◊	◊
Ctenophora	12	3	IP	◊	◊	◊
Platyhelminthes	-	56	32	IP	◊	◊
Annelida						
Archiannelida	20	1161	◊	◊	◊	◊
Polychaeta	250		◊	◊	◊	◊
Nematoda	-	180	92	IP	◊	◊
Sipuncula	35	31	◊	◊	◊	◊
Echiura	33	26	◊	◊	◊	◊
Nemertea	3'	-	3	IP	◊	◊
Priapulida	-	1	IP	◊	◊	◊
Brachiopoda	-	1	1	IP	◊	◊

Kingdom : ANIMALIA						
Group / Taxa	Check list targets		Progress Status			
	Venkataraman et al., (2005)*	Biosearch**	Checklist preparation‡	Species data sheet	Field identification schema	Expert Review
Chaetognatha	30	30	28	IP	◊	◊
Arthropoda						
Insecta	-	3609	11	IP	◊	◊
Cirripedia	104		IP	◊	◊	◊
Branchiopoda	-		27	◊	◊	◊
Mysidacea	75		IP	◊	◊	◊
Pycnogonida	-		6	◊	◊	◊
Euphausiacea	23		◊	◊	◊	◊
Stomatopoda	121		IP	IP	◊	◊
Macrura	55		IP	◊	◊	◊
Brachyura	389[2]		389	◊	◊	◊
Anomura	162		IP	◊	◊	◊
Mollusca	3370 1783[3,4,5]	3439	1783	✓	IP	◊
Bryozoa	200	150	IP	◊	◊	◊
Echinodermata	765	692	608	✓	IP	◊
Chordata						
Hemichordata	12	3	IP	✓	IP	◊
Protochordata	119	-	388[6]	◊	◊	◊
Pisces	2546	4514	2583	IP	◊	◊
Reptilia	35		27	✓	✓	IP
Aves	-		146	✓	✓	IP
Mammalia	25		33	✓	IP	◊

" ✓ " – Completed, " IP " – In Progress, " ◊ " – To be initiated

*Venkataraman. K. Coastal and Marine biodiversity of India. Ind. J. Mar. Sci 34 (1), 57-75 (2005); **Kaokodkar. A. P et al. bioSearch: A glimpse into marine biodiversity of Indian coastal waters. Ind. J. Geo-Mar. Sci 42 (6), 745-748 (2013); ‡ Species list verified with WoRMS; Synonyms omitted; Repetition and unaccepted names have been deleted; ∞In Biosearch, Mangroves and seagrass have been incorporated in Magnoliophyta (flowering plants). The number 206 also includes mangrove associated plants.

[1]Shrinivaasu. S. et al. *Baseodiscus hemprichii* (Ehrenberg, 1831) (Pylum Nemertea) New distributional record from Andaman and Nicobar islands, India. Rec. zool. Surv. India 111 (Part-1), 1-4 (2011); [2]Dev Roy. M. K. An annotated checklist of Mangrove and Coral Reef inhabiting Brachyuran crabs of India. Rec. Zool. Surv. India 289, 1 -212 (2009); [3]Ramakrishna & Dey. A. Annotated Checklist of Indian Marine Molluscs (Cephalopoda, Bivalvia and Scaphopoda), Rec. Zool. Surv. India 320 (2010); [4]Subba Rao, N. V. Indian seashells (Part1)-Polyplacophora and Gastropoda, Rec. Zool. Surv. India 192 (2003); [5]Silas, E. G et al. Identity of common species of cephalopods of India. CMFRI Bulletin 37 (1985); [6]Meenakshi. V. K. et al. Marine Biodiversity – Taxonomy and identification of Ascidia. Technical Report submitted to MoEF (2003).

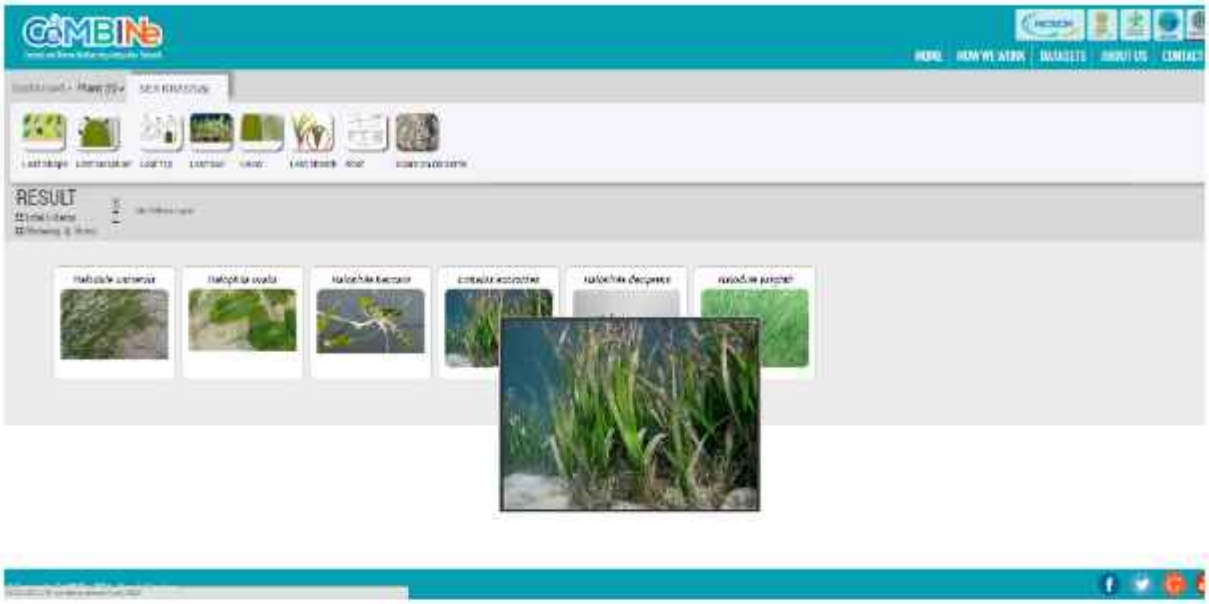


Fig. 4. Screenshot of Users page of CoMBINe Portal

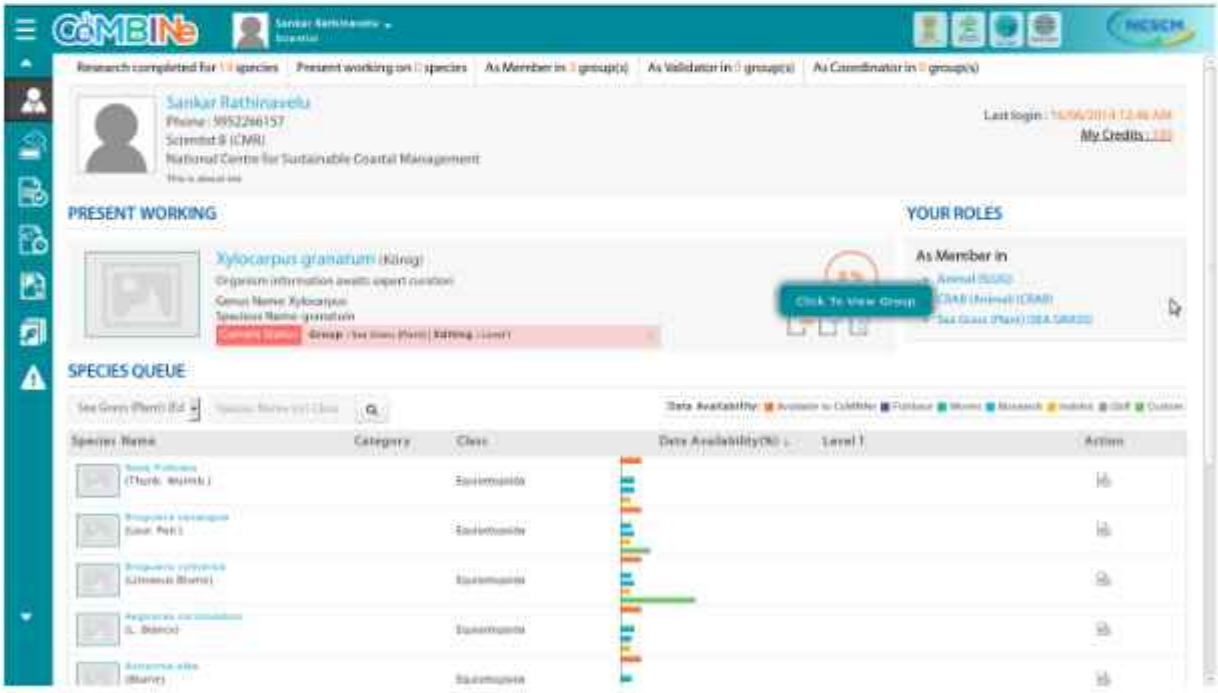


Fig. 5. Screenshot of Editors' page of CoMBINe Portal

Commercial scale cultivation of red seaweed, *Kappaphycus sp.*, has been underway in India since early 2000. The current study is undertaken in the light of the reported damage caused by these seaweeds to the coral reefs in order to assess the impact of the seaweed cultivation in Palk Bay on the coastal ecosystems in Palk Bay and Gulf of Mannar and to develop strategies for ecologically sustainable farming of selected seaweeds viz., *Kappaphycus alvarezii* and *Gracilaria edulis*.

Impact of large scale cultivation of seaweeds on coastal environment

Commercial cultivation of *Kappaphycus alvarezii,* an introduced seaweed species is common in Palk Bay, Tamil Nadu since 2003. In light of the environmental concerns raised on the potential impact of cultivation of this introduced seaweed species on the sensitive ecosystems and the dependence of the coastal community on this sector for their livelihood, this research study was undertaken with two major objectives viz., (i) to assess the impact of the seaweed cultivation in Palk Bay for about 10 years on the coastal ecosystems in the region including Gulf of Mannar and (ii) to develop strategies for ecologically sustainable farming of selected seaweeds viz., *Kappaphycus alvarezii* and an indigenous species, *Gracilaria edulis*. The detailed scope and methodology of the study including the study sites, parameters of observation and choice of seaweed species for experimental cultivation were firmed up during an expert consultation held on 24th June, 2013 with experts from academia, research institutions and industry.

Impact of seaweed cultivation on Palk Bay reef ecosystem

The reef in Palk Bay runs parallel to land (east to west direction) between longitudes 79° 17' E and 79° 8'E at the latitude 9° 17'N, starting from Munaikadu and runs east as a wall-like formation up to Thonithurai, where the reef width is more than 300 m. East of Pamban pass, the reef again starts near Thangachimadam and ends near Agnitheertham (Rameswaram). The Bay is a very shallow flat basin with an average depth of 9 m. The reef area and seagrass beds *vis-à-vis* the areas of seaweed cultivation in Palk Bay are depicted in Fig. 1.

Fig. 1. Map depicting various ecosystems in Palk Bay *vis-a-vis* the seaweed cultivation area

The Seaweed cultivation area in Palk Bay was broadly divided into three regions *viz*., Munaikadu, Thonithurai and Olaikuda. Detailed field surveys were conducted to assess the spread of *Kappaphycus* sp. in the reef area and to determine its impact on the coral reefs and seagrass beds; water quality parameters and diversity and abundance of benthic community. Coral reef and seagrass are the important ecosystems in Palk Bay. A reconnaissance survey was conducted in the entire seaweed cultivation area in Palk Bay, extending from the coast till the reef crest by manta tow survey, for a total length spanning 38.4 km. Altogether, 34 Line Intercept Transects (50 m) were laid for biophysical monitoring of the reef health and 31 quadrats (1 m^2) were laid for studying the health of seagrass beds. While species diversity and extent of coverage were observed for both coral and seagrass ecosystems, shoot density and blade length were specifically recorded for the latter. In the current field observation, a total of 38 species of scleractinian corals were observed against the 66 reported earlier from the entire Palk Bay. The percentage of live coral coverage was high (28.33) in Thonithurai region, whereas the corals were more diverse and healthier in Olaikuda, Rameshwaram Island (Fig. 2).

Fig. 2. Coral reef in Olaikuda region of Rameshwaram Island, Palk Bay

The percent cover of dead coral with algae in the transect was significant in both Munaikadu (50.31) and Thonithurai (42.22), which could be attributed to the damage caused to the reefs following the 2010 mass bleaching of corals and increased sedimentation in Palk Bay. The dead corals were covered by mud due to heavy sedimentation and turned into habitats for macro algae. The branching corals in Thonithurai post-bleaching, died and were reduced to rubbles thus, accounting for about 18% in the LIT. The percent cover of the principle benthic components in the coral reef area of Palk Bay is provided in Fig. 3.

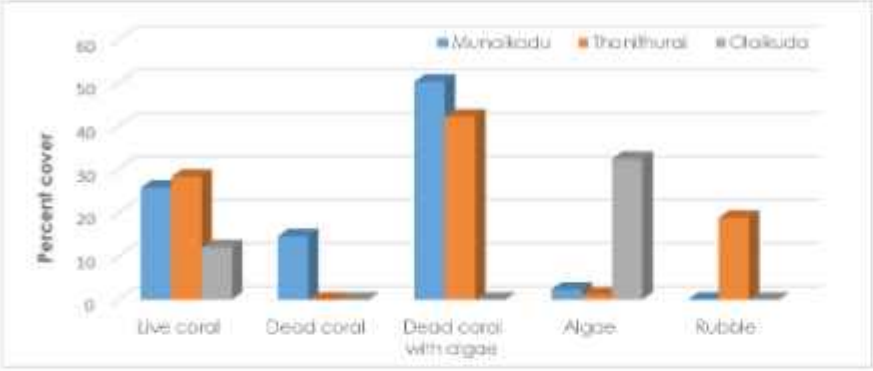


Fig. 3. Percentage cover of the principle benthic components in the coral reef area of Palk Bay

The percent cover of native seaweeds was less than 3% in Mandapam region (Thonithurai and Munaikadu), while it was 30% in Rameshwaram Island (Olaikuda). The massive colonies of *Porites* sp. in Mandapam region contributed to the higher percent cover of live corals. Branching and plate corals belonging to *Acropora* spp. and sub-massive coral colonies dominated the coral reefs in Olaikuda. The coral reefs in Olaikuda were found to be extensively covered with *Caulerpa* spp. (Fig. 4) Invasion of *Kappaphycus* over the corals could not be observed in any of the study sites in Palk Bay.

Stocheospermum spp.
on reef at Olaikkuda

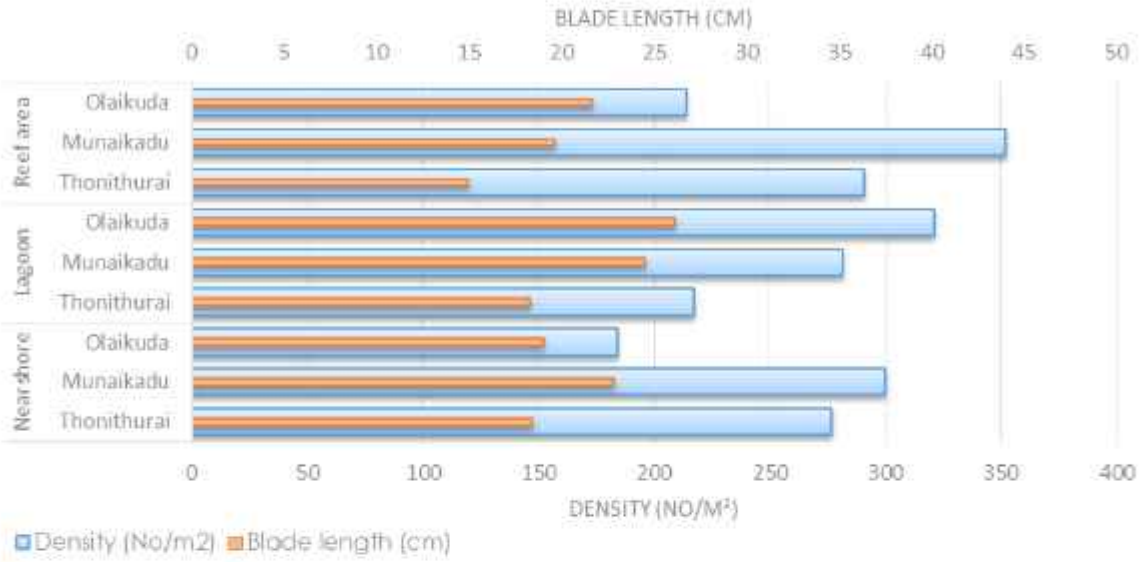
Halimeda opuntia
on reef at Munaikadu

Caulerpa spp.
on reef at Thonithurai

Fig. 4. Coral reef affected by native seaweeds

A total of nine seagrass species were observed in the study area against the 11 reported earlier and *Cymodocea serrulata* was the dominant species in the region. The variation between the shoot density and the blade length of *Cymodocea serrulata* did not vary significantly ($p>0.05$) between the study locations (Fig. 5).

The mean shoot density/m^2 ranged between 253.50±61.32 and 285.52±69.14 across the regions. The pattern of shoot density in Olaikuda, where seaweed cultivation is being practised for about 10 years, was significantly ($p<0.05$) different from that in other two regions. At Olaikkuda, the density of seagrass in the nearshore area was less than that in the lagoon. The blade length was highest in the lagoon (22.96±4.14 cm), followed by near shore area (20.08±2.38 cm) and reef area (18.74±3.45 cm), which could be due to the higher depth of the lagoon (>2m) in comparison with nearshore and reef area (0.5-2.0m). The mean blade length was the least in Thonithurai (17.20±1.96 cm), which could partly be explained by the shading effect of the seaweed rafts and photo-acclimatization of seagrass to the reduced light availability at the disturbed nearshore stations. Some patches of the seagrass beds near the seaweed culture sites in Munaikadu were covered with filamentous algae (Fig. 6). The hydrodynamic microclimate, caused by the seaweed culture, boat operation in the region, waves and currents, etc strongly acted on the plants resulting in the deterioration of seagrass beds in the nearshore region of Palk Bay. Benthic communities are integral to the coastal and marine ecosystems. Apart from their role in the food chain as *food for higher groups*, benthic communities are recognized as indicators for change in the ecosystem due to natural or anthropogenic causes.



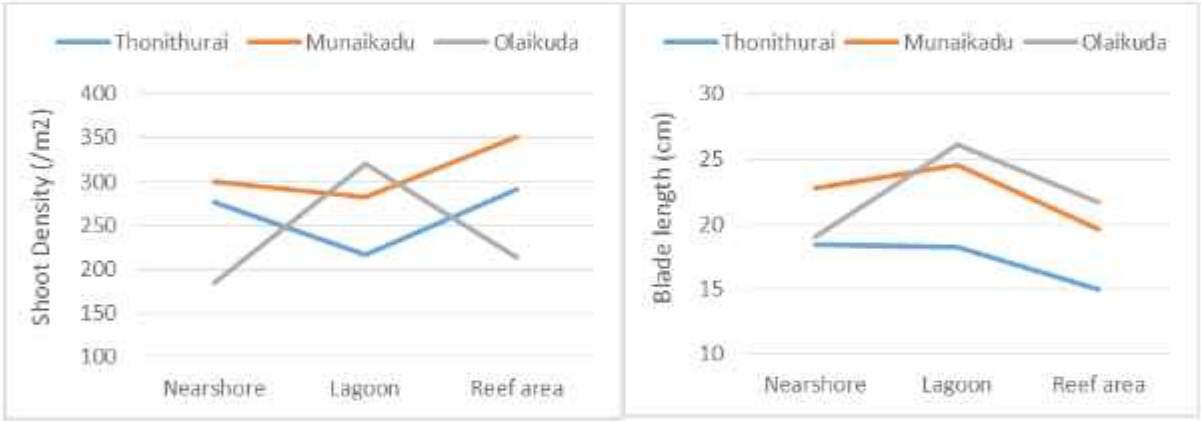
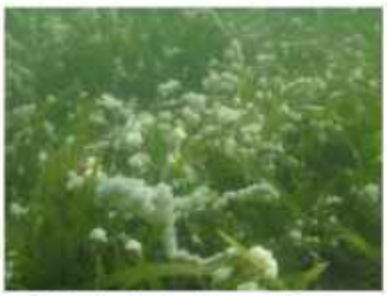


Fig. 5. Shoot density and blade length of *Cymodocea serrulata* in Palk Bay

Earlier studies have reported that cultivation of seaweeds would lead to reduction in the population of macro-benthos in the farming areas due to increased predation by juvenile fishes and disturbance of the bottom. In the current study, distribution and abundance of macro and meio-benthos were investigated in the seaweed cultured areas and control sites. In Palk Bay, 37 species of polychaetes belonging to 15 families were recorded, with Eunicidae being the most abundant family and *Cirriformia* sp., the most abundant species. The population density of polychaetes in Thonithurai (575 ± 204) and Munaikadu (455 ± 234) was found to be significantly ($p<0.05$) higher than that in Olaikuda (369±45), which could be attributed to the monoline method of seaweed cultivation in Olaikuda. Difference in the diversity and abundance of benthic communities between the farmed and control sites was not significant ($p>0.05$) at Munaikadu and Thonithurai. The significant reduction ($p<0.05$) in macrofaunal assemblage observed at Olaikuda could be attributed to the monoline culture practised here, wherein the lines constantly brush against the bottom sediments. Interestingly, the population of *Cirriformia sp* was observed to have recovered to their normal level, when the monoline seaweed culture was not undertaken.

In case of molluscs, *Cerithium morus*, *C. corallium* and *C. scabridum* (Potamiididae) were dominant in all the stations followed by *Trochus* spp. and juveniles of gastropods and bivalves. Juvenile fishes belonging to the families Siganidae, Gerridae and Mugilidae were the most dominant foragers on the benthic communities under culture rafts. The studies on the meiobenthos with specific focus on nematode assemblage are underway in order to understand the alteration of meio-benthic communities, if any.



Epiphytic tunicates over Seagrass blades at Thonithurai

Healthy seagrass bed at Thonithurai

Seagrass patch covered by filamentous algae in Munaikadu

Fig. 6. Seagrass beds in Palk Bay

The hydrographic parameters [salinity, temperature, dissolved oxygen, pH), nutrient parameters (dissolved inorganic nutrients, ammonia, nitrite, nitrate, phosphate, silicate) and chlorophyll-*a* were measured following standard procedures across three seasons (south-west monsoon, north-east monsoon and spring inter-monsoon) from the culture and control sites. The past data were grouped as before culture (prior to 2003), during culture (2006-2012) and the current period (2013-2014), compared and statistically analyzed with current observations in order to relate with the impact of seaweed cultivation (Fig. 7&8). The significant ($p<0.05$) variation observed in case of physical parameters between current and past aggregate data could be attributed to seasonal and local hydrographic setting, as significant variation ($p<0.05$) was also observed for each of these parameters in the study area between seasons. As the seaweed culture is undertaken in near shore area with shallow waters, the bottom topography, shading and impediment of water movement by rafts also contribute to the variations. The significant ($p<0.05$) variation in DO level between the culture areas and control areas and also aggregates of past data could be attributed to the increased intensity of rafts in the culture area.

No significant variation ($p>0.05$) was observed with respect to other chemical parameters between the current and previous data aggregated to two time periods. However, the variation in the concentration of nutrients across different seasons were significant ($p<0.05$). Ammonia and nitrate are assimilated by seaweeds and seagrasses as nutrients, however, long-term changes are insignificant because the Bay of Bengal is seasonally enriched with inorganic nutrients from the major rivers draining into it during monsoon and the transport of nutrients across the coastal waters by the coastal and tidal currents. The level of phosphate reported from this region varied between 0.08 and 9.88 µmol, which could be due to samples being taken at different locations in Palk Bay and across seasons. Land runoff and mixing of soil particle tend to increase phosphates to near shore waters. Owing to the wide variation in the concentration of chlorophyll pigments in earlier reports, no significant ($p>0.05$) variation could be observed between the current level and the earlier periods. The chlorophyll pigments however, showed a significantly ($p<0.05$) higher concentration in the culture areas than in control sites which could be due to the re-suspension of benthic algae attached to the substratum. The study showed that the variations in the physico-chemical properties of water could not be directly attributed as an impact of seaweed farming in Palk bay. Rather, the changes are seasonal and observed to be within the range for this part of the coast. The study shows that the coral reefs and seagrass beds in the Palk Bay are subjected to various natural and anthropogenic pressures. These ecosystems are best managed with location-specific conservation management plans to be prepared by involving all stakeholders.

Impact of seaweed cultivation on Gulf of Mannar reef ecosystem

In the light of the reports on invasion of *Kappaphycus* in Gulf of Mannar, detailed underwater surveys were carried out in 12 islands. *Kappaphycus* invasion was observed in 3 of the surveyed islands *viz.*, Krusadai, Shingle and Mulli (Fig. 9). The reefs in Koswari and Van Islands were extensively covered by native seaweeds like *Halimeda gracilis* and *Caulerpa taxifolia* to an extent of 70-80% in specific locations.Analysis of the data with respect to the distribution, abundance and status of corals, seagrass, seaweed and the benthic community and the status of water quality in Gulf of Mannar is underway. The natural and anthropogenic factors that contributed to the spread of Kappaphycus in GoM are being studied and strategies for conservation of these sensitive ecosystems in GoM and Palk Bay are being evolved.

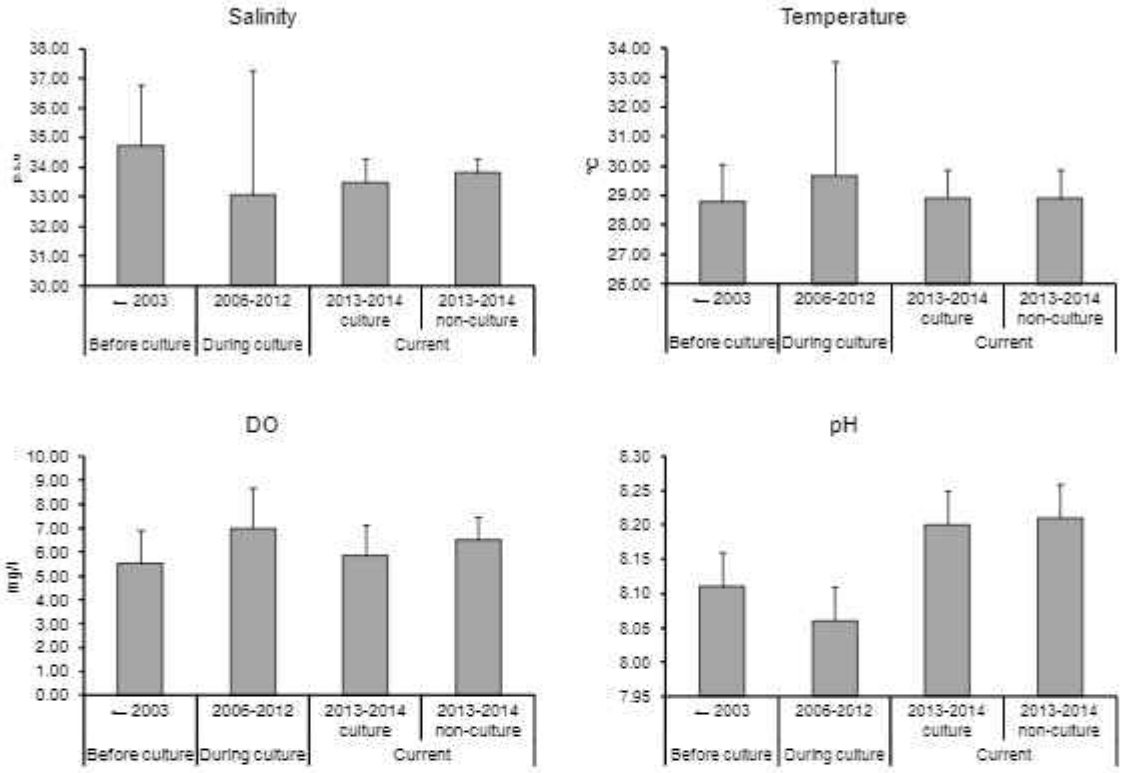


Fig. 7. Comparison of current hydrographic parameters with past aggregate data in Palk Bay

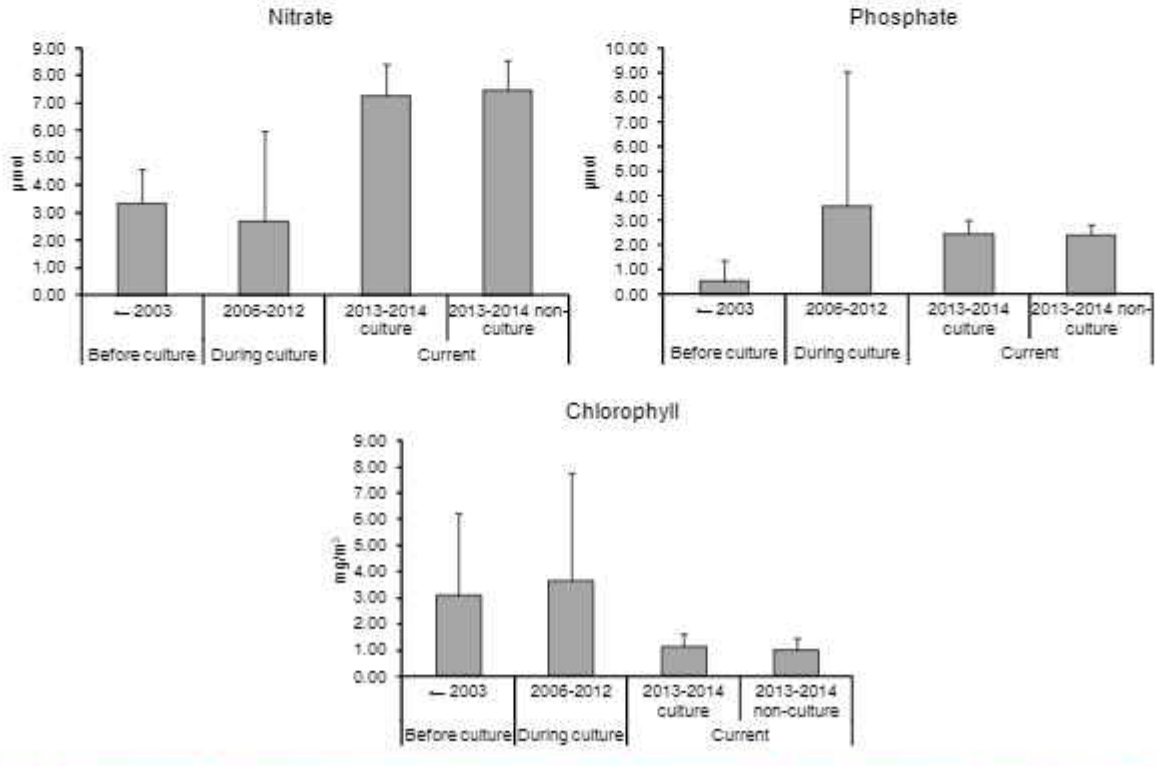


Fig. 8. Comparison of current nutrient parameters and chlorophyll with past aggregate data in Palk Bay

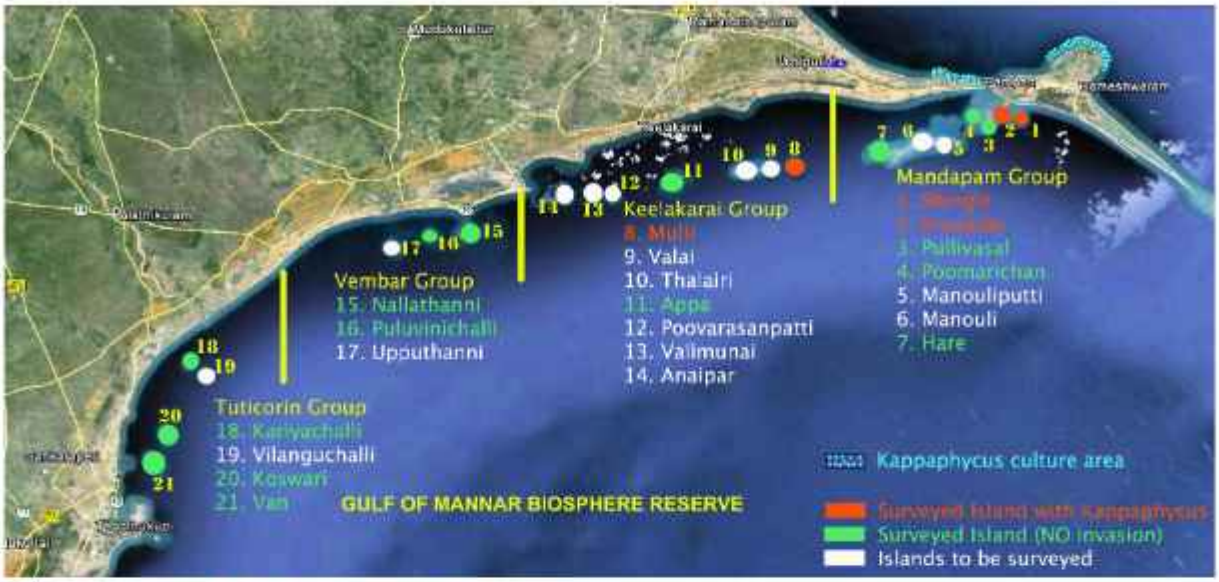


Fig. 9. Study sites in Gulf of Mannar and current status of field surveys

Development of eco-friendly seaweed cultivation methods

The second major objective of the research study was to develop location-specific ecologically sustainable seaweed cultivation methods for *Kappaphycus alvarezii,* an introduced species and *Gracilaria edulis*, an indigenous species. Marine Algal Research Station, Central Salt and Marine Research Institute (CSMCRI), Mandapam and Fisheries College and Research Institute (FCRI), Thoothukudi have been involved for establishing the experimental seaweed farms and monitoring the environmental parameters respectively. After the reconnaissance survey, three sites *viz.*, Nagapattinam and Thoothukkudi in Tamil Nadu and Miyani at Gujarat have been identified for establishment of the experimental seaweed mariculture units. The tube net method for *Kappaphycus alvarezii* and triangular raft method for *Gracilaria edulis* are under evaluation against the conventional rectangular raft method of seaweed cultivation. Further, arrangement of rafts has also been altered with the view to reduce environmental foot prints.

During Aug-Sep, 2013, there was an outbreak of ice-ice disease in *Kappaphycus alvarezii* cultivated in the Palk Bay region, which resulted in loss of entire standing crop (18950 rafts). Weekly averaged Global Level 3 Mapped Thermal IR SST products derived from the MODIS (MODerate Resolution Imaging Spectroradiometer) sensor onboard Aqua satellite (PODAAC, 2002) were processed using image processing software. The mean values of the SST observations taken at 15 points each around Mandapam and Thoothukkudi were used for plotting and interpretation (Fig. 11). Weekly average SST imagery showed consistently higher temperatures (above 28°C) in the Palk Bay and North Gulf of Mannar region compared to the southern Gulf of Mannar (around Thoothukkudi). The observation lead to the hypothesis that exposure to higher temp (an increase of 2°C) in the seaweed cultivation areas together with high intensity seaweed farming, would have led to the outbreak of ice-ice disease in *K. alvarezii*, owing to their physiological vulnerability to thermal stress. The study conducted at FCRI indicated that *Planococcus* sp (20%) dominated the infected seaweed samples followed by *Arthrobacter* sp and *Pseudomonas* sp.

CSMCRI has established a seed multiplication farm at Mullimunai in Palk Bay (Fig. 12) region following the loss of entire *Kappaphycus alvarezii* biomass to the ice-ice disease outbreak. The baseline environmental parameters in the experimental farm sites established at Thoothukkudi and Mullimunai have been determined and are being monitored periodically. The impact of seaweed cultivation on the coastal environment is believed to be less when the rafts are laid perpendicular to the coast than when laid in parallel orientation. Preliminary studies reveal that *K. alvarezii* cultivated in rafts laid in vertical orientation had a significantly ($p<0.01$) higher daily growth rate (5.01%) and single plant biomass (76.67 ± 16.65g) than their counterparts grown in horizontal orientation (1.87%; 28.54 ± 11.12g respectively).

The research on seaweed cultivation so far were aimed at production maximization and the current study undertaken by NCSCM with CSMCRI and TNFU would help in developing location-specific seaweed farming methods with least ecological footprints.

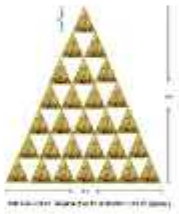
The research on seaweed cultivation so far were aimed at production maximization and the current study undertaken by NCSCM with CSMCRI and TNFU would help in developing location-specific seaweed farming methods with least ecological footprints.

Conventional rectangular rafts for *Kappaphycus alvarezii*

Tube net method for *Kappaphycus alvarezii*

Triangular rafts for *Gracilaria edulis*

Conventional rafts arrangement



Raft arrangements to reduce environmental foot prints

Fig. 10. Activation methods for selected species

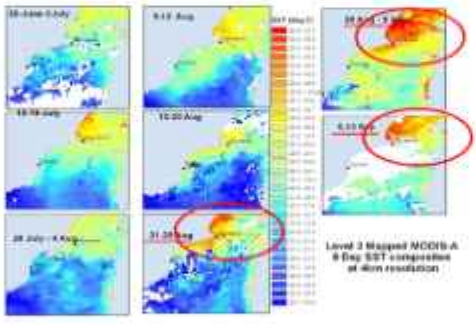


Fig. 11. Eight-day SST composite maps of GoM and Palk Bay and Mean SST plot in Mandapam highlighting the period and scale of anomaly

Elite germplasm production at Mullimunai

Outdoor culture

Basket culture (acclimation)

Monoline culture

Fig. 12. Experimental Seaweed farm at Mullimunai

Knowledge, Governance and Policy Division

This division will work as a central repository for the dispersed information on the Indian coast. Coastal management requires all the stakeholders to be interconnected at different scales in order to share information, knowledge and data to solve problems and conflicts facing the coastal area and livelihood of the coastal communities. The knowledge management system of the centre would assist those interested in coastal governance to access the most relevant information of coastal issues. This division would also provide advisory to the government on coastal governance and policy issues. The major groups under the division are: (i) the Information Bank, (ii) the Communication and Dissemination Group, (iii) the Capacity Building Group, (iv) the Coastal Law and Policy Group, and, (v) the Partnership and Networks Group.

The coast is of high-importance both ecologically and economically. The high diversity of activities has resulted in extensive alteration of coastlines worldwide. A balance has to be struck between various activities to ensure sustainable coasts. An effective approach is the use of integrated coastal management.

Strategies and Guidelines for National Implementation of Integrated Coastal Zone Management

Coasts worldwide are high priority area for development stimulated by globalization and trade requirements. From being a zone of few activities such as navigation and fisheries, space in coastal areas is under high demand for a variety of activities such as the development of ports and harbours, industries and settlements, causing increasing pressure on coastal ecosystems. Since most development-related activities are sector-specific and highly competitive, there is often conflict for space and resources. Existing management approaches however, are primarily sectoral addressing specific problems symptomatically rather than using a holistic perspective.

Since 1991 when the Coastal Regulation Zone Notification was issued under the Environment (Protection) Act, 1986, only a width of 500 m from the high tide line along the coast is subject to regulation with respect to activities in that area based on the zoning principles. In 2006, India introduced the National Environment Policy (NEP) which suggested that the following actions be taken:

a. Revisit the Coastal Regulation Zone (CRZ) notifications to make the approach to coastal environmental regulation more holistic, and thereby ensure protection to coastal ecological systems, coastal waters, and the vulnerability of some coastal areas to extreme natural events and potential sea level rise. The Integrated Coastal Zone Management (ICZM) plans need to be comprehensive, and prepared on strong scientific basis by experts with the participation of the local communities both in formulation and implementation. The ICZM plans should be reviewed at pre-determined intervals to take account of changes in geomorphology, economic activities, settlement patterns, and coastal and marine environmental conditions.

In 2010, the Ministry of Environment and Forests, with assistance from the World Bank, initiated the Integrated Coastal Zone Management (ICZM) Project that would:

- adopt an integrated management approach, with people's participation;
- promote livelihood security of the coastal communities, and
- protect the ecosystems while promoting sustainable development.

Integrated management of the coastal and marine areas in general and the ICZM project in particular is expected to have long-term benefits. Development of economic infrastructure in the coastal zone, along with protection of ecological and cultural backgrounds and traditional rights is crucial to India's growth and development.

In Phase I, development and implementation of State Level approaches to ICZM (in the three States of Gujarat, Orissa and West Bengal), has been initiated with the objective to develop and empower state level authorities to adopt appropriate ICZM approaches consistent with national strategies. One of the major recommendations was to prepare ICZM plan for small coastal stretches as pilot sites (Fig. 1). Preparation of ICZM plan for any area is a process oriented activity. While the overall structure for the preparation of ICZM plans is well known, there is little by way of a practical guidance document. In 2012-13, the structure of the planning process was finalized after extensive discussion and consultations. To help in operationalizing this, a national guideline for the development and implementation of ICZM plans in India titled "Strategies and Guidelines for National Implementation of Integrated Coastal Zone Management (ICZM)" was prepared and was made available to the state project management units in December 2013. This document provides information on the guiding principles for ICZM in India, the legal and regulatory framework, a detailed task and activity list for each of the five phases.

Under each phase, the following information is provided:

- The various tasks under each phase are listed
- Activities under each task are detailed; if necessary, tasks are subdivided into sub-tasks
- Where required terms of reference for consultants are provided
- Deliverables at the end of each phase are listed
- Reports and other documents to be prepared are listed at the end of each phase.

Support to develop and finalise terms of references is being provided to the SPMU currently implementing the ICZM programme.

Capacity building

An interactive display system (fig. 2) has been developed to provide training in the process of preparation of ICZM plans. This system enables the learner to systematically go through the entire planning process and also has the provision of storing images, graphs, maps and videos to explain the issues in various locations.

Case Study of ICZM Plan for Dandi in Collaboration with SPMU, Gujarat

Dandi is a coastal village in the Navsari district of Gujarat, located on the Arabian Sea shore. It is famous for Mahatma Gandhi's 1930 salt march when he walked from Sabarmati Ashram near Ahmedabad to Dandi and picked up grains of salt. This march triggered the Civil Disobedience Movement and was an important part of the Indian independence movement. The MoEF in collaboration with the SICOM, aided by the Gujarat Ecology Commission has undertaken the project for the development of a green memorial at Dandi. Called The Green Action for National Dandi Heritage Initiative (G.A.N.D.H.I) Project, it aims at the overall Development and conservation of the environment of Dandi and its surrounding villages, based on Gandhian principles and teachings on environmental conservation and village development.

In 2010, Dandi and the villages of Samapar, Matwad and Onjal covering an area of about 20,000 ha were declared an "Eco Sensitive Zone" under the Environment Protection Act 1986. This was prompted not only by the historical importance of Dandi but also because of the fragile coastal ecosystem that has mudflats, long beaches, sand dunes and wetlands. The area is also being affected by coastal erosion and pollution. An integrated coastal management plan for the area is to be prepared to promote conservation of natural resources as well as to regulate other activities, *inter alia*, the setting up of industrial units in the vicinity and ecotourism (Fig.3-10).

Preparation of a guidance document for CRZ 2011

The Coastal Regulation Zone Notification was first issued in 1991 under the Environmental (Protection) Act, 1986. In 2011, a fresh notification was issued with extensive modifications over the previous (1991) version. Though there is greater clarity in the 2011 Notification compared with the 1991 Notification, it was considered essential to prepare a document that would provide illustrations, explanations and supplementary information for the various sections of the Notification.

This guidance document (currently in draft form) explains the coastal regulation zone as defined by the CRZ 2011 Notification using illustrations and photographs. For example, a bird's eye view of all the coastal regulation zones is given below(Fig.11).

An important part of the CRZ 2011 is the hazard line which is a composite erosion-flood line that is to be demarcated along the Indian coast. The development of this line is illustrated in the figure below which shows the different 'lines' that go into the preparation of a composite hazard line (Fig.12).

As a first step to the planning process, a series of maps of the Dandi area, including the villages of Matwad, Dandi, Onjal, Aat, Samapar, Sultanpur and Khamblav, have been prepared by the NCSCM to enable understanding of the current land use, distribution of population, ecologically sensitive areas as well as vulnerability due to flooding and sea level rise.

The CRZ is further classified into four classes. CRZ I includes ecologically sensitive areas, CRZ II includes coastal areas that are extensively built up, CRZ III include most of the rural areas and CRZ IV includes the water and sea-bed falling within the territorial limits. Activities prohibited in the CRZ are described along with exceptions and additional information in the form of tables for easy understanding. A chapter is devoted to the process of regulation of activities in the coastal zone while another details the preparation of coastal zone management plans.

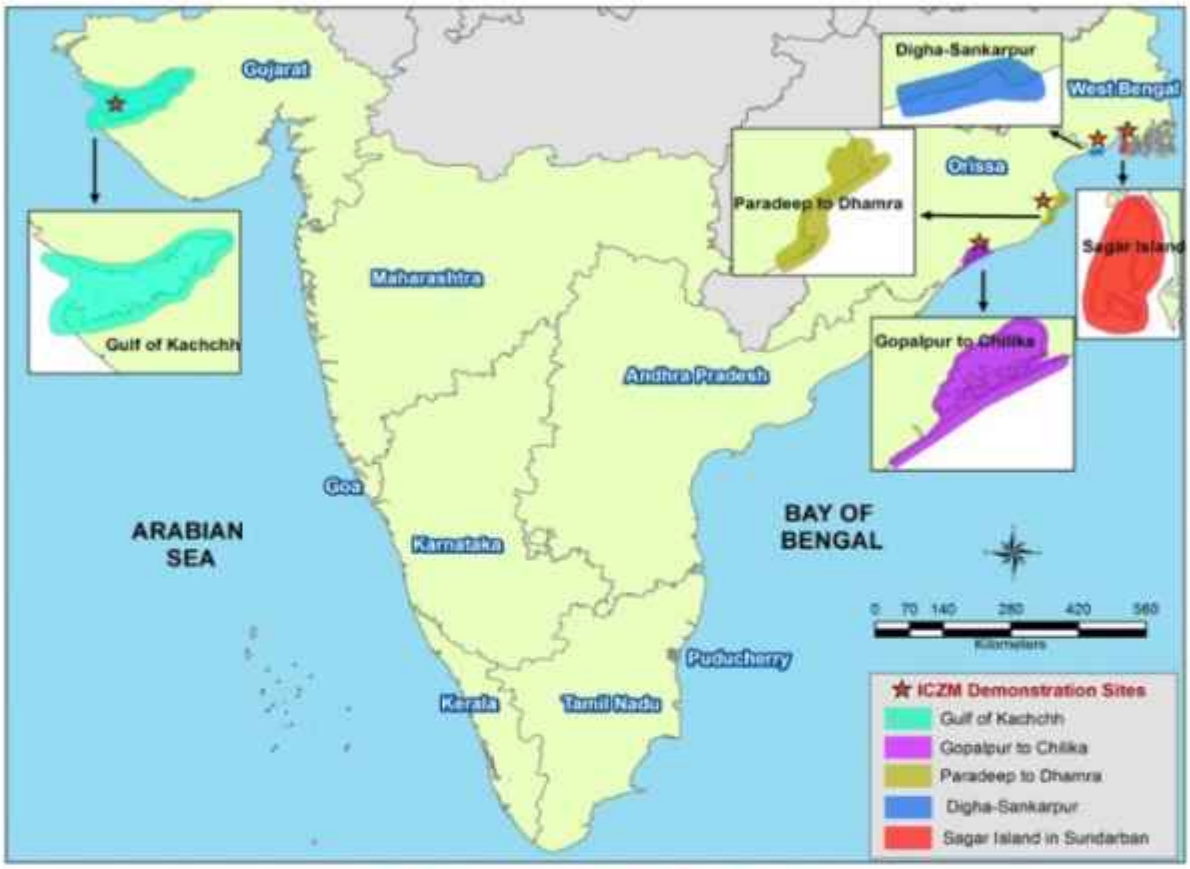


Fig. 1. Location of ICZM sites – Phase I

Fig. 2. Interactive display Board Used for Training in ICZM

Fig. 3. Map of the Dandi area showing the villages

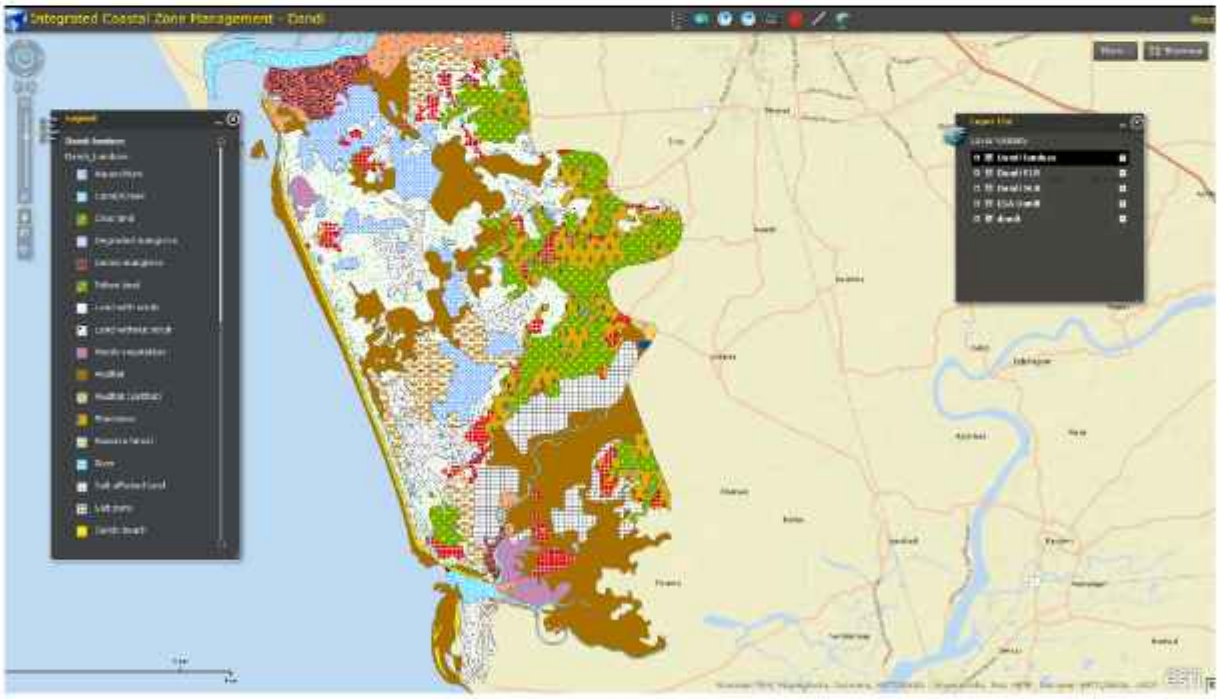


Fig. 4. Land use map for Dandi area

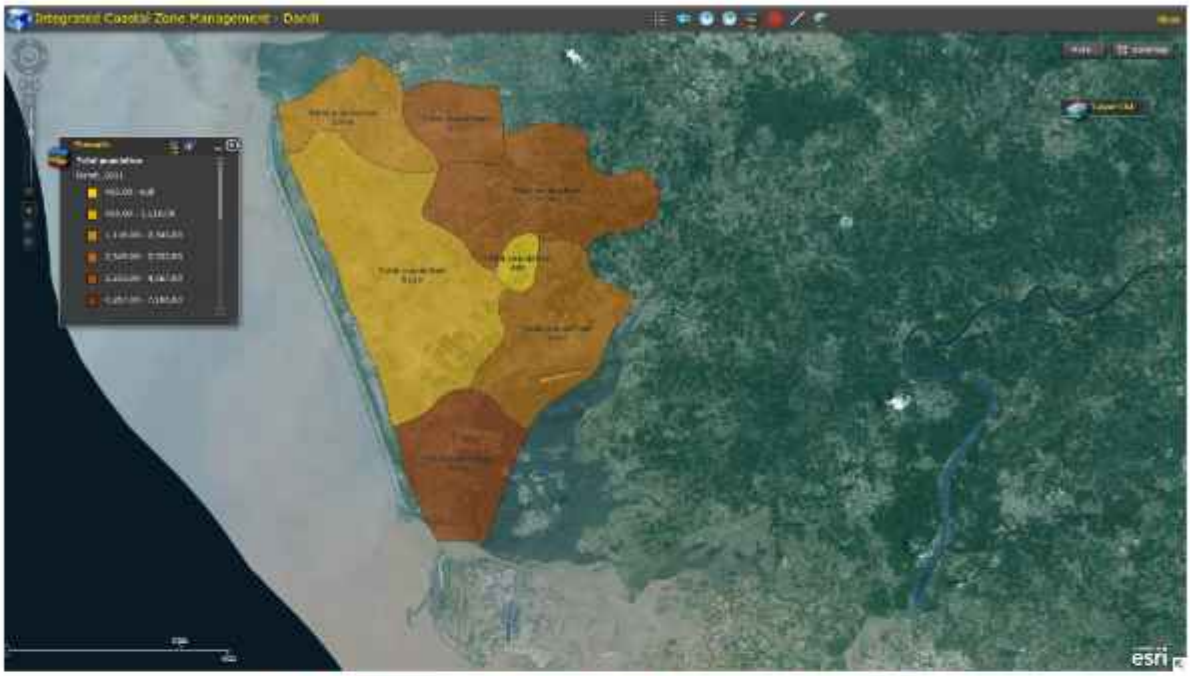


Fig. 5. Population of Dandi and the surrounding villages

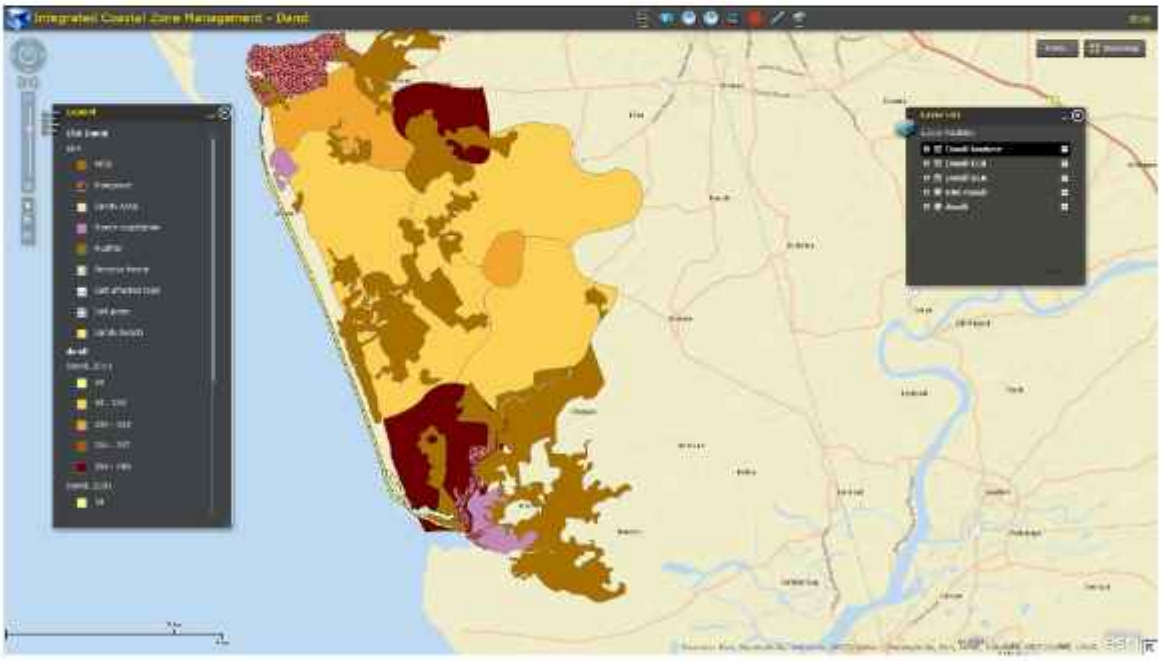


Fig. 6. Ecologically Sensitive Areas in the Dandi area

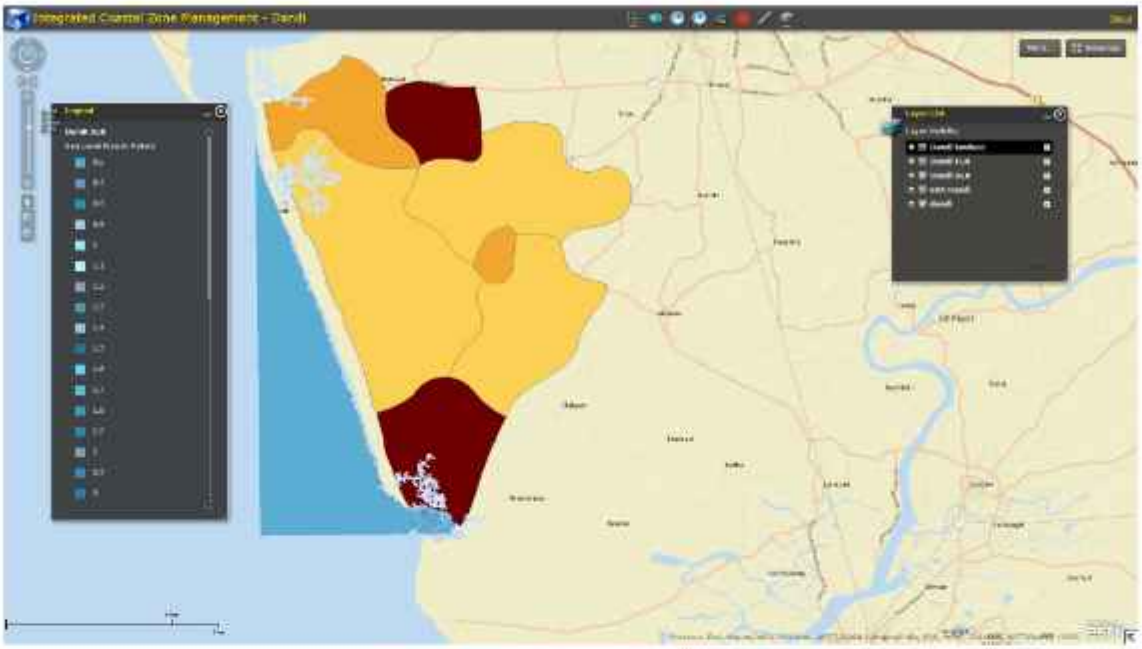


Fig. 7. Sea level rise vulnerability -1

Fig. 8. Sea level rise vulnerability -2

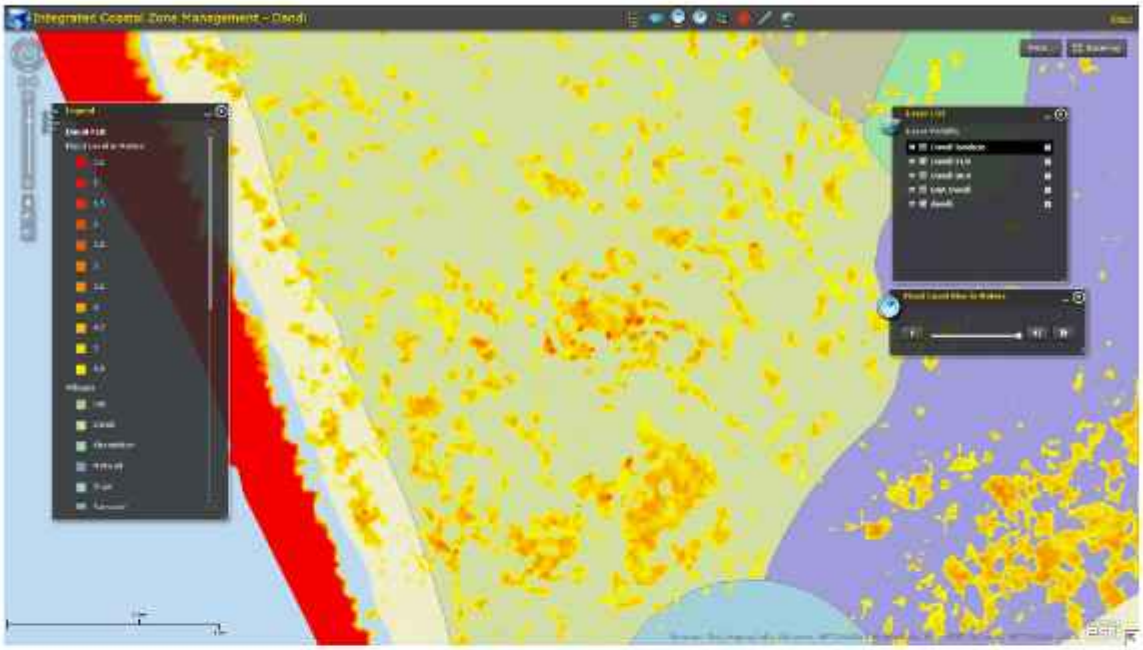


Fig. 9. Flood risk vulnerability-1

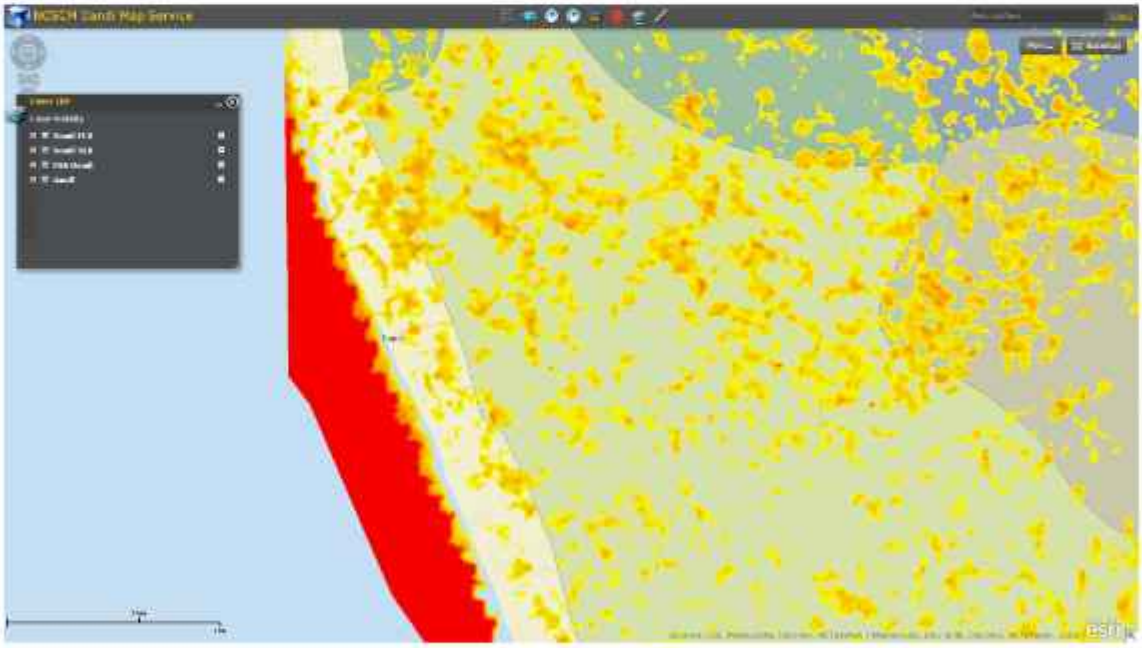


Fig. 10. Flood risk vulnerability -2

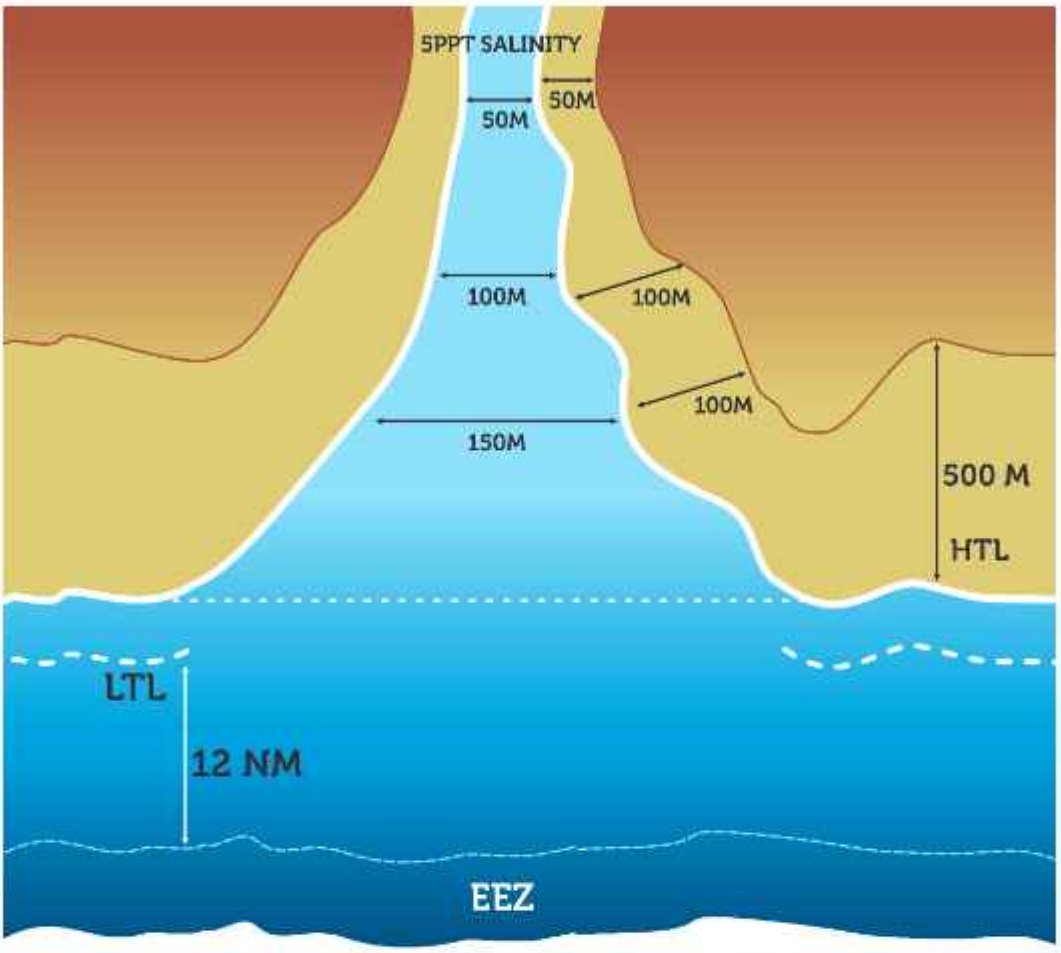


Fig. 11. Coastal Regulation Zones (CRZ 2011): Conceptual representation

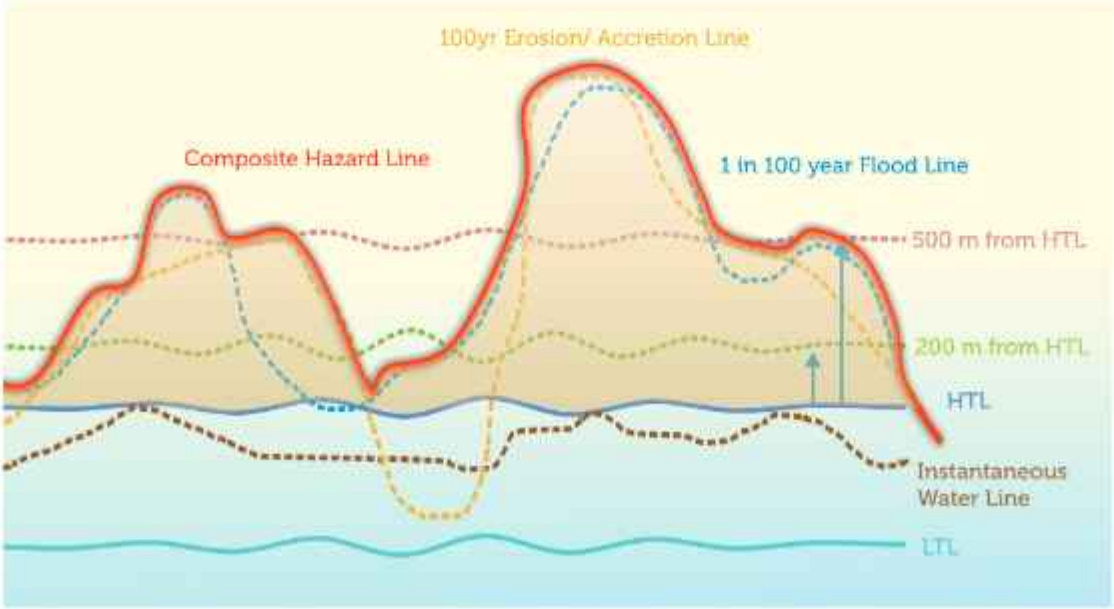


Fig 12. Conceptual representation of the various lines associated with composite hazard line

Coastal Environmental Impact Assessment

This division would provide input and advice on all components of coastal environmental impact assessment. The division would study all relevant aspects to establish baseline environmental conditions of specific coastal areas. CIA Division would study the cumulative environmental, economic and social effects of regional development prospects on coastal and marine resources and environment. This Division would suitably advice management measures for Ecologically Sensitive Areas in the coastal and marine areas. The major groups under the division include: (i) Coastal and Marine Sciences, (ii) Coastal and Marine Engineering and Infrastructure, (iii) Cumulative Coastal Environmental Impact Assessment, (iv) Social Assessment and Gender, and (v) Coastal Tourism and Heritage.

The high degree of complexity in coastal zones has led to emphasis on adoption of integrated coastal zone management (ICZM) as a governance mechanism by considering various aspects of human activities and their management. Cumulative environmental impact assessment (CEIA) is an integral part of ICZM processes, considering cumulative impacts of development of the coastal/marine areas. CEIA helps to link the different scales of environmental assessment, focusing on how developmental plans are designed and the effects of a particular plan.

Assessment of Cumulative Coastal Environmental Impacts [ACCES]

Majority of the world's population live in coastal zones- combining terrestrial-aquatic areas and revolving around the land–sea interface. Such areas face many environmental and management challenges, due to a combination of environmental impacts that arise in both open ocean areas and those areas inherent to coastlines, such as the impacts of land based activities. The high degree of complexity in coastal zones has led to emphasis on adoption of integrated coastal zone management (ICZM) as a governance mechanism by considering various aspects of human activities and their management. Cumulative environmental impact assessment (CEIA) is an integral part of ICZM processes, considering cumulative impacts of development of the coastal/marine areas. CEIA helps to link the different scales of environmental assessment, focusing on how developmental plans are designed and the effects of a particular plan.

Current assessments for environmental impacts are usually carried out on micro level (either site-specific or project specific) for any proposed developmental activity, rather than considering its cumulative effects along with several other existing activities on the coastal stretch. Thus, current practice has been based on piecemeal approaches and detailed studies for cumulative impacts have not been carried out on a regional/broader level. Environmental degradation due to unsustainable human practices and activities now seriously endangers the entire production system of the planet.

The planet is facing an unprecedented mass extinction of floral and faunal species, raising sea level, rising atmospheric temperature, coupled with the increasing frequency of flood and storms. This happens due to the unregulated industrialization and rapid urbanization which is responsible for the ecological imbalance on the planet. In view of the growing concerns on progressive environmental deterioration of vulnerable coastal and marine ecosystem of India, National Centre for Sustainable Coastal Management (NCSCM), Chennai, has indented to monitor the cumulative impact of coastal environment along the Indian coast.

Framework for the Cumulative Environmental Impact Assessment for the Gulf of Kachchh Gujarat

A Framework for the Cumulative Environmental Impact Assessment for the Gulf of Kachchh (GoK) is being prepared in consultation with national, international environmental experts and stakeholders. The conceptual Framework of CEIA is described in Fig. 1. For the cumulative impact assessment of GoK, a historical timeline of the major events since pre-independence era (Fig. 2) has been inventoried. Events such as establishment of industries, natural disasters, and creation of the Marine National Park among other the historical events that were documented in the timeline. There were three major events that was classified as the Extraction, Protection a nd Restoration periods in the GoK region.

In addition, the coastal activities viz. ports, industries; agriculture, domestic sewage, saltpans etc. were also considered. The assessment will help the coastal managers and policy makers to determine the current status of GoK, and provide a broad perspective to manage the developments in future. It will address the following key issues in the assessment study:

- Sustainability of the Gulf of Kachchh to the present.
- Manage and plan for future developments from social, economical, and environmental perspectives.
- Most importantly, it will help to develop strategies and response to mitigate the impacts through state machinery and comprehensive pollution management plan of ICZMP

The framework was generated following the Workshop on Cumulative Environmental Impact Assessment of Gulf of Kachchh, conducted in GEER Foundation, Gandhinagar, Gujarat, on 5th-6th September, 2013. The Workshop incorporated local expertise – qualitative data (and not quantitative) about the natural resources and features of the Gulf of Kachchh, the potential pressures affecting them, and the current conservation efforts along the region.

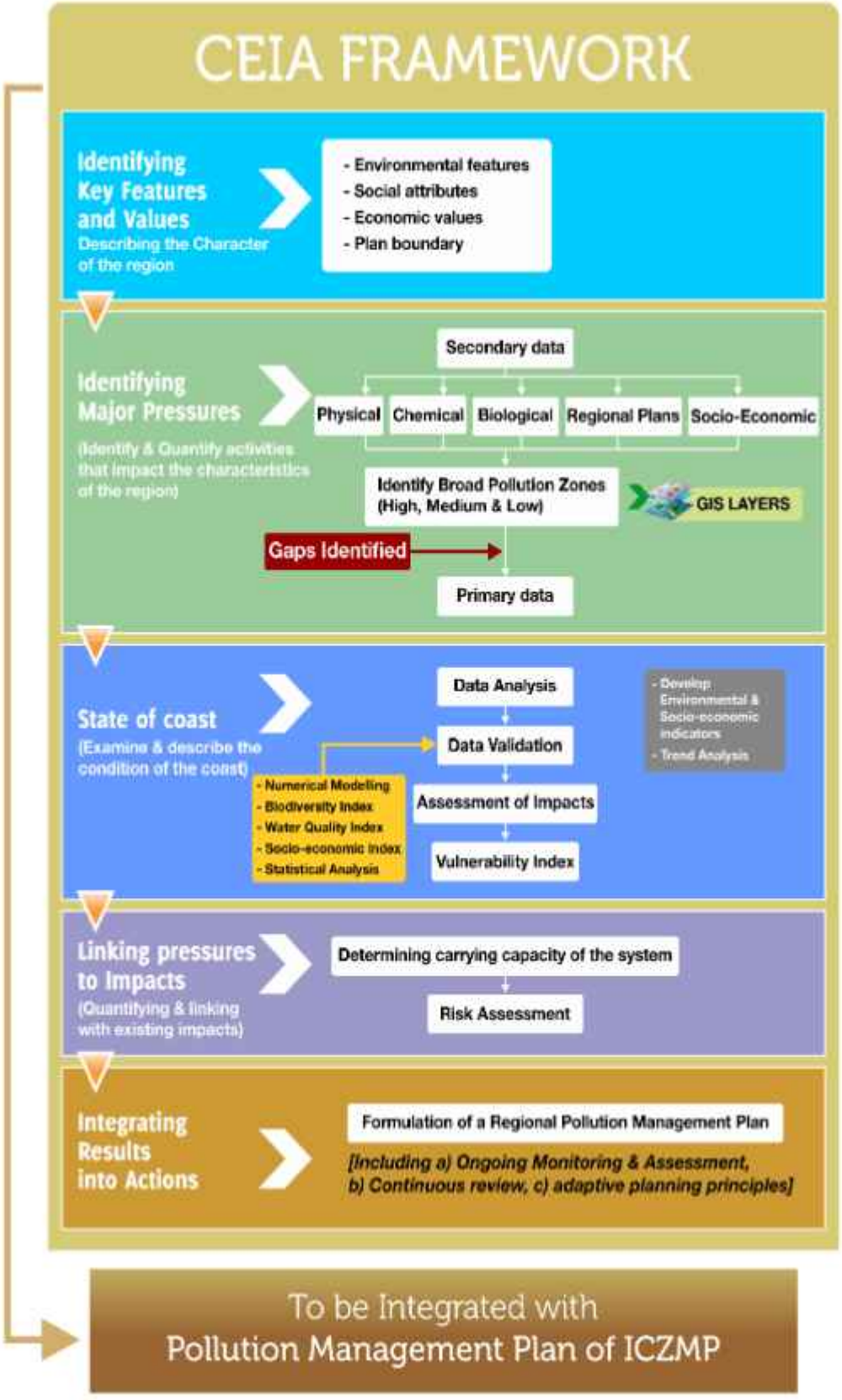


Fig. 1. Framework Conceptualization of CEIA

Fig. 2. Historical timeline of events in the GoK since the pre-independence era

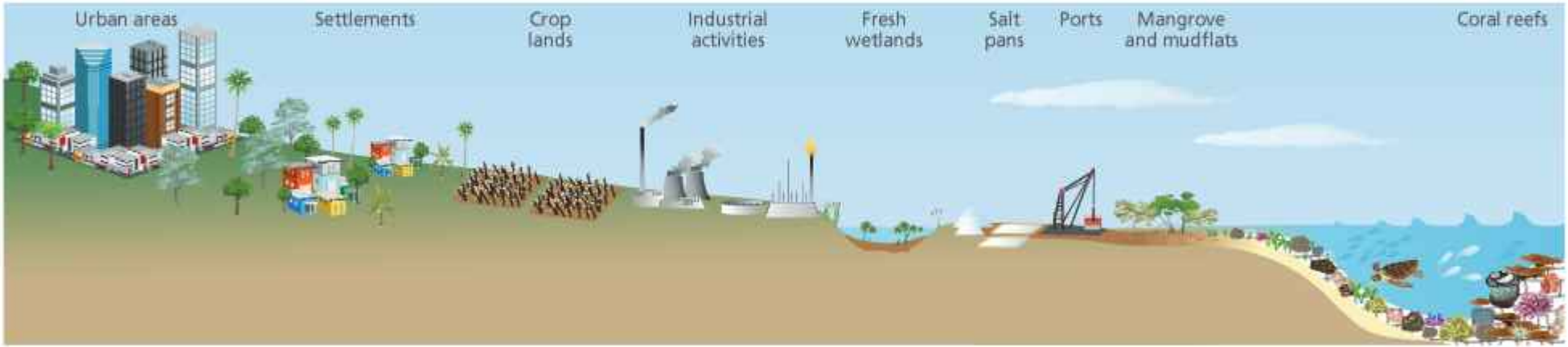


Fig. 3. A general conceptual representation of the various human activities and natural ecosystems in the Kachchh

Framework conceptualisation

The assessment framework is divided into a 5-step process that will lead to improved management planning for the GoK region. An overview of each step, followed by recommendations, including actions and information required to fulfil the Cumulative Environmental Impact Assessment.

Key Features and Values

The environmental characteristics of the region including the social, economic and environmental values placed upon them (Fig. 3), describing the key features and values of the GoK region.

Nutrient Induced Green algae (*Ulva lactuca*) smothering on the coral colony (*Goniopora* sp.) at Pirotan Island of Gulf of Kachchh

Major Pressures

Identify and quantify the current and future activities in the region that are, or are likely to, impact the environmental characteristics and values.

Urban sewage and waste
Some urban areas and industrial townships continue to release untreated sewage and municipal waste, potentially introducing pathogens and causing eutrophication in the Gulf.

Agricultural runoff
During monsoon, storm water from farm fields picks up toxic pesticides and excess fertilisers, and deposits them, ultimately, into the Gulf, resulting in eutrophication and algal bloom events.

Turbidity
Mangrove deforestation and deep-sea dredging for ports and industrial sites deposit sediment and increase turbidity in the Gulf, which endanger coral and seagrass health.

Salt pan discharge
Increased salinity in seawater and soil from salt pan discharge—threatening coral reefs and contaminating groundwater and agricultural lands—is a significant pressure in the Gulf.

Industrial development
Oil spills and pipeline leaks, ship ballast water release, chemical plant effluent discharge, warm high saline discharge and power plant outfalls are all increasing risks to Gulf corals, seabirds, mangroves, and fisheries.

State of the Environment

Examine and describe the condition of the existing environment, identify vulnerable areas, and determine the carrying capacity of the system for current and expanded growth.

Status and trends: A comprehensive state of environment assessment is conducted within the context of the ecosystem features, and the effects that the pressures may have on those features. Accordingly, the GoK region is divided into 9 zones, and shown in Fig. 4.

Fig. 4. Zonation Map of the Gulf of Kachchh

Hotspots of vulnerability

Zone 1 – Western MNPS
Zone 1 was characterised as having moderate pressure from agricultural runoff and turbidity.

Zone 2 – Central MNPS
Zone 2 was characterised as having moderate-high pressure from sewage and urban waste, turbidity, and industrial development, and low-moderate pressure from salt pan discharge.

Zone 3 – Eastern MNPS
Zone 3 was characterised as having moderate pressure from agricultural runoff, turbidity, and salt pan discharge, and low-moderate pressure from industrial development.

Zone 4 – Islands MNPS
Zone 4 was characterised as having moderate pressure from industrial development, and low moderate pressure from sewage and urban waste and turbidity.

Zone 5 – South-eastern Gulf of Kachchh
Zone 5 was characterised as having high-moderate pressure from turbidity, and moderate pressure from salt pan discharge and industrial development.

Zone 6 – North-eastern Gulf of Kachchh
Zone 6 was characterised as having moderate pressure from sewage and urban waste, and low moderate pressure for agricultural runoff, turbidity, salt pan discharge, and industrial development.

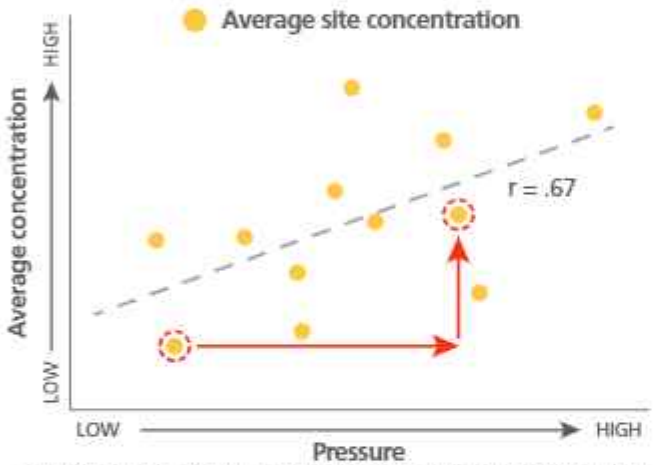
Zone 7 – Eastern central gulf of Kachchh
Zone 7 was characterised as having high pressure from sewage and urban runoff, moderate pressure from agricultural runoff, and moderate-high pressure from turbidity, salt pan discharge, and industrial development.

Zone 8 – Western central gulf of Kachchh
Zone 8 was characterised as having moderate pressure from agricultural runoff, turbidity, salt pan discharge and industrial development.

Zone 9 – North-western gulf of Kachchh
Zone 9 was characterised as having low pressure from all activities.

Linking Pressures to Impacts

Quantify past and existing pressures and determine linkages to known impacts to enable forecasting of risks associated with future developments.



A statistical model can use a relationship of pressure to impacts to project future impacts if pressures are increased.

Fig. 5. Linking Pressure to Impacts

A methodology to reasonably foresee future development of the region is a critical component of the framework. This step addresses how the assessment framework will predict the likelihood and magnitude of future impacts (Fig. 5) from new and/or growing activities in the Gulf, and the inevitable uncertainty entailed in doing so. This will require an understanding of what the relative contribution of new and/or growing activities will have towards the existing situation in the Gulf; what indicators and thresholds will be used to measure and assess this; and what specific government and/or company goals and management objectives exist or are proposed to address the activities' cumulative effects.

Integrating Results into Action

Consolidate and integrate information obtained from Steps 1 - 4 into a regional management plan that includes ongoing monitoring and assessment, continuous review, and adaptive planning.

Potential management recommendations for GoK
The types of management activities that may be required to reduce pressures on Gulf natural resources are described below.

	**Salt pans** • Improve efficiencies of salt production to produce less bittern • Recover useful chemicals from bittern
	**Agriculture** • Encourage seaweed harvesting and cultivation in high nutrient influx area without affecting the core ecosystem by local communities • Encourage organic farming methods to minimize fertiliser and pesticide use
	**Urban areas** • Improve wastewater treatment capacity and removal efficiency • Improve trash and solid waste collection
	**Dredging** • Modernize dredging methods. • Dispose of dredged material without plume generation, e.g., closed conveyance system.
	**Industry and ports** • Review industrial policies with regard to oil spill contingency plan. • Require all ports to create Emergency Management Plans. • Encourage zero discharge technology.
	**Fisheries** • Promote alternative livelihoods for local communities during monsoon season. • Increase contiguous marine protected areas. • Continue research on marine ecology and coral reefs.

The present cumulative environmental impact assessment for the Gulf of Kachchh region is the first of its kind in India that provides a broad understanding of the key pressures and values of the region. The current assessment is based primarily on key stakeholder perceptions, and available secondary data and information. Efforts are on to conduct a detailed CEIA, based on the framework proposed in Fig. 1, with appropriate primary data and State of coast reporting.

Assessment of Cumulative Environmental Impacts along the southwest coast (Goa – Alleppey) of India

As part of the research study, assessment of cumulative environmental impacts along the west coast of India from Goa to Alleppey (Fig. 6) is carried out in a cruise program. During the cruise, water, sediment and biological samples were collected and analysed from several transects on board CRV *Sagar Paschimi* (Coastal Research Vessel of Ministry of Earth Sciences) during the first week of May 2014 (Fig. 7). The cruise transects are planned on the basis of sediment cell concept. The spatial variation of physico-chemical parameters along the coastal stretch are shown in Fig. 8.

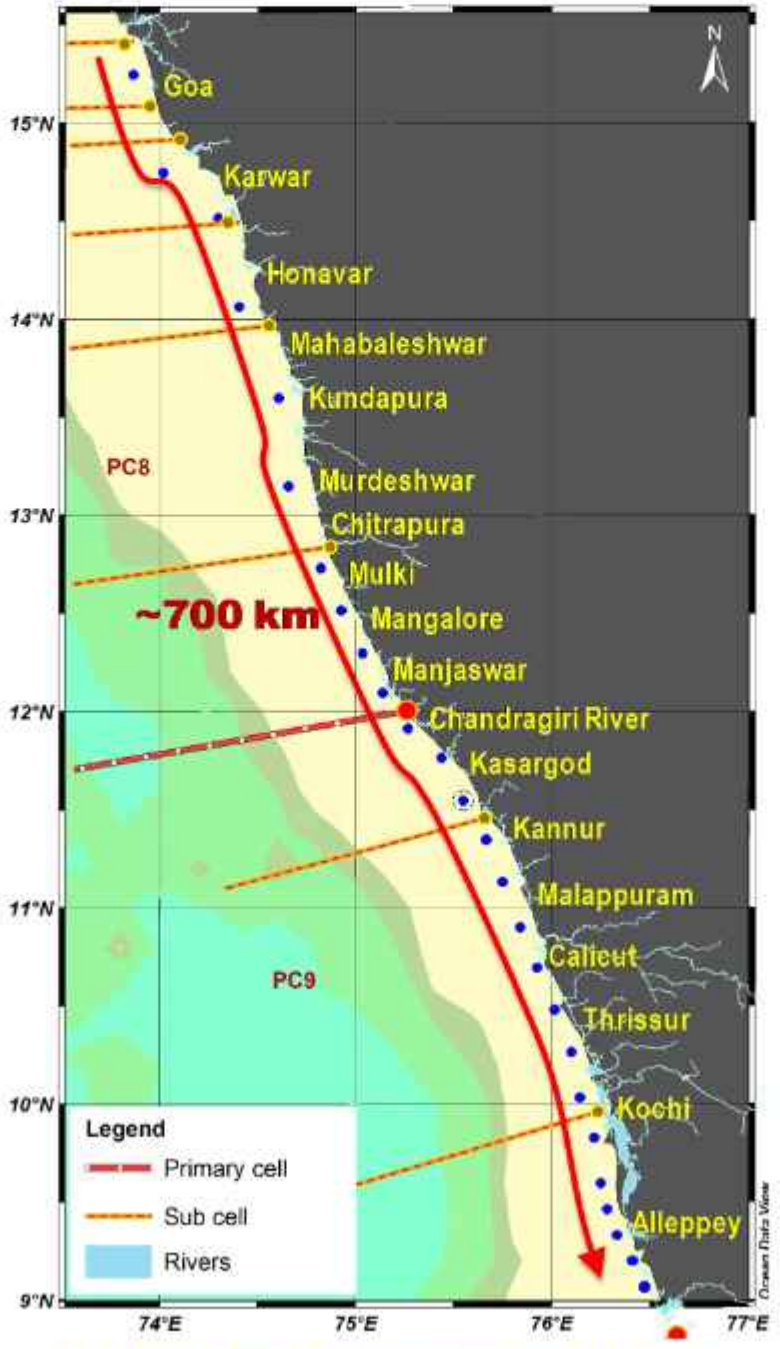
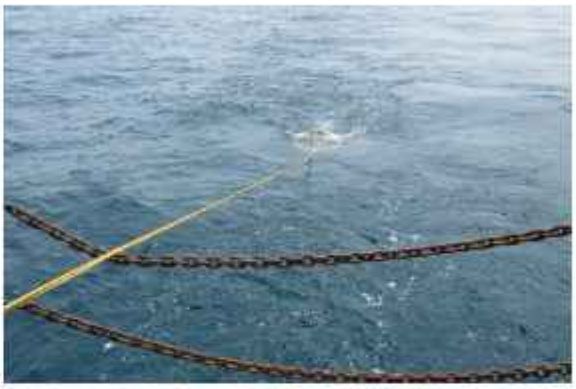


Fig. 6. Location map of cruise programme (Goa to Alleppey)

CRV Sagar Paschimi



Zooplankton sampling

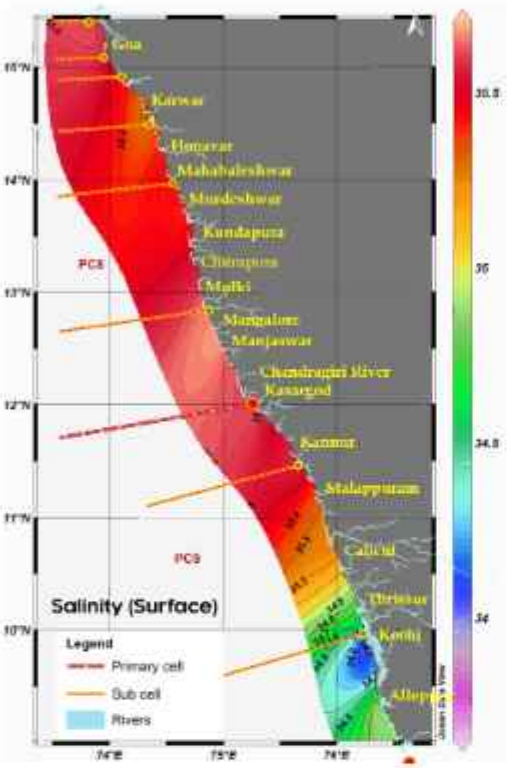
On-board sampling

On-board weather tracking

On-board analysis

On-board CTD deployment

Fig. 7. Sampling and analysis in On-board "CRV Sagar Paschimi"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PC8
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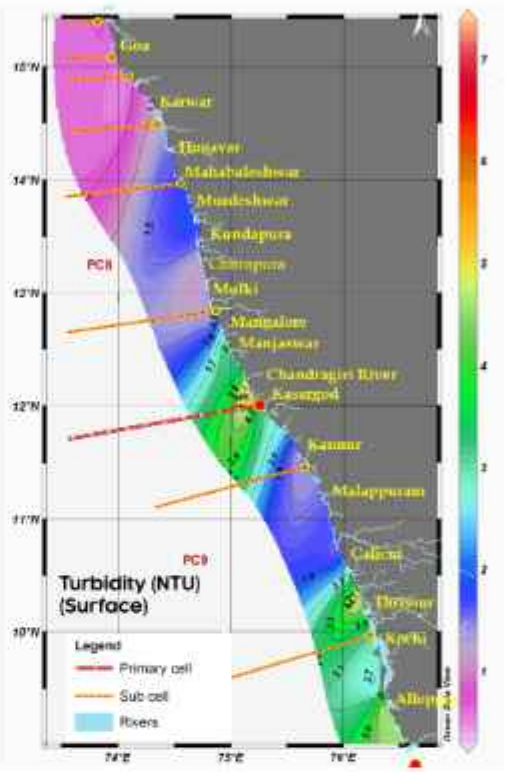
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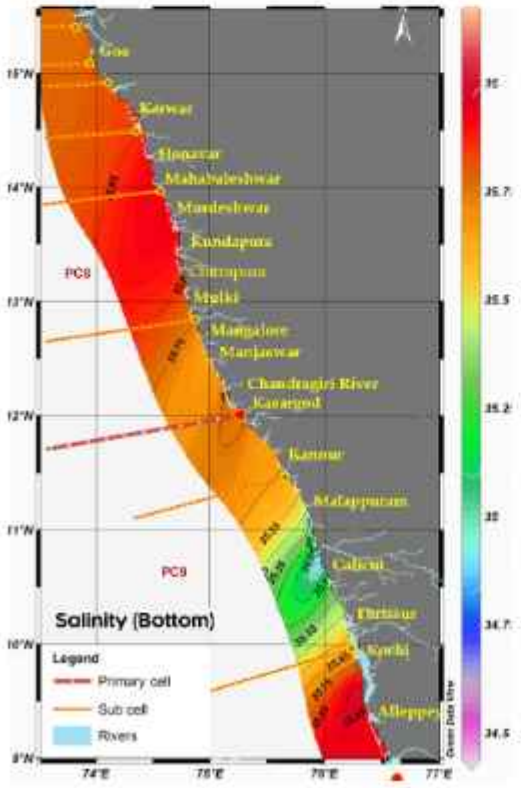
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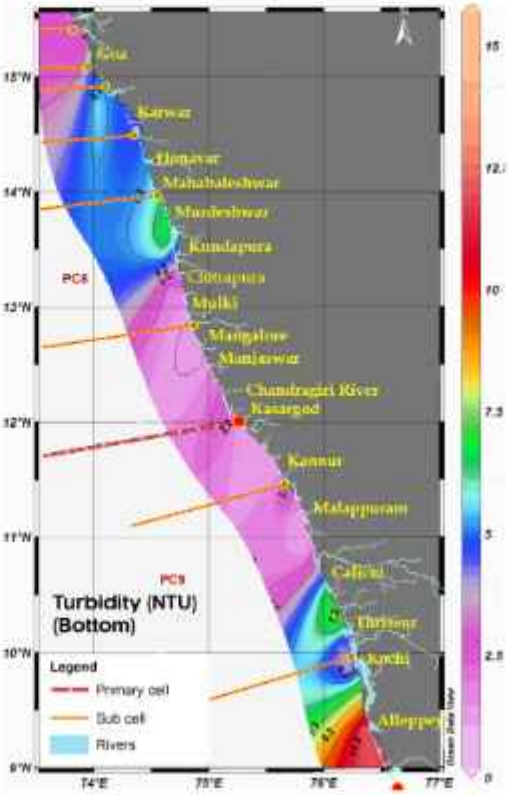
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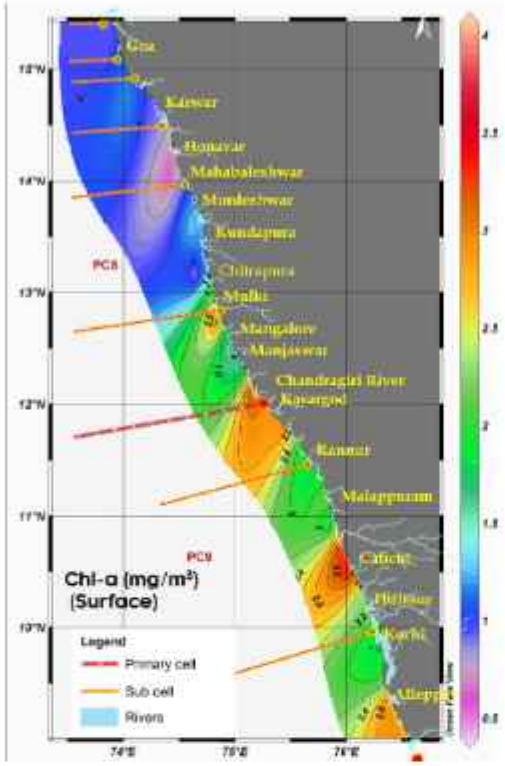
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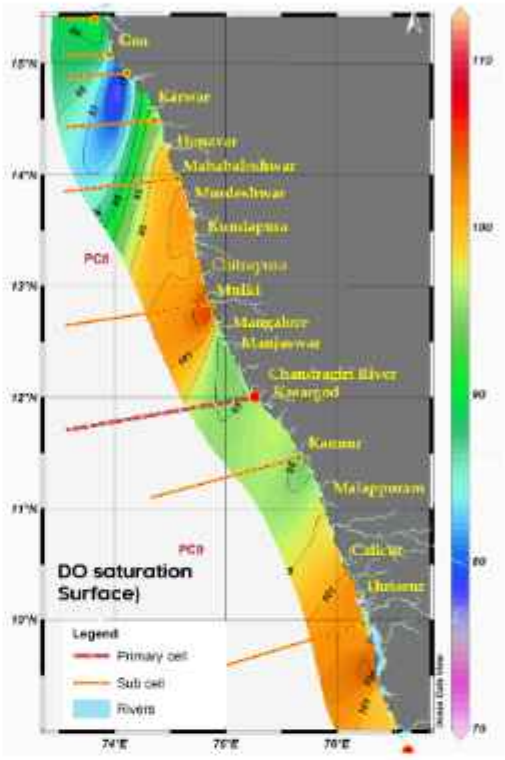
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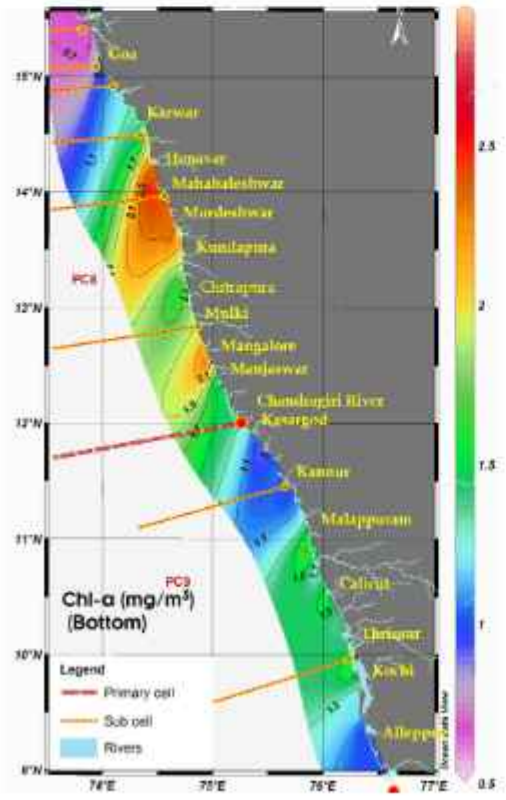
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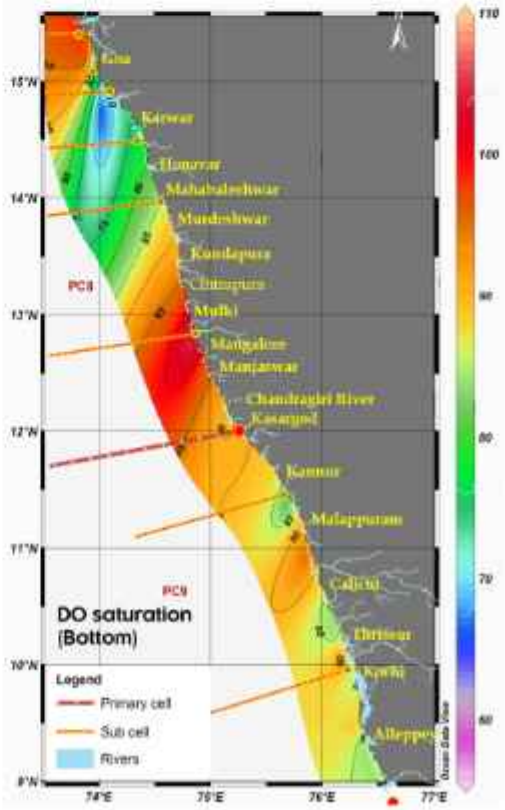
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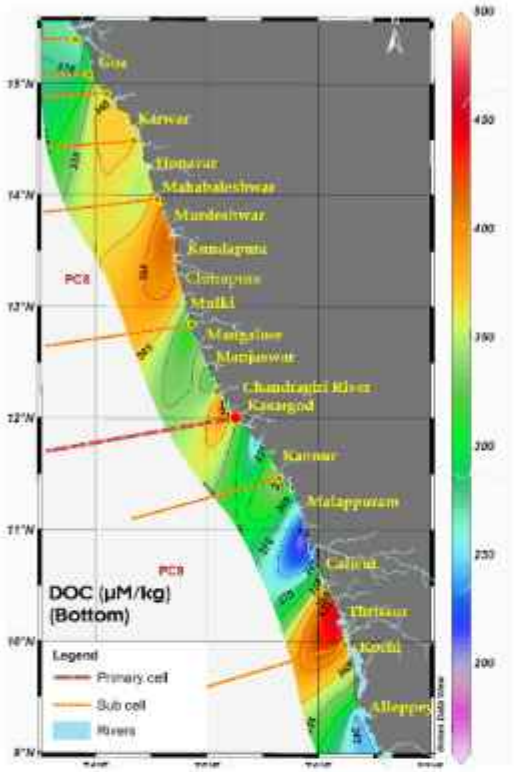
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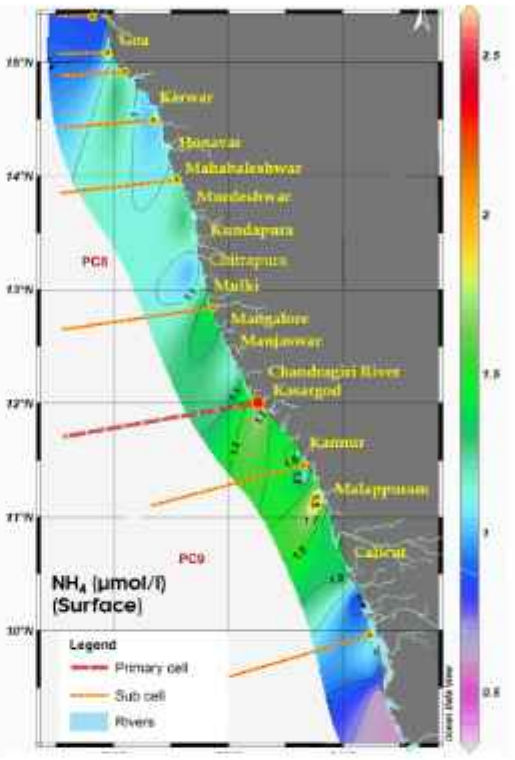
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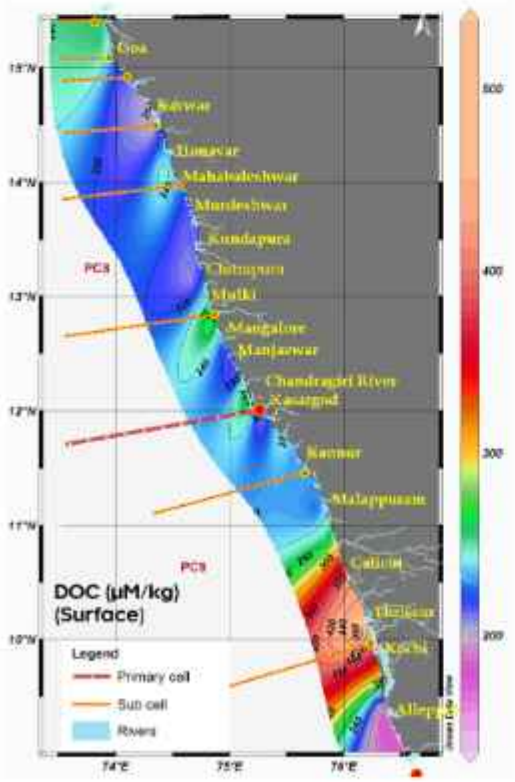
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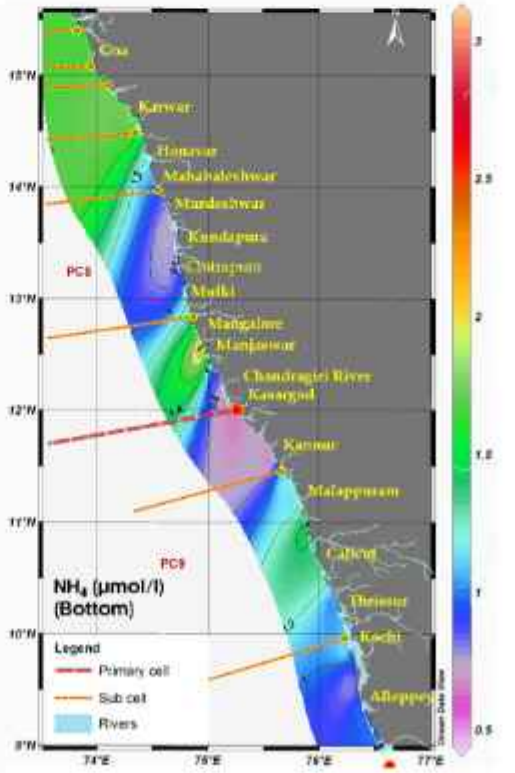
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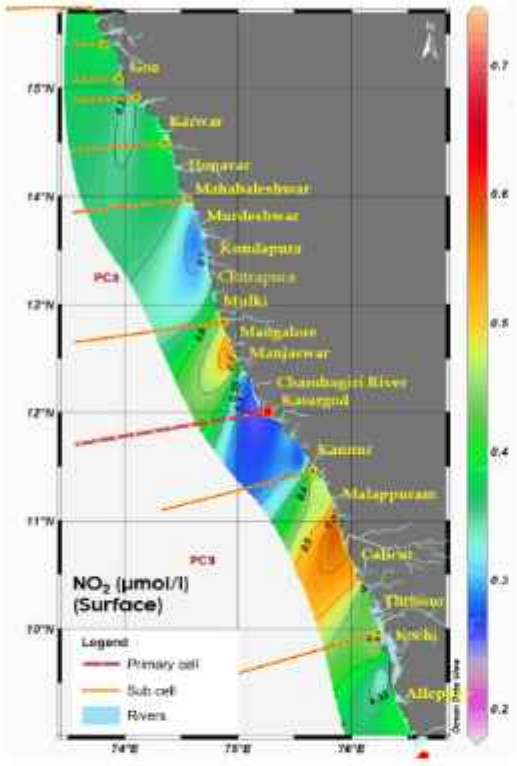
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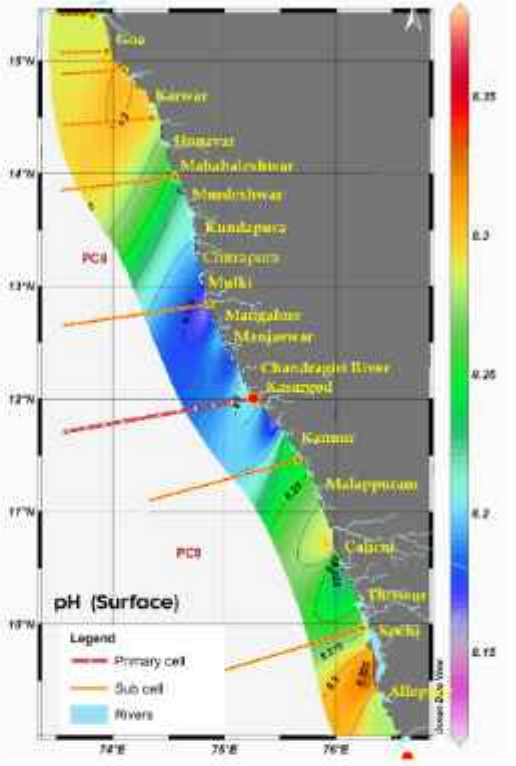
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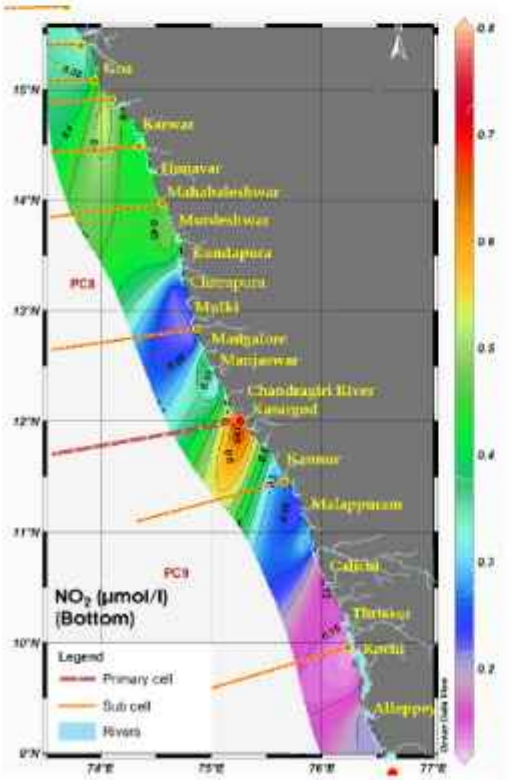
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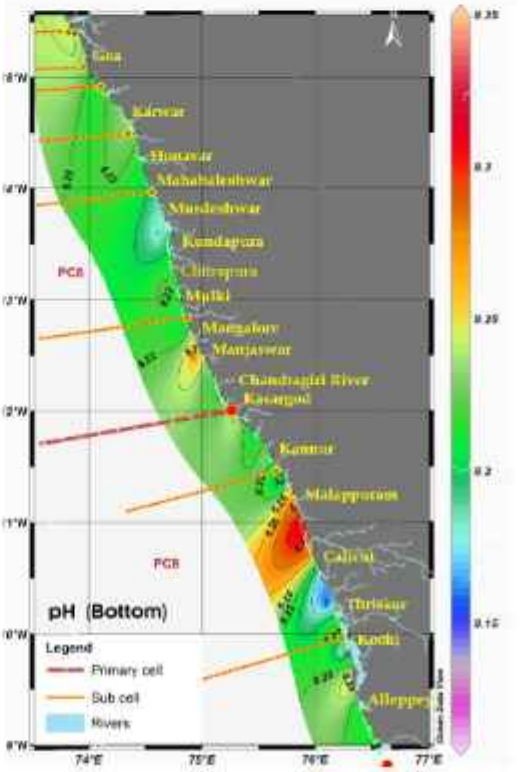
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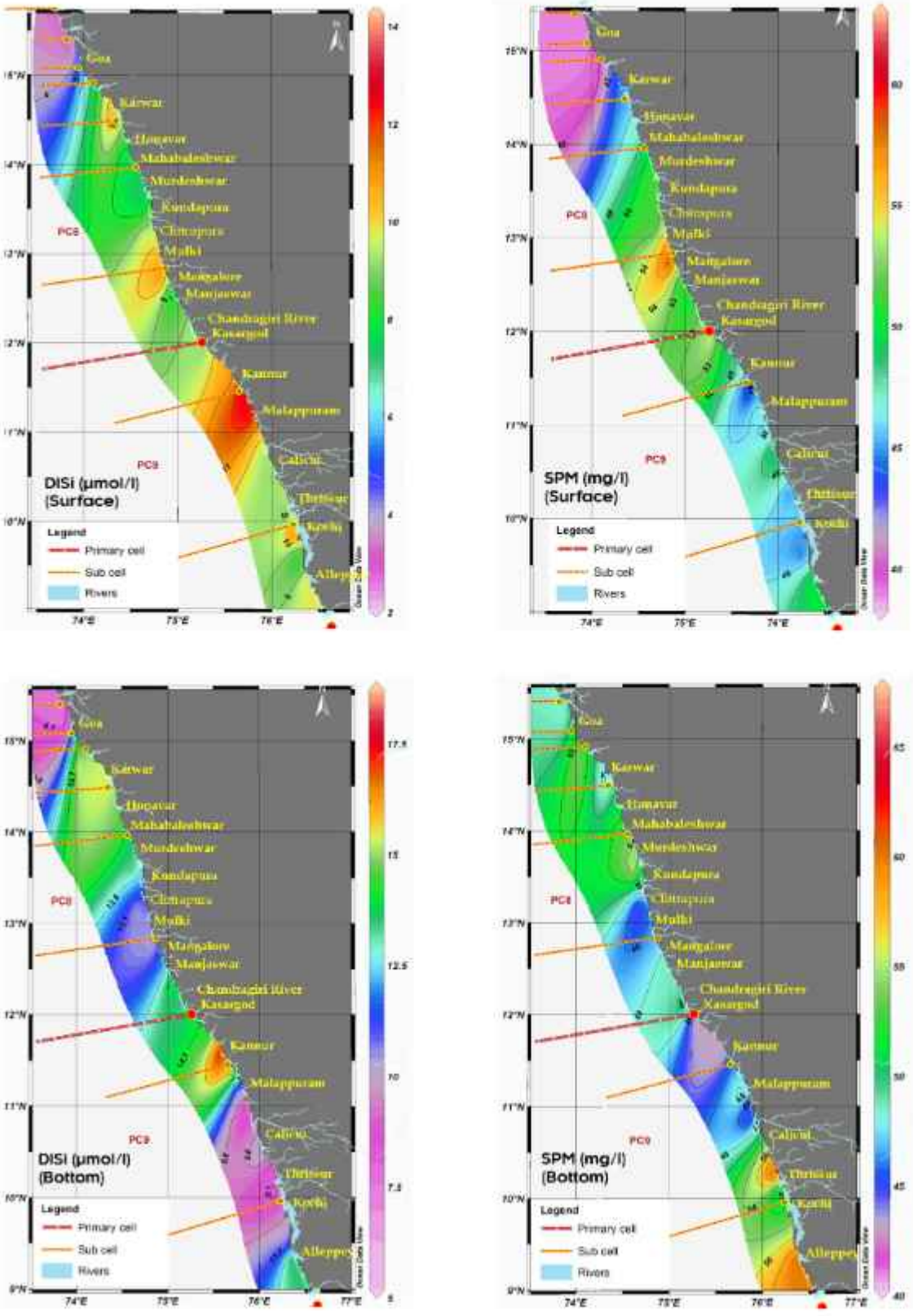


Fig. 8. Spatial variation of major physico-chemical variables (surface and Bottom) along the southwest coast of India

Multivariate statistical analysis

Multivariate analyses were carried out by using PAST version 2.15 (Hammer 2012). The concentration of Nitrate is contributed more towards the Mudbank areas such as Kalarkode and Thottapalli. Dissolved Silicate concentration was also contributed more towards the other mudbank area of Chellanum coast followed by Ellatur and Mangalore. Similarly, the contribution of SPM is also more towards the mudbank areas such as Thottapalli and Kalarkode and near coastal region of Kerala, Anchangadi. The DO saturation units are contributed more towards Mangalore followed by the Goan coast. There is no significant variation in salinity between the stations. Bray-Curtis Cluster analysis under paired linkage shows that four major clusters with 92% similarity. Among them, three clusters from Kerala coast and one mixed cluster between Kerala and Karnataka coast and two outliers such as Karwar and Goa. This cluster also provides groups of stations based on the similarity in water quality parameters observed in this study (Fig. 9). These groups of stations are influenced by the most relevant point sources of nutrients and urban sewage form a single cluster. Moreover, stations which are in close proximity to the anthropogenic activities falls in same cluster (Calicut to Cochin) and Alleppey mudbank stations falls in same cluster.

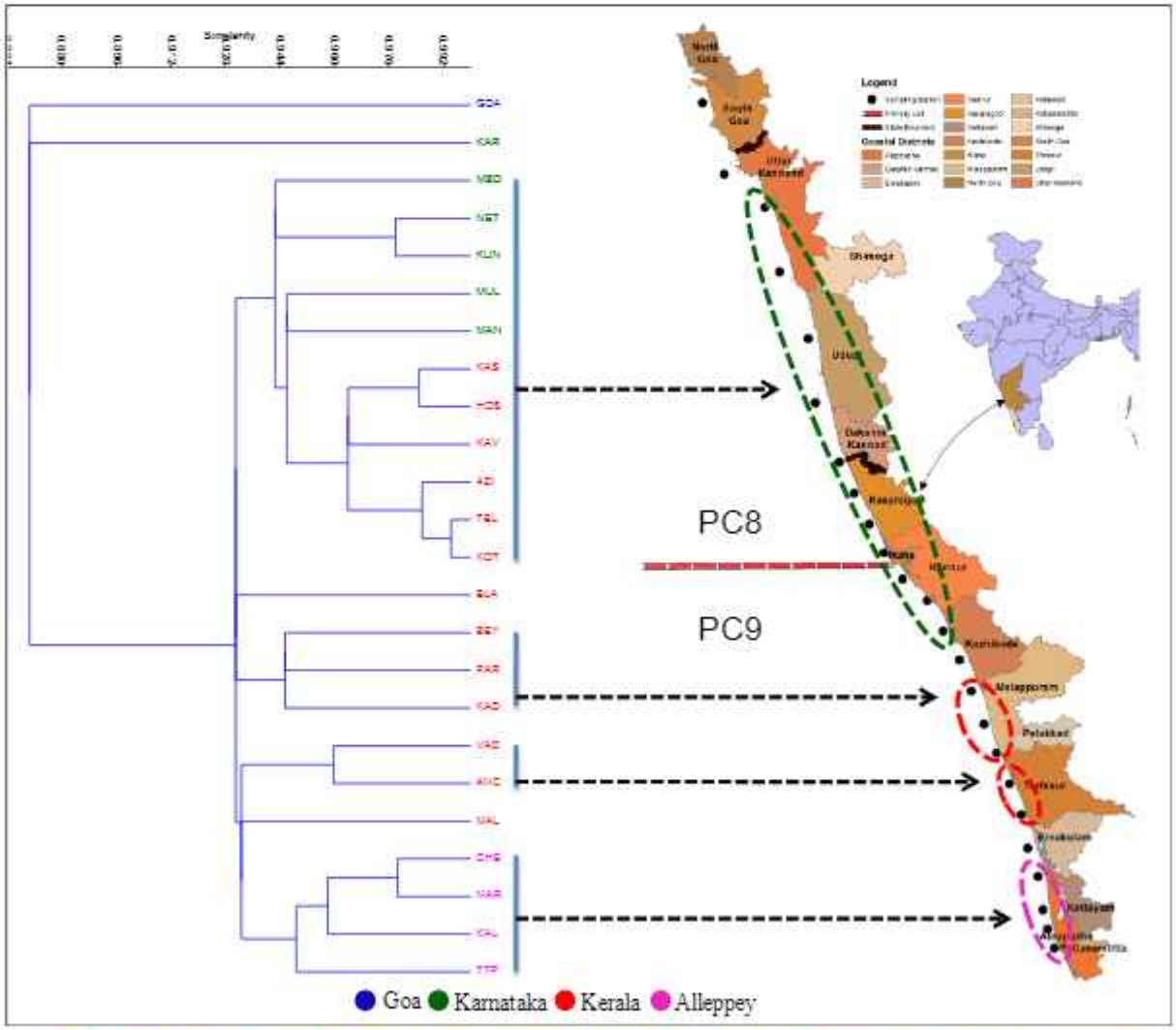


Fig. 9. Bray-Curtis Cluster analysis under paired linkage based on observed water quality parameters along the western coast

Nutrient budgeting of turbid (muddy) coastal waters using the LOICZ model

NCSCM Chennai for the first time in India has proposed to use the multi-box Muddy LOICZ approach for nutrient budgeting in the Indian coastal ecosystems such as lakes, lagoons, and estuaries. The Muddy LOICZ budget is the modified and updated version of the LOICZ model taking into account the effect of "suspended particulate matter" (Kd factor) in budgeting. During the meeting it was proposed to apply the multi-box Muddy LOICZ model for nutrient budgeting in the Indian coastal ecosystems. The ecosystems proposed for nutrient budgeting are both from east and west coast of India, and are shown in Fig. 10.

Fig. 10. Map indicating coastal ecosystems proposed for MUDDY LOICZ nutrient budget Model

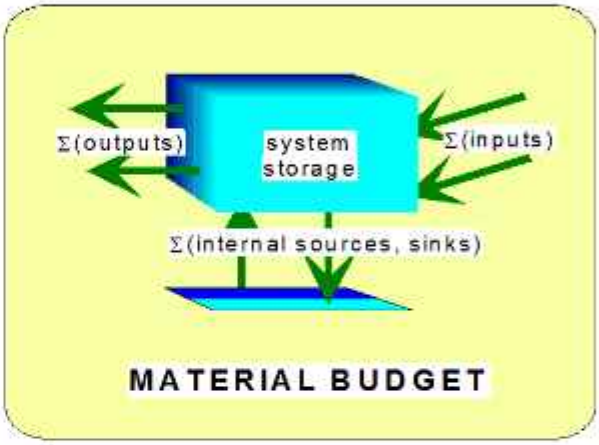
Anthropogenic inputs of nutrients to coastal zones have increased steadily and exceptionally up to three times in the last few decades (Rabalais et al.,1996; Moffat 1998; Smith et al., 2003). Changes in land use and land cover pattern results in such major modifications due to the freshwater runoff, sediment transport, fluxes of carbon and nutrients to coastal ocean (Walsh 1991). The nutrient inputs to the coastal ocean may enhance primary production and provide an additional sink for atmospheric carbon (Hung and Kuo 2002). However, the magnitude of the fluxes is such that the transfer of organic matter from land to ocean via the coastal systems treated as a key link in the global carbon cycles (Richey et al., 1990).

Therefore, the natural and human derived organic matter discharged into coastal seas may partially or totally be respired, providing a source of carbon dioxide. Thus, due to the intense anthropogenic disturbance estuaries are often considered to be net heterotrophic ecosystems and act as a source of CO_2 (Frankignoulle et al., 1998; Mukhopadhyay et al., 2002; Biswas et al., 2004). Whether the coastal systems act as net carbon sources or as sinks remains debatable, largely because coastal systems vary substantially in response to the external change.

Although, there is difficulty in obtaining carbon and nutrient budgets from the direct observations and syntheses, biogeochemists have employed various models to simulate nutrient and carbon budgets in coastal ecosystems applying simplified calculations (Kaul and Froelich 1984; Billen et al 1985; Smith et al., 1991; Yanagi 1999; McKee et al 2000). Meanwhile, LOICZ (Land-Ocean Interactions in the Coastal Zone) has developed the Biogeochemical Modeling Guidelines (Gordon et al 1996) to implement the nutrient and carbon budgets. This model has been widely tested and used for C-N-P budgets in estuarine and coastal systems (Hall et al., 1996; Smith and Crossland 1999; Smith et al., 1999; Dupraet al., 2000). Carbon metabolism in a shallow coastal body varies between temperate and tropical regions primarily due to rapid system response to change of external forcing (Pernetta and Milliman 1995).

Approach

The biogeochemical fluxes and metabolism of nutrients and carbon in an estuary may be deciphered through the use of LOICZ biogeochemical budget model (Smith et al., 1991; Gordon et al., 1996). The schematic diagram of the nutrient budget model is shown here.



Recently, this model was improvised for its best implication in the muddy ecosystems having high SPM concentration (> 100 mg l^{-1}) by Wolanski and Swaney (2009). Since, most of the Indian estuaries carry high loads of sediment from the upstream; they are often considered as highly turbid coastal ecosystems. This would be a very new and unique study in terms of understanding the contribution of suspended particulate matter to the coast and the associated biogeochemistry. This biogeochemical budget model is a steady-state box model from which non-conservative nutrient and carbon budgets can be constructed from non-conservative distributions of nutrients and water budgets which in turn are constrained from the salt balance under a steady state assumption. The non-conservative flux of a material is estimated from the flux deviation between inputs and outputs based on the salt and water balances. Conservation of mass is one of the most fundamental concepts of ecology and geochemistry. The budget is calculated assuming that the materials are conserved in a system. The difference of Σ [sources – sinks] = Σ outputs - Σ inputs

Salt Budget

The salt balance of a system forms the basis of the nutrient budget calculation. At steady state, the following box model equation describes the salt flux.

$$\frac{V_{sys}dS_{sys}}{dt} = V_Q S_Q + V_{PE} S_{PE} + V_G S_G + V_O S_O + V_R S_R + V_X (S_{ocn} - S_{sys})$$

$$V_X = (-V_R S_R - V_G S_G)/(S_{Ocn} - S_{Syst})$$

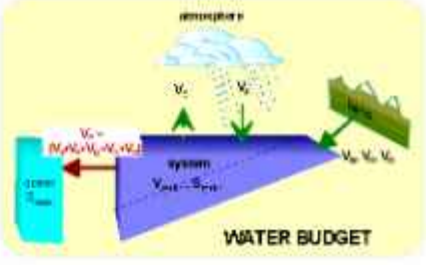
Water Budget

The water budget in the estuary can be derived from the balance of salt transported through the estuary, using salt as a conservative tracer. Under steady-state conditions, the water mass balance can be estimated by using the equation:

$$dV_{syst}/dt = V_Q + V_P + V_E + V_G + V_O + V_R$$

At steady state:

$$V_R = -(V_Q + V_P + V_E + V_G + V_O)$$



Nutrient Budget

Dissolved nutrient budgets are estimated from water budgets and measured nutrient concentrations in each box model compartment. The nutrient budgets are derived from dissolved inorganic (i.e. DIN, DIP and DIC) concentrations. Non-conservative fluxes of DIN (ΔDIN), DIP (ΔDIP) and DIC (ΔDIC) can be derived from the following equations (Gordon et al 1996).

$$\Delta DIN = -(\Sigma DINoutflux - \Sigma DINinflux)$$

$$= -[(1-\Delta Kd)\, VrDINr + Vx\{(1-\Delta Kd)\,(DINocn - DIPsys)\} + VqDINq]$$

$$\Delta DIP = -(\Sigma DIPoutflux - \Sigma DIPinflux)$$

$$= -[(1-\Delta Kd)\, VrDIPr + Vx\{(1-\Delta Kd)\,(DIPocn - DIPsys)\} + VqDIPq]$$

and

$$\Delta DIC = -(\Sigma DICoutflux - \Sigma DICinflux)$$

$$= -[(1-\Delta Kd)\, VrDICr + Vx\{(1-\Delta Kd)\,(DICocn - DICsys)\} + VqDICq]$$

Where, Kd is partition coefficient due to turbidity in water, according to Wolanski and Swaney (2009). DINq, DINsys, DINocn and DINr denote the mean DIN concentration in the river, estuary, oceanic water and the residual-flow boundary respectively. According to Gordon et al 1996, DINr can be determined as (DINocn+DINsys)/2, and similarly the DIPr and DICr.

Net Ecosystem Metabolism (NEM)

The net ecosystem metabolism (difference between primary production and respiration [p-r]) can be estimated stoichiometrically from ΔDIP and C:P ratio of organic matter being produced or consumed in the estuary. Therefore,

$$[p\text{-}r] = -\Delta DIC = -\Delta DIP^{*}(C{:}P)\ particulate$$

From the above equation, it is noted that DIP alone is used in the calculation of [p-r] because production or consumption of DOP is regarded as one of the possible sinks or sources for ΔDIP, according to Gordon at al 1996. The particulate organic C:P ration in the estuary cannot be determined and hence, the Redfield ratio (106) shall be adopted for the Stoichiometry calculation.

Nitrification and Dentrification

Nitrogen metabolism in the estuary, expressed as net result of nitrogen fixation and dentrification (Nfix-Denit) can be derived from the difference between non-conservative nitrogen flux and expected nitrogen removal through the biological uptake.

$$[Nfix\text{-}Denit] = \Delta N\ observed - \Delta N\ expected$$

$$= \Delta N\ observed - \Delta P^{*}(N{:}P)\ particulate$$

In the above equation, the Redfield N:P ratio can also be applied for calculation. This calculation will demonstrate whether the estuary is a source or sink for the fixed nitrogen.

SPM Paradigm in Nutrient Budget: Kd Factor

The partition coefficient (Kd), is defined as the ratio between the particulate nutrient concentration and the total nutrient concentration when the system is at equilibrium. The Kd factor varies from region to region and site-specific. Generally, the generic or default Kd values can result in significant error when used to predict the impacts of particulate matter in the budget. Therefore, for the site specific model calculations, Kd factor is derived for our applications from the measured nutrient concentrations.

The Kd value for the Chilika Lake computed for both the dry period and wet period are as follows (Fig. 11 & 12). Similarly, the Kd factor will be computed for each of the ecosystems proposed for muddy LOICZ nutrient budgeting.

The Kd value for the dry period is 180, derived from the graph as shown in Fig. 11, through the best fitting curve using the formulae as follows.

Kd = SPM/(SPM+180)

and the Kd value for the wet period is 220, derived from graph as shown in Fig. 12, through the best fitting curve using the formulae as follows.

Kd = SPM/(SPM+220)

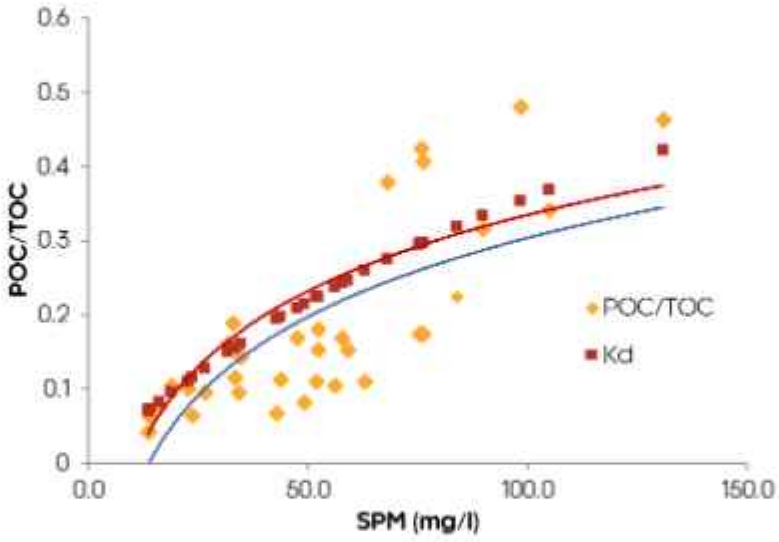


Fig. 11. Computation of Partition Coefficient (Kd) for the dry period

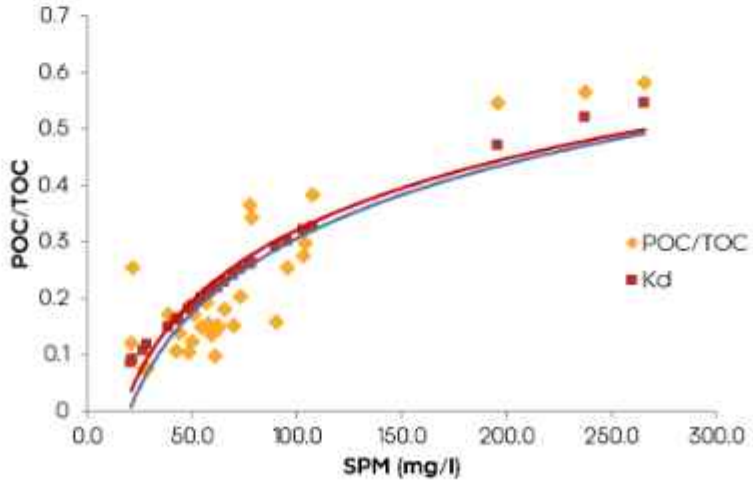


Fig. 12. Computation of Partition Coefficient (Kd) for the wet period

The Coastal Environmental Health Report Card synthesizes the scientific information and converts it to an image-rich format that is easily accessible to a wide audience. Apart from enabling easier means of communicating science, report cards also tend to be means of powerful human motivator: creating peer pressure (among civic leaders and local community). These Environmental Health Report Cards have been used to catalyze improvements in ecosystem health, guide restoration efforts, and stimulate relevant research.

Coastal Ecosystem Health Report Card (ECOHEALTH)

The Coastal Environmental Health Report Card synthesizes the scientific information and converts it to an image -rich format that is easily accessible to a wide audience. Apart from enabling easier means of communicating science, report cards also tend to be means of powerful human motivator: creating peer pressure (among civic leaders and local community). These Environmental Health Report Cards have been used to catalyze improvements in ecosystem health, guide restoration efforts, and stimulate relevant research.

There have been very few attempts to study different aspects of coastal ecosystem indices, their status along the Indian subcontinents. A team of scientists from Maryland University as well as National Centre for Sustainable Coastal Management (NCSCM), India are working on the health report card for coastal ecosystems of India. The details provided in the report card provide information that can help, guide and focus on restoration efforts. In this study, efforts are also made to apply the DPSIR (Driver-Pressure-State-Impact-Response) framework for the ecosystem health. In view of the growing concerns on progressive environmental deterioration of vulnerable coastal ecosystem of India, National Centre for Sustainable Coastal Management (NCSCM), Chennai, has identified some of the coastal ecosystems which are in need of immediate restoration and measures to ensure the sustainable development with optimum resource exploitations (Fig. 1). Environmental data collected from time-series and monthly measurements will be used to develop the Ecosystem Health Report Card.

Fig. 1. Map indicating locations of various ecosystems for preparation of Coastal Ecosystem Health Report Card

Fig. 2. Report Card – Process

The health status of a coastal ecosystem can be accessed by analyzing various water quality parameters and its biological diversity. The environmental data (physical, chemical and biological) has utmost importance for the preparation of the ecosystem health report card. These data can be collected from both primary and secondary sources.

Coastal Ecosystem Health Report Card for the Marine National Park and Sanctuary, Jamnagar, Gujarat

Marine National Park and Sanctuary (MNPS), Gulf of Kachchh, Gujarat is one of the proposed series of ecosystems for the preparation of health report card. The Gulf of Kachchh in the state of Gujarat is characterized with coral reefs and extensive mangroves, and a host of resident and migratory birds, coupled with large industrial conglomerations. The southern coast of the gulf has been declared as the Marine National Park (MNP) bordered by the Marine Sanctuary.

A science workshop was conducted with the objective of identifying threats, developing indicators, thresholds and a framework in the form of a graded report card (Fig. 3). The GEC, in partnership with NCSCM and the Integration & Application Network from the University of Maryland Centre for Environmental Science, convened a science workshop bringing together local, regional stakeholders and international experts, who together identified 12 indicators of ecosystem health (Fig. 4).

Workshop on ecosystem Health report Card, Jamnagar

Avicennia marina

Stichodactyla sp.

Acanthastrea hillae

Goniopora minor

Field survey at Khijadiya Bird Sanctuary

Narara reef, Jamnagar

Fig. 3. Workshop on coastal ecosystem health report card for Marine National Park, Jamnagar

How the report card was prepared

The three day workshop witnessed active participation from the organizations involved, help to develop the four zones (the islands and the western, central, eastern gulf), the ecosystem health indicators (water quality, biodiversity and fisheries) along with their threshold values. The health grade would be computed from the monitored data and using the developed thresholds for each of the indicator. Additional indicators may be included in future once the measures for data collection are in place. This first health report card serves as a baseline that will be used to assess if the implemented environment management plans are in place and working properly in the MNPS.

Measuring Ecosystem Health

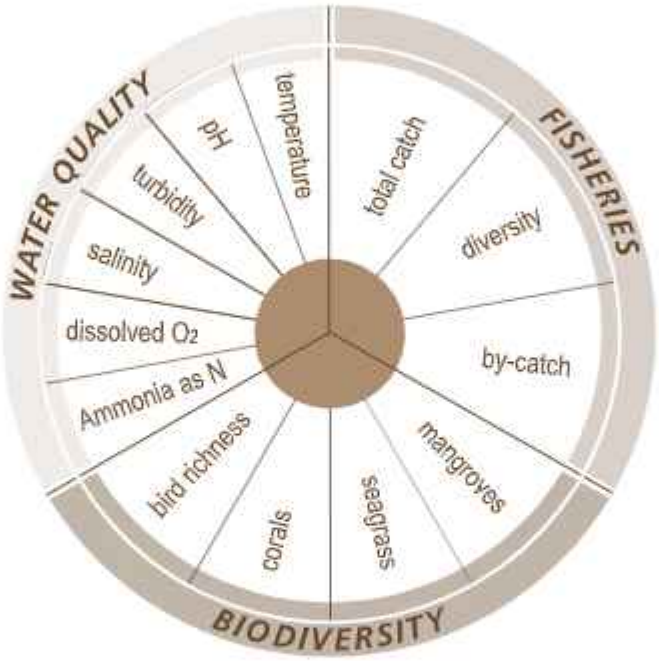


Fig. 4. Indices used to derive ecosystem health grade

Measuring ecosystem health of the MNPS is conducted using 12 indicators organized into three main indices: Water Quality, Fisheries, and Biodiversity. Together, these indicators represent the features of the MNPS ecosystem that are valued (e.g., coral reefs, mangroves, seagrass, and birds); and represent the threats (e.g., pollution, overfishing, and erosion) to these values.

Desirable conditions guide ecosystem change

Desirable conditions of the indices are based on available guidelines, current scientific knowledge, and/ or historical data and trends.

Calculating the ecosystem grade for MNPS-Jamnagar

The Marine National Park and Sanctuary (MNPS) of Jamnagar was divided into four reporting zones, each of which made a report card grade. The grades were calculated from the water quality, fisheries, and biodiversity data collected for the year 2011-2012 from MNPS area. The monitoring will allow the grades to be updated periodically, providing a means to track the environmental changes over time.

What do the grades mean?

A 80–100%. All water quality and biological health indicators meet desired levels. Quality of water in these locations tends to be very good, most often leading to very good habitat conditions for fish and shellfish.

B 60–80%. Most water quality and biological health indicators meet desired levels. Quality of water in these locations tends to be good, often leading to good habitat conditions for fish and shellfish.

C 40–60%. There is a mix of good and poor levels of water quality and biological health indicators. Quality of water in these locations tends to be fair, leading to fair habitat conditions for fish and shellfish.

D 20–40%. Some or few water quality and biological health indicators meet desired levels. Quality of water in these locations tends to be poor, often leading to poor habitat conditions for fish and shellfish.

F 0–20%. Very few or no water quality and biological health indicators meet desired levels. Quality of water in these locations tends to be very poor, most often leading to very poor habitat conditions for fish and shellfish.

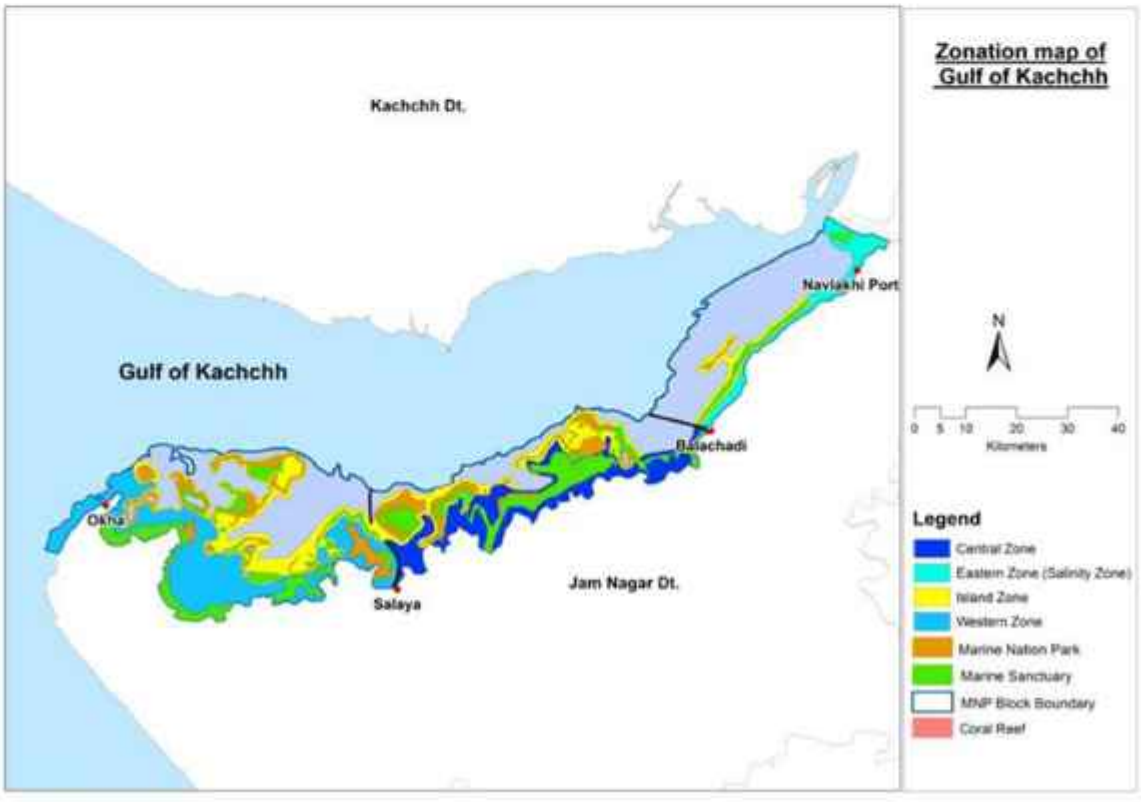


Fig. 5. Four zone map of Marine National Park and Sanctuary

Marine National Park and Sanctuary (MNPS), Jamnagar Health Report Card

For the Marine National Park and Sanctuary, the indices on water quality, fisheries, and biodiversity are being computed for the ecosystem health grade report card preparation.

Pressures affecting the MNPS ecosystem

The MNPS is subjected to constant pressures from both natural processes and human activities (Fig. 6). The problems highlighted here are pollution, overfishing, and erosion, all of which can result in a degradation of the marine habitat. By identifying these pressures through efforts like this ecosystem health report card and subsequent management actions, the likelihood of the MNPS to sustain itself is improved.

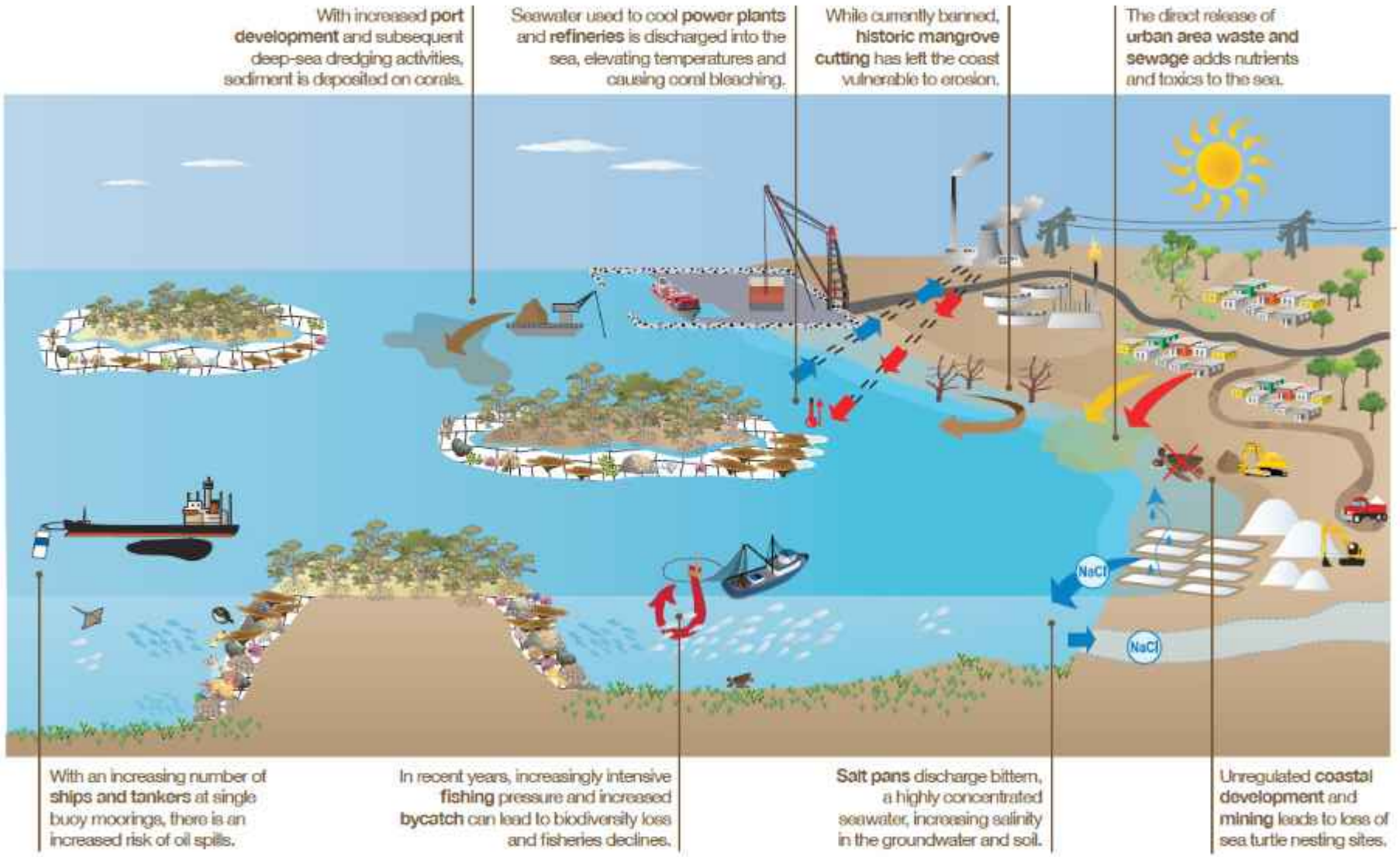


Fig. 6. Activities along Marine National Park and Sanctuary, Gulf of Kachchh

The detection and prediction of regional environmental change has become goals for numerous national and multinational organizations. Sentinel sites are used to better understand the regional environmental issues by focusing on the resources and efforts taken to manage at the local scale. Discrete locations in coastal and marine environments that have the operational capacity for intensive study and sustained observations to detect the changes in the ecosystems they represent. Nested sets of sentinel sites selected to better understand the ecosystem conditions at specific temporal and spatial scales in order to address the science and management priorities.

Establishment of Sentinel sites for Coastal Management

The detection and prediction of regional environmental change has become goals for numerous national and multinational organizations. Sentinel sites are used to better understand the regional environmental issues by focusing on the resources and efforts taken to manage at the local scale. Discrete locations in coastal and marine environments that have the operational capacity for intensive study and sustained observations to detect the changes in the ecosystems they represent. Nested sets of sentinel sites selected to better understand the ecosystem conditions at specific temporal and spatial scales in order to address the science and management priorities.

In this context, National Centre for Sustainable Coastal Management (NCSCM), Chennai, has identified the coastal sites where long-term monitoring program would be carried out (Fig. 1 & 2) to understand the changes that requiring precise assessments which is classified as follows:

- Climate change
- Coastal Process & Shoreline changes
- Water quality & Biogeochemical fluxes
- Ecology, and Coastal Livelihood
- Deltaic characteristics and Natural hazards

An overview of the coastal sentinel site program

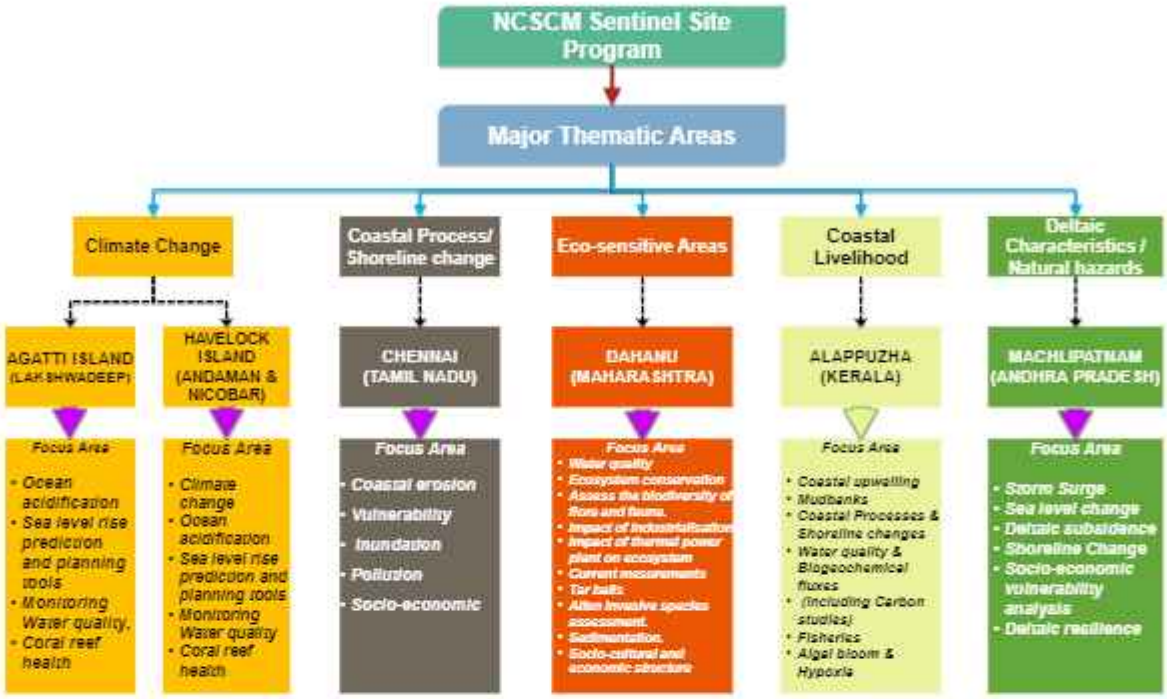


Fig. 1. Schematic representation of NCSCM "Sentinel Site" program indicating major focus areas

Selection of sites as Sentinel Sites is based on unique coastal signatures in a manner that they would act as sensors of change. Examples include coastal erosion, protection of natural resources, sea level rise, and establishing accurate height measurements along coastal locations particularly in places with dense populations and bustling coastal and maritime activity. The NCSCM Sentinel Site program capitalizes on these activities in partnership with consortium institutions and local efforts to help solve concrete problems that people are facing in coastal areas. This program is designed to provide the long-term information and parameters required for an integrated ecosystem approach to address five key issues as mentioned above.

Approach

Monitoring for the "Sentinel" site would be carried out through reconnaissance survey for the proposed coastal ecosystems. In this survey various indicator parameters on chemical, physical, biological characteristics would be analysed to understand the hydro-ecological status of the ecosystem before establishing the continuous monitoring station. The approach of the research study is shown in Fig. 3.

System Design and Implementation

Based on the requirements of monitoring at selected coastal ecosystems along the Indian Coast, a high-performance marine monitoring data transmission network and real-time information publishing system will be designed and implemented, which would be of higher level of enhancement of data collection and transfer method (Fig. 4). It will provide automatic data collection, transmission and storage, processing and analysis, data products publishing and sharing, along with remote dynamic monitoring of the observation sites. The information of NCSCM observation system shall mainly include the following.

- Construction of multi-factor automatic acquisition and processing platform.
- The layout of network of GSM/wireless data transmission.
- Foundation of database and platform of data product.
- Construction of service platform for data sharing and standardization information.

Fig. 2. Map indicating locations of Sentinel monitoring sites all along the coast of India

Fig. 3. Schematic Approach for the establishment of Sentinel sites

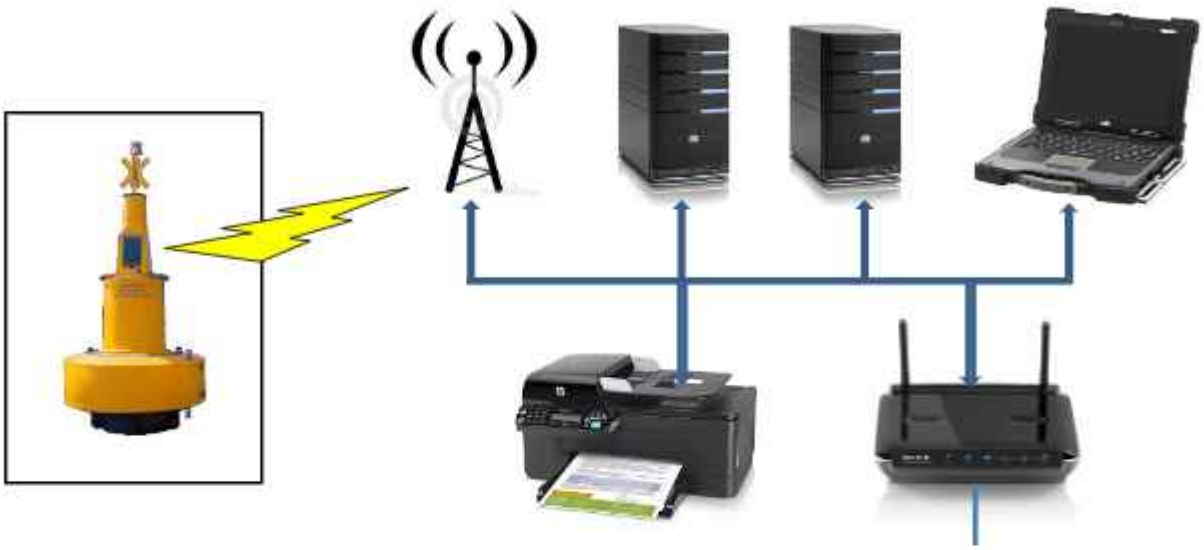


Fig. 4. Schematic diagram of the Marine Data Buoy Network

Calcification ($CaCO_3$ production) in the reef waters of Neil & Havelock Island, Andaman Islands (Climate change– NCSCM Sentinel Site Program)

Neil Island, Andaman

NCSCM-Sentinel sites, Neil and Havelock Island, Andaman Islands are investigated for the climate change phenomenon in its coral reef ecosystems. In this connection a survey was conducted during the month of February 2014, in two islands and the parameters analysed were meteorological, physico-chemical, dissolved nutrients, total alkalinity (TA), dissolved inorganic carbon (DIC), dissolved organic carbon (DOC), chlorophyll *a*, O_2 saturation, pCO_2, CO_2 flux, saturation index (Ω_{ca} & Ω_{ar}) and primary production.

The Neil Island benthic diversity is mostly the occurrence of live corals followed by sandy and rubble bottom. *Porites* sp. is dominated the coral communities in this environment. The mean live coral cover reported in this Island was 46%. *Acropora* sp., *Cyclosereis* sp., *Favia* sp., *Favites* sp., *Fungia* sp., *Galaxea* sp., *Leptosereis* sp., *Lobophyllia* sp., *Motipora* sp., *Pachysereis* sp., *Pavona* sp., *Pectinia* sp., *Pocillopora* sp. and *Seriatopora* sp. are also contributed in the Scleractinian coral cover. The biodiversity of Neil Islands, Andaman is shown in Fig. 5.

Mangrove ecosystem

Bio-shield on the coast

Seagrass

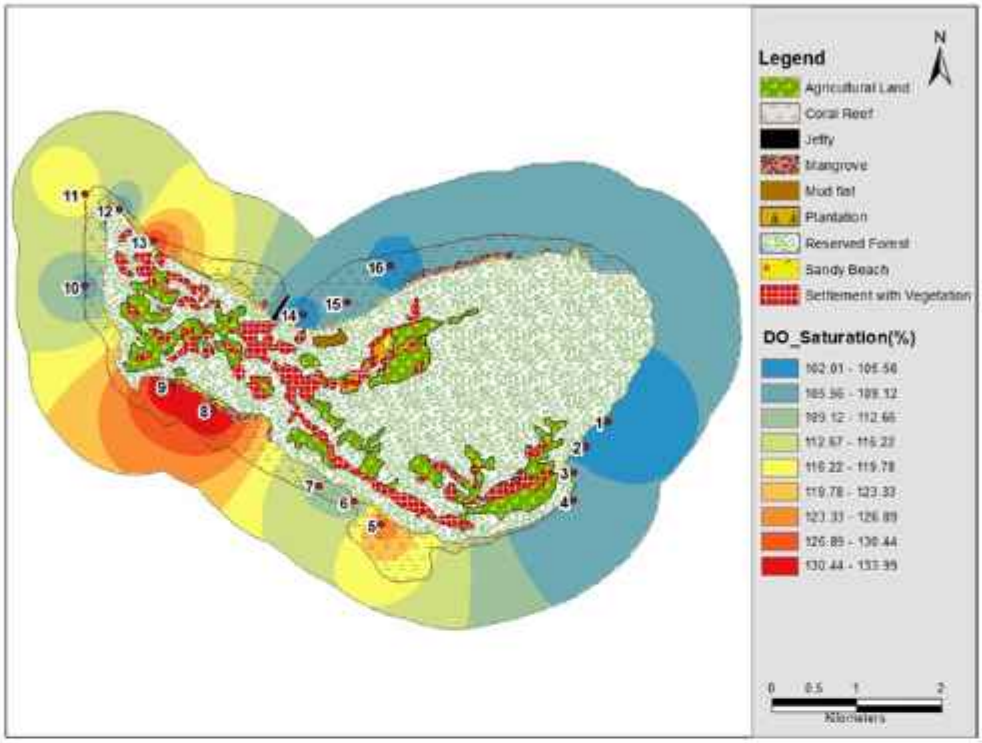
Sea cucumber, *Holothuria* sp.

Banded snake eel, *Myrichthys colubrinus*

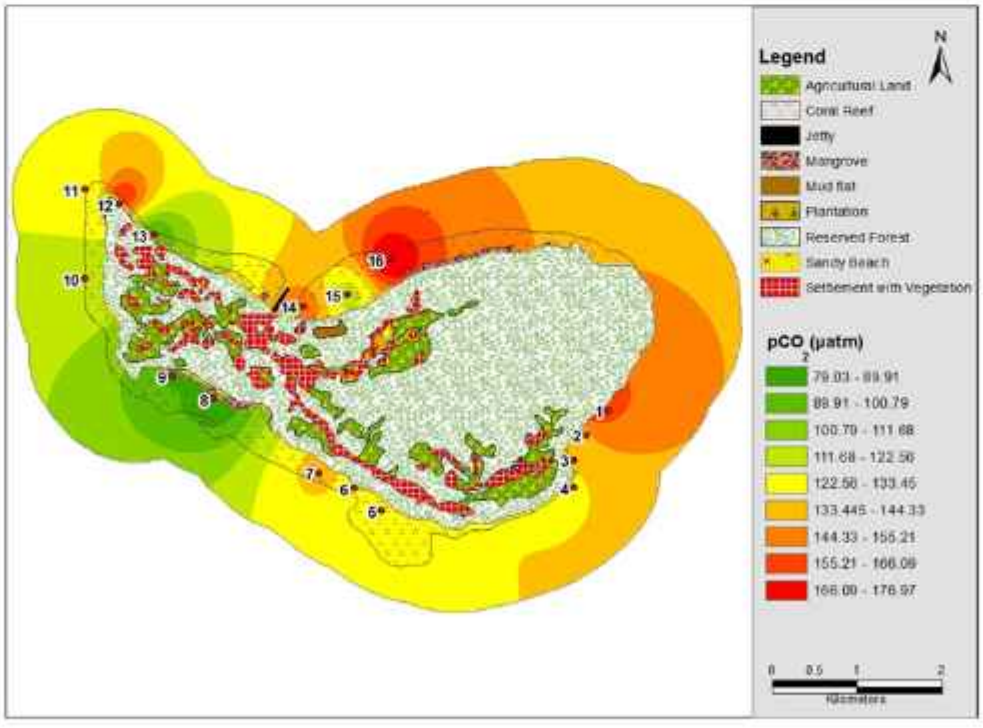
Heliopora colony

Fig. 5. Biodiversity of Neil Island, Andaman

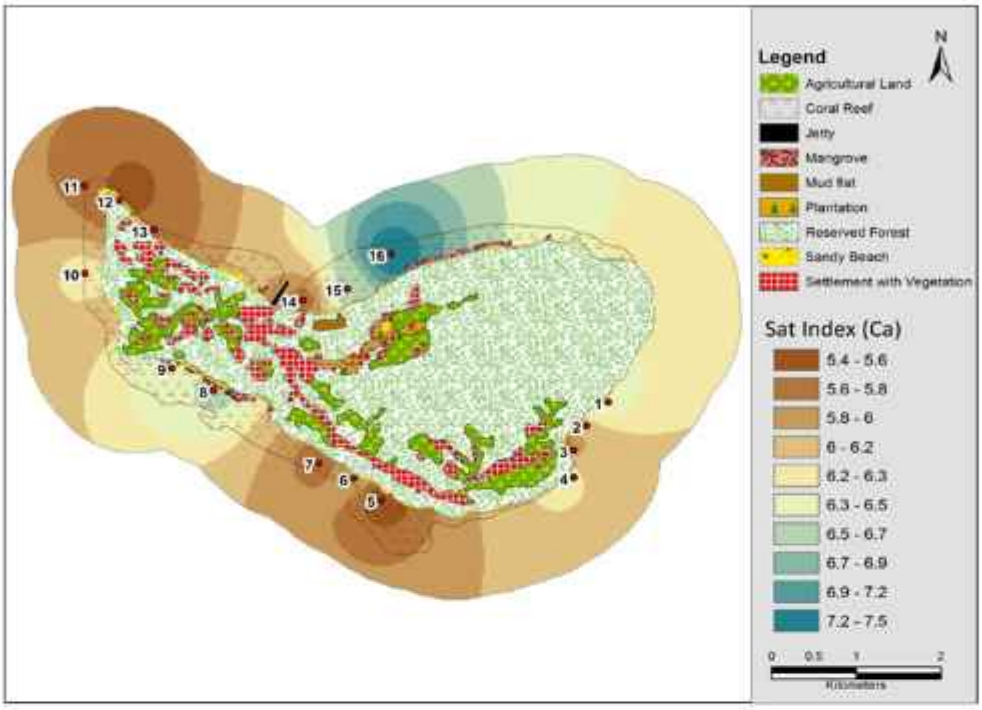
1. The spatial variation of selected parameters in the Neil Island is shown in Fig. 6-9. The reef waters from Sitapur, Ramnagar, Neil Kendra, Lakshmanpur and Bharatpur coast of Neil Island were analysed and the significant results observed are as follows.
2. Th e reef waters are highly under-saturated with carbon dioxide (CO_2) as compared to the atmospheric level which varied from 79 to177 µatm on a spatial scale. The CO_2 flux is mostly negative and varied from -0.20 to -13.0 mmol m-2 d-1 indicates the atmospheric CO_2 sink in the reef waters of Neil Island.
3. Same time, the dissolved oxygen (O_2) are highly super saturated which varied from 102-134%.
4. The supersaturated O_2 level and under-saturated CO_2 indicates high level of phytoplankton production in the reef waters of Neil Island, and therefore a CO_2 sink.
   - *The saturation index due to calcite (Ω_{ca}) is oversaturated (>1) which is varied from 5.4 to 7.5. Similarly, the saturation index due to aragonite (Ω_{ar}) which varied from 3.6 to 5.0 is also super saturated (>1) in the reef waters. The higher saturation index implies the $CaCO_3$ production in the reef waters which is a CO_2 releasing phenomenon to the atmosphere. However, during this observation the pCO_2 level is lower as compared to the atmospheric level showing its sink in the reef waters.*
5. To understand the pCO_2 predicaments caused by photosynthesis and calcification, an index based on the molar ratio between organic to inorganic production (Ψ) is used, as a criterion for the CO_2 sink-source in the reef waters of Neil Island.
6. Frankignoulle et al., 1994, proposed a critical value for Ψ factor as 0.6 (molar ratio of released CO_2 to precipitated $CaCO_3$). When Ψ>0.6, the organic production is larger than approximately 0.6 times net inorganic production. In the present study, the Ψ values varied from 2.45 to 3.10 which indicate the dominance of organic production and therefore sink of CO_2 in the reef waters off Neil Island.
   - *From this survey, it can be deciphered that the recent proliferation of coral polyps in the Neil Island, by which significant amount of $CaCO_3$ are produced in the system and the resultant CO_2 released is consumed in its reef waters for the organic production.*



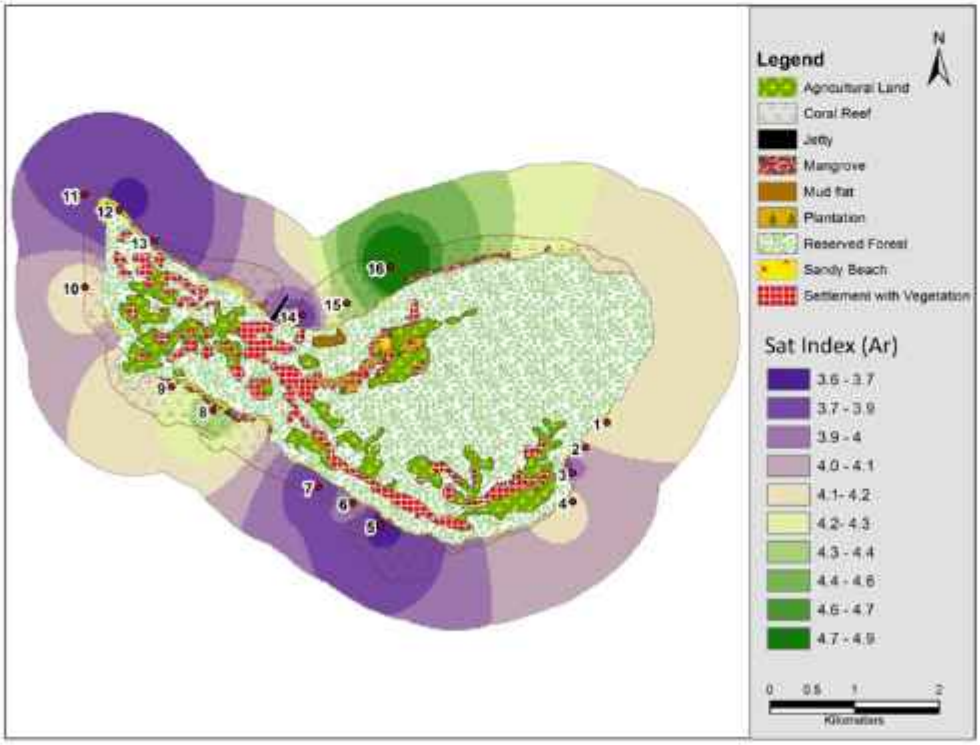
Dissolved oxygen saturation (%)



Partial pressure of carbon dioxide (pCO_2)



Calcite saturation index (Ω_{ca})



Aragonite saturation index (Ω_{ar})

Figs. 6 - 9. Spatial variation of selected parameters in the reef water off Neil Island

Havelock Island, Andaman

The Havelock Island benthic diversity is mostly the occurrence of live corals with their associated communities and dead corals with algae (Fig. 10) The South Andaman including the Havelock Island is dominated by *Porites* sp. The other coral species recorded in this Island are *Acropora* spp., *Favia pallida*, *Montipora* sp., *Fungia concinna*, *Goniopora* sp., *Diploastrea* sp., *Lobophyllia robusta*, *Gardineroseries* sp., and *Favites abdita*. The average coral cover in the benthic environment of this island is 22% (Marimuthu et al., 2013). The other life-form categories observed in this island are sponges, soft corals and other organisms such as clams, sea cucumber, sea stars etc. The abiotic forms observed in the benthic environment are rubble, rock and sandy bottom.

The reef waters of Radhanagar, Elephanta, Kalapatar and Govindnagar beach of Havelock Island were analysed for the CO_2 dynamics (Fig. 11 through 14). The CO_2 dynamics in the reef waters of Havelock Island varied in a similar manner unlike the Neil Island. The saturation index due to calcite (Ω_{ca}) and aragonite (Ω_{ar}) in the reef water of Havelock Island is slightly lower than the Neil Island which indicates the slower rate of calcification in Havelock Island as compared to the Neil Island. The reason for low saturation index may also be due to the influence of some other carbon process that shift the reef waters from calcification towards dissolution, which could be an ocean acidification process (Fig. 11 through 14). However, the existence of such phenomenon in the reef water of Andaman Islands can only be established with the regular monitoring of its reef waters.

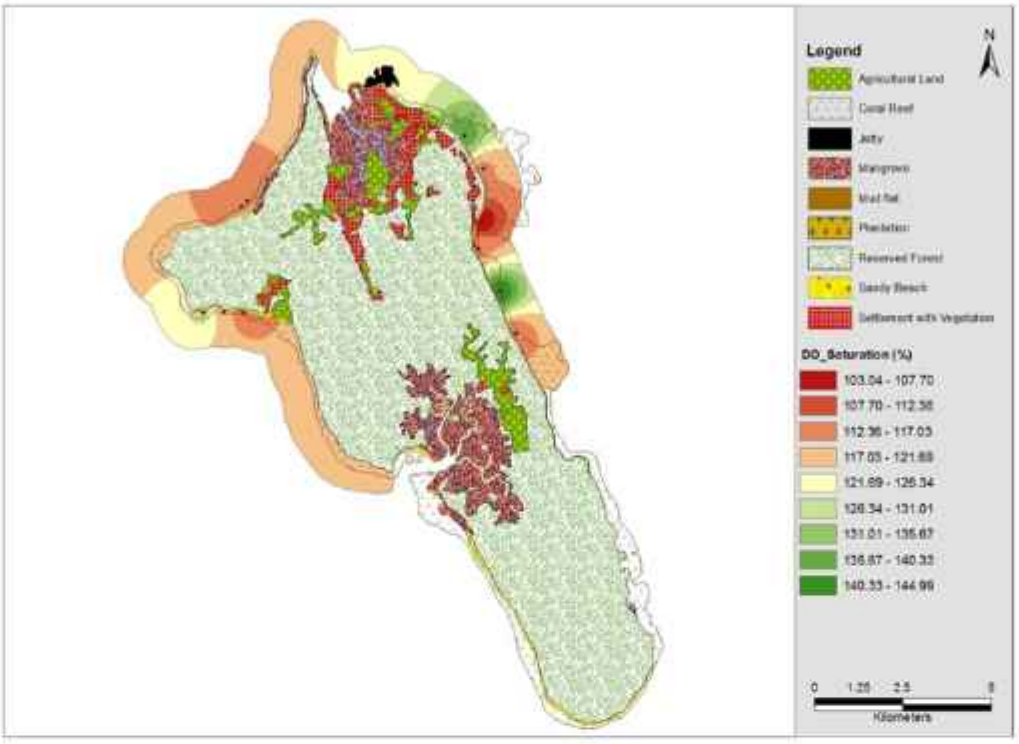
Coastal vegetation

Intertidal region

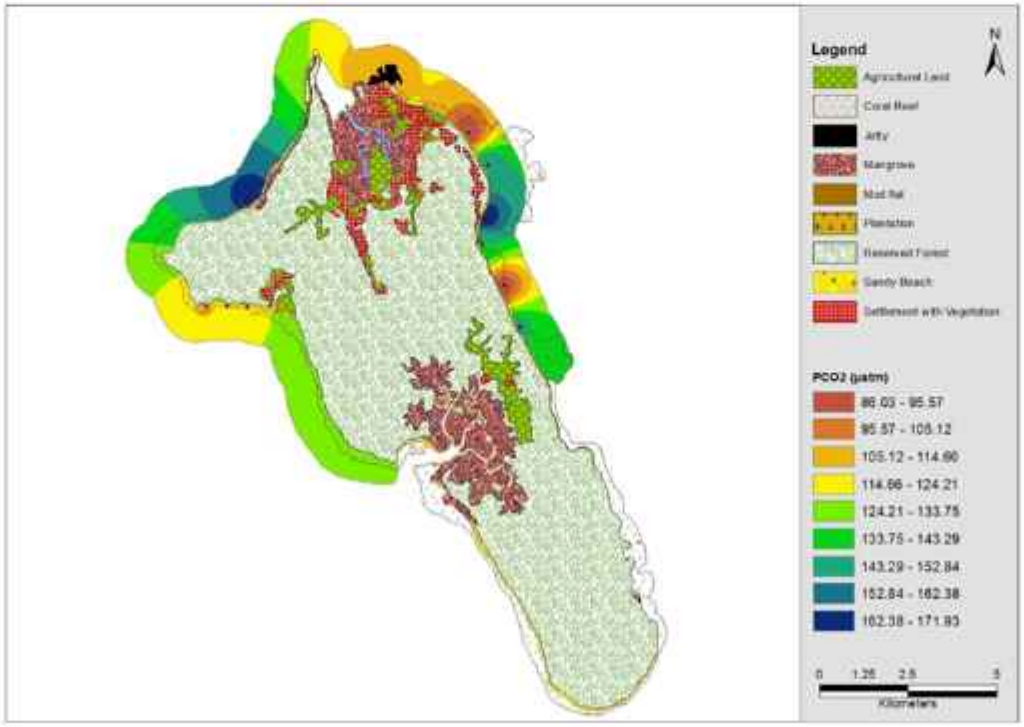
Lobophytum sp.

Acropora sp.

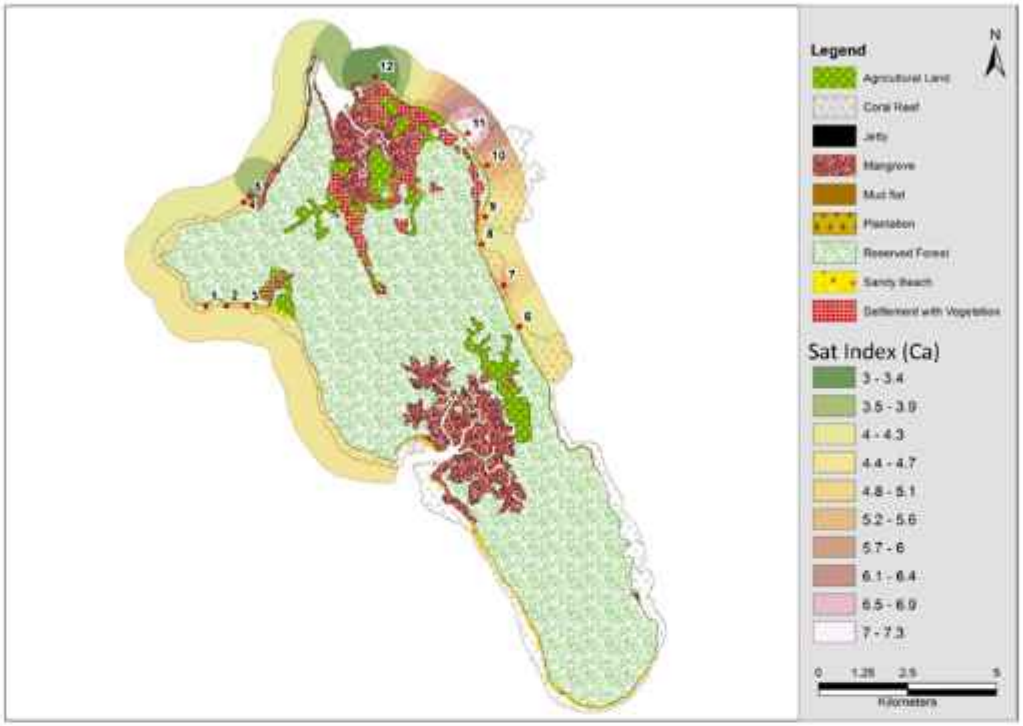
Fig. 10. Biodiversity of Havelock Island



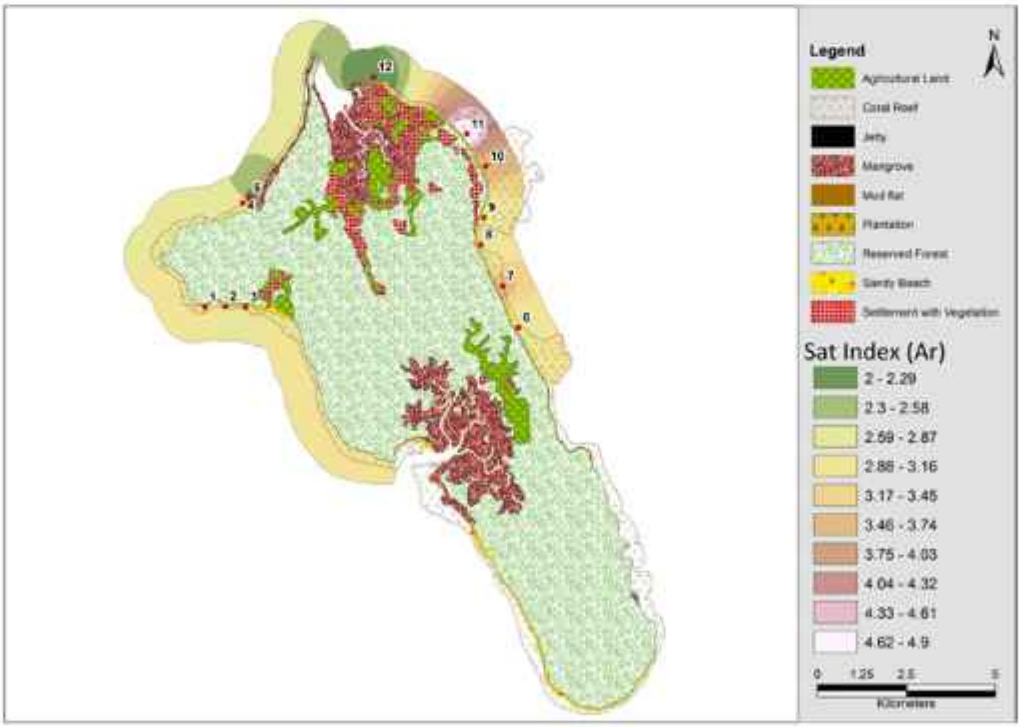
Dissolved oxygen saturation (%)



Partial pressure of carbon dioxide (pCO_2)



Calcite saturation index (Ω_{ca})



Aragonite saturation index (Ω_{ar})

Figs. 11 - 14. Spatial variation of selected parameters in the reef water off Havelock Island

Assessment of Alleppey Mudbank system on coastal livelihood

Among other major thematic areas of NCSCM-Sentinel site program, Alleppey (Fig. 15) comes under hydro-ecology and coastal livelihood. The importance of the coastal ecosystems is the formation of mudbanks due to its unique coastal processes that sustain the coastal livelihood to a large community. A field survey was conducted along the coast of Alleppey to analyse and interpret the biogeochemistry of this phenomenon.

Fig. 15. Location map of Alleppey (Mudbank)

Alleppey district at a glance

S.No	Variables	Description
1	Longitude	North latitudes- 9°05 and 9°54 East longitudes- 76°17 and 76°40
2	Revenue Divisions	2 (Alappuzha &Chengannur)
3	Taluks	6Nos. (Cherthala, Ambalappuzha, Kuttanad, Karthikappally, Mavelikkara & Chengannur)
4	Villages	91
5	Gram Panchayat	73
6	Community Development Blocks	12
7	Geographical area (Sq km)	1414
8	District Population (Census 2001) & Population Density	2,105,349 1489 persons/sq.km
9	GEOMORPHOLOGY Major physiographic units Major Drainages	Coastal plain and Mid land Pamba and its tributaries
10	LAND USE (Hectares)	
11	Forest area	Nil
12	Net area sown	94328
13	Cultivable area	3356
14	Climatic Characteristics	
15	Atmospheric Temperature	At Alleppey the maximum temperature ranges from 28.8 to 32.7ºC whereas the minimum temperature ranges from 22.6 to 25.5ºC. The average annual maximum temperature is 30.7ºC and the average annual minimum temperature is 23.9 ºC.
16	Humidity	The humidity is higher during the monsoon period, June to September. It is around 87% at Alappuzha
17	Lakes	Vembanad Lake, Kayamkulam Lake
18	Rivers	Manimala River, Pamba River, Achancovil River,
19	Wind	The wind is predominantly from east and north-eastern directions during morning hours and during the evening hours the predominant wind direction is from west and northwest. The wind speed is low in Kayamkulam. The wind speed is high during May (13.6 kmph)
20	Rainfall	Approx. 2000mm
21	Fishermen Population	87,027

S.No	Variables	Description
22	Fishermen Population per km length	1307
23	Infrastructure	Industries (2611 – Medium & small scale) Minor port (2nos.) Fishing harbor (4nos.) Fish processing centre (44nos.) Ice plants (7nos.)
24	Socio-economic conditions	Major population comprises of agricultural laborers and coir workers. Though in literacy rate Alleppey district ranks second when compared to other districts, the employment rate is not proportionate to the literacy rate.
25	Water Transport	The commercial canals connecting the nook and corner of this district are its life line. Canals, rivers and backwaters afford an easy and cheap mode of transport of goods and men which was one of the main reasons for the importance of Alleppey town as the major commercial centre of older times.
26	Sea Coast	Alleppey has a flat unbroken sea coast of 82 Km in length which is 13.9 % of the total coastal line of the state. An interesting phenomenon of this seacoast during the month of June is the periodic shifting of mudbank popularly known as "Chakara" within a range of 25 Km in Alappuzha-Purakkad coast due to hydrolic pressure when the level of backwater rises during south-west monsoon.

Alleppey is one of the well-developed coastal districts in southern part of Kerala State covering an area of 1,414sq.km and is the smallest district accounting 3.64% of the area of the State. It is surrounded by Lakshadweep Sea on the west, Kottayam and Pathanamthitta districts in the east, Kollam district in the south and Ernakulam district in the north. The Pamba River drains over an area of 804 sq.km of the district and form a deltaic region skirting the south eastern, southern and south western fringes of Vembanad Lake. Vembanad Lake, the largest backwater in the State lies on the north eastern part of the district separating Alleppey from Kottayam district. Ambalappuzha- Purakkad area in the Alleppey district is famous for mudbanks, which form a rich source of fish. These features appear during south-west monsoon aided by sea waves causing ejection of loose sub-terraneans material through churning action. The mudbanks are few metres away from the high water mark and fall within inter tidal zone. Mudbanks are unique features in Alleppey coast being an area of Research.

General characteristics of Mudbanks

The formation of mudbanks triggers an active fishing season in the coastal environments of Kerala. The mudbanks generally occur on the alluvial belt of the coast extending from Thrikkunnapuzha to Cannanore over a distance of 270 km which is more significantly characterised by backwaters of Kerala. The mudbanks appear most often a week or so after the onset of the southwest monsoon. The phenomena bring about suspension of sediments in a semicircular region, affording calm and turbid waters (Fig. 16).

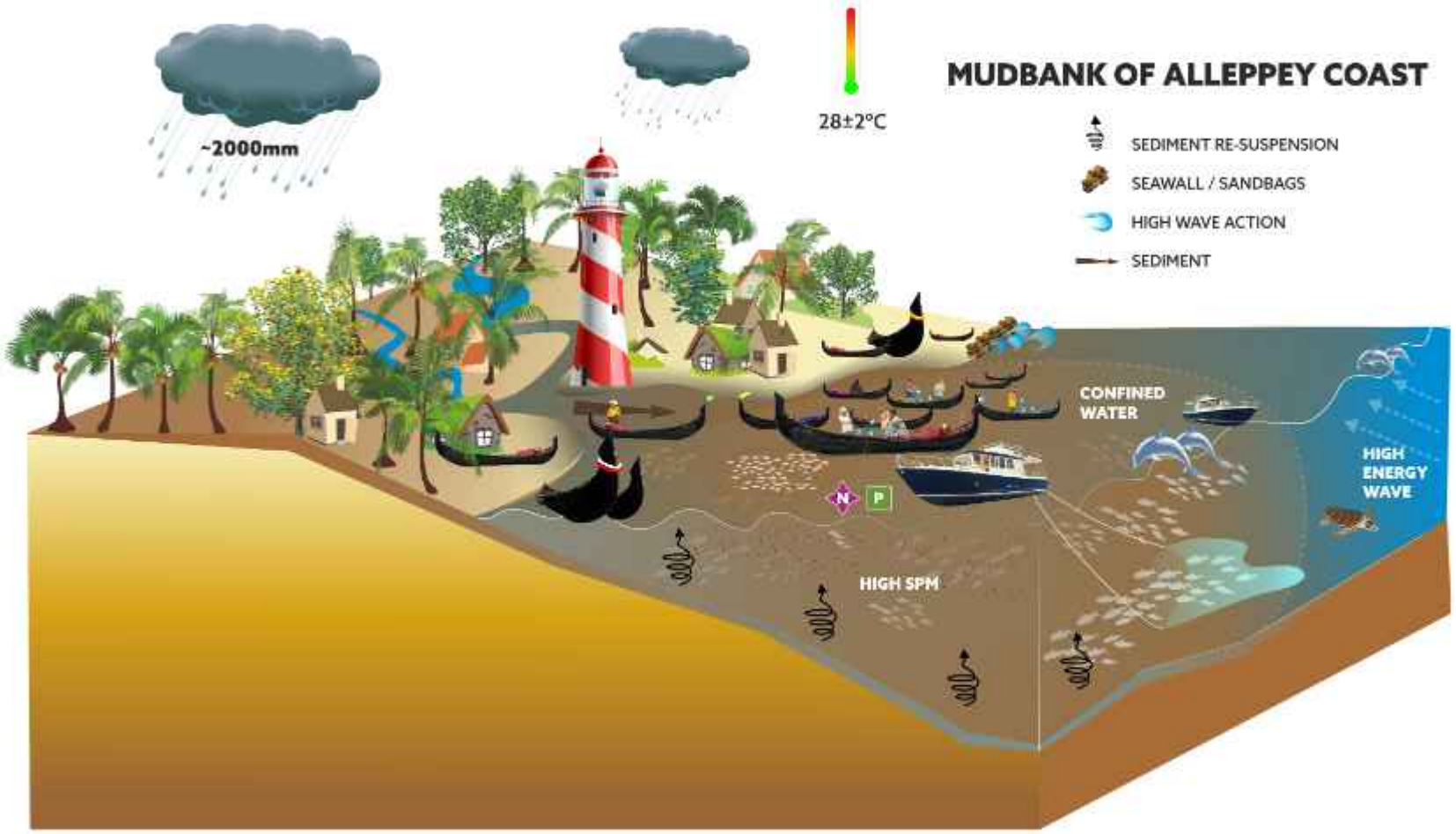


Fig. 16. Conceptual diagram for Alleppey Mudbank

A seaward extent of 5 to 6 km and alongshore extent of 4 to 6 km have been recorded. The banks are laden with heavy suspension of fine clay (90% of < 6 μ) at surface and highly viscous bottom sediments of unconsolidated ooze-like liquid mud. The formation of mudbank plays a major role in moulding the social and economic set up of the coastal population of the region, by providing a stable fishing ground during the monsoon season. The mudbanks act as wave dampers and protect portions of the beach from erosion and help in trapping the sediment which leads to the growth of the adjoining beach (Fig. 17). The mudbank fishery, locally known as "Chaakara" fishery is a unique phenomenon along the Kerala coast during the south-west monsoon period. The fishery of this area during the chaakara season plays a vital role in the economy of this entire coastal belt. Fluctuations in the magnitude of the fishery has been noticed over the years. Nearly 1500 dugout canoes locally known as "Vanchi" or "Vallam" operate daily in this area during the peak of the mudbank fishery.

Species composition of fish along Alleppey coast

About 50 species, of fish and 6 species of prawns are recorded from these regions. Fishes of the families Carcharinidae, Clupeidae, Dussumieridae, Dorosomidae, Engraulidae, Chirocentridae, Tachysuridae, Hemiramphidae, Sphyraenidae, Mugilidae, Polynemidae, Ambassidae, Theraponidae. Sillaginidae, Lactaridae, Siganidae, Carangidae, Gerridae, Leiognathidae, Pomadasydae, Sciaenidae, Trichiuridae, Scomberomoridae, Stromateidae, Cynoglossidae, Chirocentridae and Drepanidae were encountered in the landings. Of the prawn species *Penaeusindicus*, *Metapenaeus dobsoni* and *Parapenaeopsis stylifera* were the abundant ones. *Metapenaeus monoceros*and *Maffinis* were also encountered in smaller quantities.

Socio-economic survey of Alleppey Mudbank

Local Fishing boats - Ambalapuzha

Thottapalli Fishing Harbour

View of Mudbank - Alleppey

Fig. 17. Field survey at Alleppey Mudbank, "SENTINEL" site

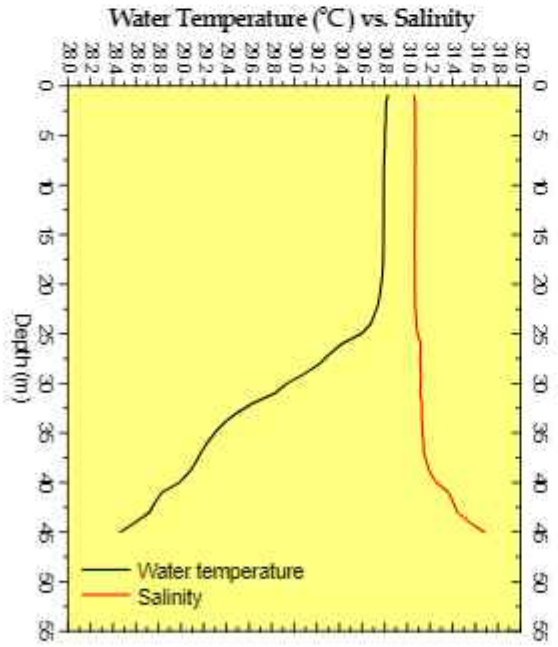
Socio-Economic and Infrastructure facilities in the Alleppey Mudbank

With the onset of the monsoon fishery at the mudbanks, a small fishing village turns into a big business centre. Thousands of fishermen and other people assemble here. To meet the fishing requirements and other human needs an elaborate infrastructure is needed. Sufficient number of crafts and gears, preservation and marketing facility and also means of quick transportation of fish are the essential. Above all every fisherman has to be guaranteed for a reasonable price for his commodity. There are very good transportation facilities all along the Kerala coast and hence quick movement of the catches by insulated trucks is possible.

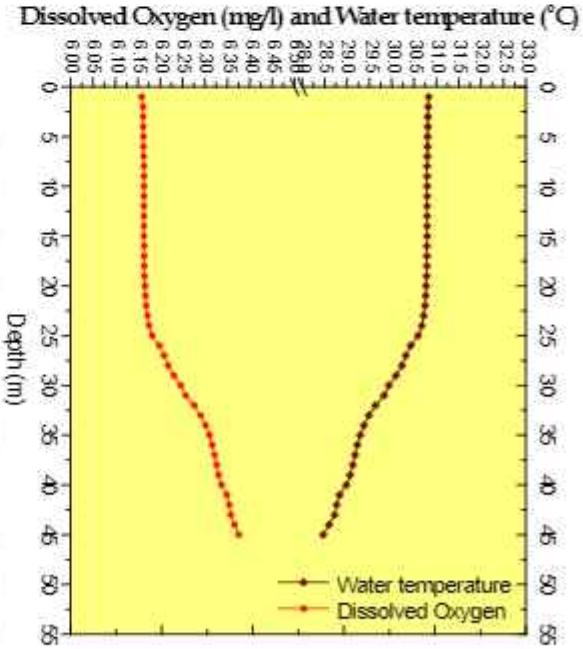
Most of the fishermen who come for fishing are not permanent dwellers of this region, but come from far off places for fishing with hired crafts and gears. The fisher folk who assemble at the mudbanks belong to various castes and religions and speak different languages. In spite of such diversity in social behaviour, worship and way of life, they all live in perfect harmony. A major portion of the income may have to be given as rent for the boat and net. Fishermen used to get fairly good amounts as advance from either money lenders or other agents before they start to the mudbank area. Such advance becomes a burden on them as they are forced to pay heavy interest or give their fish catch at the rates prescribed by the agents.

General Hydrography of Alleppey mudbank

Average water column temperature at shelf waters off Alleppey varies between 28.47°C and 30.82°C (mean 30.16 ± 0.80°C). Vertical profile of hydrographical properties along the shelf waters of Alleppey is shown in Fig. 18 and 19.



The Temperature-Salinity diagram
(Alleppey Mudbank)



Temperature Vs. Dissolved Oxygen
(Alleppey Mudbank)

Fig. 18. Relationship between Temperature and Salinity (T-S diagram) and Temperature and Dissolved oxygen at Alleppey 25 Km offshore

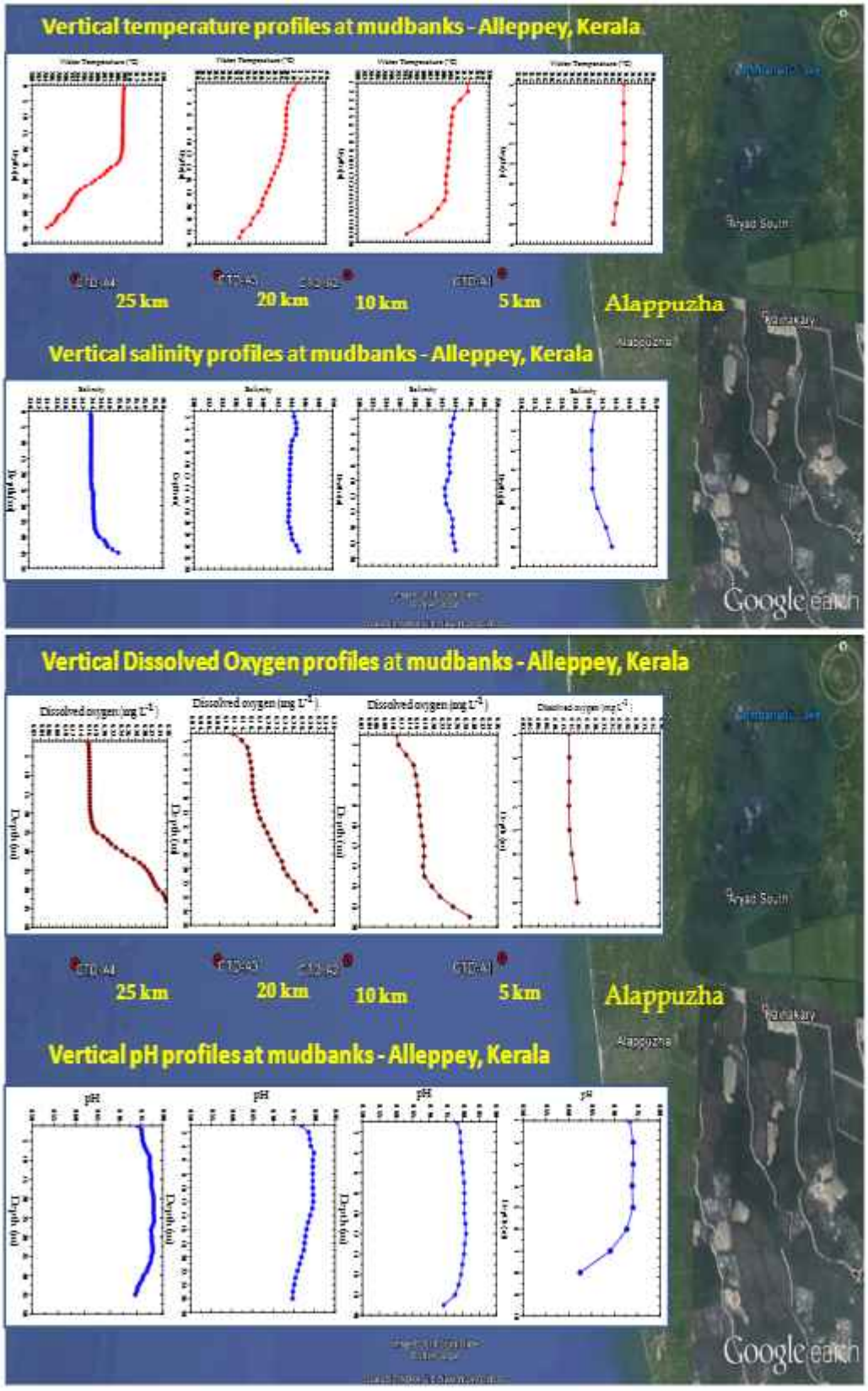
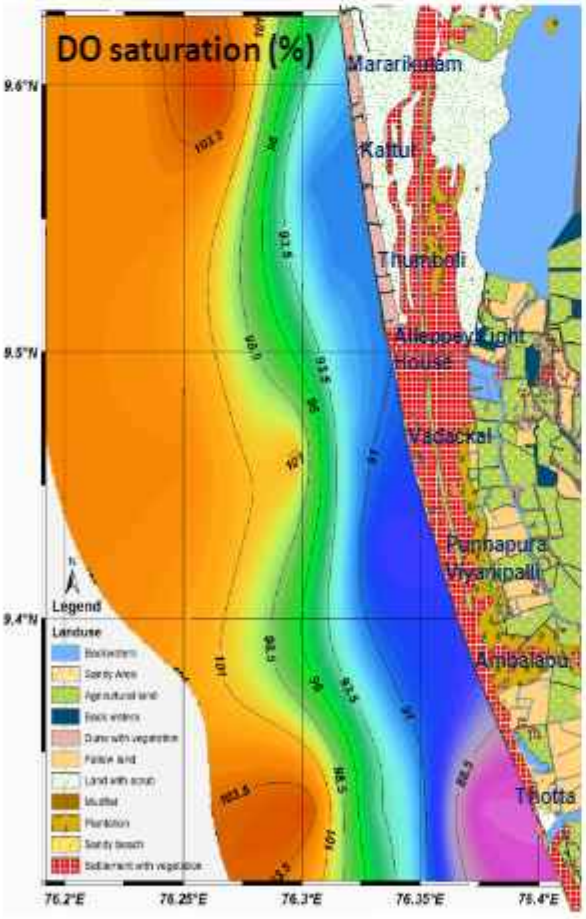
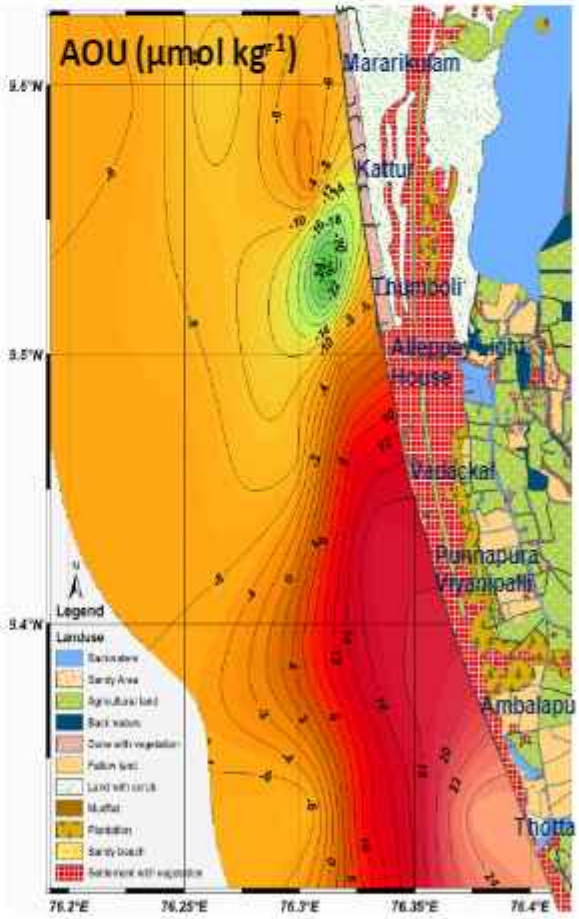


Fig. 19. Vertical profile of Temperature, Salinity, DO and pH at (Alleppey Mudbank)

Vertical profile of Temperature shows evidence of Thermocline at water depth of 25 m. Salinity at the surface waters was slightly lesser than the deeper water and was found to increase with depths. Dissolved O_2 vs. temperature plot shows increase in O_2 concentration in deeper water with decrease in temperature. This may be due to the presence of O_2 rich low temperature water. The concentration of DO in the water column of Alleppey ranged from 6.15 mg l^{-1} to 6.22 mg l^{-1} (6.22 ± 0.76 mg l^{-1}). The pH values do not show any significant variation with respect to the depth.

The observations in general indicate the presence of high nutrients along the Alleppey coast. In the mudbank region, the release of nutrients form sediment cannot be ruled out. The phosphate concentrations did not show any spatial variation in the water, but higher concentrations of ammonia, nitrate and silicate were observed at selected regions starting in the near shore regions and extending offshore (Fig. 20). The nitrate concentrations are higher towards Mararikulam and Thottappalli region upto >7 µmol $l^{-1}$and decreased towards the offshore region. A slight shift but with a similar trend was observed for ammonium with the source centred at Punnapura. The elevated nitrite and phosphate levels around Alleppey may be due to the coastal input through the backwaters, which receives substantial quantity of nutrients through various anthropogenic sources.





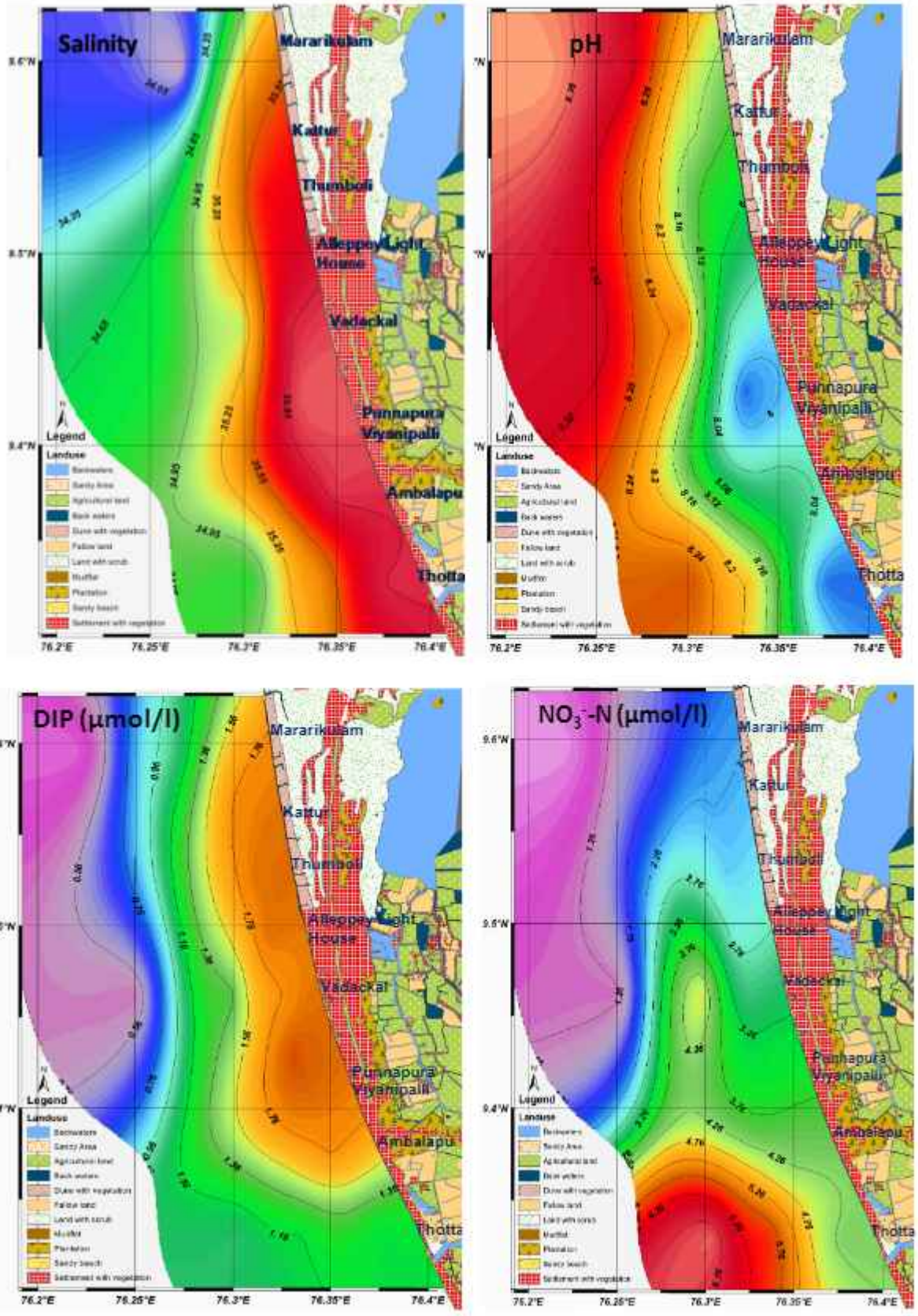


Fig. 20. Spatial variation of O_2 saturation, AOU and Salinity, pH, DIP, and NO_3

The high concentration of Phosphate might be related to the regenerative activity of sediments and especially its contribution from the mudbank region. It is to be noted, that though Cochin backwaters discharge substantial amount of phosphorus to the coastal waters of Alleppey, the sediments of the mudbank are also regulating phosphorous to the overlying waters through adsorption-desorption process. Observations in general indicated the high presence of nutrients along the Alleppey coastal waters. The partial pressure of CO_2 (pCO_2) data revealed a significant variation in its saturation level on spatial scale. The pCO_2 was higher along the mudbank with an average of 502 ± 303 µatm. At all the mudbank stations, the pCO_2 levels were supersaturated with a significant spatial gradient towards the offshore (Fig. 21). The CO_2 flux was in agreement with the spatial variation of surface water pCO_2 and also the hydrodynamic properties of the mudbank water. On a spatial scale, the CO_2 air-water flux ranged between (-6.79 to 86.5 mmol m^{-2} d^{-1}) and several fold high at mudbank, with an average of (25.7 ± 30.5 mmol $m^{-2}d^{-1}$).

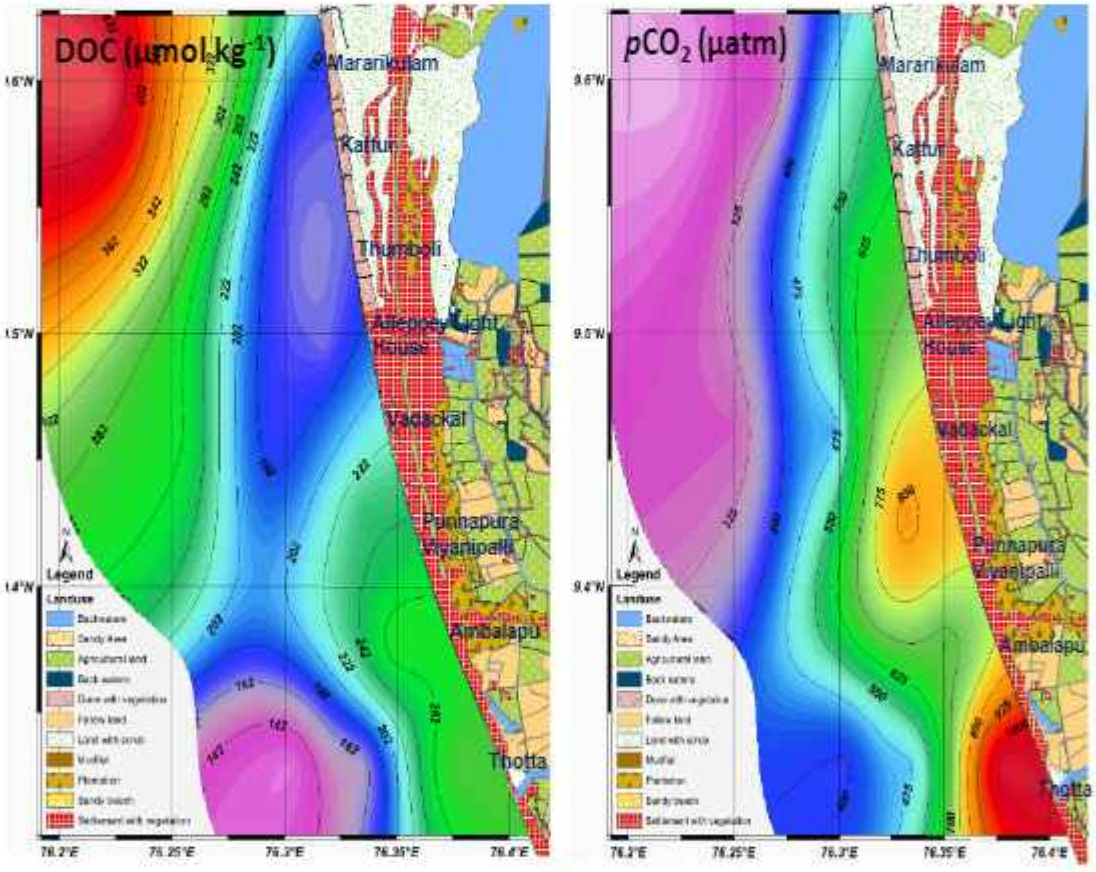
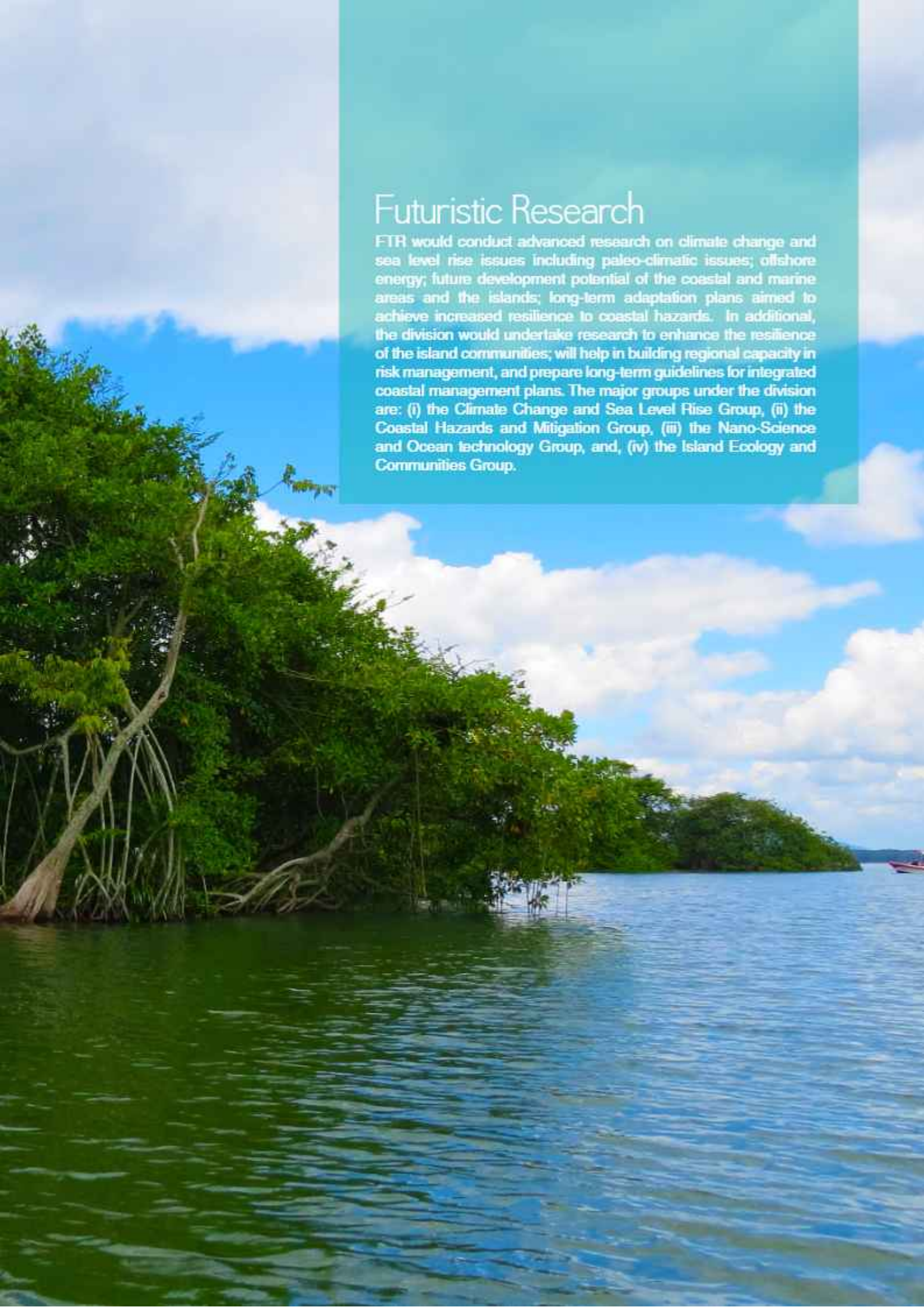


Fig. 21. Spatial variation of pCO_2 and CO_2 air-water flux at the Alleppey Mudbank

Near-shore waters of the Southwest coast of India (Arabian Sea) have a special environmental significance due to the occurrence of mudbanks. The present study on Alleppey mudbank indicated a possible nutrient supply from backwaters to the coastal waters that fuel rich primary production along Alleppey coast, which in turn support a rich source of fishery. The coexistence of elevated pigment concentration (chlorophyll a) and ammonia showed a preference of ammonia among the nutrients for primary production. The elevated nitrite and phosphate levels around Alleppey may be due to the coastal input through the backwaters, which receives substantial quantity of nutrients through various anthropogenic sources. Mudbank aided by sea waves cause re-suspension of loose sub-terraneous material through churning action to the water column especially during south-west monsoon. This high suspended matter results in increased turbidity and with high density water adjacent to the coast, causing a confined area of calm and least wave action. Understanding the hydro-ecological phenomenon of the mudbank system is complex requires continuous monitoring in terms of nutrients, carbon dynamics and its socio-economic aspects.


FTR



Futuristic Research

FTR would conduct advanced research on climate change and sea level rise issues including paleo-climatic issues; offshore energy; future development potential of the coastal and marine areas and the islands; long-term adaptation plans aimed to achieve increased resilience to coastal hazards. In additional, the division would undertake research to enhance the resilience of the island communities; will help in building regional capacity in risk management, and prepare long-term guidelines for integrated coastal management plans. The major groups under the division are: (i) the Climate Change and Sea Level Rise Group, (ii) the Coastal Hazards and Mitigation Group, (iii) the Nano-Science and Ocean technology Group, and, (iv) the Island Ecology and Communities Group.

Coastal vegetated ecosystems namely marshes, mangroves, and seagrass, termed "blue carbon", are well known for their effective, high rates of annual carbon sequestration and the storage of the sequestered C on longer time scales. Despite their global area (~ 0.5% of the sea bed) are one to two orders of magnitude smaller than that of terrestrial forests, the contribution of vegetated coastal habitats per unit area to long-term C sequestration is much greater (it has 70% of the ocean's carbon storage capacity). Additionally, these are productive and are of immense ecological and socioeconomic importance as well as they act as nutrient regeneration and shore stabilization agents.

Blue Carbon Ecosystems: Offsetting Carbon Emissions

The global average atmospheric carbon dioxide concentration increased to 401 parts per million (ppm) in May 2014 (http://co2now.org/), highest level in the past 8 million years. The Intergovernmental Panel on Climate Change (IPCC) estimates that by the year 2050, global CO_2 emissions must be reduced by 85% from levels seen in 2000 to prevent a global mean temperature increase of 2°C. To reduce atmospheric CO_2 concentrations a more recent approach has been suggested that include combined reduction of anthropogenic CO_2 sources (mitigation) with supporting CO_2 uptake and storage through the conservation of natural ecosystems with high C sequestration rates and capacity.

Coastal vegetated ecosystems namely marshes, mangroves, and seagrass, termed "blue carbon", are well known for their effective, high rates of annual carbon sequestration and the storage of the sequestered C on longer time scales. Despite their global area (~ 0.5% of the sea bed) are one to two orders of magnitude smaller than that of terrestrial forests, the contribution of vegetated coastal habitats per unit area to long-term C sequestration is much greater (it has 70% of the ocean's carbon storage capacity). Additionally, these are productive and are of immense ecological and socioeconomic importance as well as they act as nutrient regeneration and shore stabilization agents.

Scientific evaluation of the C sequestration capacity of coastal ecosystems and their potential role in comparison to terrestrial forest types has not been assessed in great detail in India. Furthermore, quantification of the greenhouse gas fluxes from the coastal wetlands under varying spatial and temporal conditions are still inconsistent in the Indian subcontinent as most of the studies use different methodologies. The East coast has been well studied and inventorized with respect to mangrove ecosystems, whereas there are very few studies from the west coast, thus making the comparison more challenging. There is a strong need to assess the source/sink of GHGs using a universal methodology to elucidate the actual role of these unique ecosystems towards the release of GHGs and its impact on regional/ global climate change. The research on *Blue Carbon: Offsetting carbon emission by conserving coastal vegetative ecosystems along the Indian coast* (BECOCE) is being carried out in all major mangroves and seagrass ecosystems of India following standard protocol. The mandate is to determine the actual role of these unique ecosystems towards the release of GHGs vs. their carbon sequestration potential, and thus, consequent impact on global climate change. Assessment of the impact of anthropogenic stresses (habitat loss, land use change and pollution) and natural variables (salinity, temperature and carbon dioxide) on the carbon sequestration capacity of these ecosystems is also an important subject of the study. The research study BECOCE includes the following mandates:

- Assessment of Blue Carbon Sequestration potential in seagrass and mangrove ecosystems
- Estimation of greenhouse gas fluxes from mangrove and seagrass ecosystems and the factors influencing it
- Correlation with satellite based measurements of carbon sequestration potential with field measurements
- Modelling and prediction of the fate of Carbon sequestration capacity of coastal ecosystems under changed climatic conditions

Blue carbon ecosystems of India

Seagrass Ecosystems

Seagrass has been one of the poorly studied ecosystems in India compared to others coastal ecosystems such as mangrove and seaweeds, though there have been a considerable amount of research has been carried out in the temperate and tropical ecosystem of other countries. Seagrass habitats in India are restricted from the lower intertidal zone to the open shores and in the lagoons, mainly mudflats and sandy environment (Fig. 1)

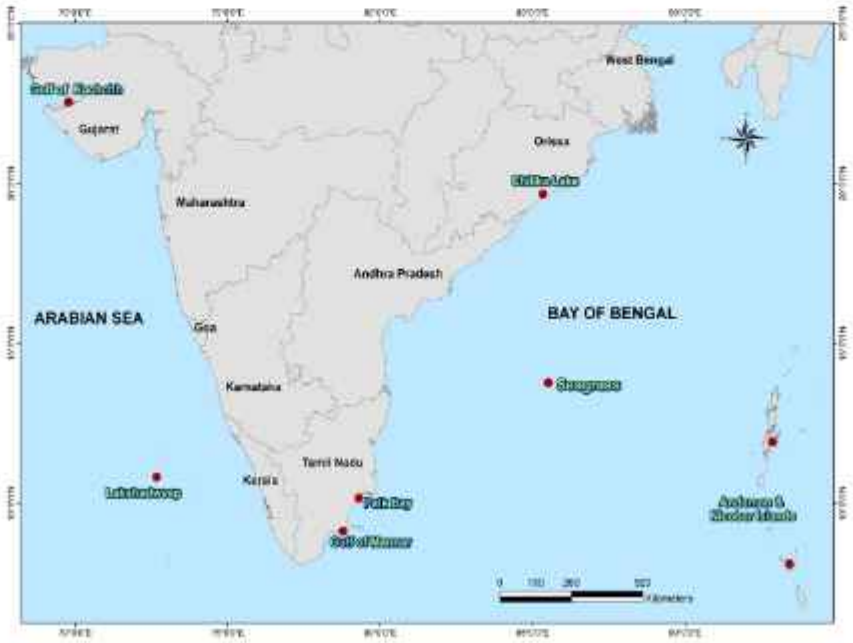


Fig. 1. Dominant Seagrass ecosystems of India

Luxurious beds of seagrass are observed along the Chilika Lagoon, southeast coast (Gulf of Mannar and Palk Bay) and a number of islands of Lakshadweep (Arabian Sea) and Andaman and Nicobar (Bay of Bengal). Gulf of Mannar and Palk Bay are associated with densest area cover (30 sq. km) of seagrass whereas; It is estimated that the lagoons of the major islands of Lakshadweep have approximately 1.12 sq. km of seagrass meadows. In Andaman and Nicobar Islands, islands such as Teressa, Noncowrie, Katchal, and Great Nicobar have dense beds covering an area of total 0.8 sq. km. In is reported that these seagrass beds can be either in patches (large and small) or in stretches (long or broken). The maximum seagrass cover, abundance, and species richness are usually associated with regions with high salinity with little variation throughout the year.

Mangrove Ecosystems

Indian mangroves are distributed in about 6,740 km^2 (Fig. 2) which constituted 7% of the total Indian coastline. The deltaic mangroves on the east coast represent 57% (2,738 km^2) of the country's total area of mangroves while the oceanic mangroves (Andaman and Nicobar) account for 20% (383 km^2) of total Indian mangrove. The mangroves of Sundarban and Bhitarkanika mangroves are tide dominated allochthonous type of mangroves. The tidal range is high with strong bidirectional current as well as the main river channels are funnel shaped with extensive tidal flats, colonized by mangroves. The Corianga mangroves of Andhra Pradesh (Godavari) and Pichavaram- Muthupet mangroves Tamil Nadu (Cauveri) are river dominated allochthonous type with characteristics rapid deposition of terrigenous material. The Gujarat mangroves (Gulf of Kutch and Khambat) are of peculiarly bedrock valley type, drowned by rising sea level. The relatively small delta area could be seen at the head of the valley, Carbonate platform on low energy coasts type of mangroves are present in Andaman and Nicobar Island and they are slowly accreting due to the accumulation of marl (calcareous) and peat, coral reef or sand. Fringe mangrove growth is luxurious in the shallow water area of these islands. Mangroves on the East coast of India has been well studied and inventorized with respect to GHGs, whereas there have been very few studies from the West coast and Oceanic mangroves

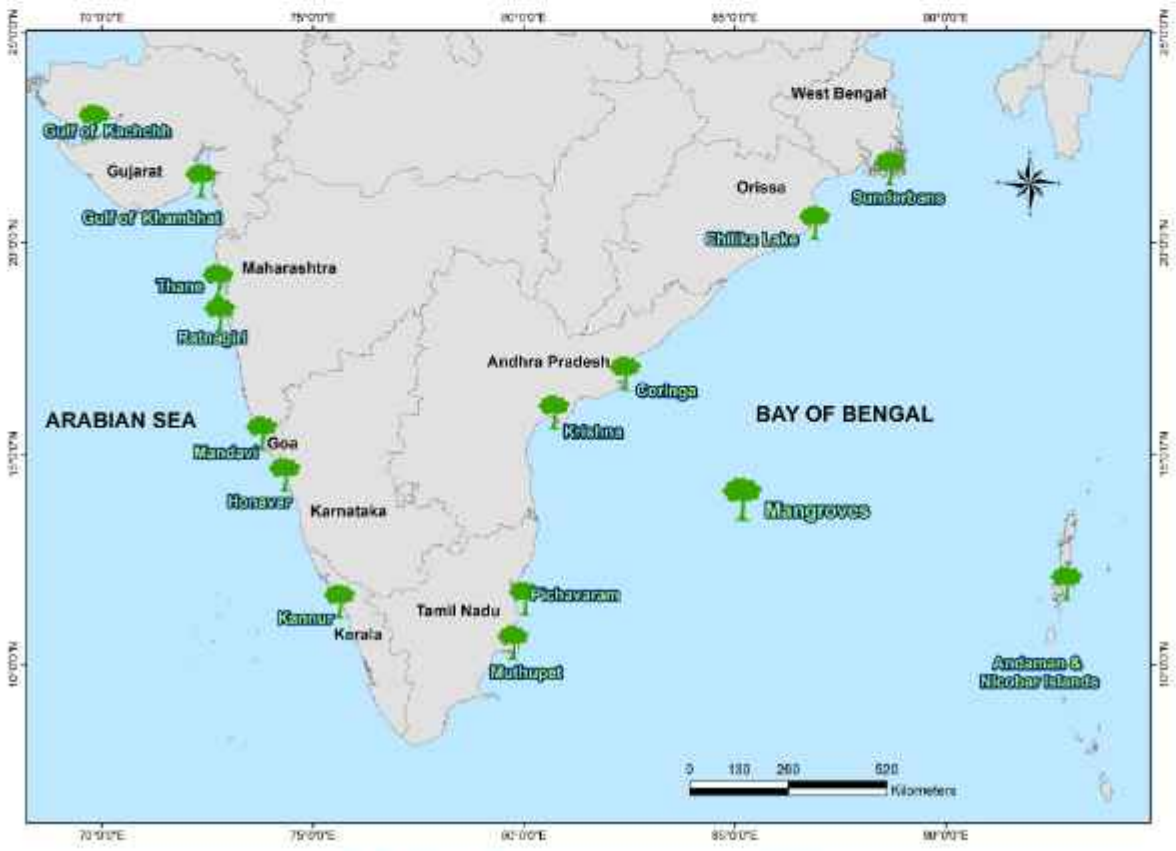


Fig. 2. Major Mangrove ecosystems of India

Sampling Strategy and Analytical Methodology

In 2013-2014, field campaigns were carried out seasonally in Palk Bay and Chilika Lagoon (seagrass ecosystems) and Pichavaram and Andaman-Nicobar Island for carbon sequestration sequestration studies under the in-house project "BECOCE".

In these ecosystems extensive spatial sampling is being carried out to understand the biogeochemistry as well as distributional pattern. In order to understand the role of tidal influx and light limitation, diurnal (24 hour) sampling campaigns was also carried out at selected locations. Water, air, sediment (surface and core) and biomass samples were collected from each location. Measurement of greenhouse gases (CO_2 and CH_4) was carried out by using various standard techniques (*Fig. 3)*, to elucidate their role in global climate change, if any.

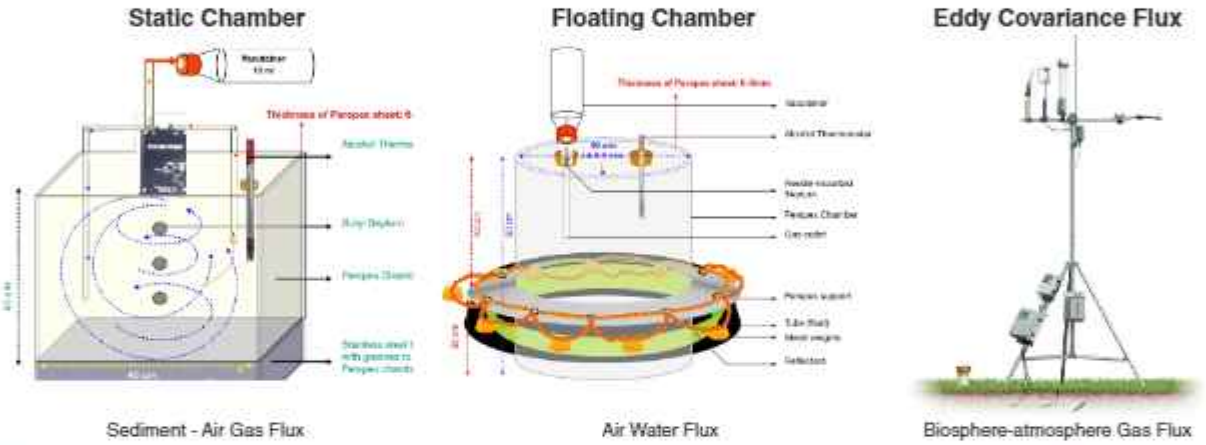


Fig. 3. Various techniques for greenhouse gas flux measurements a. Sediment -Air Gas Flux, b. Air - Water Gas Flux, c. Biosphere - Atmosphere Gas Flux

Using pH and TA, pCO_2 of the water sample at *in-situ* temperature was calculated using Dickson and Millero constants. Dissolved CH_4 was analyzed by single phase equilibration gas chromatography (Upstill-Goddard et al. 1996). Nutrients were analyzed by spectrophotometric methods by Grasshoff et al. (1999). Nitrate (NO_3^-) and Nitrite (NO_2^-) was analyzed by using Cadmium Reduction and Di-azo methods, respectively. A relative error of accuracy was ±2% for dissolved inorganic phosphorus (DIP), ±3% for nitrate, and ±5.2% for ammonia. The detection limits were 0.06 µM L^{-1} for DIP, 0.1 µML^{-1} for dissolved inorganic nitrogen (DIN).

Sediment samples were oven dried at 60ºC. Each sample of 50 µg weights was taken in a silver capsule and de-carbonated by HCl fumes. Then the samples were again dried and analyzed through NC Soil Analyser (Thermo Finnigan, *FlashEA 1112*) using L-Aspartic Acid as standard for calibration. The precision of the analysis was checked against Soil Reference Material NCS and it was within ± 0.5 % of the accuracy. Computation of Gross Primary Production (GPP), Community Respiration (CR), and Net Community Production (NCP) by open water mass balance of O_2 was carried out as per Odum (1956). The computations were made by considering a 24 hour cycle starting at 9 AM on a given day. Daily integrated CR (mmol O_2 m^{-2} d^{-1}were computed as follows:

$$CR = [\ \Sigma(Q_{O2n})_{t+1} - (Q_{O2n})_t\ ) + \Sigma\ F_{O2n}\ ] / H_n \times 24$$

Where, $(Q_{O2n})_{t+1} - (Q_{O2n})_t$ is the change in Q_{O2} during night time (Q_{O2n}) between two hourly intervals (t), F_{O2n} is the air–sea O_2 exchange at each 't' during night time computed using Ho et al. (2006) gas transfer parameterization as a function of wind speed and measured u_{10} (where the efflux of O_2 from water to atmosphere corresponds to positive F_{O2n}), and H_n is the night time duration given by:
$H_n = 24 - H_d$,

Where, H_d will be computed from an astronomical model (http://www.usno.navy.mil/USNO/astronomical-applications). Daily integrated GPP (mmol O_2 m^2 d^{-1}) was computed using the formula:

$$GPP = [\ \Sigma(Q_{O2d})_{t+1} - (Q_{O2d})_t\ ] + \Sigma\ F_{O2d} - CR$$

Where, $(Q_{O2d})_{t+1} - (Q_{O2d})_t$ is the change in Q_{O2} during daytime (Q_{O2d}) between two t, F_{O2d} is the air–sea O_2 exchange at each t during daytime. On some occasions rapid changes of water temperature in conjunction with high wind speed events could indicate a drastic change of water masses, and metabolic data for these periods would be discarded (Champenois and Borges, 2012).

Distribution of Seagrass in Chilika lake

Prior to 2000, the Chilika Lake (Fig. 4) just had 20 sq. km of seagrass meadow which has now expanded to over 86.84 sq. km. In the brackish water lagoon, five seagrass species like *Halodule uninervis, Halodule pinifolia, Halophila ovalis, Halophila ovata* and *Halophila beccarii* have been recorded (Plate 1). Of these, three are found to be new. Before opening up of the new mouth of Chilika in 2000, most common seagrass recorded was *Halophila ovalis*, which is more tolerant of low salinity and low light than the other species. After the new mouth was opened, *Halophila* strands were found to show profuse growth and spread to deep-water zones. *Halophila* sp. was recorded for the first time in the deep waters in the creeks of the Krushnaprasad Island with the prolific growth during the post-monsoon months forming extensive meadows. The biodiversity pattern of the lagoon followed the ambient water quality controlled by the distribution of seagrass bed. This study revealed the highest seagrass biodiversity in the southern sector. Additionally, it was observed that seagrass meadows of the lake are expanding in spite of anthropogenic pressure, which is a sign of healthy ecosystems. Thus, the lake contains the most important and significant actual habitat for in situ conservation of biological diversity, including rare species of birds and animals. In addition, the lagoon supports about 37 species of reptiles and amphibians.

Halodule uninervis

Halodule pinifolia

Halophila Ovalis

Halophila beccarii

Plate 1. Major seagrass species found at Chilika lagoon.

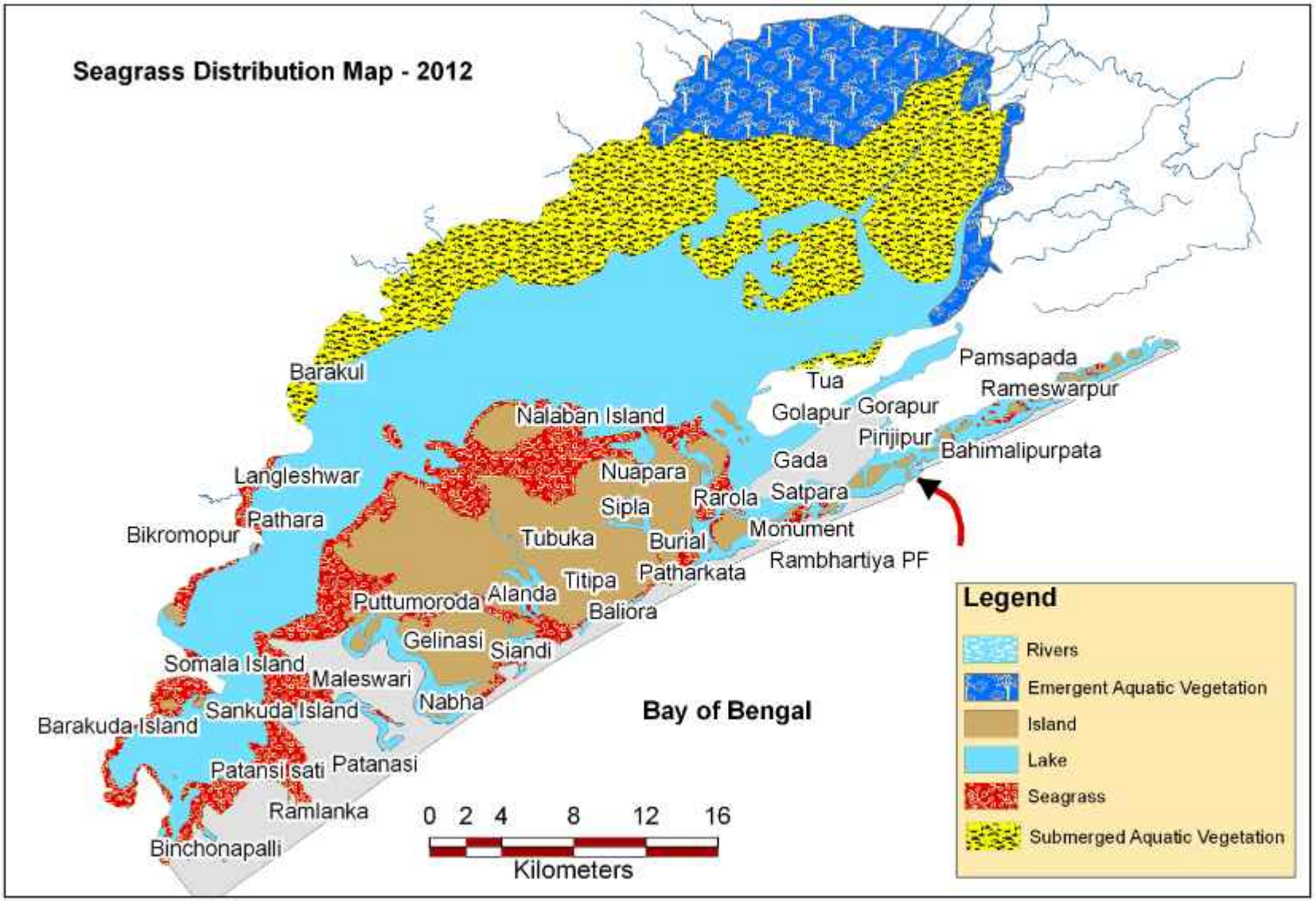


Fig. 4. Spatial distribution of seagrass, sub-merged aquatic vegetation and emergent aquatic vegetation in the Chilika lagoon, India.

Distribution of Seagrass in Palk Bay

Palk Bay harbors extensive and very healthy seagrass beds throughout the stretch (Fig. 5) from Olaikuda (south) to Nagapattinam (north). The species diversity is high having 10 species and more. *Cymodocea serrulata* and *Halodule pinifolia* were predominant in Adhirampattinam and adjacent area. *Halodule uninervis, Halophila ovalis*, *Halophila stipulacea,Thalassia hemprichii* and *Syringodium isoetifolium* occured in discrete mono-specific or mixed populations (Plate 2). In Mallipattinam, *Halodule pinifolia* forms an extensive bed with patchy distribution of *Halophila stipulacea*. *Enhalus acoroides* is restricted to the shallow and the sheltered zone of Kattumavadi. In Manamelkudi, Mimisaland Kottaipattinam south of Mimisal, the calm sea harbors mono-specific and mixed populations of as many as nine seagrass species. Extensive mono-specific beds of *Halophila ovalis* occurred near the Mimisal estuary.

Cymodocea serrulata

Thalassia Hemiprichii

Syringodium isoetifolium

Enhalus acoroides

Plate 2. Major seagrass species found at Palk Bay

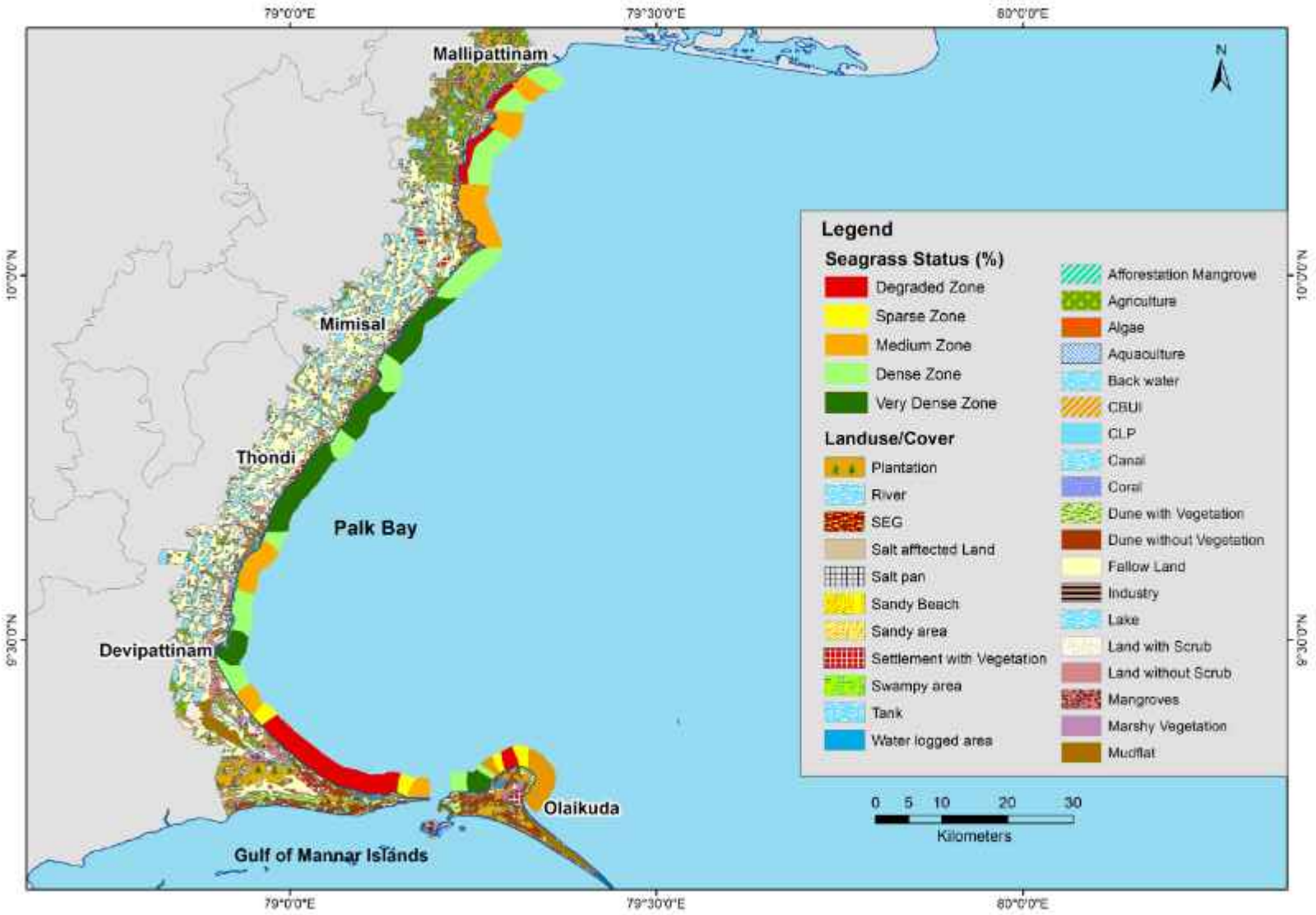


Fig. 5. Spatial distribution and density of seagrass and associated vegetation in Palk Bay

Significant Results

Improving water quality of surrounding waters and adjacent reef

Marine sediments with high organic matter input may results hostile conditions for plant life. High inputs of organic matter lead to increased bacterial activities, thus increasing the anoxic environment. This often results in the accumulation of phytotoxic compounds, e.g. sulfide. Seagrass acts as an oxygen pumping agent through their roots to the surrounding thus, creating a relatively oxidized rhizosphere. Higher dissolved oxygen in seagrass bed in the Chilika was observed as compared to degraded bed, indicating enhanced photosynthetic rates. The diurnal variations in dissolved oxygen level were almost similar irrespective of species (Fig. s 6a and 6b) at Palk Bay. The maximum dissolved oxygen concentration was observed during late afternoon, as high temperature and sunlight restricts productivity. However, the data are from single season, just after the offset of monsoon, hence the turbidity was high with significant freshwater input. Fig. 7 represents the spatial variation in DIN & DIP concentration in the Seagrass ecosystem of Palk Bay was given in.

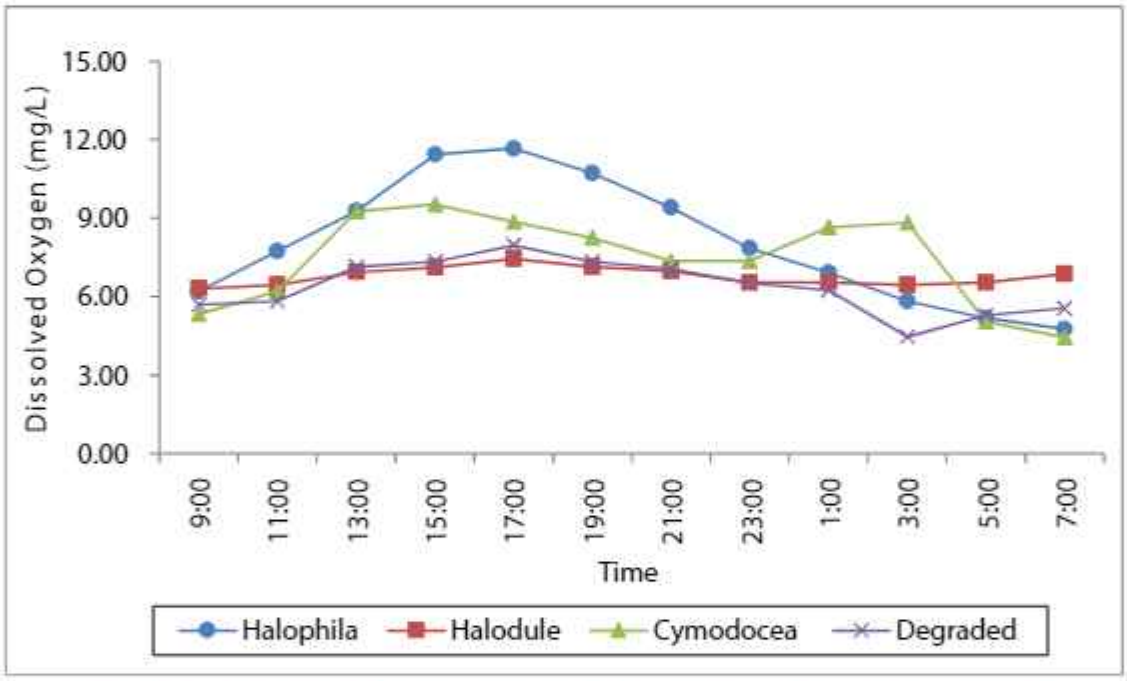


Fig. 6a: Diurnal variations in dissolved oxygen concentration in seagrass ecosystems

Primary productivity and biodiversity of seagrass ecosystem

Seagrass beds constitute extremely productive ecosystems in shallow coastal waters. Their complexity in both structure and function is due to the great diversity and abundance of organisms present. The results of the study highlight the importance of seagrass as '**bioshields**', reducing or mitigating impacts of unsustainable fish farms and land use practices on the coastal environment. This ecosystem service is currently under threat by a multitude of factors, both natural and human-influenced. High primary productivity by the seagrass indicates higher consumption of micronutrients which in turn keeps the water cleaner, reducing the probability of phytoplankton blooms in this area (Fig. 8). In addition, high productivity, reduces the pCO_2 level in the water by consuming large amounts of dissolved inorganic carbon. Net ecosystem productivity and water column productivity were measured at different seagrass beds in Palk Bay, dominated by three major species, namely, 1. *Cymodocea serrulata*, 2.*Syringodium isoetifolium*, 3.*Enhalus acroides*. Seagrass productivity was measured in two different seasons (Wet and Dry) in the Palk Bay during November, 2013 (wet) and May 2014 (Dry). *Cymodocea serrulata*, and *Syringodium isoetifolium* bed was selected for the study, due to their dominance in this region.

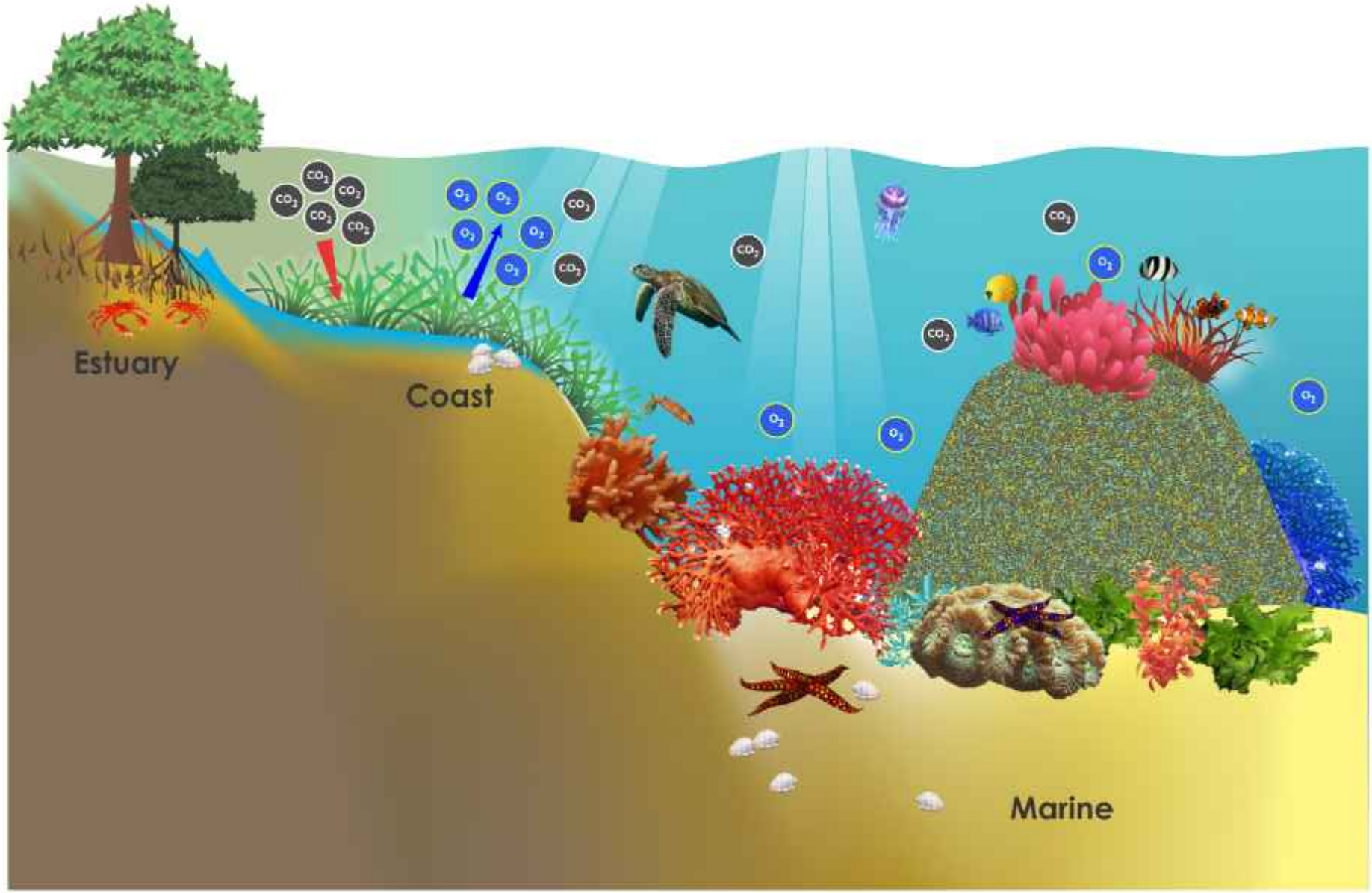


Fig. 6b: Conceptual model of Oxygen release by seagrass

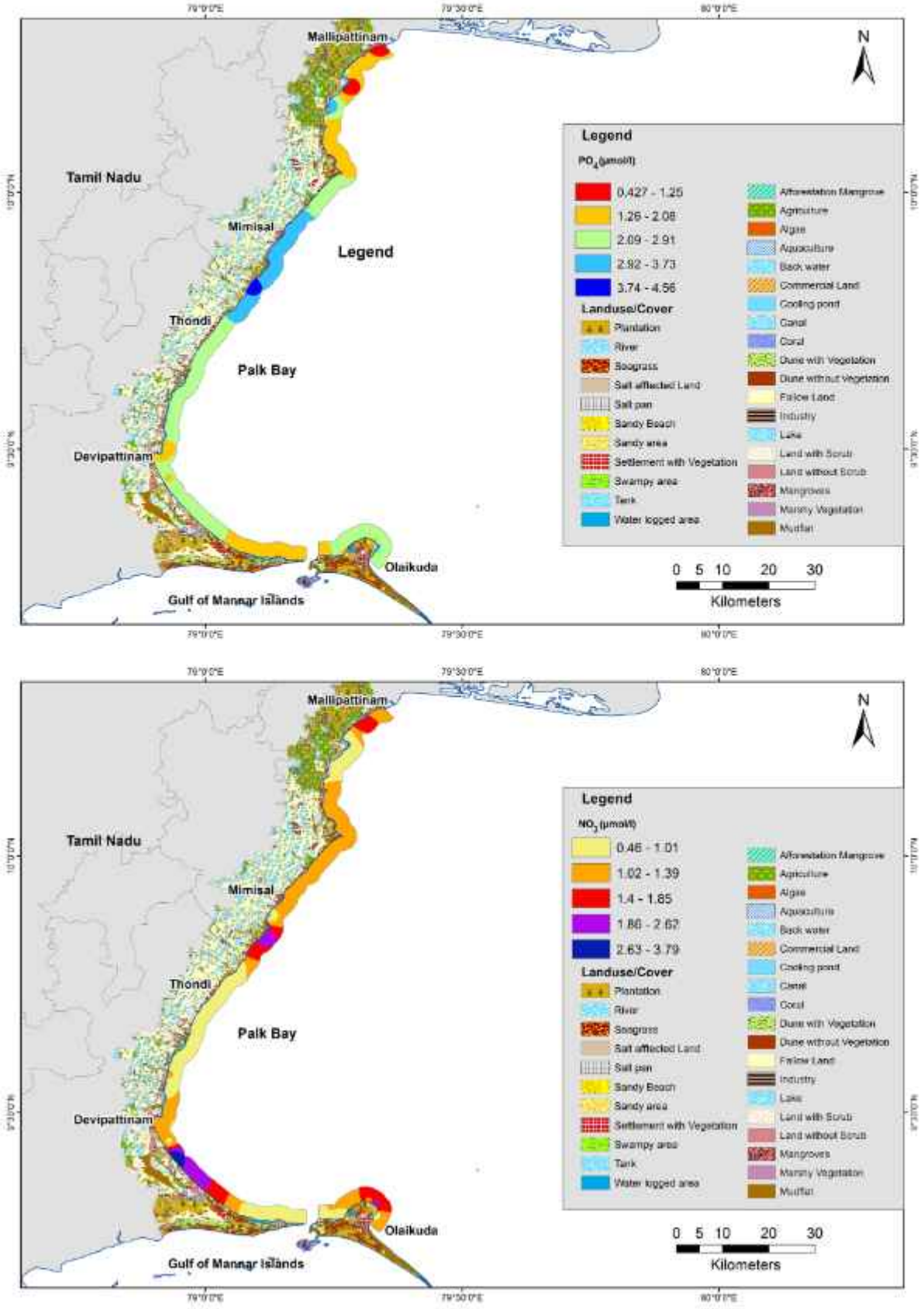


Fig. 7. Spatial variation in DIN & DIP concentration in the Seagrass ecosystem of Palk Bay

The mean water column net primary productivity (7.3±5.93 mmol C m^{-2} day^{-1}) in the wet season (November, 2013), was ~12 times less than the net ecosystem primary productivity (84.95±12.23 mmol C m^{-2} day^{-1}), which is mostly contributed by seagrass. The net dissolved inorganic nitrogen and phosphorus consumed by the system, was calculated to be, 10.98 mmol N m^{-2} day^{-1} and 0.3 mmol P m^{-2} day^{-1}, respectively (converted from carbon units using the Redfield O_2 : C : N : P ratio of 138. 106.16.1). The mean water column chlorophyll-a concentration was 1.28±031 mg m^{-3}. During the dry season (May, 2014), water column respiration exceeded the water column gross productivity, although, net ecosystem productivity was found higher than that of the wet season, largely owing to the active primary productivity by the benthic seagrass community under enhanced light and temperature conditions. The mean water column chlorophyll-a concentration (0.66±0.23 mg m^{-3}) was two times lower than that of the wet season.

Subtropical and tropical marginal seas are well known as the net sources of atmospheric CO_2 and the waters are characterized by high pCO_2 values. Russell et al (2013) recently showed a positive growth response of seagrass (*Cymodocea serrulata)* under the high pCO_2 condition. High primary productivity provides relatively low pCO_2 in coastal waters, which can cause a higher degree of aragonite/calcite saturation and could be beneficial for the adjacent coral reef ecosystems (seaward). The present study revealed that the seagrass waters in Palk Bay were highly supersaturated with respect to aragonite and calcite in association with the high net primary productivity.

Gross primary production (GPP) rates (mean ± SE = 172.9 ± 11.1 mmol O_2 m^{-2} d^{-1}) tended to be significantly higher than the corresponding respiration (R) rates (mean ± SE = 143.6 ± 10.1 mmol O_2 m^{-2} d^{-1}), indicating that seagrass meadows tend to be autotrophic ecosystems, reflected in a positive mean net community production (NCP 27.2 ± 5.8 mmol O_2 m^{-2} d^{-1}) (Fig. 9a & b) and a mean P/R ratio above 1 (1.55 ± 0.13). Results from Palk Bay indicate mean NCP in excess of 4.55 t C ha^{-1} yr^{-1}, well above that of undisturbed Amazonian forests (1.02 t C ha^{-1} yr^{-1})that is considered to be the strongest carbon sinks on land.

The carbon sequestration rate observed from the seagrass meadows of Palk Bay is significantly above the global mean NCP (1.02 t C ha^{-1} yr^{-1}) of seagrasses but is under the top 10% of the global seagrass meadows in terms of their carbon sink. Reliable and accurate estimates of seagrass biomass are essential for estimating productivity and establishing links between other estuarine components.

High primary productivity provides relatively low pCO_2 to coastal waters, which can cause a high degree of aragonite/calcite saturation. This could be beneficial for the adjacent coral reef ecosystems in terms of coral growth. Subtropical and tropical marginal seas are well known as the net sources of atmospheric CO_2 and the waters are characterized by high pCO_2 values. Recent studies suggest a positive growth response of seagrass (*Cymodocea serrulata)* under the high pCO_2 conditions. This study indicates that the seagrass waters in Palk Bay are highly super-saturated with regard to aragonite and calcite, which are encouraging signs of coral growth and recovery. Fig. 10 represents the inter-comparison of the metabolic activities between the ecosystems dominated by various seagrass species of Chilika Lagoon and Palk Bay.

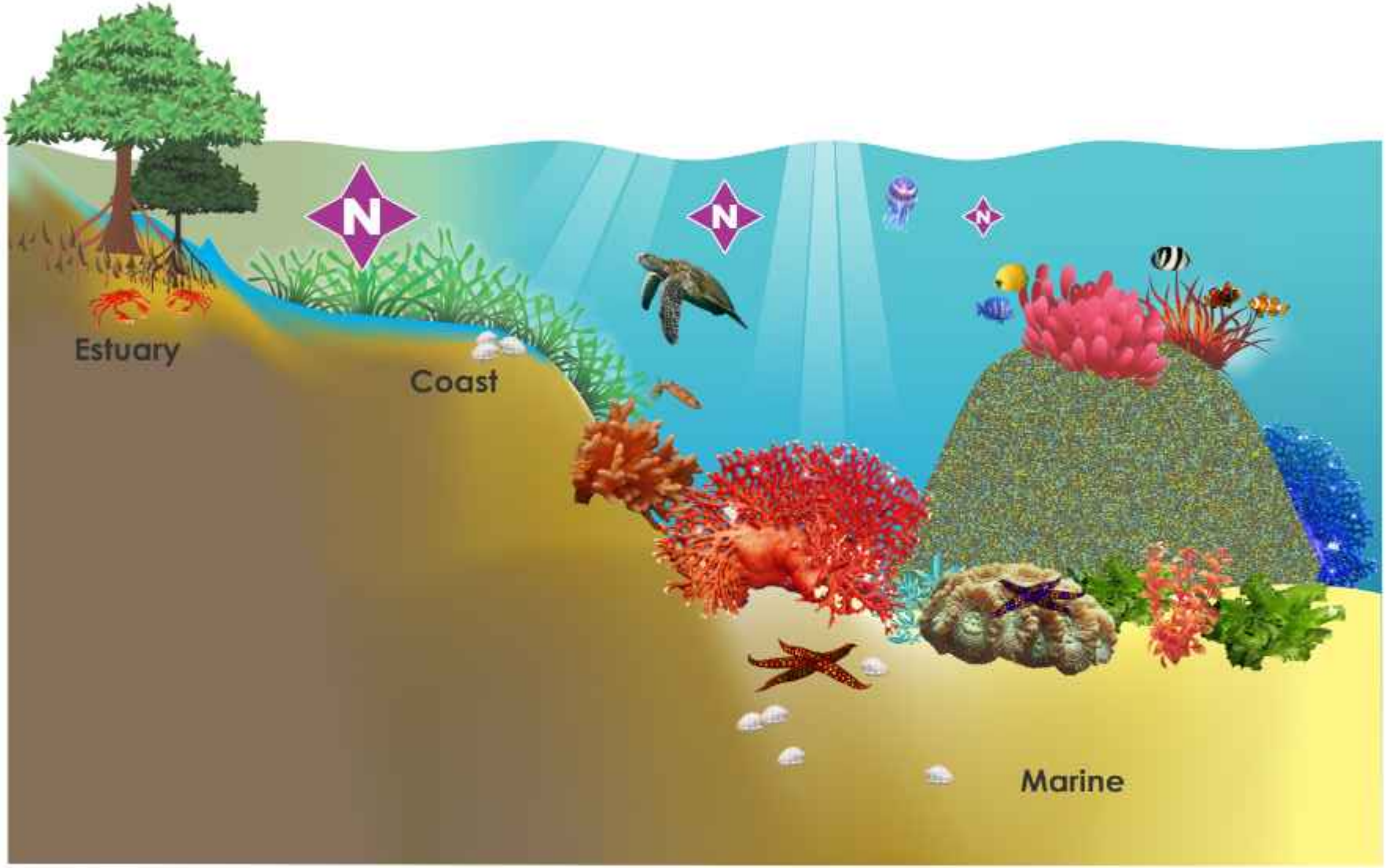


Fig. 8. Conceptual model of nutrient uptake and utilization by seagrass

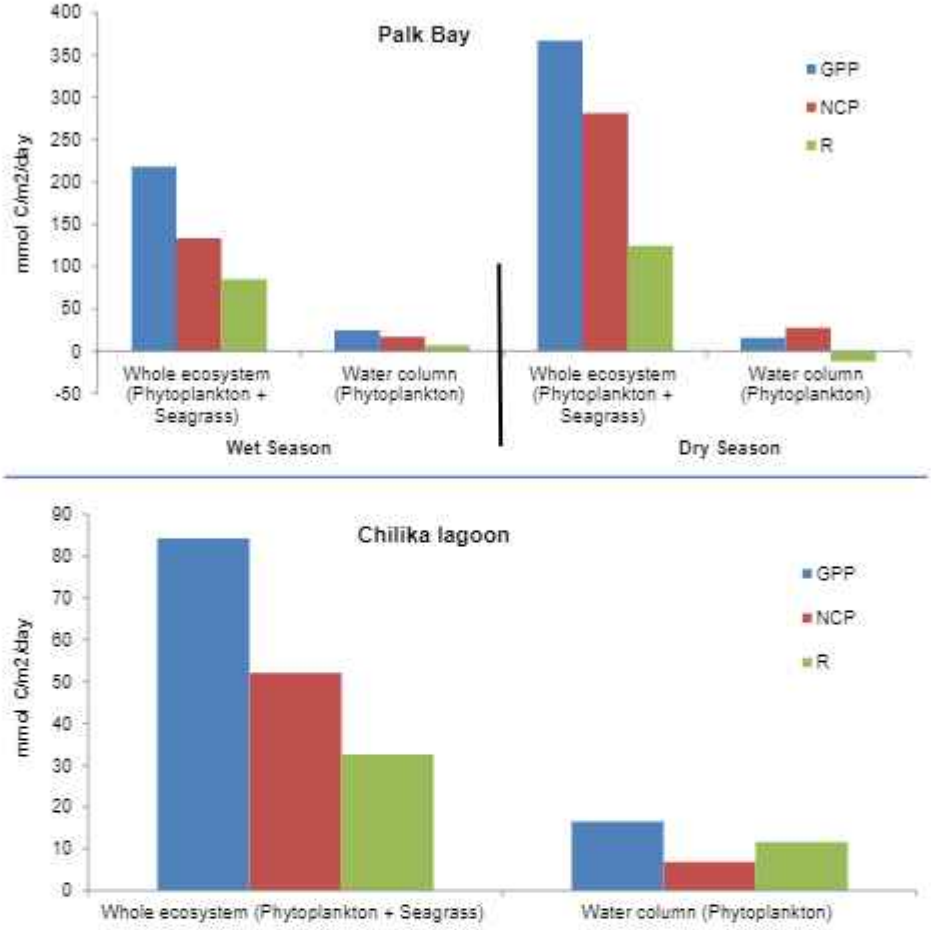


Fig. 9. a. Relative contribution of the water column productivity with respect to the whole ecosystem system productivity, dominated by seagrass species in Palk Bay & b. Chilika Lagoon

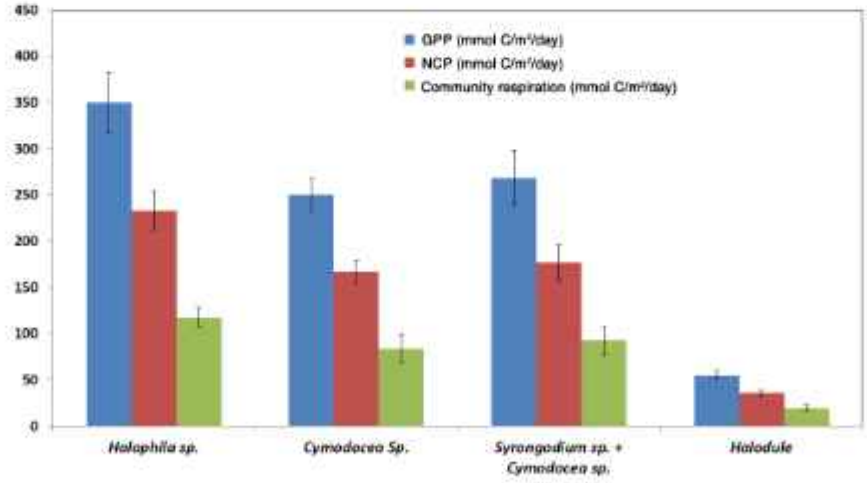


Fig. 10. Gross primary productivity, net community productivity and community respiration in seagrass ecosystems (species wise).

Dissolved CO_2 and CH_4 in Chilika seagrass bed (Lagoonal system) and Palk Bay seagrass bed (Open Ocean)

Seagrass ecosystems are also known to be CO_2 limited and photosynthetically less active in seawater, because of their inefficient utilization of bicarbonate (HCO^-_3), which forms the majority of dissolved inorganic carbon, for photosynthesis. Seagrass actively uses dissolved CO_2 and thus increasing the growth rates. The biological capture of CO_2 by seagrass ecosystem is distinctly observed from the variation of pCO_2 concentration between seagrass and non-seagrass beds (Fig. 11).

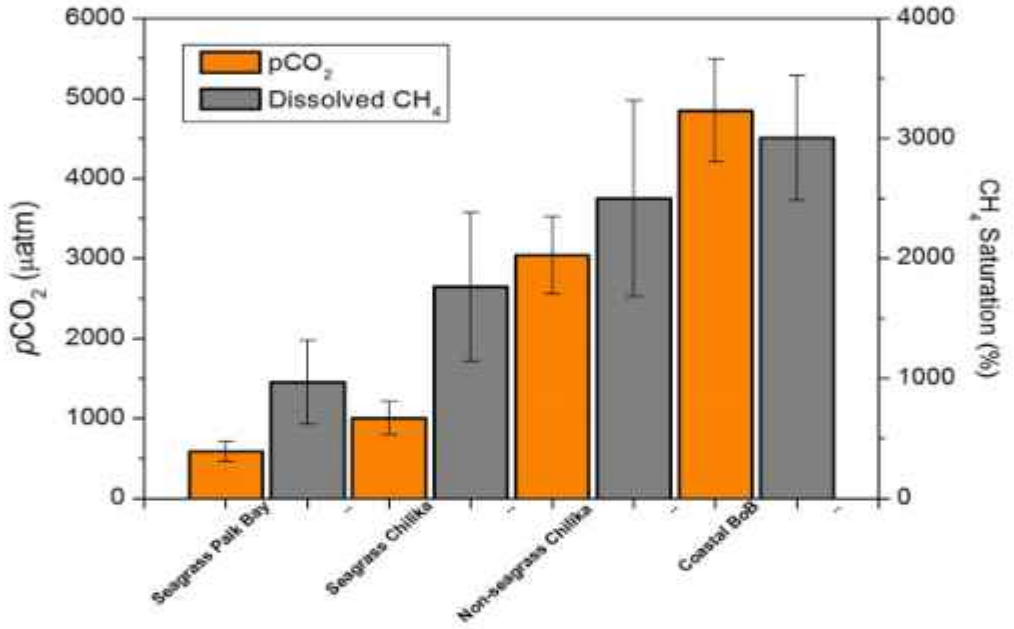


Fig. 11. Variation of gaseous C concentration in surface waters of seagrass and non-seagrass beds

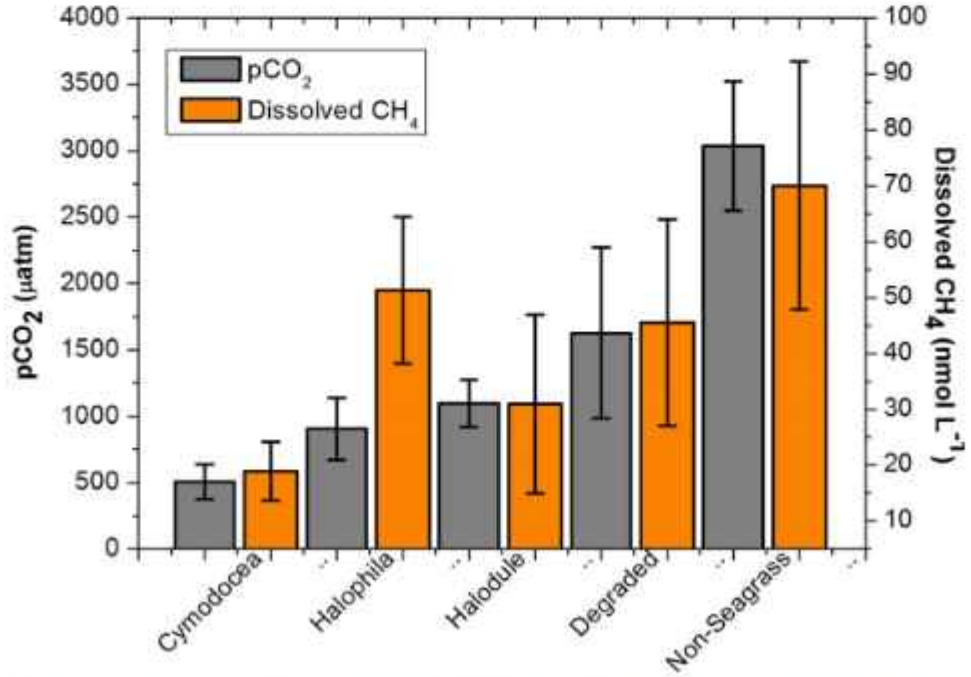


Fig. 12. Species specific variation of gaseous C concentration in various seagrass ecosystems

Very little data on the CH_4 saturation of seagrass waters is available worldwide. Efforts have been made for the first time in this study to quantify the net CH_4 exchange from Indian seagrass bed. The initial results showed that the CO_2 concentrations in the seagrass waters were ~3 (for Chilika) and 8 times (for Palk Bay) lower than the non-seagrass waters along the Indian coast, respectively (Fig. 11). Very less data are available on CH_4 saturation from the Bay of Bengal waters. The present study indicates that the degree of CH_4 saturation was ~2 times lower in the seagrass waters than the coastal waters of the Bay of Bengal.

Cymodocea sp. dominated waters in Palk Bay showed the lowest concentration of both CO_2 and CH_4 among all other species, during the wet season (rainy season) (Fig. 12).

Diurnal variation of dissolved CO_2 concentration revealed very active biological activities (photosynthesis and respiration) and a large difference of CO_2 concentration between day an night time was recorded in the most of the seagrass ecosystems (Fig. 13). Diurnal variation of dissolved CH_4 was not consistent in most of the seagrass beds, although a minimum and a maximum was recorded during the evening hours and early morning hours, respectively in the *Halophila* dominated bed.

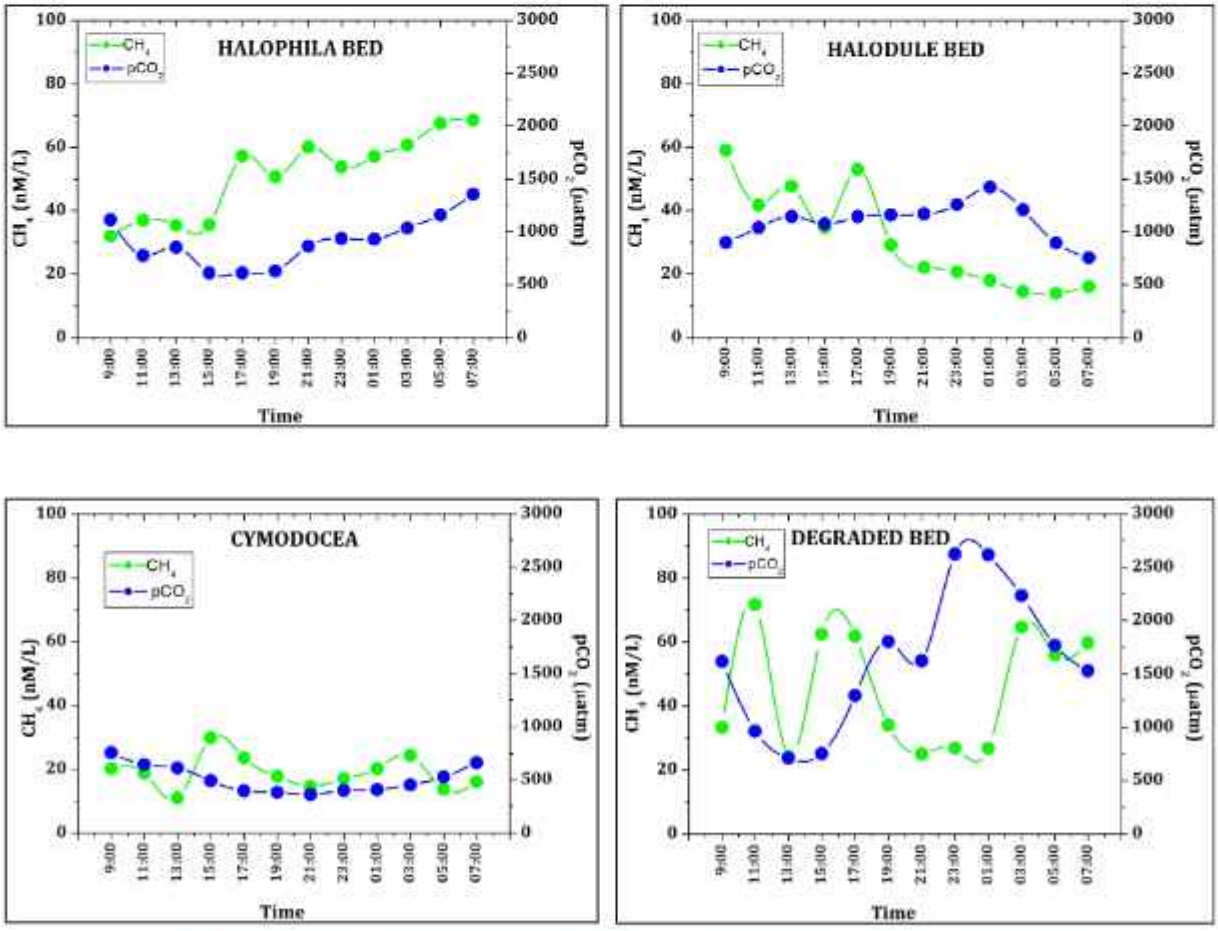


Fig. 13. Diurnal variation of gaseous C concentration in various seagrass ecosystems

Dissolved CO2 and CH4 concentrations of mangrove surrounding waters of Andaman

Mangroves, as a typical tropical coastal system, are expected to have higher rates of metabolism due to relatively higher temperatures. Further, the high dynamic range of seasonal, diurnal and spatial variations of the trace gas concentrations ultimately influences the air-sea trace gas fluxes. Therefore, an extensive survey has been undertaken to better understand a part of C cycling in terms of the diurnal variations of pCO_2 and dissolved CH_4 concentrations in Andaman mangroves surrounding waters.

Three diurnal samplings were carried out in North Andaman (Diglipur), Middle Andaman (Bakultala) and South Andaman (Wright Myo) regions. The pCO_2 concentrations revealed that, all the studied sites were supersaturated with respect to CO_2 concentration in the atmosphere (Fig. 14). The oversaturation of CO_2 in all the sites with respect to atmospheric equilibrium, which is the general feature in the waters surrounding mangrove forests reported by Borges et al (2003). Similarly, dissolved CH_4 concentrations showed higher concentrations ranged between 26 and 234 nmol L^{-1} with higher average values (194 nmol L^{-1}) found in Wright Myo mangroves. In Wright Myo human interference is comparatively greater than the other mangrove regions. Among all the three regions, South Andaman – Diglipur is comparatively pristine; this is reflected in the pCO_2 and dissolved CH_4 concentrations of this area (~2 times lower than the other sites).

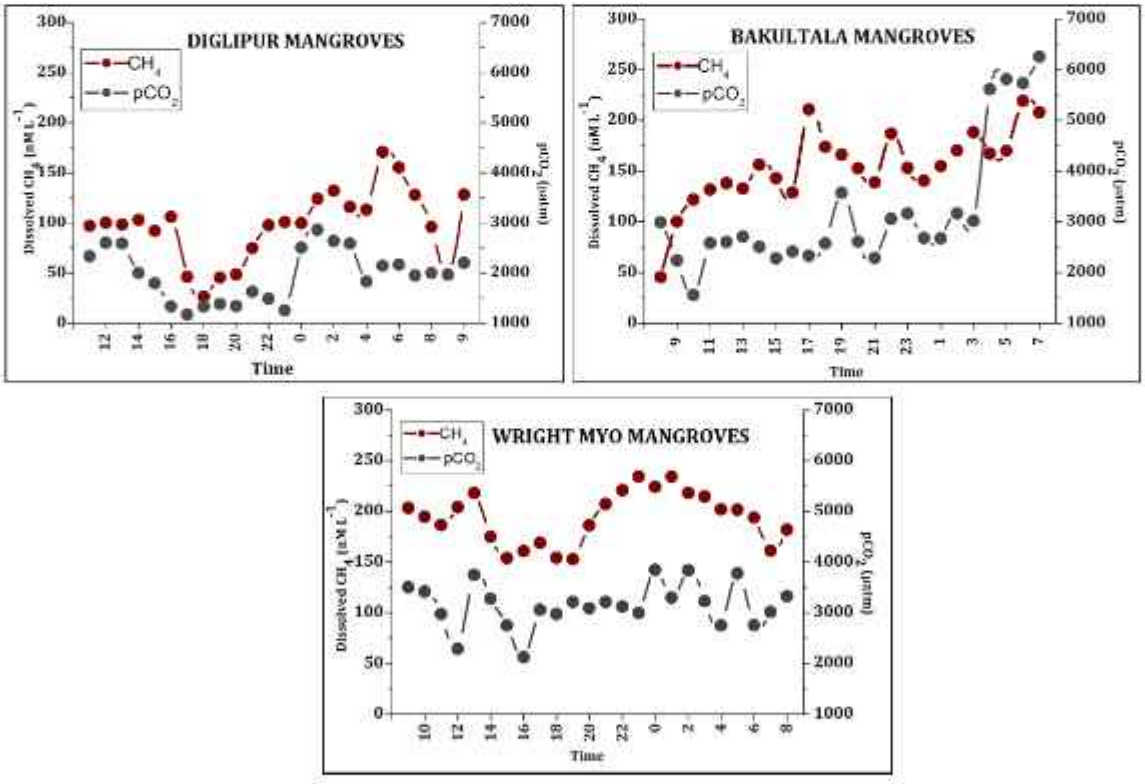


Fig. 14. Dissolved CH_4 and pCO_2 concentrations in Andaman mangrove surrounding waters

Potential Carbon Sequestration

Seagrass was divided into above ground biomass (AGB; leaves/sheaths) and below-ground biomass (BGB; roots/rhizomes). All material retained by the 3-mm mesh (excluding algae, mangrove leaves, Rhizophorapropagules) was collected. All seagrass and detrital samples were oven-dried (90°C, 24-48 h) and weighed. Samples were not treated with acid because there was little epiphyte contamination. Dry biomass of individual species revealed the clear dominance of BGB over AGB for most of the

species except *Cymodocea rotundata*. Above ground biomass varied between 21.6 and 47.44 g dry weight m^{-2} and below ground biomass between 37.064 and 63.6 g dry weight m^{-2}.The ratios (dry wt.) of below to above ground biomass ranged between 0.92 and 3.27 (Fig. 15). Total carbon content in the dry seagrass biomass was measured by an elemental analyzer and finally expressed in terms of carbon. The below ground biomass was found higher than its counterpart in all the species except *Cymodocea rotundata*. The below-ground biomass of primary producers with root systems can be buried for centuries to millennia centuries to millennia. This makes the seagrass ecosystem a potential CO_2 sink and can be effective in mitigating the negative impacts on the ocean ecosystems during ocean acidification events.

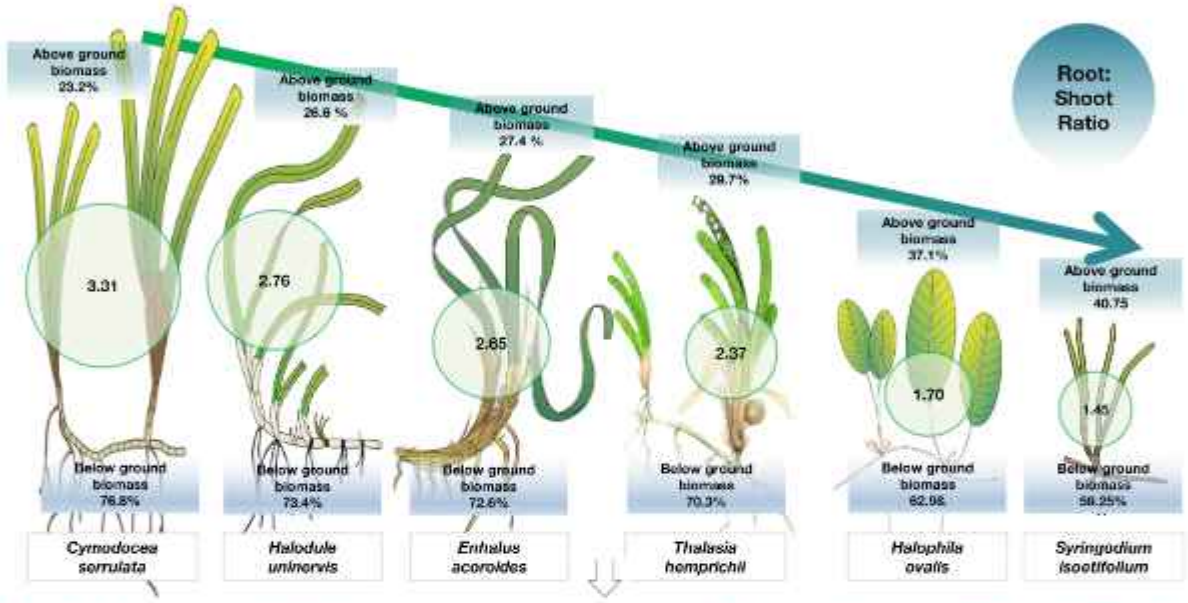


Fig. 15. Dry biomass of individual seagrass species along with their partitioning in AGB and BGB studied in Palk Bay and Chilika Lagoon

Organic carbon in the top 1 m of seagrass soil was measured and it varied from 2 to 0.44 % in *Cymodocea* sp. bed, whereas in *Syringodium isoetifolium* bed, it varied from 0.83 to 0.43%. Other than biomass, carbon can be present in an ecosystem in different forms (both inorganic and organic). A large fraction is present in dissolved condition and the rest remains as particulate form. The amount of carbon present in the seagrass covered area (85.5 sq. km) at Palk Bay (Average depth ~2m) in the form of dissolved inorganic carbon is calculated to be 4480 Mg C and as dissolved organic is 840 Mg C. Considering the total area (85.5 sq. km) covered with thick seagrass vegetation (>70%), live biomass were calculated to be 2524 Mg C in Palk Bay. Organic carbon in the top 1 m of seagrass soil was measured and it varied from 1.54 to 0.32 % in *Halophila* sp. Bed (Fig. 16), whereas in *Halodule* sp. bed, it varied from 1.54 to 0.45%.The amount of carbon present in the seagrass covered area (~80 sq. km) at Chilika Lagoon (Average depth ~1.5 m) in its various forms was calculated from the initial data (Fig. 17). The fraction of dissolved inorganic carbon is calculated to be 2652 Mg C and as dissolved organic carbon is 771 Mg C. Considering the total area (85.5 sq. km) covered with thick seagrass vegetation (>70%) live biomass was calculated to be 2375 Mg C in Chilika Lagoon

Efforts have been made to quantify the carbon standing stock at a single point in time as a measure of watershed condition in the seagrass ecosystem in Chilika Lagoon. Two major species of seagrass: 1. *Halophila ovalis*, 2. *Halodule uninervis* were studied for this purpose. Results indicate efficient transport and storage of sequestered carbon (through photosynthesis) from the above ground to below ground by the seagrass. Seagrass is also known for slowing down currents near the bottom, which increases the deposition of small sediment particles and decreases their erosion and re-suspension.

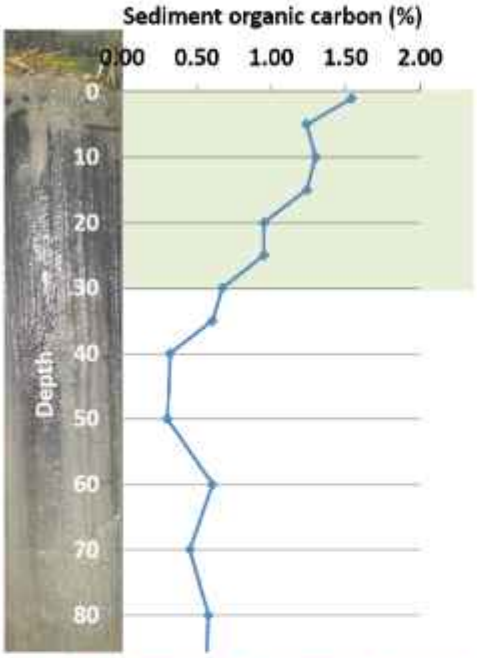


Fig. 16 : Variation of sediment organic carbon with depth at Halophila bed

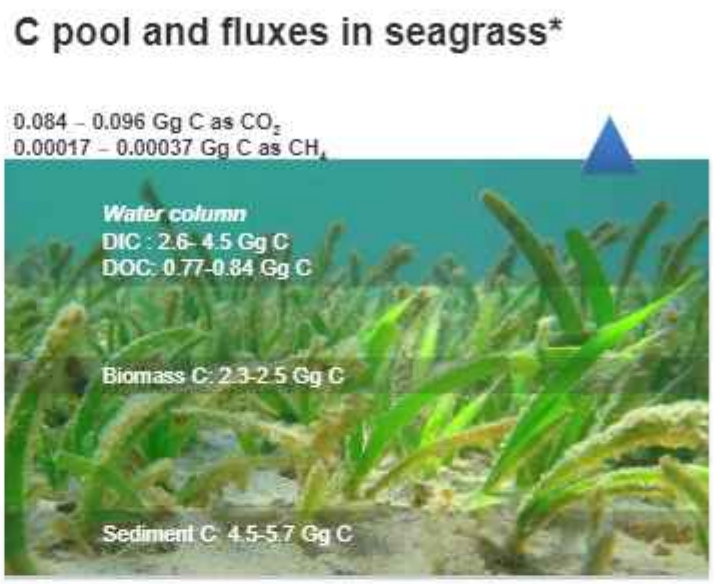


Fig. 17. Pools of Carbon in seagrass ecosystem

Seagrass roots also play an important part in stabilizing sediments and limiting disturbance caused by burrowing deposit-feeders. In spite of receiving lower amount of sediment and fresh water input, the sedimentation rate of the southern sector (with high abundance of seagrass) was found higher than that of the central sector of the Lagoon.

Carbon stored as Mangrove Above ground biomass and below ground biomass

Mangrove biomass were estimated in three locations (i.e. Bakultala, Diglipur and Write Mayo) of Andaman Island. The dominance of *Rhizophora* mangroves was observed in all the three locations followed by *Bruguiera* sp. and *Ceriops* sp. For the estimation of mangrove above ground biomass, trunk diameter D (in cm), total tree height H (in m) and wood specific gravity q (in g/cm^3) were measured and the following non-destructive allomatric equation given by Chave et al, (2005) was used.

$$\ln(AGB) = -1.786 + 2.47 \ln(D) + \ln(\rho)$$

For estimating below ground biomass, the following equation was used

$$BGB = 0.199^{*} \rho^{0.899*} D^{2.22}$$

The mean height of Andaman mangroves was >10 m and was higher than the mean height of the estuarine mangroves of Indian sub-continent. The above ground wet biomass of Andaman mangroves ranged between 36.71 to 19.25 kg m^{-2}, whereas the below ground biomass ranged 10.87 to 19.10 kg m^{-2} (Fig. 18). The water content of this mangrove biomass was found to be ~60% of the wet biomass.

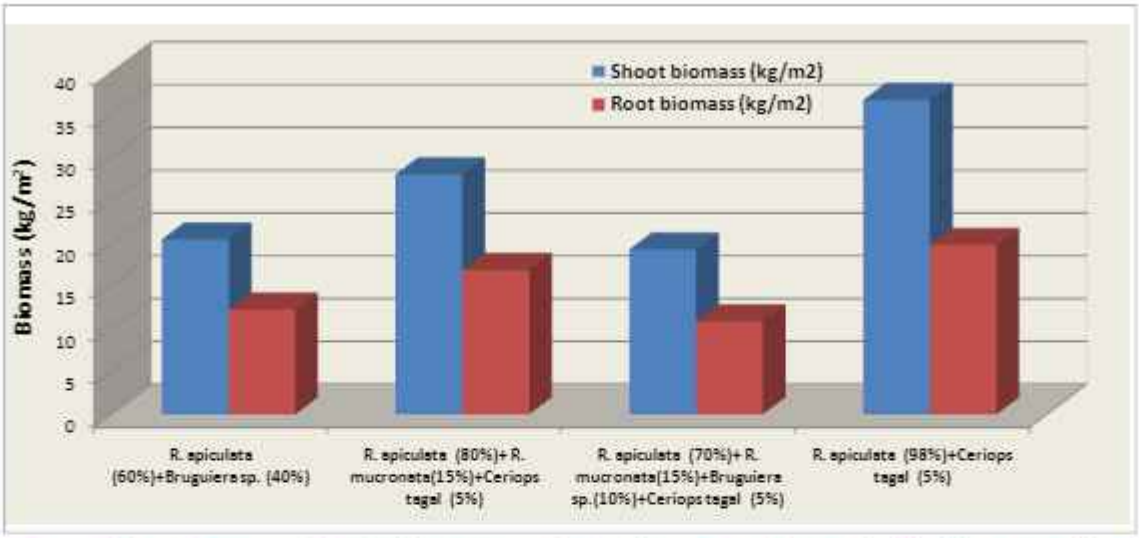


Fig. 18. Allometric approach (Statistical Allometric technique; Non-destructive), for the estimation of Mangroves biomass in Andaman Island, India.

Assuming ~43% of the dry biomass of the mangrove plant as elemental carbon the range of ABG and BGB was estimated to be 3.3- 6.3 g carbon m^{-2}, and 3.4 -1.9 g carbon m^{-2}, respectively. *Rhizophora mucronata* showed the highest AGB to BGB ratio of 1.91, followed by *Rhizophora apiculata*, *Bruguiera* sp. and *Ceriops tagal*. The mean AGB (44.90 t C ha) value calculated in the present study from the *Rhizophora* sp. dominated ecosystem, was well in association with the AGB (49.54 t C ha) reported from the Sundarban Mangrove forest dominated by *Avicennia* sp. These results indicate higher efficiency of mangrove to store photosynthetically fixed carbon in the above ground compared to below ground.

A Remote Sensing technique to estimate mangrove Biomass in Pichavaram - Coleroon Estuarine Mangrove ecosystem was undertaken and the results were presented in the Fig. 19. Carbon sequestration Potential of these mangroves was also estimated by using *NDVI Proxy Approach (*Fig. 20).

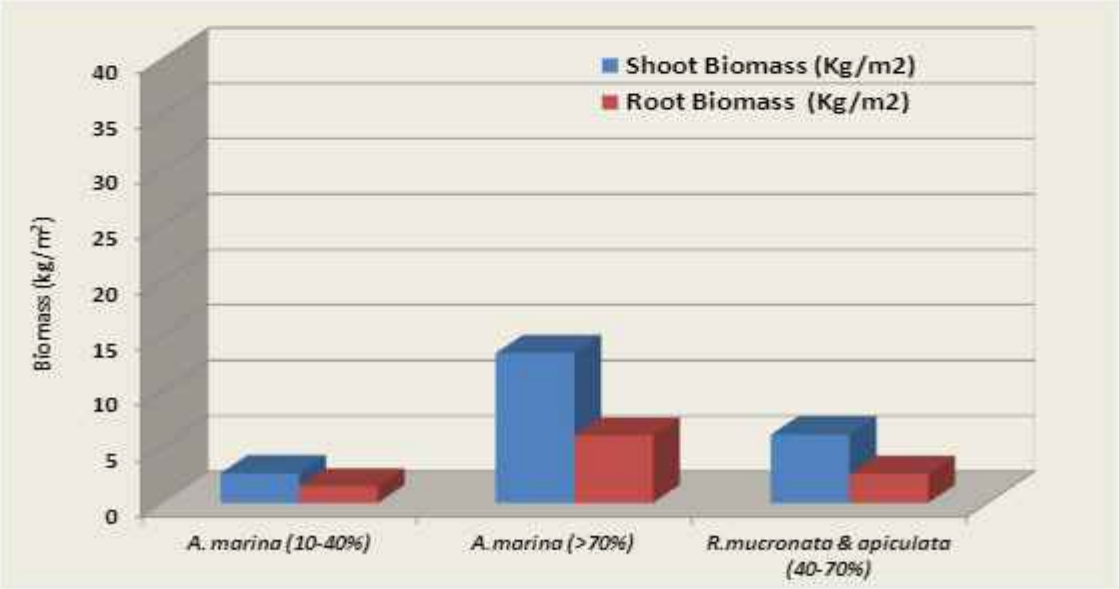


Fig. 19. Estimated Biomass in Pichavaram - Coleroon Estuarine Mangrove species through Remote Sensing approach

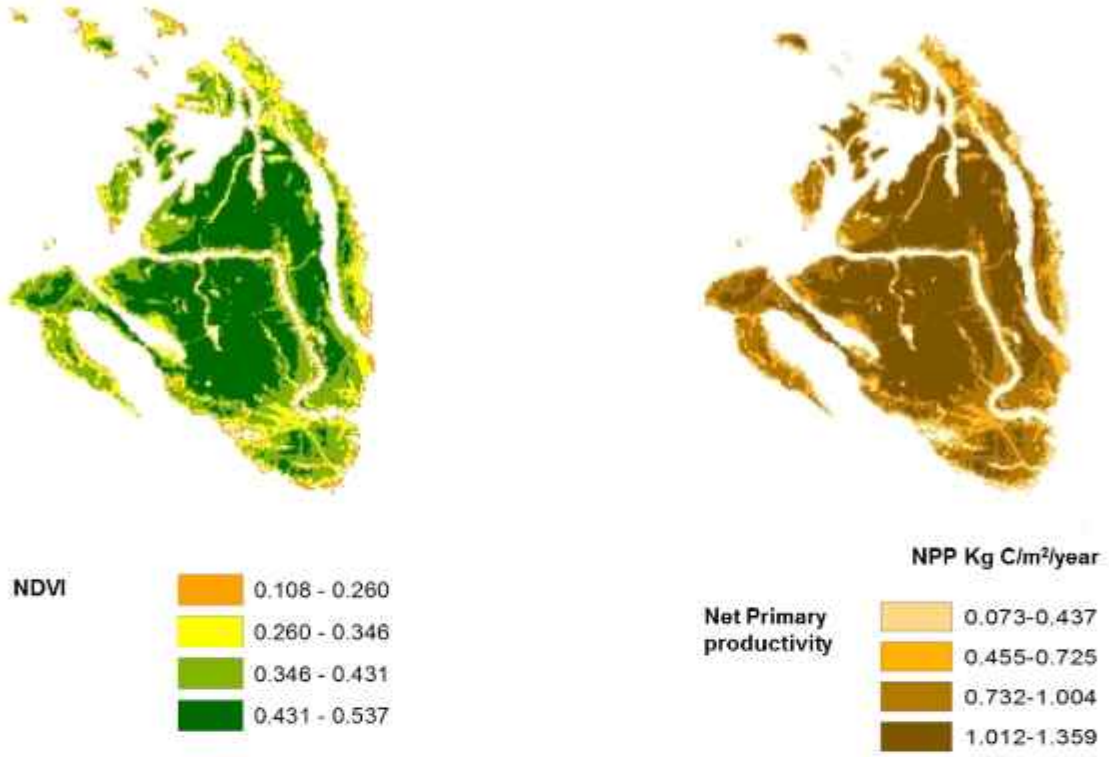


Fig. 20. Estimation of Carbon sequestration Potential of Pichavaram mangroves NDVI Proxy Approach

Role of seagrass in Shoreline stabilization: Concept of Bioshield

Seagrass beds are also observed to reduce the turbidity of coastal waters by reducing the quantity of sediment suspended in the water. By slowing down the currents near the bottom, the deposition of fine sediment particles is increased. The rate of mobilization by waves and current is low in seagrass dominated sediments thus, reducing the erosion of the coastline. In addition, the burrowing activities of various deposit feeders are also limited by the seagrass roots this stabilizing the sediments. In Chilika effect of the seagrass in reducing the suspended particulate matter load was significant (Fig. 21). The variations were also distinct in Palk Bay, though it worthy to note that these results are from the monsoon (wet period), a stressed period for seagrass.

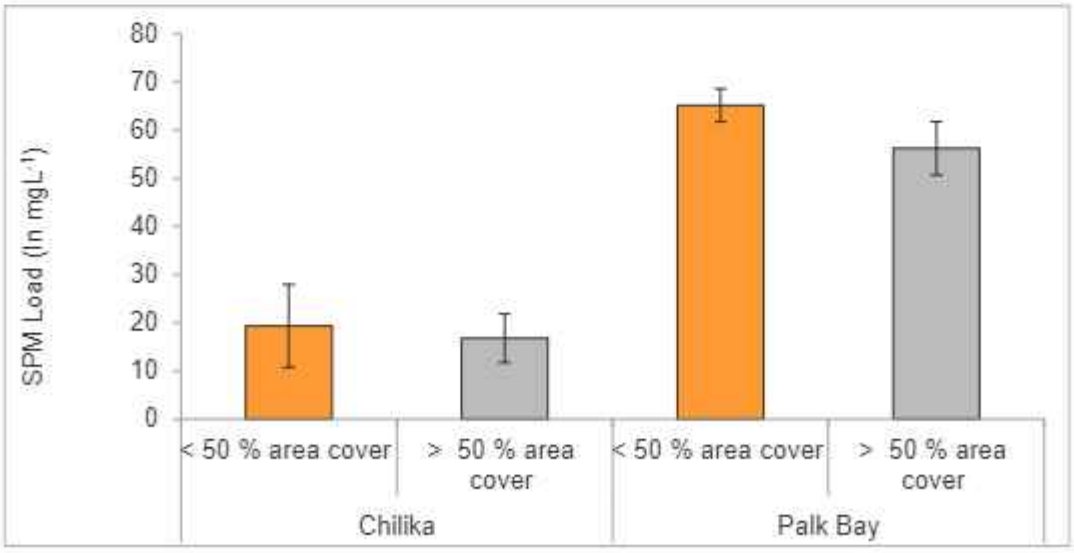


Fig. 21. Variation of Suspended particulate matters in Chilika and Palk Bay (The bar represents the average spm load of locations with seagrass cover more than 50 % and less than 50%. The error bar represents the variation in the values of SPM load at different locations)

Seagrass meadows are sensitive integrators of sediment loading from human activities, and also provide higher value ecosystem service like sediment stabilization. Direct effect of dampening of waves and currents by seagrass canopies leads to increased sediment deposition and decreased re-suspension. Seagrass canopies can directly intercept suspended sediment particles and acts as an efficient filter of suspended particles. The collision of suspended particles, epiphytic layers and exopolymeric secretion from epiphytes on the seagrass leaves triggers the filtering and retaining capacity of particles out of the water column.

The higher ratio of canopy height to water column height cause some alteration in the vertical water flow profile and thereby the trapping efficiency. Excess sediment loads to the coastal waters is one among the important anthropogenic cause of sea grass decline (Short et al. 2001). The suspended sediment concentration in Chilika seagrass zone varies from 8.8 - 29.8 mg l^{-1}, which is lower compared to the highly turbid northern and central part of the lagoon. In the Palk Bay seagrass region, the suspended sediment concentration varies from 47.2 - 69.6 mg l^{-1}.

Apart from carbon sequestration, the seagrass act as a major sediment stabilizing agent, though, root rhizome network and the leaf canopy. It reduces the re-suspension of the sediment by currents and waves, as a result the sediments vegetated by seagrass are less likely to be mobilized by waves and currents, thus reducing the coastal erosion (Fig. 22). This was distinctly observed in Palk Bay, where the waters with seagrass cover <50 % showed relatively higher suspended particulate matter load compared to the thick seagrass cover (~80-100%).

Sedimentation rate is an important tool for clarifying the origin of material transport, mixing and deposition in aquatic systems. Artificial and natural radioisotopes like ^{210}Pb and ^{137}Cs can be used as tracers to provide useful information to identify various processes and to track the anthropogenic impact on aquatic systems. Sedimentation rate plays a key role in the rate of accumulation of C and its burial rate in seagrass sediments, and thereby contribute towards reduction of global warming. Increased sedimentation was observed by Das and Jena (2008) in the Chilika Lagoon (1.8, 1.1 and 0.85 cm yr^{-1} in the northern, southern and central sectors, respectively) compared to the estimated rate of 0.40, 0.25 and 0.66 cm yr^{-1}.

The seagrass distribution was dominantly present in the southern sector of the Chilika lake. Similarly, higher sedimentation rates were also observed in the sediment core taken from the southern sector (0.6-0.7 cm yr^{-1}), compared to the sediment core taken from the central sector (~0.4 cm yr^{-1}). In Palk Bay, the rate of sedimentation was greater during the onset of the southwest monsoon season and the annual sediment load is 58.8×10^6 m^3, which cause a sea depth reduction of one cm yr^{-1}.

Thus, there exist a close intricate relationship between societies and nature, and seagrass ecosystem is no exception. Seagrass ecosystems are observed to play an important role in ecological functions and ecosystem services such as food web dynamics, seascape interactions and ecological resilience potential. Irrespective of the location, i.e., tropical or temperate, they have shown to stabilize the sea floor, sequester carbon and create conducive conditions for fisheries and other coastal/ marine habitats.

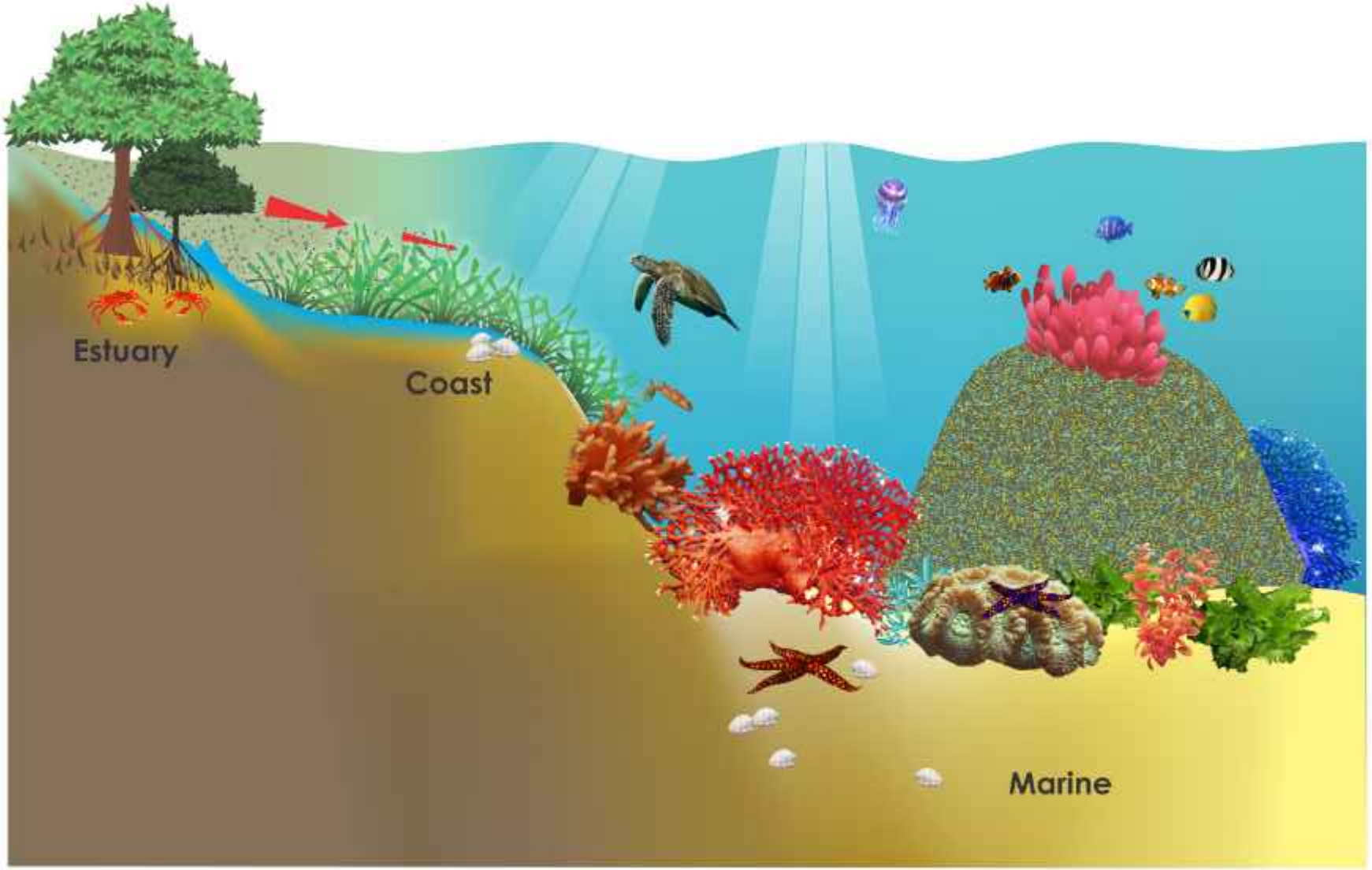


Fig. 22. Conceptual diagram depicting the role of seagrass ecosystem on sediment stabilization

A feasibility assessment of potential offshore wind energy resources has been conducted by the National Centre for Sustainable Coastal Management [NCSCM], Ministry of Environment and Forests. In order to assess the potential, a Weather Research Forecasting (WRF) model has been configured to the coastal regions of mainland and islands (Andaman & Nicobar and Lakshadweep) of the India from the coast up to the EEZ for simulation of offshore wind potentials.

POTENTIALS OF OFFSHORE WIND ENERGY RESOURCES FOR INDIA

Offshore Wind Energy Potentials

A feasibility assessment of potential offshore wind energy resources has been conducted by the National Centre for Sustainable Coastal Management [NCSCM], Ministry of Environment and Forests. In order to assess the potential, a Weather Research Forecasting (WRF) model has been configured to the coastal regions of mainland and islands (Andaman & Nicobar and Lakshadweep) of the India from the coast up to the EEZ for simulation of offshore wind potentials. The model simulations have been conducted for all months in the Year 2012 and offshore wind energy potentials at different water depths in the Indian EEZ were assessed. Diurnal and monthly averaged wind speeds were extracted for different potential locations from the model results and wind power density has been estimated. Further, wind energy blocks have been developed using eight wind speed classifications. The gross offshore electrical power and energy was estimated from the eight offshore wind energy blocks.

The wind energy blocks have been developed using eight different categories of wind speed as classified by India's Central Electricity Regulatory Commission [CERC]. The developed wind energy blocks are used to estimate the gross electrical power and potential energy per hour or month for the period of 2012. Critical analysis of gross electrical power and potential energy per hour or month has been carried out for different sediment cells by considering the concept of sediment cell delineation. The sediment cell delineation explains changes in the coastal geomorphological, sediment moment, littoral drift, man-made littoral barriers, and coastal alignments. The sediment cell delineation concept is very useful to establish offshore wind forms and estimation of available gross electrical power and energy in the potential areas.

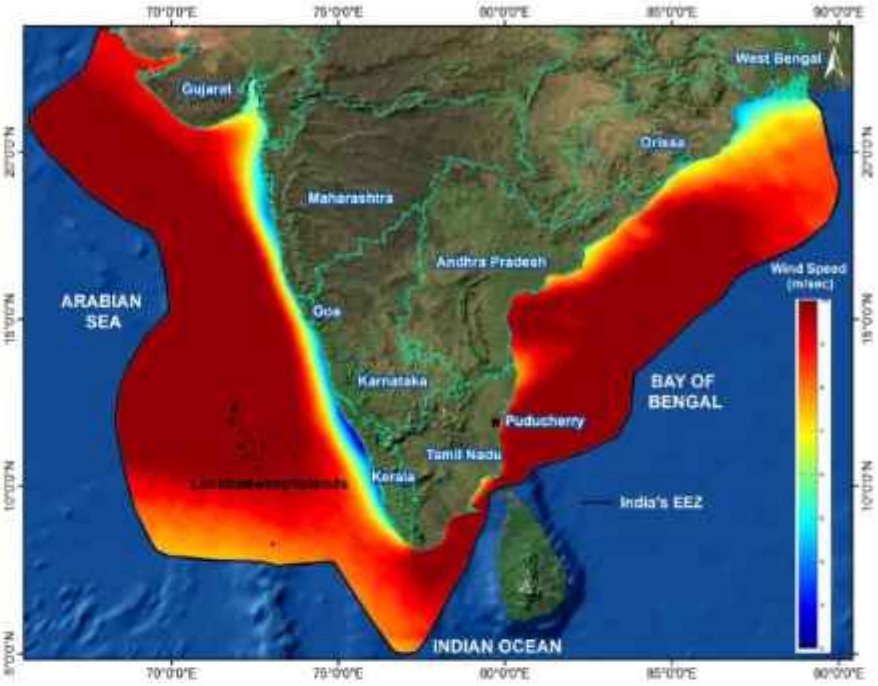


Fig. 1. Wind distribution over the Indian EEZ at 50-m height during July 2012

The variation in offshore electrical power and wind energy at different water depths such as 0–30 m, 30–50 m, 50–100 m, 100–200 m, and 30–200 m was estimated. The quantity of electrical power is observed to be 5434 GW on the west coast as compared to 3274 GW on the east coast of India. The model results revealed that the states such as Tamil Nadu, Gujarat, and Andhra Pradesh (South) are high potential sites for offshore wind energy by considering a sustained wind speed of >7.5 m/sec. These three potential sites – Gujarat, Tamil Nadu, and South Andhra Pradesh, were found to have wind speeds>7.5 m/sec for 9, 10, and 9 month period respectively out of 12 months for the year 2012. South and west coastal regions of India had high wind speed distribution and are reflected in the electric power and energy distribution. The maximum gross electrical power has been predicted at about **1,510 GW** during summer monsoon (southwest) season and it varied between 250 and 800 GW in other seasons along the mainland coast. The total annual gross offshore electrical power is about **8,710 GW** along mainland coast for the year 2012.

Although potentials exist along the entire country's coastline, care was taken to consider and exclude designated Coastal and Marine Protected Areas, Ecologically Sensitive Areas, navigational and shipping routes, potential fishing areas and bird migration routes, where offshore installations are not recommended. Hence of the total potential of 8710 GW, about 5442 GW at depths between 30-200m of potential power could be harnessed from offshore wind energy (Figs. 1 through 4). Similarly, about 598 GW could be harnessed from the depths of 30-200m from the Andaman and Nicobar Islands.

Table 1. Total annual offshore wind electrical power (GW) for the Mainland and Islands of India (from coast up to 200 NM)

	Mainland	Andaman & Nicobar Islands	Lakshadweep Islands
Electrical Power (@30-200m depth) in GW	5442	598	54

Bird Migratory Routes

While it is essential to identify strategic locations for offshore wind energy potentials, care has been taken to identify sensitive offshore locations where bird migration/ conservation interests and wind energy development may conflict. The availability of data and knowledge (or lack of it) on these environmental issues needs to be established. India is one of the largest seabird populations in Asia and many locations hold internationally important bird populations. In addition some offshore regions along the Indian coast could probably overlap the migratory routes of various bird species. There was thus a need to identify suitable locations where bird migration and wind energy development may become an important issue for consideration. The bird migratory routes along the coast of India are shown in Fig. 5.

Marine Protected Areas (MPA)

India initiated action through the State governments to create a network of MPAs under Wildlife (Protection) Act, 1972. A vast majority of coral reefs and mangroves are part of the MPAs in the country. By the definition of IUCN in Indian's context, the Protected Areas (PAs) in marine environment in India are primarily classified into three categories, which are as follows:

Category I: This category of MPA covers mangroves, coral reefs, creeks, algal beds, estuaries, lagoons, intertidal areas, and seawater.

Category II: This category covers the island PAs under the substantial part in intertidal zone and a small part of terrestrial ecosystems in Andaman and Nicobar and Lakshadweep Islands.

Category III: This category covers the PAs in coast, terrestrial ecosystems, and intertidal areas partially influenced by marine environment or island; inland wetlands in coastal zone with opening in sea or influenced by coastal environment; sandy beach and mudflats (Singh, 2003). These PAs are not considered as MPAs.

MPAs in India comprise national parks and wildlife sanctuaries, which belong to categories I and II. They cover coastal wetlands, mangroves, coral reefs, and lagoons. The total area of 31 MPAs (33 sanctuaries and national parks) in India is 6, 04,645.2 ha (Source: Ministry of Environment and Forests). The east coast and Andaman Islands have a large number of MPAs, whereas the mainland provinces have poor representation. West Bengal, Orissa, and Andhra Pradesh states have major shares of MPAs while areas are yet to be identified in Karnataka, Kerala, and Lakshadweep Islands for declaring as sanctuary or national park in the marine environment. The average size of India's MPA is 20,214 ha, although the majority of them are less than 10,000 ha in size. There are 31 MPAs (Fig. 6) in the country and only 11 marine parks and sanctuaries have an area of more than 10,000 ha.

Major Shipping Routes

Shipping routes could be affected due to the installation of offshore wind turbines. Wind farm design parameters are very essential to reduce the risk of rotor blade collision with recreational craft which is a main cause for concern. The navigation impacts of offshore wind farms are assessed on the following parameters:

- The number, size and type of local vessels
- The number, size and type of national and international vessels
- Annual events that are not covered in a short term monitoring
- Wave height and sea state conditions
- Seasonal variations including weather conditions
- A range of possible incidences

The major ports and harbours are indicated in Fig. 7. Based on the sediment cell demarcation, the major ports and harbours are identified in PC-7, 8, 10, 13, 16, 20, 22, and 26. The estimation of offshore electrical power and potential per year should avoid the effective area of the port and harbour locations and their navigation routs. This study helps to know the available gross electrical power and potential per year in the potential sites.

Coastal and Marine Ecosystems

Mapping of ecologically sensitive areas and MPAs has been undertaken in this study that would guide in the establishment of offshore wind energy farms at locations far from such ESAs and MPAs. Fig. s 8 and 9 are given as examples below. In summary, preliminary results are promising and provide sufficient confidence to conduct further analysis on offshore wind integration, effective offshore wind potential development, and policy making. The development of wind energy blocks and constructive offshore wind farms using advanced offshore wind energy technology would ensure that large, cheap, and clean resource available in India is exploited as quickly and cost-effectively as possible.

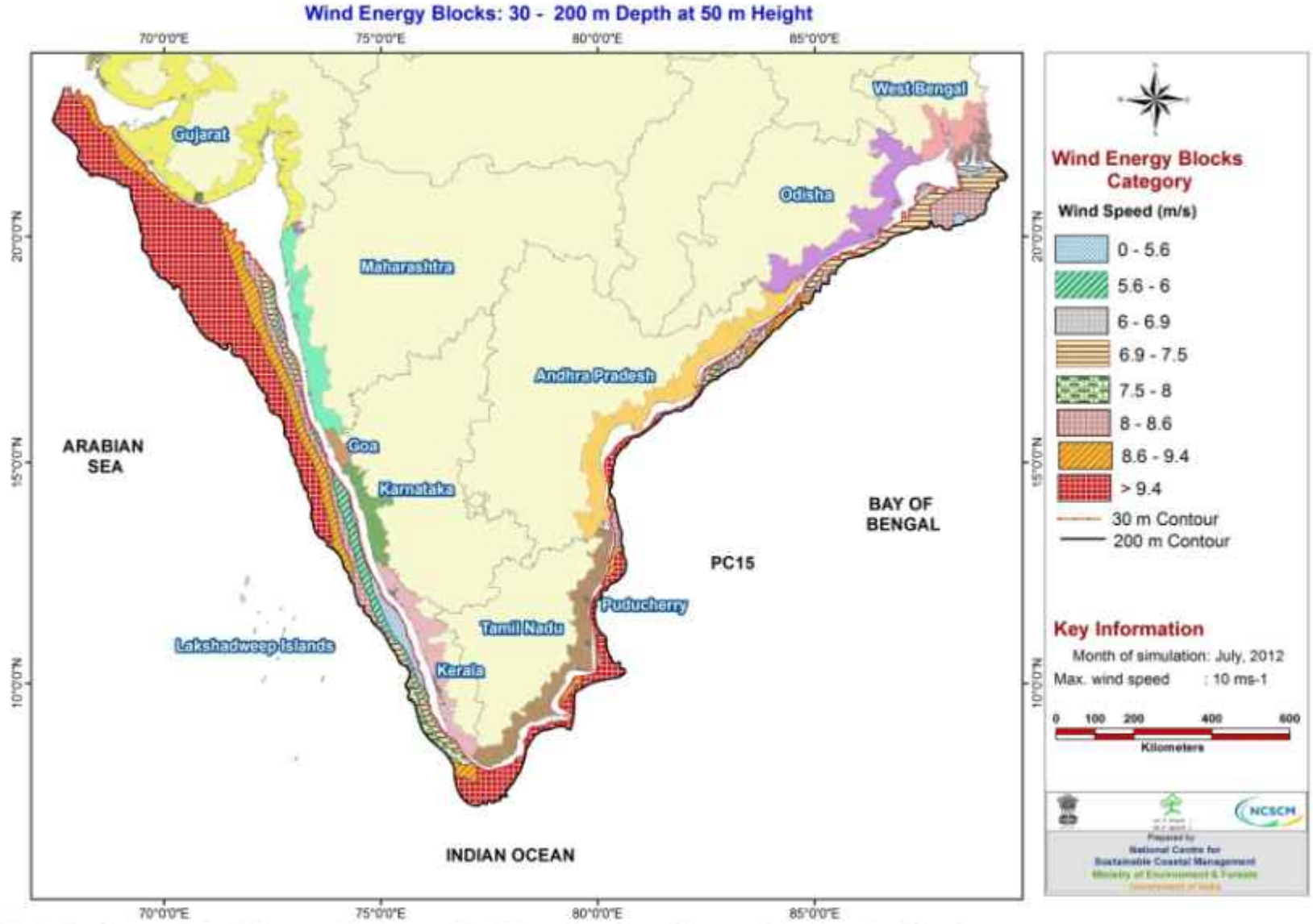


Fig. 2. Development of wind energy blocks from 30 to 200 m depth along the coastal regions of mainland.

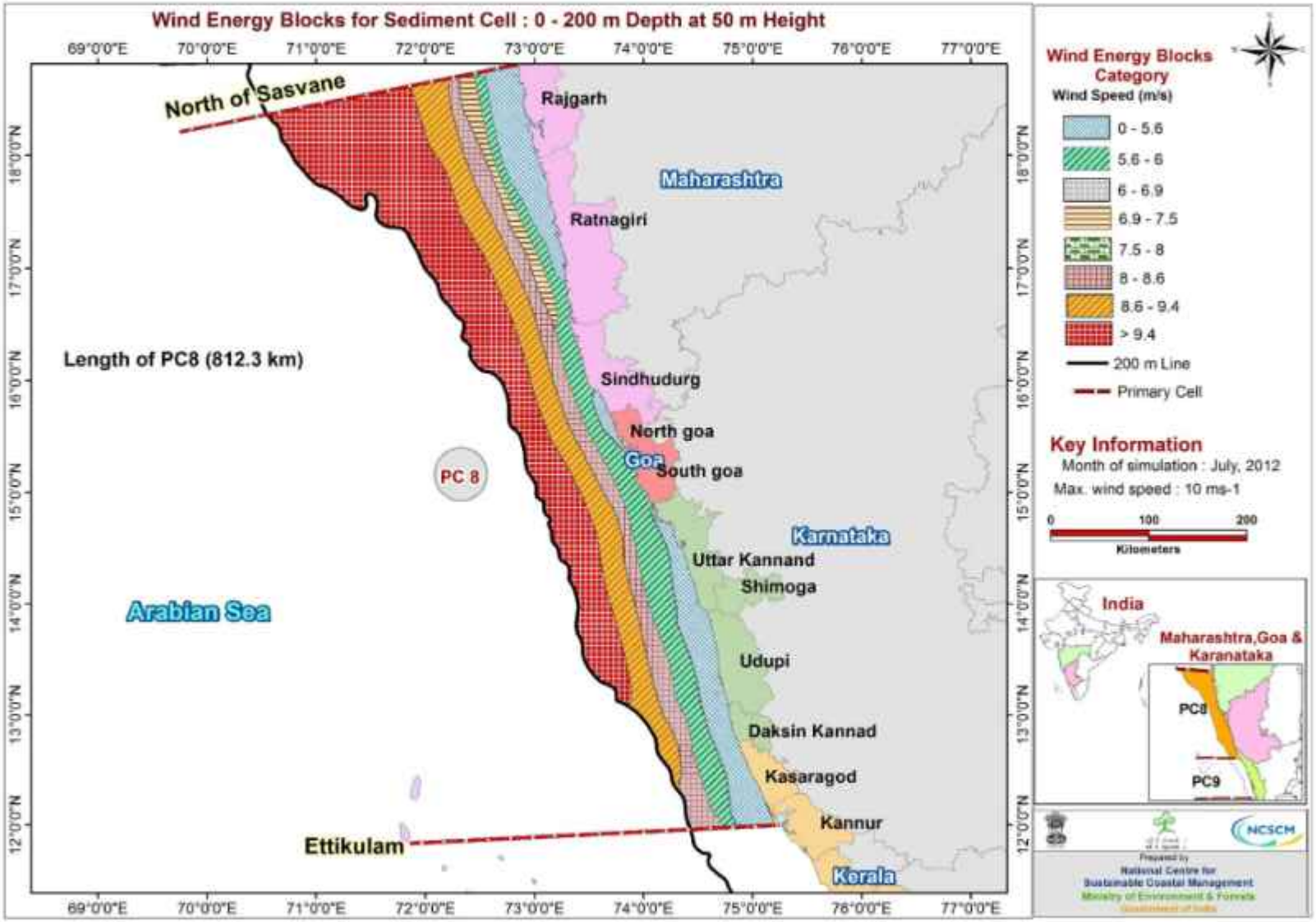


Fig. 3. Development of offshore wind energy blocks in Primary Cell 8 along the West Coast of India for July 2012

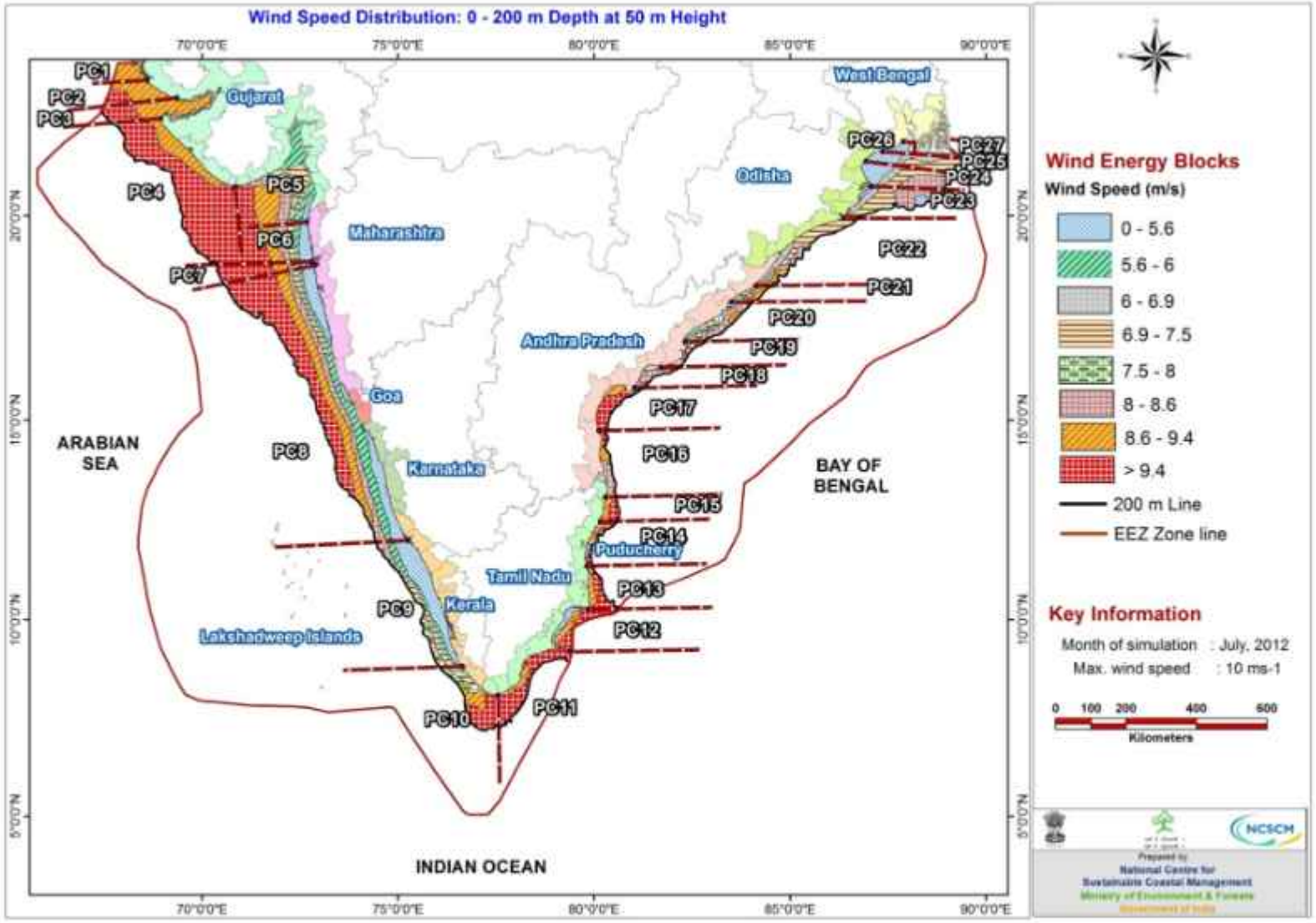


Fig. 4. Development of offshore wind energy blocks from 0 to 200 m water depth using eight categories of wind speed at 50m height in Primary Cells1 through 27 along the west and east coasts of India for the year 2012.

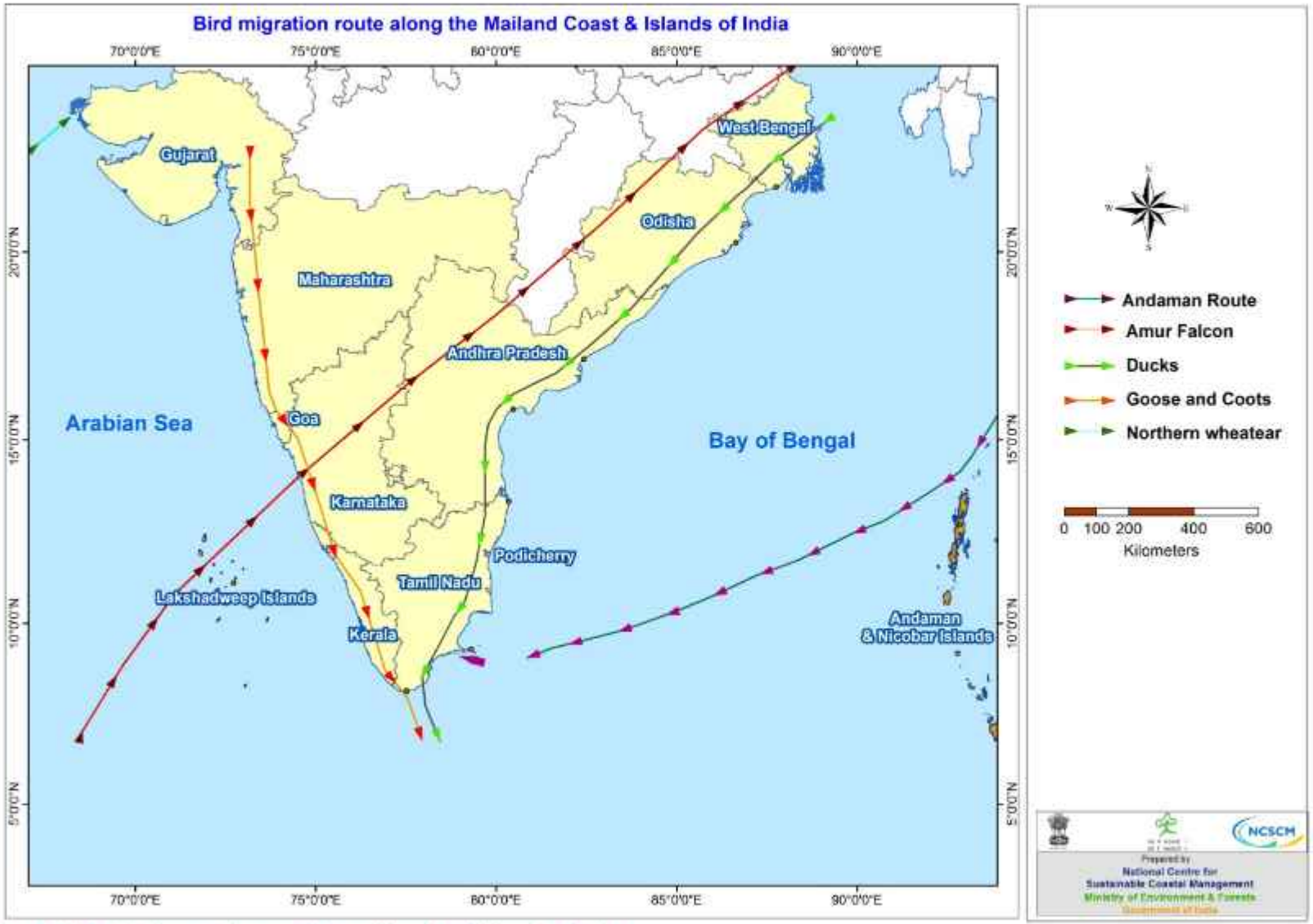


Fig. 5. Bird migratory routes over the mainland and Islands of India

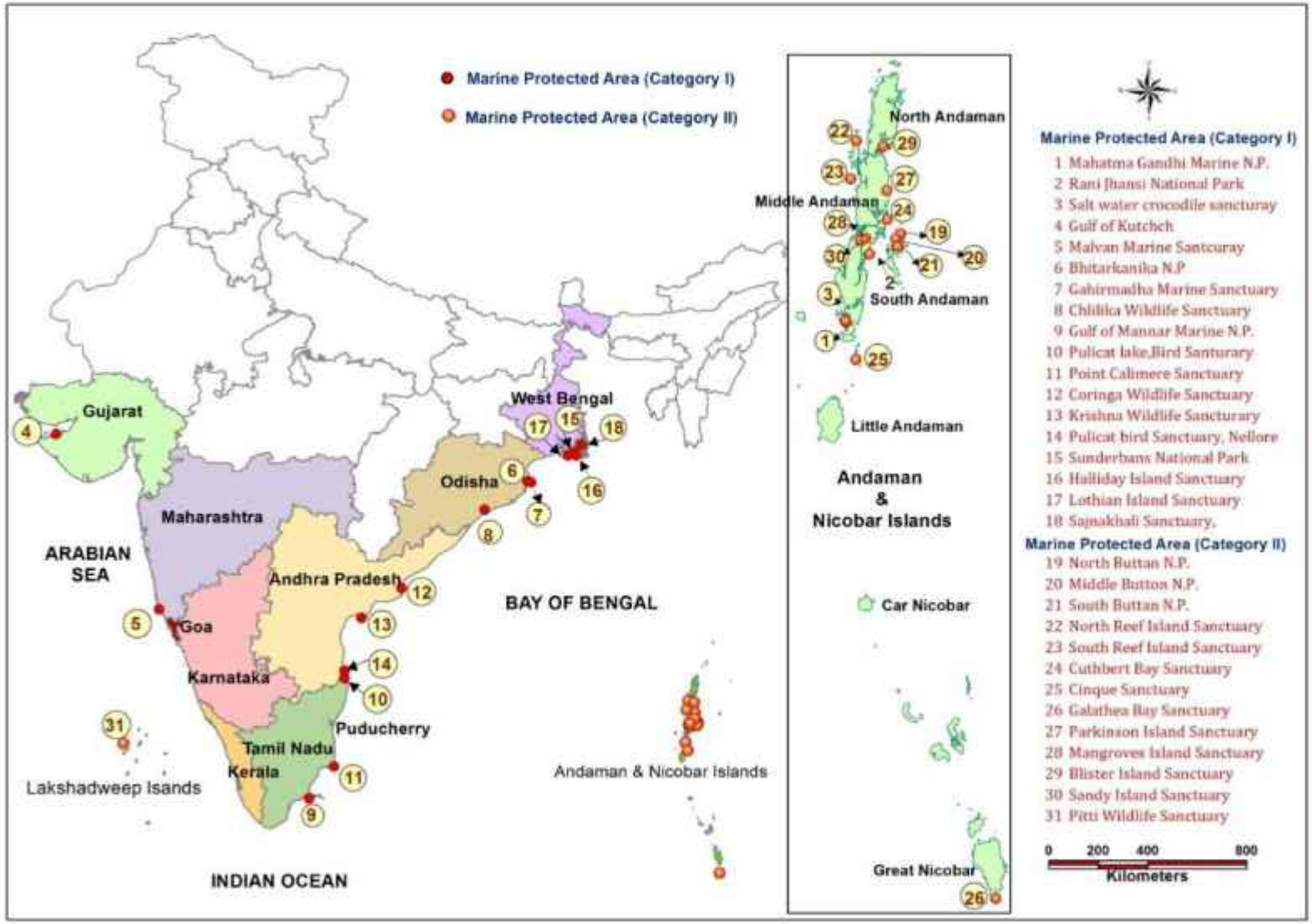


Fig. 6. Locations of Marine Protected Areas in India

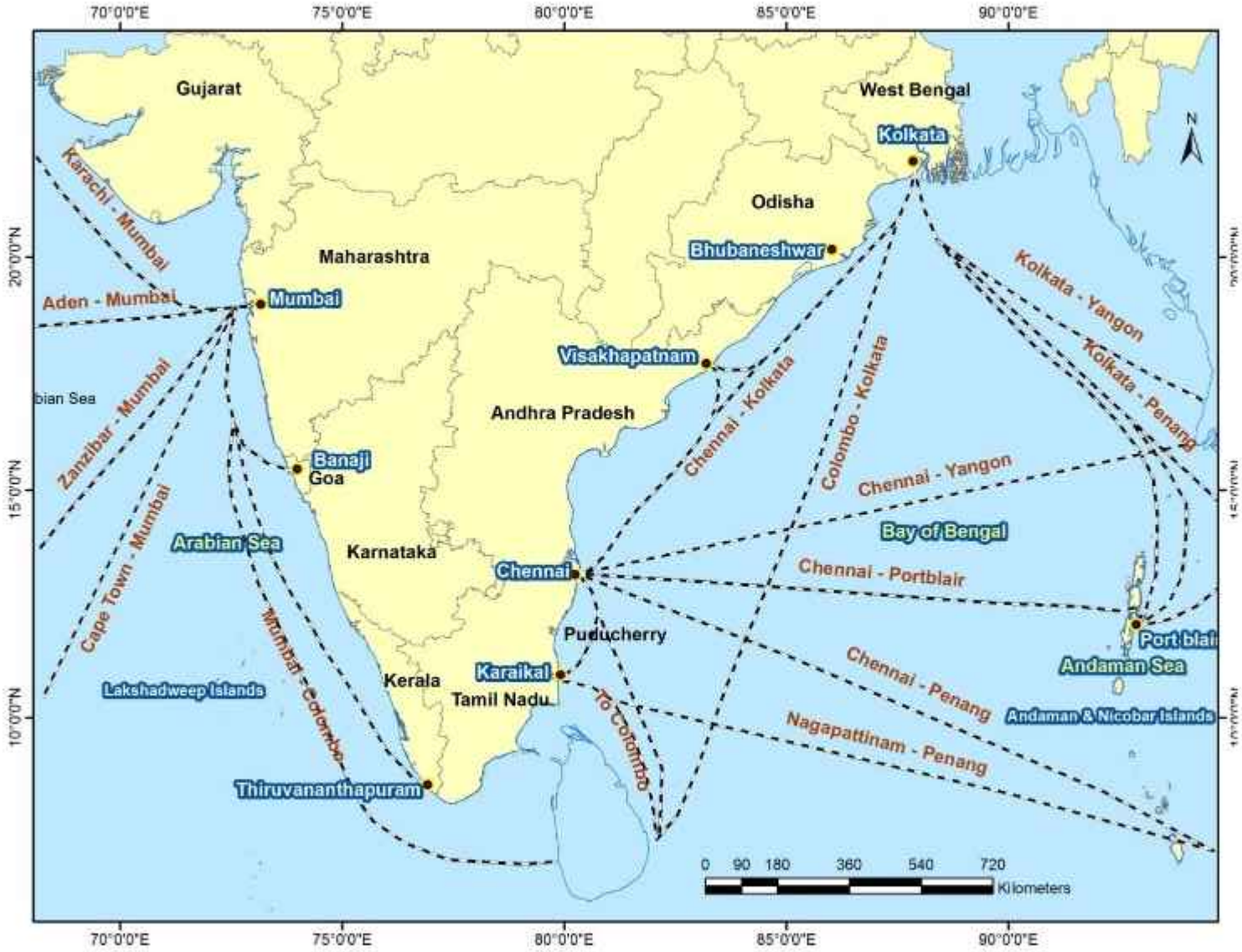


Fig. 7. Navigation routes along the mainland and islands of Indian Coast (source: maps of India)

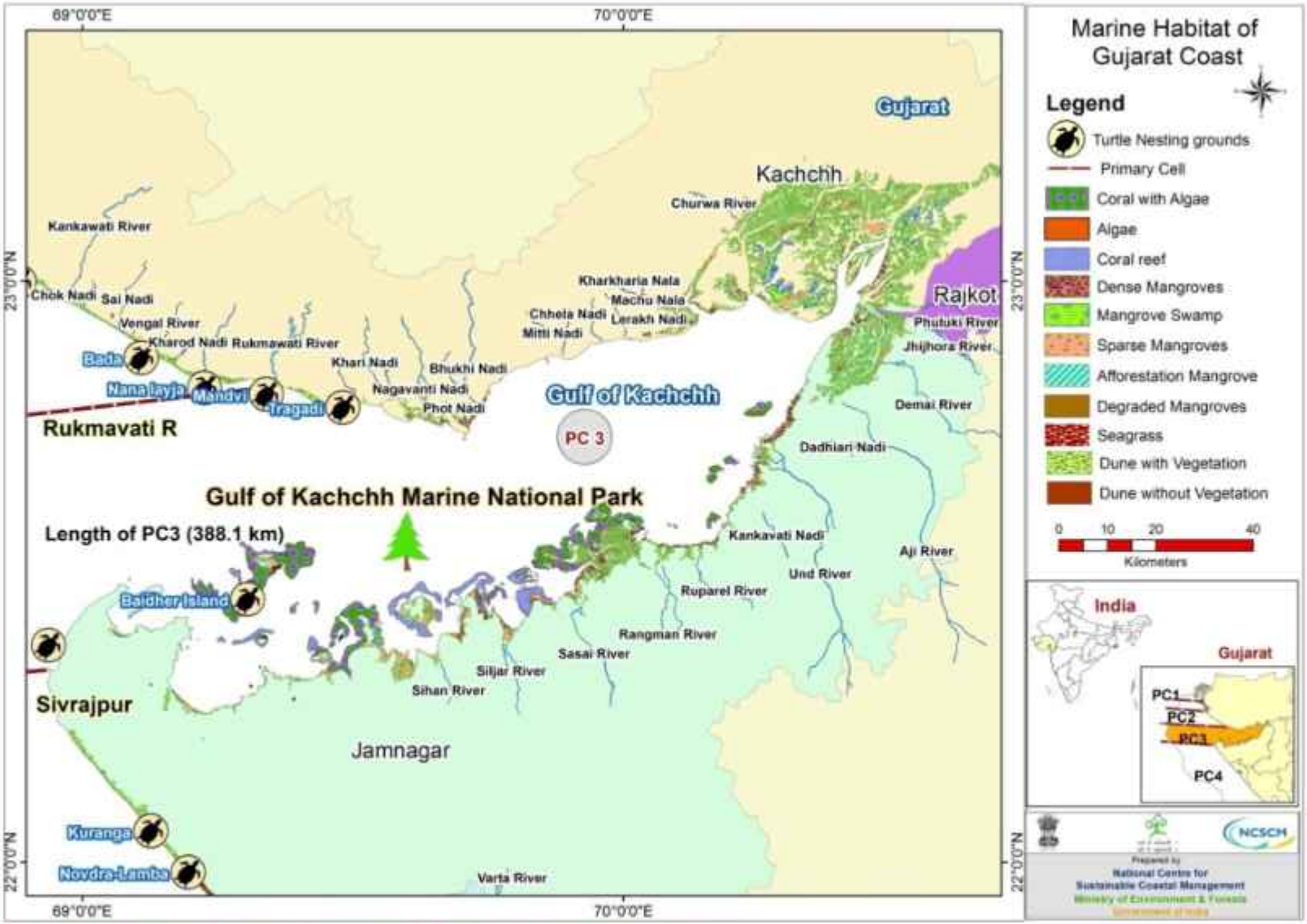


Fig. 8. Marine habitats in India: An example from the Gulf of Kachchh coast

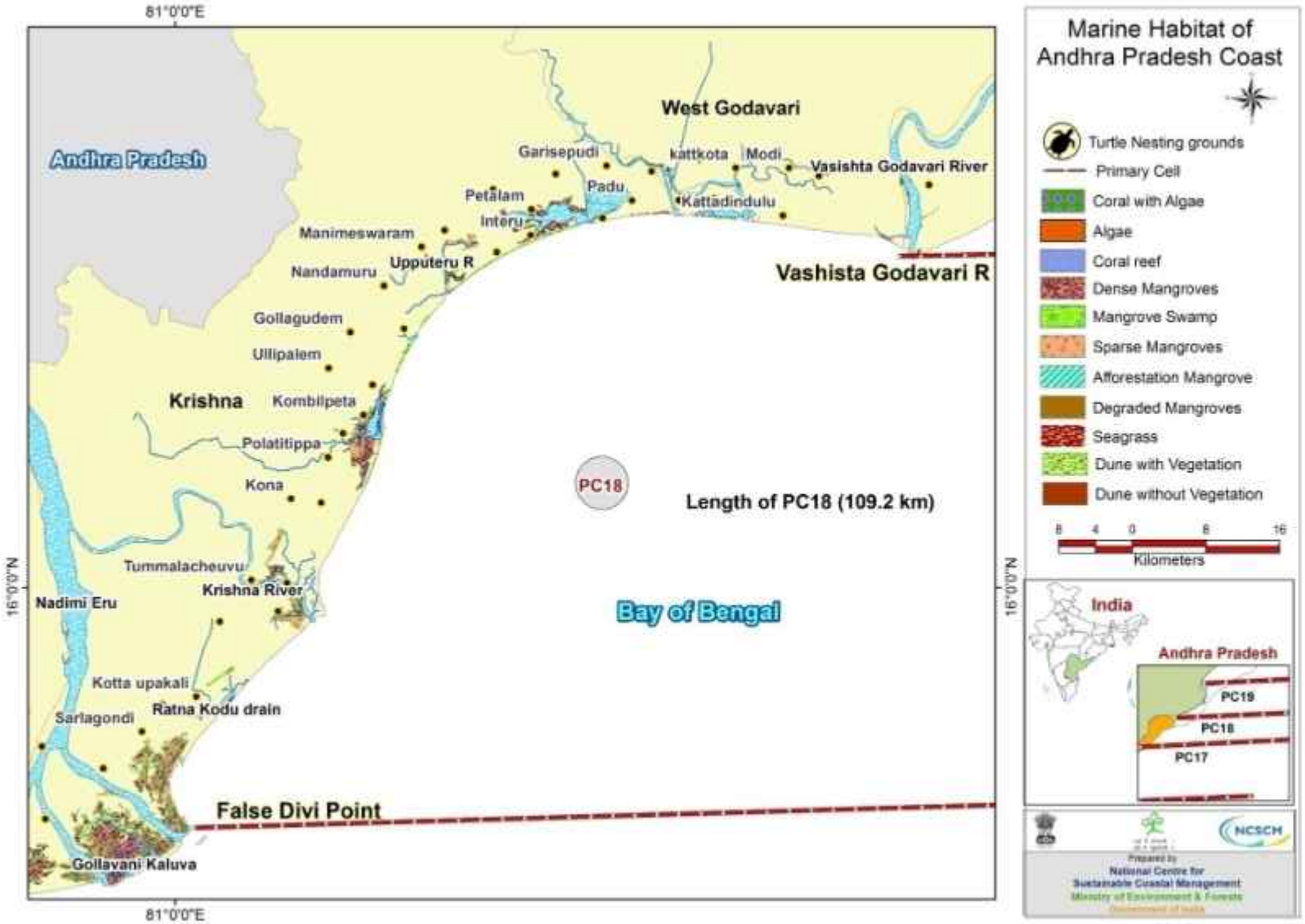


Fig. 9. Marine habitats in India: An example from the Andhra Pradesh coast

The gross offshore electrical power and energy is estimated from the developed offshorewindenergyblocksalongAndaman & Nicobar Islands during the year 2012.

Potentials of Offshore Wind Energy Resource for Andaman & Nicobar Islands [POWER]

Wind power generation along the coast has presumed high importance with demand for large energy requirements coming from the rapid development of coastal areas. In the Andaman & Nicobar Islands of India, the wind power generation is very much essential to reduce the power interruption and expenditure for fuels in future. It is expected that an important part of the future expansion of wind energy utilization will come from offshore sites than onshore due to the high elevated terrains over the A & N Islands.

The Weather Research Forecasting (WRF) model has been configured to the coastal regions of Andaman & Nicobar Islands by covering the EEZ for the simulation study of offshore wind potential. The model simulations have been conducted for the year 2012 and offshore wind energy potentials in the A & N Islands' EEZ were assessed. Diurnal and monthly averaged wind speeds are extracted for different potential locations from the model results and wind power density is estimated. Further, the wind energy blocks have been developed using wind speed classifications. The gross offshore electrical power and energy is estimated from the developed offshore wind energy blocks along Andaman & Nicobar Islands during the year 2012.

Gross offshore electrical power and energy is estimated from the developed offshore wind energy blocks along Andaman & Nicobar Islands during the year 2012. Model simulations indicated that the following Islands have high potential sites for offshore wind energy by considering wind speed more than 7.5 m/sec during 2012.

- Curlew Island
- Stewart Island
- Spike Island
- Flat Bay Island
- Rutland Island
- Viper Island
- Neil Island and
- Havelock Island

As of wind speeds recorded during the year 2012, Rutland Island is estimated to have maximum wind speed of 8.24 m s^{-1} and would be ideally suited to locate an onshore or offshore wind farm.

The maximum gross electrical power for the entire A&N Islands including its EEZ has been estimated to be ~137 GW during the summer monsoon and varied from 13 to 70 GW in other seasons of year 2012. The annual gross offshore electrical power is about 890 GW. Considering MPAs, ESAs and shipping and navigation routes, the maximum harnessable electrical power has been estimated to be 598GW at depths of 30–200m. Any future development in material technology might lead to extraction of more electrical power at lower wind speeds along the A&N islands. Comparison of wind power potential estimates between the mainland coast and the Islands is given in Table 22. This study helps the investors and industries assess the benefits of commercial viability from sustainable offshore wind energy.

Table 22. Comparison of wind power potentials

	Mainland Coast for 2012 (by NCSCM)	Island Coast for 2012 (by NCSCM)
Wind energy potential	• 5,442 GW (offshore at 50-m height within the depth 30–200m)	• 598 GW(offshore at 50-m height within the depth 30–200m))

Preliminary results are promising and provide sufficient confidence to conduct further analysis on wind integration, effective onshore & offshore wind potential development, for policy making for investments. The development of wind energy blocks and constructive onshore/ offshore wind farms using advanced wind energy technology would ensure that the large, cheap, and clean resource would be available in India and exploited as efficiently and cost-effectively as possible.

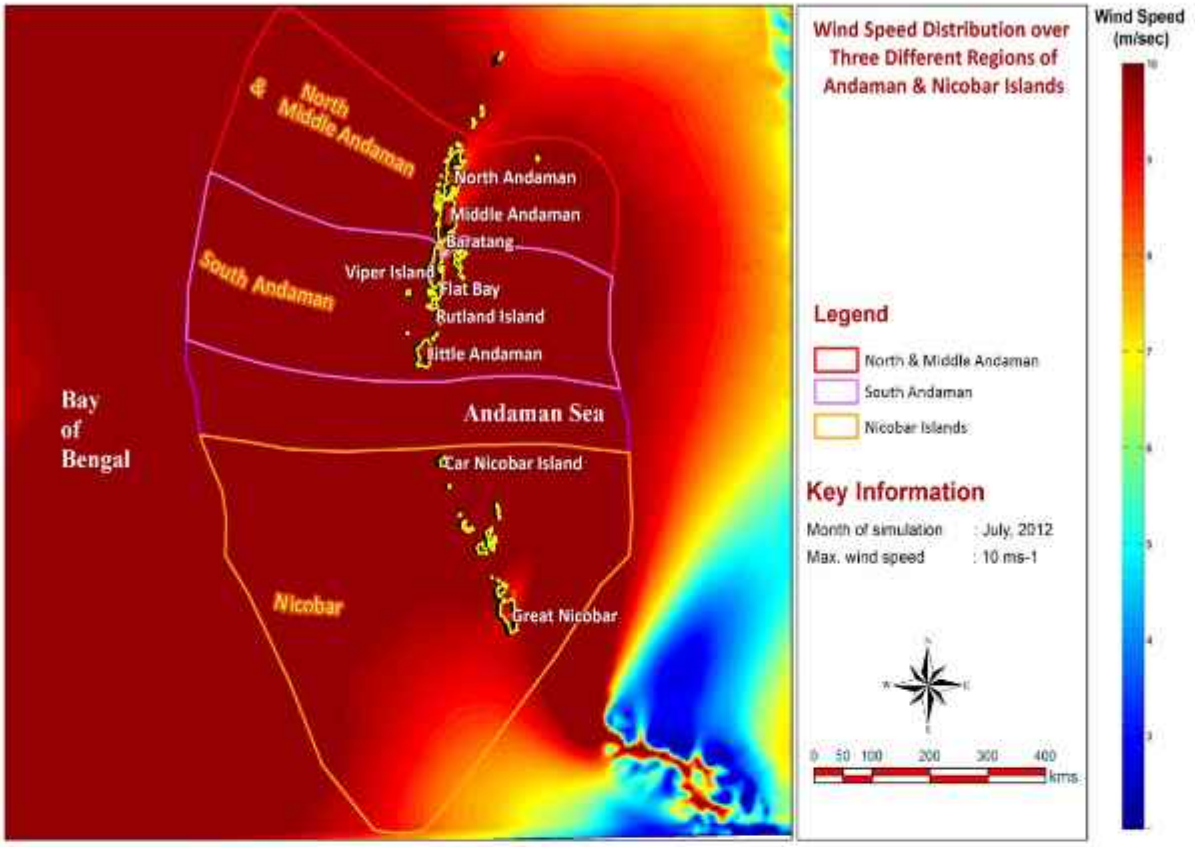


Fig. 1. Wind distribution at 50 m height over Andaman & Nicobar Islands during July 2012

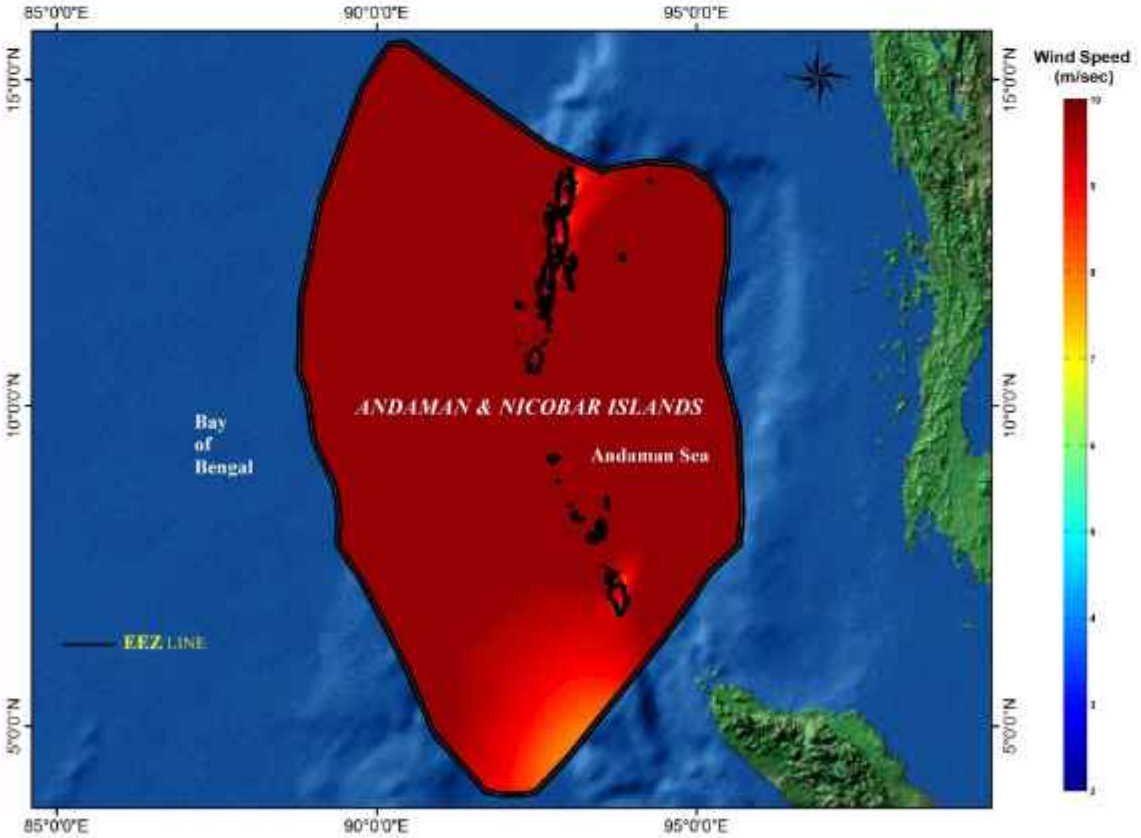


Fig. 2. Wind distribution at 50 m height over the EEZ of Andaman & Nicobar Islands during July 2012

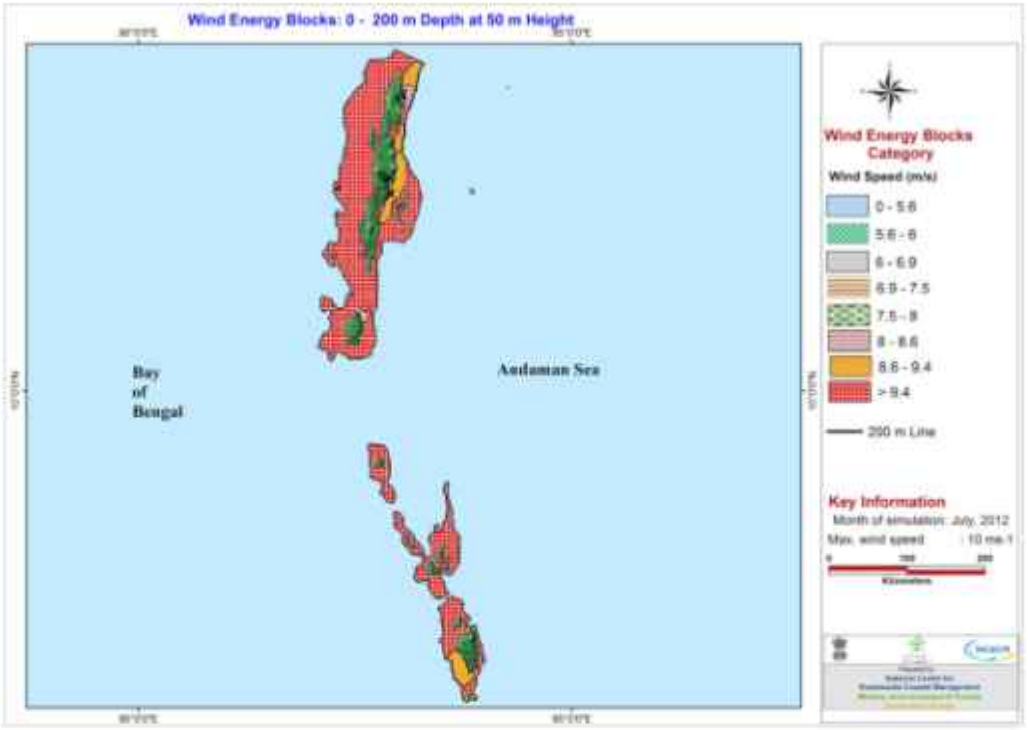


Fig. 3. Development of offshore wind energy blocks along the coastal regions of Andaman & Nicobar Islands during July 2012

Location	Mean Wind Speed (m/s)
Curlew Island	8.16
Stewart Island	8.20
Spiks Island	8.19
Flat Bay	8.16
Rutland Island	8.24
Viper Island	8.18
Neil Island	8.16
Havelock Island	7.92

Fig. 4. Islands with high onshore and offshore wind power potential in Andaman & Nicobar Islands

The fundamental principle of the Eco-hydrology numerical modeling is to make the hindcast, nowcast and forecast the scenarios for Chilika Lagoon. A few scientific modeling tools are pre-requisite to estimate the various impacts on the ecosystem health of Chilika Lagoon with the inclusion of potential conflicting variables to the modelling tools.

Eco-hydrology Model for Chilika Lagoon

The Chilika lagoon situated on the east coast of India in Odisha state (Fig. 1) is one of the largest tropical lagoonal systems in Asia. The lagoon is ~64.5 km long and the width varies from 18 km in North to 5 km in South. Depth of the lagoon varies between 0.9 and 2.6 m in dry period between 1.8 and 3.7 m in the wet season. The maximum area of the lagoon is ~992 km^2 during wet season to minimum 815 km^2 during dry period. Nearly 52 rivers and small streams are the main source of fresh water into the Lagoon. The tributaries of Mahanadi such as Daya, Nuna and Bhargavi are mainly responsible for the large fresh water and sediment influx to the lagoon. The lagoon has two mouths, one is near Arakhakuda with a 24 km long narrow and curved channel parallel to the Bay of Bengal and the other is the"new mouth" at Sipakudaat a distance of 14 km from the main lagoon. Based on the physico-chemical and biological characteristics, the lagoon is classified into four different sectors i) northern sector, ii) central sector, iii) southern sector and iv) outer channel. It is very dynamic ecosystem with unique assemblage of freshwater, brackish and saline water.

In recent years, Chilika lagoon is undergoing severe ecological changes due to heavy influx of sediment along with fresh water, shifting of the lagoon mouth, eutrophication, biological sedimentation, increased turbidity, overfishing, and loss of biodiversity. In order to prevent further environmental degradation in the lagoon, there is a need for a science-based integrated management planincluding numerical modeling. The fundamental principle of the Eco-hydrology numerical modeling is to make the hindcast, nowcast and forecast the scenarios for Chilika Lagoon. A few scientific modeling tools are pre-requisite to estimate the various impacts on the ecosystem health of Chilika Lagoon with the inclusion of potential conflicting variables to the modelling tools.

Eco-hydrology Model

The Eco-hydrology model is very simple and realistic model. This is a 1D model and the equations are expressed by finite differential methods. It has the facility to divide the domain into number of cells. The cell division concept is very useful to understand the physical, biochemical processes between the cells and their interactions. The model explains the flushing and mixing processes (Fig. 2) through the parameterization of hydro- and fine sediment dynamics. The ecological sub-model incorporates 10 state variables that are important in controlling the ecosystem which explains the dominant physical and biological processes in the Lagoon.

Model Input Parameters

The following input parameters are required to initiate the eco-hydrology model simulations as follows:

1. river flow rates (m^3/sec), salinity
2. suspended solids concentration (mg/l)
3. nutrients, phytoplankton, zooplankton, benthic animals
4. carnivorous/omnivorous fish, detritus, zooplanktivorous fish
5. daily conversion rates of species i.e., rate of biomass, daily death rates of species
6. daily production of species, migration parameters, and daily rates of water loss in meter from evaporation

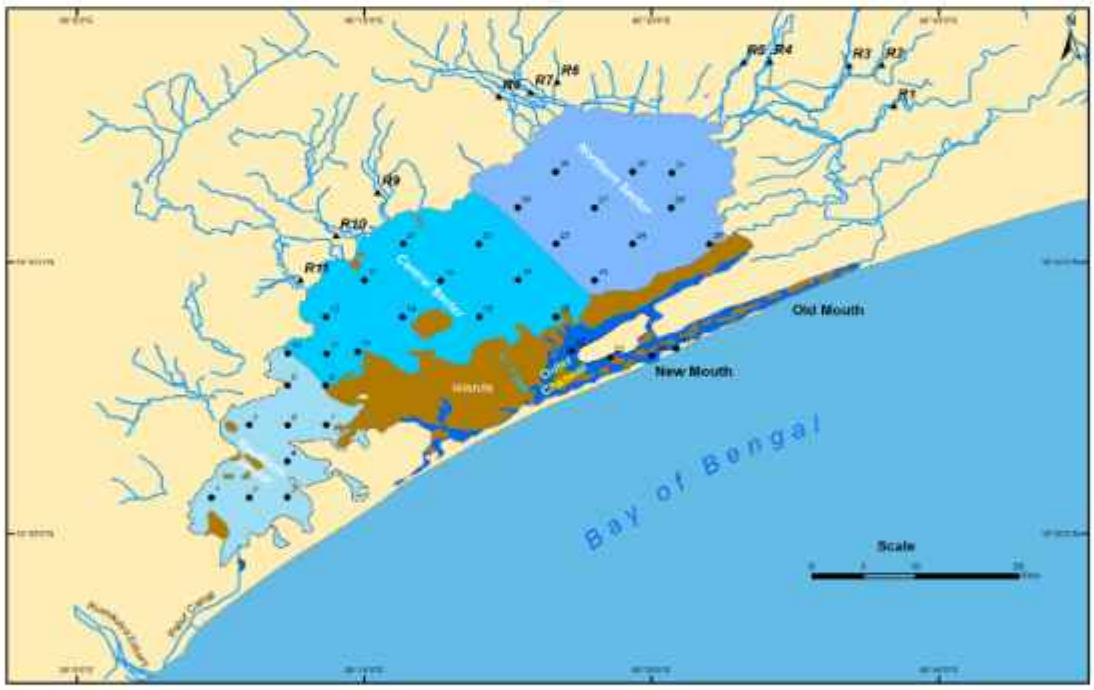


Fig. 1. Map of Chilika Lagoon with sampling stations

Model Calibration

The eco-hydrology model is applied with a perception of understanding the food web transfer structure in the Chilika Lagoon and a detailed food web transfer structure for the Chilika Lagoon is given in Fig. 3. In order to understand the interactions between the food web components and their variations in the Lagoon, it has been divided into 20 Cells based on the salinity gradient. In the model configuration, the fist cell is the river water discharge point and the last cell is high saline point near the ocean mouth. The cell demarcations and their volume in the Lagoon are given in Fig. 4.

As the very first step, the model has been configured for Chilika Lagoon and a sensitivity experiment to assess the reliability of the model in two separate scenarios using different flow rates for both dry and wet period has been conducted. The model results and its predictions for the two different scenarios are explained in the following section.

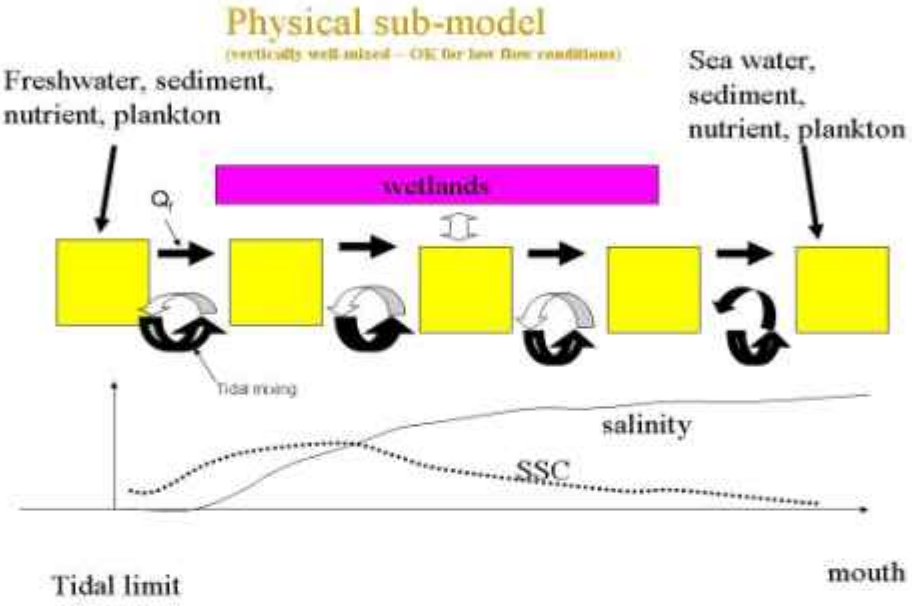


Fig. 2. The hydrodynamic mixing model

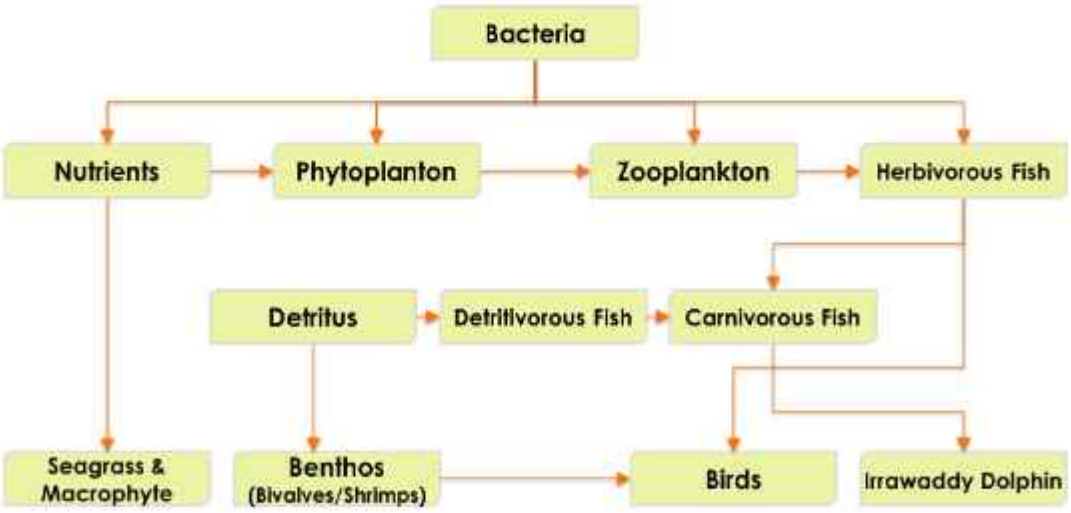


Fig. 3. Flow chart of Food web transfer structure of Chilika Lagoon

Scenario 1. Dry Period

The model for dry season is simulated with the river flow rate of 9.76 m^3/s and variation in the population of carnivorous fishes was determined (Fig. 5). The model simulations indicated that the population of carnivorous fish increased from Cells 3 to 6 onwards with a maximum population in Cell 5. Similarly a marginal increase in population of carnivorous fish was observed between cells 15 and 19.

Scenario 2. Wet Period

For the wet season, the model was simulated with a river flow rate of 11.72 m^3/s; and the effect on the various components of the food web transfer was evaluated. Similar to the dry season, higher population of carnivorous fish was observed between the cells 3 and 6 and the maximum population was in Cell 5 (Fig. 5). The model simulated for these two seasons at different flow rates does not vary significantly as the flow rates considered in the two periods are relatively close. The model needs to be simulated with the actual field data to predict the actual fish population in the Lagoon.

Fig. 4. Demarcation of Model Cells based on the salinity gradient in Chilika Lagoon

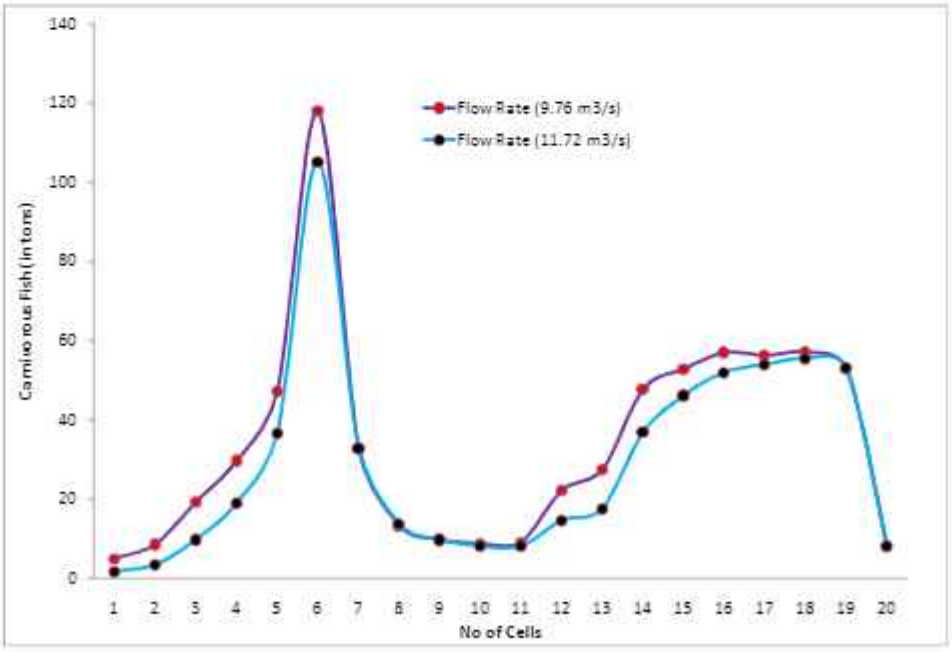


Fig. 5. Comparison of carnivorous fish population with respect to distance from the river water discharge point to the ocean with different flow rates

The model is also configured for the future prediction of fish population in the Lagoon with same flow rates but at different time periods. The model has been simulated for 200 days completing a seasonal cycle. The predicted abundance of carnivorous fish based on simulation for 57 and 155 days are shown in Fig. 6.

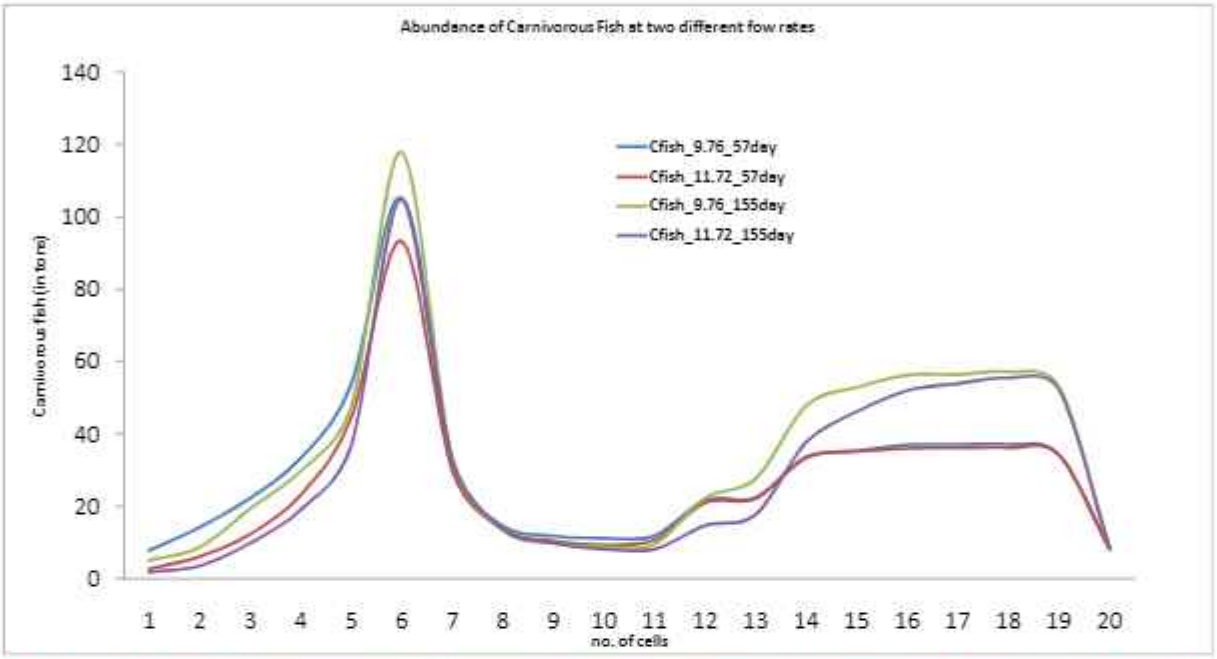


Fig. 6. Prediction of carnivorous fish concentration with respect to distance from point of river water discharge to the Bay of Bengal based on different flow rates

Summary

It can be concluded that the model predictions are reliable and useful for future prediction of the ecosystem health of Chilika Lagoon. More realistic simulations of the model depend on the food web transfer structure of Chilika Lagoon and initial data of individual component in the food web structureto strengthen future predictions. Results from the model simulations will be corroborated with actual field measurements in order to obtain the accuracy of the model estimates and to enable future predictions for the lagoon.


SESSIONS

Integrated Island Management

The Integrated Island Management (IIM) - an unit of FTR, would prepare a model framework for integrated island management plan. The goal of the IIM is to help ensure the future socio-ecological sustainability of the Indian islands, Andaman and Nicobar and the Lakshadweep by preparing an Integrated Island Management Plan. The IIM would undertake scientific approaches, coupled with indigenous knowledge for the better management of the islands and its resources. The IIM would consider the indigenous governance structures and knowledge - particularly in tribal dominated islands. The islands being pristine areas, this division would undertake long-term historical analysis including monitoring of the oscillations of crucial environmental variables.

To protect the coastal environment of the Andaman & Nicobar (A&N) and Lakshadweep group of Islands, separate Island Protection Zone (IPZ) Notification, has been notified by the Ministry of Environment and Forests (MoEF) on 6th January 2011 under the Environment (Protection) Act, 1986. As per the IPZ Notification, 2011, Integrated Island Management Plans (IIMPs) are required to be prepared by UTs of A&N and Lakshadweep indicating their existing and proposed developments, conservation and preservation schemes, dwelling units including infrastructure projects such as schools, markets, hospitals public facilities, etc.

Preparation of Integrated Island Management (IIM) Plans for Andaman and Nicobar Islands:

To protect the coastal environment of the Andaman & Nicobar (A&N) and Lakshadweep group of Islands, separate Island Protection Zone (IPZ) Notification, has been notified by the Ministry of Environment and Forests (MoEF) on 6th January 2011 under the Environment (Protection) Act, 1986. As per the IPZ Notification, 2011, Integrated Island Management Plans (IIMPs) are required to be prepared by UTs of A&N and Lakshadweep indicating their existing and proposed developments, conservation and preservation schemes, dwelling units including infrastructure projects such as schools, markets, hospitals public facilities, etc.

The IIM Plans for A&N Islands are being prepared by the NCSCM in accordance with the guidelines provided in the IPZ Notification, 2011 with the following objectives:

i. **To ensure long-term preservation and conservation of ecology of islands by developing appropriate management strategies.**
ii. **To regulate existing developmental activities and suggest developmental activities that are compliable to ecology of islands without compromising environment and also ensuring sustainable livelihood opportunities to the islanders.**
iii. **To suggest measures for reduction of impact of natural disasters.**

In a meeting held with the Secretary (Environment), A&N Administration on 9th October, 2013 at NCSCM, it was decided to prepare IIM Plans for the following fifteen inhabited islands in the first phase:

North & Middle Andaman	South Andaman District	Nicobar District
Ross & Smith Island	Rutland Island	Bampooka Island
Strait Island	Flat Bay Island	Chowra Island
Aves Island		Kamorta Island
Curlew Island		Kondul Island
		Nancowrie Island
		Teressa Island
		Katchal Island
		Little Nicobar Island
		Pilowmillow Island

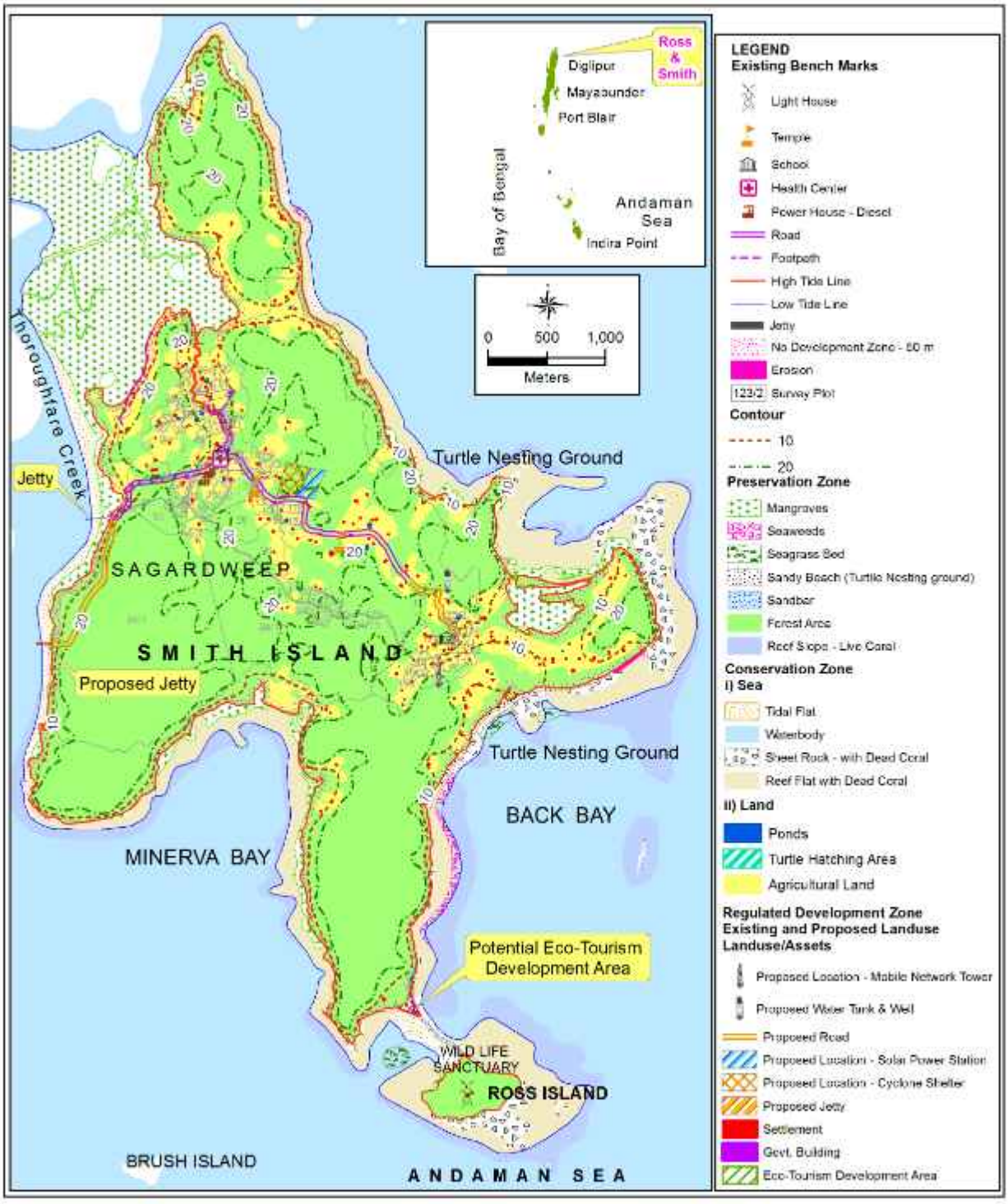
The preliminary field surveys were undertaken during the year 2013-14 in four islands viz., Smith Island (North Andaman), Aves Island (Middle Andaman), Flat Bay Island (South Andaman) and Rutland Island (South Andaman) to collect data on elevation, HTL/LTL, Ecologically Sensitive Areas (ESAs), existing developments and other land use & land cover features. The draft IIM Plan has been prepared for three islands of A&N viz., Smith Island, Aves Island and Flat Bay Island, *interalia*, indicating all the existing and the proposed developments, conservation and preservation schemes and infrastructure projects. All the draft plans prepared will be discussed in the stakeholder's meeting for their suggestions/comments.

IIM Plan for Smith Island (North Andaman):

The Smith Island is located on the eastern side of the North Andaman Island and falls under the Diglipur Tehsil of the District of North & Middle Andaman. According to the Forest Statistics 2009, the total geographical area of the Smith Island is about 2,470 ha. Out of the total geographical area, the total forest area is 1,579 ha (63.93 %) and the non-forest area is 891 ha. (36.07%). The total shore length is around 38 km.

The island has extensive coverage of mangrove vegetation on the north western side and narrow fringing reefs on eastern and southwestern sides of the island. The reef flat contains mainly rocks, sand and dead coral heads. Extensive coral growth starts at a depth of four meters and extends up to 10 meters with a gradual slope. The western reef is sheltered and dominated by *Porites* spp. while the eastern reef is dominated by *Acropora spp*. In the draft IIM Plan, a uniform setback distance of 50 m is assigned around the island as a conservation measure to regulate developmental activities. Further, the draft Plan specifies the areas for conservation and preservation and proposed developments as given below:

Components of Smith Island's IIM Plan	
Proposed Conservation Areas	Coral reefs, Dead coral mixed with algae & seaweeds, Mangroves , Sand beaches, Jetty area , Tourism destination
Proposed Preservation Areas	Live coral cover, Seagrass beds and Turtle nesting site.
Proposed Developments shown in IIM Plan	Proposed location for mobile network tower Proposed site for water tank Proposed Jetty with road connectivity at Sagar Dweep village Proposed location for solar power station Eco-Tourism development area.


Ross & Smith
Diglipur
Mayaaunder
Port Blair
Bay of Bengal
Andaman Sea
Indira Point
0 500 1,000
Meters
Thoroughfare Creek
Jetty
Turtle Nesting Ground
SAGARDWEEP
SMITH ISLAND
Proposed Jetty
Turtle Nesting Ground
BACK BAY
MINERVA BAY
Potential Eco-Tourism Development Area
WILD LIFE SANCTUARY
ROSS ISLAND
BRUSH ISLAND
ANDAMAN SEA
LEGEND
Existing Bench Marks
Light House
Temple
School
Health Center
Power House - Diesel
Road
Footpath
High Tide Line
Low Tide Line
Jetty
No Development Zone - 50 m
Erosion
123/2 Survey Plot
Contour
10
20
Preservation Zone
Mangroves
Seaweeds
Seagrass Bed
Sandy Beach (Turtle Nesting ground)
Sandbar
Forest Area
Reef Slope - Live Coral
Conservation Zone
I) Sea
Tidal Flat
Waterbody
Sheet Rock - with Dead Coral
Reef Flat with Dead Coral
II) Land
Ponds
Turtle Hatching Area
Agricultural Land
Regulated Development Zone
Existing and Proposed Landuse
Landuse/Assets
Proposed Location - Mobile Network Tower
Proposed Water Tank & Well
Proposed Road
Proposed Location - Solar Power Station
Proposed Location - Cyclone Shelter
Proposed Jetty
Settlement
Govt. Building
Eco-Tourism Development Area


Coconut Cultivation


Paddy Cultivation


Agriculture Activity


Bitter Gourd Cultivation


Habitation Area


View of Forest Area at Smith Island


Mangrove with Pneumatophore Roots


Mangrove with Stilt Roots


Tourism development at Smith Island


Dead coral rocks exposed during low tide at Smith Island

Information board at Ross and Smith Island


Beach area at Smith Island


Protected turtle nesting area at Smith Island


Settlement area at Smith Island

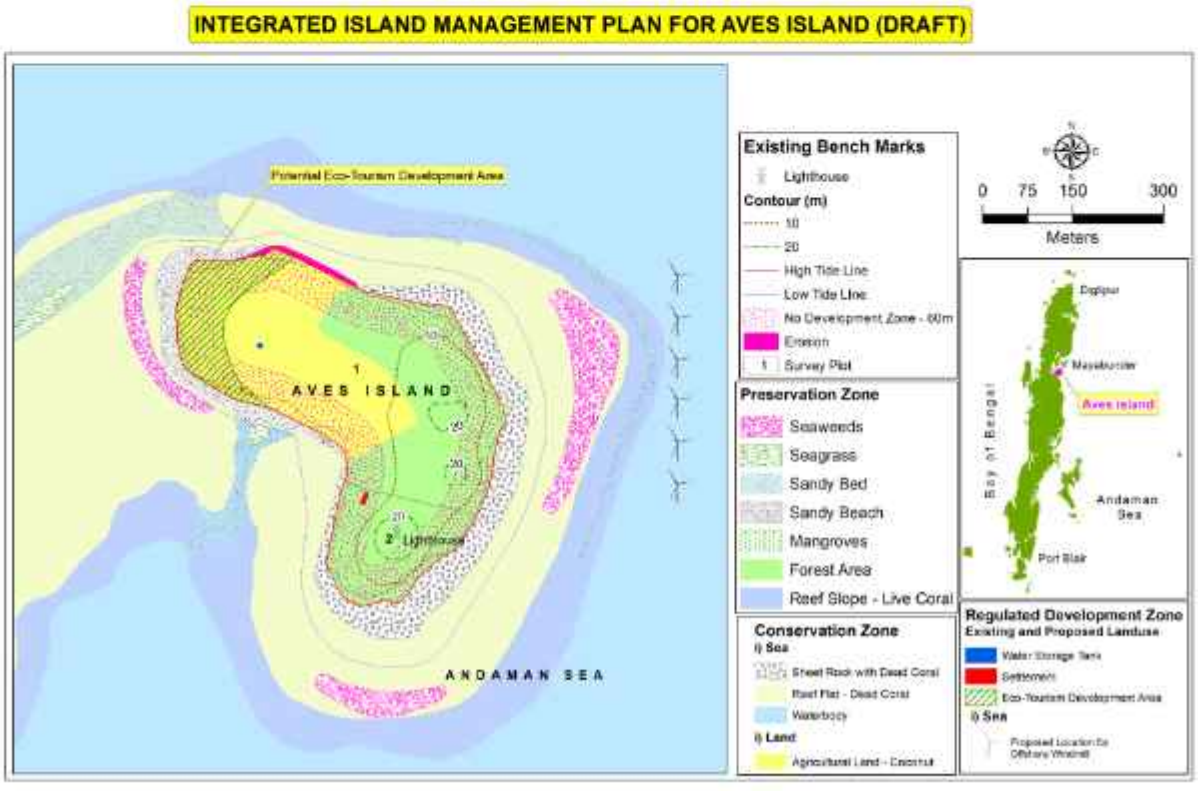
Aves Island (Middle Andaman)

The Aves Island is situated on the eastern side of Mayabundar Tehsil in North & Middle Andaman District of A&N Islands. The total geographical area of the island is about 20 ha (0.20 km^2) with perimeter of 1.87 km. The geographical location of the island lies down between 12°54'4.52" to 12°55'09.02" N Latitude and 92°55'52.51" to 92°56'13.07" E Longitude. Aves Island has a plain topography in the northern side whereas the southern side has a hilly area with a maximum elevation of 24m. This island is covered by coconut plantation and forest and is known for its sandy beaches attracting tourism.

The draft IIM Plan of Aves Island specifies the areas for conservation and preservation and indicates spatial plans for Eco-tourism development and offshore wind energy. The plan also suggests a uniform setback distance of 60 m around the island as a conservation measure to regulate developmental activities in the Aves Island.

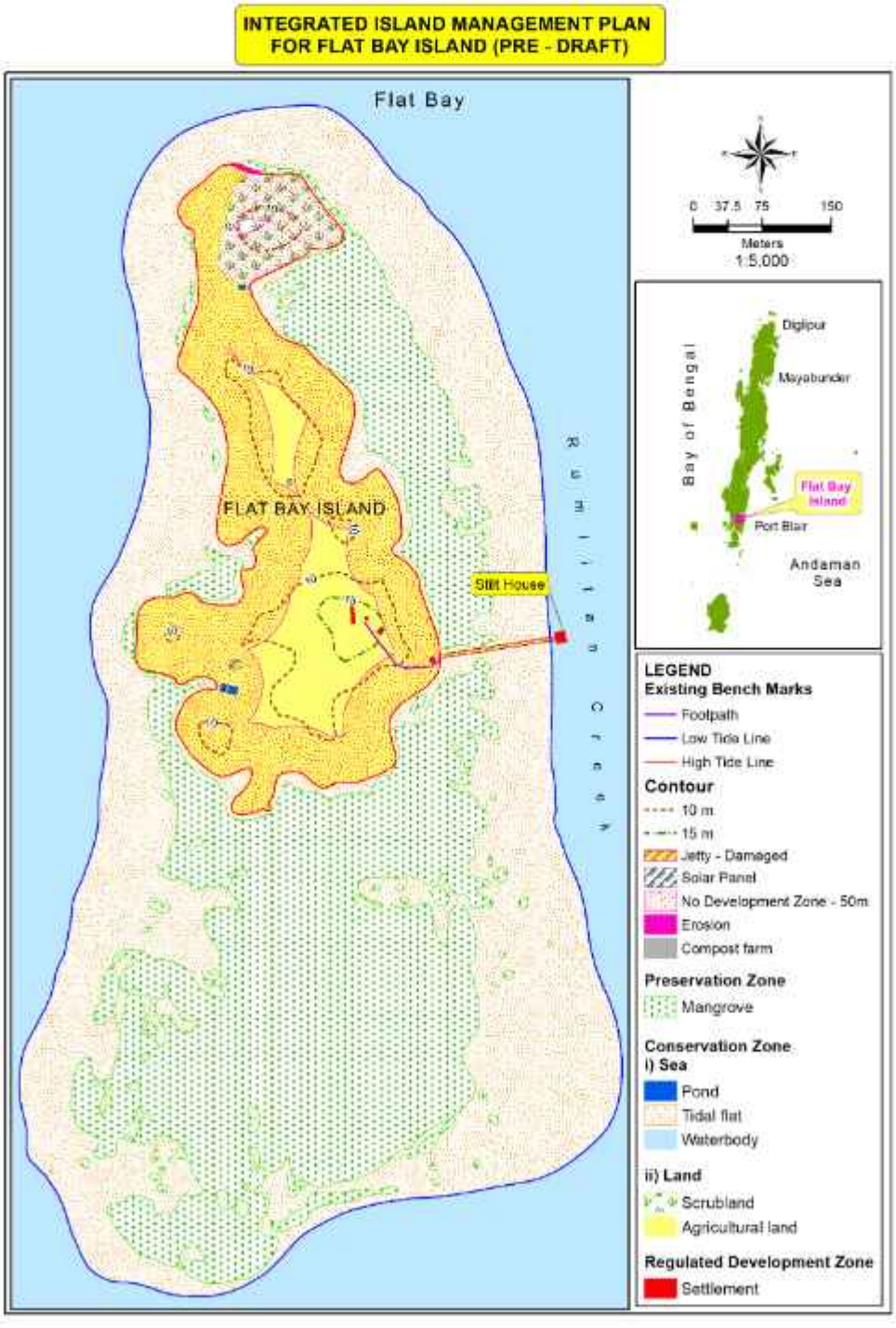
Coral Reef of Aves Island: Coral reefs occur all around the island from a depth of 4 meters to 14 meters, except at the southern end, where the seabed is covered mainly by rocks. On the eastern and northern sides, *Acropora* and *Porites* dominate the coral reefs while on the western side coral reefs are dominated by *Porites*. The reef flat contains mainly rocks, sand and dead coral heads. Mangroves vegetation is not found in this island.

The island did not receive much damage during the earthquake occurred on 26th December 2004 on the interface of India and Burma plates. Pre-tsunami records showed live coral cover to be 62% and a slight decline to 50%. Earlier *Acropora* constituted 40% followed by *Porites* (23 %). After the tsunami, *Acropora* constituted 83 % and *Porites* 16 % of the community. The tsunami generated earthquake was not violent in this area.



Flat Bay Island (South Andaman)

The Flat Bay Island is situated on the western side of Port Blair of Ferrargunj Tehsil in South Andaman district, between 11°38'25.20"N to 11°38'3.11"N Latitude and 92°41'11.92"E to 92°41'20.51"E Longitude, with total area of around 10 hectare. The topography of the Island is undulating nature with maximum elevation of 17m. The island is surrounded by mangroves and tidal flat. The draft IIM Plan of Flat Bay Island specifies the areas for conservation and preservation and suggests a uniform setback distance of 50m around the island as a conservation measure to regulate developmental activities.



Preparation of Sea Level Rise (SLR) Inundation Map for Smith Island (North Andaman):

Sea level rise associated with coastal flooding will become a significant issue in the next 100 years especially as human populations continue to grow and occupy the coastal zone. In order to demonstrate the possible impacts of inundation on coastal zone of Smith Island and its Ecologically Sensitive Areas, based on various scenarios of sea level rise and flooding (0.5m, 1m, 2m and 3m sea level rise from HTL) due to storm surge, tsunamis and shallow coastal flooding, the Sea Level Rise (SLR) Inundation Map has been prepared. GIS, remote-sensing techniques derived data and field surveyed information were used to assess the possible impacts of inundation over the island land use/land cover. The topography of the Smith Island is hilly and undulating with a maximum elevation of about 100m.

It was estimated that 0.56 percent (14 ha) of the total land area of Smith Island is predicted to be inundated at 0.5 m SLR and 0.97 percent (24 ha) of the total area of the island is predicted to be inundated with 1m SLR from HTL. Creeks and low lands adjacent to the shoreline increase the risk of inundation and the extent of maximum inundation zone goes up to approximately 50 m to 100 m landward while an 1m of sea level rise from high tide line. The study also perceives that the southern tip and north east regions are highly vulnerable to SLR. An enlarged inundation map of southern tip of Smith Island is shown below:

The potential changes in habitat as a result of SLR may threaten turtle population viz., green turtle and the Olive Ridley, which are dependent on Smith Island. Also, the changes in the beach areas, where tourism activity is happening, would lead to loss in tourism development and associated income. The settlements are concentrated on the north central part of island in Sagar Dweep revenue village. As per the Census data 2011, the Smith Island has a population of 600 persons (Male: 328; Female: 272; No of households being 160). Among the other islands in Diglipur Tehsil, the Smith Island has more population next to the North Andaman which has the total population of 10,625. The population in the island is safe from the impact of coastal flooding, tsunami, sea level rise, as they are located in the in elevated area.

The tidal waves (tsunami) have been reported in A&N Islands in 1881, 1941 and 2004. The earlier tsunamis did not cause loss of life and property as there was no significant population in this island and moreover the population is spread in the elevated area. The coastal forests present in the island protect the coastlines from tsunami. Due to the earthquake occurred on 26th December 2004 on the interface of India and Burma plates, the Smith Island of the North Andaman region appears to have been raised by half a meter, resulting in exposure of the reef flat on the eastern side and mangrove area on north western side. The tsunami generated out of the earthquake was not violent in this area and water only rose by around 2.5 meters.

In order to ensure safety to human life, location of settlement areas need to be based on the elevation. The areas up to 10 m elevation from the coastline have been marked for location of settlements and other relevant establishments. The SLR Inundation map would help managers to anticipate where risks are highest and to prepare the coastal zone management plan for Smith Island.

Preparation of Island Coastal Regulation Zone (ICRZ) Plans for Andaman and Nicobar Islands:

The IPZ Notification, 2011 also prescribes that the UT of A&N is required to prepare its mandatory Island Coastal Regulation Zone (ICRZ) Plans in accordance with the prescribed guidelines, to regulate developmental activities in the Island Protection Zone (IPZ).

A&N Islands comprises 572 Islands, Islets and rocky outcrops. However, only 37 islands are inhabited (10 islands in the South Andaman District, 14 in the North & Middle Andaman District and 13 in the Nicobar District) (Source: Census data 2011). Total geographical area of A&N Island is 8249 sq. km (Andaman group: 6408 sq.km; Nicobar group: 1841 sq.km) with a coastline of 1962 km. Among the total inhabited islands, the following islands require ICRZ Plans:

North & Middle Andaman	South Andaman District	Nicobar District
1. Baratang Island	1. Havelock Island	1. Car Nicobar Island
2. Long Island	2. Little Andaman Island	2. Great Nicobar Island
3. Middle Andaman Island	3. Neil Island	
4. North Andaman Island	4. South Andaman Island	

SLR Inundation Map - Southern part of Smith Island

This unit has been assigned with the task of preparation of ICRZ Plans for the above ten (10) islands with the following objectives and also scientific assistance will be provided to A&N Administration in preparing an ICZM plan for a selected area in the A&N Islands:

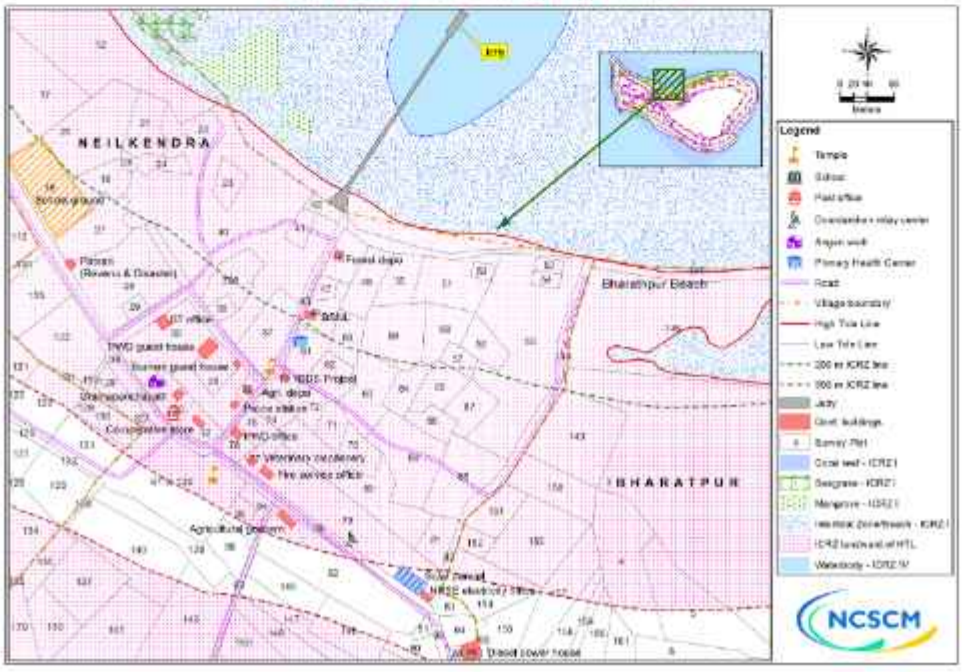
i. To ensure long-term preservation and conservation of ecology of islands by developing appropriate management strategies.
ii. To ensure livelihood security to the fishing communities, tribals and other local communities living in the coastal areas.
iii. To promote development in a sustainable manner based on scientific principles, taking into account the dangers of natural hazards in the coastal areas including sea level rise due to global warming.

During the year 2013-14, preliminary field surveys were undertaken in two islands namely Havelock and Neil to collect information on HTL/LTL and ESAs for preparation of ICRZ Plans. Draft ICRZ Plan for Neil Island (South Andaman) has been prepared, *interalia*, indicating HTL/LTL and ESAs. The draft plan will be discussed in the stakeholder's meeting for their suggestions/comments.

ICRZ Plan for Neil Island: The Neil Island has a total area of 18.9 square km. The geographical co-ordinates of the island lies between $11^0$48' to $11^0$51' N and $93^0$02' to $93^0$00' E. The island is located 40 kilometers northeast of Port Blair. The island has a forest cover of 6.47 km². As per the 2011 census, the island has a total population of 3040 which includes 1624 males and 1416 females. The island has one jetty at Bharathpur, which serves as the entry-exit point of the island.

The draft ICRZ Plan contains information on categories of ICRZ areas, HTL, LTL, 200m & 500m regulation areas (at 1.5000 scale), as per the guidelines. The Island is biologically rich in forest, coral reef, sandy beach and mangroves. The coral reef of the Neil Island is of fringing reef type which occurs on the eastern and western side of the island, with patch reefs to the north and south. The dominant species in the reef are *Porites lobata, Favia favus* and *Echinopora lamellosa*. Mangroves in Neil Island are the most sensitive and fragile ecosystem which are vulnerable to the coastal environmental changes including sea level rise and hydrological variations. The dense mangrove is found on the northern side of the Island; east to the Bharatpur Jetty. The mangrove patch is nearly 1.5 km in length as well as 200 meters of maximum width. There are sparse mangrove patches near the beach region of the Islands (Radha Nagar, Lakshmanpur and Neilkendra). The dominant mangrove species found in the Island are *Lumnitzera racemosa, Rhizophora apiculata, R. mucronata* and *Avicennia marina.*

Draft ICRZ Map - Part of Neil Island




ISE

Integrated Social Sciences and Economics

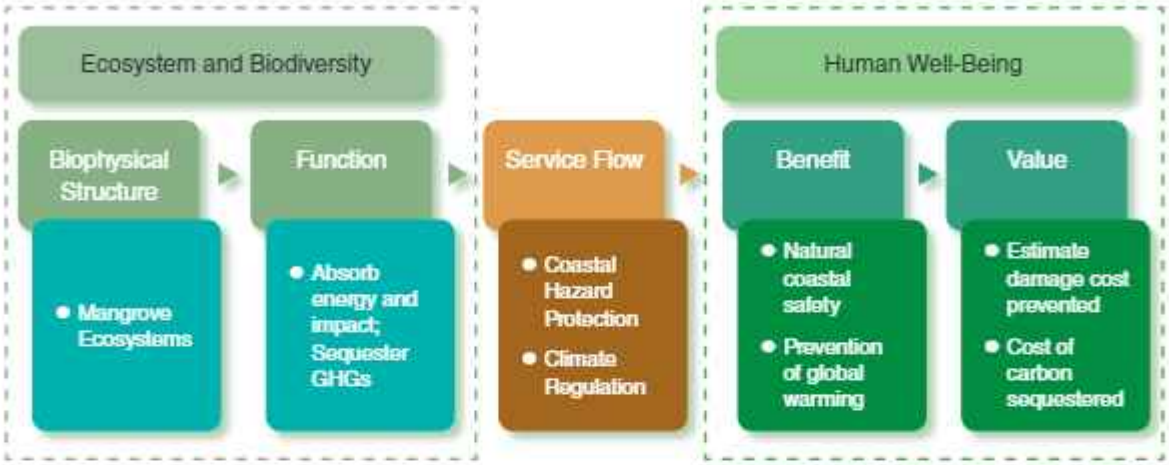
The ISE would focus on coastal communities and their livelihoods. In particular, the ISE would focus on community based approach to coastal vulnerability and coastal management with collaboration with other divisions of the NCSCM. Research interests of ISE would include social aspects of the coastal management, traditional wisdom, and the regional and national level solutions for livelihood security and improved community level resilience against coastal hazards. The major groups under the ISE are: (i) the Coastal Livelihood and Demography, (ii) the Traditional Knowledge, (iii) the Employment and Education, (iv) the Coastal Community, Culture and Heritage, (v) the Regional Planning, (vi) the Coastal Conflicts Study, and (vii) the Coastal Ecosystem Economics.

Economic values of the critically important coastal ecosystem services derived from studies in India and across the South Asian region have been identified and prioritized based on several ecological, social and economic factors. Strategies for addressing the issues related to incorporating the values in the national green accounting system, valuation methodologies and role of institutions in the valuation and implementation have been evolved.

Assessment of Coastal and Marine Ecosystem Goods and Service: Linking Coastal Zone Management to Ecosystem Services in India

The research study aims to develop a framework that links the functioning, provisioning and valuation of services provided by coastal ecosystems to human population, which involves prioritising critically important ecosystems, valuing the goods and services delivered and finally linking the value to social welfare among and beyond coastal communities.

A comprehensive review of coastal ecosystem services valuation studies in India and across the South Asian region was made to identify and prioritize services values of critically important ecosystems. Descriptive statistical analysis (mean, median, range, standard deviation values for each of the ecosystems based on the estimated values) was carried out for the values of each category of service; namely provisioning, supporting, cultural and regulating services (Millennium Ecosystem Assessment 2005). The major ecosystems covered include mangroves, seagrass, estuaries, sandy beaches and coral reef. These ecosystems, have been classified as CRZ-I areas - Ecologically Sensitive Areas in the CRZ (2011) Notification.



Two consultation workshops with subject experts and policy makers were organised to:

- Prioritise key coastal ecosystem services,
- Document success stories in ecological valuation
- Discuss critical issues of the valuation process which includes appropriate methodologies to be adopted, influence of government institutions on values of services, the approaches to transfer knowledge from the academic to the policy domain and
- Finally to integrate coastal ecosystem values to national environmental accounting.

Fig. 1. Expert Consultation Workshop - Linking Ecosystem Services

The coastal ecosystems, as identified by the CRZ (2011) notification, were prioritised based on several ecological, social and economic factors. It was observed that services such as coastal protection, carbon sequestration, soil regulation, biodiversity/habitat and fisheries provided by mangroves, sea-grass, salt-marshes, coral reef and estuaries respectively are among the most important in India and that the terms of reference for EIAs would need to expand its scope beyond just provisioning services (drinking water, agriculture, livestock and fisheries) (Table 1).

Table 1. Prioritising of Ecosystem and Ecosystem Services

Coastal Eco system goods & Services		Estuary	Coral reefs	Sea grass	Salt marsh	Mangroves	Sandy beaches	Sand dunes	Heritage sites
Provisional Services									
A.	Food& raw materials,								
B.	Traditional and bio-physical products								
Regulatory Services									
C.	Coastal protection								
D.	Carbon sequestration								
E.	Soil fertility								
F.	Air, water purification								
Recreational Services									
G.	Employment								
H.	Cultural services								
I	Aesthetic services								
J.	Educational services								
Supportive Services									
K.	For ecological cycles								
L.	Bio diversity								
M	Pollination								
N.	Ground water recharging								

Legends:

Extremely Important | Very Important | Moderately Important | Less Important | Not Ranked

The expert consultations recognized the importance of incorporating coastal ecosystems within the framework of the System of Environmental and Economic Accounting (SEEA) and the need for adopting changes in the ecosystem valuation methodologies as per the Indian policy context. It was observed that local and national institutional structures have an influence on the sustainable delivery of coastal ecosystem services and hence on its economic values. It was also recognized that the policy design, appraisal and implementation are reliant on the local and national institutions in place.

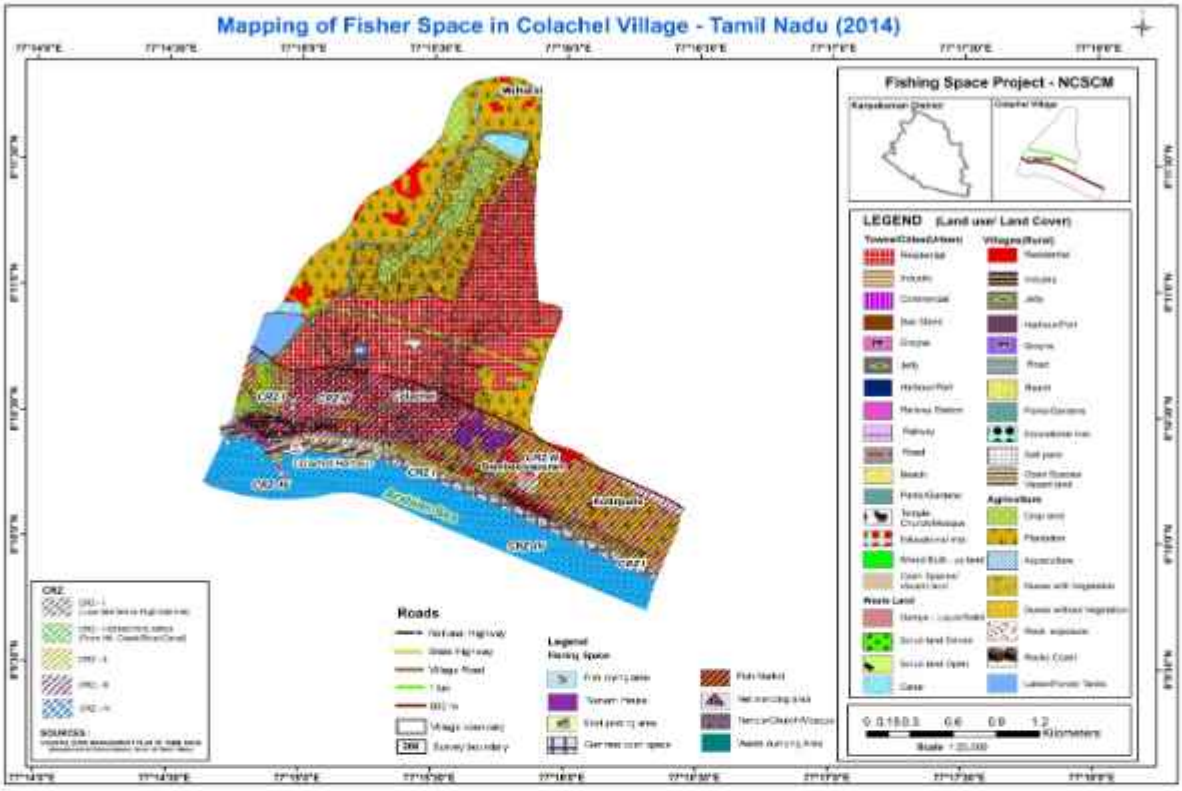
As a follow up to the consultations, a report on the valuation methodologies specific to Indian coastal ecosystems and a draft guide book on the concepts used in the valuation of coastal/ marine ecosystem services has been prepared, which would provide a methodical approach to coastal ecosystem valuation, with case studies from India and other South Asian countries.

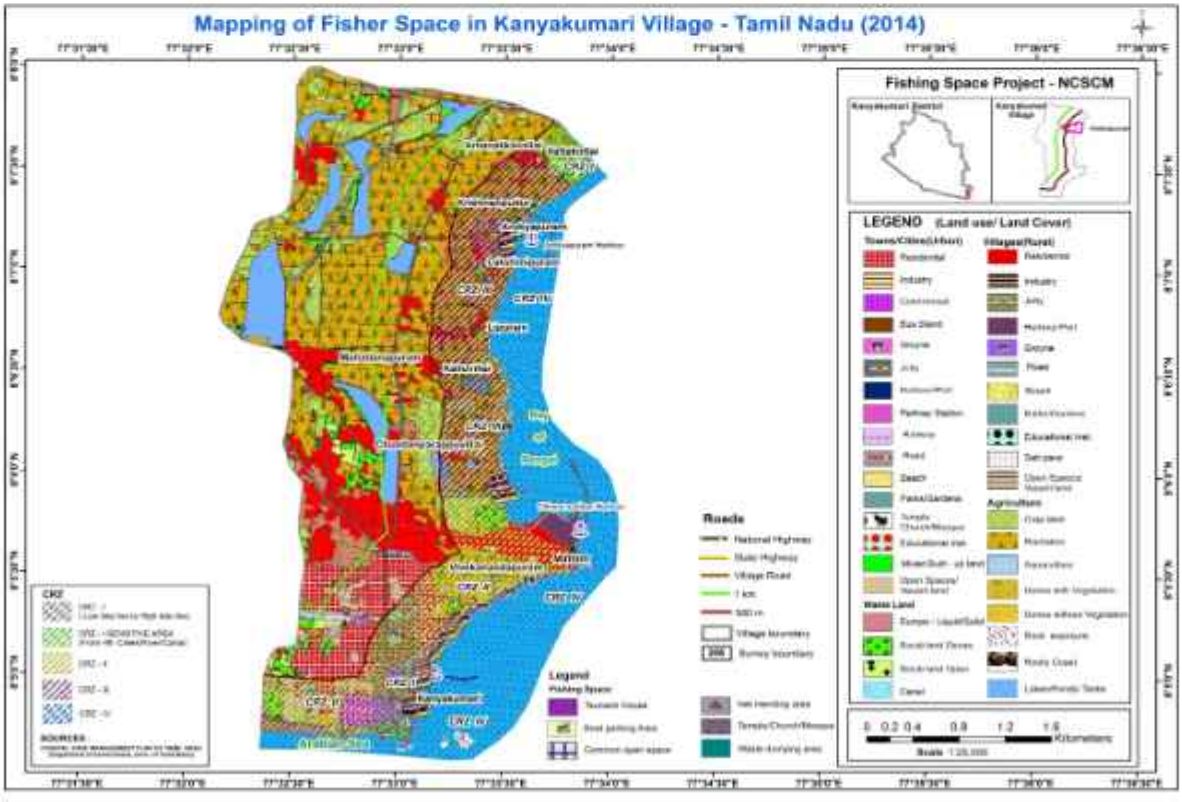
The changes in the utilization of coastal physical space by the traditional fishing communities and governance and conservation issues are studied. Standard protocol and guidelines for mapping of fishing space have been developed.

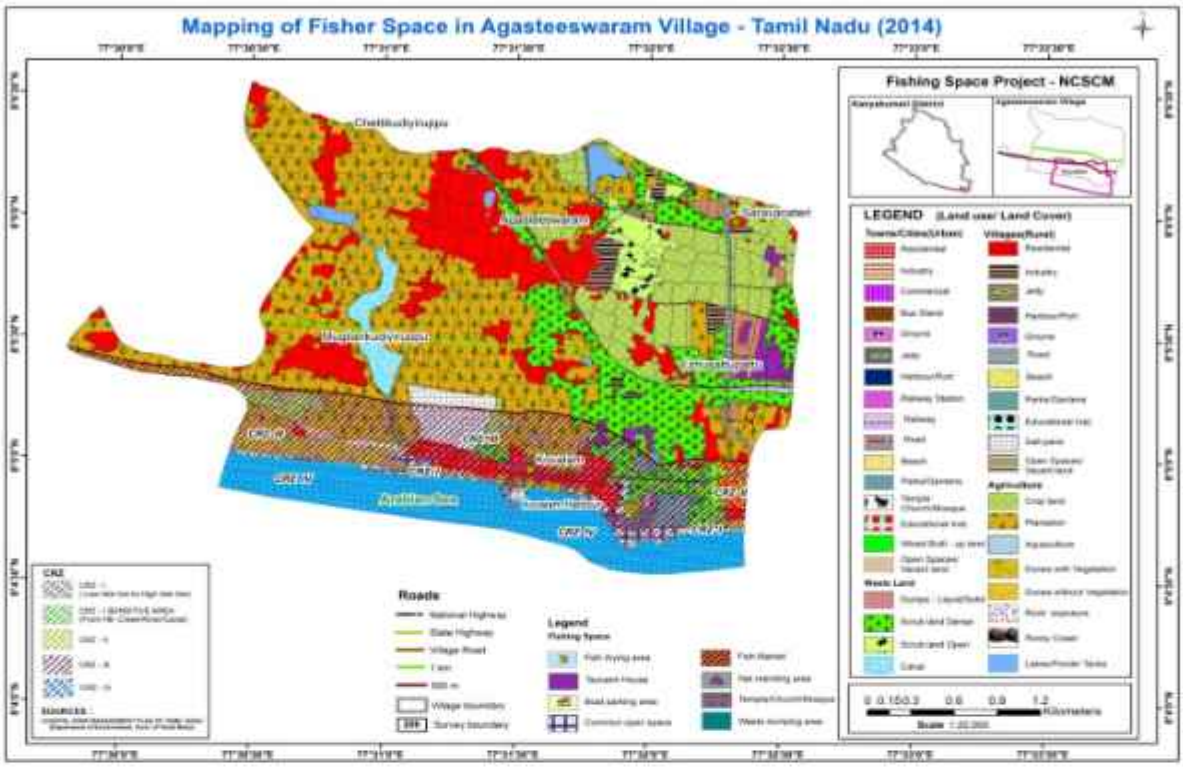
Mapping of Fishing Space: Socioeconomic Impact of Coastal Land Use/Land Cover Changes on Fishers Livelihood in India

The project aims at studying the changes in the utilization of coastal physical space and economic value of land used by the traditional communities for their occupation-related activities in coastal zone and to conserve these spaces by mapping, demarcating and incorporating them as socially and economically important areas in the CZMPs.

The fishing space includes areas such as those used for fish-drying, boat parking, net mending, rehabilitation centres etc. Mapping the fishing space would help to understand the urban and rural pressures leading to shrinking of fishing space. Mapping of fishing spaces in GIS involves geo-rectifying the Landsat and LISS III images; enhancement using contrast stretching and other methods for better identification of features; creation of the spatial framework of land use geodatabase based on the Space Application Centre (SAC) classifications; detailed interpretation of land-use/land-cover categories and collection of GPS co-ordinates and field photographs of the fishing space to ground-truth the data. Land use/Land cover maps with demarcation of coastal fisher space were then finalised. Cadastral information, coastal structures like ports, harbours, Groynes, jetties etc. and Coastal Regulation Zones are the other layers incorporated in the map (Figs. 1-3).


Mapping of Fisher Space in Colachel Village - Tamil Nadu (2014)
Fishing Space Project - NCSCM
LEGEND (Land use/ Land Cover)
Roads
Legend
Fishing Space
CRZ
SOURCES
Kilometers


Mapping of Fisher Space in Kanyakumari Village - Tamil Nadu (2014)
Fishing Space Project - NCSCM
LEGEND (Land use/ Land Cover)
Roads
Legend
Fishing Space
CRZ
SOURCES
Kilometers



Figs. 1 - 3

Two stakeholder workshops were held in Tamil Nadu and Karnataka to discuss issues relating to coastal land use/land cover and impacts of coastal erosion on fishing spaces

Fig. 4. Stakeholder Workshopson fishing space

The household data collected by M.S. Swaminathan Research Foundation, Chennai was analysed to develop a framework for evaluating the alternative strategies for coastal conservation and management in the context of ICZM and understand the factors that determine the influx and outflow of population to and from coastal villages respectively.

Coastal Profiling: A Socio-Demographic Analysis

The **M.S. Swaminathan Research Foundation, Chennai** (MSSRF) had collected comprehensive household data on fisherwomen in five states (Kerala, Tamil Nadu, Andhra Pradesh, Gujarat and Odisha) during 2011-12, with a research grant from the World Bank. The data was acquired from MSSRF and analysed.

The study aimed at developing a framework for evaluating the alternative strategies for coastal conservation and management by considering the total population, population density and occupational distribution in the context of ICZM. Villages, in general, tend to witness a significant migration of their population to urban centres owing to various socio-economic factors but in some coastal villages the reverse is often observed. The study aims at understanding the factors that determine the influx and outflow of population to and from coastal villages respectively. The socio-demographic analysis of coastal population helps in developing strategies to address the problems of food security, distributional issues, poverty, education and skills, role of women, displacement and resettlement issues etc.

In order to address the multiple demands of protecting coastal resources and the livelihoods of coastal communities and long term management approaches such as ICZM, the socio-demographic analysis would be highly useful. The study focused on assessing the socio-economic impact on livelihood changes among the coastal population by considering the social and demographic parameters like Total population, Literacy changes, Sex ratio, etc.

The village boundaries were demarcated with the help of GIS and the names of the villages were compared with the National Census documents. A detailed demographic analysis of 9 coastal states (Andhra Pradesh, Karnataka, Kerala, Tamil Nadu, Maharashtra, Gujarat, West Bengal and Odisha) was undertaken by extracting the data from the three decadal National Census data (1990, 2001 and 2011). The temporal changes in the density and occupational changes also provide the changing sources of income and livelihood.

The coastal population on an average has grown at a rate of 2% which is much higher than the average annual population growth rate of 1.5 % during 2001-2011. The 73 coastal districts (out of a total of 593) have a share of 20% of the national population living within 50 km from the coastline. The coast also includes 77 cities and towns, including some of the largest and most dense urban agglomerations - Mumbai, Kolkata, Chennai, Kochi and Visakhapatnam. As per the 2010 Marine Census, it was estimated that 47 % of ~40 million fishers in India live below the poverty line and most of them are traditional fishers. Thus any decline in the share of fish produced would lead to loss of income to the coastal community.

The significant increase in coastal population, infrastructure development attracting settlements along the shoreline, rising fishing assets, fishing intensity and tourism development are some of the factors likely to have an impact on coastal ecosystem goods and services. Therefore, it is important for coastal planners to consider differential impact on different stakeholder groups while preparing the management plans. The density during the period 2001-2011 in coastal villages up to 1 km from HTL was almost constant. The population growth in coastal states, coastal districts and the population within one km from the high tide line (HTL) are shown in Figs. 1-3. The density of population within the district and also within one km from the coast is depicted in Fig. 5&6.

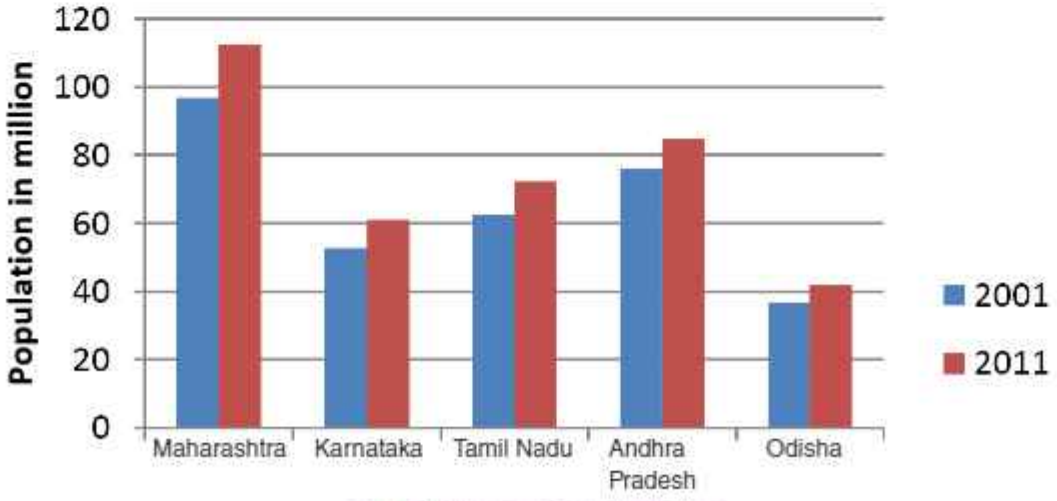


Fig. 1. State-wise Total Population

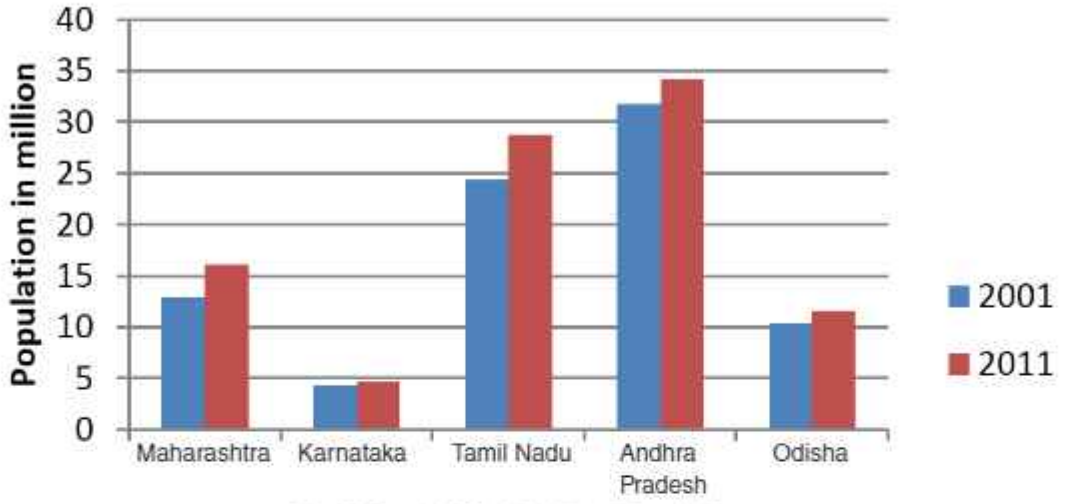


Fig. 2. Coastal District - Total Population

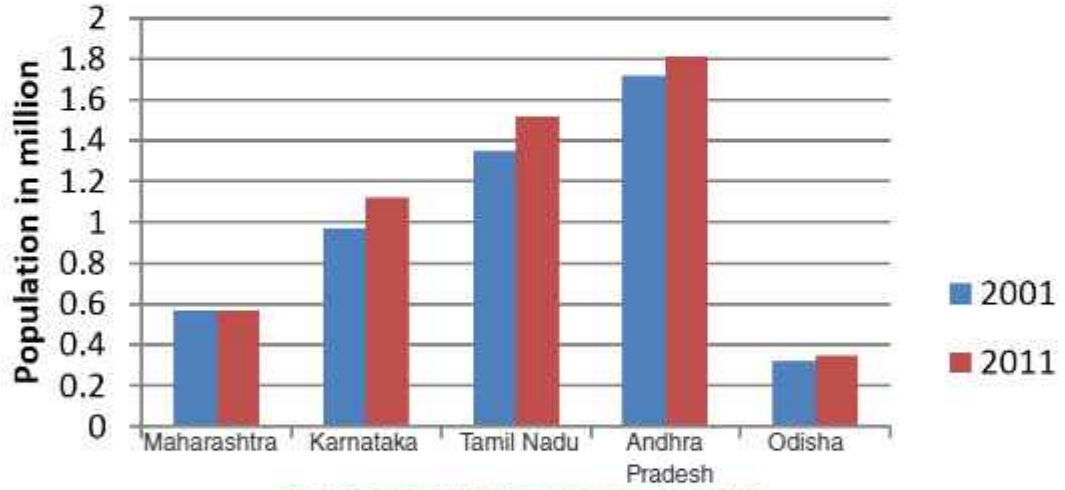


Fig. 3. Total Population 1KM from Shoreline

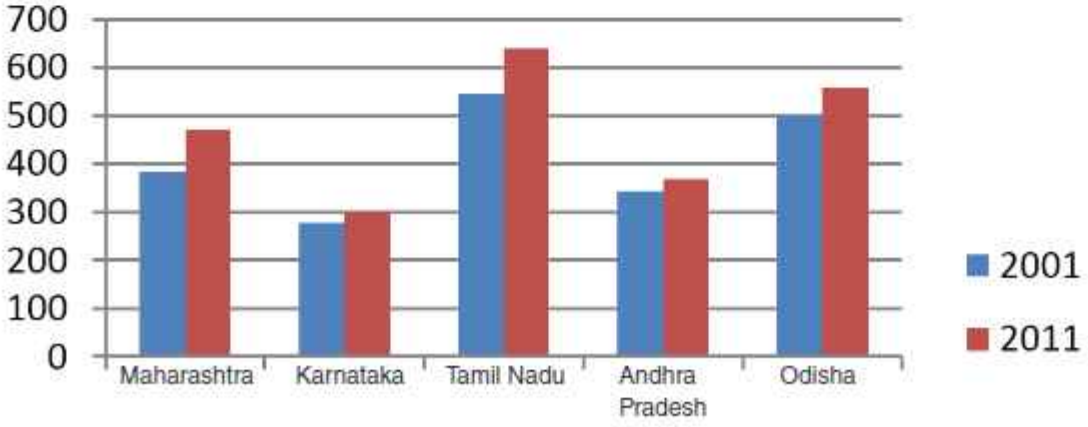


Fig. 4. Population Density - Coastal District

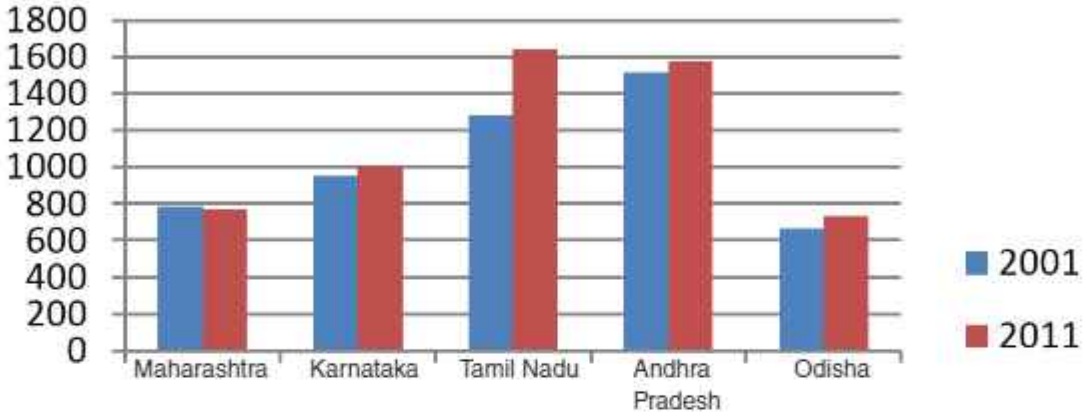


Fig. 5. Population Density - 1KM from HTL

Tamil Nadu and Maharashtra present a significant difference in the demographic transition during the last one decade (2001-2011). The total population of coastal districts of Tamil Nadu increased from 24 million to 28 million and density increased to 546/km2 to 640/km2 during the period. Interestingly, the population and density of Tamil Nadu within 1 km from the coast is one of the highest in the country. The population density up to 1 km from the HTL increased from 1280/km2 to 1642 /km2 representing an annual average growth rate of 2.3 percent. On the other hand, Maharashtra presents a marginal decline in the density of population within one km from the coast although the overall coastal district population density has increased. The density of population in Karnataka increased marginally for the coastal districts as a whole although there has been significant increase (53persons/km2) within one km from the coast. In Odisha the population of the coastal districts and density of population does not show significant growth.

The population density within one km shows an increase by 11 percent during 2001-2011. The substantial increase in the population density within one km of the coast over the last decade represents the increased risks to life and property in the event of any coastal disasters. The population density within one km of the shoreline in from Tamil Nadu has increased from 1280 to 1642 persons/km2. The rehabilitation and resettlement cost in the event of coastal erosion and other hazards would be enormous.

The data will be used for assessing the vulnerability of coastal population and as a measurement tool for analysing the average number of population that will be affected by any type of natural calamities like sea erosion, Tsunami, etc. This information would be an additional layer in the process of mobilising data for the ICZM process. As a next step, the census data will be extracted up to seven km from the shoreline to demarcate the area likely to be affected.

Consortium partner institutions & research program

Inventorisation and database creation on microbial diversity along Indian coast

Focal Point

Dr. Maitree Bhattacharya,
Department of Biochemistry, University of Calcutta, Kolkata

Coordinating Division at NCSCM:

Coastal and Marine Resources Conservation Division

Biodiversity is at present receiving increasing attention due to need of conservation and sustainable utilization. Investigations of Indian biodiversity records illustrate research gaps in coastal and marine biodiversity and its particularly true in case of microbial diversity. Indian coastal waters are extremely diverse due to geomorphologic and climatic variations along the coastline. Microbes form an important constituent of the marine ecosystem owing to their ecological roles in addition to the bio-prospective potential. The studies on their diversity carried out by various academic and research institutions are not available in public domain. The present study aims at inventorizing the microbial diversity on Indian coast and construct a detailed strategy for bridging the gaps. This study will form a knowledgebase to offer broad spectrum information about the coastal microbes which will provide insights into the microbial diversity, their temporal and spatial variation, and even changing profile.

Specific objectives

- To construct an inventory of the microbial diversity along the Indian coastline
- To identify lacunae in the existing knowledgebase
- To generate new database as a strategic measures to bridge this gap

The scope of the study would cover the entire Indian coast line including Islands represented by various ecosystems viz., mangroves, coral reefs, seagrasses, tidal mud flats, sea beaches and intertidal areas. In the first phase, the inventorization of existing biodiversity data would be undertaken. Secondary data would be collected from public domain using Pubmed, Scopus, J-Gate, while the microbial biodiversity data from unpublished sources like theses, dissertations, lab-reports and monographs would be retrieved by visiting the respective institutions. The strategies to bridge the lacunae in the knowledgebase will be prepared with detailed research approach and sampling plan.

During the subsequent phases, field and lab works would be undertaken for the ICZM areas viz., West Bengal, Orissa and Gujarat and for the rest of the coastal India including Islands. The microbial database created under this research study will be integrated with the CoMBINe database of NCSCM.

Coastal Profile: A Socio Economic Assessment of Coastal Resource Based Livelihood Activities for the Coast of Odisha

Focal Point

Prof. L. K. Vaswani, Director, KIIT School of Rural Management
KIIT University, Bhubaneswar – 751024

Coordinating Division at NCSCM:

Integrated Social Sciences and Economics Division

The study broadly intends to make a socio-economic assessment of livelihood activities which are significantly influenced by degradation of ecosystems, and in turn ecosystems services, and to identify unsustainable livelihood practices. The study focused on two coastal stretches - Gopalpur-Chilika and Paradip-Dhamra – known for their ecological wealth and economic activity.

Specific objectives

- To delineate socioeconomic profile of coastal communities
- To examine local communities perceptions on how changes in the biodiversity, ecosystems, and ecosystem services due to natural and anthropogenic causes have constrained their options for livelihoods
- To identify the vulnerabilities and adaptation options and strategies exercised by communities with changes in coastal ecosystem services
- To identify/segregate sustainable and unsustainable livelihood practices
- To understand the role of policies and welfare schemes in supporting sustainable livelihood practices and suggest actions to mitigate unsustainable practices
- To examine the linkages between livelihood security, infrastructure and development schemes

The research study was sanctioned in April 2014. An inception meeting with representatives of KIIT (Bhubaneswar) was organised and the work-packages and time-lines were discussed and the road map was finalized.

Assessment of Coastal and Marine Ecosystem Goods and Service: Linking Coastal Zone Management to Ecosystem Services in India – Consortium Component

Focal Point

1. **Dr. K. Kavi Kumar**, Professor (Environmental Economics), Madras School of Economics, Chennai
2. **Dr. Pranab Mukhopadhyay**, Goa University, Taleigao Plateau, Goa 403206

Coordinating Division at NCSCM:

Integrated Social Sciences and Economics Division

Madras School of Economics (MSE) and Goa University are the two consortium partners of NCSCM tasked with undertaking valuation studies of different coastal ecosystems across the country. The terms of reference to carry out the valuation studies across selected coastal ecosystems have been prepared and provided to both MSE and Goa University. The funds allocated for the two consortium partners have been approved and duly released to ensure appropriate work-packages are initiated as soon as possible. During the first Inception meeting it was agreed to that the

1. First deliverable would be macro-level estimates of services provided by coastal ecosystems identified in the CRZ notification. The values would be estimated using the meta-analysis approach and the report would be finalised by early February 2015.
2. Two ecosystems were chosen – Turtle Nesting Sites (Goa University) and Estuaries (Madras School of Economics) – for an in-depth valuation exercise owing to their ecological and social importance and the lack of valuation information globally.
3. Two stakeholder workshops and SWOT analyses are being planned identify important services provided by the two chosen ecosystems. ISE Division would assume lead role in coordinating the collection of both primary and secondary data including physical accounts of coastal resources, fisheries stock, household-consumption expenditure and tourism related data.

Appraisal of occupational hazards, entrepreneurial capacity and decision making role of women in coastal communities of India

Focal Point

Dr.J.D. Sophia, Principal Scientist, M S Swaminathan Research Foundation, III Cross Road, Taramani Institutional Area Taramani, Chennai – 600 113

Dr. V. Selvam, Senior Director, M S Swaminathan Research Foundation, III Cross Road, Taramani Institutional Area Taramani, Chennai – 600 113

Coordinating Division at NCSCM:

Integrated Social Sciences and Economics Division

MSSRF conducted comprehensive field studies five states namely Gujarat and Kerala in the west coast and Tamil Nadu, Andhra Pradesh and Odisha in east coast with the help of identified NGOs in each state. The sample villages and respondents were drawn by devising multi-stage sampling technique combining different sampling methods.

The primary data collected by MSSRF during 2011 was procured by NCSCM during February 2014 as suggested by World Bank and data analysis was done by ISE Division by keeping the following objectives:

- The contribution of fishing and related coastal ecosystem services to the family income.
- To quantify the direct economic benefits received and derived from ecosystems
- Decision making role of women in various paid and non-paid activities.
- Occupational health risks faced by women in their income generating and household activities

In addition to develop state-wise status report of the households and profiling fisherwomen based on various development parameters, the study also attempted to compare social status between the states. However, analysis of the data for Gujarat could not be undertaken due to the non-availability of coding sheets.

Methodology

The coded data files were used for analysis and comparative study across four coastal states of India viz. Kerala, Tamil Nadu, Andhra Pradesh and Odisha. Purposively, women representatives from the households were selected as respondents. The average household income of respondents of each state was divided into quartiles and named as an income group in following ways:

- Poor: Less than 1st Quartile
- Subsistence: Less than 2nd Quartile and Greater than 1st Quartile.
- Well off: Less than 3rd Quartile and Greater than 2nd Quartile.
- Rich: Less than 4th Quartile and Greater than 3rd Quartile.

The classification of households based on the respective state average income has been done since the conditions of poverty vary across the coastal states. The key parameters used in the analysis are household income, education, age at marriage, debt status, debt purpose, debt source, saving status, gender wise preference for saving institution, insurance status/ coverage, state govt. insurance entitlement, assets ownership, sanitation availability and its use, health status, access to different health services, reasons for not using govt. health facilities, avg. household income w.r.t. different fishing areas, avg. daily income from fishing and non-fishing sector, status of fisherman, status of fisher women in decision making, participatory role of women in fishing activities.

Analysis of data reveals that the socioeconomic status of the households as measured by some of the above parameters are that intensity and relative proportion of poverty is relatively high in Odisha compared to coastal villages of Tamil Nadu and Kerala, especially in education, health services, age at marriage, sanitation facilities and insurance, apart from their household income. A Brief summary of results from analysis of all the coastal villages of TN, Kerala, Andhra Pradesh and Odisha is given below:

Table 1. Average monthly household income of respondents in different income group across the states

Particulars	TN	Kerala	AP	Odisha	Total
Sample Size	1137	943	2002	1477	5559
Average Household Income (Rs.)	8005	7969	3026	4910	5978
1st Quartile (Rs.)	4500	3900	2000	3000	2500
2nd Quartile (Rs.)	7100	6500	3000	4200	4000
3rd Quartile (Rs.)	10800	11000	4000	6000	6200
Coefficient of Variation	0.58	0.66	0.42	0.6	0.75

The results indicate that 60 percent of all respondents are illiterate. Of the total respondents, 55 percent have married before attaining the age of 18 yrs. The analysis shows that 70 percent of all respondents' family are in debt. Loans are procured more by the female members of a family compared to male members as the former are considered more likely to return the debt amount on time. Three-quarters of the respondents have savings and Self Help Groups (SHG) is a preferred savings institution compared to any other. Of the people who save, 50 percent have their savings registered under their name. It was observed that 31 percent of respondents reported to having some form of insurance coverage. The results also indicate that just over 35 percent of all respondents reported to having sanitation facilities but of the respondents that possess sanitation, 80 percent of them are not using it due to lack of maintenance and scarcity of water. As per the standard body-mass index, a quarter of all respondents are found to be underweight. But for the coastal villages in Odisha, half of all respondents are found to be underweight. Long distances and the lack of effective treatments in Government healthcare are among the most cited reasons for not visiting Government healthcare centres. Among the women respondents who answered to the question on the occupation of their men, it was reported that 43 percent are dependent on deep sea fishing, 37 percent in traditional and 20 percent in motorised fishing capable of reaching fishing grounds up to 20-30 nautical miles. The data indicates that 50 percent of all respondents have reported that their decisions are limited to only non-productive work whereas decisions regarding productive work are taken by other members (i.e. male) of the family. It was observed that 40 percent of respondents reported that other members in family play an important participatory role in fishing activities whether it is a preparatory task, post harvesting or it is marketing of fish catch.

International Research Programs

BELMONT FORUM

National Centre for Sustainable Coastal Management (NCSCM), under a Memorandum of Understanding (MoU) with the BELMONT FORUM has undertaken two research studies 1. DELTAS and 2. TRUC, focusing on the resilience and coastal vulnerability of the Deltas and Urban Coasts.

DELTAS: Catalyzing action towards sustainability of deltaic systems with an integrated modeling framework for risk assessment

Deltas are economic and environmental hotspots, food baskets for many nations, and home to a large portion of the world population. They sustain rich, bio-diverse ecosystems and related services. Most deltas are also international and regional transportation hubs that support intense economic activity. Yet, deltas are deteriorating at an alarming rate due to climate impacts (e.g., sea level rise and flooding), human-induced catchment changes (e.g., water and sediment flow reduction), and local exploitation (e.g., sand, groundwater, and hydrocarbon extraction). The international science community recognizes the need to develop a solid knowledge base for protecting these vulnerable coastal systems, and this BF initiative leads the way by coordinating and enhancing innovative international work towards the development of a science-based framework for delta sustainability.

The project will develop a versatile modelling framework that may be applied from local to national levels to evaluate the unique functioning, critical stressors, and vulnerability of the world's deltas. The framework will ingest social, economic, physical and ecosystem data into an open-access repository and will allow planners to model and deliver optimized, viable solutions for their region. In areas for which detailed data are sparse, an infrastructure for critical data gathering will be developed and modelling and prediction tools will be customized. The framework will initially be applied to three case-studies for which local and regional partnerships are already in place, including the Ganges-Brahmaputra-Meghna (GBM), Mekong, and Amazon deltas.

Why Deltas for a Belmont Forum Initiative?

River deltas around the world are economic and environmental hot spots occupying approximately 1% of the Earth's land area but housing more than 500 million people, rich in biodiversity, and high in economic productivity. Yet, deltaic systems are among the world's most delicate and vulnerable socio-ecological systems, residing at the boundary between land and water, and subject to upstream human control, local resource exploration, and climatic impacts (e.g., IPCC, 2007, Fig.. 1). As important areas for agriculture and fisheries production, deltas play a major role in national, regional and global resource chains. For example, as "rice bowls" to the world, deterioration of the mega deltas of Asia poses serious threats to food security for the more than half of the world's population that relies on rice as a staple food (Hoanh et al., 2010). These human dimensions and ecological implications of deteriorating or disappearing deltas cannot be overstated. There is an urgent need to rally the international community for a focused effort toward a holistic physical-socioeconomic understanding of deltas as vulnerable systems undergoing change. Such understanding is a basic requirement for their long-term management, protection, and restoration. Recognizing this need, the Belmont Forum has identified coastal vulnerability as a focused priority, with an overarching goal "to deliver knowledge needed for action to mitigate and adapt to detrimental environmental change and extreme hazardous events" (cf. ICSU, 2010).

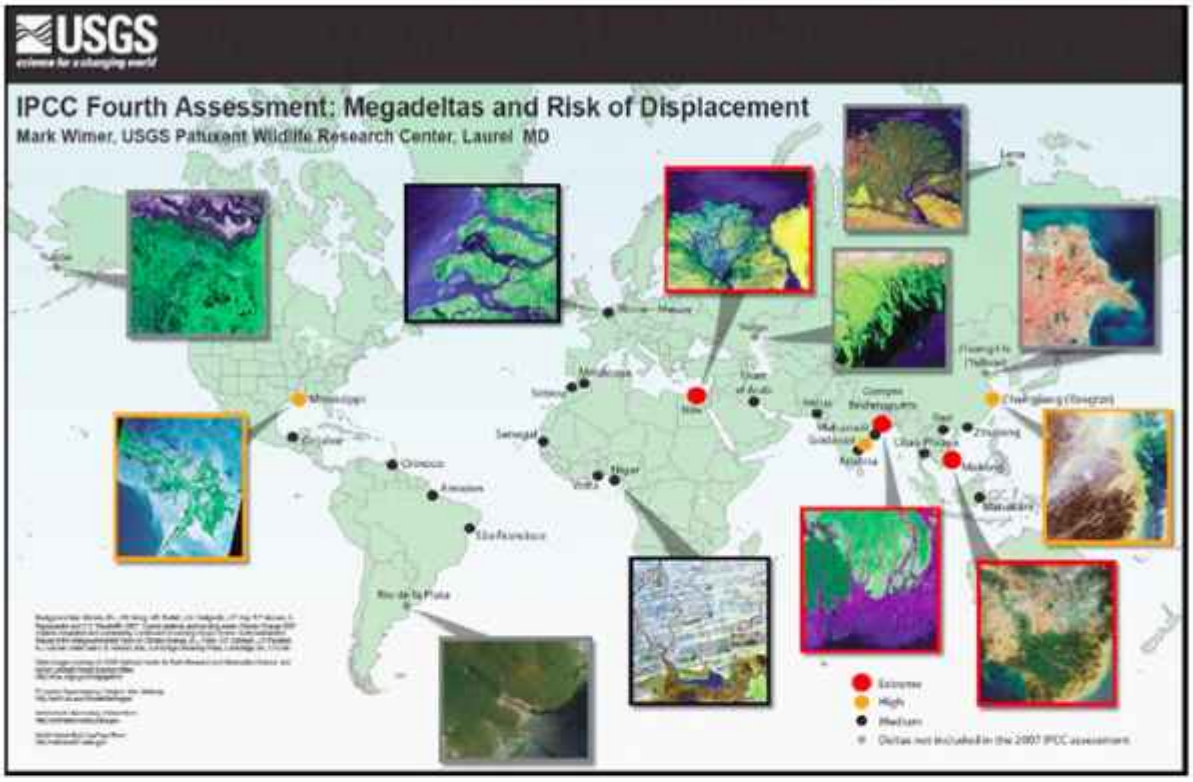


Fig. 1. Mega deltas around the world were identified in the 4th IPCC report as one of the most vulnerable environments threatened by climate and human-induced changes.

Research Plan of Deltas

The overall goal of the BF-DELTAS project is to unify our scientific understanding of deltas as coupled socio-ecological systems and to develop a science-based integrative modeling framework that can be used to assess delta vulnerability and guide sustainable management and policy decisions at the regional and local scales. The main premise of the proposed work is that although each delta is unique, integrative frameworks that capture the socio-ecological working of these systems can be developed and encapsulated in decision support tools which can be adopted locally, in collaboration with regional experts and stakeholders, for sustainable delta management.

The specific objectives (and components) of the proposed research (see Fig. 2) are:

Objective 1. Advance sustainability science for deltas **(Delta-SRES)** by developing a theoretical framework for assessing delta vulnerability and the possibility for transitions to undesired biophysical or socio-economic states under various scenarios of change.

Objective 2. Co-develop, in close collaboration between scientists and stakeholders, an open-access, science-based, integrative modeling framework called the Delta Risk Assessment and Decision Support Tool **(Delta-RADS)**, which can operate at a regional level and provide a quantitative basis for investigating and comparing scenarios and trade-offs for decision making.

Objective 3. Consolidate and make readily available relevant data on bio-physical, social, and economic parameters **(Delta-DAT)**, which can be used by the community at large to assess critical parameters, compute vulnerability metrics, and provide input data to the Deltas-RADS modeling framework.

Objective 4. Develop Global Delta Vulnerability Indices **(Delta-GDVI)** that capture the current and projected physical-social-economic status of deltas around the world ("delta vulnerability profiles"), which will serve to identify and support the critical needs and priorities for research, funding, and action.

Objective 5. Work with regional teams and stakeholders to put the products of Objectives #1-4 into action **(Delta-ACT)** by demonstrating the implementation of the developed framework to three major deltas with diverse physical-social environments: the Ganges-Brahmaputra-Meghna (GBM), Mekong, and Amazon deltas.

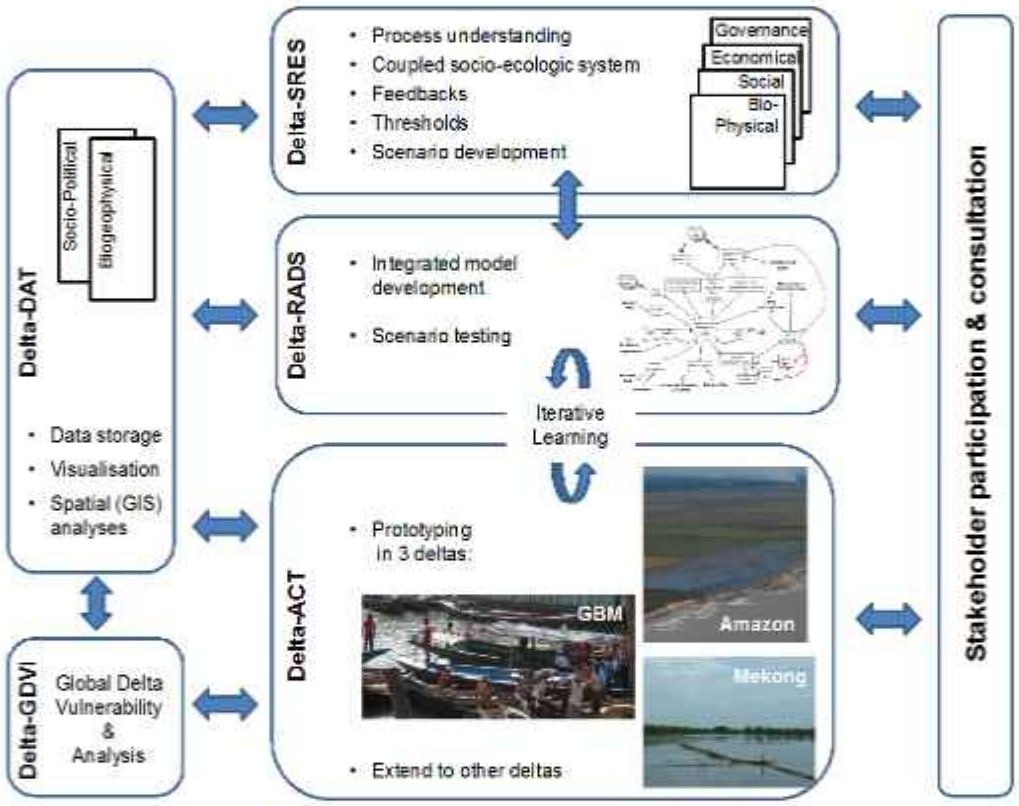
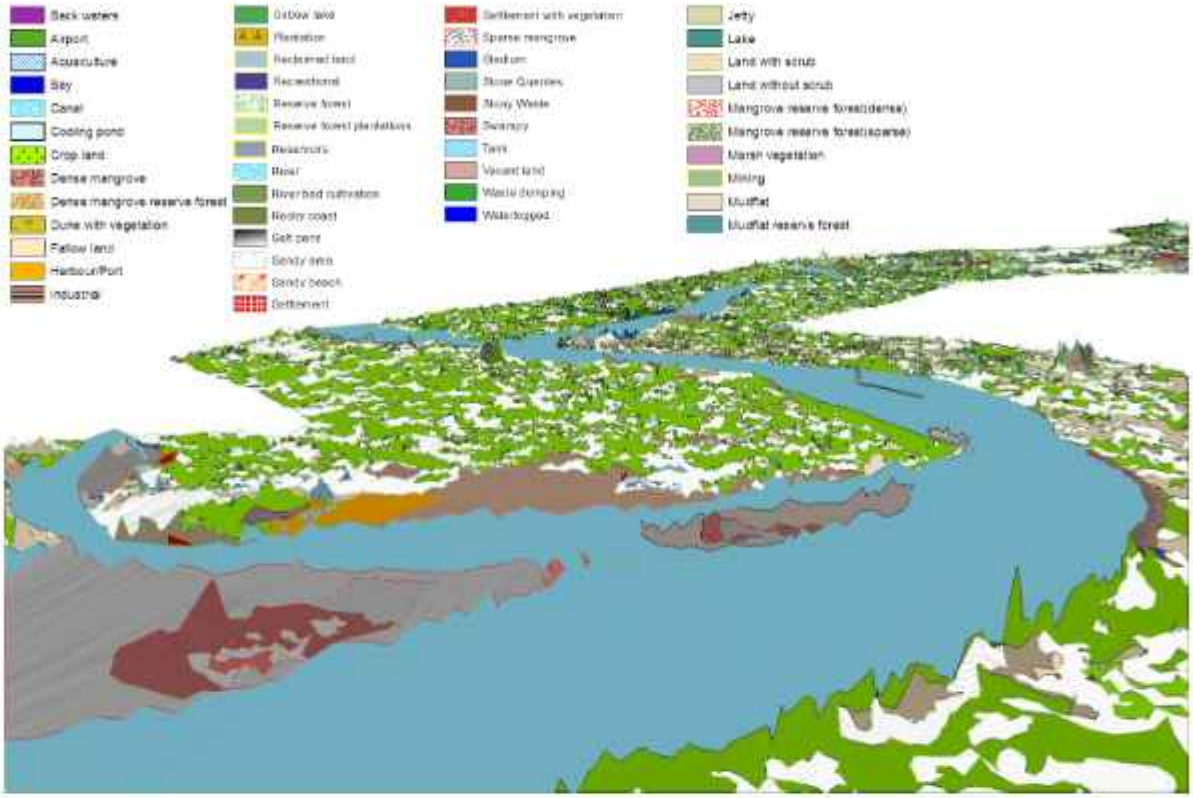


Fig. 2. Key components of the BF-DELTAS project, whereby deltas are treated as fully coupled socio-ecological systems and scientist-stakeholder feedback is emphasized at all levels. The bidirectional arrows indicate the interconnectivity of tasks toward achieving the goal of the project.

Significant Results

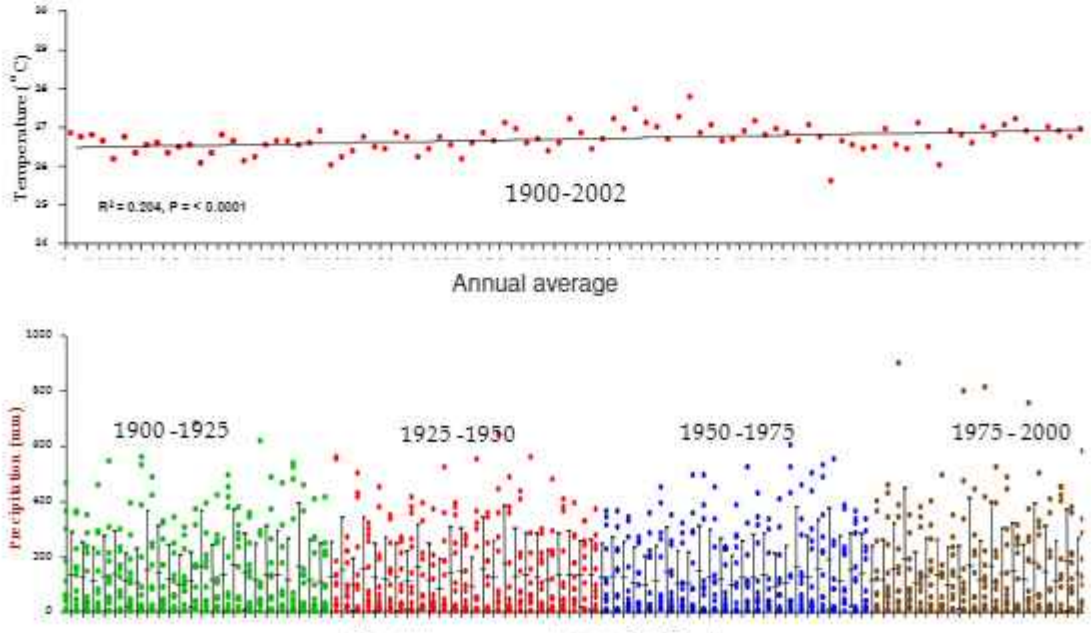
The most important activities under the research study pertaining to the Ganga-Brahmaputra-Meghna Delta are as follows;

***SRTM Topographic data*:** The SRTM data from the Gangetic delta has been collected and elevation map is prepared. The maps need to be validated at field with RTK GPS/Total station datasets. The vulnerable areas along the delta will be classified based on the topographic datasets.



***Demography and socio-economic*:** The census data on socio-economic and demographic variables for 3 decades e.g. for the year 1991, 2001, and 2011 is collected and compiled for the coastal villages of deltaic region from Farakka Barrage to downstream Hooghly estuary. The collected data shall be incorporated in the Geospatial data platform.

Climatic variability: Climatic variability on temperature and precipitation for 100 years from year 1900 to 2001 is collected and analysed to know the climate change effects in the 11 dist of Gangetic delta. For example, the analysed data for Kolkata district is given below.



Mapping ecosystem dynamics: The time series multilayer satellite imagery are being processed for the land use/land cover (LU/LC) map of Gangetic delta. The mangrove decline, land loss due to erosion, coastline change, urban development, etc shall be determined by analysing the time series LU/LC map of 30 years from 1990, 2003, and 2013.

Data assimilation on ecosystem dynamics: The bio-physical, ecological, geomorphology, and climate data from the Gangetic delta region shall be compiled in a IT- enabled GIS modelling system.

FAST-TRACK PAPERS (FTPs)

As a part of the research study, the following contributions are made for the preparation of Fast Track Papers by the BF-DELTA group.

FTP 1. Recent trends in the GB, Mekong, and Amazon deltas: climatic, ecological, geomorphological, and economic trends.

Contribution: *Climatic variability and deltaic ecology in Ganges.*

FTP 2. Who are the delta people in the GB, M, and A deltas?: demographic and socio-economic trends.

Contribution: *Demographic and occupational changes in Ganges delta.*

FTP 3. Modelling approaches in deltas: hydro-eco-geomorphologic aspects and links to ecosystem services and human dimension.

Contribution: *Nutrient conservation dynamics in Ganges delta using LOICZ and NANI model.*

TRUC: Transformation and Resilience on Urban Coasts (TRUC)

Transformation opens new opportunities for living with risk where existing systems are generative of vulnerability and hazard or where preventing systems failure is impossible, it also recognises the cultural specificity of resilience and transformation where change or stability may benefit some actors more than others, now and in the future. The relationship between resilience and transformation is arguably most acute on highly urbanized coasts where interactions between concentrated human activity and environmental dynamics are at their most intensive and transformations can be observed. TRUC is focussed on this relationship in five coastal megacities: Kolkata, Lagos, London, New York and Tokyo.

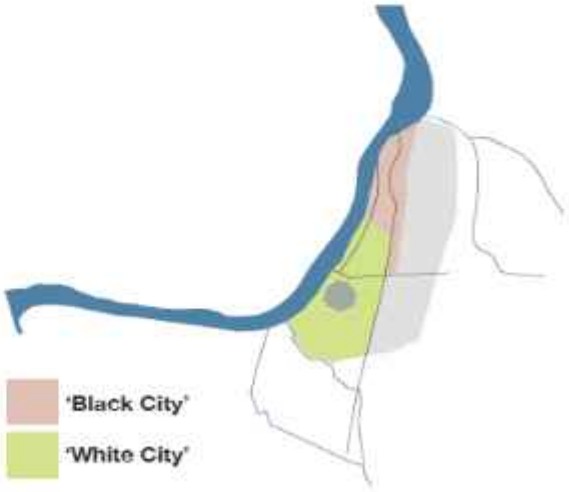
TRUC will build an original integrated, participatory framework in collaboration with stakeholders to first characterise and then identify interactions between bio-physical, land-use and decision making processes. The aim is to reveal the pathways and trade-offs through which systems interactions constrain or open opportunities for resilience or transformation how these outcomes themselves interact and influence sustainable development; offering scope for considerable theoretical, methodological and practical advancement. TRUC combines models developed by consortium members: an integrated urban energy and water balance model (SUEWS), a global anthropogenic heat flux model (LUCY) and a scenario modelling methodology developed by UNU. Work will be at the city level and drill down to the city region/community level. NCSCM research study will be focused on the megacity Kolkata.

Research Plan of the BF-TRUC

TRUC will develop and test an integrated, participatory framework combining three existing analytical tools. It aims to assess the interaction of biophysical, land-use and adaptive management systems in highly urbanized coasts at risk from natural hazards (flood and temperature). Urbanized coasts lie within 50m elevation and 100km distance of mean high water (UNEP 2005). The TRUC approach will be applied to Tokyo, New York, London, Kolkata (and Lagos, in the German partner application), totalling 110million people at risk.

The major objectives of the of the BF-TRUC research study are:

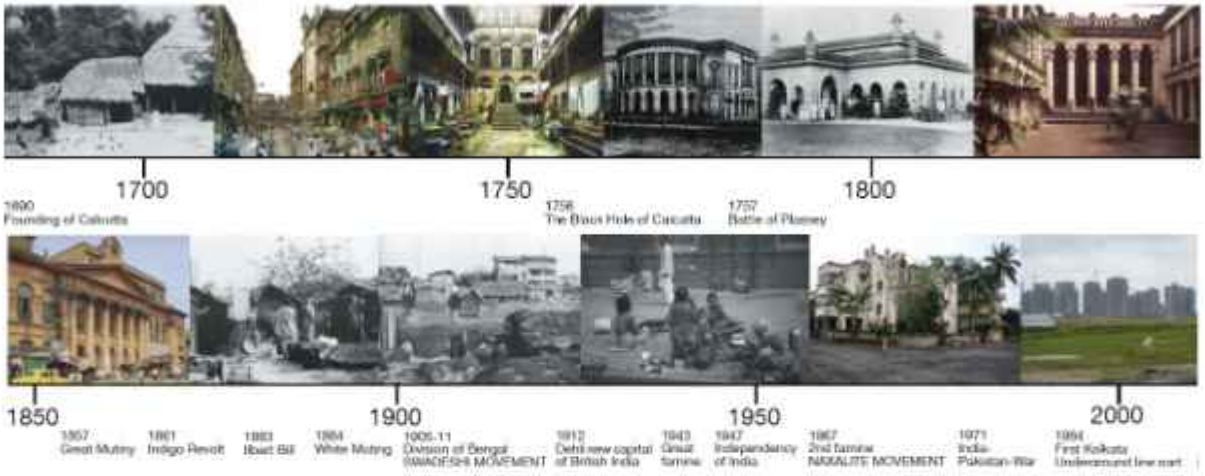
- Conceptualise resilience, transition and transformation for urban sustainability and security.
- Develop and test an integrated approach for biophysical and social vulnerability assessment.
- Provide space for stakeholders, researchers and students to reflect on urban development and risk management priorities and approaches.



Spatial transformation of Kolkata

- Comparing colonial distribution of spaces
- Former White town - large buildings, open spaces – tourist spots – gets special attention from government
- Former Native town (Black town) – larger part of KMC – high population density – mixed land use pattern – high slum population
  - Narrow lanes, inadequate space, traffic congestion, fire outbreaks etc

Housing History of Kolkata City



Population Growth in Kolkata City

Population Growth

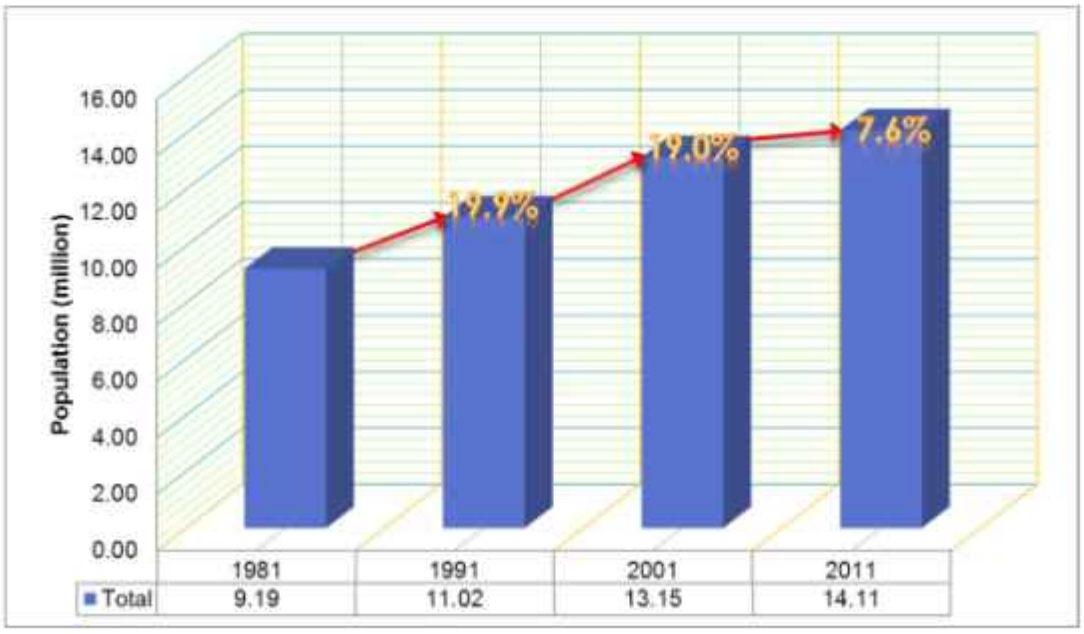
Settlement Typology

Kolkata is India's 3rd largest megacity and 8th largest Urban Agglomeration.

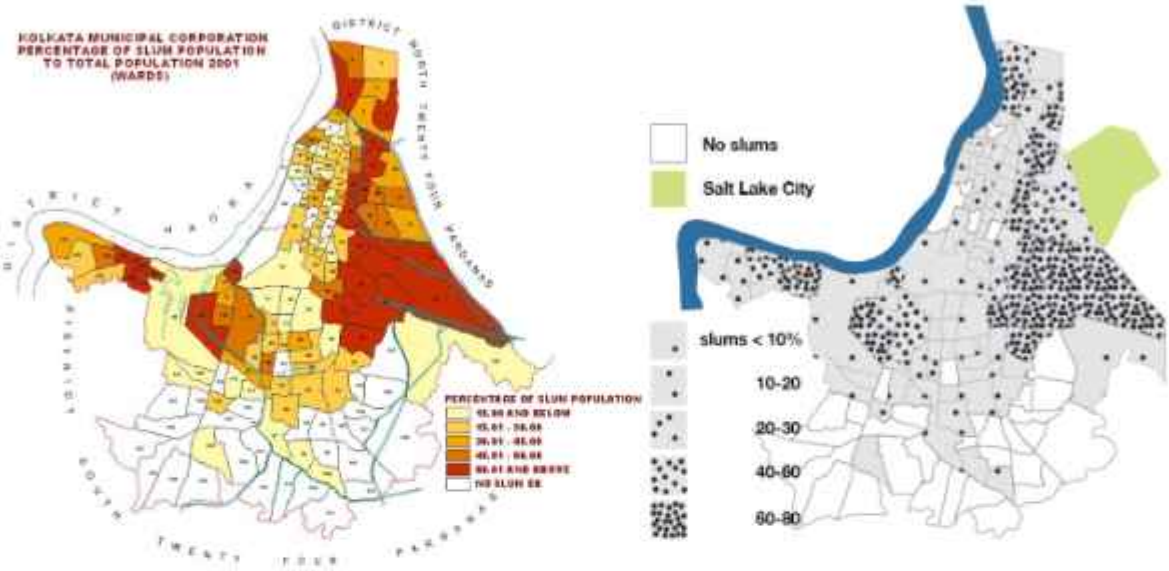
Location	Area	Population (million)	Population Density (km²)
West Bengal	88752	80.0	904
Kolkata Metropolitan Area	1852	14.7	7950
Kolkata Municipal Corporation	187	4.6	23149

Urban Development Trends and Drivers for Population growth

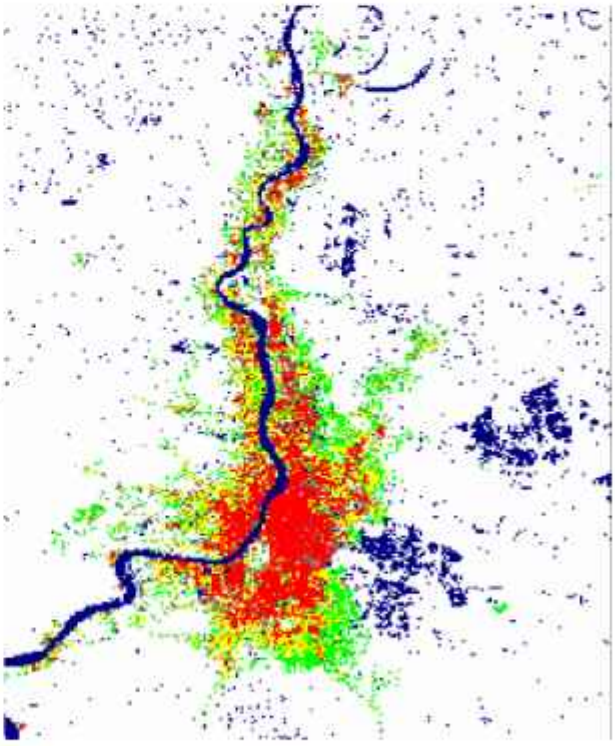
- Headquarters of British Indian government;
- Refugee influx 1940s, 1970s during partition, liberation of Bangladesh; Kolkata
  - Urban Area is important as it received 54,509 persons from other countries, most likely Bangladesh (Migration data, Census 2001)
- Only important city in east India.
- Oldest major port; only riverine port – serves a vast hinterland
- Industries – relatively low- jute manufacturing, light and heavy engineering, leather, textiles etc.



Slum Distribution in Kolkata



Areas of Increased Development



- Map of urban growth around Kolkata
- Red coloured area indicates high growth
- Yellow colour indicates moderate growth and
- Green indicates low growth
- Blue patches are water bodies

Governance for Disaster Management

West Bengal Disaster Management Department

- WB State Disaster Management Policy and Framework, Department of Disaster Management
- Disaster Management Plan: West Bengal (2009-10)
- Police Commissioner and Team
- The Fire Brigade (renamed as Emergency Services) with its network of fire stations
- Strong media influence; multiple radio (FM) channels
- Many educational institutions (Jadavpur University, Calcutta University, WB Institute of Juridical Sciences, Indian Institute of Management; Also HQ of Zoological Survey if India, Indian Statistical Institute)
- The role of science in decision-making/framing –
  - Jadavpur University –Disaster Management Plan for West Bengal; Climate Change Adaptation framework for Kolkata UAA

Events and Recognitions

Workshop / Conferences / Short Courses (2013 – 2014)

31 – 12

MARCH - APRIL 2014

Ecosystems – Governance and Services

This Indo- Dutch training program was conducted to build a nexus between Ecosystem Services and principles of governance. A batch of 15 masters students from the University of Amsterdam and Anna University participated in the program.

Venue: NCSCM, Chennai

22

APRIL 2013

A Roadmap towards Coastal Sustainability

This workshop was aimed to highlight the importance of Integrated Coastal Management process with sustainability as its central theme. This workshop was attended by policy makers, Ministry officials and officials of the state project monitoring units.

Venue: SCOPE Building, New Delhi

27 – 01

MAY - JUNE 2013

Short Course on ICZM

The goal of this course was to provide a comprehensive overview on Integrated Coastal Zone Management. The NCSCM provided technical support in organizing capacity building program for coastal managers.

Venue: College of Fisheries, Mangalore

2 –3

SEPTEMBER 2013

Coastal Ecosystem Health

This workshop focussed on the issues related to Marine National Park (MNPs) and Sanctuary, Gulf of Kachchh, Gujarat summarizing the coastal ecosystem well-being.

Venue: Jamnagar, Gujarat

5 – 6

SEPTEMBER 2013

Cumulative Environmental Impact Assessment for Gulf of Kachchh, Gujarat

This workshop on Environmental Impact Assessment helped in evaluating and understanding socio-economic, cultural and human-health impacts specifically to the Kachchh region.

Venue: Gandhinagar, Gujarat

10 – 13

DECEMBER 2013

Small- Scale Fisheries Governance: Development of Wellbeing and Sustainability

This international conference brought together the fishing community, issues of Governance (accountability & access), wellbeing and sustainability. NCSCM sponsored the session on sustainability and NCSCM scientists took part in the presentations and sessions.

Venue: CESS, Hyderabad

Expert & Stakeholder Consultations

24 JUNE 2013

Impact of large scale cultivation of Seaweeds on coastal environments

The expert consultation was organized as part of the seaweed research and it focussed on the cultivated species around Palk Bay and its impact on coastal environment.

28 JUNE 2013

CoMBINe – Coastal and Marine Biodiversity Integration Network

The scope of this meeting was to outline the conceptual framework, methodology, to build a National Architecture and Roadmap for CoMBINe.

8 OCTOBER 2013

ESAs Mapping – I

This expert consultation meeting was part of the on-going national level research study on delineating ESAs and CVCAs. The discussions focussed on using mapping techniques to delineate Sand Dunes, Rock cliffs, Archaeological and Heritage sites.

10 – 11 OCTOBER 2013

ESA Mapping –II

As part of the on-going national studies, consultation meeting was held seeking expert suggestions on the methods to be adopted for delineating coral reefs, mangroves, sea grass, seaweeds and littoral forests.

21 OCTOBER 2013

ESA Mapping – III

As part of the series of expert consultations on mapping and delineating of coastal/marine ESAs the second expert consultation meeting was organized with focus on physical features of coastal ecosystems such as mudflats, salt marshes and lagoons. Biological species like Horseshoe crab habitats bird and turtle nesting grounds.

22 OCTOBER 2013

Status of Erosion Line Mapping

The review of work completed and in progress on erosion line mapping was the task of this consultation meeting

19 DECEMBER 2013

Finalization on Delineation of Sub cells

The purpose of this meeting was to finalise the delineation of sub cells in the mapping process.

29 JANUARY 2014

Linking Coastal Zone Management To Ecosystem Services

An expert consultation workshop was organized to identify the research areas, methodological framework and prioritising ecosystem services for quantification by evaluating coastal/ marine ecosystem services.

26 APRIL 2014

Delineation of sediment cells along the West and East coasts of India

A technical review committee meeting was organized to review the progress of delin eation of sediment cells along the West and East coasts of India.

Community Interactions:

25– 26 SEP 2013

Wellfish Study

This meeting was conducted to encourage and facilitate community participation and feedback towards the Wellfish Study.

Venue: Rameshwaram, Tamil Nadu

17 FEBRUARY 2014

Mapping of Fishing Spaces

The stakeholder consultation workshop was organized to plan the activities on mapping of fishing spaces with stakeholders.

Venue: Nagercoil, TamilNadu

17 MARCH 2014

Mapping of Fishing Spaces

This Consultation workshop was part of the state wise stakeholder meetings to plan the mapping of fishing spaces with stakeholders.

Venue: Suratkal, Karnataka

Recognitions

The NCSCM scientists worked as research supervisors for the students of Institute for Ocean Management (Department of Civil Engineering) Anna University (2013–14):

M. Tech Coastal Management

Name	Title of the Thesis	Supervisor
C. Viswanath	Application of Geospatial Technologies for assessing noise pollution due to multiple sources in a fast developing landscape	Prof. Dr. R. Ramesh, Director
M. Vani	Effect of Brine Dispersion on coastal regions using Dispersion Model: A case study on Tamil Nadu Coast	
M. Rubila Jasmine	Effect of seasonal winds on wave characteristics along the east coast of India using SWAN model -	
S. Pushpalatha	Cumulative Impact Assessment of air pollution in North Chennai by using GIS and Interaction Matrix	
C. Viswanath	Application of Geo-Spatial Technologies for assessing noise pollution due to multiple sources in a fast developing landscape	
R. Nagalakshmi	Change detection analysis of Vedaranyam coastal wetland and impact on Mangrove dependent community	Dr. Ramachandra Bhatta and Dr. Kakolee Banerjee
G.R. Gururaja	Assessment of ecological and economic impacts of natural collection of Alginophytes in Gulf of Mannar	Dr. P. Krishnan
A. Ponmozhi	Assessment of Ecological and economic impacts of large scale cultivation of Carragenophytes in Palk bay	
J.R. Rajapriyadharshni	Oil Spill Trajectory Forecast with the aid of GNOME	Dr. S. Rajakumari
S. Revathi	Mapping onshore flooded areas and identification of flood prone areas using DEM in Odisha Coast	
S. Vasudevan	Remote sensing and GIS technique to delineate coastal aquaculture sites from Muttukadu to Puducherry, Tamil Nadu	Dr. K.J. Sarunjith
M.H. AtheesYasin	Mapping of mangroves and assessing Carbon Sequestration Potential in Pichavaram mangroves using Remote Sensing	Dr. Gejo Anna
G. Sudharson	Spatial Dynamics and Prediction of change in a coastal area using Remote Sensing and GIS	Ms. Mary Divya Suganya
K. Balamurugan	Numerical Simulation of ship stability for Beam Sea Environment	Mr. U. Saravanan
K. Kasiram	Assessing the impact of industrialisation at Gulf of Kachchh – A Modelling Approach	
R. Mano	Estimation of carbon footprint on road project NH–68	Dr. Kakolee Banerjee

Ph. D students Guided by Prof. R. Ramesh: completed in 2013-2014

Name	Title of the Thesis
Ms. Jennifer Immaculate Divya	Influence of terrestrial inputs on mangrove and coral reef primary productivity of the Andaman Islands
Mr. A. Paneer Selvam	Metal Speciation and its Bioaccumulation study in Vembanad Lake
Ms. S. Laxmi Priya	A Biomarker approach for assessing toxicity in marine organisms
Mr. Sandeep Saxena	Disaster Risk Reduction – Mitigation and preparedness in coastal region of state of Tamil Nadu
Mr. G. Hariharan	Bio-accumulation of pesticides and radionuclides in marine organisms

Participation of Scientists in Events

(a) Training Undergone - (i) International

Name	Training	Organized by	Date
C. R.Sreeraj	Taxonomy training program "Basics of taxonomy: describing, illustrating and communicating biodiversity"	Distributed European School of Taxonomy (DEST) at Sven Loven Centre for Marine Sciences, Kristineberg, Sweden	14 - 25 Oct 2013

(a) Training Undergone – (ii) National

Name	Training	Organized by	Date
S. Rajakumari K. O. Badarees G. Gejo Anna G. Mary Divya Suganya R. Muruganandam B. Deepika R. Madhumitha K. J. Sarunjith	Training on ArcSDE10.1 software	ESRI India Pvt Ltd., Chennai	11 - 13 Apr 2013
	Training on "Introduction to ENVI 5 Image Processing Software"	ESRI India Pvt Ltd., Chennai	17 - 19 Jun 2013
	Training on "Introduction to ArcGIS Server 10.1	ESRI India Pvt Ltd., Chennai	20 - 21 Jun 2013
	Training on RTK GPS	Janak Positioning and Surveying System	17 - 19 Jul 2013

Name	Training	Organized by	Date
R.Muruganandam S.Sathishkumar	Oracle 12C launch	Oracle India Ltd, Chennai	2 Aug 2013
S. Rajakumari K. O. Badarees G. Gejo Anna G. Mary Divya Suganya, R. Muruganandam B. Deepika R. Madhumitha K. J. Sarunjith	Training on Robotic Total Station and Handheld GNSS RTK GPS.	Aimil instrumentation and technologies, Chennai.	7 Aug 2013
S. Rajakumari K.O. Badarees G. Gejo Anna G. Mary Divya Suganya R. Muruganandam B. Deepika R. Madhumitha K. J. Sarunjith	Training on Erdas Appolo Server	Intergraph Geospatial Ltd., Hyderabad	12 - 13 Aug 2013
Debasis Tudu	Training in Ecosystem modelling	ICMAM	19 - 23 Aug 2013
Margi Purohit Manik Mahapatra Priya Rajiv	Training Programme on Integrated Coastal Zone Management	Administrative staff college of India (ASCI) & sponsored by Society of Integrated Coastal Management (SICOM), MoEF, New Delhi	02 - 06 Sep 2013
G. Mary Divya Suganya B. Deepika	Refresher course on ICZM	College of Fisheries, Mangalore	28 - 31 Oct 2013
Dipnarayan Ganguly Kakolee Banerjee	Eddy Covariance training at IISc Bangalore	LICOR, Indian Institute of Science (IISc), Bangalore	20 - 22 Nov 2013
P. Naren Priya Rajeev	Data Analysis Using SAS	National Academy of Agricultural Research Management And Tamil Nadu Veterinary and Animal Sciences University	25 - 30 Nov 2013
V. Deepak Samuel K.R. Abhilash R. Sankar	SCUBA - Open Water Diving, PADI certification	Temple Adventures Pondicherry	04 - 08 Dec 2013

Name	Training	Organized by	Date
Debasis Tudu U. Saravanan G. Hariharan	SCUBA - Open Water Diving, PADI certification	Temple Adventures Podicherry	23 - 26 Jan 2014
K.G. Ananda Kumar	Training on Contract Labour Regulation Act	MSME – Development Institute	28 Jul 2013
K.G. Ananda Kumar Alok Ranjan Samal	Training on TDS & Remuneration Planning	Princeton Academy, Chennai	25 Oct 2013
K.G. Ananda Kumar	Training on Right to Information Act & Citizen Charter	Integrated Training & Policy Research	16-18 Jan 2014
Alok Ranjan Samal	Training on World Bank Procurement Procedure	National Institute of Financial Management	17-28 Feb 2014
Alok Ranjan Samal	Training on Tax Regulation	NIIT Imperia & KPMG	28-June-2014 till Oct 2014 (twice a week)
K.G. Ananda Kumar	Training on Disciplinary Rules & Procedures	National Academy of Human Resource Development	11-14 June 2014

(b) Workshop/Seminars/Meetings (outside NCSCM)

Name	Workshop / seminars / meeting	Role	Organized by	Date
R. Ramesh Purvaja Ramachandran	Workshop-cum-Training Program on Integrated Coastal Zone Management Planning and Shoreline Management of Odisha	Resource Person	SPMU, Odisha	26 Apr 2013
Ramachandra Bhatta P. Krishnan		Participant		

Name	Workshop / seminars / meeting	Role	Organized by	Date
R. Ramesh	IGCP 588 conference	Resource Person	IUGS UNESCO, Earth Observatory of Singapore, Nanyang Technological University, Singapore and NCSCM	20 - 24 May, 2013
P. Krishnan R. Sridhar K.R. Abhilash C.R.Sreeraj V. Sachithanandam R. S. Robin Dipnarayan Ganguly T. Mageswarn Manik Mahapatra R. Sankar		Presenter		
Purvaja Ramachandran B. Nagarajan S. Rajakumari V. Deepak Samuel Gurmeet Singh Kakolee Banerjee A. Paneer Selvam		Participant		
R. Ramesh	Training Workshop on ICZM at Mangalore	Resource Person	Karnataka Veterinary, Animal & Fisheries Sciences University and College of Fisheries and NCSCM	29 - 30 May 2013
Purvaja Ramachandran Ramachandra Bhatta P. Krishnan Kakolee Banerjee		Participant		
B. Deepika	Lecture on "Spatial Mapping of Coastal Resources"	Participant	College of Fisheries, Mangalore	30 May 2013
P. Krishnan	Indo-German Biodiversity Programme on Conservation and Sustainable Management of Existing and Potential Coastal and Marine Protected Areas	Presenter	GIZ and MoEF	05 - 06 Jun 2013
Ramachandra Bhatta Priya Rajeev	Workshop on welfare measures for marine fisher folk in Tamil Nadu-Design and Implementation issues	Participant	Public Affairs Centre, fish MARC, ANSA	17 Jun 2013
V. Deepak Samuel Margi Purohit	International Workshop on Mangrove Conservation	Participant	Gujarat Ecology Commission	26 - 27 Jul 2013

Name	Workshop / seminars / meeting	Role	Organized by	Date
R. Ramesh Purvaja Ramachandran	Science workshop on Coastal Ecosystem Health Report Card for Marine National Park and Sanctuary (MNPs), Gulf of Kachchh, Gujarat	Resource Person	Gujarat Ecological Commission (GEC), Marine National Park, Jamnagar - Gujarat	02 - 03 Sep 2013
Ajay Kumar Ray R.S. Robin S.Yogeshwari Debasis Tudu U.Saravanan Kakolee Banerjee V.P. Sathiya Bama		Participant		
R. Ramesh Purvaja Ramachandran Ajay Kumar Ray R.S. Robin S.Yogeshwari Debasis Tudu U.Saravanan	Science workshop on A Framework for Cumulative Environmental Impact Assessment for the Gulf of Kachchh, Gandhinagar, Gujarat	Resource Person	Gujarat Ecological Commission (GEC), GEER Foundation , Gandhinagar	5 – 6 September 2013
V. Deepak Samuel S.Yogeshwari Priya Rajeev	Participation in village feedback workshop: Wellfish Project, Rameswaram	Participant	Wellfish Project: University of Northumbria and NCSCM	26 September 2013
P. Krishnan	GIZ Consultative Workshop on Conservation and Management of existing and potential MPAs	Participant	GIZ, New Delhi	05 - 06 Sep 2013
T. Mageshwaran	National Seminar on "CRZ Mapping: Issues & Concerns"	Participant	Andhra Pradesh State Remote Sensing Application Centre (APSRAC)	08 Oct 2013
Ramachandra Bhatta P. Krishnan	Refresher course on Integrated Coastal Zone Management (ICZM)	Resource Person	College of Fisheries, Mangalore	28 - 29 Oct 2013
G Mary Divya Suganya B. Deepika		Participant		
V. Deepak Samuel	Invited Talk –Candidate species for Marine and Freshwater ornamental fishes	Resource person	Dept. of Biotechnology, Sathyabama University, Padur, Chennai in collaboration with MSME	13 Nov 2013
Ramachandra Bhatta	Seventh Biennial Conference of The Indian Society for Ecological Economics	Resource person	Tezpur University, Assam	05 – 08 Dec 2013

Name	Workshop / seminars / meeting	Role	Organized by	Date
Ramachandra Bhatta V. Deepak Samuel	International Conference "Small-Scale Fisheries Governance: Development for Wellbeing Sustainability"	Panellist	CESS, TBTI and ISAM, Hyderabad	11 Dec 2013
V. Deepak Samuel	Training Programme on species conservation plan of Dugong & Sea turtle conservation programme	Resource Person	The Wildlife Warden, Ramanathapuram	23 Dec 2013
P. Krishnan	Training Workshop on Integrated Coastal Zone Management (ICZM)	Resource Person	Zoological Survey of India, Digha.	05 Jan 2014
V. Deepak Samuel	National level conference on "Zoology for future education and research"	Chair Person	Queen Mary's college, ZSI SRC and MBRC	23 Jan 2014
P. Krishnan	Consultation on Development of Augmented PFZ Advisories for Islands	Resource Person	Central Island Agricultural Research Institute, Port Blair	27 - 28 Jan 2014
P. Krishnan	National Conference on "Advances in marine biosciences and technology – Current status, prospects and challenges"	Resource Person	AMET University Chennai	14 Mar 2014
P. Krishnan	Indo-Dutch Course on Ecosystem Governance and Services	Resource Person	Institute for Ocean Management (IOM), Anna University at NCSCM	31 Mar - 12 Apr 2014
V. Deepak Samuel	International consultative workshop titled "Across landscapes: Conserving coastal and marine biodiversity"	Resource Person	MoEF-UNDP-GEF	09 - 10 May 2014

Publications

Publications in National / International Journals

2013 and 2014

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Official Committees Formed

Research Coordination Office (RCO)

Members:

1. Dr. Ramachandra Bhatta Scientist G & Division Chair - ISE Division	Program Coordinator
2. Dr. Purvaja Ramachandran Scientist G & Division Chair - ISE Division	Research Coordinator
3. Dr. D. Asir Ramesh Scientist E, NCSCM	Scientist (i/c) for Consortium Research
4. Dr. P. Krishnan Scientist E, NCSCM	Scientist (i/c) for In-house Research
5. Dr. R. Sridhar Scientist E, NCSCM	Member Secretary

Programme Advisory Committee

1. Dr. M. Baba Former Director, CESS, Trivandram	Chairman
2. Dr. B.R. Subramanian Former Director, ICMAM PD, Chennai	Member
3. Dr. D. Chandramohan Former *Deputy Director, NIO, Goa*	Member

Concept Appraisal Committee (CAC)

Purpose: To appraise the concept and design of the consultant for the NCSCM building, facilities and laboratories

1. Prof. Ranee Vedamuthu Dean, School of Architecture and Planning Anna University, Chennai	Chairperson
2. Prof. A.R. Santhakumar Structural Engineer Former Emeritus Professor, IIT Chennai	Member
3. Prof. Suresh Kuppusamy Former Dean, School of Architecture and Planning Anna University, Chennai	Member

Technical Specification Evaluation Committee (TSEC)

Purpose: To evaluate the technical specifications of various equipments procured by NCSCM.

Members:

1. Dr. B. R. Subramanian Former Advisor, MoES	Chairman
2. Dr. Purvaja Ramachandran Scientist G, NCSCM	Member
3. Maj. Gen. Dr. B. Nagarajan Former Additional Surveyor General, Survey of India	Member
4. Dr. S. Srinivasalu Professor, Institute for Ocean Management *Anna University, Chennai*	Member
5. Dr. R. Murugesan Scientific Officer, SAIF, *IIT* Madras	Member
6. Dr. K. Shivkumar Head, MPG Group Atomic Minerals Division, Hyderabad	Member
7. Dr. V. Kannan Former Head, *Environmental Survey Laboratory* *BARC*, Kalpakkam, Tamil Nadu	Member
8. Dr. V. Ravichandran Professor and Head, Department of *Nuclear Physics* University of Madras, Chennai	Member
9. Dr. V. Ranga Rao Scientist – E, ICMAM Project Directorate Ministry of Earth Sciences, Chennai	Member
10. Dr. Thamban Meloth Scientist-E & Program Director, Cryospheric Science Division National Centre for Antarctic and Ocean Research, Ministry of Earth Sciences, Goa	Member
11. Dr. P. Chandramohan Managing Director INDOMER Hydraulics Chennai	Member
12. Dr. D. Chandramohan Former *Deputy Director* *National Institute of Oceanography, Goa*	Member
13. Dr. Robin R.S Scientist C, NCSCM	Member Secretary

Committee to review Consortium Research Proposals

Purpose: To coordinate with Consortium Research Institutes and to review and recommend suitable course of action on the proposals submitted by consortium institutions.

Members:

1. Dr. D. Chandramohan Senior Scientific Consultant, NCSCM	Chairman
2. Dr. B. R. Subramanian Senior Scientific Consultant, NCSCM	Member
3. Dr. V. Kannan Scientific Consultant, NCSCM	Member
4. Dr. Purvaja Ramachandran Scientist G & Division Chair, NCSCM	Member
5. Dr. Ramachandra Bhatta Scientist G & Division Chair, NCSCM	Member
6. Dr. P. Krishnan Scientist E, NCSCM	Member Secretary

Research Publications Review Committee

Purpose: To review the research publications made from NCSCM before being published/presented.

Members:

1. Dr. D. Chandramohan Senior Scientific Consultant, NCSCM	Chairman
2. Dr. B. R. Subramanian Senior Scientific Consultant, NCSCM	Member
3. Dr. Ramachandra Bhatta Scientist G & Division Chair, NCSCM	Member Secretary

Technical Review Committee on Mineral Mapping of Indian Coasts

1. Dr. P.S. Parihar, Director, Atomic Minerals Directorate for Exploration and Research, Hyderabad	Chairman
2. Dr. A. Senthil Vel Additional Project Director, SICOM	Member

3.	Mr. Maran Director (Marine Wing), GSI	Member
4.	Dr. T.N. Prakash Scientist F, NCESS, Thiruvananthapuram	Expert Member
5.	Mr. M. Dharmaraj Senior Scientific Consultant, NCSCM	Member
6.	Dr. P. Krishnan CMR Division, NCSCM	Member Secretary

Technical Review Committee for Sediment Cell Mapping

1.	Dr. M. Baba Former Director, CESS, Trivandrum	Chairman
2.	Dr. A. Senthil Vel Additional Project Director, SICOM	Member
3.	Dr. Purvaja Ramachandran Scientist G & Division Chair, NCSCM	Member
4.	Sh. M. Dharmaraj Senior Scientific Consultant, NCSCM	Member Secretary

Technical Review Committee for Mapping of ESAs

1.	Dr. R. Ramesh Director, NCSCM	Chairman
2.	Dr. Purvaja Ramachandran Scientist G & Division Chair, NCSCM	Member
3.	Dr. Ramachandra Bhatta Scientist G & Division Chair, NCSCM	Member
4.	Dr. B. R. Subramanian Senior Scientific Consultant, NCSCM	Member
5.	Dr. D. Chandramohan Senior Scientific Consultant, NCSCM	Member
6.	Sh. M. Dharmaraj Senior Scientific Consultant, NCSCM	Member
7.	Dr. P. Krishnan CMR Division, NCSCM	Member Secretary

Edifice

Elevation of our new facility

Construction in progress

Admin Block (Front view)

Geo Block (Front view)

Laboratory block (Top View)

Server Room

NCSCM Team

Scientists

Dr. Ramesh R
Director

Dr. Purvaja Ramachandran
Scientist G & Division Chair

Dr. Ramachandra Bhatta
Scientist G & Division Chair

Dr. Rajakumari S
Scientist E

Dr. Asir Ramesh D
Scientist E

Dr. Sridhar R
Scientist E

Dr. Krishnan Pandian
Scientist E

Dr. Ajay Kumar Ray
Scientist E

Dr. Gejo Anna G
Scientist D

Dr. Deepak Samuel V
Scientist D

Dr. Badarees K O
Scientist D

Dr. Gurmeet Singh
Scientist C

Dr. Robin R.S.
Scientist C

Dr. Dipnarayan Ganguly
Scientist C

Mr. Abhilash KR
Scientist C

Mr. Muruganandam R
Scientist C

Dr. Debasis Tudu
Scientist C

Ms. Yogeshwari S
Scientist C

Dr. Sachithanandam V
Scientist C

Mr. Sreeraj C R
Scientist C

Ms. Mary Diviya Suganya G
Scientist C

Mr. Saravanan Umapathy
Scientist B

Dr. Sarunjith KJ
Scientist B

Dr. Paneer Selvam A
Scientist B

Ms. Madhumitha R
Scientist B

Dr. Kakolee Banerjee
Scientist B

Dr. Shesdev Patro
Scientist B

Dr. Sarkar R
Scientist B

Mr. Mageswaran T
Scientist B

Ms. Priya P
Scientist B

Ms. Margi Purohit
Scientist B

Ms. Deepika B
Scientist B

Mr. Manik Mahapatra
Scientist B

Administration Staff

Mr. Ananda Kumar KG
Manager(Admin/HR)

Mr. Alok Ranjan Samal
Manager(Finance/Accounts)

Ms. Nithya S
System Administrator

Ms. Mary Premila L
Stenographer

Mr. Rajesh U
Office Assistant cum Driver

Technical Staff

Mr. Sathishkumar S
Applications Engineer

Ms. Ramya Sivagnanam
Junior Application Engineer

Mr. Madhava Rao Chennupati
Junior Software Engineer

Ms. Rosy Siji AG
Data Entry Operator [D]

Ms. Jayasri Priya M
Data Entry Operator [D]

Mr. Issac Rajan J
Field Assistant

K. RAMANAN, F.C.A.,
Chartered Accountant
AH - 46, Shanthi Colony
Anna Nagar, Chennai - 600 040.
E-mail : krishnamurthy_ramanan@yahoo.com

Office : 044-2621 5936
Res : 044-2654 3854
Mobile : 98401 49391

To
The Director
National Centre for Sustainable Coastal Management
Anna University Campus
Guindy
Chennai-600025

Dt: 28.03.2017

Dear Sir,

Sub: Statutory Audit for FY:2014-15- Management Letter

In connection with our audit of the financial statements of the NCSCM Project for the Year ended 31st March 2015, we have familiarized ourselves with Project documents, the internal guidelines & circulars applicable during the period under audit. We also reviewed the business of the Project and evaluated the accounting systems and related internal controls of the Project in order to plan and perform our audit.

This letter to Project Management includes observations noted during the course of our audit examination in the following areas:

- Opportunities for strengthening financial management records, systems and controls, together with recommendations for improvement :-
  i) Advance to Staff:
  Detailed reconciliation needs to be done to show staff wise TA advances & others. Credit balance in staff a/c should be nullified in books by transferring to appropriate debit balances. The management has to complete this before next audit.
  ii) Advance to KIIT University:
  The management has promised to finalize the reports sent by KIIT after scrutinizing the expense statement sent by them. This advance is to be squared off as early as possible since it is overdue as on date.
  iii) Staff Advance (Contingency):
  Certain staff accounts (3 in number) are to be reconciled and taken into account before 31.03.2017.
  iv) Fixed Assets Register:
  Events after the Balance Sheet date: We understand that one of the asset Wave Rider Buoy costing around Rs.53.46 lakhs was lost during field research in the FY:2016-17. A FIR with police has been filed and an insurance claim has been lodged.
  Fixed Asset Register is being maintained properly and entries are upto date. However we suggest maintaining an Asset movement Register since certain equipments are taken for field visits. Asset identification marks/numbers are not recorded in certain cases. Location of the asset should be written in Fixed Asset Register.
- Status of maintenance of Project books and records : Maintained upto date.
- Accuracy of Project financial statements : Satisfactory
- Compliance with prescribed procurement procedures : Satisfactory
- Status of prior audit recommendations : No recommendation made.

The matters contained in this Management Letter are intended solely for the information of The Project Management, for such timely consideration and action as Project Management may deem appropriate. They have all been considered by us in formulating the audit opinion expressed on the project financial statements in our audit report dated 28.03.2017 and they do not alter the opinion expressed in that audit report.

We wish to take this opportunity to thank Project Management for the courtesies and cooperation extended to our auditors

Yours Faithfully

K. RAMANAN & CO. K. RAMANAN M. No. 019177 AH - 46, SHANTHI COLONY CHENNAI - 40 Chartered Accountants

CA.K.RAMANAN
M.No. 019177
For K.Ramanan & Co
Chartered
Accountants
FRN No. 02926S

K RAMANAN, F.C.A.,
Chartered Accountant
AH - 46, Shanthi Colony,
Anna Nagar, Chennai - 600 040.
E-mail : krishnamurthy_ramanan@yahoo.com

Office : 044-2621 5936
Res : 044-2654 3854
Mobile : 98401 49391
kramanan1949@gmail.com

INDEPENDENT AUDITOR'S REPORT

To

The Project Director,

National Centre for Sustainable Coastal Management

Chennai

Report on the Financial Statements

We have audited the financial statements of National Centre for Sustainable Coastal Management(NCSCM), which comprise the Balance Sheet as at 31 March 2015, the Income & Expenditure Accounts and Receipts & Payments Accounts for the year then ended, and a summary of significant accounting policies, notes to accounts and other explanatory information.

Management's Responsibility for the Financial Statements

Management is responsible for the preparation of these financial statements that give a true and fair view of the financial position, financial performance and cash flows of the Society in accordance with the Accounting Standards applicable and issued by the Institute of Chartered Accountants of India. The Society has prepared and maintained accounts in accordance with the Financial Manual adopted by the society. This responsibility includes the design, implementation and maintenance of internal financial control relevant to the preparation and presentation of the financial statements that give a true and fair view and are free from material misstatement, whether due to fraud or error.

Auditor's Responsibility

Our responsibility is to express an opinion on these financial statements based on our audit. We conducted our audit in accordance with the Standards on Auditing issued by the Institute of Chartered Accountants. Those Standards require that we comply with ethical requirements and plan and perform the audit to obtain reasonable assurance about whether the financial statements are free from material mis-statement.

An audit involves performing procedures to obtain audit evidence about the amounts and disclosures in the financial statements. The procedures selected depend on the auditor's judgment, including the assessment of the risks of material misstatement of the financial statements, whether due to fraud or error. In making those risk assessments, the auditor considers internal control relevant to the Society's preparation and fair presentation of the financial

statements in order to design audit procedures that are appropriate in the circumstances. An audit also includes evaluating the appropriateness of accounting policies used and the reasonableness of the accounting estimates made by management, as well as evaluating the overall presentation of the financial statements.

We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our audit opinion.

Opinion

In our opinion and to the best of our information and according to the explanations given to us, the financial statements read along with the Notes to accounts give the information required by the Act in the manner so required and give a true and fair view in conformity with the accounting principles generally accepted in India:

a) in the case of the Balance Sheet, of the state of affairs of the Company as at March 31, 2015;

b) in the case of the Income & Expenditure Account the excess of income over expenditure and in the case of Receipts & Payments Account, of the cash flows for the year ended on that date.

For K.Ramanan & Co.
Chartered Accountants
(FRN: 02926N)

(CA.K.RAMANAN)
PROPRIETOR
M.NO. 019177

Place: Chennai
Date : 28/03/2017

NATIONAL CENTRE FOR SUSTAINABLE COASTAL MANAGEMENT

Annexure to the Balance Sheet as on March 31st,2015

ACCOUNTING POLICIES & NOTES TO ACCOUNTS

A Significant Accounting Policies :

1. ***Basis of Accounting :***
   a) The Society follows the cash basis system of accounting in the preparation of accounts.
   b) The accounts are prepared under the historical cost convention and on the basis of going concern concept.
2. ***Fixed Assets & Depreciation :***
   a) Fixed assets are stated at their original cost of acquisition inclusive of inward freight, duties & expenditure incurred in the acquisition, construction/installation including part of salaries and wages paid to own staff.
   b) The assets transferred as grant in aid are written off as revenue expenses.
   c) The depreciation is not charged on the fixed assets by the society.
3. ***Current Assets And Loans & Advances:***
   In the opinion of the management, current assets, loans and advances as shown in the Balance Sheet have a value of realization in the ordinary course of business at least equal to the amount at which they are stated.

B Notes to Accounts :

1. Events after the date of Balance Sheet:-
   We understand that one of the asset Wave Rider Buoy costing around Rs.53.46 lakhs was lost during field research in the FY: 2016-17. A FIR with police has been filed and an insurance claim has been lodged.
2. Fixed Asset register is being maintained properly and entries are upto date. However we suggest maintaining an Asset movement Register since certain equipments are taken for field visits. Asset identification marks/numbers are not recorded in certain cases. Location of the asset should be written in Fixed Asset Register.
3. Being a Society it is not mandatory to give previous year's figures in the Balance Sheet.

For National Centre for Sustainable Coastal Management

Director

Director
National Centre for Sustainable Coastal Management
Ministry of Environment, Forest and Climate Change
Government of India, Anna University Campus
Chennai - 600 025, India

As per Audit Report of even date attached
For K.Ramanan & Co
Chartered Accountants

(CA.K.Ramanan)
Proprietor
Place: Chennai
Date : 28.03.2017

NATIONAL CENTER FOR SUSTAINABLE COSATAL MANAGEMENT

NATIONAL CENTER FOR SUSTAINABLE COASTAL MANAGEMENT
ANNA UNIVERSITY CAMPUS
GUINDY, CHENNAI-600025.

Consolidated Receipts and Payments Account for the year ended on March 31st, 2015

(in Rs.)

RECEIPTS	AMOUNT	PAYMENTS	AMOUNT
Opening Balance		**Current Liabilities**	
Bank Accounts	2,89,08,555.96	Bid Security	28,43,000.00
		Car Advance	18,200.00
Current Liabilities		GIC	1,800.00
Bid Security	19,11,000.00	GPF	5,000.00
Car Advance	16,800.00	GPF Advance	1,48,200.00
GIC	1,440.00	GSLI	1,560.00
GPF	5,000.00	NPS	76,530.00
GPF Advance	1,36,800.00	PF	3,91,973.00
GSLI	1,440.00	Professional Tax	2,15,170.00
NPMU - Fund Received	32,50,00,000.00	Retention Money-Renaatus	1,70,850.00
NPMU - Interest on FD	40,96,046.00	TDS Payable - Others	39,31,366.00
NPMU -SB Interest	39,956.00	TDS PAYABLE - STAFF	47,13,905.00
NPS	71,035.00	VAT TDS	1,19,641.00
PF	3,60,075.00	Provisions	82,74,327.00
Professional Tax	1,51,203.00	NCR RECOVERIES	7,96,276.00
Retention Money-Renaatus	51,62,326.00	Performance Guarantee	1,03,454.00
TDS Payable - Others	37,74,174.89	Paid to NCSCM by ESA	382.00
TDS PAYABLE - STAFF	46,66,495.00	DELTAS - TDS others	255.00
VAT TDS	2,23,936.00	TRUC - TDS others	255.00
Provisions	85,82,329.00		
NCR RECOVERIES	17,85,038.00	**Fixed Assets**	
Performance Guarantee	8,67,519.00	INVESTMENT COST	1,79,88,039.00
Received from NCSCM by ESA	1,70,396.00	Physical	23,97,54,775.85
NPMU	3,52,17,524.00	Project Management	77,17,869.00
DELTA - TDS others	255.00	Facilities & Equipments - DELTA	1,39,579.00
TRUC - TDS others	255.00	Facilities & Equipments - TRUC	1,37,528.00
DELTA- Interest on Grants in Aid	48,394.00		
MOES - DELTA	27,30,000.00	**Investments**	
MOES - TRUC	16,80,000.00	FIXED DEPOSIT - UBI SHORT TERM	3,80,375.00
Fixed Assets		**Current Assets**	
Physical	28,47,503.00	Deposits (Asset)	34,26,55,008.00
		Sundry Debtors	10,000.00
Investments		Advances	6,32,63,916.00
FIXED DEPOSIT - UBI SHORT TERM	1,50,00,000.00	Contingency Advance	3,03,300.00
		TA Advance	7,57,930.00
Current Assets		MPM Travel Xs Pvt Ltd.	1,06,708.00
Deposits (Asset)	29,73,03,071.00		
Advances	5,04,68,338.00	**Indirect Expenses**	
Contingency Advance	1,80,185.00	Capacity Building & Projects	42,89,009.47
TA Advance	6,30,211.95	Communication	21,18,511.00
		Operational Cost	8,10,81,944.36
Indirect Incomes		Sedimental Cell Project	42,58,097.00
Miscellaneous Income	1,29,221.00	Utilisation of Fund: DELTA	87,712.00
		Utilisation of Fund: TRUC	59,755.00
Indirect Expenses			
Capacity Building & Projects	1,300.00	**Closing Balance**	
Operational Cost	3,70,894.00	Bank Accounts	90,05,316.00
Closing Balance			
Bank Accounts	33,26,339.88		
Total	79,59,27,057.68	Total	79,59,27,057.68

For National Centre for Sustainable Coastal Management

Director
National Centre for Sustainable Coastal Management
Ministry of Environment, Forest and Climate Change
Government of India, Anna University Campus
Chennai - 600 025, India

Place: Chennai
Date : 28/05/2017

As per the Audit Report of even date attached
For K.Ramanan & Co
Chartered Accountants

K. RAMANAN & CO
K. RAMANAN
M. No. 019177
AH - 45, SHANTHI COLONY
CHENNAI - 40
Chartered Accountants

(CA. K.Ramanan)
(M.No. 019177)
FRN: 029265

NATIONAL CENTRE FOR SUSTAINABLE COASTAL MANAGEMENT

MINISTRY OF ENVIRONMENT, FOREST & CLIMATE CHANGE
GOVERNMENT OF INDIA
ANNA UNIVERSITY CAMPUS
CHENNAI-600025

Consolidated Income and Expenditure Account for the year ended 31st March, 2015

(In Rs.)

Particulars	Amount	Amount	Particulars	Amount	Amount
Indirect Expenses			**Indirect Incomes**		
1.NCSCM		11,98,68,890.33	**1.NCSCM**		37,47,64,263.18
Capacity Building & Projects	62,79,445.47		Miscellaneous Income	61.00	
Communication	21,18,511.00		Grants in Aid	37,47,64,202.18	
Hazard & ESA Mapping	3,06,00,081.00				
Operational Cost	7,66,12,755.85				
Sedimental Cell Project	42,58,097.00				
2.TRUC & DELTA			**2.TRUC & DELTA**		4,66,263.00
Utilisation of Fund Delta	87,712.00	1,89,156.00	Grants in Aid DELTA	2,27,291.00	
Utilisation of Fund Truc	1,01,444.00		Grant in Aid TRUC	2,38,972.00	
3. ESA & CVCA MAPPING			**3. ESA & CVCA MAPPING**		
Operational Cost		1,11,22,049.50	Grants in Aid		1,88,39,658.50
Excess of income over expenditure		**26,28,90,089**			
Total		**39,40,70,184.68**	**Total**		**39,40,70,184.68**

For National Centre for Sustainable Coastal Management

Director
National Centre for Sustainable Coastal Management
Ministry of Environment, Forest and Climate Change
Government of India, Anna University Campus
Chennai - 600 025, India

Director

Place: Chennai
Date : 28.03.2017

As per the Audit Report of even date attached
For K.Ramanan&Co
Chartered Accountants

K. RAMANAN & CO
K. RAMANAN
M.No. 019177
AH - 46, SHANTHI COLONY
CHENNAI - 40
Chartered Accountants

(CA K RAMANAN)
(M.NO 019177)
FRN: 029265

NATIONAL CENTRE FOR SUSTAINABLE COASTAL MANAGEMENT

MINISTRY OF ENVIRONMENT, FOREST & CLIMATE CHANGE
GOVERNMENT OF INDIA
ANNA UNIVERSITY CAMPUS
CHENNAI-600025

Consolidated Balance Sheet as on 31st March 2015

(In Rs.)

Liabilities	Sch. No.	Amount	Assets	Sch. No.	Amount
Capital Account:-			**Fixed Assets:-**		
Corpus Fund	1	37,92,87,496.85	Investment Cost	-	4,72,51,054.00
			Physical	-	32,38,61,405.85
Current Liabilities:-			Project Management (ESA)	-	77,17,609.00
Provisions	2	2,88,917.00	Equipment (DELTA)	-	1,39,579.00
NCR Recoverles	-	9,88,762.00	Equipment (TRUC)	-	1,37,528.00
Perfomance Guarantee	-	8,55,645.00			
Bid Security	-	28,75,000.00	**Investment:-**		
NPMU - Fund Received	3	9,54,26,701.28	Flexi balance UBI	7	1,76,00,375.00
NPS	-	1,190.00	Current a/c UBI	7	18,68,976.12
Professional Tax	4	4,048.00			
Retention Money	-	58,01,573.00	**Current Assets:-**		
TDS - Payable others	-	3,23,570.89	Deposits	-	3,18,81,937.00
TDS - Payable staff	-	2,69,751.00	Sundry Debtors	6	1,06,708.00
WCT	-	3,74,327.00	Advances	5	5,98,18,746.00
Interest on Grant(T&D)	-	48,394.00	TA Advances	5	1,05,195.05
MOES- DELTA	-	25,02,709.00			
MOES- TRUC	-	14,41,028.00			
	-				
TOTAL		49,04,89,113.02	TOTAL		49,04,89,113.02

For National Centre for Sustainable Coastal Management

Director
National Centre for Sustainable Coastal Management
Ministry of Environment, Forest and Climate Change
Government of India, Anna University Campus
Chennai - 600 025, India

Director
Place: Chennai
Date : 28.03.2017

As per the Audit Report of even date attached
For K.Ramanan & Co
Chartered Accountants

K. RAMANAN & CO
K. RAMANAN
M. No. 019177
AH-46, SHANTHI COLONY
CHENNAI - 40
Chartered Accountants

(CA. K.Ramanan)
(M.No. 019177)
FRN: 02926S

NATIONAL CENTRE FOR SUSTAINABLE COASTAL MANAGEMENT

MINISTRY OF ENVIRONMENT, FOREST & CLIMATE CHANGE
GOVERNMENT OF INDIA
ANNA UNIVERSITY CAMPUS
CHENNAI-600025

Schedules forming part of the accounts for the Year ended 31st March, 2015

Schedule-1 : Corpus Fund

Particulars	Amount
NCSCM	37,12,92,780.85
ESA & CVCA	77,17,609.00
TRUCK & DELTA	2,77,107.00
TOTAL	**37,92,87,496.85**

Schedule-2 : Provisions

Particulars	Amount
NCSCM	2,33,240.00
ESA & CVCA	55,677.00
TRUCK & DELTA	-
TOTAL	**2,88,917.00**

Schedule-3 : NPMU Fund Received

Particulars	Amount
NCSCM	7,90,48,835.78
ESA & CVCA	1,63,77,865.50
TRUCK & DELTA	-
TOTAL	**9,54,26,701.28**

Schedule-4 : Professional Tax

Particulars	Amount
NCSCM	3,948.00
ESA & CVCA	-
TRUCK & DELTA	100.00
TOTAL	**4,048.00**

Director
National Centre for Sustainable Coastal Management
Ministry of Environment, Forest and Climate Change
Government of India, Anna University Campus
Chennai - 600 025, India

Schedule-5 : Advances

Particulars	Advances	TA Advances
NCSCM	5,60,58,887.00	-
ESA & CVCA	37,59,859.00	71,883.05
TRUC & DELTA	-	33,312.00
TOTAL	**5,98,18,746.00**	**1,05,195.05**

Schedule-6 : Debtors

Particulars	Amount
TRUC & DELTA (MPM TRAVEL XS PVT. LTD.)	1,06,708.00
TOTAL	**1,06,708.00**

Schedule-7 : Bank Accounts

Particulars	Flexi Balance: UBI	Current A/c Advance
NCSCM	3,80,375.00	24,27,576.67
ESA & CVCA	1,34,10,000.00	-6,10,811.55
TRUC & DELTA	38,10,000.00	52,211.00
TOTAL	**1,76,00,375.00**	**18,68,976.12**

Director
National Centre for Sustainable Coastal Management
Ministry of Environment, Forest and Climate Change
Government of India, Anna University Campus
Chennai - 600 025, India

NATIONAL CENTER FOR SUSTAINABLE COSATAL MANAGEMENT

ANNA UNIVERSITY CAMPUS

GUINDY

CHENNAI - 600025

Receipts and Payments Account for the year ended on March 31st, 2015

(In Rs.)

RECEIPTS	AMOUNT	PAYMENTS	AMOUNT
Opening Balance		**Current Liabilities**	
Bank Accounts	2,69,08,555.96	Bid Security	28,43,000.00
		Car Advance	18,200.00
Current Liabilities		GIC	1,600.00
Bid Security	19,11,000.00	GPF	5,000.00
Car Advance	16,800.00	GPF Advance	1,48,200.00
GIC	1,440.00	GSLI	1,560.00
GPF	5,000.00	NPS	76,530.00
GPF Advance	1,36,800.00	PF	3,91,973.00
GSLI	1,440.00	Professional Tax	2,15,170.00
NPMU - Fund Received	32,50,00,000.00	Retention Money-Renaatus	1,70,850.00
NPMU - Interest on FD	40,98,046.00	TDS Payable - Others	39,31,366.00
NPMU -SB Interest	39,956.00	TDS PAYABLE - STAFF	47,13,905.00
NPS	71,035.00	VAT TDS	1,19,641.00
PF	3,60,075.00	Provisions	80,69,346.00
Professional Tax	1,51,103.00	NCR Recoveries	7,96,276.00
Retention Money-Renaatus	51,62,326.00	Performance Guarantee	1,03,454.00
TDS Payable - Others	37,74,174.89		
TDS PAYABLE - STAFF	46,66,496.00	**Fixed Assets**	
VAT TDS	2,23,936.00	Investment Cost	1,79,88,039.00
Provisions	83,21,671.00	Physical	23,97,54,775.85
NCR Recoveries	17,85,038.00		
Performance Guarantee	5,67,519.00	**Investments**	
		FIXED DEPOSIT - UBI SHORT TERM	3,80,375.00
Fixed Assets			
Physical	28,47,503.00	**Current Assets**	
		Deposits (Asset)	32,46,75,008.00
Investments		Sundry Debtors	10,000.00
FIXED DEPOSIT - UBI SHORT TERM	1,50,00,000.00	Advances	5,37,95,116.00
Current Assets		**Indirect Expenses**	
Deposits (Asset)	29,29,93,071.00	Capacity Building & Projects	42,89,009.47
Advances	5,02,98,338.00	Communication	21,18,511.00
		Operational Cost	7,56,24,159.86
Indirect Incomes		Sedimental Cell Project	42,58,097.00
Miscellaneous Income	1,29,221.00		
		Closing Balance	
Indirect Expenses		Bank Accounts	51,43,105.00
Capacity Building & Projects	1,300.00		
Operational Cost	3,54,894.00		
Closing Balance			
Bank Accounts	27,15,528.33		
Total	**74,98,42,267.18**	**Total**	**74,98,42,267.18**

For National Centre for Sustainable Coastal Management

Director

Director
National Centre for Sustainable Coastal Management
Ministry of Environment, Forest and Climate Change
Government of India, Anna University Campus
Chennai - 600 025, India

Place: Chennai
Date : 28.03.2017

As per the Audit Report of even date attached
For K.Ramanan & Co
Chartered Accountants

K. RAMANAN & CO
K. RAMANAN
M. No. 019177
AH - 45, SHANTHI COLONY
CHENNAI - 40
Chartered Accountants

(CA. K.Ramanan)
(M.No. 019177)
FRN: 02926S

NATIONAL CENTRE FOR SUSTAINABLE COASTAL MANAGEMENT

MINISTRY OF ENVIRONMENT FOREST &CLIMATE CHANGE
GOVERNMENT OF INDIA
ANNA UNIVERSITY CAMPUS
CHENNAI-600025

Income and Expenditure Statement for the year ended 31st March,2015

(In Rs.)

Particulars	Amount	Amount	Particulars	Amount	Amount
Indirect Expenses		**11,98,68,890.33**	**Indirect Incomes**		**37,47,64,263.18**
Capacity Building & Projects	62,79,445.47		Miscellaneous Income	61.00	
Communication	21,18,511.00		Grant in Aid	37,47,64,202.18	
Hazard & ESA Mapping	3,06,00,081.00				
Operational Cost	7,66,12,755.86				
Sedimental Cell Project	42,58,097.00				
Excess of income over expenditure		**25,48,95,372.85**			
Total		**37,47,64,263.18**	**Total**		**37,47,64,263.18**

For National Centre for Sustainable Coastal Management

Director
Director
National Centre for Sustainable Coastal Management
Ministry of Environment, Forest and Climate Change
Govt. of India, Anna University Campus
Chennai - 600 025, India

Place:Chennai
Date:28.03.2017

As per the Audit Report of even date attached
For K.Ramanan&Co
Chartered Accountants

K. RAMANAN & CO
K. RAMANAN
M. No. 019177
AH - 45, SHANTHI COLONY
CHENNAI - 40
Chartered Accountants

(CA K RAMANAN)
(M.NO 019177)
FRN: 029265

NATIONAL CENTRE FOR SUSTAINABLE COASTAL MANAGEMENT

MINISTRY OF ENVIRONMENT, FOREST & CLIMATE CHANGE
GOVERNMENT OF INDIA
ANNA UNIVERSITY CAMPUS
CHENNAI-600025

Balance Sheet as on 31st March, 2015

(In Rs.)

Liabilities	Sch. No.	Amount	Assets	Sch. No.	Amount
Capital Account:-			**Fixed Assets:-**		
Corpus Fund	-	37,12,92,780.85	Investment Cost	3	4,72,51,054.00
			Physical	4	32,38,61,405.85
Current Liabilities:-					
Provisions	1	2,33,240.00	**Investment:-**		
NCR Recoveries	-	9,88,762.00	Fixed Deposit - UBI	-	3,80,375.00
Perfomance Guarantee	2	8,55,645.00			
Bid Security	-	28,75,000.00	**Current Assets:-**		
NPMU - Fund Received	-	7,90,48,835.78	Deposits	5	3,18,81,937.00
NPS	-	1,190.00	Sundry Debtors	-	10,000.00
Professional Tax	-	3,948.00	Advances	6	5,62,56,275.00
Retention Money	-	58,01,573.00	Bank Accounts	7	24,27,576.67
TDS - Payable others	-	3,23,570.89			
TDS - Payable staff	-	2,69,751.00			
VAT TDS	-	3,74,327.00			
TOTAL		**46,20,68,623.52**	**TOTAL**		**46,20,68,623.52**

For National Centre for Sustainable Coastal Management

Director
National Centre for Sustainable Coastal Management
Ministry of Environment, Forest and Climate Change
Government of India, Anna University Campus
Chennai - 600 025, India

Director

Place: Chennai
Date : 28.03.2017

As per the Audit Report of Even date Attached
For K.Ramanan & Co
Chartered Accountants

K. RAMANAN & CO
K. RAMANAN
M. No. 019177
AH - 4E, SHANTHI
COLONY
CHENNAI - 40
Chartered Accountants

(CA. K.Ramanan)
(M.No. 019177)
FRN: 02926S

NATIONAL CENTER FOR SUSTAINABLE COSATAL MANAGEMENT

MINISTRY OF ENVIRONMENT, FOREST & CLIMATE CHANGE
GOVERNMENT OF INDIA
ANNA UNIVERSITY CAMPUS
GUINDY
CHENNAI-600025

Schedules forming part of the accounts for the Year ended 31st March, 2015

Schedule-1 : PROVISIONS

Particulars	Amount
EMPLOYEE PROVIDENT FUND	73,910.00
LABOUR CESS	-28,773.00
LIQUIDITY DAMAGES	1,88,103.00
TOTAL	**2,33,240.00**

Schedule-2 : PERFORMANCE GUARANTEE

Particulars	Amount
ABP ENGINERING LEAFE AREA INDEX METER	34,250.00
AMKETTEE ANALYTICS	69,300.00
CREATIONS	34,557.00
ELECTRONIK LAB	10,000.00
GLOBAL TECHNOLOGIES CHENNAI	2,47,525.00
MICRO SCIENCE	1,32,000.00
MICRO SCIENCE -DC	1,45,197.00
SHASHANTI VENTURES PVT LTD	40,860.00
SWAN ENVIRONMENT PVT LTD	41,632.00
UNIVERSAL TECHNOLOGIES	36,774.00
VEDAMAYA SOFTWARE	63,550.00
TOTAL	**8,55,645.00**

Schedule-3 : Investment Cost

Particulars	Amount
COMPUTERS & SYSTEMS	3,30,48,302.00
EQUIPMENTS & FACILITIES	33,71,409.00
CIVIL WORKS	92,76,069.00
FURNITURE & FITTINGS	6,45,568.00
VEHICLE	9,09,706.00
TOTAL	**4,72,51,054.00**

Director
National Centre for Sustainable Coastal Management
Ministry of Environment, Forest and Climate Change
Government of India, Anna University Campus
Chennai - 600 025, India

Schedule-4 : Physical

Particulars	Amount
CONSTRUCTION OF NEW BUILDING & FACILITIES	9,75,86,129.00
GOODS & EQUIPMENTS (SCIENTIFIC)	21,45,10,752.85
OFFICE& IT EQUIPMENTS	1,17,64,524.00
TOTAL	**32,38,61,405.85**

Schedule-5 : Deposits

Particulars	Amount
LC MARGIN	3,01,61,937.00
FLEXI BALANCE	17,20,000.00
TOTAL	**3,18,81,937.00**

Schedule-6 : Advances

Particulars	Amount
ADVANCE TO CONTRACTOR	71,43,589.00
ADVANCE TO OTHER INSTITUTIONS	69,29,583.00
ADVANCE TO PARTNER INSTITUTIONS	64,49,029.00
CONTINGENCY ADVANCE	3,93,893.00
TA ADVANCE	5,13,028.00
ADVANCE FOR ESA	1,97,388.00
ADVANCE TO STAFF OTHERS	-73,583.00
ADVANCE TO STAFF: TA	4,534.00
ADVANCE TO NRSC, HYDERABAD	3,45,82,684.00
GAYATRI AUTO SERVICE	25,349.00
TRUC PROJECT	73,663.00
TV SUNDARAM MOTORS	17,118.00
TOTAL	**5,62,56,275.00**

Schedule-7 : Bank Accounts

Particulars	Amount
UBI CURRENT A/C	-27,15,528.33
UBI SEDIMENT CELL SAVING A/C	51,43,105.00
TOTAL	**24,27,576.67**

Director
National Centre for Sustainable Coastal Management
Ministry of Environment, Forest and Climate Change
Government of India, Anna University Campus
Chennai - 600 025, India

ESA & CVCA MAPPING

NATIONAL CENTER FOR SUSTAINABLE COASTAL MANAGEMENT
MINISTRY OF ENVIRONMENT, FOREST & CLIMATE CHANGE
ANNA UNIVERSITY CAMPUS
GUINDY
CHENNAI - 600025

Receipts and Payments Account for the year ended on March 31st, 2015

(in Rs.)

RECEIPTS	AMOUNT	PAYMENTS	AMOUNT
Current Liabilities		**Current Liabilities**	
NCSCM	1,70,396.00	NCSCM	382.00
Provisions	2,60,658.00	Provisions	2,04,981.00
NPMU	3,52,17,524.00		
		Fixed Assets	
Current Assets		Project Management	77,17,609.00
Deposits	43,70,000.00		
Advance to Institutes	1,70,000.00	**Current Assets**	
Contingency Advances	1,80,185.00	Deposits	1,77,80,000.00
TA Advance	6,30,211.95	Advance to Institutes	94,68,800.00
		Contingency Advances	2,38,300.00
Indirect Expenses		TA Advance	7,57,930.00
Operational Cost	16,000.00		
		Indirect Expenses	
Closing Balance		Operational Cost	54,57,784.50
Bank Accounts	6,10,811.55		
Total	**4,16,25,786.50**	**Total**	**4,16,25,786.50**

For National Centre for Sustainable Coastal Management

Director
National Centre for Sustainable Coastal Management
Ministry of Environment, Forest and Climate Change
Government of India, Anna University Campus
Chennai - 600 025, India

Director
Place: Chennai
Date : 28.03.2017

As per the Audit Report of even date attached
For K.Ramanan & Co
Chartered Accountants

K. RAMANAN & CO. K. RAMANAN M. No. 019177 AH - 45, SHANTHI COLONY CHENNAI - 40 Chartered Accountants

(CA. K.Ramanan)
(M.No. 019177)
FRN: 02926S

ESA&CVCA MAPPING

NATIONAL CENTER FOR SUSTAINABLE COSATAL MANAGEMENT
MINISTRY OF ENVIRONMENT, FOREST & CLIMATE CHANGE
ANNA UNIVERSITY CAMPUS
GUINDY
CHENNAI-600025

Income and Expenditure Statement for the year ended 31st March, 2015

(In Rs.)

Particulars	Amount	Amount	Particulars	Amount	Amount
Indirect Expenses		1,11,22,049.50	Indirect Incomes		1,88,39,658.50
OPERATIONAL COST	1,11,22,049.50		GRANTS IN AID	1,88,39,658.50	
Excess of income over expenditure		77,17,609.00			
Total		1,88,39,658.50	Total		1,88,39,658.50

For National Centre for Sustainable Coastal Management

Director

Director
National Centre for Sustainable Coastal Management
Ministry of Environment, Forest and Climate Change
Government of India, Anna University Campus
Chennai - 600 025, India

Place: Chennai
Date : 28.03.2017

As per the Audit Report of even date attached
For K.Ramanan&Co
Chartered Accountants

K. RAMANAN & CO.
K. RAMANAN
M. No. 019177
AH - 45, SHANTHI COLONY
CHENNAI - 40
Chartered Accountants

(CA K RAMANAN)
(M.NO 019177)
FRN: 02926S

ESA & CVCA MAPPING

NATIONAL CENTRE FOR SUSTAINABLE COASTAL MANAGEMENT
MINISTRY OF ENVIRONMENT, FOREST & CLIMATE CHANGE
GOVERNMENT OF INDIA
ANNA UNIVERSITY CAMPUS
CHENNAI-600025

Balance Sheet as on 31st March, 2015

(In Rs.)

Liabilities	Sch. No.	Amount	Assets	Sch. No.	Amount
Capital Account:-			**Fixed Assets:-**		
Corpus Fund	-	77,17,609.00	Project Management	2	77,17,609.00
Current Liabilities:-					
Provisions	1	55,677.00	**Current Assets:-**		
NPMU	-	1,63,77,865.50	Deposits : Flexi Balance	-	1,34,10,000.00
NCSCM	-	1,97,388.00	Advances to Institutes	3	37,59,859.00
			TA Advance	-	46,583.05
			Contingency Advance	-	25,300.00
			Bank Accounts	-	-6,10,811.55
TOTAL		2,43,48,539.50	TOTAL		2,43,48,539.50

For National Centre for Sustainable Coastal Management

Director
National Centre for Sustainable Coastal Management
Ministry of Environment, Forest and Climate Change
Government of India, Anna University Campus
Chennai - 600 025, India

Director

Place: Chennai
Date : 28.03.2017

As per the Audit Report of even date attached
For K.Ramanan & Co
Chartered Accountants

K. RAMANAN & CO.
K. RAMANAN
M. No. 019177
AN - 46, SHANTHI COLONY
CHENNAI - 40
Chartered Accountants

(CA. K.Ramanan)
(M.No. 019177)
FRN: 02926S

ESA & CVCA MAPPING

NATIONAL CENTRE FOR SUSTAINABLE COASTAL MANAGEMENT
MINISTRY OF ENVIRONMENT, FOREST & CLIMATE CHANGE
GOVERNMENT OF INDIA
ANNA UNIVERSITY CAMPUS
CHENNAI-600025

Schedules forming part of the accounts for the Year ended 31st March, 2015

Schedule-1 : Provisions

Particulars	Amount
TDS OTHERS	17,674.00
TDS SALARY	2,678.00
LABOUR CESS	14,634.00
PROFESSIONAL TAX	20,691.00
TOTAL	**55,677.00**

Schedule-2 : Project Management

Particulars	Amount
3G DONGLE	13000.00
AIR CONDITIONERS	259900.00
CIVIL WORKS	1463378.00
DESKTOP COMPUTER	922964.00
OTHER FACILITIES & EQUIPMENTS	151580.00
SCANNER & PRINTER	13067.00
SOFTWARES INCLUDING CUSTOMISATION	674160.00
TABLETS	2158960.00
UNDER WATER CAMERA	32000.00
WORK STATION COMPUTER	2028600.00
TOTAL	**77,17,609.00**

Schedule-3 : Advance to Institutes

Particulars	Amount
CEE AHEMADABAD	670200.00
CMFRI KOCHI	387884.00
KVFSU-BIDAR	-121018.00
WBUAFS KOLKATA	344859.00
WII DEHRADUN	487600.00
ZSI	753196.00
ANAMALAI UNIVERSITY	705000.00
ICAR UNIT CIARI PORT BLAIR	459066.00
REGISTRAR IIS BANGALURE	73072.00
TOTAL	**37,59,859.00**

Director
National Centre for Sustainable Coastal Management
Ministry of Environment, Forest and Climate Change
Anna University Campus
Chennai - 600 025

K. RAJAGHAN & CO. CHENNAI-40 Chartered Accountants

TRUC & DELTA

NATIONAL CENTER FOR SUSTAINABLE COASTAL MANAGEMENT
MINISTRY OF ENVIRONMENT, FOREST & CLIMATE CHANGE
ANNA UNIVERSITY CAMPUS
GUINDY
CHENNAI - 600025

Receipts and Payments Account for the year ended on March 31st, 2015

(in Rs.)

RECEIPTS	AMOUNT	PAYMENTS	AMOUNT
Current Liabilities		**Current Liabilities**	
DELTA-PROFESSIONAL TAX	100.00	DELTAS-TDS OTHERS	255.00
DELTAS-TDS OTHERS	255.00	TRUC-TDS OTHERS	255.00
INTEREST ON GRANTS IN AID	48,394.00		
MOES-DELTAS	27,30,000.00	**Fixed Assets**	
MOES-TRUC	16,80,000.00	FACILITIES&EQUIPMENTS-DELTA	1,39,579.00
TRUC-TDS OTHERS	255.00	TRUC-FACILITIES&EQUIPMENTS	1,37,528.00
		Current Assets	
		Kakolee Banarjee- Cont Adv	65,000.00
		Mpm Travel Xs Pvt Ltd	1,06,708.00
		Indirect Expenses	
		UTILISATION OF FUND DELTA	87,712.00
		UTILISATION OF FUND TRUC	59,756.00
		Closing Balance	
		Bank Accounts	36,62,211.00
Total	44,59,004.00	Total	44,59,004.00

For National Centre for Sustainable Coastal Management

Director
National Centre for Sustainable Coastal Management
Ministry of Environment, Forest and Climate Change
Government of India, Anna University Campus
Chennai - 600 025, India

Place: Chennai
Date : 28/03/2017

As per the Audit Report of even date attached
For K.Ramanan & Co
Chartered Accountants

K. RAMANAN & CO. K. RAMANAN M.No. 019177 AH-45, SHANTHI COLONY CHENNAI-40 Chartered Accountants

(CA. K.Ramanan)
(M.No. 019177)
FRN: 029265

TRUC&DELTA

NATIONAL CENTER FOR SUSTAINABLE COSATAL MANAGEMENT

MINISTRY OF ENVIRONMENT, FOREST & CLIMATE CHANGE

ANNA UNIVERSITY CAMPUS

CHENNAI-600025

Income and Expenditure Statement for the year ended 31st March, 2015

(In Rs.)

Particulars	Amount	Amount	Particulars	Amount	Amount
Indirect Expenses		**1,79,156.00**	**Indirect Incomes**		**4,56,263.00**
UTILISATION OF FUND DELTA	87,712.00		GRANTS IN AID DELTA	2,27,291.00	
UTILISATION OF FUND TRUC	1,01,444.00		GRANTS IN AID TRUC	2,38,972.00	
Excess of income over expenditure		**2,77,107.00**			
Total		**4,56,263.00**	**Total**		**4,56,263.00**

For National Centre for Sustainable Coastal Management

Director
National Centre for Sustainable Coastal Management
Ministry of Environment, Forest and Climate Change
Government of India, Anna University Campus
Chennai - 600 025, India

Director

Place:Chennai
Date :28.03.2017

As per the Audit Report of even date attached
For K.Ramanan&Co
Chartered Accountants

K. RAMANAN & CO. K. RAMANAN M. No. 019177 AH - 46, SHANTHI COLONY CHENNAI - 40 Chartered Accountants

(CA K RAMANAN)
(M.NO 019177)
FRN002926S

TRUC & DELTA

NATIONAL CENTRE FOR SUSTAINABLE COASTAL MANAGEMENT

MINISTRY OF ENVIRONMENT, FOREST & CLIMATE CHANGE

GOVERNMENT OF INDIA

ANNA UNIVERSITY CAMPUS

CHENNAI-600025

Balance Sheet as on 31st March 2015

(In Rs.)

Liabilities	Sch.No	AMOUNT	Assets	Sch.No	AMOUNT
Capital Account:-			**Fixed Assets:-**		
Corpus Fund	1	2,77,107.00	FACILITIES&EQUIPMENTS-DELTA	2	1,39,679.00
			TRUC-FACILITIES&EQUIPMENTS	3	1,37,528.00
Current Liabilities:-			**Current Assets:-**		
DELTA - Professional Tax	-	100.00	Bank Accounts	4	38,62,211.00
Interest on Grants in Aid	-	48,394.00	Kakolee Banarjee- Cont Adv	-	33,312.00
MOES-DELTAS	-	25,02,709.00	Mpm Travel Xs Pvt Ltd	-	1,06,708.00
MOES-TRUC	-	14,41,028.00			
NCSCM	-	10,000.00			
Total		**42,79,338.00**	**Total**		**42,79,338.00**

For National Centre for Sustainable Coastal Management

Director
National Centre for Sustainable Coastal Management
Ministry of Environment, Forest and Climate Change
Government of India, Anna University Campus
Chennai - 600 025, India

Place: Chennai
Date : 28/03/2017

As per the Audit Report of even date attached
For K.Ramanan & Co
Chartered Accountants

K. RAMANAN & CO. K. RAMANAN M.No. 019177 AH - 46, SHANTHI COLONY CHENNAI - 40 Chartered Accountants

(CA. K.Ramanan)
(M.No. 019177)
FRN: 029265

TRUC & DELTA

NATIONAL CENTRE FOR SUSTAINABLE COASTAL MANAGEMENT
MINISTRY OF ENVIRONMENT, FOREST & CLIMATE CHANGE
GOVERNMENT OF INDIA
ANNA UNIVERSITY CAMPUS
CHENNAI-600025

Schedules forming part of the accounts for the Year ended 31st March, 2015

Schedule-1 : Corpus Fund

Particulars	Amount
CORPUS DELTA	1,39,579.00
CORPUS TRUC	1,37,528.00
TOTAL	**2,77,107.00**

Schedule-2 :DELTA Equipments

Partculers	Amount
DELTA PRINTERS	1,27,679.00
DELTA CHAIR	11,900.00
TOTAL	**1,39,579.00**

Schedule-3 : TRUC Equipments

Partculers	Amount
TRUC ALMIRAHA	20,500.00
TRUC DESKTOPS	56,722.00
TRUC PRINTERS	60,306.00
TOTAL	**1,37,528.00**

Schedule-4 : Bank Accounts

Partculers	Amount
FLEXI ACCOUNT	38,10,000.00
UNION BANK OF INDIA	52,211.00
TOTAL	**38,62,211.00**

Director
National Centre for Sustainable Coastal Management
Ministry of Environment, Forest and Climate Change
Government of India, Anna University Campus
Chennai - 600 025, India

K. RAMJIRAM & CO. CHENNAI-40 Chartered Accountants

FORM NO. 10B

[*See* rule 17B]

Audit report under section 12A(b) of the Income-tax Act, 1961, in the case of charitable or religious trusts or institutions

We have examined the balance sheet of NATIONAL CENTRE FOR SUSTAINABLE COASTAL MANAGEMENT , AABAN 2289A [name and PAN of the trust or institution] as at 31/03/2015 and the Profit and loss account for the year ended on that date which are in agreement with the books of account maintained by the said trust or institution.

We have obtained all the information and explanations which to the best of our knowledge and belief were necessary for the purposes of the audit. In our opinion, proper books of account have been kept by the head office and the branches of the abovenamed institution visited by us so far as appears from our examination of the books, and proper Returns adequate for the purposes of audit have been received from branches not visited by us , subject to the comments given below:

In our opinion and to the best of our information, and according to information given to us , the said accounts give a true and fair view-

(i) in the case of the balance sheet, of the state of affairs of the above named institution as at 31/03/2015 and

(ii) in the case of the profit and loss account, of the profit or loss of its accounting year ending on 31/03/2015

The prescribed particulars are annexed hereto.

Place CHENNAI
Date 29/03/2017

K. Ramanan

Name	K RAMANAN
Membership Number	019177
FRN (Firm Registration Number)	02926S
Address	AH-46, SHANTHI COLONY, ANNA NAGAR, CHENNAI-600040.

ANNEXURE

Statement of particulars

I. APPLICATION OF INCOME FOR CHARITABLE OR RELIGIOUS PURPOSES

1.		Amount of income of the previous year applied to charitable or religious purposes in India during that year (₹)	394070124
2.		Whether the **institution** has exercised the option under clause (2) of the Explanation to section 11(1) ? If so, the details of the amount of income deemed to have been applied to charitable or religious purposes in India during the previous year (₹)	No
3.		Amount of income **accumulated or set apart** for application to charitable or religious purposes, to the extent it does not exceed 15 per cent of the income derived from property held under trust **wholly** for such purposes. (₹)	Yes 61
4.		Amount of income eligible for exemption under section 11(1)(c) (Give details)	No
5.		Amount of income, in addition to the amount referred to in item 3 above, accumulated or set apart for specified purposes under section 11(2) (₹)	0
6.		Whether the amount of income mentioned in item 5 above has been invested or deposited in the manner laid down in section 11(2)(b) ? If so, the details thereof.	Not Applicable
7.		Whether any part of the income in respect of which an option was exercised under clause (2) of the Explanation to section 11(1) in any earlier year is deemed to be income of the previous year under section 11(1B) ? If so, the details thereof (₹)	Not Applicable
8.		Whether, during the previous year, any part of income accumulated or set apart for specified purposes under section 11(2) in any earlier year-	
	(a)	has been applied for purposes other than charitable or religious purposes or has ceased to be accumulated or set apart for application thereto, or	No
	(b)	has ceased to remain invested in any security referred to in section 11(2)(b)(i) or deposited in any account referred to in section 11(2)(b)(ii) or section 11(2)(b)(iii), or	No
	(c)	has not been utilised for purposes for which it was accumulated or set apart during the period for which	No

		it was to be accumulated or set apart, or in the year immediately following the expiry thereof? If so, the details thereof	

II. APPLICATION OR USE OF INCOME OR PROPERTY FOR THE BENEFIT OF PERSONS REFERRED TO IN SECTION 13(3)

1.	Whether any part of the income or property of the **institution** was lent, or continues to be lent, in the previous year to any person referred to in section 13(3) (hereinafter referred to in this Annexure as such person)? If so, give details of the amount, rate of interest charged and the nature of security, if any.	No
2.	Whether any part of the income or property of the **institution** was made, or continued to be made, available for the use of any such person during the previous year? If so, give details of the property and the amount of rent or compensation charged, if any.	No
3.	Whether any payment was made to any such person during the previous year by way of salary, allowance or otherwise? If so, give details	Yes

Details	Amount(₹)
DR. R RAMESH	**2282400**
DR. R PURVAJA	**1911844**

4.	Whether the services of the **institution** were made available to any such person during the previous year? If so, give details thereof together with remuneration or compensation received, if any	No
5.	Whether any share, security or other property was purchased by or on behalf of the **institution** during the previous year from any such person? If so, give details thereof together with the consideration paid	No
6.	Whether any share, security or other property was sold by or on behalf of the **institution** during the previous year to any such person? If so, give details thereof together with the consideration received	No
7.	Whether any income or property of the **institution** was diverted during the previous year in favour of any such person? If so, give details thereof together with the amount of income or value of property so diverted	No
8.	Whether the income or property of the **institution** was used or applied during the previous year for the benefit of any such person in any other manner? If so, give details	No

III. INVESTMENTS HELD AT ANY TIME DURING THE PREVIOUS YEAR(S) IN CONCERNS IN WHICH PERSONS REFERRED TO IN SECTION 13(3) HAVE A SUBSTANTIAL INTEREST

S. No	Name and address of the concern	Where the concern is a company, number and class of shares held	Nominal value of the investment(₹)	Income from the investment(₹)	Whether the amount in col. 4 exceeded 5 per cent of the capital of the concern during the previous year-say, Yes/No
Total					

Place **CHENNAI**
Date **29/03/2017**

K. Ramanan

Name	**K RAMANAN**
Membership Number	**019177**
FRN (Firm Registration Number)	**02926S**
Address	**AH-46, SHANTHI COLONY, ANNA NAGAR, CHENNAI-600040.**

Form Filing Details	
Revision/Original	Original