NCSCM

NATIONAL CENTRE FOR
SUSTAINABLE COASTAL MANAGEMENT

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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

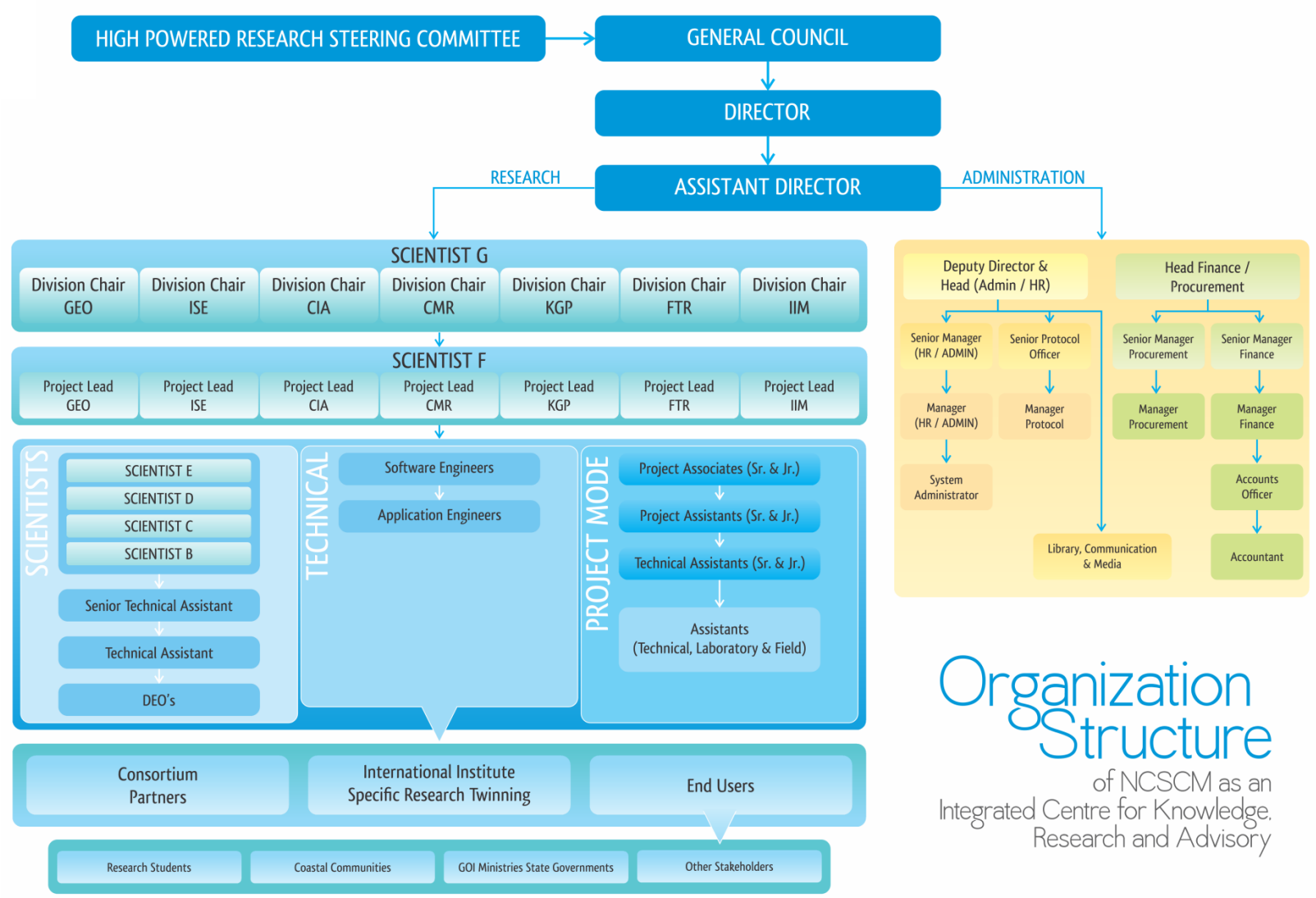
An Introduction

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. The outputs from research at NCSCM would aid in the better protection, conservation, rehabilitation, management and policy design of the coast.

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.

Organization Structure



Organization Structure

of NCSCM as an Integrated Centre for Knowledge, Research and Advisory

About NCSCM

The National Centre for Sustainable Coastal Management (NCSCM) was established by the Society of Integrated Coastal Zone Management (SICOM) of the Ministry of Environment & Forests (MoEF) in 2010 as an autonomous institution with the vision of promoting sustainable coasts through increased partnerships, conservation practices, scientific research and knowledge management for the benefit and wellbeing of current and future generations. NCSCM is designed to support the nationwide adoption of ICZM approaches through the development and provision of cutting-edge science, knowledge and networking with relevant national and international institutes of repute. These will be realized through inter and trans-disciplinary scientific research, advisory capacities and by imparting knowledge into a seamless, holistic decision support system. The necessary research builds upon and integrates expertise within the coupled social-ecological systems.

Research Divisions of

NCSCM

The Geospatial Sciences Division (GEO)

The objectives of the GEO are to provide scientifically-based decision support system to a wide variety of users, to promote environmentally sound use of coastal resources by employing the state of-the-art technology in geographic information systems (GIS) modeling, and field surveys. The major groups under the GEO are: (i) the Land Survey, (ii) the Hydrographic Survey, (iii) the Cartography, (iv) the Digital Photogrammetry, Digital Image Processing and ALTM Laboratory, and (v) the GIS Work Centre and Data Warehousing.

Integrated Social Sciences and Economics Division (ISE)

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.

Coastal Impact Assessment Division (CIA)

This division would provide input and advice on all components of coastal environment impact assessment. The division would study all relevant aspects to establish baseline environmental conditions of specific coastal areas. It 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 are: (i) the Coastal and Marine Sciences, (ii) the Coastal and Marine Engineering and Infrastructure, (iii) the Cumulative Coastal Environmental Impact Assessment, (iv) the Social Assessment and Gender, and (v) the Coastal Tourism and Heritage.

Conservation of Coastal and Marine Resources Division (CMR)

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. he 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, (Hi) the Coastal Energy Group, and, (iv) the Marine Protected Areas Group.

Knowledge, Governance and Policy Division (KGP)

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.

Futuristic Research Division (FTR)

FTR would conduct advanced research on climate change and sea level rise issues including paleo-dimatic 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.

Integrated Island Management Division

The Integrated Island Management Division (MM) would prepare a model framework for integrated island management plan. The goal of the MM 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 MM 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.

The IIM would develop guidelines for hazard preparedness and evolve climate change adaptation and mitigation strategies for the Islands. Some of the major goals are to develop integrated island management / green island economy concept and to explore, in conjunction with island populations, ecotourism development as a particular option. The IIM would provide tools for mainstreaming Disaster Risk Management based on experiences from selected island countries worldwide. The IIM division would undertake specific 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.

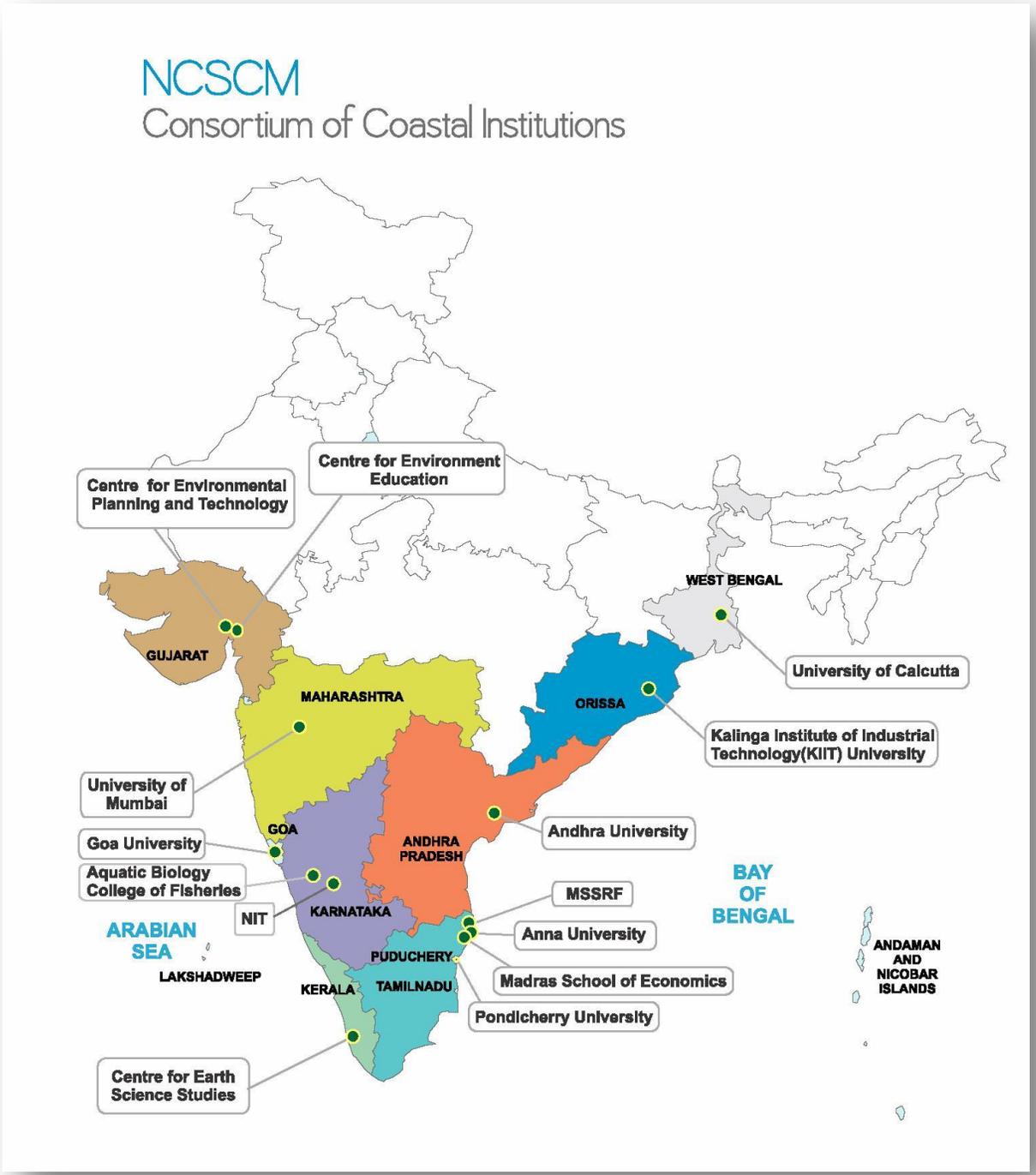
Consortium Partner Institutions

The Ministry of Environment and Forests recognized that the issues related to the coast are too diverse and complex to be addressed by one research organization and hence there is a need to strengthen the capacity of regional universities and research units along the coast so as to be the research consortium partners of NCSCM, Chennai. The idea is novel and NCSCM is the first central research consortium organization to have such a focused collaboration with regional universities.

Fourteen institutions have formed a consortium with the National Centre for Sustainable Coastal Management, Anna University Chennai and signed the Anna University declaration on 21st June 2010 to that effect. The salient features of the Declaration are:

1. Preparing immediate preventive and remedial action, wherever possible, using existing knowledge, resources, plans and processes for conservation and protection of the coastal environment and safeguarding the livelihood of local communities who depend upon the resources from the coastal and marine areas.
2. Promoting access and undertaking high quality targeted research in the area of coastal and marine area management and facilitating transfer of technology and information
3. Collecting compiling and disseminating information in the area of coastal and marine environment management through networking among States/ Institutions.
4. Encouraging cooperative and collaborative action and partnerships, among governmental institutions and organizations, communities, the private sector and non-governmental organizations which have relevant responsibilities and/or experience;
5. Assisting institutional strengthening and human resources development for capacity building in ICZM.

NCSCM has put in place a road map for strengthening and expanding the existing NCSCM consortium, stakeholder network and prioritize the community interface. NCSCM supports its partner consortium institutes by strengthening their core area of research, and build capacities on the core research mandates of the NCSCM. Such networks and partnerships will formalize multidisciplinary interactions in order to effectively address key coastal research problems. Research proposals are being prepared by the CIs jointly with the scientists of NCSCM in order to address the coastal issues through systematic research.



NCSCM has undertaken pioneering study on various areas of immediate concern to aid in furthering the objectives of scientific management of the Indian coast.

NCSCM is developing a conceptual framework and process guidelines for ICZM in order to help the coastal state governments in preparing the detailed ICZM plans. The major research programmes of NCSCM are:

1. ICZM Process Guidelines: A roadmap towards coastal sustainability
2. National Assessment of Shoreline Change for India
3. High Resolution Erosion Mapping
4. Sediment Cell Mapping and development of SMP
5. Coastal Ecosystem Health Assessment & Report Card
6. Offshore Wind Energy Potential

In addition to the above, in the light of the emerging research issues related to coastal protection and the need for systematic study, the High Power Research Steering Committee (HPSC) of NCSCM has identified broad research areas for NCSCM and its consortium partners. Research projects have been prepared to undertake a comprehensive study on the identified areas. The projects thus identified are: 1 Blue carbon - Offsetting carbon emissions by conserving coastal vegetation

2. Delineation of Ecologically Sensitive Areas (ESA) and Critically Vulnerable Coastal Areas (CVCA)
3. Development of a database on marine diversity
4. Island Coastal Regulation Zone (ICRZ) Plan and Integrated Island Management (MM) Plan for the Islands
5. Economic valuation of coastal and marine ecosystem goods and services in India
6. Inventorization of greenhouse gases from different coastal ecosystems

The research achievements under these projects are summarized in the following sections.

Knowledge and governance policy

ICZM Process Guidelines:

The Knowledge, Governance and Policy Division is proposed as a central repository for the dispersed information on the Indian coast. Coastal management requires all the stakeholders (scientists, politicians, NGOs, private sector, communities, etc) to be interconnected at different scales in order to share information, knowledge and data to solve problems and conflicts facing the coastal area and its livelihood. The knowledge management system of the centre is assisting those interested in coastal governance to access the most relevant information on coastal issues. This division is also serve as an advisory to the government on coastal governance and policy issues of coastal management.

The coast is a high priority area for development activities spurred by globalization and trade requirements. Since most development activities are sectoral and highly competitive, there is often conflict for space and resources. The pressure on natural ecosystems is high and has resulted in extensive destruction and degradation of coastal ecosystems in the recent past. In order to achieve sustainable development of the coast, integrated coastal zone management [ICZM] has been recommended as a tool. ICZM is a planning **and** coordinating process, where the primary purpose **is to** bring together various concerned agencies to work towards common objective [s].

In India, since 1991, the Notification issued under the Environment [Protection] Act, 1986 has been used for coastal protection by classifying a 500m zone from the high tide line as the Coastal Regulation Zone, [CRZ] where [development] activities are severely restricted. The notification was reissued in 2011. While managing the coastal area has to be firmly rooted in the legislation, the 500m boundary is not always practical or meaningful for managing the coastal area as impacts on the coast can originate beyond the 500m that **is** regulated. ICZM provides a larger perspective for development-related activities as well as conservation of coastal ecosystems. The coast is also a highly vulnerable area especially with reference to impacts of climate change and sea level rise. There is also conflict for space and resources. Working within the constraints of limited space for competing resources, ICZM can help by providing a mechanism along with tools that allow development activities underscored by the precautionary **principle** while ensuring rational **resource allocation** and conservation of ecosystems. It also ensures incorporation of environmental and social concerns in the developmental activities.

The process of preparing an ICZM plan is discussed under the following five phases:

Phase I Inception

Phase II Coastal Profiling

Phase III Visioning and Strategy Formulation

Phase IV Planning and Integration

Phase V Implementation, Monitoring & Evaluation

Capacity building is built into each phase and would vary depending on the stakeholder and the task to be performed. Similarly, various tools are available that can be used in supporting the different tasks in the preparation of the ICZM Plan.

Phase I

The "Inception" Phase is designed to provide the foundation for the development of an ICZM Plan. It begins with the formation of a Facilitation Team [FT] by the nodal department [e.g. Department of Environment], which coordinates the activities through the entire process. The FT may take the assistance of external agencies/institutions at various stages in the process. The initial activity carried out by the FT is to outline the plan boundary [ICZM planning area], the preparation of a background note on the major problems in the plan area as well as a brief profile of that plan area [resources, livelihoods, developmental activities [such as ports, industries] and a list of stakeholders which includes the local coastal communities. Since a variety of stakeholders with different levels of knowledge and understanding are to be involved, an awareness campaign and capacity building exercise has to be organized for each group of stakeholders before holding a combined stakeholder consultation that discusses the key issues in the plan area, broadly defines goals and objectives and the plan boundary. An inception report is then prepared.

Phase II

The second phase is **'Coastal Profiling'.** The first activity here is collection and collation of information on the physical features of the coast, coastal processes, resources, land use and land cover and socio-economics with special focus on coastal livelihoods and the dependence of local communities on natural resources. This information would provide a broad overview of the land-people-ecosystem interactions and enable derivation of the important issues, their causes, priorities, and consequences, inorder to provide a scientific basis for developing a strategic management plan for the area. This would be prepared in a GIS format to enable the development of a "Decision Support System" during plan preparation as well as implementation. The second activity in this phase is a review of the legal and institutional framework governing the region. The outcome of this review would help analyze and identify if possible, the key stakeholder institution for plan implementation. This would also help ensure the capacity of the institution/ organization to further implement the ICZM Plan. The third activity in this phase is the collection of department/agency-wise [sectoral] plans for the region. The entire process is reviewed by an ICZM Committee [ICZM-C] constituted by the Nodal department.

Phase III

The activities in Phase III, **"Visioning and Strategy Formulation'** are geared towards the development of a stakeholder vision based on which a **"coastal strategy"** is formulated. The visioning process is a step-wise activity that ensures the involvement and eventual consensus of all stakeholders in the plan area on the development, socio-economics and conservation priorities. Once a vision is agreed upon, the stakeholders could work on how to realize the vision. This would result in the development of a coastal strategy. The goals and objectives as well as the plan boundary that were outlined in Phase I, are redefined/modified [if necessary] and formally accepted. The issues to be addressed by management sub-plans that focus on addressing the issue identified as being of priority. Examples of such sub-plans would include those for

shoreline management; pollution management and conservation are identified and listed. These would be reviewed by ICAM Committee

Phase IV

In Phase IV, **'Planning and Integration'**, continues from Phase III and first involves the development of management sub-plans with input from the departmental/agency plans for the area. Gaps identified are filled to prepare individual sub-plans. For areas with multiple issues, it is expected that there will be multiple sub-plans. Preparation of sub- plans involve detailed analysis of issues [through collection of field data] and development of solutions to solve problems including the cross-sectoral impacts. These sub-plans are now integrated into a single draft ICZM plan by examining them for congruence, and overlaps after resolving inter-departmental conflicts. The plan is also aligned for financial/budgetary allocations. An institutional structure for implementing ICZM Plan is developed and a strategy to monitor the plan implementation is formalized. The integrated plan for the chosen area is presented to the key stakeholders/ community and the feedback is incorporated into the draft ICZM plan. The draft plan is reviewed by ICZM-C before realisation. The plan also recommends appropriate legal coverage/ Notification to ensure its implementation. This is submitted to the State Government as well as to the MoEF for approval.

Phase V

The final Phase, **'Implementation, Monitoring and Evaluation'**, includes Implementation of the ICZM plan by respective departments / agencies, Monitoring and Evaluation using appropriate indicators and adaptive management, to take corrective steps where required. Thus, ICZMP also provides flexibility for change.

Geospatial science

The amenities of the Geospatial Sciences division are to provide science-based decision-support systems to a wide variety of technical and non-technical users, to promote sustainable use of coastal resources by employing state-of-the-art technology in remote sensing, geographic information systems (GIS), numerical modelling, and field validations.

Delineation of Sediment cell for the east and west coasts of India

There is an increasing pressure on the coastal zone from numerous user groups, all of whom require some kind of utilization of the coastal resources. Consequently, a comprehensive planning effort is required in order to secure a balanced sustainable development taking all demands and restrictions into account. In India, a number of developmental research studies are being carried out all along the coast (such as construction or expansion of ports and harbours/ power plants/ tourism development/ desalination plants etc.). The sediment budget and the transport rate play vital roles in determining the stability of the coast and they are chiefly governed by the coastal processes prevalent in the area. 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 the other, 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 are identified and categorized as primary cell, sub cell and management units based on certain unique key criteria for each type. In this way the entire Indian coast will be delineated into 27 primary cells with 10 primary cells in the west and 17 primary cells on the east coasts of India.

The 27 primary cells are further delineated into 59 sub cells with 21 sub cells out of 10 PC's in the West coast and 38 sub cells out of 17 pc's on the East coast as shown in Fig 2 . Further the behaviour of sediment within each cell is studied with the existing and proposed activity at selected locations along the coast.

National Assessment of Shoreline changes of India

This shoreline change assessment for the coast of India represents long-term shoreline change for a period of 38 years from 1972-2010. Shoreline change evaluations are based on comparing four to

five historical shorelines, archived from satellite imageries for the above time period, with recent shoreline derived from LISS III images and limited field surveys. The primary goal of this study is to develop standardized methods for mapping and analysing shoreline movement so that internally consistent updates can periodically be made to record shoreline erosion and accretion. Appropriate use of remote sensing technology coupled with limited DGPS surveys was integrated in GIS platform to obtain historical shoreline information.

For the coast of India, base maps were prepared on 1:50,000 scale using the toposheet of the Survey of India and onscreen digitization of coastline using multi-date satellite images on 1:50,000 scale and stored as four different layers in GIS environment for the period between 1972 and 2010. The multi-date shorelines served as input into the USGS digital shoreline analysis model to cast various transects along the coastline. A distance of 300m (in some cases 500m) intervals were assigned to calculate the erosion/ accretion statistics in ArcGIS 9.3 software. The erosion/accretion rates are derived from "statistical analysis" of multi-date shorelines using the Linear Regression Rate (LRR) of the USGS Digital Shoreline Analysis System. In the future, it is intended to use High Resolution Satellite Imagery along with DEM to derive precise shoreline changes.

Integrated social science and economics

The Integrated social science and economics (ISE) division focuses on coastal communities and their livelihoods. In particular, the ISE division mainly focuses on community based approach to coastal vulnerability and coastal management with collaboration with other divisions of the NCSCM. Research interests of ISE division includes 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.

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

The significance of coastal and marine ecosystem is under-appreciated because of the limited understanding of their role. Most studies on ecosystem services often focus on the number of species in an ecosystem (Tilman, 1997). The value of biodiversity arises not merely from its species richness but from a large number of its ecosystem functions. These functions, among others, include its potential for restoring marine productivity, stability and sustainability. A conservation plan with the sole objective of protecting species-richness is unlikely to stand the test of economic net-benefits when compared to alternative plans of development and ecosystem conversion. It is ironical but real economic considerations often dominate policy discussion. Therefore, it is important to account for the economic values of the entire range of known coastal and marine ecosystem services in order to articulate more credible justification for conservation plans. The two-fold objectives of this research, therefore, are to identify the full range of services that coastal and marine ecosystem provides to human society and to suggest ways to value these services. The research study aims to develop a framework that links the functioning, provisioning and valuation of services provided by coastal ecosystems to human population. To do so, the study plans to prioritise critically important ecosystems, value goods and services delivered and finally link the value to social welfare among and beyond coastal communities wherein the complex interactions between ecosystem services and monetization of their impacts establish the framework to carry out our analysis (Fig. 1).

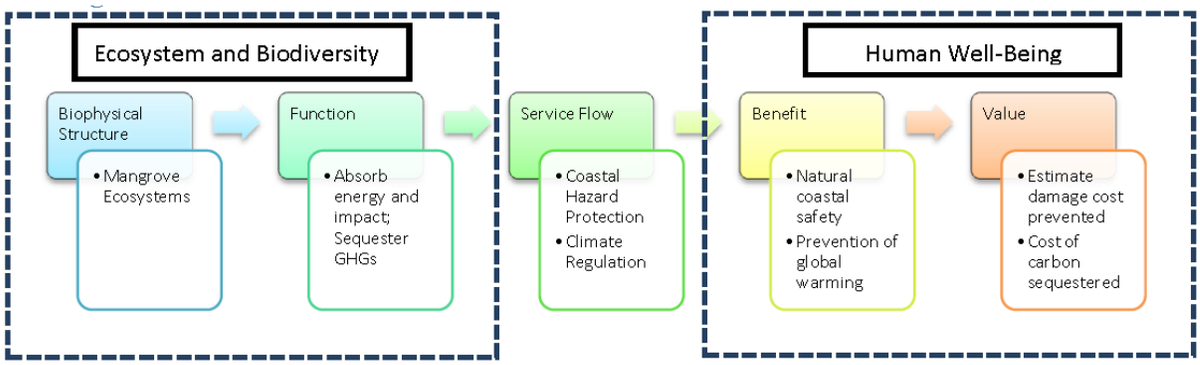


Fig. 1. Framework to carry out interactions between ecosystem services and monetization for analysis

The major ecosystems covered are mangroves, sea-grass, estuaries, sandy beaches and coral reef. These ecosystems, have been classified by the CRZ (2011) notification as ecologically sensitive areas and are classified as CRZ I. Project Objectives Biophysical Structure

•Mangrove Ecosystems Function

•Absorb energy and impact; Sequester GHGs Service Flow

•Coastal Hazard Protection

•Climate Regulation Benefit

•Natural coastal safety

•Prevention of global warming Value •Estimate damage cost prevented

•Cost of carbon sequestered Ecosystem and Biodiversity Human Well-Being

• To improve the understanding of the economic values of coastal ecosystem goods and services

• To help policy makers to incorporate the estimated economic values (market and nonmarket) into the cost-benefit analysis of coastal development projects

• To use the above ecosystem service values to promote effective and participatory management strategies for sustainable use of the coastal resources. In addition to addressing the key objectives of this study, four themes associated with the valuation of coastal ecosystem services will be researched in detail

• Incorporating coastal ecosystems within the framework of the System of Environmental and Economic Accounting (SEEA)

• Methodologies that facilitate economic valuation of coastal ecosystem goods and services in the Indian context.

• The role of local and national institutional structures on the sustainability of coastal ecosystem services.

• Extending the economic values from the academic to policy domain. Project Methodology: Madras School of Economics (MSE) and Goa University are the two consortium partners of NCSCM each tasked

with undertaking valuation studies of different coastal ecosystems across the country. A detailed research action plan with the breakup of work packages and framework of tasks for this project has been prepared. Five work packages (WPs) are planned as listed below with specific tasks under each work package.

As per the work-packages defined in the study, a comprehensive review of coastal ecosystem services valuation studies in India and across the South Asian region were made whereby critically important ecosystem services values were identified and prioritized based on descriptive statistical analysis. Two consultation workshops with subject experts and policymakers were organised at the NCSCM facility in Chennai. The first expert consultation held in October 2013 was to prioritise key coastal ecosystem services based on their ecological significance. The second expert consultation held in January 2014, with key economists, ecologists and policy-makers, was to discuss the appropriate scientific approach to ecosystem valuation and critical issues of the valuation process specifically focussing on India and South Asia. Work is currently under progress with regards to estimating monetary values of coastal ecosystems identified by the CRZ notification (2011). The first inception meeting with the consortium partners was organised on June 2014. It was agreed that macro-level estimates of goods and services of coastal ecosystems identified in the CRZ notification will be valued using the meta-analysis approach. 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. As per the scope of the research study, stakeholder workshops and SWOT analyses would be undertaken to 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, recreational and cultural services Project Beneficiaries

• Planners, local governments, local communities, to select developmental projects coastal areas and formulating ICZM plan.

• The planners of 9 coastal states will have a clear understanding of the value of the coastal resources and methodology to identify and measure the value of ecosystem services

• The research community across the states will have an opportunity to use and undertake studies on the coastal ecosystem services.

• The stakeholders will be able to use the results of the study in environmental impact assessment and decide about the proposed developmental project.

Transformation and Resilience on Urban Coasts (TRUC) (supported by Belmont Forum and Ministry of Earth Sciences, GOI, New Delhi) Focal Point: Prof. R. Ramesh, Director Co-ordinating Divisions: Integrated Social Science and Economics (ISE), Coastal Impact Assessment (CIA) and GeoSpatial Division (GEO) The TRUC project, supported by the Ministry of Earth Sciences, GOI and Belmonte Forum, is a multi-country study. Its aim is to develop and test a novel integrated framework to examine the interactions between development pathways, social and environmental systems dynamics and policy decision-making in the production and management of vulnerability to extreme events (i.e. heat waves and flooding) generated through large scale coastal urbanization processes. TRUC offers a step-change in coordinated research on urbanization and the coast applicable to global as well as local/city level impact. TRUC brings together seven world leading teams engaged in parallel research

trajectories. Within NCSCM, this trans-disciplinary project brings together a team of researchers with wide but compatible skills. Currently the ISE Division in collaboration with Geo-Spatial and Coastal Impact Assessment Divisions are undertaking the project.

Objectives

To examine the interactions between development pathways, social and environmental systems dynamics and policy decision-making in the production and management of vulnerability to extreme events (i.e. heat waves and flooding) generated through large scale coastal urbanization processes.

• To integrate biophysical and social science approaches to vulnerability assessment along with providing a comprehensive vulnerability and adaptation analysis and policymaking tool.

• To develop combined model outputs to appraise key trends in the processes shaping future urban morphology and hazard conditions, and the purchase development and risk management policy can have on this, e.g. on green spaces and retention areas, or upgrading informal settlement, and implications for the distribution of vulnerability and hazard exposure.

This analysis is important to better understand social-environmental urbanization and risk processes in megacities, including the influence of decision-making culture, and of direct utility 2 to urban stakeholders balancing alternative risk management and underlying development goals. While providing an overarching framework, the integrated methodology will be influenced by the data availability of individual case study sites. A sensitivity analysis will help to advance these scenario tools even further. The variety of case study cities included in TRUC will test its global applicability. The ISE Division has undertaken a preliminary ward-wise assessment of Kolkata based on secondary data available on the following socio-economic indicators – public institutions, dependency ratios, personal/public health, access to water, sanitation, health and education services and infrastructure, housing conditions and property values, gender equity etc. from independently published reports, Directorate of Economics and Statistics reports, Planning Commission reports and National Census. Two specific development indicators namely “literacy rate” (the ratio of total literates to total population) and “worker participation rate” (the ratio of total workers to total population) were used to rank the wards/regions in the city under the following three categories. - High literacy and high worker-participation (Highly developed wards/regions) - Low literacy and low worker-participation (Under-developed wards/regions) - Average literacy and worker-participation (Wards/regions that fall outside highly developed and underdeveloped areas) The ISE Division is also currently planning workshops by inviting key stakeholders from wards belonging to each of the above categories. The objectives of the workshops are to ground-truth the data collected through secondary sources of information and to yield further stakeholder feedback on adaptive and mitigating capacity of the city against natural coastal hazards.

Coastal Environmental Impact Assessment

The Coastal Environmental Impact Assessment (CIA) Division is involved in providing continuous inputs and advices on all components of coastal environmental impact assessment. This division specifically addresses all components of an EIA in order to establish baseline environmental conditions of a specific coastal area. It is involved in identification, predict and assess the significance of environmental, economic and social effects of any development proposal including effects on air, water, noise levels, archeology and cultural heritage, land use, ecology and nature conservation, and community effects. The division also appropriately advises mitigation options, monitoring measures to prevent, reduce or remedy significant adverse environmental and social impacts on the coast. This division will be equipped with highly advanced instruments like AAS, HR-ICP MS, GS-MS, microbial identification system etc to generate the highest quality of data useful for decision making for the ecosystem managers.

ONGOING AND PROPOSE IN-HOUSE RESEARCH STUDY

Coastal ECOsystem HEALTH Report Card (ECOHEALTH)

Summary of Research Study

Increasing pollutant inputs to coastal waters have been associated with rising human population densities, changes in land use, coastal development activities and the intensification of agricultural and aquaculture practices. Problems associated with water quality degradation are increasingly a threat to aquatic systems worldwide, particularly in Coastal ecosystems. For example, nutrient enrichment from urban wastewater and agricultural runoff is responsible for excessive phytoplankton production, the decline of submerged aquatic vegetation, increasing abundance of nuisance algae blooms and increasing extent and duration of hypoxic and anoxic waters in many areas of the Coastal waters.

Assessing Ecosystem health requires a framework for setting objectives, selecting, monitoring and reporting on appropriate indicators that contribute to the overall health of a system. The aim of the EcoHealth program is to provide an integrated approach to ecosystem health monitoring along the India peninsula. The EcoHealth program includes a number of physical, chemical and biological indicators to determine the health of coastal waters. The combination of coastal waters& health indicators that identify short-term (water chemistry), intermediate term (zooplankton, macro-invertebrates), and long term responses (fish and riparian vegetation) provides a robust program for quantifying coastal ecosystem health and prioritizing management actions.

Scientifically robust, quality assured data generated by EcoHealth would give a complete picture of the current state of our coastal waters. The information generated thus allows Local Government, Policy makers and other natural resource managers to better manage aquatic ecosystems and evaluate natural resource management activities for their effectiveness. Annual Report Cards are an important part of the research program and provide a regional assessment of each ecosystem, highlighting where the health of an ecosystem is improving and where management action would further be required.

Keywords: *Coastal ecosystem health, Coastal Pollution, Eutrophication, Indicators, Phytoplankton, Seagrass, Submerged Aquatic Vegetation, Water quality, Ecosystem Health Index*

Background

Rationale of the study: Including work done in India and elsewhere

The sustainable use of coastal ecosystems is to assess the system's condition, which is a complex process due to natural gradients and variability intrinsic to coastal areas, as well as ongoing structural and functional changes occurring due to human impacts. In response to such complexity, scientists have sought to identify and select the most adequate parameters to define the ecological quality or health status of coastal waters. Previous studies have explored the use of a number of metrics, indices, and analytical frameworks to increase the credibility and robustness of coastal ecosystem health status determinations (Borja, 2005; Borja et al., 2004, 2000; Orfanidis et al., 2003; Dennison et al., 1993; Buchanan et al., 2005). Multimetric indices are important ecosystem management tools that can give robust indication of the ecosystem status. Ecosystem indices include those dealing with benthic macro-invertebrates (Weisberg et al., 1997; Engle and Summers, 1999; Borja et al., 2000; Borja et al., 2007), fish (Barbour et al., 1992; Kerans and Karr, 1994; Hughes et al., 1998), phytoplankton (Buchanan et al., 2005; Lacouture et al., 2006) and submerged aquatic vegetation (Dennison et al., 1993). Different metrics can be combined to create health status indices and assessments, and this has been done in several coastal ecosystems in order to document the effects and extent of coastal impact (Jordan and Vaas, 2000; Pantus and Dennison, 2005; Ecosystem Health Monitoring Program, 2007; Borja et al., 2004; Borja and Dauer, 2008; Dennison et al., 2009).

There have been very few attempts to study the different aspects of coastal ecosystem indices status along the Indian subcontinents in an integrated manner. 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 team is currently finalizing the methodology for the study, based on which information will be generated and devised. Chilika is the first ecosystem where Coastal Ecosystem Health Assessment Report Card is developed in India. Coastal Ecosystem Health index of Chilika includes water quality indicators (chlorophyll 'a', dissolved oxygen, water clarity and nutrients) and three biotic indicators (bay grasses [submerged aquatic vegetation], Benthic Index of Biotic Integrity [soft bottom only] and Phytoplankton Index of Biotic Integrity). The purpose behind preparing an ecosystem health report card was to develop an integrated ecosystem health assessment for Chilika Lake and its tidal tributaries using the identified reporting indicators and top-level indices, create a ranking valuation scheme to compare ecosystem health assessments both geographically and over time (annual assessments) and effectively communicate the integrated ecosystem health assessments with spatially explicit maps and rigorous scientifically based analyses to the community.

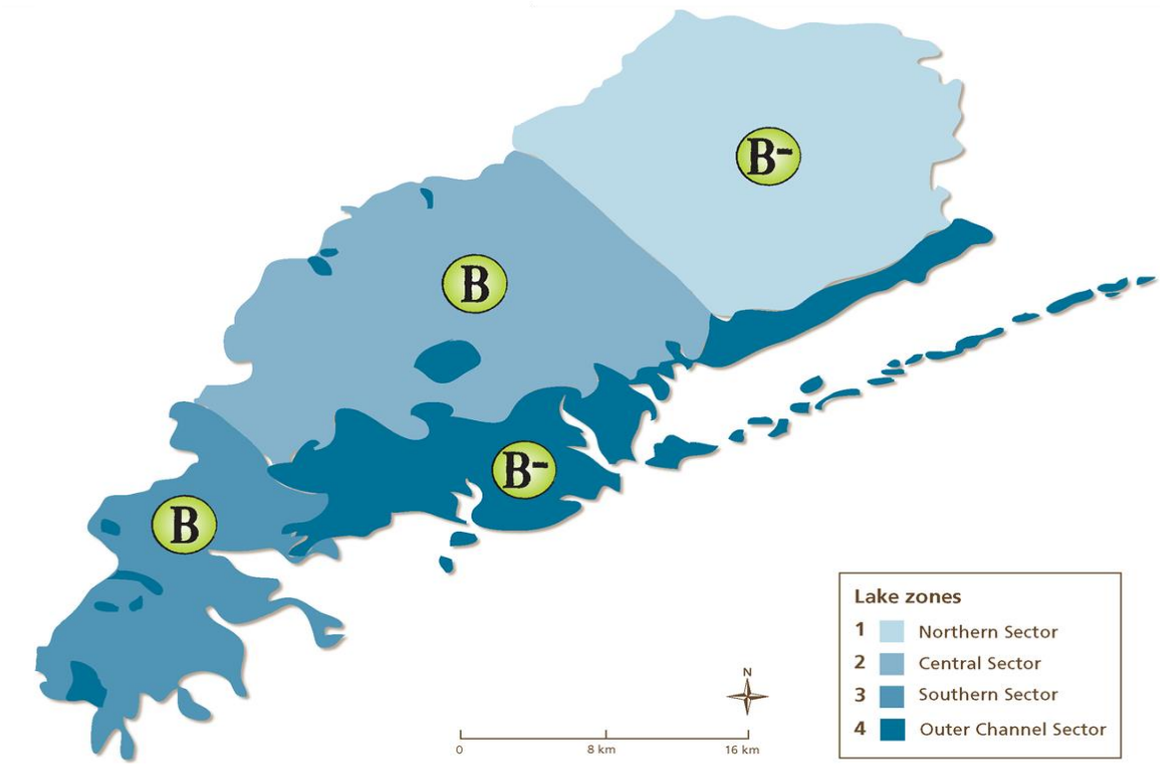


Fig. 2: Overall water quality index score for Chilika Lake

The Chilika Lake report card is unique in that it provides a geographically detailed and integrated approach to form numerical rankings of three reporting regions (namely, Northern, Southern and Central) on an annual basis (Fig. 2). This approach compliments those focusing on assessment over longer time frames. The geographic detail provided in the report card reflects the complexity of Chilika Lake and its tributaries, providing information that can help, guide and focus on restoration efforts. The report card is a developing product, with a more complete assessment of Bay health expected in the future. In this study, efforts were made to apply the DPSIR (Driver-Pressure-State-Impact-Response) framework for coastal waters of India.

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 identified Coastal and marine areas which are in need of immediate restoration and measures to ensure sustainable development with optimum resource exploitation. This study is expected to explore and formulate an environmental health report card (EHRC) to rejuvenate coastal and marine environment. The project is motivated by a requirement to improve the understanding of the varied processes for the conservation in view of its deteriorating ecology. The study proposes to characterize a several test sites (Ecosystem) initially in the coastal waters with respect to deteriorating status. Environmental data collected from time-series and monthly measurements will be used to develop an Ecosystem Health Report Card.

Assessment of Cumulative Coastal Environmental impactS [ACCES]

Summary of the Research Study

The primary focus of this research study is to provide coastal managers and regulators a methodology to address cumulative impacts along the coast. The study aims at developing a comprehensive guideline to assess the cumulative impacts of coastal development (past, present and future). This would help in establishing measurable goals, baselines and benchmarks against which cumulative impacts of land based and coast-based developmental activities can be evaluated. Cumulative Coastal Environmental Impact Assessment [CEIA] is an evolving concept that identifies foreseeable future actions within the space and time boundaries that have been/ could contribute to cumulative stresses on the coast.

Rationale

Coastal regions are of immense significance since majority of the earth's population live in highly urbanised coastal cities with accelerated developmental activities (Shi et al., 2004). Coastal areas face abundant environmental and management challenges, due to a combination of impacts that arise both in open ocean areas and those areas inherent to coastlines, such as the impacts of land based activities. The high degree of complexity of activities in coastal zones has led to emphasis on adoption of Integrated Coastal Zone Management (ICZM) as a governance mechanism. Cumulative Environmental Impact Assessment (CEIA) is an integral part of ICZM processes, considering cumulative impacts of developments along 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. The CEIA process predicts the consequences of development relative to the assessment of existing environmental quality. It helps in assessing whether the level of development is within or if it exceeds the environment's assimilative capacity; i.e., its ability to sustain itself. The scale of CEIA is beyond the scope of a small scale single developmental plan and requires broader temporal and spatial boundaries than those used in the project based or site-specific assessments as effects may occur at remote locations far from the project in space and time.

Objectives

a) Developing guideline for Cumulative Environmental Impact Assessment (CEIA)

b) Determining the State of the Coast (along mainland coast of India)

c) Assessing the pressure on the identified stretches along the coast through carrying capacity studies

State of Coast reporting

State of coast reporting along the coast of India has been conducted as a part of ACCES research study. For the purpose of this study, the coast of India was divided into segments based on the sediment cell concept, which was developed for the Integrated Coastal Zone Management Plans (ICZMP).As a part of the ACCES research study, coastal sampling will be carried out. Water, sediment and biological samples would be collected and analysed from various transects by undertaking cruise programme to understand the baseline status of our mainland coast.

Existing Activities

1. Monitoring of the entire coast of India at 25km interval at 10 m depth to identify key hotspots of pollution from land based activities
2. Assessment of pesticide concentration along the coast
3. Distribution of natural and anthropogenic radionuclide in the marine environment
4. Nutrient budget using LOICZ Biogeochemical Approach
5. Bio-magnification and biotransformation of pollutants using bio-assay experiments

• *Establishment of "Sentinel" Site for Coastal Management*

Real-time forecast of coastal ecosystems will improve the fundamental understanding of role of ecosystems of land-ocean boundary, as this will allow the managers the tools to answer 'what-if' questions about the coastal environment. The expected output will be ecosystem health report on coastal ecosystems of India, under changing environmental conditions with a long term database of multidisciplinary parameters, which will be directly relevant to the ICZM Program. It is expected to provide appropriate interventions that would help in restoration of water quality and productivity of the coastal waters. The outcome of the project will lead to development of a forecasting online tool "Sentinel outlook" that will enable us to predict development of such conditions for the benefit of local communities.

Under the project, installation of Automatic Weather Station (AWS) and Data Buoy shave been deployed in three locations namely Kurusadai Island, Gulf of Mannar (Tamil Nadu), Chester Island (South Andaman) and Kavaratti Island (Lakshadweep). Similarly, installation of Automatic Weather Station and Data Buoy deployment would be deployed at (Maharashtra).

Deliverables:

Collection of long-term time series data using real time monitoring system.

- Water quality
- Metrological data

Objectives

For determining and understanding the dynamics and coastal process of the marine systems along the Indian coast, it requires a continuous monitoring for various chemical, physical, and biological parameters. Keeping this in mind, few Indian coastal ecosystems were identified for continuous monitoring and the following work packages are designed for the "Sentinel" site programme. The objectives of the study are as follows:

1. Provide appropriate intervention to help coastal management.
2. Collection of long term time series data using real time monitoring system.
    - Water quality
    - Metrological data
    - Waves, tides, current etc.
    - Generation of a long term database for coral reef monitoring
3. Observation of coral bleaching events caused due to natural (El-Niño type events) or anthropogenic (land-based inputs) activities
4. Develop science-based management plan for the conservation and protection of coral reef ecosystems based on long-term observations
5. Development of online web portal for “CReON”.
6. Deployment of settlement tripod (for recruitment rate) and sediment traps (for sedimentation rate estimation)
7. Assessing coral reef ecosystem health in connection with changes in biological and physical indicators to develop i) Coral Health Index (CHI) and ii) health of associated flora and fauna that influence coral health, by developing Sea Life Index (SLI)
8. Assessment of microbial communities associated with corals (Beneficial microbial flora and pathogens) – to understand the association of microbial communities with coral health, bleaching and recovery

Work Packages

WP 1	Criteria for selection of sentinel site	
	Tasks	
1.1	• Coral Reef Observation Network (CReON) • Collection of long term time series water quality and metrological data • Sentinel Data Buoy Network (SDBN) • Automatic weather station (AWS) • Observation of coral bleaching events caused due to natural (El-Niño type events) or anthropogenic (land-based inputs)	Same as Phase I

	activities	
WP 2	**Data synthesis and translation**	
2.1	(i) Water Quality Index (WQI) Coral reef ecosystem health assessment (ii) Coral Health Index (CHI) (iii) Sea Life Index (SLI) (iv) Impact of sedimentation on coral health (v) Recruitment pattern of coral spats using settlement tripod (vi) Microbial communities associated with corals (Beneficial microbial flora and pathogens) (vii) Long term observation of temperature & light on reefs	Same as the Phase I
WP 3	**Development of online web portal for sentinel sites**	
3.1	• Assist in developing science-based strategies for decision makers on coastal development.	Additional Activity

Methodology

NCCM Sentinel Site Program (NCSCM SSP)

The Indian coastline, and more particularly the fragile islands, is subjected to several geo-morphological changes due to natural processes and manmade activities. Coral reefs are one of the most complex and dynamic ecosystems of India. In India, Gulf of Kutch, Gulf of Mannar, Andaman & Nicobar, Lakshadweep Islands and Malvan are the major coral reef ecosystems. In addition, coral reefs are climatologically important because they provide an accurate long-term record of the climate change and seasonal climate variability in many remote tropical oceans.

Conservation of Coastal and Marine Resources

The principal mandate of Conservation of Coastal and Marine Resources (CMR) is to guide the use of the living and non-living natural resources for diverse and often conflicting sectorial 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.

Delineation of Ecologically Sensitive Areas and Delineation of Critically Vulnerable Coastal Areas (CVCA)

India has a very long coastline with various types of ecosystems viz., tidal mudflats, mangroves, estuaries, lagoons, beaches, marshes, vegetated wetlands, coral reefs etc. Many of these coastal ecosystems, which are known for their rich biodiversity, serve as unique habitats or seasonal nesting sites for specific marine organisms. Over the years, the coastal habitats have been degraded and destroyed due to anthropogenic forces. The government has declared selected coastal and marine areas as protected areas under the Wild Life (Protection) Act, 1972 and Environment (Protection) Act, 1986. However, the contribution of marine protected areas (MPAs) is only 4% of the total protected areas (PAs) and 1.3% of the continental shelf area of the country. The National Environment Policy, 2006 aims **at** protecting and **conserving critical** ecological systems and resources which are essential **for life** support, livelihoods, economic growth and highlights the need for identifying and giving legal status to Environmentally Sensitive Zones in the country and formulate area development plans for these zones on scientific basis, with adequate participation by the local communities.

India's conservation plan is based on the philosophy of identifying and protecting representative **sensitive habitats** across all the ecosystems. **There are already a** number of legal instruments to **enable** protection of identified areas viz.. Wild Life (Protection) Act, 1972, Forest (Conservation) Act, 1980 and Environment (Protection) **Act, 1986**, Indian Forest Act, **1927**, Biological **Diversity** Act, 2002 and Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006. The Coastal Regulation Zone (CRZ) 2011 notification, issued under the Environment Protection Act, 1986 classifies the areas that are ecologically sensitive and the geomorphological features which play a role in maintaining the integrity of the coast under CRZ I Category.

Scientific data on the ecologically sensitive areas (ESA) with respect to physical, chemical and biological components with associated issues such as resource use and socio-economics of dependent population are far from complete. Guidelines to designate an area as ESA have been in existence, albeit on broad terms allowing open ended decision making to the state government, thus providing them with avenues to adopt diversified criteria. Further, mapping of all aspects of an ESA would pave way for better management and enforcement of relevant regulatory provisions. In this background, a

comprehensive research project has been initiated to define coastal and marine ESAs and identify the parameters for their delineation and demarcation in order to aid in the implementation of the CRZ Notification, 2011.

The project is envisaged to be carried out by the NCSCM scientists, cross cutting the technical divisions involving the experts from Consortium Institutions (CI) from all the coastal states. Some activities will be undertaken simultaneously while some will be carried out sequentially, taking inputs from other activities. Detailed work packages have been made by NCSCM for undertaking the study which was deliberated in the consultative meeting with the CIs. A road map has been prepared for the execution of the project activities with the CIs and external experts.

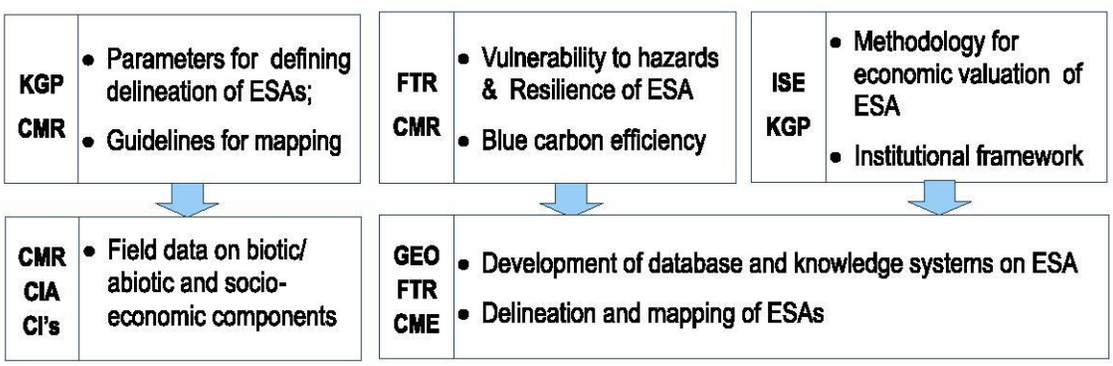


Fig. 3. A broad framework for implementation of the project is given below.

The Coastal Regulation Zone (CRZ) 2011 notification issued under Environment (Protection) Act, 1986 has brought a new coastal area under the regulatory regime, the Critical vulnerable coastal areas (CVCA), which represents the area requiring special consideration for protecting the critical coastal environment with the involvement of coastal communities including fisher folk.

As a first step, a comprehensive list of potential CVCAs will be prepared through experts consultation with representatives of coastal stakeholders, state forest departments, regional NGOs, etc. Then, guidelines for - identifying, planning, notifying and implementing CVCAs will be developed and the potential CVCAs will be evaluated against them. A multi-stakeholder consultation will be held to determine the buffer zones and boundaries of CVCAs. The guidelines for preparation of integrated management plan (IMP) for the CVCAs will be developed through extensive consultations based on the issues of conservation and management of CVCAs, infrastructure needs of the local communities and the impact of sea level rise and other natural hazards. The contemporary and traditional knowledge of the coastal communities on resource use will be utilized in the planning process.

The relationship between changes in natural systems with protection and corresponding changes in socioeconomic welfare is the central focus of ESAs. The present approach with baseline data set on biological, geological and socioeconomic factors would identify the areas of high human impact based on land use, population pressure, infrastructure and access. The positive changes in the ecological conditions through improved biophysical resources and other benefits would be quantified into economic returns. The institutional framework for management of CVCAs would also be developed based on community participation.

This research would aid in accumulating scientific data on the social and ecological aspects of the CVCAs. Further, the local community will be sensitized on the merits of official notification of the area which in turn would also help in garnering wider acceptance among the local population. The spatial maps on ecological features with associated environmental data will form the knowledge base on the nation's ESAs and CVCAs, which in turn would aid in their conservation and sustainable management. It will also help in meeting the country's obligations under the Convention on Biological Diversity (CBD) and other international agreements, without compromising on the interests of the traditional users of coastal and marine areas.

Development of a Database on Marine Diversity

Biodiversity is arguably the most precious resource on the earth. Information about biodiversity is vital to a wide range of scientific, social, educational, medicinal and commercial uses, given the dependence of mankind on natural systems. Our accumulated knowledge about biodiversity and the environment will become ever more important towards developing a sustainable world, following the increasing pressure on the natural ecosystems caused by population growth.

A number of bio-resource databases have been made by various agencies across the world. Some are regional databases, some are on broad classes of habitats, while some are for specific taxa. The

Ocean Biographic Information System (OBIS) created by the Census of Marine Life, is now part of the Intergovernmental Oceanographic Commission (IOC) of UNESCO and strives to document the ocean's diversity, distribution and abundance of life. A distinct feature in the documentation of bio-resources of late, is the shift from mere textual documentation to digital formats. Recent developments in the field of information technology, availability of requisite software expertise and the convergence of interests among biologists and government agencies have combined together to provide a clear platform to develop digital databases of bio-resources.

It is envisaged to undertake a systematic study to address the core issues viz., lack of unified national architecture for collection and maintenance of marine biodiversity data; lack of comprehensive database covering biological, geo-spatial and molecular/genetic information and online tools for character-based field identification. The project would help to collate the biodiversity data scattered across the institutions and develop an interactive platform keeping in view of the needs of the current and future uses of the database.

Firstly, the framework of existing national and global databases on biodiversity with special reference to coastal and marine areas will be reviewed. A template incorporating all the desirable features of existing biodiversity databases will be developed keeping in view of the recent technological advances in bioinformatics and taxonomy. The existing gaps in the databases will be determined and a detailed strategy for bridging them through field observations will be delineated. Focused consultations would be held among the experts of specific taxonomic group and a comprehensive database on the morphological and anatomical features used for identification will be developed. The key characters that are crucial for field identification across various taxa of marine biota will be determined, which in turn would aid in real-time field identification of coastal and marine organisms. The program envisages developing a novel technology-driven identification platform which can be scaled up with the emerging information and space technologies.

Futuristic Research Division

The Futuristic Research Division (FTR) Division is involved in conducting state-of-the-art research on climate change and sea level rise including paleoclimate. With the efficient utilization of the advanced instrumentation facilities, the Division will provide research based updates on climate change and coastal hazards to assist states and districts coastal authorities and scientists working on climate change/ coastal hazards. Scientific research and a decision-support service that illustrates the potential impacts due to coastal flooding, inland flooding and other meteorological information will be made available from this division. In addition, this division is committed to enhance the resilience of the island communities through risk management, collective action and partnerships to improve coordination, build regional capacity in risk management, and strengthen and sustain resilient communities. The division is conducting regular field research, geospatial analysis and prepare the integrated coastal management plan for better management of the Island's resources and improved livelihood of its people.

Blue Carbon: Offsetting carbon emission by conserving coastal vegetative ecosystems along the Indian coast

The global average atmospheric carbon dioxide concentration increased to 401 parts per million (ppm) in May 2014, the 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 CO2 concentrations a more recent approach has been suggested that include combined reduction of anthropogenic CO2 sources (mitigation) with supporting CO2 uptake and storage through the conservation of natural ecosystems with high C sequestration rates and capacity. Marine and coastal ecosystems, specifically mangroves, tidal marshes and seagrass are systems that are recognized for their role in partially mitigating global climate change through the storage and sequestration of carbon dioxide. These ecosystems are also vitally important to the livelihoods of many coastal communities around the world, through a myriad of ecosystem goods and services they provide. Blue Carbon is "biologically fixed" by marine vegetation and microorganisms and sequestered by burial in sediments and when left undisturbed, blue carbon repositories are secure for millennia. 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).

Scientific evaluation of the C sequestration capacity of these coastal ecosystems and their potential role in comparison to terrestrial forest types has not carried out in India in many details. 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 methodology. The East coast has been well studied and

inventorized with respect to mangrove ecosystems, whereas there have been very few studies from the west coast, thus making the comparison more challenging. The in-house study 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 in India following standard and uniform 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. In this study, blue carbon ecosystems, in particular mangroves and seagrasses along the Indian coast would be mapped using satellite images of appropriate resolution and digital image processing techniques. Seagrass habitats in India are restricted from the lower intertidal zone to the open shores and in the lagoons, mainly mudflats and sandy environment. 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 and Andaman and Nicobar. Gulf of Mannar and Palk Bay are associated with the densest area cover of seagrass whereas, in Chilika, the seagrass distribution expands to over 86.84 sq. km.

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) emphasizes on 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

Research findings of the project will contribute to the National Carbon Project (NCP) by generating carbon sequestration data from various coastal ecosystems of India.

The Source-Sink Inventory of Greenhouse Gases from Indian Mangroves: A Review

Coastal ecosystems, found along the continental margins, exchanges large amounts of matter and energy with the open ocean and constitutes one of the most biogeochemically active areas of the biosphere. Despite their relatively small area, accounting for just 7% of the World Ocean's surface, coastal zones play an important part in the global Carbon (C) cycle and in buffering human impacts on marine systems.

Greenhouse gases (GHGs) are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of

infrared radiation emitted by the Earth's surface, the atmosphere and clouds. This property causes the greenhouse effect. The Global warming potential (GWP), which is a measure of the contribution of a given mass of greenhouse gas to global warming over a specific time interval, is used to convert CH_4 and N_2O emissions from mangrove ecosystems in India to their CO_2-equivalent for comparing their GHG impacts. The GWP for CH_4 is 25, while for N_2O it is 298 over 100 years. These GWP values are used to express the CH_4 and N_2O flux to the atmosphere in terms of their CO_2 equivalence amount[2]. Several studies showed that coastal ecosystems, such as estuaries, mangrove waters, salt marsh waters and coral reefs are assumed to be a net source of greenhouse gases especially CO_2, CH_4, N_2O, because they receive massive inputs of organic matter, which is decomposed in the coastal ocean and releases carbon dioxide (CO_2). Soil anoxicity in the presence of high organic carbon could stimulate the anaerobic process like denitrification, sulphate reduction, methanogenesis, which can ultimately lead to the release of N_2O (also a byproduct of nitrification), H_2S and CH_4 to the atmosphere. Borges et al. reported oversaturation of CO_2 in different mangrove forest surrounding waters, suggesting that this surface water can be a significant source of CO_2 to the atmosphere, though the entire ecosystems (sediment, water and vegetation) are probably sinks. The direction and magnitude of air-water CO_2 exchanges strongly depend on the type of ecosystem at the coast (healthy/ degraded), the ocean currents dominating at a respective coast (e.g. whether tide dominated or wind dominated) and the geographical latitude (temperate, tropical, subtropical). Mangrove waters are also rich in nutrients and tend to have higher rates of primary productivity, which in turn leads to more organic material falling to the depth, depleting the oxygen levels and creating favorable conditions for methane-producing bacteria-methanogens. Under anaerobic conditions mangrove sediments (in the presence of the substrates and methanogens) produce methane (CH_4), which is then transferred from *sediments* into the overlying *waters* (sediment to water flux). The CH_4 that escapes both aerobic and anaerobic CH_4 oxidizers (both in sediment and water) ultimately enters the atmosphere, contributing to the greenhouse effect. Increased nitrogen input to mangrove sediments due to rising anthropogenic activities, along with the periodic tidal flooding creates anoxic sediment conditions, thereby enhances anaerobic microbial nitrogen metabolism (denitrification). This process along with nitrification (oxidation of ammonia to nitrate in the oxic environment) together significantly contributes to nitrous oxide (N_2O) formation in the system.

In this present review three major greenhouse gases (CO_2, CH_4 and N_2O) from the mangrove ecosystems along the Indian coast were selected. Mangrove wetlands are well known as a significant natural source/sink of these greenhouse gases. The purpose of the present GHG inventory is to share the available information about these greenhouse gases from the mangrove wetlands in India. Measurements of these gas emissions are relatively sparse from both Indian mangrove forest sediment and surrounding waters. This paper compiles current knowledge on CO_2, CH_4 and N_2O fluxes (air-water, sediment-air and canopy-air) for the first time from Indian mangrove ecosystems. One of the key objectives of this paper is to identify the major gaps in GHG flux studies of Indian mangroves, based on which future studies can be directed to get a more comprehensive understanding.

Mangrove forests consist of a consortium of tree and shrub species that inhabit at the confluence of land and sea, and can withstand very hostile and inhospitable conditions (like: higher salinity, tidal extremes, wind velocity, high temperature and muddy anaerobic soil

conditions). Globally, mangroves are estimated to cover 137,760 km^2 (based on satellite image analysis) in 118 countries and territories in the tropical and subtropical regions of the world. Indian mangroves are distributed in about 4956 km^2 (Figure 4), which constituted about 3.6% of the world's mangroves. In the Country's total area under the mangrove vegetation, 57% is recorded on the east coast and 23% on the west coast. The bay islands (Andaman and Nicobar) account for 20% of the country's total mangrove area. The Sundarbans is the largest mangrove forest in the world, located in India and Bangladesh. The mangroves have a vast existence on the east coast of India due to the nutrient-rich alluvial soil formed by the rivers - Ganges, Brahmaputra, Mahanadi, Godavari, Krishna and Cauvery and perennial supply of freshwater along the deltaic coast. However, mangroves on the west coast are of peculiarly bedrock valley type, scattered, comparatively smaller than the east coast.

GHG emission data from Indian mangroves were gathered from published literatures and available unpublished theses. Current data status shows mangroves only from the east coast of India have been studied in details. Whereas, west coast of India has significant areas of mangrove coverage, which is not studied in the same frequency. Three types of fluxes of CO_2, CH_4 and N_2O have been considered for inventorization, a) Air-water flux; b) sediment-air flux; and c) canopy-air / biosphere-atmosphere flux, respectively.

Mangrove sediments are well known as natural sources of greenhouse gases, whereas the entire ecosystems (sediment, water and vegetation) are probably sinks for atmospheric CO_2. Fluxes from the coastal waters including mangrove wetlands and estuaries often play a significant role in GHG emissions to the atmosphere. Air-water as well as biosphere-atmosphere interactions often can control the atmospheric trace gas composition at a regional scale. Lack in a comprehensive database on GHG emissions from the ecologically important coastal ecosystems in tropical countries is a well-established fact. These coastal ecosystems could be of huge potential in terms of their GHG source/sink strength. Among several mangrove ecosystems in India, Sundarbans is known to be dominated with *Avicennia* sp. followed by other mangrove species like *Ceriops* sp., *Excoecaria* sp. Pichavaram and Muthupet mangroves are also known to be dominated by *Avicennia* sp., whereas *Rhizophora* is the pioneer species at Wright Myo, Andaman Islands. Difference in species distribution along the coastal waters can change the transfer rate of organic material between various biotic and abiotic compartments, which in turn can alter the emission fluxes of various greenhouse gases from the soil/water/canopy to the atmosphere (Clough 1997). Recently, Kathiresan et al. (2013) extensively studied the net canopy CO_2 flux between two Indian mangrove species (*Rhizophora mucronata* and *Avicennia marina*) and showed 24% higher net canopy photosynthesis by the latter species than the former.

Air-water flux of greenhouse gasses from the mangrove

A large variation of CO_2 emission from Indian mangrove waters has been reported by various research groups. CO_2 fluxes ranged from -2358 to 24655 molC m^{-2} yr^{-1} (Figure 5). Few researchers showed that the mangrove waters can change its nature as a sink or a source along with season and space. Earlier very high magnitude in source sink strength was reported from the Sundarbans mangrove ecosystem. More recent studies reported relatively lower emissions from these mangrove waters (i.e. inner and middle and outer part of Sundarban estuarine waters). Many of these mangroves are close proximity to the urban areas along the

coast (e.g. Impact of Kolkata metropolitan to Sundarbans or Chennai metropolitan over Adyar estuary). Variable human influence, anthropogenic load etc. on these ecosystems often causes the inter-annual variation in CO_2 emission from the mangrove waters. CO_2 flux from the other mangrove dominated rivers of the east coast of India and the Andaman Nicobar Islands were well within a limited (lower) range. The smaller catchment area with relatively lesser fresh water runoff into these rivers relative to the Sundarbans water could be responsible for the limited variation in air-water CO_2 flux from these mangrove dominated rivers. The large deviation in the CO_2 fluxes reported by various researchers could be due to the use of various gas transfer velocities considered for its calculation. This gas transfer velocity is often controlled by the combined effect of diffusive and turbulent processes on both sides of the interface that limit the transfer of gas between the bulk water and air phases. The physical forcing for gas transfer is wind stress and buoyancy at the sea surface, Whitecaps/bubble production, wind/wave interactions and surface films all play a role in determining the rate of gas transfer [33]. Difference of sampling methodology (depends on the calibration of the sampling/estimation systems and the associated uncertainty of estimation) also can cause a huge difference in the flux calculations. Although, there was a good agreement in CO_2 flux data derived by using the direct and indirect methods[34]. Most of these water bodies remained supersaturated with respect to the CO_2 with occasional under-saturation caused by post-monsoonal phytoplankton bloom. Often these waters reflect the adjacent soil biogeochemistry, which changes in regular basis with time and space. As the organic load in the sediment changes with space (spatial variation in terms of the proximity to the anthopogenic sources, density and type of mangrove etc.) and time (temporal variation in terms of fresh water input, rainfall, supply of mangrove litter), the oxidation reduction state also changes resulting a variation in the greenhouse gas fluxes. The mean of CO_2 flux reported from the Indian mangrove waters along the east coast of India was estimated to be 20.18 molC m^{-2} yr^{-1}(average of all the reported annual mean value) (Figure 5). The mean CO_2 flux from worlds mid-latitude estuaries are 16 $\pm$ 11 molC m^{-2} yr^{-1} (between 0 - 23.5°S) and 14$\pm$20 molC m^{-2} yr^{-1} (between 0 - 23.5°N)[35], which indicates that Indian mangrove waters as a significant CO_2 source to the atmosphere compare to the global air-water CO_2 flux values from the estuaries. The present study also showed that the Indian mangrove waters contribute higher CO_2 air-water flux relative to the global mean CO_2 flux from the mangrove waters (~ 18 molC m^{-2} yr^{-1}; [8]).

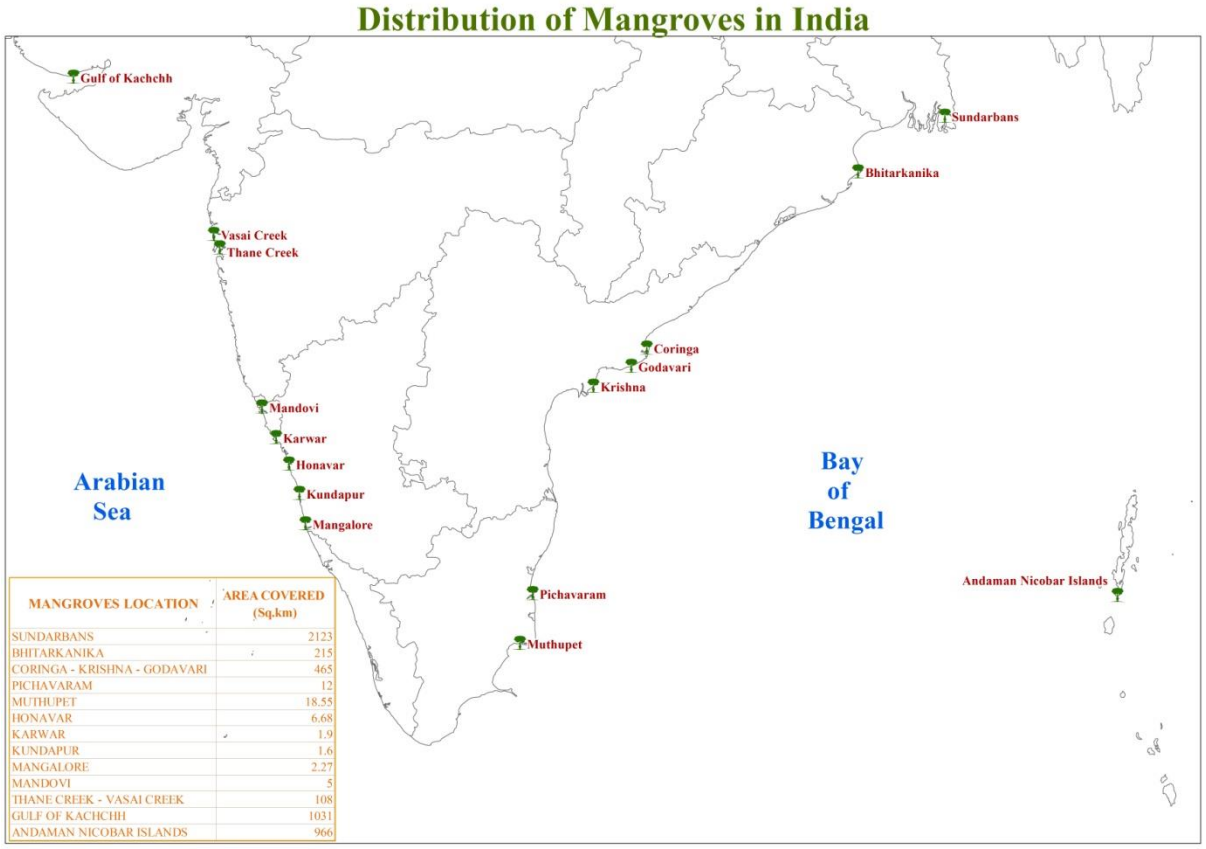


Figure 4: Map showing the distribution of mangrove along the Indian coast

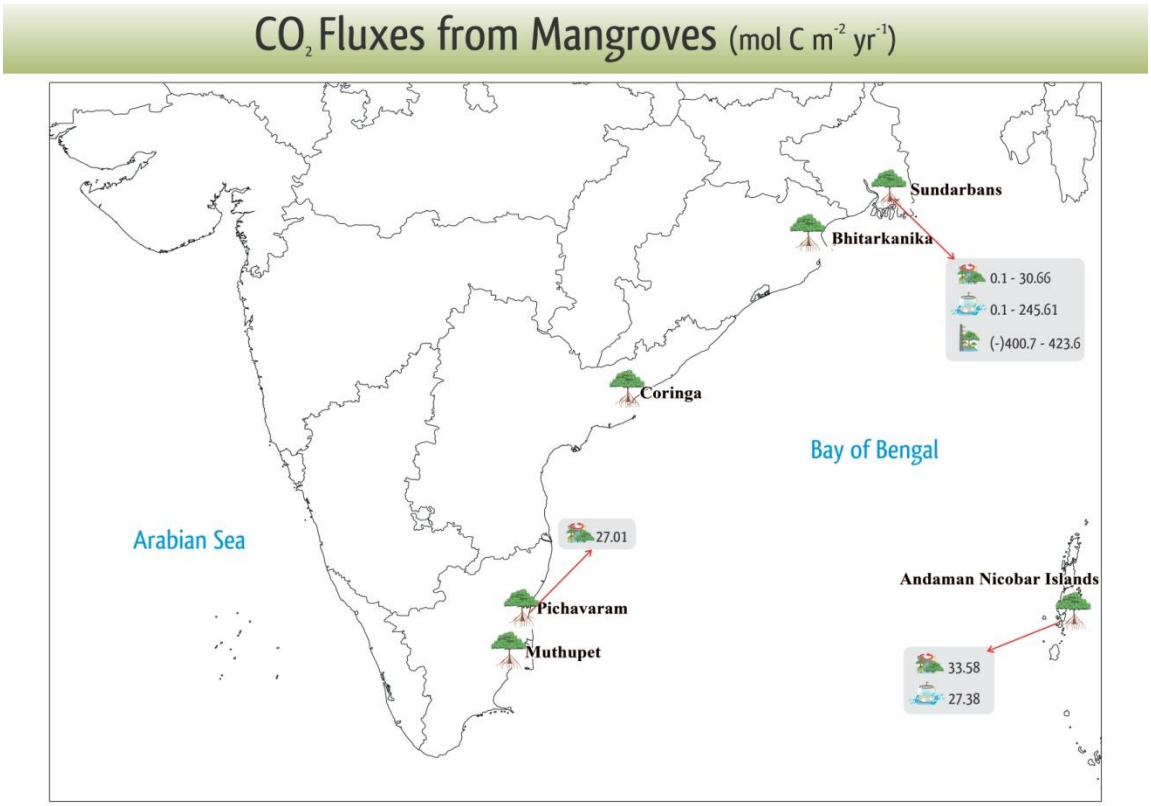


Figure 5: CO_2 flux from various parts (water/soil/canopy) of mangrove ecosystem

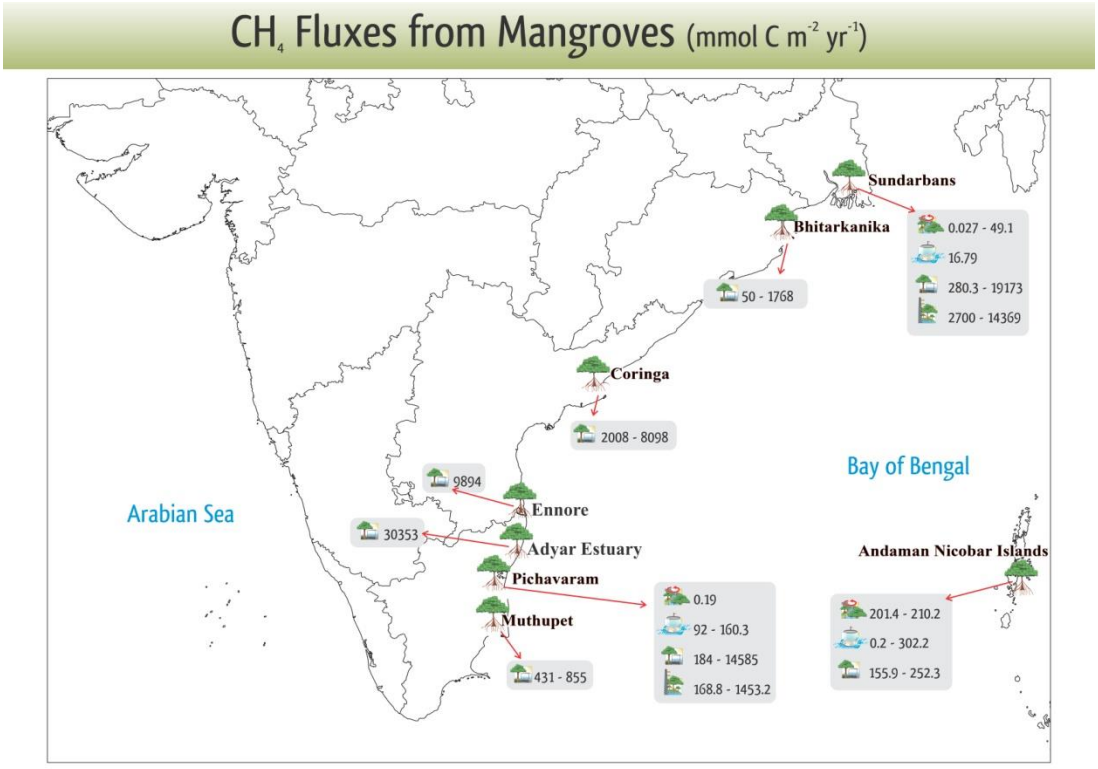


Figure 6: CH_4 flux from various parts (water/soil/canopy) of mangrove ecosystem

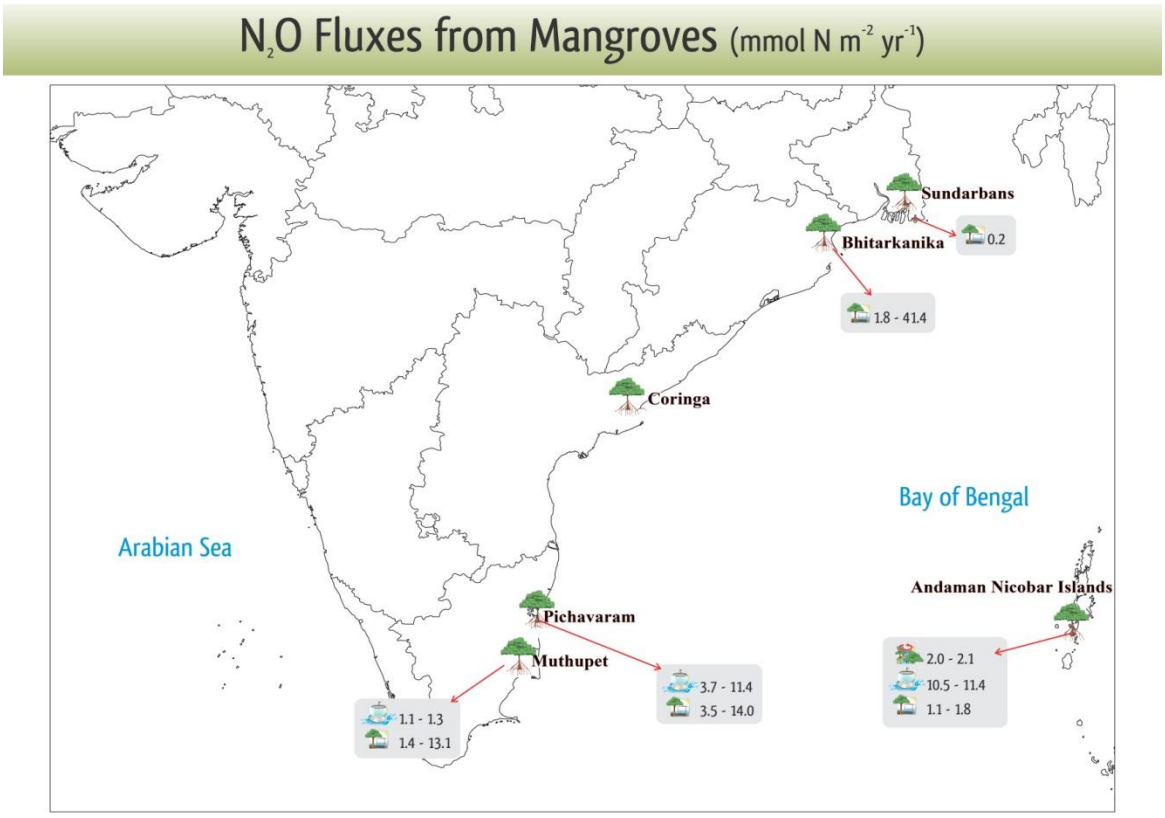


Figure 7: N_2O flux from various parts (water/soil/canopy) of mangrove ecosystem

Methane flux from mangrove waters also showed large variations (Figure 6). Except one report, most of the work reported mangrove waters as a persistent CH_4 source to the atmosphere. Mangrove sediment (with low oxygen) acted as a major source of methane and was indicated by the enriched concentration in the sediment pore water (e.g. pore water was 19 times greater than those of surface water). Andaman waters, which are relatively free from much human activity showed relatively high air-water methane flux. Most of the cases these trace gases are transferred from sediment to the water column. The concentration of this dissolved gas and their flux to the atmosphere are therefore largely depend on the tidal condition, mangrove type, soil characters etc. The CH_4 flux from the mangrove waters along the east coast of India was ranged between 0.027 and 17502 mmolC m^{-2} yr^{-1}.

No data on N_2O air-water flux was available from Sundarbans waters. N_2O flux along the eastern coast ranged between 1.1 and 11.4 mM N m^{-2} s^{-1} (Figure 7). Along the west coast GHG emission data are still very sparse. Most of these studies were done in very shallow water (<20 m), where the water column never became anoxic. This indicated that N_2O is mostly produced from bottom sediments enriched with organic loads. Most of the published data were considered to determine the mean air water flux of N_2O from the mangrove waters of Indian coast and it was calculated to be 5.36 mmol N m^{-2} yr^{-1} (Figure 7). The quantification of individual GHGs in a common scale is based upon their radiative properties, which may be used to estimate the potential future impacts of emissions of those gases into the atmosphere. The standard practice was followed to report GHG emissions in tonnes of CO_2 equivalents (CO2e) which is a universal unit of measurement used to indicate the global warming potential of a greenhouse gas, expressed in terms of the global warmingpotential of one unit of carbon dioxide(http://www.defra.gov.uk/environment/economy/reporting/).
In general, not much seasonal trend was reported for either CH_4 or N_2O from most of the undisturbed mangrove areas (Barnes et al, 2006) in India. Mangrove systems largely or moderately influenced by anthopogenic loads often showed some spatial and seasonal trend in terms of the greenhouse gas fluxes, depending on the quality and quantity of the imported material to the mangrove waters (Chauhan et al, 2008). All the mean values of greenhouse gas emissions reported from Indian mangrove waters were converted into their CO_2 equivalent amount (Fig. 8 a,b,c).

Greenhouse gas fluxes from Sediment

Mangrove sediments are known for its high anoxic nature. Beside allochthonous sources, the sediments receive huge amount of organic carbon in terms of leaf litter on a regular basis. Unfortunately, a very less number of publications are available, which reports direct soil emission of CO_2 from mangrove soils along the Indian coast. For the measurement of the GHG flux, most of the studies in India followed the inexpensive static chamber method to quantify spatial variations between different habitats of the same ecosystem during a relatively short time period. The soil CO_2 efflux from Sundarbans mangroves ranged between 1.21 and 1.78 µmol m^{-2} s^{-1} during the summer months (pre-monsoon) study period (Figure 2) with a mean of 48.25 $\pm$ 5.43 molC m^{-2} yr^{-1} . All these results indicated that mangrove sediments as a persistent source of CO_2 to the atmosphere.

In terms of methane flux, the Sundarbans, the largest mangrove of the world, showed an enormous variation in sediment-air values (Table 1). Mukhopadhyay et al., observed negative flux of CH_4 in Sundarbans mangrove, which suggested that these mangroves can act as a sink

for CH_4, indicating the dominance of methanotrops over methanogenic bacterial activities. However, more recent studies on the Sundarbans reported a relatively lower but significant CH_4 flux with a range from 4734 to 19173 mmol m^{-2} d^{-1} [36](Figure 3). Varying degree of fresh water flux along with varying extent of litter supply regulating the availability of the substrate to the mangrove sediment could often controls the balance between the methanogenesis and methanotrophy. These processes along with variation in the soil temperature could cause the interannual variation in CH_4 production/oxidation and its flux to the atmosphere from the mangrove sediment[39] . Exceptionally high CH_4 emission flux was recorded from Adyar Estuary (Fig. 3) with some mangrove patches along the catchment area. These high values were mostly attributed to the high loads of domestic/industrial sewage coming from adjacent Chennai metropolitan[40] . Seasonally, the variation of CH_4 flux is not consistant from the Indian mangroves. Fresh water flux often enriched the mangrove sediment with organic matter, which often caused higher soil anoxicty stimulating the CH_4 flux [36]. Bubble ebullition from the sediment caused by the higher water levels in monsoon also can enhance the rate of CH_4 flux to the atmosphere[41] (Purvaja et al, 2004). In contrary, few scientists reported, that increased litterfall during non-monsoon months often can increase the soil CO_2 flux to the atmosphere[27].

The static chamber approach was taken in most of these studies of sediment to air N_2O flux measurement in Indian mangrove systems. N_2O flux from mangrove sediments was measured by several researchers and the highest values were obtained from the Bhitarkanika waters. All the results of N_2O flux from sediment to air were within a range of 0.2 to 41.4 mmol m^{-2} d^{-3}(Figure 4). Various degrees of sediment denitrification in different mangrove ecosystems results the variation in the N_2O emission to the atmosphere [42]. Several efforts have been made to measure N_2O emission from the Arabian Sea, while almost no data is available from the coastal ecosystems along the west coast of India. Fernandes and Bharathi, [42] reported N_2O emission rate from the mangrove sediments while measuring the denitrification rate along the Goa coast and the flux values reached as high as 1.95 nmol N_2O-N g^{-1} h^{-1}. But this reported values were not expressed in terms per unit area.

The majority of the studies reported highest CH_4 and N_2O emissions from mangrove soils in the post-monsoon, when litter fall was maximum enriching the soil organic carbon to a higher degree[43]. Annual litter fall from Sundarbans mangrove is estimated to be 1173.85 g dry wt. m^{-2} a^{-1}, and reported to be the main reason for the enhanced soil anoxicity, which in turn enhance the denitrification and methanogenesis rates in the sediment[27]. Increase in the number of pneumatophores after monsoon, also contribute to plant-mediated emission for greenhouse gas[41].It was calculated from our study that the mean annual CO_2, CH_4 and N_2O flux in the static chamber method were $1.2x10^7$, $8.94x10^6$ and 4.68×10^5 tons CO_2 e yr^{-1} respectively (Figure 5a, b, c).

Below-canopy gas exchange

CO_2 in mangrove systems generates mainly from biogenic respiration processes in the soil and releases to the atmosphere. Mangrove vegetation often can play a significant role in capturing the emitted CO_2 gas from the atmosphere by sequestering through the photosynthesis process. Instead of measuring direct CO_2 emission from soil few researchers tried to measure whole ecosystem metabolism in terms of CO_2 flux by using micrometeorological flux calculation method[44]. The basic concept of these micrometeorological methods is that gas transport from the soil surface is accomplished by eddies that displace air

parcels from the soil to the measurement height, and that the vertical flux measured at that reference level is identical to the efflux from the soil[45]. Micrometeorological techniques have advantages over chamber systems in that they do not modify the micro-environment of the soil surface[45] and can measure soil CO_2 efflux continuously over long time periods. Another advantage is that they integrate larger surface areas. Janssens et al. clearly depicted that micrometeorological techniques are not suited to estimate soil CO_2 efflux in a forest with undergrowth; however, they do provide valuable information on below-canopy gas exchange.

The canopy-air flux of CO_2 showed large variation from the soil emission flux in the Sundarbans mangrove forest. Previously various researchers reported the role of mangrove forest as a net sink of CO_2 from the atmosphere. In the static chamber measurement of soil CO_2 emission the role of mangrove canopy, known for their CO_2 sink nature, was entirely ignored. The sink strength of the mangrove forest reached up to 401 molC m^{-2} yr^{-1}. Earlier Mukhopadhyay et al. depicted the same mangrove system as a net source of CO_2 to the atmosphere by using identical methodologies. These results indicated that the CO_2 source sink strength of mangrove forest changes inter-annually depending on rainfall pattern, temperature and other environmental parameters.

In general, at a seasonal scale the magnitude of CO_2 source/sink strength (of the mangrove vegetation) was relatively lower during monsoon compare to the other seasons. Low atmospheric temperature, solar radiation and vapour pressure deficit during the monsoon could be responsible for the lower degree of metabolic process in the mangrove vegetation compare to the rest of the year. One pilot study had been carried out to get some idea about the carbon sequestration in the mangrove of west coast india but no data on CO_2 or any other greenhouse gas fluxes were available. Globally, mangroves take up (sequester) approximately 1.5 metric tons/hectare/yr of carbon or 550 g $CO_2/m^2/yr$ (mean) from the atmosphere. The mean CO_2 sequestration rate reported from the Sundarban mangrove systems was ~2.6 times higher (1469 g $CO_2/m^2/yr$) than the global mean values.

CH_4 flux from the mangrove canopy by micrometeorological method was reported only from Sundarbans [38, 49] ecosystems. Mangrove canopy flux showed a great range between 0.016 and 14369 mmol m^{-2} d^{-1}. Extrapolating the mean flux of CO_2 and CH_4, the mean annual of CO_2 and CH_4 flux from all the Indian mangrove forests by micrometeorological processes were calculated to be -6.7 x 10^6 and 8.9 x 10^6 tons CO_2 e yr^{-1}, respectively (Figure 8a and b). These studies indicated that, although mangrove occupies only 0.66% of India's total forest area, the net CO_2 sequestration (considering the emission of CH_4) could reach as high as 1.32% of India's total CO_2 sequestration by all the forest. The CO_2 flux data from the forest area has not been collected uniformly using identical methods all over the country. For a more realistic understanding of net ecosystem metabolism, the untouched areas specially the west coast of India should be thoroughly studied.

The study revealed a large spatio-temporal variation in the major greenhouse gas emissions from different mangrove systems along the Indian coast. GHG fluxes (both magnitude and direction) from the water, sediment and canopy showed an interesting nature which clearly delineated their source/sink nature in terms of emission and sequestrations. Both, mangrove sediment and water acted as a perennial source of these GHGs, whereas the vegetation acted as a net sink for CO_2. These results indicated that a change in the surface character (i.e.

water/sediment/canopy) can significantly alter the magnitude as well as the direction of trace gas fluxes within the system.

The net canopy flux of CO_2 from mangrove vegetation clearly showed the opposite trend to that of sediment-air and air-water fluxes. The forest acts as a significant sink when micrometeorological methods were considered. This result showed that the mangrove canopy can process a large amount of anthopogenically emitted CO_2 by sequestering them in the biomass. Both inter and intra system variability in GHG emission indicates differences in species distribution, rainfall pattern, resource availability within as well as inside them. Mangrove forests account for about 2.4% of tropical forest (www.fao.org/forestry/mangroves), hence accuracy improvement of global carbon sink quantification is essential in the mangrove swamps. The western coast with a significantly large area of mangrove forests is still remained untouched in terms of GHG emission. More detail study including all the mangrove ecosystems in India using a universal methodology, which will be useful to elucidate further the actual role of these unique ecosystems towards the release of GHGs and its impact on global climate change. Being one of the most carbon-rich forests in the tropics and containing about 2.5 fold greater carbon storage (on average 1023 Mg C per hectare) relative to Boreal, Temperate and Tropical upland forests, mangrove forests could be very useful to play important role in reducing the rate of atmospheric CO_2 increase. The present review showed that both mangrove waters and the sediment are mostly act as sources of CO_2 to the atmosphere, whereas the below-canopy gas exchange studies indicated its potential role as a sink of atmospheric CO_2. In addition, variable rates of greenhouse gas emission fluxes from polluted and non- polluted mangrove systems can significantly regulate the regional as well as the global atmospheric gas compositions. Relatively unpolluted /pristine mangrove like Bhitarkanika or Andaman mangrove could be used as reference to delineate the natural and anthropogenic sources of greenhouse from the mangrove systems along the Indian coast to the atmosphere. The present study strengthens the earlier concept, which depicted the mangrove water as an overall source of CO_2 to the atmosphere, though the entire ecosystems (sediment, water and vegetation) are probably sinks for atmospheric CO_2. Introduction of more CO_2 in the atmosphere in near future could lead to higher mangrove productivity which in turn contribute to higher litter fall. More organic carbon in the sediment from mangrove litter as well as the higher anthropogenic load, could enhance the anoxic condition which could enhance higher degree of greenhouse gas emissions from all the compartments of mangrove ecosystem in the near future. Synchronisation of methodologies in terms of time and space to measure greenhouse gas fluxes could provide a more realistic view determining the sink or source nature of the various compartments (water, sediment and vegetation) of mangrove vegetation.

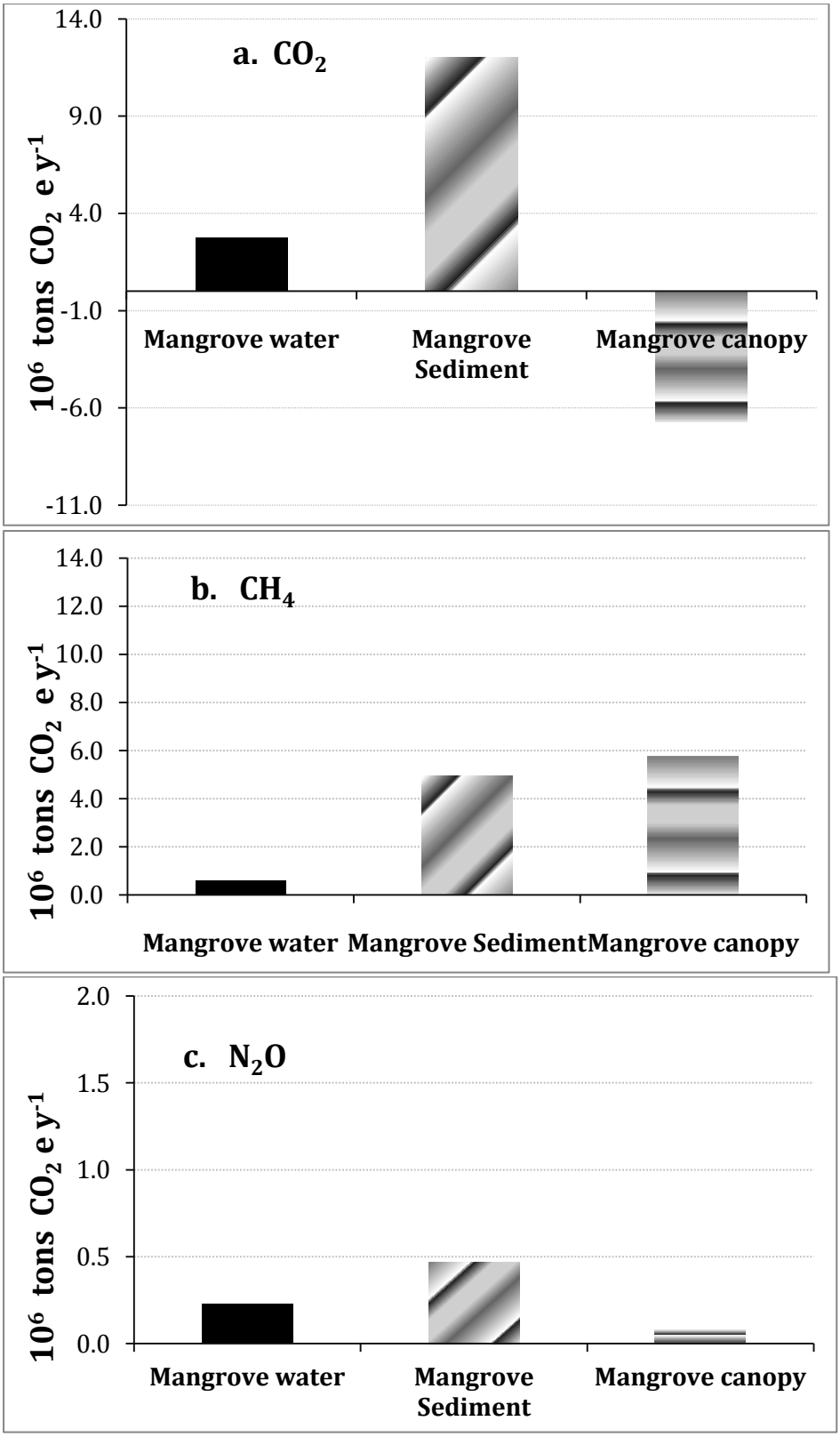


Figure 8: Net greenhouse gas fluxes from different parts of mangrove ecosystem a. CO_2, b. CH_4, c. N_2O (calculated in terms of CO_2 equivalent for total mangrove area in India).

Integrated Island Management

The Integrated Island Management (IIM) division is presently working to 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 division undertakes scientific approaches, coupled with indigenous knowledge for the better management of the islands and its resources. The IIM considers the indigenous governance structures and knowledge - particularly in tribal dominated islands. The islands being pristine areas, this division undertakes long-term historical analysis including monitoring of the oscillations of crucial environmental variables.

The IIM is involved in developing guidelines for hazard preparedness and evolve climate change adaptation and mitigation strategies for the Islands. Some of the major goals are to develop integrated island management / green island economy concept and to explore, in conjunction with island populations, ecotourism development as a particular option. The IIM is also involved in providing tools for mainstreaming Disaster Risk Management based on experiences from selected island countries worldwide. The IIM division undertakes specific 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.

Island Coastal Regulation Zone (ICRZ) Plan and Integrated Island Management (IIM) Plan for the Islands

The Ministry of Environment and Forests under the Environment (Protection) Act, 1986 has notified the Island Protection Zone (IPZ) Notification, 2011 alongside the Coastal Regulation Zone (CRZ), 2011 with the objective of

- Ensuring livelihood security to the fishing communities, tribals and other local communities living in the coastal areas.
- Conserving and protecting coastal stretches.
- Promoting development in a sustainable manner based on scientific principles, taking into account the dangers of natural hazards in the coastal areas and sea level rise due to global warming.

Andaman & Nicobar (A&N) Islands comprises 572 Islands, Islets and rocky outcrops. There are 37 inhabited islands. Out of which, 10 islands in the South Andaman District, 14 in the North & Middle Andaman District and 13 in the Nicobar District. Total geographical area of A & N Islands is 8,249 sq. Km with a coastline of 1,962 km. The Lakshadweep archipelago consists of 36 islands with an area of 32 sq km. There are 12 atolls, three reefs, five submerged banks and ten inhabited islands in the Lakshadweep.

These two groups of oceanic islands are home to some of the country's most thriving biodiversity hotspots. While the islands of Middle Andaman, North Andaman, South Andaman, Greater Nicobar, Baratang, Havelock, Little Andaman, Car Nicobar, Neil and Long islands in Andaman and Nicobar Islands are to be managed as per the Island Coastal Regulation Zone (ICRZ) Plan, the rest of the islands in Andaman and Nicobar and all the islands in

Lakshadweep are to be managed in accordance with the Integrated Island Management (IIM) Plan, as provided under the IPZ Notification, 2011.

While preparing an ICRZ plan, the hazard line, which is demarcated based on tides, waves, sea level rise and shoreline changes, would be taken into account. The ICRZ would address vulnerability to human life and properties, based on elevation, geomorphology, sea level trends and horizontal line displacement and indicate suitable areas that are safe for locating dwelling units and other infrastructure. All developmental activities would be regulated within the framework of ICRZ Plan.

The IIM plan would indicate all the existing and the proposed developments, conservation and preservation schemes and dwelling units including infrastructure projects such as, schools, markets, hospitals, public facilities and the like, which would be collected from the respective union territory (UT) administration. Ecologically sensitive areas and the developmental activities in the islands including requirements of the Ministry of Defence would also be taken into consideration while preparing the Integrated Islands Management (IIM) Plan, as specified in the IPZ Notification, 2011. Appropriate safeguard measures to protect the life and property of the local communities and infrastructure from natural hazards would be indicated in the IIM Plan. All developmental activities, listed under the Island Protection Zone Notification, 2011, would be regulated within the framework of IIM Plan of Andaman and Nicobar and Lakshadweep.

NCSCM would develop the process guidelines and extend technical assistance to the UT Administration in preparing the Island Coastal Regulation Zone (ICRZ) Plan and Integrated Island Management (IIM) Plan while the respective UT administration would prepare the ICRZ / IIM Plans for regulating developmental activities in their coastal environment including for ICZM plan preparation for a selected area or Island as desired by UT Administration.

The list of scientist joined in various divisions during 2012 and 2013 in NCSCM

Name	Designation	Division	Field of Expertise
Dr. Purvaja Ramachandran	Scientist G & Division Chair	FTR	Cumulative Environmental Impact Assessment, ICZM & Climate Change
Dr. Rajakumari S	Scientist E	GEO	GIS and Remote sensing
Dr. Asir Ramesh D	Scientist E	ISE	Coastal Community and Institutional and Governance Analysis of Coastal Development
Dr. Sridhar R	Scientist E	IIM	Island and coastal Management
Dr. Krishnan Pandian	Scientist E	CMR	Coastal conservation & management
Dr. Sarunjith KJ	Scientist B	GEO	Coastal Geospatial Analysis
Dr. Paneer Selvam Arumughan	Scientist B	FTR	Coastal Environmental Impact Assessment
Ms. Madhumitha Rajakanthan	Scientist B	GEO	Coastal Geospatial Analysis
Dr. Kakolee Banerjee	Scientist B	FTR	Greenhouse Gas Emission from Coastal Environment
Dr. Sankar R	Scientist B	CMR	Coastal Pollution
Dr. Ramachandra Bhatta	Scientist G & Division Chair	ISE	Social and economic analyst
Mr. Saravanan Umapathy	Scientist B	CIA	Physical Oceanographer
Dr. Shesdev Patro	Scientist B	CMR	Coastal conservation expert

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

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4. Coastal Sediment Cells _A Guide for Coastal Managers – Y 2013
5. Eutrophication and Ocean Acidification Publication - Y2013
6. Lagoons, Lives and Livelihood - Special Publication (CBD COP 11) - Y 2012

N. C. Mittal & Co.
Chartered Accountants

INDEPENDENT AUDITOR'S REPORT

To

The Project Director,

National Centre for Sustainable Coastal Management

Chennai

Report on Financial Statements

We have audited the Financial Statements of National Centre for Sustainable Coastal Management (NCSCM), which comprises the Balance Sheet as at March 31, 2013, and Receipts & Payment Accounts for the period then ended, and a summary of significant accounting policies 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 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 of India. 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 misstatement.

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

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Email: ncmittalandco@yahoo.com, info@ncmittalandco.com
Firm's Website: http://ncmittalandco.com *Resourse Website*: www.auditfirm.net
Offices at: Chennai, Jaipur, Hissar, Kolkatta, Chandigarh, Rajkot, Bangalore, Dehradun, Faridabad and London (UK)

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 give the information required by the Act applicable 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, 2013;*

b. *in the case of the Receipts & Payments Account, of the cash flows for the year ended on that date.*

For N. C. Mittal & Co.
Chartered Accountants
FRN 000237N

(CA KARUNESH MITTAL)
PARTNER
M. NO. 095976

Place of Signature: Chennai
Date: 29-09-2014

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 **31/03/2013** 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:

NIL

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 **31/03/2013** and

(ii) in the case of the profit and loss account, of the profit or loss of its accounting year ending on **31/03/2013**

The prescribed particulars are annexed hereto.

Place **CHENNAI**
Date **29/09/2014**

Name **KARUNESH MITTAL**
Membership Number **095976**
FRN (Firm Registration Number) **000237n**
Address **NCMC HOUSE 730 SECTOR 3 0 FARIDABAD**

N.C. MITTAL & CO. INDIA FRN 000237N CHARTERED ACCOUNTANTS

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 (₹)	**49773226**
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 **finally 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. (₹)	**No**
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.	**No**
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 (₹)	**No**
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**

N.C. MITTAL & CO. INDIA FRN 000237N CHARTERED ACCOUNTANTS

	(c)	has not been utilised for purposes for which it was accumulated or set apart during the period for which it was to be accumulated or set apart, or in the year immediately following the expiry thereof? If so, the details thereof	**No**

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	**No**
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 **29/09/2014**

Name **KARUNESH MITTAL**
Membership Number **095976**
FRN (Firm Registration Number) **000237N**
Address **NCMC HOUSE 730 SECTOR 3 0 FARIDABAD**

Form Filing Details	
Revision/Original	Original

NATIONAL CENTRE FOR SUSTAINABLE COASTAL MANAGEMENT
Annexure to the Balance Sheet as on March 31, 2013

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 Company accounts are prepared under the historical cost convention and on the basis of a going concern.

2. ***Fixed Assets & Depreciation :***

a) The society has no fixed assets as on date of the balance sheet. 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.

d) The assets after being taken out of use are written off net of the sale value of the asset or scrap of asset from the books of accounts.

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 realisation in the ordinary course of business at least equal to the amount at which they are stated.

B **Notes to Accounts**

Figure for the previous year have been regrouped and/or rearranged where necessary.

For National Centre for Sustainable Coastal Management

Director

Director
National Centre for Sustainable Coastal Management
Ministry of Environment and Forests, Government of India
Chennai - 600 025, India

As per the Audit Report of Even Date Attached
For N. C. Mittal & Co.
Chartered Accountants

N. C. MITTAL & CO. INDIA 000237N CHARTERED ACCOUNTANTS

(CA Karunesh Mittal)
Partner
Place: Chennai
Date: 29-09-2014

NATIONAL CENTRE FOR SUSTAINABLE COASTAL MANAGEMENT

KOODAL BUILDING
ANNA UNIVERSITY CAMPUS,
GUINDY,
CHENNAI

Income & Expenditure Account

As at March 31, 2013

(In Rupees)

Expenditure	Amount	Income	Amount
Expenditure		**Grant received**	**49773226.41**
Capacity Building & Projects	*3152348.10*		
Communication	*858184*		
OPERATIONAL COST	*18425196.57*		
Monitoring & Evaluation	*1145420.74*		
Surplus transferred to Corpus Fund	2,61,92,077.00		
Total	**4,97,73,226.41**	**Total**	**4,97,73,226.41**

Notes on Accounts & Accounting Policies are annexed to the Income & Expenditure Account

For National Centre for Sustainable Coastal Management

Director

Place: Chennai
Date: 29-09-2014

Director
National Centre for Sustainable Coastal Management
Ministry of Environment and Forests, Government of India
Koodal Building, Anna University Campus
Chennai - 600 025, India

As per the Audit Report of Even Date Attached
For N. C. Mittal & Co.
Chartered Accountants

(CA Karunesh Mittal)
(M. NO. 095976)
Partner
FRN 000237N

NATIONAL CENTRE FOR SUSTAINABLE COASTAL MANAGEMENT

KOODAL BUILDING
ANNA UNIVERSITY CAMPUS,
GUINDY, CHENNAI

Balance Sheet

As at March 31, 2013

(In Rupees)

Liabilities	Amount	Assets	Amount
Corpus Fund	*3,86,09,731.00*	**Fixed Assets**	
Current Liabilities		*Assets Under Construction*	2,97,851.00
Society for Integrated Coastal Management	*5,70,34,281.59*	*Computers & System*	52,08,653.00
		Equipment & Facilities	17,07,367.00
		GIS Softwares	*19283151.00*
		Image Processing Software	*5775000.00*
		CIVIL WORKS	*46,82,664.00*
		Vehicle	*9,09,706.00*
		Watet Quality and Genaral Utility Software	*745339.00*
		Investments	
		FIXED DEPOSIT - UBI SHORT TERM	*5,00,00,000.00*
		Current Assets	
		Bank Accounts	*70,34,281.59*
Total	**9,56,44,012.59**	**Total**	**9,56,44,012.59**

Notes on Accounts & Accounting Policies are annexed to the Banlance Sheet

As per the Audit Report of Even Date Attached
For N. C. Mittal & Co.
Chartered Accountants

For National Centre for Sustainable Coastal Management

Director
National Centre for Sustainable Coastal Management
Ministry of Environment and Forests, Government of India
Koodal Building, Anna University Campus
Chennai - 600 025, India

Place: Chennai
Date: 29-09-2014

(CA Karunesh Mittal)
(M. NO. 095976)
Partner
FRN 000237N

NATIONAL CENTRE FOR SUSTAINABLE COASTAL MANAGEMENT

KOODAL BUILDING
ANNA UNIVERSITY CAMPUS,
GUINDY,
CHENNAI

Receipts & Payment Account

For the period ended on March 31, 2013

In Rupees

Receipts	Amount	Payment	Amount
Current Liabilities		**Opening Balance**	
Comtroller KVA & FSU	*92510.00*	Bank Accounts	*1720890.00*
Society for Integrated Coastal Management	*2608398.00*	**Current Liabilities**	
Professional Tax	*7665.00*	*Comtroller KVA & FSU*	*92510.00*
TDS Payable - Professionals	*837930.00*	*Professional Tax*	*7665.00*
TDS PAYABLE - STAFF	*660282.00*	*TDS Payable - Professionals*	*837930.00*
Investments		*TDS PAYABLE - STAFF*	*660282.00*
FIXED DEPOSIT - UBI SHORT TERM	*159124171.46*	**Fixed Assets**	
Current Assets		*CIVIL WORKS*	*1742891.00*
Advances to Others	*142000.00*	*Vehicle*	*41000.00*
ADVANCES	*1020595.00*	Assets Under Construction	*297851.00*
		Computers & Systems	*5208653.00*
		Equipment and Facilities	*1707367.00*
		GIS Softwares	*10673976.00*
		Image Processing Software	*5775000.00*
		Watet Quality and Genaral Utility Software	*745339.00*
		Investments	
		FIXED DEPOSIT - UBI SHORT TERM	*103204171.46*
		Current Assets	
		Advances to Others	*142000.00*
		ADVANCES	*1295000.00*
		Indirect Expenses	
		OPERATIONAL COST	*18330791.57*
		Capacity Building & Projects	*2972348.10*
		Communication	*858184.00*
		Monitoring & Evaluation	*1145420.74*
		Closing Balance	
		Bank Accounts	*7034281.59*
	16,44,93,551.46		16,44,93,551.46

Notes on Accounts & Accounting Policies are annexed to the Receipts & Payments Account

For National Centre for Sustainable Coastal Management

Director
National Centre for Sustainable Coastal Management
Ministry of Environment and Forests, Government of India
Place: Chennai
Date: 29-04-2014

As per the Audit Report of Even Date Attached
For N. C. Mittal & Co.
Chartered Accountants

(CA Karunesh Mittal)
(M. NO. 095976)
Partner
FRN 000237N