NCSCM

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

ANNUAL REPORT

2021-22

NATIONAL CENTRE FOR SUSTAINABLE COASTAL MANAGEMENT

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1. About NCSCM

The National Centre for Sustainable Coastal Management (NCSCM) was established by the Ministry of Environment, Forest and Climate Change (MoEF&CC) in 2011, as an autonomous institution to support the protection, conservation, rehabilitation, management, and policy advice of the coast. NCSCM supports the nationwide adoption of the Integrated Coastal Zone Management (ICZM) approach by utilizing decision support systems based on cutting-edge science and knowledge and through networking with communities, government structures, and relevant reputable national and international institutions.

India has a long coastline of 7,500 km, harbouring diverse ecosystems and unique biodiversity. However, the coast faces myriad issues including destruction and degradation of the rich ecosystems, pollution from agriculture run-offs, domestic and petrochemical industries, and importantly, the vast coastal population exerting pressure on the natural resources for livelihoods and sustenance. Moreover, the coastal and marine waters are also potential areas for development, which is promoted by the Government to support economic growth. Realizing the necessity for an integrated approach towards coastal management and conservation, the Government of India embarked upon the Integrated Coastal Zone Management Project (ICZMP) for the holistic development of the coast within the regulatory framework of Coastal Regulation Zone (CRZ) Notification, 2011 and the Island Protection Zone (IPZ) Notification, 2011.

2. Vision and Mission

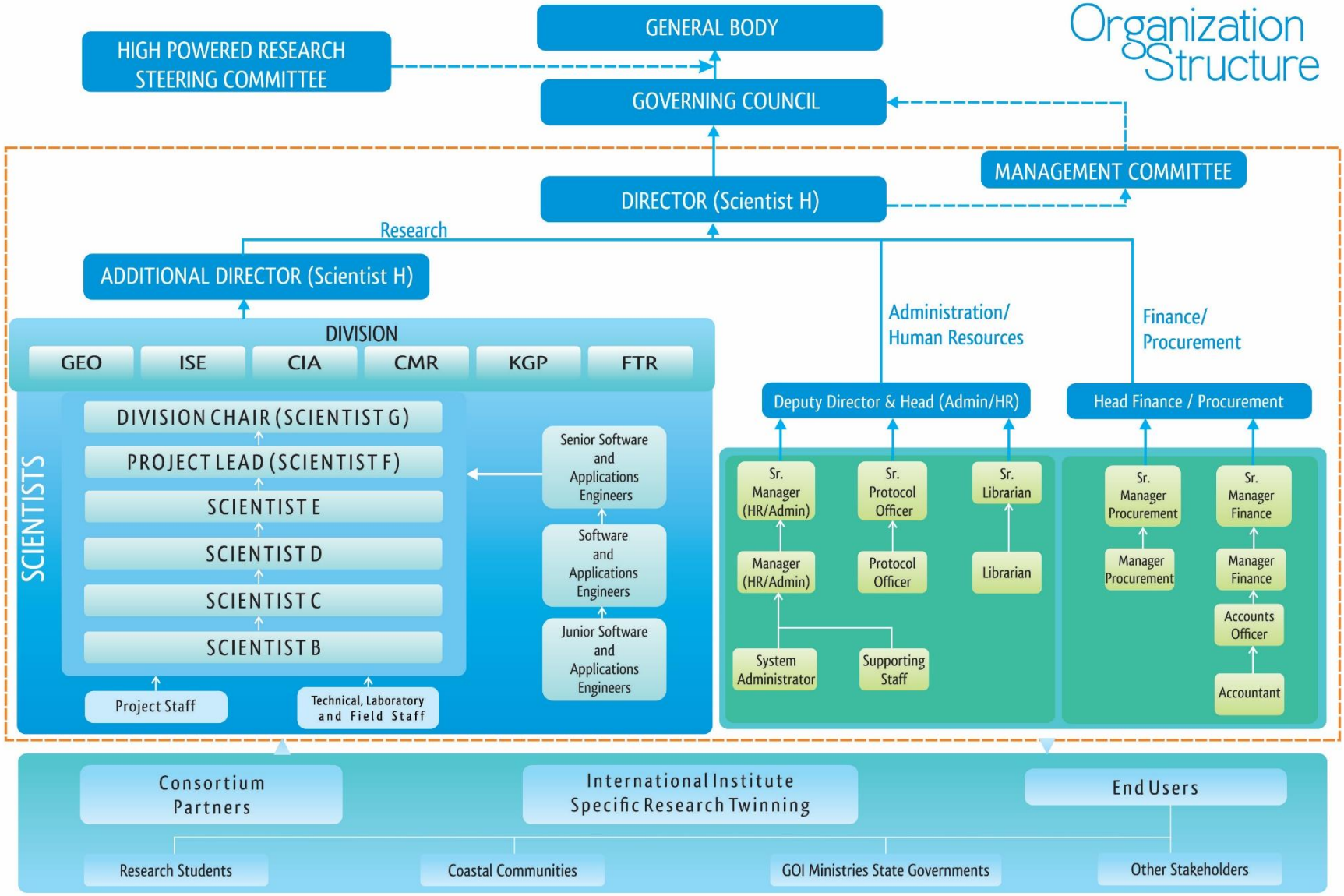
Vision

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

Mission

Support integrated management of the coastal and marine environment for livelihood security, sustainable development and hazard risk management by enhancing:

Organization Structure



General Body

S. No.	Name of the Member
1	Hon'ble Union Minister for Environment, Forests and Climate Change, Government of India
2	Prof. M.S. Swaminathan, Member of Parliament (Rajya Sabha)
3	Dr. K. Kasturirangan, Member, Planning Commission
4	Shri. Madhav Gadgil, Member, National Advisory Council
5	Secretary, Ministry of Environment, Forests and Climate Change
6	Dr. Shailesh Nayak, Secretary, Ministry of Earth Sciences
7	Dr. K. Radhakrishnan, Chairman, ISRO, Bangalore
8	Vice Chancellor, Anna University, Chennai
9	Additional Secretary, MoEF
10	Registrar, Anna University, Chennai
11	Financial Advisor, MoEF&CC
12	National Project Director, SICOM, MoEF&CC
13	Adviser, Impact Assessment Division, MoEF&CC
14	Adviser (E&F), Planning Commission
15	Chairman, Central Pollution Control Board
16	Prof. A. Jayaraman, National Atmospheric Research Laboratory, Tirupati
17	Prof. G.M. Samuel Knight, Professor of Civil Engineering, Anna University, Chennai
18	Prof. M. Sekar, Dean, College of Engineering Guindy, Anna University, Chennai
19	Director, NCSCM, MoEF&CC
20	Director, National Institute of Ocean Technology, Chennai
21	Director General, Survey of India, Dehradun
22	Director, National Remote Sensing Centre, Department of Space
23	Director, National Institute of Oceanography, Goa
24	Director General (Fisheries), ICAR, New Delhi
25	Director, NLSIU, Bangalore
26	Director, Centre for Climate Change and Adaptation Research, Anna University, Chennai
27	Secretary, Environment and Forests Department, Government of Gujarat
28	Secretary, Environment and Forests Department, Government of Maharashtra
29	Secretary, Environment and Forests Department, Government of Goa
30	Secretary, Environment and Forests Department, Government of Karnataka
31	Secretary, Environment and Forests Department, Government of Kerala
32	Secretary, Environment and Forests Department, Government of Tamil Nadu
33	Secretary, Environment and Forests Department, Government of Puducherry

S. No.	Name of the Member
34	Secretary, Environment and Forests Department, Government of Andhra Pradesh
35	Secretary, Department of Environment, Government of Orissa
36	Secretary, Environment Department, Government of West Bengal
37	Additional Director and Head of Administration and Human Resources Development Unit of NCSCM
38	Six Divisional Chairs of NCSCM
39	Two representatives of NGOs engaged in development and social service activities in the coastal areas (one from the east coast and one from the west coast, nominated by the General Body)
40	Two representatives of coastal communities (one representative of the traditional coastal fisherpersons, and one representative of the traditional non-fishing trade of the coastal areas) (Nominated by the General Body)
41	Three women, of BPL families from among the traditional coastal communities, one each from three coastal states, nominated by NCSCM upon a majority decision of the General body provided it is duly recommended by the Governing Council. Each application for membership should be proposed and seconded by members of the General Body.

High Powered Research Steering Committee (HPSC)

S. No.	Name of the Member
1	Hon'ble Union Minister for Environment, Forests and Climate Change, Government of India [Ex-Officio Chairperson]
2	Prof. M.S. Swaminathan, Member of Parliament (Rajya Sabha) [Expert Member]
3	Dr. K. Kasturirangan, Member, Planning Commission [Expert Member]
4	Dr. K. Radhakrishnan, Chairman, ISRO, Bangalore [Expert Member]
5	Secretary, MoEF&CC [Ex-Officio Member]
6	Vice Chancellor, Anna University, Chennai [Ex-Officio Member]
7	Adviser, Impact Assessment Division, MoEF&CC [Ex-Officio Member]
8	Director, National Centre for Sustainable Coastal Management, Anna University Campus, Chennai [Ex-Officio Member]
9	National Project Director, SICOM, MoEF&CC [Ex-Officio Member-Secretary]

Governing Council (GC)

S.No.	Name of the Member
1	Secretary, Ministry of Environment, Forest and Climate Change [MoEF&CC] [Ex-Officio Chairperson]
2	Special/ Additional Secretary, MoEF&CC [Ex-Officio Vice Chairman]
3	Director, National Remote Sensing Centre, Department of Space, Government of India [Ex-Officio Member]
4	Secretary, Higher Education, Government of Tamil Nadu [Ex-Officio Member]
5	Registrar, Anna University, Chennai [Ex-Officio Member]
6	National Project Director, Society of Integrated Coastal Management, MOEF&CC [Ex-Officio Member]
7	The Adviser (E & F), Planning Commission [Ex-Officio Member]
8	Director, NIO, Goa [Ex-Officio Member]
9	Director General, Survey of India, Dehradun [Ex-Officio Member]
10	Director, NIOT, Chennai [Ex-Officio Member]
11	Director, NLSIU, Bangalore [Ex-Officio Member]
12	Director, Centre for Climate Change and Adaptation Research, Anna University, Chennai [Ex-Officio Member]
13	Chairman, CPCB [Ex-Officio Member]
14	Director General (Fisheries), ICAR, New Delhi [Ex-Officio Member]
15	Dr. K. Radhakrishnan [HPSC Representative]
16	Dr. K. Kasturirangan, Member, Planning Commission [Expert Member]
17	Shri. Madhav Gadgil, Member, National Advisory Council [Expert Member]
18	Dr. Shailesh Nayak, Secretary, MoES [Expert Member]
19	Prof. A. Jayaraman, National Atmospheric Research Laboratory, Tirupati [Expert Member]
20	Prof. G.M. Samuel Knight, Professor of Civil Engineering, Anna University, Chennai [Expert Member]
21	Prof. M. Sekar, Dean, College of Engineering Guindy, Anna University, Chennai [Expert Member]
22	Director, NCSCM [Ex-Officio Member-Secretary]

Management Committee (MC)

Sl. No.	Name of the Member
1	Secretary/Additional Secretary, MoEF&CC handling CRZ matters
2	Project Director, SICOM
3	Director, NCSCM

3. Divisions of NCSCM

Coastal Environmental Impact Assessment (CIA)

The Coastal Environmental Impact Assessment Division (CIA) would undertake systematic monitoring and integration of environmental, social and economic impacts to overcome critical pollution limits on the coast and the adjoining marine environment.

CIA Division would provide input and advice on all components of coastal environmental impact assessment. This would incorporate components of a cumulative effect's assessment, including identification of sources of environmental impacts, notably- industrial expansion along the coast, port development, waste disposal from land based and sea-based sources, coastal aquaculture etc. The division would study all relevant aspects to establish baseline environmental conditions of specific coastal areas and the cumulative environmental, economic and social effects of regional development prospects on coastal and marine resources and environment.

The CIA Division would suitably advise management measures for CVCAs in the coastal and marine areas. Studies to be conducted by the CIA Division include:

- Apportionment of coastal and marine pollution hotspots
- Study of Sentinel Sites
- Impact of urbanization on coastal megacities
- Coastal ecosystem health (including development of coastal Water quality index and report card)
- River Mouth System, incl. Deltas and Estuaries and coastal Aquifers
- Development of guidelines for cumulative analysis of coastal Infrastructure Development Projects
- Nutrient management and HABs

Additionally, a set of valuable coastal ecosystem components (viz. river mouths, deltaic systems, coastal aquifers, mangrove forests, coral reefs in addition to many others) was examined, focusing on circulation and siltation, coastal water quality, sediments and the benthic community. Based on observations, "tipping points", to determine cumulative impacts arising from the aggregate of human activities, was developed. A comprehensive assessment of ecosystem health was developed using Ecosystem Health Indicators for use in driving policy decisions. This is to enhance and support the science, management and restoration of coastal ecosystems through the integration of geographically detailed assessments and forecasts.

Conservation of Coastal and Marine Resources (CMR)

The Conservation of Coastal and Marine Resources Division (CMR) develops guideline strategies for conservation and long-term sustainable use of coastal and marine resources that encompass societal interests and the integrity of ecosystems.

The primary mandate of CMR is to guide the use of the living and non-living natural resources for diverse, and often conflicting, sectoral activities, so that the continued viability of all aspects of resource usage and ecosystem health can be secured. The important aspect is to Strategy the conservation of coastal and marine resources in ways that promote human wellbeing, for present and future generations. Key issues in the management of coastal resources include the loss of biodiversity and habitats through human-related pressures, and the impacts of biodiversity loss to coastal livelihoods. The CMR Division provides inputs to the KGP Division to help promote knowledge about coastal and marine ecosystems and their functioning for effective ecosystem-based management. The CMR Division devise strategies and plans along with the ISE Division for reduction of current and emerging pressures on the coastal and marine resources through adaptive management and co-management activities.

The CMR division undertake research studies on the following key topics:

- Development of Critically Vulnerable Coastal Area (CVCA) management strategy/ plan
- Mapping of ESAs
- Mapping of coastal mineral resources
- Coastal ecosystem modelling
- Development of restoration strategies/ plans for degraded coastal and marine habitats

The CMR 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.

Futuristic Research (FTR)

The Futuristic Research Division (FTR) pursue innovative research and assess technological, policy and societal responses to inform adaptation and mitigation strategies to achieve sustainability and improve the resilience of coastal community.

The objectives of the FTR Division are twofold: I) energy security for coastal community and ii) climate change adaptation and mitigation for improved resilience. This division assess risks, impacts and vulnerabilities through regional and decadal scale analysis and models by improving the benefits from forecasts of future

environmental conditions and their consequences for people. Through innovative research, this division examine the potentials of energy security from renewable sources and those that have neutral impacts on other aspects of coastal sustainability. This include harnessing the potential of offshore wind energy for climate change adaptation and energy security in coastal regions of India. In another dimension, the FTR undertake advanced research towards minimizing carbon emissions and maximizing carbon sequestration and storage by sea grasses, tidal marshes and mangroves. The studies make an important contribution by ensuring that climate change concerns are better integrated with ongoing or planned activities that support ecosystem integrity including the management and use of bio-diversity resources. The FTR conducts targeted research and monitoring to quantify the greenhouse gas emissions from coastal ecosystems including those due to ecosystem degradation, land-based pollution and land use change.

The FTR's core strength is on cutting-edge work in paleoclimate reconstruction, geochronology, modelling, and synthesis. Paleoclimate reconstructions is used as windows into physical mechanisms of climate change, and its implications on socio-ecological, coastal and marine systems. The aim of FTR is also to quantify and predict the impact of ocean acidification on bio-diversity and ecosystem functioning and the potential industrial scale production of biodiesel from halophyte cultivations.

Some of the key innovative research FTR conducted includes:

- Offshore renewable and non-conventional energy source potential (macro-picture)
- Algal/ Halophyte cultivation for Bio-diesel (Industrial scale production)
- Blue carbon studies
- Coral bleaching
- Ocean acidification
- Invasive Alien Species
- Greenhouse gas fluxes from coastal ecosystems
- Urbanization of coastal zones

FTR's concerns include the vulnerability of coastal populations to natural disasters, and those related to climatic change.

Geospatial Sciences (GEO)

The Geospatial Sciences Division (GEO) is designed to provide information on the state of the coastal and marine environment through advanced observing and forecasting systems.

The aim of the GEO Division is to examine the application of Geographic Information Systems (GIS) and Remote Sensing (RS) to coastal management, coastal and marine monitoring, and hazard assessment. The primary thrust of this division is to develop a

"Shoreline Management Plan" for the coastal states of India, including its Island territories.

- Erosion Mapping Hazard Line Mapping (with inputs from Survey of India)
- Coastal Geomorphology
- Sediment Cell delineation
- Mapping, delineation and demarcation of Ecologically Sensitive Areas (ESAs)
- Mapping, delineation and demarcation of Critically Vulnerable Coastal Areas (CVCAs)
- Land-use Zoning
- Coastal protection measures
- Bathymetry
- Coastal process studies
- Sea-Use Zoning

The prime focus of GEO is to integrate coastal data and information to help guide management efforts such as coastal and marine spatial planning, and coastal zoning to derive science-based strategies towards Integrated Coastal Zone Management Plan (ICZMP).

Integrated Social Sciences and Economics (ISE)

The Integrated Social Sciences and Economics Division (ISE) conducts inter- and transdisciplinary research which takes account of coupled natural, social and economic systems.

ISE's key focus is on community-based approach to coastal vulnerability and coastal management. This division actively addresses the social-ecological dynamics in coastal systems, and the transitions towards an ecosystem approach and other means to address integrated coastal management. Methods include ecological and social field studies (inventories, interviews), meta-analysis, and theoretical development. The goal is to reduce vulnerability of coastal populations, especially to natural hazards that are likely to be exacerbated by climate change and to ensure true participation of community in coastal management for sustained benefits. Research interests of ISE include social aspects of coastal management, traditional knowledge, and regional and national level solutions for livelihood security and improved community level resilience against coastal hazards.

A few key examples of studies conducted by the ISE Division include:

- Socio-cultural profile of all traditional coastal communities
- Livelihoods Survey including development of coastal profile
- Survey and Mapping of fishing spaces
- Traditional Ecological Knowledge
- Customary and traditional institutions and Governance

- Assessment and valuation of coastal resources (living and non-living)
- Economic assessment of Ecosystems (Use and non-use values)
- Development of Co-management regimes
- Collect policy relevant economic indicator data on the economic value of the coastal and marine ecosystems
- Provide economic data and analysis to improve coastal and marine area management

Integrated Island Management (IIM) - (A Unit of FTR)

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

The IIM develops 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 provided 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.

Knowledge, Governance and Policy (KGP)

The Knowledge, Governance and Policy Division (KGP) facilitate the overarching requirement in the area of knowledge and skills development in coastal management, considering the needs of the research community, stakeholders, policy makers and the society. The KGP Division integrate data relevant to coastal management and create a national scientific knowledge base that facilitates improved decision making and policy formulation at the highest government and sectoral levels. The KGP Division undertake the following major programs:

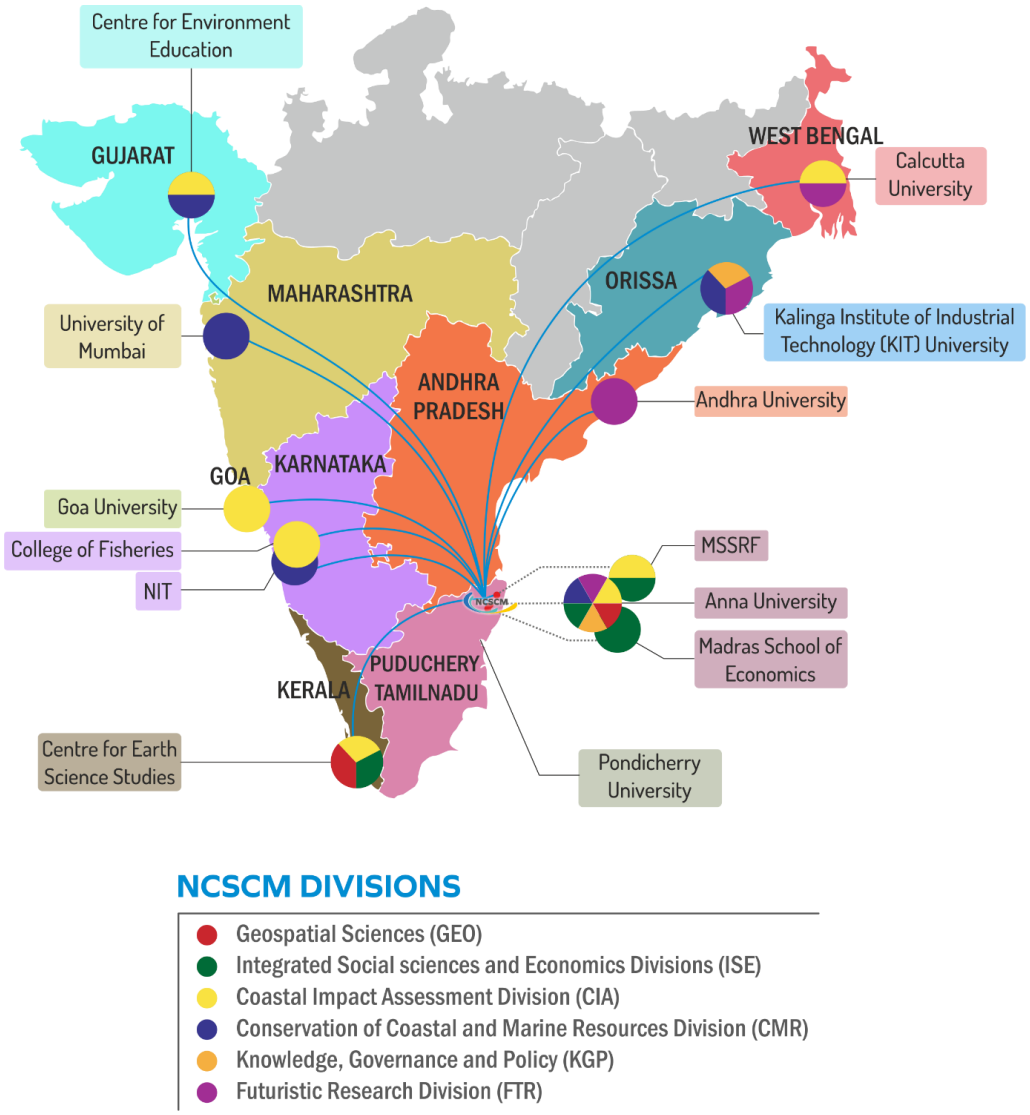
- Collection of all international best practices in ICZM and analysis of appropriate ICZM practice that can be used/ adopted in India with suitable modifications
- Preparation of the evolution of ICZM ideas in various countries

- Information on all base Coastal Zone Acts and judicial pronouncements of all countries to be collected
- A database of all judicial pronouncements related to coastal areas from the various Indian High Courts and the Supreme Court; and the Environmental Tribunals
- Guidelines for the preparation of ICZM Plan for State/ UT Governments (including sub-plans such as shoreline management plan) was evolved
- Training of trainers for integrated coastal planning and management
- Compilation of database and analysis of gender issues in coastal areas
- Communicating science and policy to the coastal communities and other key stakeholders
- Creation of a National database repository for coastal management

The KGP work as a central repository for the dispersed information on the Indian coast. The division prepares guidelines for the preparation of ICZM plans for State/UT governments including the various strategies to be evolved by the other departments such as for shoreline management. 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 division also enable networking at the local, regional, national and global levels. The KGP division is also be active in communicating science at various levels, especially at the local level in the vernacular. Training of trainers and other capacity building programmes are organized periodically to build a strong and viable system for sustainable coastal management.

Partnerships & Networking

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 partners of NCSCM, Chennai. The idea is novel and NCSCM is the first central research organization to have such a focused collaboration with regional universities. Fourteen institutions have formed a consortium with the National Centre for Sustainable Coastal Management. NCSCM has put in place a road map for strengthening and expanding the existing NCSCM consortium, stakeholder network and prioritizing the community interface. NCSCM supports its partner consortium institutes by strengthening their core area of research, and building 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.



4. Key Research Activities

NATIONAL	
1	Assessment of Coastal Erosion and Recommendation for Suitable Interventions- Green Coastal Infrastructure
2	Benthic Ecosystem and Ocean Acidification
3	Restoration of Pulicat lagoon, Monitoring Lagoon Ecosystem Health and Lagoon Management Plan
4	Holistic Conservation and Integrated Management Plan of Wetlands
5	Safety Risk Assessment and Bathing Water Quality Testing in three Beaches of India
6	Joint study on Seaweed Cultivation, Potential and Ecological Safeguards in the Gulf of Mannar, Tamil Nadu (along with ICAR-CMFRI and CSIR-CSMCRI)
7	Long Term Monitoring Plan for the Ecosystem based Conservation Management for Bhitarkanika Conservation Area Phase -II
INTERNATIONAL	
1	South Asia Nitrogen Hub Project (UKRI-GCRF, UK - 2021-2024)
2	Circular Economy Solution preventing Marine Litter in three Ecosystems (2022-2024)
3	Linking the Land-based Activities with Ecosystem Dynamics of Pulicat Lagoon in India (UNEP, Nairobi; Yr2021)

I. Assessment of Coastal Erosion and Recommendation for Suitable Interventions- Green Coastal Infrastructure

1. Introduction

Coastal process studies play a vital role in identifying erosion hotspots and in understanding the prime causes of erosion along the coast of India. The coastal zone has natural geomorphic features such as beaches, sand dunes, estuaries, mangroves and coral reefs. Of these, estuaries, mangroves and coral reefs are high biodiversity habitats supporting a variety of marine fauna and flora. The coastal zone provides space for many human uses including mariculture, fishing, tourism, settlements, industries, port activities, navigation and waste disposal. It is subjected to inclement weather conditions during monsoon and is prone to cyclones, causing extensive flooding and inundation of seawater by storm surges. Recent impacts from climate change have made coastal zones more vulnerable to increased intensity of wave action and sea level rise with consequent effects resulting in increased erosion. Other negative impacts of erosion and sea level rise are salt water intrusion and likely submergence of deltaic areas and low-lying coastal land.

The areas around the coast of India are also developed for fisheries, settlements, tourism, energy infrastructure, agriculture, marine infrastructure and industries. Coastal areas worldwide are major destinations for tourism, which represents the fastest growing sector of the global economy. At present tourism sector in India contributes up to 6.23% to the national GDP and 8.78% of the total employment of the country. The industry has a greater potential for enhancing tourism along the mainland and island coast of India. Changing climatic conditions, increase in storm intensity in recent decades, sea level rise, and increased population pressure are likely to cause even more coastal erosion in the future. In recent years, continuous increase in human pressure and unusual development over the coastal regions has led to changes in shoreline and eventually causes to high erosion along the coast.

The extent of erosion along the coast of India has also been determined by the National Centre for Sustainable Coastal Management (NCSCM) using long-term satellite data from 1990 to 2021. It is estimated that about 500 km of the coast is facing severe erosion, and about 464 km of the coast is covered with rubble mound or revetment type cement seawall. Approximately 100 sq.km of the beach/ coastal land area have been lost in the past. Estimates indicate that the annual economic losses due to coastal erosion at ~450 ha per year can be valued at about Rs. 1000 crores of protection work and mitigation measures including their maintenance expenses are therefore exorbitant.

Specific activities will be carried on assessing the shoreline change and its impact through a comprehensive coastal process study and by developing and implementing

a robust Shoreline Management Plan. In addition, available shoreline solutions involving protection of the coast using nature-based solutions and promoting green coastal infrastructures to the extent possible will be identified.

2. Study Site

It is proposed to develop "*Green Coastal infrastructure*" at two suitable locations of highly eroding coast along the Indian coast (Figure 2). This involves a five-step scientific strategy (Figure 1) involving components such as site evaluation with geophysical and ocean state parameters, collection of primary data, design of the conceptual green infrastructures using numerical modelling studies, evolution of the developed conceptual design structures, and cost benefit analysis.

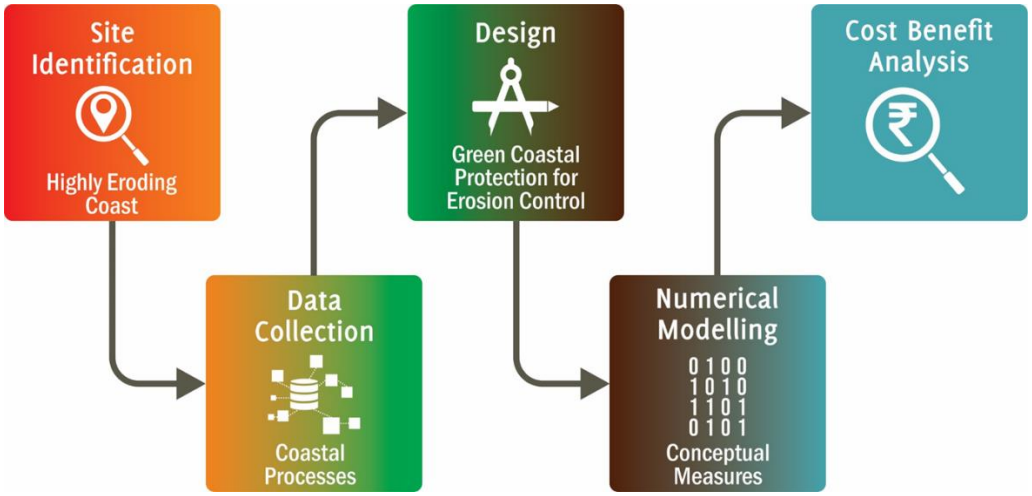


Figure 1: Framework schematic for develop living shoreline infrastructure

3. Objectives

The aim is to expand on the available shoreline solutions involving protection of the coast using nature-based solutions and promoting green coastal infrastructures to the extent possible.

The specific objectives are as follows

i) Identify hotspots of highly eroding coastline of India based on the economic and social conditions along the coast
   - *Siting of high erosion areas*
   - *Sediment budget, coastal sediment cells and strategy for coastal protection*
   - *Hazard Line - demarcation of risk zones*
   - *Demographic and social aspects*

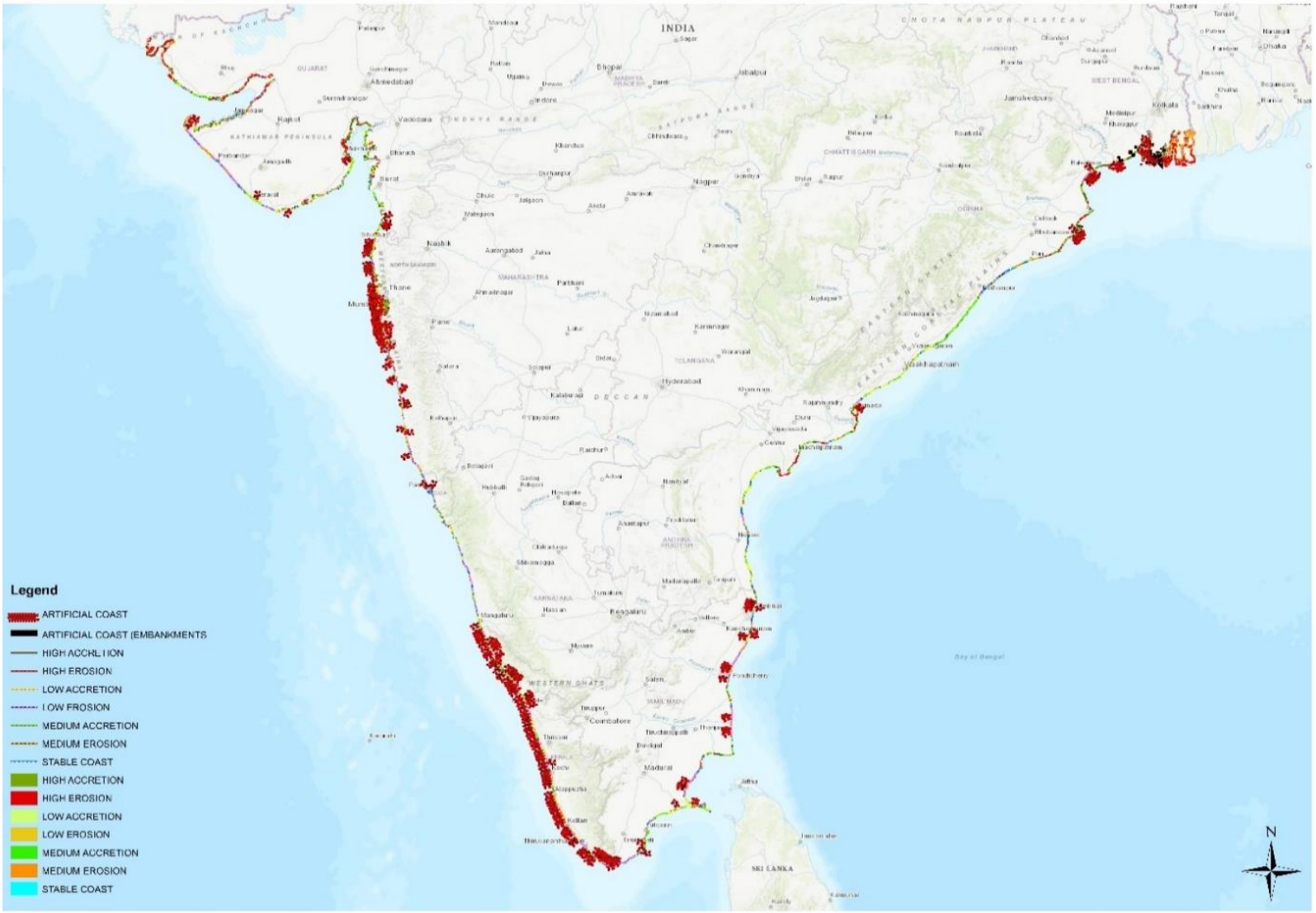


Figure 2: Assessment of shoreline changes along the coast of India

Ecologically Sensitive Areas

Land use and Land cover for the coast of India

ii) Development of criteria for the implementation of green coastal infrastructures along the highly eroding coastline
   - *Assessment of coastline for Living Shoreline Suitability Factors*
   - *Siting and design considerations*
   - *Primary and Secondary Data - coastal process study*

iii) Design of conceptual green coastal protection measures to control the erosion and to enhance the coastal ecosystems
   - *Evaluation of Design of green, grey and hybrid coastal structures*
   - *Numerical Modelling*
   - *Evaluation of designed green coastal infrastructure*
   - *Stability testing of the conceptually designed coastal protection measure using index and process-based models*

iv) Cost Benefit Analysis for pilot interventions

v) Implementing green coastal infrastructure at 2 pilot sites along with coastal States/ UTs with State/UT Budget.

4. Methods

A brief outline of the methodology is provided as follows:

Table 1:Methodology

Sl. No	Key Activity	Methods/Approach
1	**Identify hotspots of highly eroding coastline of India based on the economic and social conditions along the coast**	
1.1	*Siting of high erosion areas*	• Based on Physical Aspects, Ecological Aspects, Social Aspects and Economic Aspects, siting of high erosion areas will be identified
1.2	*Sediment budget, coastal sediment cells and strategy for coastal protection*	• The three levels of mapping: i) delineation of coastal sediment cells; ii) mapping the CZMPs, and iii) assessing the erosion/ accretion of the coastline would provide areas for prioritizing coastal protection.
1.3	*Hazard Line - demarcation of risk zones*	• In hazard line, wherever, the erosion line supersedes flood line, it indicates very high erosion rates at such locations. This information will be used for risk zoning and mapping of hotspots of erosion for appropriate coastal protection
1.4	*Demographic and social aspects*	• Blocks-wise demographic data to assess the social vulnerability of the coastal population due to coastal erosion

Sl. No	Key Activity	Methods/Approach
1.5	*Ecologically Sensitive Areas*	• Coastal Vulnerability model would be used to validate the importance of coastal ecosystems in coastal erosion control
1.6	*Land use and Land cover for the coast of India*	• GIS based land-use planning tool for coastal areas based on the exposure of various land uses and land cover to coastal erosion will be developed. • Key land uses and land cover would be mapped at high resolution and an exposure value would be assigned based on coastal erosion at historical and future time scales
2.	**Development of criteria for the implementation of green coastal infrastructures along the highly eroding coastline**	
2.1	*Assessment of coastline for Living Shoreline Suitability Factors*	• Suitability analysis and numerical modelling for different types of living shoreline treatments along the coastlines of India
2.1.1	*Siting and design considerations*	• The physical factors will be identified and assessed for an appropriate suitable design selection involving Design Criteria Classification Ranges and Appropriate Conditions for Various Living Shoreline Approaches (Miller, 2015)
2.1.2	*Coastal process study*	• A database will be created from in-situ measurements and field surveys of sediment, river and oceanographic data such as sediment characteristics, turbidity, river bathymetry, river discharge, waves, tide, currents, shoreline profiles, and bathymetry. • Beach profile measurements will be conducted for the estimation of beach volume • Based on primary and secondary dataset coastal processes will be studies
3.	**Design of conceptual green coastal protection measures to control the erosion and to enhance the coastal ecosystems**	
	Evaluation of Design of green, grey and hybrid coastal structures	• The energy conditions of the coastline will be used to identify appropriate site-specific interventions, based on the prevailing hydrodynamic conditions • The living shoreline techniques will be used to understand their benefits and to identify the suitable locations along the Indian coast.
	Numerical Modelling	• Index and process-based numerical coastal modelling will be conducted for evolution of conceptual green coastal protection measures
4	***Cost Benefit Analysis***	• Net present value (NPV) and benefit cost ratio (BCR) will be used for Cost-benefit analysis

5. Outcome

The outcome of the study are described below:

- Siting of High Erosion Areas

Coastal process studies play a vital role in identifying erosion hotspots and in understanding the prime causes of erosion along the coast of India. The coastal zone has natural geomorphic features such as beaches, sand dunes, estuaries, mangroves and coral reefs. Of these, estuaries, mangroves and coral reefs are high biodiversity habitats supporting a variety of marine fauna and flora. The zone provides space for many human uses including mariculture, fishing, tourism, settlements, industries, port activities, navigation and waste disposal. It is subjected to inclement weather conditions during monsoon and is prone to cyclones, causing extensive flooding and inundation of seawater by storm surges. Recent impacts from climate change have made coastal zones more vulnerable to increased intensity of wave action and sea level rise with consequent effects resulting in increased erosion. Other negative impacts of erosion and sea level rise are salt water intrusion and likely submergence of deltaic areas and low-lying coastal land.
This study would use geographic information system (GIS) to provide a suitability analysis and numerical modelling for different types of living shoreline treatments along the coastlines of India such as,

1. Areas that are suitable for a living shoreline method (nature based solutions);
2. Coastlines suitable for a hybrid solution (combination of natural and structural methods) and
3. Not suitable for living shorelines.

The identification would be based on a variety of parameters that could be assessed utilizing existing GIS information and numerical model simulations. The results of these analysis is used to identify the eroding hotspot sites along the Indian coast. The outcome obtained for Tamil Nadu coast is detailed below:
Tamil Nadu, located in the south-east of Peninsular India, has a coastline of approximately 1076 kilometers. The coast is classified into four types based on its natural characteristics: alluvial plain coast, deltaic coast, sand dune coast, and barrier beaches coast. The coastline extends from Erayamanthurai in Kanniyakumari district to Pulicat along the east coast and includes estuaries and deltas of ecological importance, major and minor ports, fishing harbours, international heritage monuments, tourist destinations, pilgrimage centres etc.

The average tidal range along the coast of Tamil Nadu is ~1 m, and its effect is insignificant compared to other stretches of the Indian coast. The waves, on the other hand, are more dominant along the coast. Wave-induced sediment transport, such as longshore and cross-shore transport, dominate the Tamil Nadu coast. The

approximate rate of net littoral drift along the Tamil Nadu coast is 1.2×10^6 m^3/yr (Sanil Kumar et al 2000). A few coastal districts, such as Chennai, Chengalpattu, Nagapattinam, Thanjavur, Ramanathapuram, and Kanniyakumari, are more vulnerable to extremely severe cyclones, and coastal erosion. The major sectors such as agriculture, fisheries, trade, and communication are well-developed along the coast of Tamil Nadu. The coast has become more vulnerable to significant erosion, frequent and high intensity storm surges in recent years.

Satellite based analysis and numerical model simulations revealed prevalence of erosion at various levels along the coast of Tamil Nadu. Several stretches along the coast Tamil Nadu have high rates of erosion along the coast (Figure 3). The extent of coastal erosion along the coast of Tamil Nadu were identified from the studies of shoreline change analysis and simulations of numerical models. However, the identified locations will be validated with the field observations in the future and will be considered for suitable green mitigation measures.

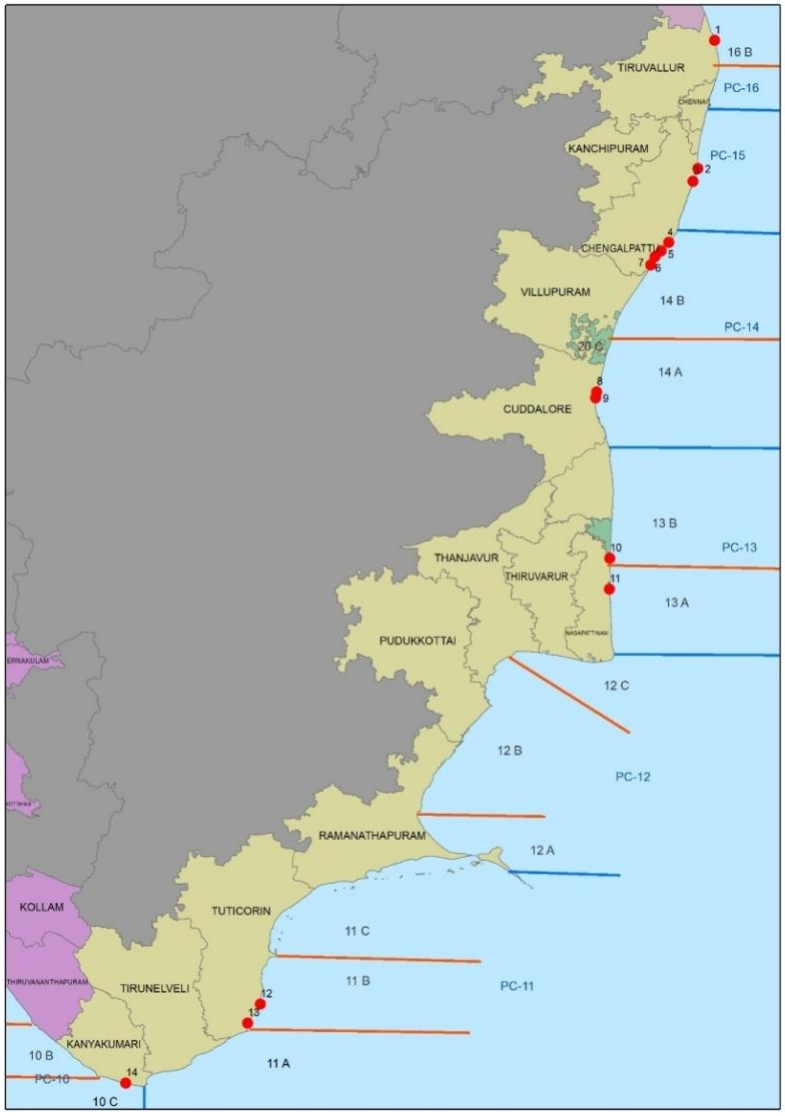


Figure 3. Erosion hotspots along the coast of Tamil Nadu based on the shoreline Change analysis and numerical simulations

Table 2: Identified Erosion Hotspots along the Tamil Nadu coast

S.No.	District	Location	Nature of the coast
1	Tiruvallur	Pulicat Lake bar mouth	Alluvial plain
2	Chengalpattu	Thiruvidandhi	
3		Nemmeli	
4		Kanathur	
5		Mugaiyur	
6		Kokilamedu	
7		Rahathnagar	
8	Cuddalore	Sangolikuppam	
9		Periyakuppam	
10	Nagapattinam	Samanthapettai	
11		Velankanni church	
12	Tuticorin	Rajkahnnanagar	Sand dune
13		Kulasekarapatinam	
14	Kanyakumari	Chothuvalai	Barrier beach

- **Shoreline Change Assessment**

The rate of shoreline changes and erosion/accretion zones were calculated for the East and West coast of India using high resolution satellite images for the period 1990 – 2021. The results obtained from the study reveals that about 30% of the coast is eroding, about 25% has accretion, 39% has stable coast and 6% of the coast is protected by seawalls. About 2% of the coast has high erosion, 7% has medium erosion and 22% has low erosion. The shoreline status of Tamil Nadu coast for the period 1990 - 2021 is shown in table 3.

Table 3: Erosion/Accretion status along Tamil Nadu (1990 – 2021)

Shoreline Classification	Length (km)	% of Erosion and Accretion	Cumulative % of Erosion and Accretion
High Erosion	15.58	1.56	30.15
Medium Erosion	69.23	6.92	
Low Erosion	216.92	21.67	
Artificial Coast : Seawalls	61.31	6.13	6.13
Rocky Coast	4.36	0.44	0.44
Stable Coast	386.40	38.61	38.61
High Accretion	15.63	1.56	24.68

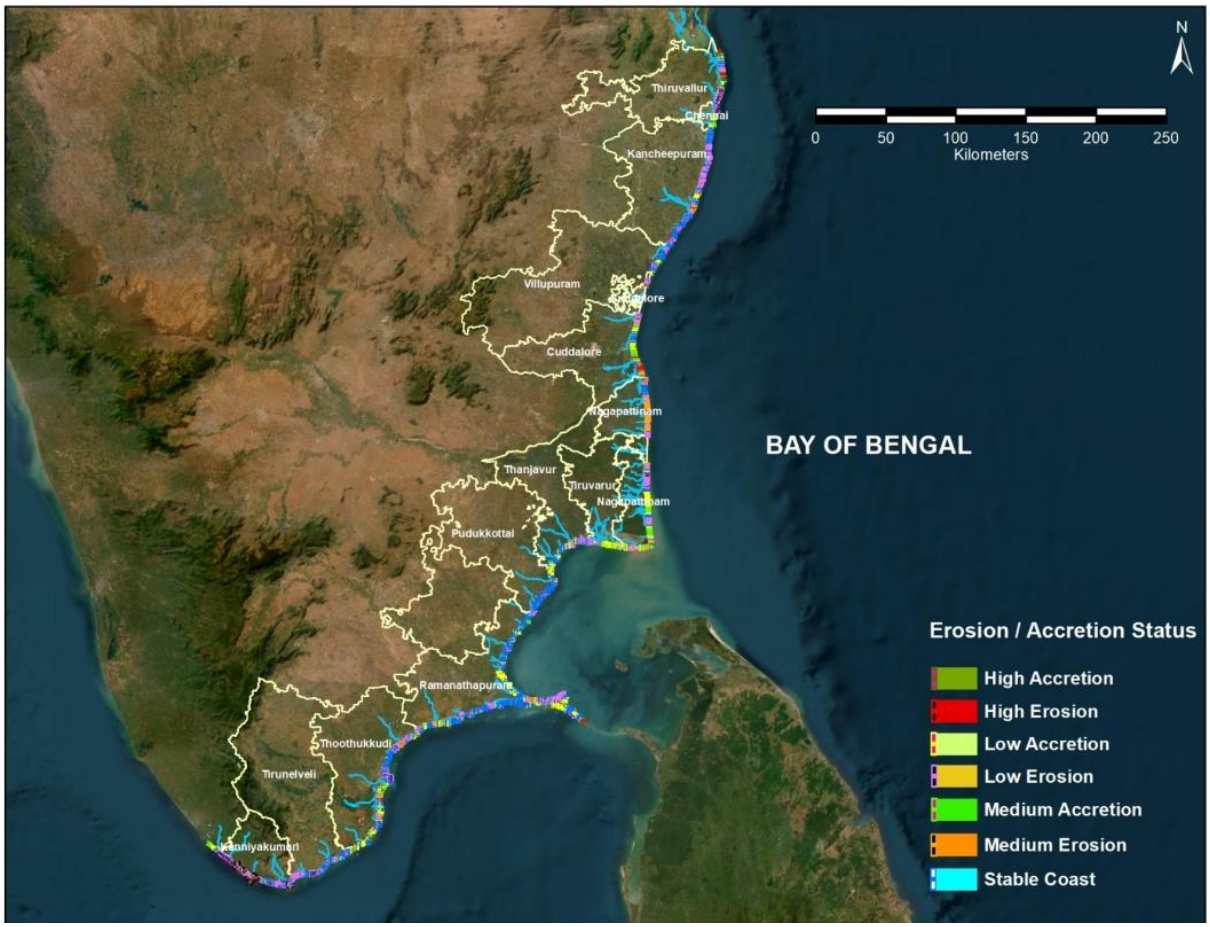


Figure 4. Shoreline status along Tamil Nadu (1990 – 2021)

Length of the Tamil Nadu coast: 1000.85 km

- **Coastal Sediment Cells**

Sediment cell is a stretch of coast between boundaries, which partly or wholly contain sediment movement and that any change in the sediment movement within a cell does not significantly affect the sediment flow of the adjacent cells (Pethick et al. 2013). It is the basic functional unit of the coast. Within its boundaries, the coastal processes act as coherent and integrated system.

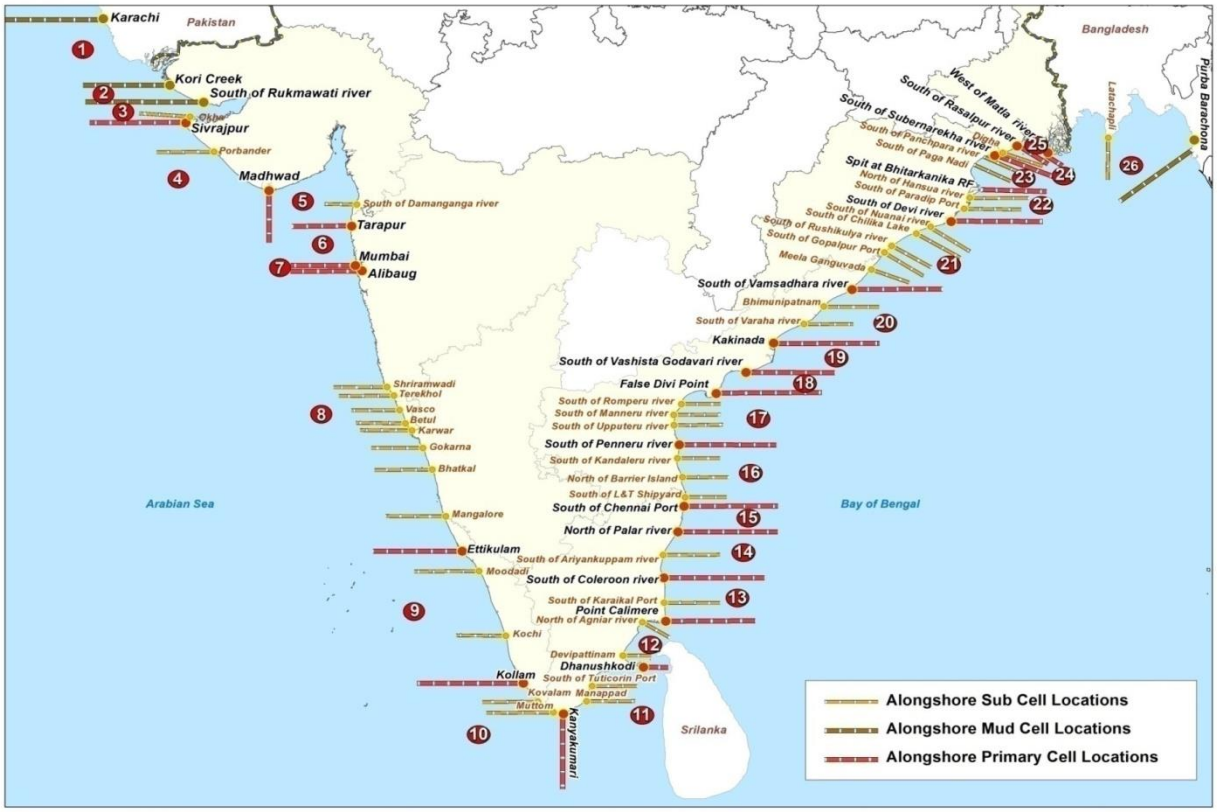


Figure 5. Primary and Sub cells along the Indian Coast, 2011 (Source: NCSCM)

An understanding of the way in which this system function allows us to identify the impacts of development and to mitigate so as to effectively manage the coastal stretch. Based on the rigidness of the barriers to movement of alongshore sediments, a sediment cell can be classified into Primary and Sub cells. Based on 2011 data, the East and west coast of India excluding islands were delineated in to 26 primary cells and 58 sub cells by NCSCM (Fig 5) Ramesh et al 2020. In view of the coastal developments and changes in the pathways of the coastal sediments a reconsideration of the delineated sediment cells is essential periodically to plan strategies for green coastal infrastructure. For the reconsideration of the delineated sediment cells, preparation of the temporal data to validate primary and sub cells are in progress.

- **Hazard Line demarcation**

The composite line of the extreme flood and erosion line is termed as “Hazard Line”. NCSCM has mapped the Hazard line for the mainland of India. The significant application of the hazard line is to plan strategies to combat increasing threats to coastal livelihood security and developments.

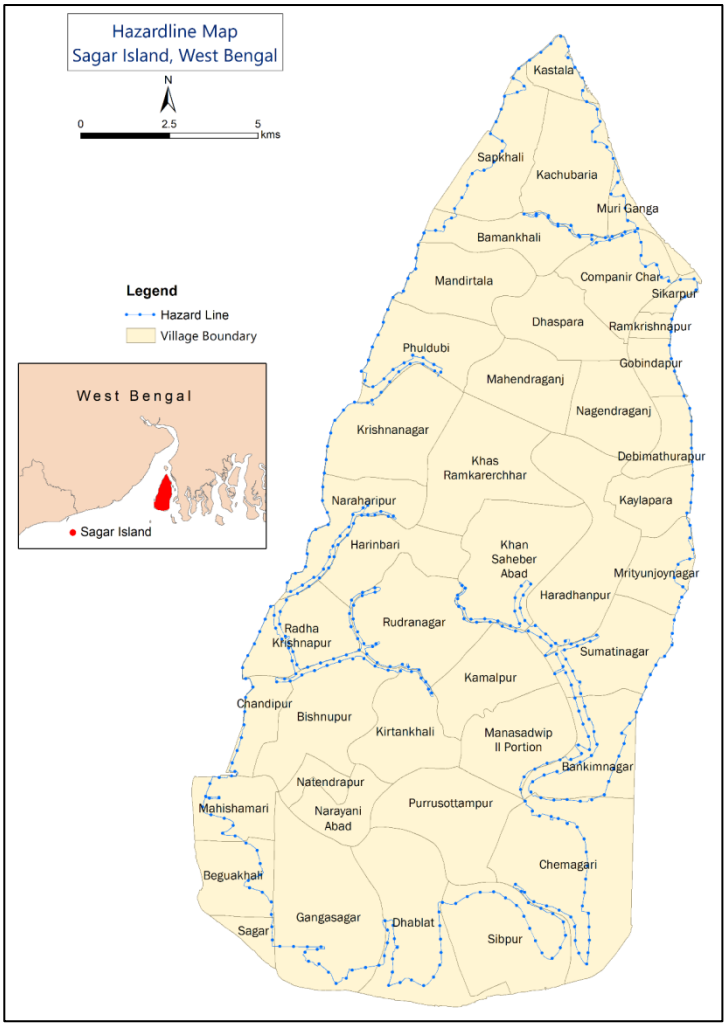


Figure 6. Hazard Line demarcation for Sagar Island, West Bengal

- **Demographic and social aspects (and social-economic vulnerability)**

Coastal communities directly or indirectly depend on the coastal resources for their livelihoods and infrastructure benefits. They face various natural and anthropogenic hazards including coastal erosion. To protect the life and livelihoods of the coastal communities and to prevent investments in the coastal areas, demographic and socio-economic assessments in the erosion hotspots of the coastal regions of India are important. This socio-economic study on the coastal erosion hotspots collects and analysis baseline information on the demography, livelihoods, and other socio-economic important parameters of the vulnerable coastal population to recommend suitable treatment methods to mitigate the risks and impacts on the coastal communities around the erosion hotspots. The significant socio-economic parameters include block-wise demographic, health status and facilities, educational infrastructures, employment, and infrastructure such as road network, rail, bridges, and other infrastructures that are influenced by the erosion hotspots to suggest suitable mitigation measures and green coastal investments. The study will analyze the erosion impacts in the identified erosion hotspots in the coastal States & UTs and

suggest suitable risk treatment methods including green coastal infrastructures in the area.

Cost–benefit analysis

- Coastal protection works are being carried out to protect the life and livelihoods of coastal communities. Poorly designed hard structures involve high maintenance and have adverse impacts on adjacent coastlines. Nature-based Green Coast solutions that are sustainable in the long term, not only provide coastal protection but also enhanced ecosystem services and livelihoods improvement.
- Cost–benefit analysis (CBA) is a systematic approach that can help to choose between appropriate adaptation options. In this method, the potential costs and benefits of an intervention are monetized (i.e. given a monetary value) for a specific time period and then compared to determine which of the options is most economic and effective. It is carried out using the NPV or BCR.Net present value (NPV) is the sum of the discounted project benefits less the sum of the discounted project costs. The benefit cost ratio (BCR) is the ratio of the present value of benefits to the present value of costs. However, management options will be ranked differently depending on whether the NPV or BCR result is used. Understanding the difference between these two decision criteria allows the provision of a more precise cost assessments (Amadio *et al*., 2022).
- In this study, goods, and services, economic productions of the coastal stretch, and traditional livelihood benefits of the erosion hotspots are being identified. Quantification of socio-economic benefits and losses due to erosion are being estimated. This equivalent economic value shall provide justifications for developing Green Coastal Infrastructures in the erosion hotspots.

The following are the steps involved in conducting a cost-benefit analysis for green coastal infrastructures in India to ensure livelihood security and other environmental benefits such as carbon sequestration, habitat restoration, and water quality improvement:

1. Identify theGreen coastal infrastructure project goals and objectives: The first step in conducting a cost-benefit analysis is to clearly define the goals and objectives of the green coastal infrastructure project. These goals and objectives will guide the selection of performance metrics and the identification of costs and benefits.
2. Identify and quantify costs: The next step is to identify all of the costs associated with the project, including planning, design, construction, and maintenance costs. These costs should be quantified as accurately as possible.
3. Identify and quantify benefits: The benefits of green coastal infrastructure can be both economic and non-economic. Economic benefits may include

increased property values, reduced flood and erosion damage, and reduced infrastructure costs. Non-economic benefits may include improved habitat for wildlife, increased recreational opportunities, and improved water quality. These benefits should be quantified and valued as accurately as possible.

4. Compare costs and benefits: Once all costs and benefits have been identified and quantified, they can be compared to determine the net economic benefits of the project. The net economic benefits are calculated by subtracting the total costs from the total benefits.
5. Sensitivity analysis: In order to account for uncertainties in the estimates of costs and benefits, a sensitivity analysis should be conducted. This analysis involves varying the key assumptions and parameters used in the cost-benefit analysis to determine the impact on the net economic benefits.
6. Decision-making: The results of the cost-benefit analysis can be used to inform decision-making about whether or not to proceed with the green coastal infrastructure project. If the net economic benefits are positive and the project aligns with the goals and objectives of the organization or community, the project may be considered feasible.

Here are some examples of green coastal infrastructure that can be implemented in India:

1. Mangrove plantations: Mangroves are dense forests of trees and shrubs that grow along the coastline in tropical and subtropical regions. They are an effective natural barrier against storm surges and tidal waves. In India, the Sundarbans mangrove forest, located in the delta of the Ganges, Brahmaputra, and Meghna rivers, is the largest mangrove forest in the world.
2. Coral reefs: Coral reefs are diverse underwater ecosystems that provide a natural barrier against waves and storms. They also support a wide range of marine life, including fish and shellfish. India has a long coastline with several coral reef ecosystems, including the Gulf of Mannar and the Andaman and Nicobar Islands.
3. Dunes: Coastal sand dunes are formed by wind-blown sand and vegetation. They act as a buffer against coastal erosion and provide protection against storms and surges. In India, coastal sand dunes can be found in areas such as the Thar Desert and the beaches of Goa.
4. Wetlands: Wetlands are areas of land that are saturated with water. They provide natural filtration of water and protection against storm surges. India has several wetlands along its coastline, including the Chilika Lake in Odisha and the Vembanad-Kol wetland in Kerala.
5. Beach nourishment: Beach nourishment involves adding sand to eroding beaches to increase their width and height. This helps to protect coastal infrastructure and reduce the impact of storm surges. Beach nourishment projects have been implemented in several coastal areas in India, such as Mumbai and Goa.

Overall, green coastal infrastructure can provide a cost-effective and sustainable solution to protect India's coastline from the impacts of climate change and natural disasters. It is essential to promote the implementation of green coastal infrastructure through policy and financial incentives to ensure their successful implementation.

Based on the suitable site specific recommendations for vulnerable coastline, coast benefit analysis studies will be undertaken for the ongoing project.

- **Ecologically Sensitive Areas (ESA)**

Ecologically sensitive areas (ESA) along the East and West coast of India were mapped using high resolution satellite images. The details of different ESA's of 2011 are tabulated below:

Table 4: Extent of ESAs in listed in CRZ 2011 (in km^2)

Coast	State Name/UT	Ecosystems				Habitats			Geomorphological features		Others		Total
		Mangrove	Corals	Seagrass	Salt Marsh	Horseshoe crab habitat	Turtle Nesting Sites	Bird nesting Sites	Sand Dune	Mudflat	PA (RF, NP, WLH & OPA)[3]	A&H	
Section in CRZ 2011 notification		7(i)A(a)	7(i)A(b)	7(i)A(i)	7(i)A(f)	7(i)A(h)	7(i)A(g)	7(i)A(j)	7(i)A(c)	7(i)A(d)	7(i)A(e)	7(i)A(k)	
West Coast States	Gujarat[1]	1421.33	369.92	17.02	283.74	0.00	4.00	9.82	66.50	2980.63	1939.25	1.98	**7094.19**
	Maharashtra[1]	317.24	0.18	0.00	4.55	0.00	2.02	0.22	4.11	46.97	435.15	1.02	**811.47**
	Goa[1]	32.88	0.34	0.00	1.06	0.00	0.26	0.00	2.94	1.05	2.83	0.53	**41.89**
	Karnataka[1]	16.47	0.16	0.00	0.56	0.00	0.00	0.35	0.47	0.81	123.07	0.29	**142.19**
	Kerala[1]	21.12	0.00	0.00	0.00	0.00	1.17	0.00	0.00	0.00	0.37	0.18	**22.84**
	Daman & Diu UT[1]	5.22	0.00	0.00	0.40	0.00	0.00	0.00	3.82	1.88	35.88	0.55	**47.75**
East Coast States	Tamil Nadu[1]	119.10	23.30	398.80	59.40	0.00	2.63	595.45	30.93	189.43	796.16	0.79	**2215.99**
	Andhra Pradesh[1]	507.29	0.00	0.00	26.08	0.00	13.75	264.93	115.94	7.13	2310.30	0.13	**3245.57**
	Odisha[1]	264.63	0.00	87.08	131.69	29.33	8.73	730.96	96.82	70.21	1187.32	0.08	**2606.84**
	West Bengal[1]	2182.09	0.00	0.00	32.58	40.54	2.65	2632.31	2.64	131.34	3336.89	0.05	**8361.09**
	Puducherry UT[1]	4.36	0.00	0.00	0.06	0.00	0.16	0.00	0.28	4.59	0.00	0.18	**9.63**
Islands	Andaman & Nicobar Islands UT[2]	699.26	493.42	14.60	60.24	0.00	133.44	1115.20	0.00	123.91	6321.33	0.00	**8961.40**
	Lakshadweep Islands UT[2]	0.00	552.22	0.72	0.00	0.00	9.92	37.22	0.00	0.00	0.00	0.00	**600.07**
Total		**5590.99**	**1439.55**	**518.22**	**600.36**	**69.87**	**178.72**	**5386.46**	**324.45**	**3557.95**	**16488.56**	**5.78**	**34160.90**

Source: NCSCM

PA = Protected Area; RF = Reserve Forest; NP = National Park; WLH = Wild Life Habitat; OPA = Other Protected Area; A&H = Archeological & Heritage Sites;

[1]Meeting with state representatives and draft QC completed; [2]QC not initiated; High resolution data yet to be procured [3]Some RFs overlap with other MPAs

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II. Benthic Ecosystem and Ocean Acidification

Context

The phenomenon of the unprecedented increase in H^+ ion concentration and changes in the aquatic carbonate chemistry (pCO_2, pH, alkalinity, and calcium carbonate saturation state) primarily due to the rapid uptake of atmospheric CO_2 in the seawater is known as ocean acidification. As CO_2 dissolves into the ocean, it alters its chemistry. Lowering of seawater pH, caused by high dissolved pCO_2 under high atmospheric CO_2 concentration leads to a reduction in calcium carbonate saturation state. At present, the ocean is 30% more acidic than it was 200 years ago, and the rate of acidification is faster than ever. A decline of 0.1 pH units (logarithmic scale) indicates a ~30 percent rise in seawater acidity (H^+ ion concentration). Ocean acidification may result in substantial losses and redistributions of marine ecosystem services like biodiversity, habitat, food provisioning, storm protection, tourism and recreation.

Compared to the oceanic waters, coastal waters are subjected to higher anthropogenic pressure largely due to its proximity to the terrestrial environment. The decrease in pH of the coastal waters 'Coastal Acidification' is emerging as an additional global threat to the health of coastal ecosystems. Coastal ecosystems and habitats experience greater variability than those in the open ocean, due to physical, geochemical and biological processes, and terrestrial influences. Coastal acidification together with other impacts such as coastal pollution and the introduction of invasive alien species are likely to result in more fragile coastal ecosystems, making them more vulnerable to other environmental impacts.

Coastal waters are subjected to higher anthropogenic pressure largely due to its proximity to the terrestrial environment. The coastal waters and its associated biodiversity are potentially vulnerable to any changes in pH, nutrient enrichment and O_2 depletion due to various anthropogenic activities. Ecosystem responses to environmental changes has poorly been studied particularly with reference to continuous, long term monitoring of coastal ecosystems. The key issues are

- Decrease in oceanic pH
- El Nino and La Nina – sea surface temperature anomalies
- Eutrophication –nutrient enrichment from land-based sources
- Change in sea water carbonate chemistry

The combination of eutrophication and coastal acidification is likely to have greater adverse effects on coastal ecosystems. Hence, this needs to be urgently addressed. It is well known that nitrogen is the primary cause of eutrophication in many coastal ecosystems. Therefore, optimal management of coastal eutrophication suggests controlling both N and P, in part because P can limit primary production in some systems. However, there are also studies indicating that in highly productive near-

shore coastal marine environments, the effect of eutrophication on carbon cycling can counter the effect of coastal acidification on the carbonate chemistry of surface waters. Hence, changes in river nutrient delivery due to management regulation policies can lead to stronger changes in carbonate chemistry than coastal acidification.

In spite of the significant advancement in oceanographic research in India, studies on coastal and ocean acidification research in India is still scarce. The ecosystem level responses against the environmental changes have poorly been studied that deals with continuous, long term monitoring of coastal ecosystem. Time series sampling and continuous monitoring in this ecosystem is therefore essential to examine the environmental changes and subsequent impacts on the associated biota. In addition to screening for eutrophication, continuous monitoring of environmental changes and its effects on biota also becomes paramount importance.

Selected coral reef ecosystems (Gulf of Mannar in the east coast of India, Lakshadweep Island) and lagoon ecosystems (Chilika and Pulicat) will be studied to depict future responses to nutrient enrichment, coastal acidification and formation of oxygen minimum zones. Continuous monitoring of these ecosystems is essential to examine the environmental changes and subsequent impacts on the associated biota. SICOM-MoEF&CC has approved the project in November 2021. Total cost of the project is Rs.4.5 crore for a period of five years from December 2021 to 31st March 2026.

Study Site

The study will be conducted in following sites:

a) Gulf of Mannar, Tamil Nadu
b) Kavaratti Island, Lakshadweep
c) Chilika Lagoon, Odisha
d) Pulicat lagoon (Andhra Pradesh and Tamil Nadu)

Gulf of Mannar

The Gulf of Mannar is a large shallow bay forming part of the Laccadive Sea in the Indian Ocean (Figure. 1). Located on the south-eastern tip of the subcontinent, the Gulf of Mannar is known to harbor over 4,223 species of flora and fauna, making it one of the richest coastal regions in Asia. 117 hard coral species have been recorded in the Gulf of Mannar. This Marine Protected Area is surrounded by various industries including petrochemicals, fertilizer, ship building, thermal power, salt works and several other small-scale industries that drain their effluents into the sea.

The Third Global Coral Bleaching Event caused significant coral mortality in Gulf of Mannar, South-eastern India during 2016. Percentage of bleaching during April-June in Gulf of Mannar was 23.92±10.55%. Live coral cover was reduced to 22.69±9.07%

during October 2016 from 38.86±10.2 during 2015 with a significant mortality of 16.17±8.46%. Eutrophication and coastal acidification study will be conducted at Kavaratti Island.

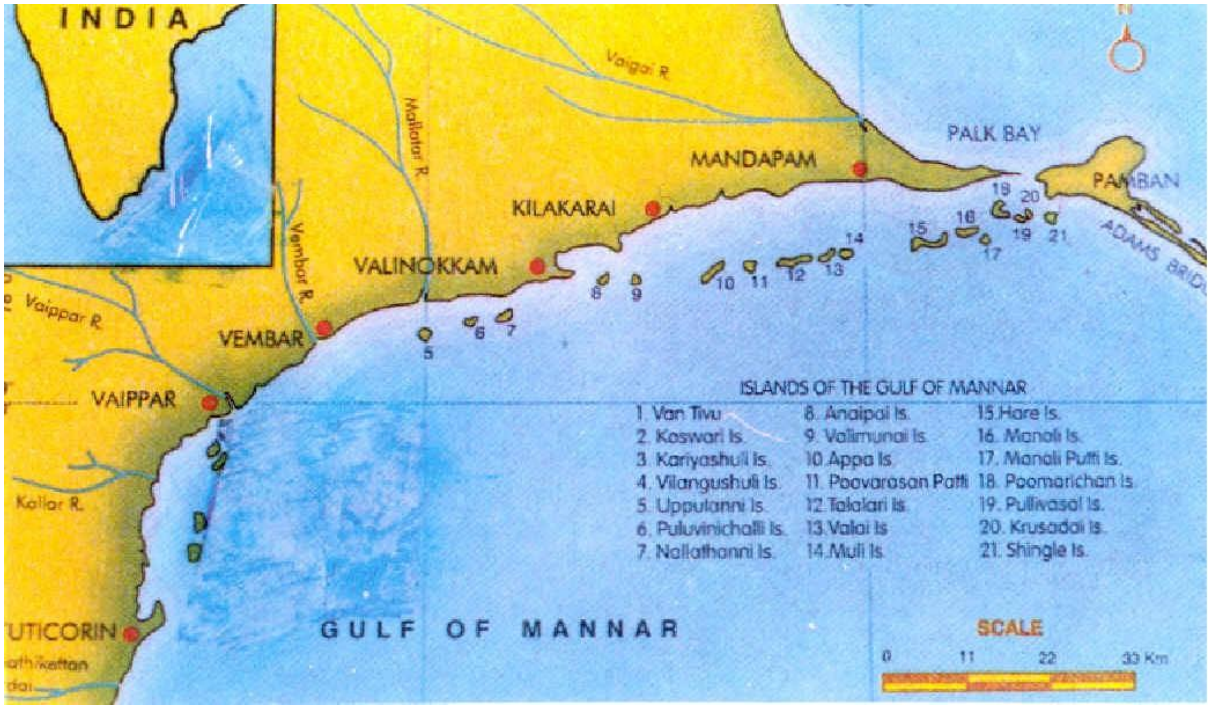

Figure. 1: Map of Gulf of Mannar

Kavaratti Island, Lakshadweep

The Lakshadweep are least studied coral atoll group situated in the northern part of the Laccadive-Chagos ridge at a distance of 200-300km from the West Coast of India. Kavaratti Island (Figure. 2) has a coral reef of 2.43 km^2. Sea grass is seen in the beach-lagoon area of this island. The island ecosystem is facing serious concerns for their sustainability over the past few decades, expressing a threat to the future generation for livelihood. The reef areas are the living places of various communities of corals belonging to different families of Acroporidae, Poritidae, Pocilloporidae, Favidae, Fungiidae, Mussidae etc. Besides a large number of species of Gastropods, Bivalves, Echinoids, Foraminifers, Ostracods and Bryozoans are also present. The sands have a low amount of silica, alumina and Fe_2O_3. Eutrophication and coastal acidification study will be conducted at Kavaratti Island.

Figure. 2: Map of Kavaratti Island, Lakshadweep

Pulicat Lagoon

Pulicat lake, the second largest brackish water lagoon in India, running parallel to the Bay of Bengal, bordering the east coast of Andhra Pradesh state, with a portion of it extending into the northern part of the Tamil Nadu state (Figure. 3). The improperly treated industrial effluents from the Ennore creek and Buckingham canal ultimately reach Pulicat lake through its bar mouth and the Bay of Bengal coastal waters. Point sources of pollution are mainly from North Chennai Thermal Power Plant, Ennore port activities, Manali Petrochemical Industries, other nearby industries and untreated urban wastes from Chennai metropolitan.

Figure. 3: Map of Pulicat Lagoon

Chilika Lagoon

Chilika Lake is a semi-enclosed, coastal lagoon on the east coast of India separated from the Bay of Bengal by a long sand bar extending about 180-275 m wide. The lake is a unique assemblage of marine, brackish and fresh water ecosystem with estuarine characters. The pear-shaped lake is about 64.5 km long and varies in width from 18 km in north to 5 km in south. On account of its rich biodiversity, the Chilika Lake was designated as a "Ramsar Site" i.e. a wetland of international importance.

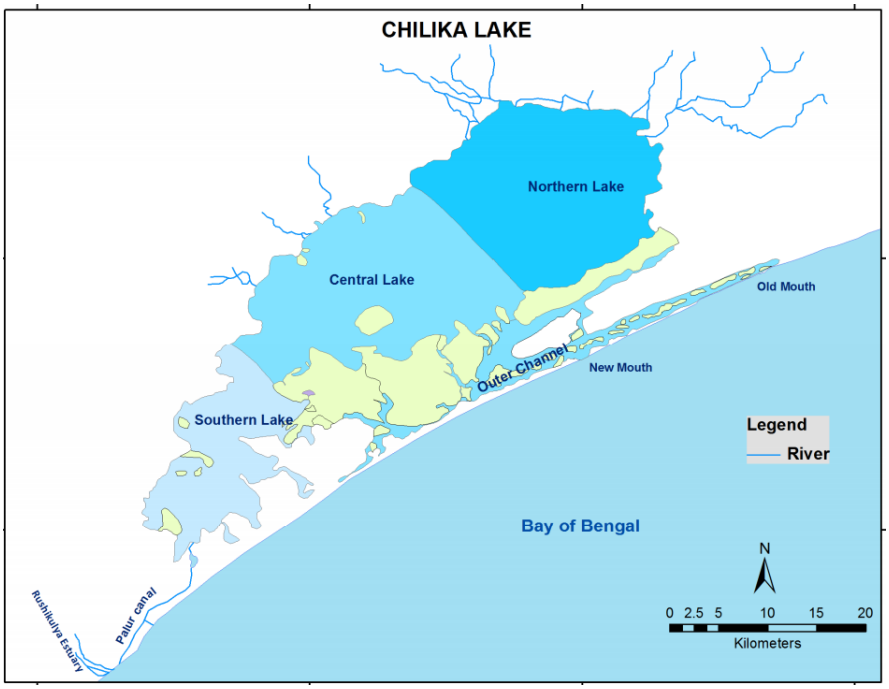

Figure. 4: Map of Chilika Lake

Objectives

The overarching aim of the study is to observe trends in oceanic pH and to determine the causes of change to sustainably manage and protect marine and coastal ecosystems. Selected coral reef ecosystems (Gulf of Mannar in the east coast of India, Kavaratti Island, Lakshadweep) and lagoon ecosystems (Chilika and Pulicat) will be studied to depict future responses to nutrient enrichment, coastal acidification and formation of oxygen minimum zones.

Continuous monitoring of these ecosystems is essential to examine the environmental changes and subsequent impacts on the associated biota. The study is based on following hypothesis:

- Coastal acidification and Hypoxia will change ecosystem structure, function, and biodiversity via both direct impacts (e.g., altered growth or survival rates, increased mortality) and indirect effects (e.g., food web and/or habitat changes).
- Ecosystem response to coastal acidification and hypoxia will vary with species-specific compositions, local environmental factors and regional climatic conditions

The principal scientific objectives of coastal acidification observational network are as follows:

1) Creation of long-term database for identification of mitigation strategies for coastal acidification.
2) Coral reef ecosystem health in connection with changes in biological and physical indicators
3) Assessment of past climate by studying Foraminifera/ Radiolarians/ Coccoliths in sediments
4) Local/ regional hotspot of coastal acidification will be recognized to identify the sources of pollution that causes stress on the reef.

Methods

The study intends to understand the causes of coastal and estuarine acidification and its associated impact on the coastal and marine biodiversity at identified locations. Detailed methodology of various activities has been explained in the Annexure 1 – Annual Action Plan. A brief outline of the methodology is given below

S.No	Name of the activity	Method/ Approach
1	Collection of real-time data to develop long term database	Realtime dataset from data-buoy at Kavaratti island and Gulf of Mannar
2	Monitor seawater chemistry associated with OA and nutrient enrichment	Periodic monitoring and long term of seawater quality for physico-chemical parameter through field survey and laboratory analysis
		Characterizing natural/anthropogenic variability of carbonate chemistry through field measurements and laboratory analysis
		Development of indices for water quality
3	Assessing coral reef ecosystem health related with changes in biological and physical indicators	Mapping Benthic habitats in coral reef ecosystem using very high-resolution satellite images
		Assessment of coral health through Line Intercept Transect (LIT) method
4	Develop (i) coral reef health index (CHI) and (ii) Health of associated flora and fauna that influence coral health by developing Sea Life Index (SLI)	Development of indices (CHI and SLI) based on field survey and analysis
5	Measurement of coral recruitment rate for selected areas and	Field based assessment of coral recruitment rate through NCSCM designed settlement tripods.

S.No	Name of the activity	Method/ Approach
	measurement of rate of sedimentation	Field based Measurement of sedimentation rate using sediment traps at GoM and Kavaratti
		Field and lab-based assessment of microbial community associated with corals
6	Monitor calcification and metabolism rates in living coral reef communities	Measurement of Net community calcification (NCC) and net community production (NCP) rate in field followed by laboratory analysis
7	Assessment of past climate by studying Foraminifera/ Radiolarians/ Coccoliths in sediment	Stable isotope analysis of Calcareous sediments containing significant Coccoliths/ Foraminifera as an environmental proxy
8	Assess the impact of coastal and estuarine acidification on molluscs, plankton, fish larvae	Laboratory based mesocosm/microcosm studies by stimulating environmental conditions.
9	Development of a benthic ecosystem and acidification database for management of coastal/ marine ecosystems	A web-based database will be developed

Inception Activities

Inception report

Divisions of NCSCM namely CIA, CMR, FTR, IIM and IT will be responsible to undertake the study. A detailed methodology and timeline have been developed and enclosed as Annual Action Plan in Annexure 1. The secondary information and related datasets with respect to the activities are being collected and field work for primary survey is being planned as per the timeline.

Key Project Indicators

Following are the key project indicators under this project;

a) Site-specific mapping of marine benthic habitats providing eco-geomorphological zonation
b) Real time coral reef monitoring systems using advanced sensor technologies - one each at Kavaratti Island and Gulf of Mannar.
c) Coral Health Index (CHI) and Sea Life Index (SLI) developed using real-time data and other seasonal biological and environmental data at Lakshadweep and Gulf of Mannar

d) Water quality index developed to identify the natural and anthropogenic stress and variability in the water quality

Significant Achievements under KPI

Expected minimum significant achievements

a) Comprehensive benthic habitat maps for Kavaratti Island and Gulf of Mannar developed
b) Comprehensive health assessment of benthic ecosystems (coral and coastal lagoons) prepared
c) Threshold of acidification beyond which the economically important benthic species become negatively impacted would be identified
d) Possibilities of a long-term solution to counter biodiversity loss identified
e) Strategies for reducing coastal and ocean acidification by introducing / restoring seagrass ecosystems identified

Outcome of the project activities

a) Estimation of primary productivity and calcification rates in coral ecosystems and coastal lagoons and, their dependency on the environmental parameters.
b) Comprehensive nutrient management plan developed for minimizing eutrophication and OMZ in coastal waters
c) Scenario building on ecosystem response to nutrient enrichment and coastal acidification through microcosm/ mesocosm and modelling
d) Mitigation strategies for coastal acidification identified
e) Site-specific appropriate interventions and alternative management options identified

It is expected that the island communities will be largely benefited through enhanced ecosystem services from the scientifically managed healthy coral reef ecosystems.

Timeline (Pert Chart)

Quarter-wise implementation plan for 2021-2026 of the Project

No.	Activities	Year 1		Year 2				Year 3				Year 4				Year 5				Year 6	
		Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
1	Collection of real-time data to develop long term data base																				
2	Monitoring seawater chemistry associated with ocean acidification and nutrient enrichment																				
3a	Assessing coral reef ecosystem health related to changes in biological indicators																				
3b	Assessing coral reef ecosystem health related to changes in physical indicators																				
3c	Mapping of benthic habitats																				
4	Developing the following indices																				
4a	Coral Health Index (CHI)																				
4b	Sea Life Index (SLI)																				
4c	Health of associated flora and fauna that influence coral health																				
4d	Marine litter index																				
5a	Measuring coral recruitment rates for the selected areas																				
5b	Measurement of rate of sedimentation in all study sites (Gulf of Mannar, Kavaratti, Chilika and Pulicat)																				
6	Monitoring calcification and metabolism rates in living coral reef communities																				
7	Measuring historic coral growth rates from coral cores relative to historic changes in seawater pH; and Sea Surface Temperature (paleoclimate studies)																				
8	Assessing the impact of coastal and estuarine acidification on molluscs, plankton, fish larvae																				
9	Developing a benthic ecosystem and coastal acidification database for management of coastal/ marine ecosystems																				
10	**Reporting**																				

III. Restoration of Pulicat lagoon, Monitoring Lagoon Ecosystem Health and Lagoon Management Plan

1. Background

Pulicat lagoon is the second largest brackish water lagoon in India after Chilika and locally called as 'Pazhaverkadu' in Tamil Nadu, a combination of three Tamil words: Pazhaya (old), vergal (root), and kadu (forest) . It is shared between two states i.e. 1/3rd in Tamil Nadu and 2/3rd in Andhra Pradesh. The Pulicat Lagoon evolved 6000 years ago at the peak of Holocene sea level rise. The present lagoon is 281 km^2, (although around 1700 A.D, the lagoon was 481 km2) extending between the town of Pulicat and Swarnamukhi River.

Due to deltaic deposits, the lagoon is extensively shallow, averaging ~1.5 m, ranging between 0.5 and 6 m respectively. The narrowest region of the lagoon is near the Pazhaverkadu village, measuring about 250 m with a narrow channel. The lagoon is separated from the Bay of Bengal by an inland spit called Sriharikota Island, which is located on the eastern side extending north to south as a narrow spit of sand-bar between the lagoon and the Bay of Bengal with an approximate width of 2 km. The lagoon at its southern end near the Pulicat town, opens into the Bay of Bengal by a narrow pass (bar-mouth) into the sea. In the northern part of the lagoon, there are two large islands, Venadu and Irakkam in Andhra Pradesh, and a smaller island called Kuruvithittu, all of which have deposits of sub-fossilized clam shells. The Buckingham Canal runs parallel on the eastern side between the Bay of Bengal and the lagoon, along the narrow sand-bar (Sriharikota Island) and joins near Annamalaichery in the south.

The main source of fresh water to the Pulicat Lagoon, is run-off from three small seasonal rivers that open into the lagoon, namely the Arani River discharging at the southern end of the lagoon in Tamil Nadu; the Kalangi River towards the mid-western region of the lagoon in Andhra Pradesh; and the Swamamukhi River at the northern end of the lagoon in Andhra Pradesh. The river Kalangi drains from the northwestern part of the lagoon, joins near Tadakuppam as Kaleru. The river Arani runs west to east on the southern side of the lagoon and branches out into two parts: one arm joins north of Pulicat town near Jameelabad, and the other arm joins on the southern side of Pulicat town near Sathankuppam. Water flows in these rivers during the northwest monsoon (October to December).

Of the several islands found in this lagoon, Sriharikota is the most prominent. Several other smaller inhabited islands exist mostly in the northern region of the lagoon. The soil in these islands is sandy and marine in origin. The islands along the Buckingham Canal and along the innumerable salt-water streams exhibit a substratum of moist soil consisting of a bed of clay filled with shells.

Resource extraction has increased in the past few years, resulting in habitat loss and degradation. Current pressures and challenges on the Pulicat lagoon are largely related to changing land use, coastal erosion and siltation, fishing, bar mouth dynamics related to tidal exchange of seawater and declining biodiversity. The lagoon is further affected by the alteration of flow and water quality through upstream check dams, modification of flow dynamics, and climate-related changes in precipitation patterns resulting in a drastic reduction in freshwater flow to the lagoon.

The land use activities in Pulicat Lake includes Agriculture, aquaculture, industrial areas, settlements, scrub lands and plantation. The major land cover in the lagoon area includes mudflats, sandy areas, marshes, mangroves and lake area. Changes in the land uses and land cover between 2020 and 2021 were assessed using satellite images. The change analysis indicated a 40% loss of agriculture lands, 14% loss of plantation areas, 1% loss of mangroves. The lake area indicated a 2% shrink due to increased siltation of sand and mud mostly in the northern portion. Figure 1 shows the significant changes in the land use and land cover features of the Pulicat Lake between 2020 and 2021 highlighted in red circles. The existing land use and land cover pattern of Pulicat lagoon has been given in Figure 1.

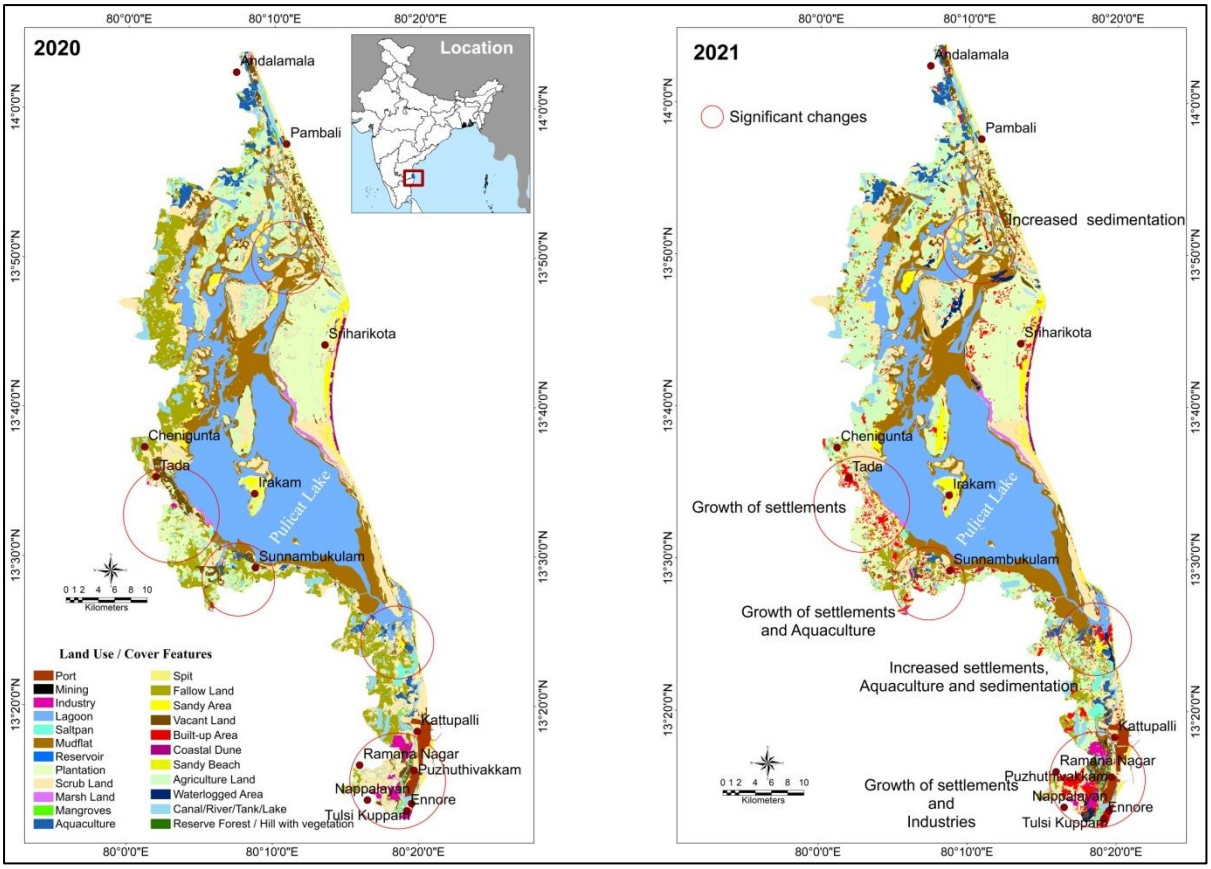

Figure 1: Land use and land cover pattern of the Pulicat Lagoon between 2020 and 2021

The above issues clearly highlight the need for coordinated and integrated lagoon management to address the ecological, physical and social challenges in the lagoon area for the wellbeing of the dependent communities and for the restoration of the lagoon ecology. To resolve various issues in Pulicat lagoon, a sustainable management plan is essential. Specific activities shall be carried out on restoring the lagoon ecosystem and enabling enhanced livelihood by addressing critical existing challenges such as fisheries, pollution, livelihood, tourism and bar mouth dynamics through policy-relevant research. To address the environmental issues of the Pulicat lagoon, MoEF&CC has approved the project on "Restoration of Pulicat lagoon, monitoring lagoon ecosystem health and Lagoon Management Plan" in November 2021. Total cost of the project is Rs. 4.5 crore for a period of five years from November 2021 to 31st March 2026. Under this project, a comprehensive Lagoon Use Management Plan including Marine Spatial Plan and identification of blue economy opportunities in Pulicat are being prepared. The study has two phases;

(**i**) Preparation of a "Lagoon Use Management Plan" outlining a strategy to ensure sustainable resource use and ecological health of the lagoon by identifying priority issues, and specific management actions to improve the needs of a diverse set of users and stakeholders of the lagoon and
(**ii**) Development of pilot interventions in the Pulicat Lagoon including marine litter with specific focus on plastics investment formulation.

At present, the status of the I phase developing "Lagoon Use Management Plan preparation plan" has been implemented by NCSCM. The annual report of the I phase has been described in this report. The II phase will be conducted after completion of the I Phase of the project. The Annual Performance Report of "Restoration of Pulicat lagoon, monitoring lagoon ecosystem health and Lagoon Management Plan" has been described in the following chapters.

2. IMPORTANT TASKS OF "PREPARATION OF LAGOON USE MANAGEMENT PLAN"

To prepare the "Lagoon Use Management Plan" 10 major activities are being conducted the list of activities are given below;

i. Shoreline Management and Bar-mouth dynamics
ii. Conservation Management
iii. Livelihood Management
iv. Fisheries Management
v. Tourism Management
vi. Disaster Management
vii. Pollution Management
viii. Climate Change Adaptation and Mitigation
ix. Lagoon Use Management Plan including Marine Spatial Plan and
x. Blue Economy opportunities for Pulicat

xi. Creation of trans-boundary institutional structure and establishment of Pulicat Development Authority for Wetland Conservation.

Various project sub-activities achievements and performance in the first year of the Project (2021 – 2022) implementation period have been explained in the following chapters.

3. SHORELINE MANAGEMENT AND BAR-MOUTH DYNAMICS

Brackish water lagoons such as the Pulicat, are distinct and valuable environments in which continual mixing of freshwater and salt water generates a complex array of habitats. Environmental flows refer to the water regime of a river, wetland or coastal zone necessary to maintain the biophysical components, ecological processes and health of aquatic ecosystems and associated ecological goods and services. To develop a shoreline management plan and Bar mouth dynamics of the Pulicat lagoon coastal stretch, the following sub-activities have been conducted (i) Determination of hydrological and ecological flows (ii) Determination of long-term and short-term coastal erosion and accretion dynamics along the lagoon coast (iii) Determination of coastal processes, beach profile, and sediment movement to understand the bar mouth dynamics (iv) Development of a shoreline management plan for the coast of Pulicat lagoon for recommendation on the implementation of green coastal infrastructure (v) Development of conceptual green infrastructure mitigation measures (vi) Cost-benefit analysis of living shorelines.

3.1 Determination of hydrological and ecological flows

Confidence in the determination of the environmental water requirements of lagoons requires detailed modelling studies linking hydrology, hydrodynamics, water quality and biotic responses. To determine hydrological and ecological flows of Pulicat lagoon ECO Lab module of MIKE 21 is being used to evaluate the productivity, the dispersion pattern and the hydrodynamic flow conditions. MIKE21 is also being used to understand the bathymetry and tides, spectral waves, hydrodynamic conditions at required time scales.

ECO Lab module in Mike 21 is being used for water quality modelling which solves the set of differential equations describing the physical, chemical and biological interactions involved in the degradation of organic matter, resulting oxygen conditions and excess levels of nutrients in Pulicat waters. In this study, five water quality variables viz. BOD, DO, Ammonia, Nitrite, Nitrate and Phosphate flow have been studied. The integrated numerical model (HD+ECO Lab model) is being used to determine the integrating properties of the flow. In addition, it computed the basic processes occurring in the water column resulting from the interaction between the currents, and major biogeochemical variables. The numerical model to assess the Pulicat bar mouth dynamics and tidal current influence and its impacts on the lagoon's shall support fishing communities for sustainable management of this inlet.

3.2. Determination of long-term and short-term coastal erosion and accretion dynamics along the lagoon coast

Table – 1 : Pulicat Lagoon – Long Term (1990-2021)			
Shoreline Classification	**Length (km)**	**% of Erosion and Accretion**	**Cumulative % of Erosion and Accretion**
Length of Coastline	**93.43**		
High Erosion	6.01	6.04	24.01
Medium Erosion	8.10	8.14	
Low Erosion	9.77	9.83	
Stable Coast	28.43	34.63	34.63
High Accretion	1.74	1.75	41.36
Medium Accretion	5.50	5.53	
Low Accretion	33.88	34.07	

The results (Table – 1) obtained from Linear Regression Rate (LRR) from 1990-2021 reveals that for a length of about 99 km 26% of the coast is eroding, about 44% has accretion and 30% has stable coast. Around 6% of the coast has high erosion, 8% has medium erosion and 10% has low erosion. Overall, the coast is accreting and is eroding at the river mouth due to the dynamics of the bar mouth. High Erosion is observed at the northern portion of Kattupalli port due to decreased sediment supply in the northern direction.

Table – 2: Pulicat Lagoon – Short Term (2010-2021)			
Shoreline Classification	**Length (km)**	**% of Erosion and Accretion**	**Cumulative % of Erosion and Accretion**
Length of Coastline	**93.41**		
High Erosion	8.58	9.19	21.64
Medium Erosion	5.87	6.29	
Low Erosion	5.76	6.16	
Stable Coast	14.61	15.64	15.64
High Accretion	4.11	4.40	62.72
Medium Accretion	19.14	20.49	
Low Accretion	35.33	37.83	

The shoreline change results (Table – 2) obtained from Linear Regression Rates (LRR) from 2010-2021 show that for a length of 93 km, about 22% is eroding, 63% is accreting, and 16% has stable coast. There is a slight increase in high erosion in short term (9%), while there is a decrease in medium (6%) and low erosion (6%) as compared to the long term change shown in Figure 2. High erosion is significantly increased near the river mouth due to the dynamic coastal process at the bar mouth. In addition, obstruction of sediment supply is observed at the convex portion of northern side of pulicat lagoon coast. This has caused medium to high erosion from long term to short term shoreline change.

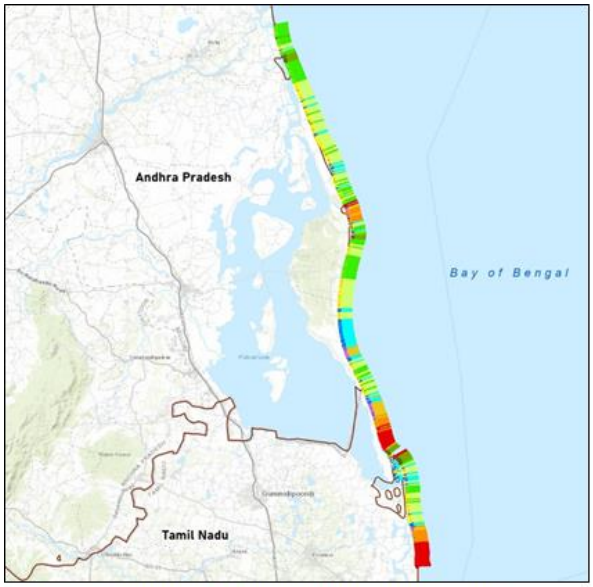

Figure 2a. Long term shoreline status of Pulicat Lagoon 1990-'21

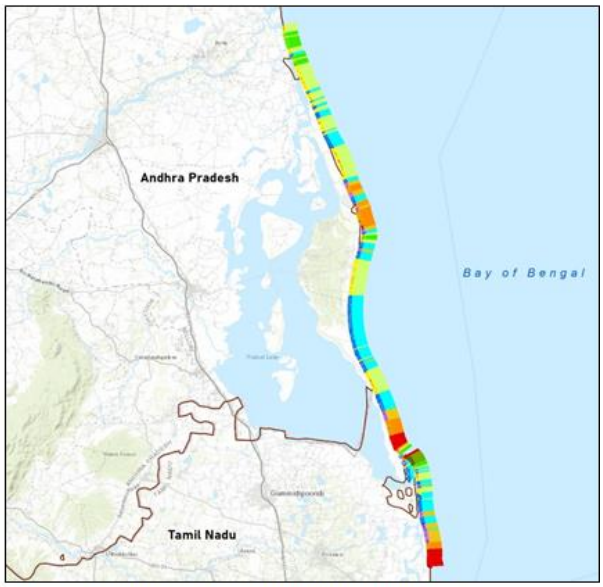

Figure 2b. Short term shoreline status of Pulicat Lagoon 2010-'21

3.3. Coastal processes, beach profile and sediment movement and bar mouth dynamics

The lagoon-ocean water exchange and seasonal position of the entrance channel (bar mouth dynamics) control the hydrodynamic characteristics of the lagoon. The evaporation rate in the lagoon, exceeds precipitation and runoff. The average depth of the lake is about 1.5m and the minimum and maximum depth varies between 0.5 to 6.0m respectively. Tidal variation within the lake is 0.6m. The comparative analysis of depth data also shows a depth reduction by 2.5m from past. The shrinking of the area is mostly in the north of the Pulicat lagoon. Sediments have been carried into the lagoons by tidal currents, river discharges, and winds. Sediment transport, river flow and oceanographic data such as waves, tide, currents, shoreline profiles, sediment characteristics, turbidity, lagoon bathymetry, river discharge, and bathymetry data are being collected to understand the coastal processes and bar mouth dynamics. Spot levels of beach profile is being measured in between HTL and LTL along the Pulicat lagoon using PPK GPS. Spot level data is used to measure at 2km stretch on either side of the accreting and eroding areas on a monthly basis for a period of 12 months. Where RTK GPS reception are obstructed, spot heights have been acquired using total stations. The survey transect lines are taken at 20 m intervals in zones of high accretion and erosion and at 50 m intervals at other locations. The collected spot level data have been processed with reference to mean sea level (MSL) and formatted in XYZ for the generation of the Digital Elevation Model (DEM).

A bathymetry survey will be undertaken within the lagoon and the adjacent coast up to 10m depth in the Bay of Bengal. DGPS positioning system and Single Beam Echo sounder system will be used for carrying out the bathymetry survey. The bathymetry survey will be carried out in the lagoon at 15m spacing and from the shoreline up to 10 m depth contour and at 300 m spacing in offshore. The raw water depth will be

processed with reference to MSL using observed tide data in survey area. In addition littoral environmental observations, measurement of waves, tides and currents, littoral currents, longshore currents, sediment budget exercise and numerical modelling to assess bar mouth dynamics are also being studied under this project period.

3.4. Development of a shoreline management plan for the coast of Pulicat lagoon for recommendation on the implementation of green coastal infrastructure

The coastal geomorphology and man-made structures such as breakwaters and groynes, intercepting the coastal processes (long-shore currents) largely influence the mouth of the Pulicat lake tidal inlet. Green coastal infrastructure such as living shoreline is one of the best approaches to managing shoreline changes and inlet dynamics. Living shorelines are a nature-based solution to shoreline erosion and tidal flooding. They are made of natural materials such as plants, sands, or rock unlike a concrete seawalls or other hard structures. Studies including models have been developed to identify suitable shore protection measures such as (i) Natural living shoreline (ii0 hybrid living shoreline (iii) Structural living shoreline.

3.5. Development of conceptual green infrastructure mitigation measures

Mathematical and computational models' outcomes are used to suggest suitable mitigation measures including soft methods such as beach nourishment, plantation (mangrove and other plantations), and creation of artificial reefs using biological organisms such as oysters at the identified high erosion hotspot locations. To recommend suitable green infrastructures and mitigation measures for Pulicat lagoon shoreline changes, site analysis are being carried out.

3.6. Cost-benefit analysis of Living Coast

The cost–benefit analysis (CBA) can help choose between a selected range of interventions. Here, the potential costs and benefits of an intervention are monetized (i.e. given a monetary value) for a specific time period and then compared to determine which of the options is most economic and effective. Primary and secondary data for the cost-benefit analysis is being carried out for the Pulicat lagoon project.

4. CONSERVATION MANAGEMENT

Under the Conservation Management of Pulicat lagoon the following activities are being carried out (i) Characterizing flora and fauna (including avifauna) and establishing conservation benchmarks by developing indicators (ii) Mapping of the Ecologically Sensitive Areas (ESA) and determination of highly stressed zones (iii) Restoration of lost/ degraded ecosystems in the lagoon as pilot (iv) Development of a robust lagoon conservation management plan.

4.1. Characterizing flora and fauna (including avifauna) and establishing conservation benchmarks by developing indicators

List of fauna and flora of the region has been prepared under characterising fauna and flora of Pulicat lagoon. A total of 180 species of plants comprising 129 dicotyledons belonging to 86 genera under 47 families and 51 monocotyledons belonging to 40 genera under 15 families have been reported. Distribution and diversity of flora and fauna of Pulicat lagoon are being carried out to develop conservation benchmarks. Biological Activity for bioprospecting study are also being conducted under this project. Under an antibacterial study, the broth microdilution method was used to evaluate the inhibitory activity against nine bacterial strains. Gram-negative bacteria (sensitive and *Escherichia coli* exerting a MIC_{50} of 150 µg/mL).

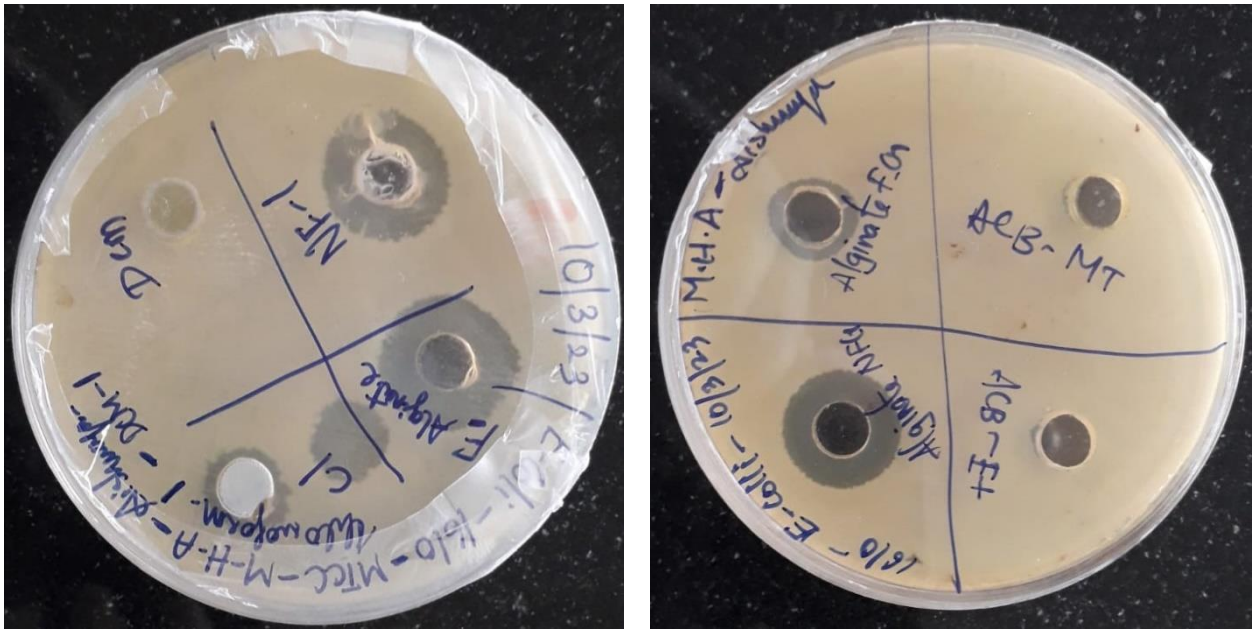

Figure 3: Antibacterial study

During the field survey, 22 flora samples were collected for the bioprospecting study of the Pulicat lagoon. In the bioprospecting analysis of the *Padina* sp (seaweed) 7 compounds were identified using methanolic extract in GC-MS data. The details of the compounds extracted and its bioprospecting application are given in Table 3.

Table – 3 : Bioprospecting of coastal Flora : Details of the compounds extracted and their bioprospecting application

Sl. No.	Retention Time (min)	Molecular Formula	Compound Name	Mol Wt.	Bioprospecting Application
1	25.89	$C_{15}H_{30}O_2$	12-methyl-, methyl ester	242.2245	Anticancer agent in leukemia cells Perfuming
2	26.48	$C_{14}H_{28}O_2$	Myristic Acid	228.2089	Therapeutic Uses; Cleansing; Fragrance in

					food, soaps, shaving creams
3	29.40	$C_{17}H_{34}O_2$	Hexadecanoic acid, methyl ester	270.4507	Perfuming; Animal feeds, Medical research
4	30.23	$C_{16}H_{32}O_2$	n-Hexadecanoic acid	256.4241	Food Additive; Enzyme Inhibitors; Cosmetic agent
5	32.14	$C_{19}H_{36}O_2$	13-Octadecenoic acid, methyl ester	296.2715	Cleansing agent;
6	32.81	$C_{18}H_{34}O_2$	Oleic Acid	282.2558	Flavouring Agents; Defoaming agent
7	47.01	$C_{29}H_{48}O$	Fucosterol	412.3705	Potential benefits of dietary seaweeds as protection against COVID-19

Figure 4: Existing ESA in Pulicat Lagoon (NCSCM, 2011)

4.2. Mapping of the Ecologically Sensitive Areas (ESA) and determination of highly stressed zones

Mapping of the ESA is essential to ascertain their extent, and their ecological and environmental health, in order to conserve these natural resources sustainably for the future. The ESAs of Pulicat lagoon areas have been studied results in the following ESAs; (i) Sand dune (ii) Salt marsh (iii) Seagrass beds (iv)Nesting ground of birds (v) Marine protected Area (wildlife sanctuaries, bird sanctuary) (vi) mangroves (small patches) (vii) Archeological site.

Ecological changes such as reduction in the natural wetland area, changes in freshwater quantity and quality, over-exploitation of lagoon resources, and disappearance of the indicator species etc., are being studied under this ESA sub-activity (Figure 4). Demarcation of the ESAs is being carried out using extensive field surveys, mapping, and analysis that shall support Conservation Management Plan for Pulicat lagoon.

4.3. Restoration of lost/ degraded ecosystems in the lagoon as a pilot

Under this project, Mangrove Seagrass, seaweed transplantation techniques, and transplantation sites have been identified. Pilot transplantation activities and preparation activities with community involvement are in progress.

4.4. Development of a robust lagoon conservation management plan

To prepare a lagoon conservation management plan, lagoon boundaries are being delineated, estimation of lagoon watershed areas, distribution and diversity of flora and fauna in the lagoon, ecotourism activities, lagoon culture, climate change, capacity building, and policy options are being studied to prepare conservation management plan of the Pulicat lagoon.

5. LIVELIHOOD MANAGEMENT PLAN

Livelihood is a means of making a living. It involves the capabilities, assets, and activities required for living. Livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets in the present and in the future, while not undermining the natural resource base (Chambers & Conway, 1992). To enhance the livelihoods of the coastal communities living in Pulicat lagoon the following sub activities have been proposed under this project (i) Strengthen access to livelihood resources among the fishing, farming and non-natural resource-dependent communities (ii) Minimize exposure to physical and social vulnerabilities due to climate and non-climate factors (iii) Identify and evaluate ecosystem goods and services for the lagoon's natural resources (iv) Improve access to health and education (v) Enhance gender balanced collectives and build their

decision making, access to market and institutional linkages and networking capacities to bring out strategic changes among marginalized men and women.

5.1. Strengthen access to livelihood resources among the fishing, farming, and non-natural resource-dependent communities

A sustainable livelihood framework has been used to identify and assess the assets or capitals of the coastal communities of Pulicat lagoon. Under this framework, livelihood capital has been classified as human capital, social capital, natural capital, physical capital, and financial capital. In this strengthening of livelihood development activity of Pulicat lagoon the following activities have been performed (1) Collection of data on demographic and socioeconomic profiles of representative village communities and access patterns to natural resources of Pulicat lake (ii) Assessing the livelihood assets' endowment pertaining to poor and wealthy sections of the community and evaluate the access to those assets using appropriate indicators (iii) Enumerate different livelihoods and determine the vulnerability context influencing those livelihoods using appropriate indices for individual and cumulative effects vulnerability index and coping strategies (iv) Analyzing the relevant policies and institutional processes influencing different livelihood strategies (v) Recommend locally relevant interventions /entry point activities to strengthen the access to livelihood-related natural resources to adopt enhanced/ additional/ diversified/ alternative livelihood options in an integrated manner.

5.2. Minimize exposure to physical and social vulnerabilities due to climate and non-climate factors

To minimize exposure to physical and social vulnerabilities due to climate and non-climate factors the following activities have been performed under this project; (i) Assessing the type, nature, and trend of physical and social vulnerabilities faced by the communities depending on Pulicat lake ecosystems for their livelihoods (ii) Evaluate how the livelihood assets are impacted by the physical and social vulnerabilities and how the access to them, livelihood strategies, and ultimately livelihood outcomes are hindered (iii) Identification of climatic and non-climatic factors that are influencing the well-being and productivity of ecosystems, effects of short term and long-term impacts on the fisheries, agriculture and other non-farm livelihoods (iv) Exploration of climate-smart mitigation and adaptive interventions like climate-smart agriculture, livestock rearing, aquaculture and other livelihood options.

5.3. Identify and evaluate ecosystem goods and services for the lagoon's natural resources

To Identify and evaluate ecosystem goods and services for the lagoon's natural resources the following activities have been performed; (i) Identification and quantification of equivalent economic values of various goods and services provided

by Pulicat lagoon ecosystems (ii) Capacity building for stakeholder's equivalent economic values of the goods and services of Pulicat lagoon to conserve the natural environment.

5.4. Improve access to health and education

To improve health education of the Pulicat lagoon coastal communities the following activities have been performed under this project; (i) Assessing the present statuses of education and healthcare of women who are dependent on natural resources of Pulicat lake (ii) Enumerating the infrastructure and facilities available for education and health care in different villages connected to Pulicat lake and assess the requirement for providing adequate education and health care to women (iii) Suggest ways to overcome the social constraints for the girl children in accessing good education and health care and possible interventions.

5.5. Enhance gender-balanced collectives and build their decision-making, access to market and institutional linkages, and networking capacities to bring out strategic changes among marginalized men and women

To enhance gender mainstreaming of the Pulicat to build their decision-making, access to market and institutional linkages, and networking capacities the following activities have been performed; (i) Identification and evaluation of current socio-economic and livelihood statuses of marginalized men and women in coastal villages around Pulicat lake (ii) Enumerate the types of collectives like Cooperatives, federations, SHGs, producer organizations, joint business groups with details of their resource use and trade and economic benefits (iii) Assess the requirements for capacity building, strengthening of community-based institutional set-up and linkages to supportive essentials like credit facilities, marketing channels, and networking for connectivity

6. FISHERIES MANAGEMENT

The recent trends in the fishery of the lagoon show that the catch has reduced by 30 to 40 % in over a decade and a half. In the year 2016, it was 2,000 tonnes against the trend to catch more than 3,000 tonnes per year in 2005 and fish wealth started depleting because of the gradual closure of the bar mouth, changes in water levels, and salinity of the water due to siltation. To enhance and sustainable production of fishery resources the following activities have been performed under this project; (i) Developing a fisheries (shell and fin fish) management plan (ii) Zoning of IMTA sites based on Marine Spatial Plan (MSP) (iii) Sustainable Fishery Management Plan.

6.1. Developing a fisheries (shell and fin fish) management plan

The Fishery Management Plan is being prepared considering the following analysis and suggestions; (i) Methods of enhancing fishery resources and harvests through

scientific interventions (ii) Enhancing post-harvest resource management techniques, practices and supply, and value chain management (iii) Analysis of increasing mariculture/ diversified fishery activities in Pulicat lagoon (iv) Analysis to expand the market for Pulicat fishery (v) Identification of IMTA (Integrated Multi Trophic Aquaculture) sites.

6.2. Zoning of IMTA sites based on Marine Spatial Plan

For the zoning of IMTA (Integrated Multi Trophic Aquaculture) sites based on the Marine Spatial Plan (MSP), suitable sites have been analyzed within the Pulicat lagoon area. The IMTA sites are being identified to create innovation, economic incentives, and long-term planning for promoting bio-mitigative solutions in the field of aquaculture. A conceptual diagram of IMTA has been given in Figure 5.

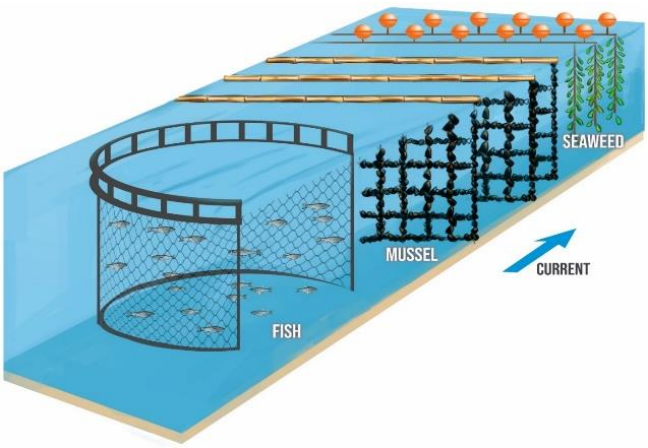

Figure 5: Integrated Multi-Trophic Aquaculture (IMTA)

6.3. Sustainable Fishery Management Plan

The increased intensity and diversity of human activities occurring in and around the Pulicat lagoon has resulted in a depletion in fishery resources, both within the lagoon and in the offshore waters essentially requiring Sustainable Fishery Management Plan. The Fisheries Development and Management Plan (FDMP) for the Pulicat Lagoon is being prepared to resolve the fisheries, environmental and social issues associated with the Pulicat Lagoon to promote sustainable fisheries. The FDMP is adopting ecosystem-based management of fisheries with a strong element of species conservation and sustainable livelihood of the fishers.

7. TOURISM MANAGEMENT

Pulicat lagoon attracts thousands of tourists every year. Shallow water boating and bird watching are important tourist attractions. In addition to the natural resource of the tourist attraction, heritage sites including the Dutch symmetry and Hindu temples are popular tourist attractions of Pulicat lagoon. Considering the tourism resources and promoting eco-tourism of Pulicat lagoon the following activities have been performed under this project (i) Assess existing tourism status and diversification of tourist areas (ii) Determine the physical, social, ecological, and environmental carrying capacities and (iii) Development of Tourism management plan.

7.1. Assess existing tourism status and diversification of tourist areas

Historically, the Pulicat lagoon was a port and trading center. Gold, pearls, precious metals, and other commodities were exported from here. The rich heritage and glory of the region remain largely untapped. This study found suitable tourism opportunities existing and to be promoted in the Pulicat lagoon. Assessment of tourism potential areas has been conducted in Pulicat lagoon during this period. Prominent tourist sites have been given in Figure 6.

Figure 6: Important tourism areas in Pulicat Lagoon (a) Birds in Pullicat lake and (b) the Dutch cemetery

7.2. Determine the physical, social, ecological, and environmental carrying capacities

To determine the carrying capacities of the lagoon the following activities have been conducted; Assessing the optimum boating density by weightage score analysis; calculation of optimum boat density; ecological carrying capacity and environmental carrying capacity; economic carrying capacity; social carrying capacity and; integrated carrying capacity.

Based on the carrying capacity analysis this project is preparing recommendations and suggesting suitable interventions that would improve the eco-tourism potential and the environmental quality of the Pulicat lagoon. The following are the initially identified recommendation for eco-tourism development; (i) signages for locations demonstrations (ii) tourism information center (iii) eco-friendly cottages for accommodation (iv) Plying of houseboats (v) facilities, locations, and construction of bird watching towers (vi) boating and natural trail areas (vii) elevated walkway with bird watching facilities etc.

7.3. Development of Tourism management plan

Based on the assessment of tourism potentials, carrying capacity assessment identified suitable interventions for eco-tourism promotion in Pulicat lagoon, a tourism management plan is being prepared under this project. The key inputs to a Tourism

Management Plan are: (i) resource assessment, including physical and cultural attributes as well as the nature, quality, and performance of existing tourism facilities (ii) footfall assessment, considering current tourists coming to the area, ongoing trends and future opportunities, and planned eco-tourism activities (iii) environment, social and other constraints that may determine carrying capacity (iv) structures for effective planning and coordination of tourism in the lagoon.

8. DISASTER MANAGEMENT

A disaster management plan for the Pulicat lagoon area is being prepared since the area is prone to natural hazards. The Disaster Management Plan is using HRVCA Framework (Hazard, Risk, Vulnerability and Capacity Assessment) with local focus and disaster risk resilience needs of the coastal communities of Pulicat lagoon area. Under this sub-activity of Disaster Management, the following tasks have been undertaken (i) Demarcation of composite hazard lines including flood and erosion lines (ii) Determine vulnerability, and disaster risk categories (iii) Assess risk zones and the population at risk (iv) Development of Disaster Management Plan.

8.1. Demarcation of composite hazard lines including flood and erosion lines

The hazard line demarcated by MoEFCC through the Survey of India (SoI) considering tides, waves, sea level rise, and shoreline changes has been used to prepare a disaster management plan for Pulicat lagoon. The hazard line delineates land areas that are at risk from coastal erosion (erosion line) and coastal flooding (flood line). The “Composite Hazard Line” would show the most landward of the two – the flood and erosion lines (Figure 7). The primary purpose of the hazard line is to identify hazard zones along the coastline that reflects a potential hazard and risk to people and their property.

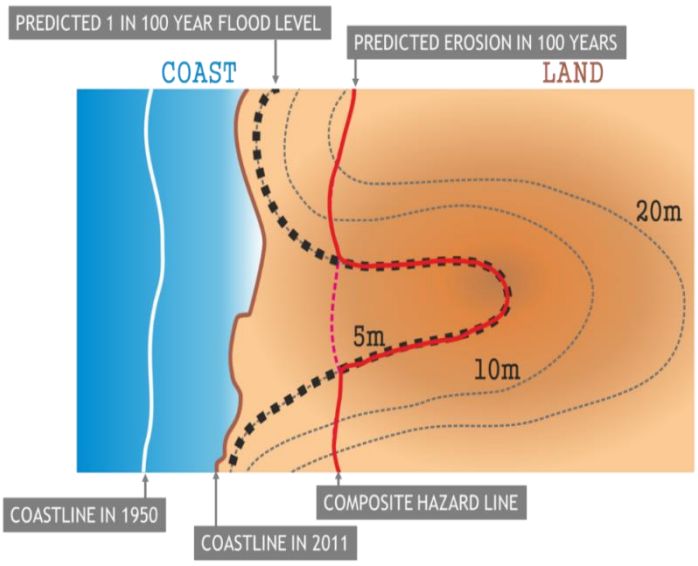

Figure 7: Concept of Hazard Line for the coast of India

8.2. Determine vulnerability, and disaster risk categories

This project determines the vulnerability and disaster risks of the villagers living in and around the Pulicat lagoon to make them prepared to mitigate the risks. Based on the land elevation of the Pulicat area, risk zones have been classified into 4 categories such as low, moderate, high, and very high-risk zones to expose the vulnerabilities

due to natural coastal hazards of the area to take necessary mitigation measures of the Government and General Public.

8.3. Determine vulnerability, and disaster risk categories

In addition, the project assesses the risk zones and provides recommendations and suggestions to reduce the risks. The project identifies the villages and the population falling in various risk zones and their socio-economic characteristics, and existing infrastructures to mitigate the coastal hazards. Analysis of existing activities related to disaster management as well as those implemented to improve the resilience of the local population are being prepared using capacity assessment.

8.4. Development of Disaster Management Plan

A disaster management plan is also being prepared using the existing infrastructures and local-level disaster management plans synchronizing with the hazard lines.

9. POLLUTION MANAGEMENT

Physical, chemical and biogeochemical measurements will be undertaken periodically (monthly or seasonal) to assess the physical, environmental and ecological health status of the lagoon. To monitor the water quality and pollution impacts on the sustainable function of the Pulicat lagoon the following activities have been performed under this sub-activity of the Pulicat project; (i) Assessment of water, sediment, and biotic health of the lagoon (ii) Determining the impacts of land-based sources of pollution and management of wastewater entering the lagoon (iii) Development of a lagoon ecosystem health report card (iv) Development of a source-to-sea framework for marine litter and plastics management and investment formulation.

9.1. Assessment of water, sediment and biotic health of the lagoon

To assess the water quality fixed locations (GPS), representing the various sectors of the lagoon have been identified to sample biogeochemical variables of the Pulicat lagoon. Seasonally, water samples have been collected for 24 h, completing a full diurnal cycle from two separate locations with diverse ecological features with a sampling frequency of 2 hours to assess the biogeochemical parameters of the Pulicat lagoon.

9.2. Determining the impacts of land-based sources of pollution and management of wastewater entering the lagoon

The general environmental, social, and economic impacts of Land-Based Sources of Pollution [LBSP], including sewage, urban wastes, industrial discharge, agricultural runoff, and a host of other sources influencing the water quality of the Pulicat environment have been identified. These pollutants lead to higher rates of biological

oxygen demand, nitrogen, phosphates, and total suspended solids in the lagoon and the near coastal waters. Degraded coastal habitats and fishing grounds, reductions of the pleasures and economic benefits of coastal tourism, depleted fisheries, loss of species and human diseases, and loss of life are among those impacts. Planning of interventions at the entry point (Deployment of Trash Boom/ robotic debris collection tools); planning of interventions at wastewater sources (sewage and effluent treatment); planning of management of solid waste in surrounding villages are in progress.

9.3. Development of a lagoon ecosystem health report card

Pulicat lagoon Ecosystem Health Report Card (EHRC) has been prepared to demonstrate the health status using long-term physicochemical observations. The environmental health report card is a transformative assessment and communication product that compares environmental data to scientific or management threshold and is delivered to a wide audience on a regular basis. Scientifically robust, quality-assured data generated by Eco-Health provides a complete picture of the current state of our coastal systems. The EHRC will help local Governments, and Policymakers.

9.4. Development of a source-to-sea framework for marine litter and plastics management and investment formulation

Marine debris also known as marine litter consists of items that have been made or used by people and deliberately discarded into the sea or rivers or on beaches; brought indirectly to the sea with rivers, sewage, stormwater, or winds; or accidentally lost, including material lost at sea in bad weather (fishing gear, cargo (UNEP, 2005). Plastics are perhaps the biggest component in marine debris today and include various forms of plastic that are highly persistent and often contain toxic chemicals or acquire from the surrounding seawater. The effects of plastics are extensive and wide-ranging, impacting human health, economics, tourism, and beach aesthetics. Microplastics and marine litter in the coastal and marine environment causes serious damage to marine life, and fisheries, death of marine animals through entanglement and ingestion of plastic debris, leaching of toxic chemicals and their introduction into the food chain. In the sub-activity on "Development of a source-to-sea framework for marine litter and plastics management and investment formulation the following activities have been initiated in Pulicat lagoon (1) Quantification of marine debris (ii)Analysis of microplastics in surface water (iii)Analysis of microplastics in coastal sediments (iv) Pathways and Distribution of microplastics and marine litter using modeling studies (v)Understand trophic interactions of microplastics in commercially important fishes and other organisms (vi)Identify common plastic polymers present and quantify adsorbed persistent organic pollutants (POPs) (mainly PAHs, PCBs and DDTs) and trace metal elements in microplastic particles. (vii) Design source-to-sea framework for marine litter and plastics management.

10. CLIMATE CHANGE ADAPTATION AND MITIGATION

The Climate Change Adaptation and Mitigation study has the following activities; (i) Quantification of greenhouse gas (CO_2, CH_4 and N_2O) emissions from the lagoon various environmental matrices and ecosystem components (ii) Determine the N-source-sink dynamics and develop a Nitrogen budget for the lagoon (iii) Development of sea level rise scenarios using Regional Concentration Pathways (RCP) scenarios.

10.1 Quantification of greenhouse gas

Measurements of CO_2 and CH_4 fluxes between the biosphere and atmosphere are vital to understanding the vegetation feedback to the climate system. Under this study, quantification of GHG fluxes from the coastal wetlands (biosphere-atmosphere, water–air, sediment-air fluxes) in varying spatial and temporal conditions are being carried out at Pulicat lagoon.

Indirect Flus of CO_2 CH_4 have been measured using a modified headspace equilibrium technique (Cole et al. 1994) with a gas chromatograph connected to a methanizer. However for Direct Flux of the CO_2 and CH_4 have been measured using floating chambers. To estimate the sediment-air flux of greenhouse gases direct measurement of trace gas fluxes using the Static Chamber Method is being applied. To estimate Greenhouse gas exchange from the biosphere, real-time measurements of GHG flux tow have been used. For below canopy gas exchange measurements, atmospheric air samples are being collected using in sterilized vacutainers.

10.2. Determine the N-source-sink dynamics

To measure watershed Nitrogen mass balances and stable isotopes approach is being used to investigate the sources, fate, and transport of nonpoint N in the Pulicat lagoon. During this period, literature surveys were carried out for the nitrogen dynamics and greenhouse gas emissions from Pulicat Lake.

10.3. Development of sea level rise scenarios using RCP scenarios

Sea-level rise is expected to exacerbate inundation, storm surge, erosion, and other coastal hazards, thus threatening vital infrastructure, settlements, and facilities that support the livelihood of island communities. Sea-level rise is expected to exacerbate inundation, storm surge, erosion, and other coastal hazards, thus threatening vital infrastructure, settlements, and facilities that support the livelihood of island communities.

IPCC (2014)44 predicted that the global mean sea level will rise between 0.26 to 0.82 m during the 21st century based on different Representative Concentration Pathway scenarios (RCPs). For simplicity and scarcity of sea level rise data in and around the Pulicat lagoon, IPCC (2014) predicted global sea level rise scenarios is being used to

estimate impacts of SLR around the Pulicat coastal stretch based on RCP2.6, RCP4.5, and RCP8.5 scenarios.

11. LAGOON USE MANAGEMENT PLAN

Under this sub-component, the following activities will be formed (i) Preparation of the Lagoon Use Management Plan (ii) Creation of transboundary institutional structure and establishment of Pulicat Development Authority for Wetland Conservation.

a) Development of a comprehensive Lagoon Use Management Plan including a Marine Spatial Plan and Blue Economy opportunities for Pulicat

The lagoon use management plan is to be developed in order to adapt to the declining ecosystem health. The lagoon use management plan outline strategy for ensuring sustainable use of Pulicat lagoon and improved water quality. Accordingly, zoning plans for various activities have been prepared which includes Marine Spatial Planning. The following subtasks would form the basis for Lagoon Use Management Plan. To develop the Lagoon Use Management Plan, the watershed area, and land areas of the Pulicat lagoon have been measured.

Land use around the Pulicat lagoon and its positive and negative impacts on the lagoon ecosystems have been studied. Various lagoon uses, issues and management options have been studied under this project to develop participatory co-management of the Pulicat lagoon resources. Zonation maps will be prepared in the final stage after the completion of all activities of the project. As a part of the Lagoon Use Management Plan preparation, an education plan to create awareness, participation in developmental activities, and promote investments in Pulicat lagoon are in progress.

b) Creation of transboundary institutional structure and establishment of Pulicat Development Authority for Wetland Conservation

The development of a transboundary institutional structure for the Pulicat lagoon covering the bordering States of Andhra Pradesh and Tamil Nadu. The transboundary organisational provides (i) Organisational plans for the co-management of States, Stakeholders and communities (ii) an Institutional mechanism to organise co-management of the Pulicat Lake developed (iii) Implementation of the “Lagoon Use Management Plan” will be initiated.

12. A GEOSPATIAL DATABASE OF PULICAT LAGOON

The geospatial database saves and disseminates the data collected from the Pulicat lagoon project. The database that contains the geographic information relevant to a specific spatial analysis or application. The geodatabase integrates the GIS application with the data storage of attribute layers, sharing a RDBMS (by data

collection from NCSCM divisions and application & storage for geospatial information system).

13. CONCLUSION

Internal periodic evaluation of the progress has been carried out for the year 2021-22. The project is developing a long-term database on physical, chemical, biological, and socio-economic parameters surveyed at Pulicat lagoon. This shall provide strategies for enhancing ecosystem health through restoration, conservation, and pollution abatement. In addition the project support for developing an integrated management plan including marine spatial planning for sustainable livelihood. The framework (roadmap) for Pulicat Lagoon Authority is being prepared and it is expected the authority will be formulated during the final stage of the I Phase of this project.

References

Chambers, R. and Conway, G., 1992. Sustainable Rural Livelihoods: Practical Concepts for the 21st Century, IDS Discussion Paper 296, Brighton: IDS. https://opendocs.ids.ac.uk/opendocs/handle/20.500.12413/775

IV. Holistic Conservation and Integrated Management Plan of Wetlands

1. Introduction

Wetlands and related ecosystems are playing an important role in ensuring supply of food, water and providing climate security. They are amongst the most productive ecosystems on Earth providing several key ecosystem services. Due to their distinct geographical distribution, water regimes, water quality, biodiversity (flora and fauna) and sediment characteristics they support diverse and unique habitats. At the same time, wetlands are extremely fragile, subjected to severe human alterations- hence becoming ecologically sensitive systems. Globally, the areal extent of wetland ecosystems ranges from 917 million hectares (m ha) (Lehner and Döll, 2004) to more than 1275 m ha (Finlayson and Spiers, 1999) with an estimated economic value of about US$15 trillion a year (MEA, 2005). As per the Convention on Wetlands of International Importance (Ramsar Convention), wetlands are defined as “areas of permanent or periodic/ intermittent inundation, whether natural or artificial, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed 6m”.

India, owing to its diverse topography and climate has a wide range of natural and human-made inland and coastal wetlands. As per the 2011 National Wetland Atlas, India has an area of 15.26 million hectares (ha) under wetlands, which corresponds to 4.6% of the land area. Despite their wide-ranging ecosystem services and biodiversity values, wetlands continue to be degraded. Wetlands are under severe threat from a range of developmental pressures due to urbanization, agriculture intensification, and industrialization. As of 21 February 2020, there were 2,388 Wetlands of International Importance (Ramsar Sites) together covering 253,870,023 hectares (ha). In 1982, The Government of India ratified the Ramsar Convention, committing to the wise use of all wetlands in India and maintain their ecological character. The Ministry has as of December 2020, there are 42 Ramsar Sites in India (Figure 1), forming an integral component of the global network of over 2388 Ramsar Sites.

The project on “Holistic Conservation and Integrated Management of Wetlands” focuses on inventorying, creating a national database, advanced research capacity development on the wetlands of India through addressing specific research needs and knowledge gaps that constrain the application of integrated approaches for conservation and wise use of the wetlands.

It would serve as a knowledge hub and enable exchange between wetland users, managers, researchers, policy-makers and practitioners; assisting the national and State/ UT Governments in the design and implementation of policy and regulatory frameworks, management planning, monitoring and targeted research specifically related to wetlands.

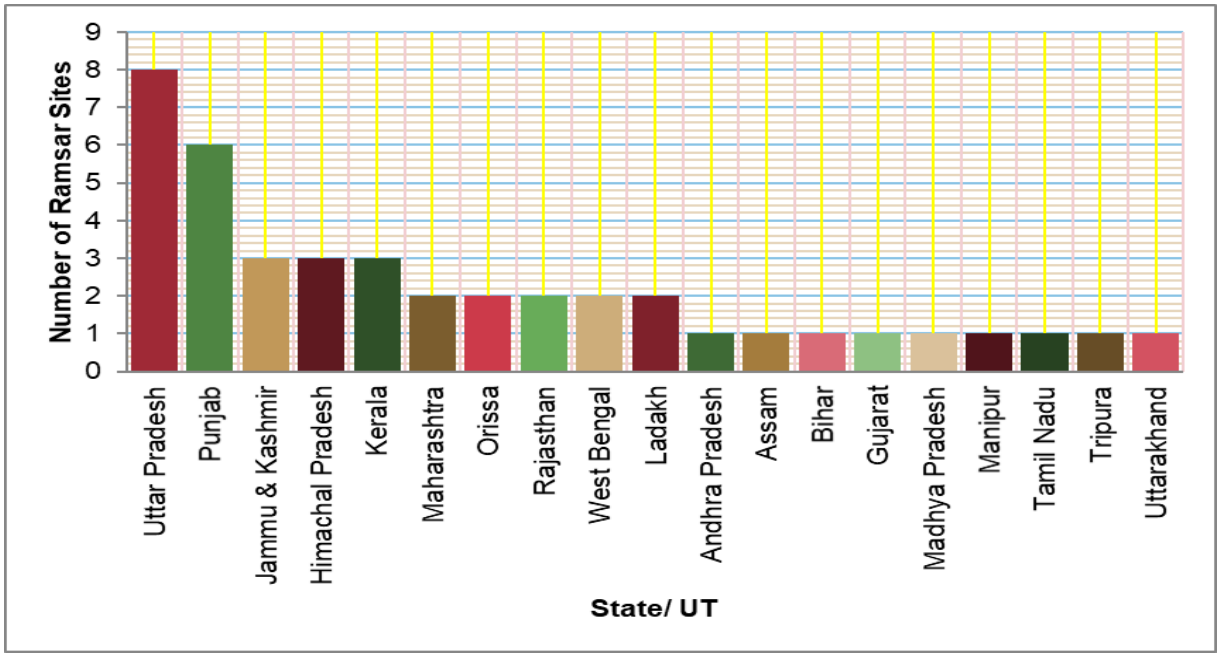

Figure 1**:** State-wise distribution of Ramsar Sites

2. Objectives

The key objectives of the project include the following:

1. Create a national database on Indian wetlands including transboundary for information needs related to wetland management
2. Undertake cutting-edge research and development on key wetland challenges for management and maintaining wetland ecosystem health
3. Incorporate climate resilience as a core concept in the design and implementation of integrated management plans for wetlands
4. Evaluate and monitor the implementation of interventions for conservation, restoration, integrated management and wise use of wetlands
5. Develop modules and impart inter- and multi- disciplinary customized courses on various aspects of wetland management to enhance wetland managerial capacity
6. Advice the government and other stakeholders on policy and scientific matters related to wetlands.
7. Create a Platform for Information Exchange between various wetland-stakeholders
8. Network with wetland managers within the South Asia region to promote South-South exchange of best practices and lessons learnt in wetland management (long term)
9. Promote traditional Knowledge and local capacity in management and wise use of wetlands

3. Study Sites

NCSCM has an existing plan of action to carry out studies in relation to development and proposal of Pulicat Lagoon as a Ramsar Site. Hence, Pullicat is being used as a demonstration site for wetland restoration where the activities pertaining to restoration will be showcased over time to show both the local community and the world-at-large. An interpretation centre is also proposed to be developed at the Pulicat lagoon. Other sites for field survey include Vedanthangal Bird Sanctuary, Karikili Bird Sanctuary, Vaduvur Bird Sanctuary, Udayamarthandapuram Bird Sanctuary, Koonthangulam Bird Sanctuary, Chitrangudi Bird Sanctuary, Bhitarkanika, Mahanadi, Gulf of Mannar.A major component of the study includes management of wetland web portal, database and inventory by NCSCM. NCSCM is handling and maintaining a national database on Indian wetlands including transboundary for information needs related to wetland management as per the mandate of the project.

4. Methods

Overall Approach: The Project's thrust area (Figure 2) is broadly categorized under seven componentsbased on the Mission given above for the wise use of wetlands.

(i) Research and Development,

(ii) Training and

(iii) Outreach

Figure 2: Components of the proposed project on holistic conservation and integratedmanagement of wetlands

Key activities and methods as planned under the project is detailed below in the Table

Table 1: Key Activities and Methods

S. No	Key Activity	Methods/Approach
1	Create a comprehensive wetland database and prepare an inventory to promote the understanding, conservation and restoration of wetlands	Mapping of major and minor wetlands using GIS and Remote Sensing
		Integration of various layer including socio-economic dataset
		Using geospatial tools, mapping and monitoring of wetlands at multiple spatial and temporal scales
2	Undertake research on wetland protection that intertwines environmental, ecological and socio-economic aspects and governance concerns	Development of inventory, and mapping of (a) changes in wetland extent, (b) changes in land use and land cover, (c) addressing vulnerability, and (d) development of a Digital Directory of Important Wetlands of India (DIWI)
		Assessment of Wetlands processes, functions, stresses and health including wetland health report cards
		Assessment of Wetlands ecological and economic values
		Application of S.M.A.R.T. indicators as management tools to set goals and objectives for wise use of wetlands
3	Incorporate climate resilience as a core concept in the design and implementation of integrated management plans for wetlands	Assessment of Wetlands functions with respect to natural hazards and climate resilience in particular with Carbon cycle (including blue carbon sequestration) , flooding and flood control, Nutrient Cycles, Biodiversity hotspots, Fisheries
4	Holistic Conservation, Restoration and Integrated Management	Development of the criteria for conserving, restoring and adaptively managing degraded wetlands through site-specific interventions and to act in re-establishing wetland ecosystem functions and services
5	Evaluate and monitor the implementation of interventions for conservation, restoration, integrated management and wise use of wetlands	Development of strategy blueprint to monitor the implementation of interventions for conservation, restoration, integrated management and wise use of wetlands
		Prepare sets of wetland assessments to determine effectiveness of restoration actions, towards integrated wetland management)
		Development of Wetlands State of Wetlands Reports

S. No	Key Activity	Methods/Approach
6	Capacity Building through Training and Skill Development	Provide training, enhance knowledge, and develop adaptive capacity towards wise use of wetlands
		Disseminate methods for inventorying wetlands as well as monitoring their health, including assessment of wetland features and diagnosis of threats to the wetland ecosystems,
		Develop capacities to use an ecosystem approach for restoration of wetlands and its catchment
		Build capacity for integration of wetland conservation with developmental planning to mitigate development threats as well as threats due to climate change
		Network to share successful experiences and best (and worst) management practices for wetland management
		Communication, education and public participation in wetland management
7	Provide Knowledge and Advisory Support	Address the knowledge gaps to support decision-making for State/ UT Wetland Authorities- on wetlands conservation, management and governance
		Provide advisory support to the Ministry, State governments and Union Territories, State Wetland Authorities, Civil Society and private sector on various aspects of Wetland conservation, restoration, integrated management and wise use
8	Partnership and Networking	Increase the knowledge base, effectiveness of networking on wetland conservation and management
		Strengthening of existing state, national and transboundary networks for sharing and disseminating information and good practices on wetland conservation
9	Community Interfacing and Outreach	Preparation of Information, Education and Communication (IEC) materials
		Interpretation centers, as an educational tool by providing multimedia exposition on the various aspects of wetlands
		Identification of skill requirements for upskilling and if necessary reskilling community members
		Develop, Pulicat lagoon as a demonstration site for wetland restoration

5. Key results

5.1. Activities completed so far on the Wetland Portal

— The wetland portal was hosted in NCSCM webserver in November 2021, with the configuration.

- Operating System: Windows 2019
- Application Server: Apache server
- Framework: PHP 7.4
- Database: Mariadb.10.4
- Content Management System: WordPress 5.7

- Wetlands portal handed over to NCSCM for future updates and maintenance with knowledge sharing done by Microware and GIZ.
- Regular backup of database on daily basis with 4 hours' time interval and portal clone every month, and code backup as and when updates have taken place.
- A wetland portal training program was conducted by GIZ on 20th December 2021 to provide a brief overview of wetland portal and to upload brief documents on the portal. Training was given to State Wetland Authorities (Tamil Nadu, Himachal Pradesh, Odisha) and NCSCM
- Regular interaction with GIZ and Microware for periodical updates of the wetland portal.
- Documentary prepared on Ramsar Wetlands for World Wetlands Day 2022.
- Migration of portal and database from windows to Linux environment to enhance security and performance.
- Configuration of redundancy server for Fault tolerance and High Availability to avoid down time of web portal

Ongoing

- Preparation of land use land cover map for Ramsar sites (based on the GIS boundary available in the https://rsis.Ramsar.org/) up to 1 km buffer
- Creation of Map Services and development of GIS based Web Map application to show the thematic layers along with the features and integration with existing portal – for the Digital Directory of important wetlands of India
- Enhancements of UI/UX design for the wetland portal for brief documents is ongoing

5.2. Status of progress:

Table 2 provides task-wise details of work undertaken on the Annual Action Plan (2022-23) and the proposed activities for 2023-24.

Table 2: Status of progress made on the annual action plan (2022-2023)

No.	Activities	Progress (as on 31 Dec 2022)
I	**THRUST AREA 1: RESEARCH AND DEVELOPMENT**	
1	**Web portal, database and Inventory**	
1.1	Mapping of boundaries of major and minor wetlands using GIS and Remote Sensing	Mapping of Indian wetlands has been done by SAC, 2011 based on 1:50,000 scale. Based on the SAC maps, classification of major and minor wetlands (area-based) hasbeen completed for entire India
		Transboundary wetlands have been identified in 5 states and 1 UT 1. Telangana 2. Andhra Pradesh 3. Tamil Nadu 4. Kerala 5. Karnataka 6. Puducherry UT
1.1.1	Hosting the atlas data on the Wetlands Portal	National Wetlands Decadal Change Atlas has been hosted in PDF format on Indian wetland portal, which was provided by MoEF&CC
1.1.2	Improvising spatial data on coastal wetlands using existing data available with NCSCM	Coastal wetland maps available on 1:25,000 scale for theentire mainland coast of India
1.2	Using geospatial tools for monitoring of wetlands at multiple spatial and temporal scales	Satellite image inventory of wetlands for various spatial temporal scales is ongoing and mapping of thematic layers for a few wetlands is in progress
1.3	Web-portal, Database, Mapping – inventory and geo database development	Integration of geometric tools on the existing map component (like base map changing and mashup of spatiallayers) have been completed
		Conversion of wetland statistics from static to dynamicgraphs is completed
		Integration of Wetland Mitra login authentication usingmobile number OTP has been established

No.	Activities	Progress (as on 31 Dec 2022)
		Selecting base map (such as Imagery, Street, hybrid) and **highlighting particular category of wetlands** (such as Ramsar Site, Significance Wetlands and other wetlands) has been completed — Minutes has been circulated, seeking approval fromportal in-charge of Wetland Division, MoEF&CC
1.3.1	Updating information and maintenance of the Wetland portal	Updating information and maintenance of the Wetland portalis completed and it is an ongoing activity till the portal is hosted in NCSCM server
		— UI/UX designing of Brief Document for adding and updating data — Designing of Brief Document Report for end users — Performance optimization of Wetland Portal Rectification of Bugs based on the feedback from the SWAs
1.3.2	Regular backup of database on daily basis with 4 hours' time interval and portal clone every month, and code backup as and when updates have taken place	For the current year the portal and its database were backed up and it is an ongoing activity till the portal is hosted in NCSCM server
1.3.3	Periodic maintenance of Wetland portal server, enhancement of server security and performance	Maintenance, enhancement of server security and performance of Wetland portal server is upscaled and it is an ongoing activity till the portal is hosted in NCSCM server
		SSL certificate for the portal has been renewed Domain name of the portal has been renewed STQC certificate initiation is on progress Monitoring visitors log has been completed
1.4	Development of Digital Directory of important wetlands of India (DIWI) including all wetlands of National Priority / reference 100 wetlands Phase II	Development of Schema designing of various parameters of wetlands and its relational linkages to various tables are in progress.
2	**CUTTING-EDGE RESEARCH (Ramsar or Prioritised Transboundary wetlands)**	Integration of various thematic layers, spatial querying and reporting system, etc. for development of Development of Digital Dashboard (DIWI) is under progress

No.	Activities	Progress (as on 31 Dec 2022)
2.1	Mapping of various Thematic layers (MAPPING [1:10,000 to 1:4000]) Integration of various layers including socio-economic dataset, LULC layers, water resources, soil, land degradation, linear infrastructure	As a Pilot scale, LULC, Linear infrastructure, and hydrology regime have been carried out for **Pulicat Lake** (Transboundary Wetland, Andhra Pradesh & Tamil Nadu State) is completed
2.2	Catchment and zone of influence delineation	River Catchment and zone of influence has been completedfor one transboundary wetland – **Pulicat Lake**
2.2.1	Changes in wetland extent	Satellite image inventory has been carried out for a various time periods to identify the changes in the extent of wetlands
2.2.2	Changes in land use and land cover	
2.3	Addressing Vulnerability	— High resolution erosion mapping has been completedfor the coasts of Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, and Odisha
		— Hazard line mapping for the coast of India iscompleted
	WETLAND ECOSYSTEM HEALTH (Ramsar or Prioritised Transboundary wetlands)	
2.5	Wetlands processes, functions, stresses and health	
2.5.1	Wetland Processes (e.g., hydrological regimes, biological productivity, etc.)	Detailed wetland processes, functions and stresses have been studied for selected wetlands (Pulicat Lagoon, Bhitarkanika Conservation Area)
2.5.2	Wetland Functions (e.g., maintaining water quality, sediment and nutrient retentions, fish spawning, prevent flooding, carbon storage, etc.)	
2.5.3	Wetland Stresses (e.g., wetland conversion for other uses, pollution, loss of biodiversity, etc.)	
2.5.4	Wetland ecosystem health (e.g., development of indicator-based indices, report cards, etc.)	Water Quality Assessment have been completed in selected important wetlands (Vedanthangal Bird Sanctuary, Karikili Bird Sanctuary, Vaduvur Bird Sanctuary, Udayamarthandapuram Bird Sanctuary, Koonthangulam Bird Sanctuary, Chitrangudi Bird Sanctuary, Bhitarkanika Conservation Area, Pulicat Lagoon). Based on that
		Ecosystem-based wetland health report cards have been prepared

No.	Activities	Progress (as on 31 Dec 2022)
2.6	State-of-Wetlands Report	
	WETLAND GOODS AND SERVICES (Ramsar or Prioritised Transboundary wetlands)	
2.7	Wetlands Ecological and Economic Values	Ecological and economic evaluation, detailed ecosystem goods and services assessment of selected wetlands have been completed (Pulicat lagoon, Bhitarkanika, Coringa)
2.7.1	Wetland Ecosystem goods and services	
2.7.2	Socio-ecological systems	
2.7.3	Cultural values	
	WETLAND CARRYING CAPACITY (Ramsar or Prioritised Transboundary wetlands)	
2.8	Wetlands and Eco-tourism	Detailed tourism carrying capacity assessment and tourism management plan have been completed for Bhitarkanika Conservation Area (BCA)
2.8.1	Wetland tourism carrying capacity	
2.8.2	Ecosystem carrying capacity	
2.8.3	Responsible tourism and management plan	
2.9	Wetlands Management by use of S.M.A.R.T. indicatorsas management tools to set goals and objectives for wise use of wetlands	Work has just been initiated
2.10	Wetland conservation and land-use planning	Land use maps are being collected for transboundary wetlands
	WETLAND AND CLIMATE CHANGE (Ramsar or Prioritised Transboundary wetlands)	
2.11	Wetlands, natural hazards and climate resilience	
2.11.1	Carbon cycle (including blue carbon sequestration)	Detailed estimation of carbon budgeting is completed for selected wetlands (Bhitarkanika, Pulicat Lagoon)
2.11.2	Flooding and flood control	Work to be initiated
2.11.3	Nutrient Cycles	Estimation of inorganic nitrogen and phosphorus cycling is completed in selected wetlands (Vedanthangal Bird Sanctuary, Karikili Bird Sanctuary, Vaduvur Bird Sanctuary, Udayamarthandapuram Bird Sanctuary, Koonthangulam Bird Sanctuary, Chitrangudi Bird Sanctuary, Bhitarkanika, Mahanadi, Pulicat Lagoon, Gulf of Mannar)
	WETLAND BIODIVERSITY (Ramsar or Prioritised Transboundary wetlands)	
2.12	Biodiversity hotspots	Biodiversity studies have been conducted in selected

No.	Activities	Progress (as on 31 Dec 2022)
2.12.1	Fisheries	wetlands (Bhitarkanika, Pulicat Lagoon) and is in progressfor other inland wetlands
2.12.2	Birds	
	Holistic Conservation, Restoration and Integrated Management	
2.13	Developing criteria for conserving, restoring and adaptively managing degraded wetlands through site-specific interventions and to take action in re-establishing wetland ecosystem functions and services	The first step is to identify and map the degraded wetlands. Criteria is being developed and to be finalized with expert consultancy.
2.13.1	Develop criteria and benchmarks for restoration and management of coastal mudflats and salt marshes	Criteria developed for restoration of coastal ecosystems/ wetlands
2.14	Evolving monitoring strategy blueprint and preparing state of wetland assessments to determine effectiveness of restoration actions, towards integratedwetland management)	Year 2 onwards
2.14.1	Develop wetland inventory, assessment and monitoring framework for coastal wetlands	Work in progress
2.14.2	Develop communication collaterals to support dissemination of the guidance	Based on stakeholder consultation with knowledge partners, dissemination of the criteria will be undertaken
II	**THRUST AREA 2: TRAINING**	
3	Capacity Building – Training and Skill Development (provide training, enhance knowledge, and develop adaptive capacity towards wise use of wetlands)	
3.1	Thematic Training Programs	A wetland training program was conducted by GIZ on 20th December 2021 to provide a brief overview of wetland portal and to upload brief documents on the portal. Training was given to State Wetland Authorities (Tamil Nadu, Himachal Pradesh, Odisha) and NCSCM.
		Training was given to State Wetland Authorities of Madhya Pradesh, Maharashtra, Goa and Chhattisgarh, which was held at Bhopal, Madhya Pradesh on 10 - 11 March 2022
3.2	Specialized training modules on topics of importance	Yet to be

No.	Activities	Progress (as on 31 Dec 2022)
4	Knowledge and Advisory Support *(address the knowledge gaps to support decision-makingfor State/ UT Wetland Authorities- on wetlands conservation, management and governance)*	Draft factsheets for 42 Ramsar Sites have been prepared and vetting by the States/ UTs is awaited.
III	**THRUST AREA 3: OUTREACH**	
5	**Partnership and Networking** *(increase the knowledge base, effectiveness, and strengthening existing state, national and transboundary networks for sharing and disseminating information and good practices on wetland conservation*	Planned for Year 2 (2023-2024)
6	**Community Interfacing and Outreach**	
6.1	Information, Education and Communication (IEC) materials	Poster on Ramsar Wetlands prepared including wetland threats, benefits and types of wetlands
6.2	Interpretation Centre	
6.2.1	Work with SACON to establish an archive all wetland interpretation centers in the country – and develop a blueprint for their infrastructure upgradation and systematic CEPA	Planned for Year 2 (2023-2024)
7	National Wetlands Day	Conducted World Wetlands Day 2022 along with the Tamil Nadu State Wetlands Authority and Government of Tamil Nadu with Addl. Chief Secretary, Dept. of Environment, Forests and Climate Change and Member Secretary, TNSWA
		Three expert talks on various wetlands themes by eminent speakers
		Documentary prepared on Ramsar Wetlands for World Wetlands Day 2022
8	Demonstration sites	

6. Significant Outcomes

- Mapping of Indian wetlands has been done by SAC, 2011 based on 1:50,000 scale. Based on the SAC maps, classification of major and minor wetlands (area-based) has been completed for entire India.
- Transboundary wetlands have been identified in 5 states and 1 union territory.
- As a Pilot scale, LULC, Linear infrastructure, and hydrology regime have been carried out for Pulicat Lake (Transboundary Wetland, Andhra Pradesh & Tamil Nadu State) is completed.
- River Catchment and zone of influence has been completed for one transboundary wetland – Pulicat Lake.
- Water Quality Assessment have been completed in selected important wetlands in Tamil Nadu. Based on that ecosystem-based wetland health report cards have been prepared.
- Biodiversity studies have been conducted in selected wetlands (Bhitarkanika, Pulicat Lagoon) and is in progress for other inland wetlands.
- Draft factsheets for 42 Ramsar Sites have been prepared and vetting by the States/ UTs is awaited.
- Maintenance, enhancement of server security and performance of Wetland portal server is upscaled and it is an ongoing activity till the portal is hosted in NCSCM server. Enhancements of the home page map and interactive wetland map.
- Integration of Wetland Mitra login authentication using mobile number OTP has been established.
- Integration of various thematic layers, spatial querying and reporting system, etc. for development of Development of Digital Dashboard (DIWI) is under progress.
- As a Pilot scale, LULC, Linear infrastructure, and hydrology regime have been carried out for Pulicat Lake (Transboundary Wetland, Andhra Pradesh & Tamil Nadu State) is completed.
- River Catchment and zone of influence has been completed for one transboundary wetland – Pulicat Lake.
- Ecological and economic evaluation, detailed ecosystem goods and services assessment of selected wetlands have been completed (Pulicat lagoon, Bhitarkanika, Coringa).
- Conducted World Wetlands Day 2022 along with the Tamil Nadu State Wetlands Authority and Government of Tamil Nadu with Addl. Chief Secretary, Dept. of Environment, Forests and Climate Change and Member Secretary, TNSWA.
- Documentary prepared on Ramsar Wetlands for World Wetlands Day 2022
- Poster on Ramsar Wetlands prepared including wetland threats, benefits and types of wetlands

7. References

1. Lehner, B. and Döll, P. (2004) Development and validation of a global database of lakes, reservoirs and wetlands. Journal of Hydrology, 296(1-4): 1-22
2. Finlayson, C.M. and Spiers, A.G. (eds.). (1999) Global Review of Wetland Resources and Priorities for Wetland Inventory. CDROM, Supervising Scientist Report 144, Canberra, Australia.

V. Safety Risk Assessment and Bathing Water Quality Testing in three Beaches of India

1. Introduction

Beaches provide a variety of ecological services, which directly and indirectly, bring many types of benefits to humans. Beaches are always tourist attraction for the recreational purpose. The choice of beaches that tourist choose depends on the quality of environment and mainly near shore water quality. Indian beaches provide a large range of recreational opportunities for the tourist and help in promoting economic activities important to coastal communities.

Unclean beaches can cause public health risk, and may reduce existing property values which can substantially inhibit economic growth of the surrounding community. Several strategies need to adopt for managing beach pollution and maintain the cleanliness of the beaches for environmental safety

The Ministry of Environment, Forest and Climate Change, with a view to protect and conserve the environment and control and abate pollution in beaches and the adjacent sea waters, has decided to identify beaches for the purpose of internationally recognised “Blue Flag” Certification; whereas the stringent “Blue Flag” Certification Standards calls for responsible and sustainable amenities and infrastructure development, cleanliness, safety and security services etc. The concept of Blue Flag Beach is being promoted internationally, to provide environmentally safe beaches for human recreation purposes.

Blue Flag certification programme was initiated by a non-profitable Organisation namely, Foundation for Environmental Education. It has stipulated criteria on water quality, environmental management, environmental education and safety that are essential to meet environmentally clean and safe beaches for human recreation purposes. Declaration of a beach as Blue Flag provides an eco-label and facilitates promoting of an environment friendly tourism. It helps in generating revenue to the local establishments and communities thus providing a good opportunity to meet their livelihood needs.

Along the Indian coast, two beaches have been identified for potential ‘Blue Flag” Certification as given below:

A. Tannirbhavi Beach, Karnataka
B. Sonapur Beach, Odisha

In this reference the beach suitability assessment surveys and risk assessment surveys will be carried out in these two beaches as a requirement for Blue Flag certification. Suitable bathing zones will be identified in the two beaches Tannirbhavi beach, Karnataka and Sonapur beach, Odisha. The identified beaches will be

monitored for bathing water quality as per the Blue Flag criteria. The Bathing water quality standards have been based on the most appropriate International and National standards and legislation.

2. Objectives

Two beaches were identified (e.g. Sonapur Beach, Odisha and Tannirbhavi Beach, Karnataka) to undertake SRA and BWQT, which is an essential prerequisite for Blue Flag Certification with following objectives

- **BEACH SUITABILITY ASSESSMENT SURVEY (BSAS)**:

  Suitability assessment at these two identified regions considering various physical, ecological, environmental, social and legal parameters

- **SAFETY AND RISK ASSESSMENT (SRA)**:

  Assess the risk and safety associated with various water activities

  - Identification of safe bathing zone and risk zone
  - Presence of rip currents in vicinity of beach
  - Presence of harmful algal bloom (gelatinous organism) and
  - Threats from sharks, sting ray, puffer fish etc.

- **BEACH WATER QUALITY TESTING (BWQT):**
  - Periodically assess beach water quality
  - Monitoring and periodic reporting
  - Preparation of beach profile report
  - Site-specific interventions to mitigate the pollution load if any (e.g. beach litter, marine debris, plastics, solid waste, waste water)

- **ECOLOGY & ENVIRONMENT:**
  - Documentation of ecology and biodiversity of the identified beach
  - Development of an appropriate conservation and management plan

3. Study Sites

Two beaches which possess serene coastal landscapes and offers abundant opportunities for coastal tourism have been identified for potential ‘Blue Flag” Certification i) Tannirbhavi Beach, Karnataka and ii) Sonapur Beach, Odisha.

The Tannirbhavi beach is located at a distance of 10km from Mangalore, Karnataka

(Figure1). It is one of the most popular tourist destinations in coastal Karnataka with an approximate footfall of 12,000 to 18,000 people per week. The Tannirbhavi Beach is about 1km long, with a gentle slope. The beach width varies from 30 to 60m from the high tide line. The coastal stretch of this beach is lined by tall trees, and has beautiful sunset view as well. This beach is well connected by road.

Figure 1. Beaches identified for SRA and BWQT surveys

Sonapur Beach is one of the best beaches on the eastern coast and a picnic spot around Berhampur and in the Ganjam District of Odisha (Figure1). Right at the junction of the Bahuda River with the Bay of Bengal, the scenic beauty of Sonapur Beach is simply enchanting. The Sonapur beach is more than 2km long, with a moderate slope in nature. The beach width varies from 40 to 90m from the berm line. Approximately 10 -30 people are on the beach or in the water at any given point in time.

Thus, the beach suitability assessment surveys and risk assessment surveys will be carried out in these two beaches i) Tannirbhavi and ii) Sonapur as a requirement for Blue Flag certification. Suitable bathing zones will be identified in the Tannirbhavi beach, Karnataka and Sonapur beach, Odisha. The identified bathing zones in these beaches will be monitored for bathing water quality.

4. Methods

4.1. SAFETY AND RISK ASSESSMENT

In order to assess the physical risk and identify the safe zones for various tourism activities, the following parameters need to be measured in the selected beaches: i) Hydrodynamics ii) Bathymetry iii) Coastal currents iv) Rip Currents v) Wave parameters and vi) Tide. The safety and risk assessment study were conducted for Tannirbhavi beach on 25th January 2021 and for Sonapur beach it was conducted on 12th February 2022. The physical aspects on depth, wave and currents were measured from breaker zone up to 0.7 km to 1.0 km in the sea. The intertidal zones (width) were measured using measuring tape/GPS. Estimation of depth in the surf zone was measured with measuring tape graduated in centimeters. In addition, depth was estimated visually while observing people present in the sea. Beyond the surf zone i.e., towards sea up to 1km (depending on the bathymetry distance will vary), depth was measured using a portable echo sounder.

Wave height was estimated based on visual observation for about 6 hrs in the beach and the current velocity and direction were determined by deploying RCM current meter (Aanderaa SeaGuard) for 30 minutes each at four locations. Based on the field observations, the sea zone has designated as Safe and Risk zones and have been used to infer the suitability of the proposed beaches for safety and risk aspects.

4.2. BEACH WATER QUALITY TESTING

Based on the risk assessment survey, sampling site will be selected from the safe bathing zone where the concentration of bathers is highest. Considering the FEE beach criteria guideline, this sampling point was considered for meeting criteria for microbiological, chemical and physical parameters of Bathing Water Quality. The physical parameters include colour, odour and turbidity whereas chemical parameters include presence of oil and grease, floating matter, dissolved oxygen (DO) and biological oxygen demand. The microbiological parameters include Intestinal Enterococci and Escherichia coli. Both Tannirbhavi and Sonapur beaches were monitored for water quality and microbiological parameters following the prescribed national/international criteria for Blue flag beaches.

The monitoring period corresponds with the official bathing season that traditionally open in the 1st of October and closes in the 31st of May every year. The first sample from Tannirbhavi beach was collected on 18th March 2022 and from Sonapur on 12th February 2022. Afterwards, the samples were collected at interval as per Bathing Water Testing Calendar following Blue flag criteria requirements. In the February-March 2022, a total of 3 water samples from Tannirbhavi and 5 water samples from Sonapur beaches were collected tested and monitored by state monitoring authorities and National Centre for Sustainable Coastal Management (NCSCM) Laboratory, Ministry of Environment, Forest and Climate Change, Government of India.

The samples were collected from 30cm below the surface water. For bacteriological analyses, water samples were collected in sterile glass bottles adhering to the WHO guidelines for microbiological sample collection, and due care was taken to avoid contamination during preservation and transportation. Hydrological parameters such as pH, salinity, DO and oxygen saturation will be measured in situ using a pre-calibrated multi-parameter Hydrolab sonde. Standard analytical methods[1] (APHA, 2017) were used for measuring other water quality parameters.

Figure. 2: Microbiological analysis at NCSCM laboratory

Microbiological samples were filtered using membrane filter paper, and placed on to appropriate agar such as the Coliform agar and M-Enterococcus agar for E. coli and Enterococcus faecalis respectively (Figure2). The Hichrome coliform plates will be incubated at 28-32°C for 24hrs while the M-Enterococcus plates will be incubated at 45°C for 24-48 hrs. After incubation, the colonies will be counted to determine the concentration of pathogens in bathing water and reported as CFU/100ml. Hazen method is used for appropriate classification of bathing water of beaches, using 95th percentile calculation. The bathing waters quality are classified according to Escherichia coli and Intestinal enterococci defined in the Blue flag beach criteria and explanatory notes 2020.

[1] Standard Methods for examination of water and wastewater 23rd Ed APHA (2017); & Water quality: Guidelines, standards and health, WHO (2001)

Apart from these assessments of harmful biological organisms and other threats to beach like sewer flows, storm water during rainfall, trash and litters, was done during the survey.

5. Key Results

5.1. SAFETY AND RISK ASSESSMENT

a) Physical Characteristics of Near-shore Waters and Sea off Tannirbhavi Beach

Bathymetry : Bathymetry of Tannirbhavi Beach varies between 0.5 to 3m within the cross-sectional distance of 132 m. Very gentle gradient (< 5°) in bathymetry was observed at 0 to 140m cross-sectional distance from the shore. At locations beyond the wave breaker zone, the variation of depth is moderate. The depth is 1m and increases up to 4.5 m for about 300m distance in the sea towards offshore.

Waves : Shore-based visual and field observations made in the sea off Tannirbhavi Beach on 25th January, 2022 indicated that the waves break at about 30m from shore at a depth of 0.5m to 0.8m during low tide and the depth may increase to 0.5m to 1m during high tide. The wave height varied from 0.2m to 0.7m during the survey. The waves approach the shore from the North of Northwest direction to the coast. During the morning hours due to low wind speed, the waves were less than 0.5m in height. As the wind speed increased along with rising tides in the afternoon, the wave height rose to about 0.7 m and splashed up to a distance of 30m from the shoreline. No sand mound formation was observed as the waves break continuously at the almost same height.

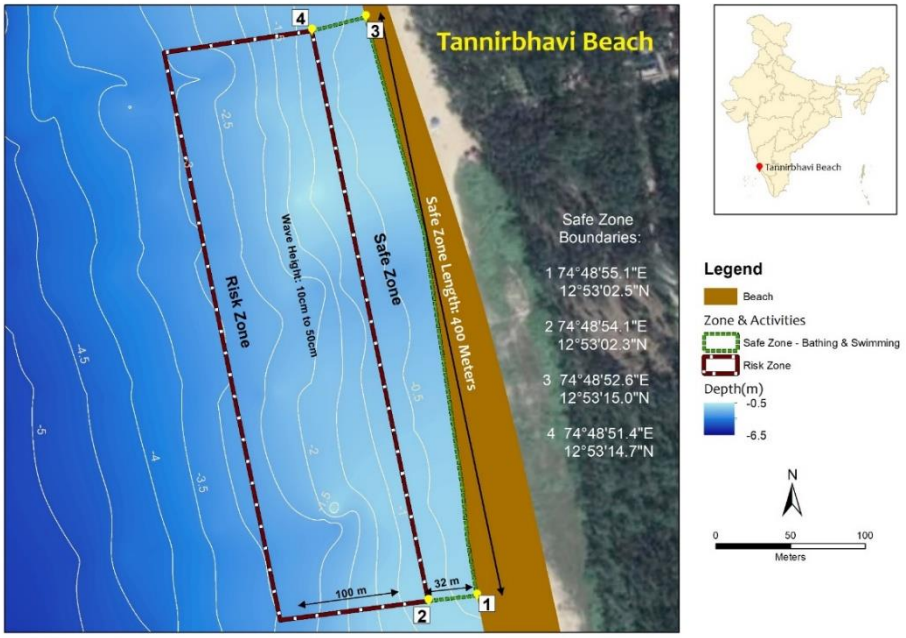

Figure 3. Map of zoning for safety and risk at Tannirbhavi Beach along with safe zone coordinates

Currents: Currents were mild ranging from 1.9 – 26.0cm/sec and do not pose danger to people near the coast. No RIP CURRENTs were observed during the period of survey. Based on the observations, the zoning map of Tannirbhavi Beach is given in Figure 3, demarcating i) Safe Zone: which is safe for wetting of legs and bathing, with water depth is about 0.8m and wave height is less than 0.6 m and ii) Risk Zone: which is suitable for water sports activities only with water depth more than 1.0 m and wave height more than 0.6 m.

b) Physical Characteristics of Near-shore Waters and Sea off Sonapur Beach

Bathymetry: Bathymetry of Sonapur Beach varies between 0.5 to 3m within the cross-sectional distance of 160 m. The moderate gradient (< 5°) in bathymetry was observed at 50 to 160m cross-sectional distance from the shore. At locations beyond the wave breaker zone, variation of depth is moderate. The depth is 1m and increases up to 4.5 m for about 320m distance in the sea towards offshore.

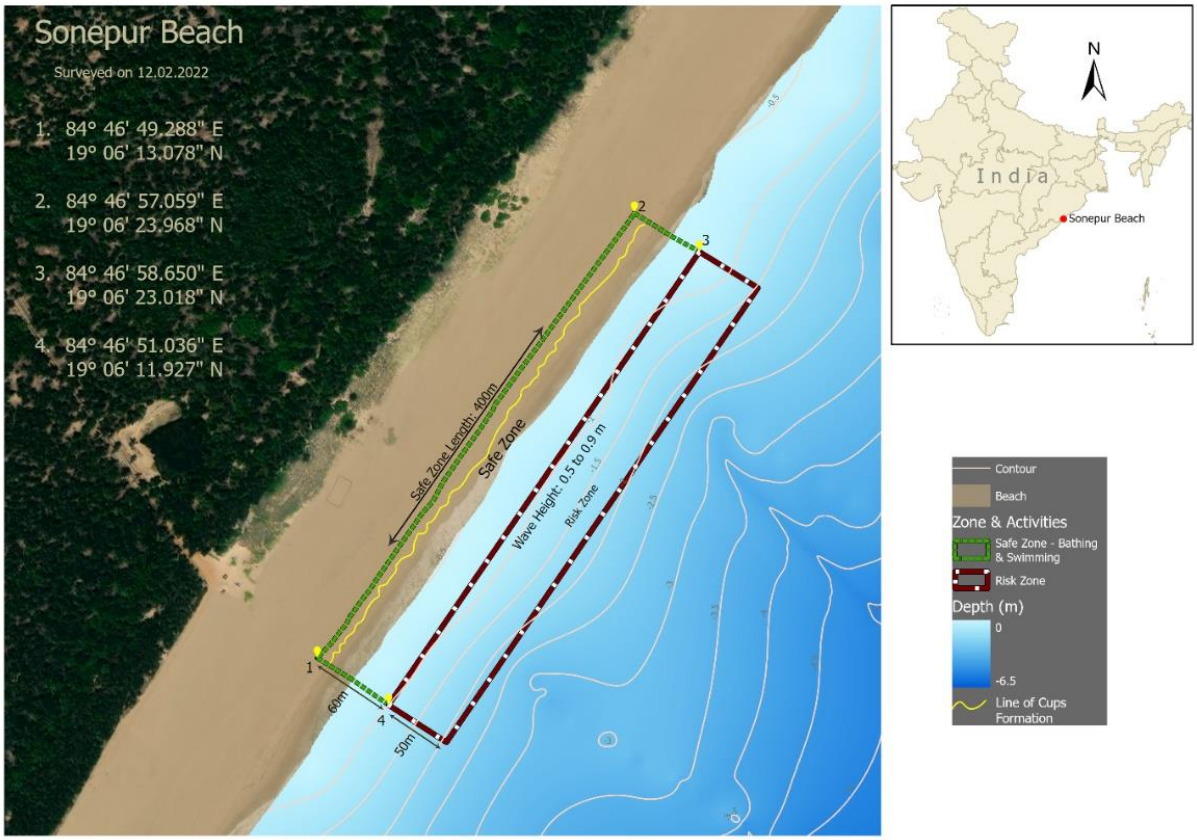

Figure 4. Map of zoning for safety and risk at Sonapur Beach along safe zone coordinates

Waves : Shore-based visual and field observations made in the sea off Sonapur beach on 12th February 2022 indicated that the waves break at about 60m from shore at a depth of 0.5m to 0.8m during low tide and the depth may increase to 0.5 m to 1 m during high tide. The wave height varied from 0.3 to 0.7m during the survey. The waves approach the shore somewhat parallel to the coast. During the morning hours

due to moderate wind speed, the waves varied from 0.3 to 0.5m in height. As the wind speed increased along with rising tides in the afternoon, the wave height rose to about 0.7 m and splashed up to a distance of 20m from the shoreline. Small sand dune formation with less than 1m height was observed.

Currents: Currents were mild ranging from 6.9 to 24.8cm/sec and do not pose danger to people near the coast. No RIP CURRENTs were observed during the period of survey. Based on the observations, the zoning map of Sonapur Beach is given in Figure 4, demarcating i) Safe Zone: which is safe for wetting of legs and bathing, with water depth is about 0.8m and wave height is less than 0.6 m and ii) Risk Zone: which is suitable for water sports activities only with water depth more than 1.0 m and wave height more than 0.6 m.

c) Biological harmful Organisms

Porpita sp. (Blue Button Jellyfish) and *Velella* sp. (By-the-Wind sailor), or any gelatinous zooplankton or algal bloom in the surface waters were not observed during the period of survey in both the beaches. Sharks or other dangerous marine organisms were not observed during the period of survey in both the beaches.

5.2. BEACH WATER QUALITY TESTING

a) Physical & Chemical Parameters:

The physical and chemical parameters of the water samples collected from Tannirbhavi and Sonapur beach were well within the permissible limits. No colour was observed in the bathing water of both Sonapur and Tannirbhavi beaches. Water seems to be crystal clear. The water does not contain any odour or foul smell during all the surveys in both the beaches. Both the beaches were free from any floating debris/matter or beach litter. No traces of Oil & Grease were observed in bathing water of Sonapur and Tannirbhavi beaches which complies with the Criteria 11 for Blue flag certification.

Table 1. Water quality properties of Tannirbhavi and Sonapur Beaches during the survey

Beaches	Sampling Dates (2022)	pH	Turbidity	Dissolved Oxygen	BOD_3
Tannirbhavi Beach	18 March	7.98	5.83	6.05	1.76
	23 March	7.86	4.31	6.42	1.60
	29 March	7.87	17.47	6.35	1.12
Sonapur Beach	12 February	8.25	3.70	7.94	2.42
	08 March	7.15	3.20	6.80	1.76
	19 March	7.82	3.70	6.99	1.39
	22 March	7.98	2.42	6.54	2.32
	28 March	7.92	18.45	7.01	1.28

Beaches	Sampling Dates (2022)	pH	Turbidity	Dissolved Oxygen	BOD_3
Desired limit		***6.5 – 8.5***	***30 NTU***	***>4.0 mg/l or 50% saturation***	***< 3 mg/l***

The pH of coastal water samples collected from Tannirbhavi and Sonarpur beaches were within the acceptable limit of 6.5 to 8.5 for bathing water quality (Table. 1). The water along the Sonapur and Tannirbhavi beach was clear and clean and maximum turbidity recorded was 18.5 NTU, which is well below the desired limit of 30 NTU. The concentrations of dissolved oxygen indicate the health of the water and its ability to sustain aquatic life. For recreational purposes, the values should not be less than 4.0 mg/l or 50% saturation. DO values recorded in both the beaches (Table 1) during the surveys indicating the healthy coastal waters well saturated with oxygen. Biochemical oxygen demand (BOD) is the amount of dissolved oxygen needed by the microbes to break down organic material; and It is an indirect measure of the sewage pollution. For bathing/recreational waters BOD values should not be greater than 3.0 mg/l. The water along the Tannirbhavi beach was pristine and free from any organic contamination was indicated by the BOD_3 range of 1.12 to 1.76 mg/l. Similarly, the water along the Sonapur beach was also free from any organic contamination as indicated by the BOD_3 range of 1.28 to 2.42 mg/l.

a) Microbiological Parameters

It was observed that microbial parameters i.e. Intestinal enterococci and *Escherichia coli* were well within the permissible limit as prescribed by FEE for certification of blue flag beaches (Figure 5 & 6).

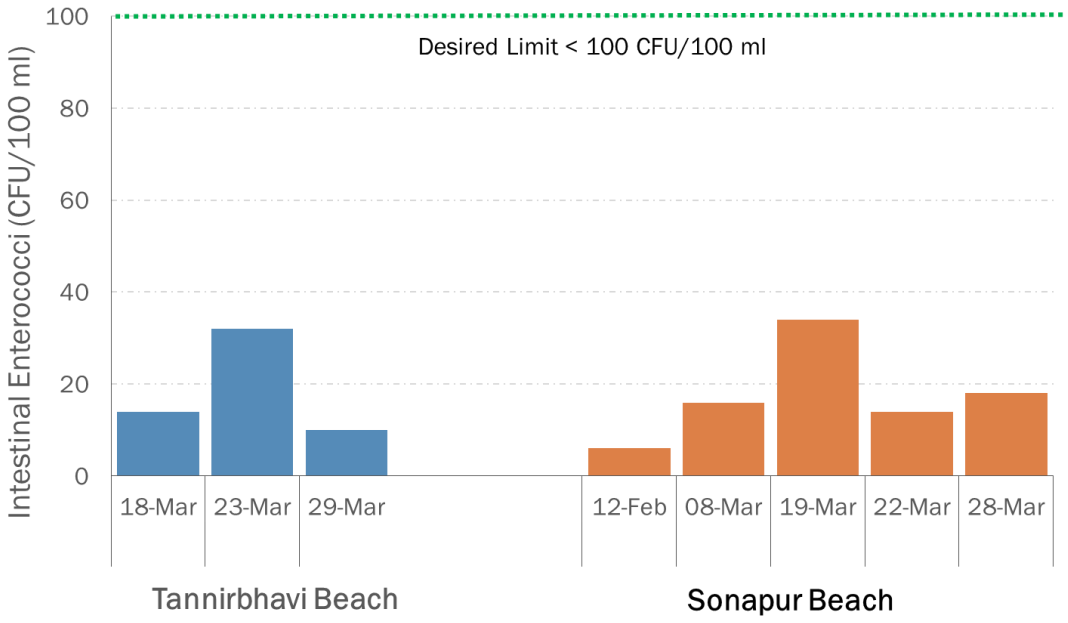

Figure 5. *Variation of Intestinal Enterococci and in the bathing water samples from Tannirbhavi and Sonapur beaches*

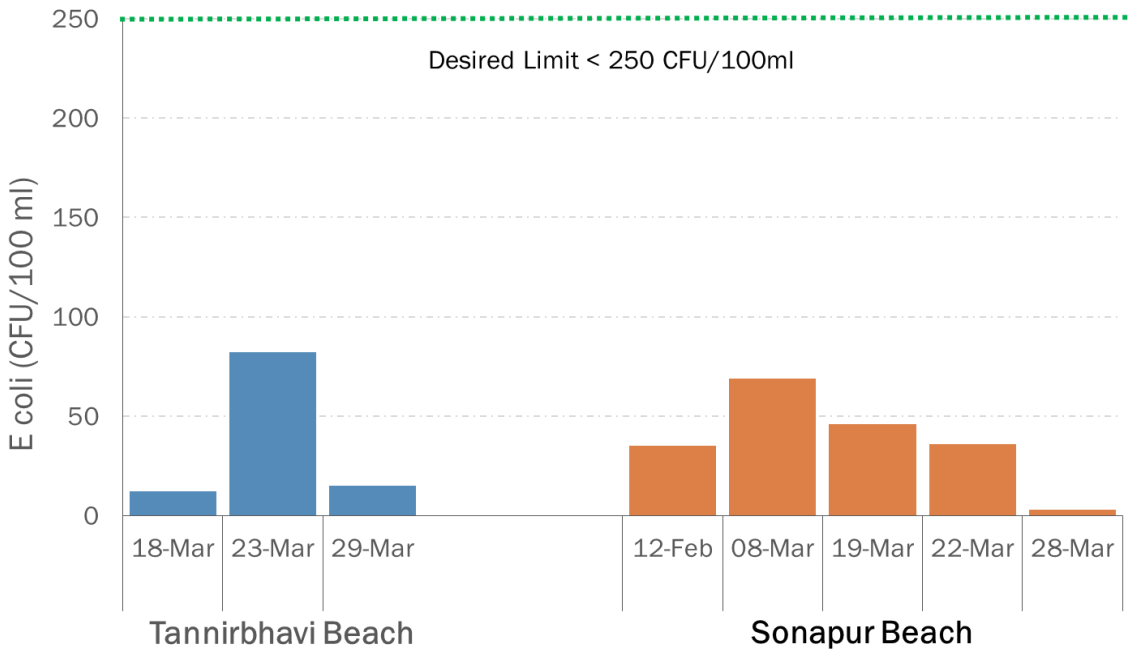

Figure 6. *Variation of E. coli in the bathing water samples from Tannirbhavi and Sonapur beaches*

The results indicate that bathing at Tannirbhavi and Sonapur beaches does not pose any risk with respect to pathogen contamination (Figures 5 & 6). The results for Intestinal enterococci and *E.coli* are under permissible limits and fall in the category of "Excellent" (Table 2).

Table 2: Classification of Category i.e. Excellent, Good, Sufficient & Poor

Parameter	Classification				Tannirbhavi (Min-Max)	Sonapur (Min-Max)
	Excellent	Good	Sufficient	Poor		
Escherichia coli (Faecal Coliform) cfu/100 ml	< 250	251-500	501-1000	>1000	**12 - 82**	**3 - 69**
Intestinal enterococci (streptococci) cfu/100 ml	<100	101-200	201-250	>200	**10 - 32**	**6 - 34**

6. Significant outcomes

- Safe zones and Risk zones were demarcated for both Tannirbhavi and Sonapur beaches.
- Bathymetry in the bathing zones of both the beaches were shows gentle slope with shallow in nature.

- Currents were mild range and do not pose danger to people near the coast.
- No Rip Currents are observed in both the beaches and no high-risk zones observed during the surveys.
- Wave heights were < 0.7m in both the beaches and safe of the beachgoers.
- No Biological harmful organisms were noted during the surveys in both the beaches.
- Physical and Chemical parameters of the water quality from the bathing zones of both the beaches are well within the permissible limits during the survey.
- Intestinal enterococci and *E. coli* values from both the beaches are under permissible limits during the surveys, and fall in the category of “Excellent”.
- Overall water quality of Tannirbhavi and Sonapur beaches were falling in the excellent category and the healthy water conditions are well maintained during the surveys.

7. References

Standard Methods for examination of water and wastewater 23rd Ed **APHA (2017)**; & Water quality: Guidelines, standards and health, WHO (2001)

VI. Joint study on Seaweed Cultivation, Potential and Ecological Safeguards in the Gulf of Mannar, Tamil Nadu (along with ICAR-CMFRI and CSIR-CSMCRI)

1. Introduction

India's Blue Economy can be defined as a subset of the national economy comprising of the entire system of ocean resources and man-made economic infrastructure in marine and onshore coastal zones within India's legal jurisdiction, which aid in the production of goods and services and have clear linkages with economic growth, environmental sustainability and national security. The Blue Revolution is further expanded by promoting aqua culture, cage culture, seaweed and algal harvesting and sustainable marine capture by adopting an ecosystem approach to fisheries management. Mariculture activities such as production of algae is being promoted by enunciating a comprehensive National Mariculture Policy.

The Central Government encouraged the coastal states to take up seaweed farming under the Pradhan Mantri Matsya Sampada Yojana (PMMSY) which places thrust on it as a means of livelihood and its diversification. In the 2021-22 budget, Union Finance Minister had announced a Multipurpose Seaweed Park in Tamil Nadu considering seaweed farming "an emerging sector with potential to transform the lives of coastal communities."

A virtual meeting was held on 1st September 2020 at 1.30 PM to discuss the issues related to seaweed cultivation in India. The meeting was attended by representatives of NITI Aayog, NCSCM, CSIR-CSMCRI, ICAR-CMFRI and MoEFCC. Based on the deliberations and discussions, it was decided that a Joint study by ICAR-CMFRI, CSIR-CSMCRI and NCSCM will be undertaken to study the exact impact of seaweed cultivation on the corals and seagrass by undertaking 5 cycles along the Gulf of Mannar and Palk Bay for a span of 1 year.

The terms of reference as per the OM (of CS III Division F. No. 8-82/2019/WL dated 7.9.2020 from MoEFCC) of the joint study on seaweed cultivation in the coast of Tamil Nadu is as below:

i. The joint study is to be conducted by NCSCM, MoEFCC, CSIR-CSMCRI and ICAR-CMFRI;
ii. The study would be undertaken to understand the exact impact of seaweed cultivation on corals and seagrass by collecting the data for 5 cycles along the coast of Tamil Nadu, around Gulf of Mannar and Palk Bay in a span of one year;
iii. The expenditure incurred for the joint study would be shared by the three scientific institutes;
iv. The three scientific institutes would conduct the joint study after obtaining all the requisite permissions and clearances; and

v. The joint study report after completing 5 cycles of cultivation may be submitted to this Ministry and NITI Aayog for further consideration.

Following the ToR above, NCSCM, MoEFCC along with CSIR-CSMCRI and ICAR-CMFRI undertook a reconnaissance survey to provide an initial assessment of the technical feasibility of cultivating seaweeds along the coast of Gulf of Mannar, Tamil Nadu. The project was initiated by the April 01, 2022 upon receipt of the 1st instalment of the sanctioned funds.

2. Objectives

NCSCM was entrusted with the task of undertaking the environmental monitoring and impact assessment.

a) Environmental Monitoring

- Identification of drivers of environmental change due to seaweed farming
- Water quality assessment during culture and post-harvest at Gulf of Mannar and compare with the existing culture sites at Palk Bay
- Hydrodynamic surveys to determine waves, tides and currents at the farming sites and adjacent coastal waters
- Organic carbon and nitrogen concentration in the surface sediments and particulates
- Assessment of Plastic debris (including microplastics)

b) Ecological Monitoring

- Primary productivity analysis and plankton (photo and zoo) community structure during and post seaweed cultivation
- Fish diversity, meiobenthos, macrobenthos, epiphytes and epizooites
- Seaweed-Microbial interactions and key functions of seaweed-associated bacterial communities

c) Impact Assessment

- Hydrodynamic modelling of waves, tides and currents
- Impacts (both positive and negative) on ecologically sensitive areas such as coral reefs and seagrass ecosystems (coral health index and sea life index)
- Evaluation of impacts (if any) on coral and seagrass health and herbivore fish population
- Impact assessment of seaweed farming on the fish diversity, meiobenthos, macrobenthos and epiphytes

d) Guidelines

- Preparation of guidelines for environmental and ecological safeguards.

e) Reporting

- Interim and Final Reports

3. Study Sites

This project is proposed to expand the commercial farming efforts to new areas especially in Gulf of Mannar, Tamil Nadu for its potential in commercial cultivation of Kappaphycus alvarezii to achieve sustainable production of biomass. Commercial farming of Kappaphycus alvarezii has till date contributed in expanding livelihood options and has brought benefits in terms of enhanced income and local employment, but has been perceived as having potential environmental impacts. In order to evolve ecologically sustainable seaweed cultivation practices, experimental farming was initiated at three locations by CSIR-CSMCRI as follows:

(i) Ervadi, Ramanathapuram District (Lat: 09.20521°N; 78.72351°E);
(ii) Chinna Ervadi, Ramanathapuram District (Lat: 9°2091'N; Long: 78°7278'E);
(iii) Pudumadam, Ramanathapuram District (Lat: 9°29'17; Long: 79°00' 22).

ICAR-CMFRI will undertake the trial on a participatory mode by involving local fishers from identified two sites in Ramanathapuram District, i.e.,

(i) Nochiurani, Ramanathapuram District (Lat: 09.27101°N; Long: 79.00199°E;
(ii) Seeniappadharga, Ramanathapuram District (Lat: 09.26075°N; Long: 79.06823°E

- The ICAR-CMFRI will undertake farming trials in the two identified sites.
- The ICAR-CMFRI will undertake periodic growth studies, documentation of underwater seaweed and associated resources in the culture site.
- Periodic sharing of primary data shall be ensured among the three institutes.

4. Methods

The potential sites were pre-selected through a first-stage screening based on certain biophysical parameters and GIS based assessment. The identified areas were physically inspected to locate the sites conducive for cultivation in terms of physical, geographic, ecological and environmental factors, following standard protocols. A joint team of researchers from NCSCM, MoEFCC, CSIR-CSMCRI and ICAR-CMFRI surveyed the area along the Gulf of Mannar coast from Rameswaram to Thoothukudi between January 5 and 8, 2021.

The team surveyed the locations identified by CSIR-CSMCRI and ICAR-CMFRI. Coastal areas were visually evaluated based on previously surveyed areas. Access roads to the farms and shoreline characteristics (if protected by seawalls or are eroding) were documented for each site. Seawater properties were evaluated onsite using a multi-parameter water quality probe**.** Presence of sensitive ecosystem as listed under CRZ notification was also considered for finalizing the culture sites.

Further, based on the above Terms of Reference, and the results of the preliminary survey at Gulf of Mannar (report submitted in January 2021 by NCSCM), detailed

discussions were held with the Additional Secretary and Chairperson and the three institutions. It was agreed to continue the experimental farming of seaweed at the recommended sites in Gulf of Mannar and that this joint proposal would contain the following two components:

i) assessment of seaweed cultivation potential in the Gulf of Mannar and Pak Bay, Tamil Nadu and
ii) determining the environmental and ecological impacts of seaweed cultivation on the coastal environment, coral reef and seagrass ecosystems.

Step 1: Pre-screening – GIS-based site selection

The potential sites were pre-selected through a first-stage screening based on certain biophysical parameters and GIS based assessment.

- Sheltered from strong wave action, current and winds (good water movement or where there is a rapid water turnover, but not heavy enough to damage)
- Enclosed bay along the shoreline.
- Water current between 20 to 40 cm per minute. (One to two knots during peak ebb and flood)
- Low siltation and turbidity with good clarity and light penetration.
- Without mouth of rivers or where there is a heavy freshwater runoff with salinity from 27 to 35 parts per thousand.
- Water depth not be less than 2 feet during the lowest tide and more than 7 feet during high tide
- Stable bottom composition with sandy or rocky
- Appropriately away from sensitive ecosystems like Coral reefs, seagrass beds and marine protected areas. Not in an area of essential habitat or endangered species and an appropriate distance from protected shore birds
- At least 1 km away from municipal beaches/ recreational area/ fishing harbour/ jetty/ pier/ groynes

In GIS environment all thematic layer sea physio-chemical parameter viz. wind speed, current, temperature, salinity, near shore bathymetry, sea surface bottom and ecologically sensitive area, and other demography parameters viz, population, any town or municipalities, drainage network of fresh water influx, proximity of road and other network connectivity were prepared GIS software. all layers were transformed to raster format with fixed spatial resolution and superimposed by weighted overlay analysis. Weighted overlay is one method of modelling suitability was adopted to combine all thematic layers by assigning rank according to the multi influencing factor (MIF) of that particular layer and weightage for each thematic layer. Weighted overlay analysis is a simple method to analyse multiclass maps based on the relative importance of each thematic layer and a layer's class. The delineation of site suitability analysis was made by grouping the values into distinct prospect zones, i.e. suitable and not suitable, and these values are then recorded to new cells in an output raster layer. Suitability map was prepared based on this output raster dataset.

Step 2: Field Surveys

The identified areas were physically inspected to locate the sites conducive for cultivation in terms of physical, geographic, ecological and environmental factors, following standard protocols. A joint team of researchers from NCSCM, MoEF&CC, CSIR-CSMCRI and ICAR-CMFRI surveyed the area along the Gulf of Mannar coast from Rameswaram to Thoothukudi between January 5 and 8, 2021. The team surveyed the locations identified by ICAR-CMFRI and CSIR-CSMCRI.

Survey undertaken by joint survey team at Gulf of Mannar

Step 3: Evaluation and finalization of Potential Sites

The potential sites were visually evaluated based on the pre-screening assessment. Access roads to the farms and shoreline characteristics (if protected by seawalls or are eroding) were documented for each site. Seawater properties were evaluated onsite using a multi-parameter water quality probe**.** Presence of ecologically sensitive areas (ESA) as listed under the Coastal Regulation Zone (CRZ) Notification (2011) were considered for finalizing the culture sites. Based on the field surveys, the proposed seaweed farming/ culture sites were finalized and are listed below in Table 1. Based on the preliminary survey findings on seagrass cover, water quality and other environmental parameters, six potential sites for experimental farming of seaweeds were finalized under the Chairpersonship of the Additional Secretary, MoEF&CC.

Table 1: Proposed Seaweed Culture Sites in the Gulf of Mannar

S.No.	Place	Latitude, Longitude	Site suitability Assessment
1	Ervadi (Ramanathapuram)	09.20521°N; 78.72351°E	Suitable
2	Chinna Ervadi (Ramanathapuram)	09.20837°N; 78.72818°E	Suitable
3	Pudumadam (Ramanathapuram)	09.27296°N; 78.98627°E	**Highly Suitable**
4	Nochiyurani (Ramanathapuram)	09.27101°N; 79.00199°E	**Highly Suitable**
5	Seeniappadharga (Ramanathapuram)	09.26075°N; 79.06823°E	**Highly Suitable**
6	Vellapatti (Thoothukudi)	08.89034°N; 78.17469°E	Suitable

Further, based on the above Terms of Reference, and the results of the preliminary survey at Gulf of Mannar (report submitted in January 2021 by NCSCM), detailed discussions were held with the Additional Secretary and Chairperson and the three institutions. It was agreed to continue the experimental farming of seaweed at the recommended sites in Gulf of Mannar and that this joint proposal would contain the following two components:

iii) Assessment of seaweed cultivation potential in the Gulf of Mannar and Pak Bay, Tamil Nadu and

iv) Determining the environmental and ecological impacts of seaweed cultivation on the coastal environment, coral reef and seagrass ecosystems.

The institutional responsibilities of this joint study as agreed at the meeting are as follows:

- ICAR-CMFRI and CSIR-CSMCRI will undertake the work related to seaweed culture and the related best practices;
- MoEF&CC-NCSCM, will undertake the environmental and ecological assessments in the culture sites and their impact (if any) on the adjacent coral reef and seagrass ecosystems and propose environmental and ecological safeguards for cultivation.

Photographs taken during the preliminary survey for selection of potential sites for seaweed cultivation at Gulf of Mannar and Palk Bay

5. Results

Progress of work undertaken by CSIR-CSMCRI

1. The biomass yield of *G. edulis* at site-1 during the first cycle was 0.80 kg fresh wt m^{-2} and the second cycle was 5.98 kg fresh wt m^{-2}.
2. During the two cultivation cycles, no biomass was harvested at site 2. Among the two cycles, the second cycle reported a higher DGR (5.97 % day^{-1}) than the first cycle (1.91 % day^{-1}).
3. In the second cycle, plant length (12.31.69 cm), branch length (3.98±0.31 cm), and bushiness (315.2±13.31 cm) were all higher when compared to the first site.

4. The biomass per rope increased to 1305±658.45 g from 110±15 g. The number of plants seeded initially ranged between 21 and 22, and 19.2±2.86 plants were observed at site 1 during the second cycle.
5. The highest biomass (26.1 kg FW/raft) was harvested at site 1 during the second cycle, followed at the same site during the first cycle (5.56 kg FW/raft).
6. Site-1 had a higher growth rate and biomass yield in cycle 2 than in cycle 1, due to the moderate wind and wave action.
7. Due to the high wave action and winds, and the increased surface water temperature, no biomass was observed after 45 days in both cycles at Site-2.
8. Other than the temperature, epiphytes are the major concern in *G. edulis* cultivation. Rueness et al. (1987) and Jones (1959) opined that epiphytic green alga seriously affected *Gracilaria* cultivation by overgrowing bamboos, shading, and accumulating large quantities of silt. Site-1 was also associated with *Ulva intestinalis* on the raft and rope, and they did not affect the *G. edulis* growth during the first and second cycles. At site-2, the raft and rope had patches of blue-green algae (*Lyngbya* sp.) along with silt as epiphytes.

Progress of work undertaken by NCSCM

- The hydrodynamic data of tide, current and wave was collected at at the same location where the rafts were deployed. Tide, current, and wave data were collected at 10-minute intervals.
- The tidal amplitude varied between 0.26 and 0.59m, and the tidal range was about 0.33m. The current speed varied from 2.01 to 9.35cm/sec, with an average speed of 4.83cm/sec.
- The predominant directional flow of the current is observed in the West of North West (WNW) direction
- The significant wave height (Hs) and peak period varied from 0.02 to 0.04m and 9.66 to 20.48 (sec) respectively (Figure 11). The mean range of significant wave height (Hs) (0.03m) and peak period (Tp) (13.02sec) was observed during the study. As the Palk Bay is protected by the Indian peninsula and the northern tip of Sri Lanka, swells cannot reach the bay and therefore, the locally generated wind wave is predominant in this region.
- In general, with the exception of DO in Ervadi during October, there are no significant differences in pH or salinity between seaweed and non-seaweed stations. Typical decline in nutrient concentration in the seaweed culture sites compared to non-seaweed sites were not observed.
- Noctiluca bloom occurred at Ervadi in the months of September and October, probably due to excessive nutrients from land-based sources
- High turbidity and fish mortality were observed as a result of harmful algal bloom
- Fouling on the rafts by filamentous algae, sponges and barnacles were noted
- Based on field observations, live coral cover was higher at Thonnithurai (15 %) when compared to Ervadi, Gulf of Mannar (6 %)

- Similarly, seagrass cover is higher (57 %) at Thonnithurai when compared to Ervadi (40.25 %)
- No major impacts were observed on the benthic communities due to seaweed culture activities at Thonnithurai and Ervadi.
- The macrofaunal species composition showed the the dominance of Gastropoda, followed by Bivalvia, Amphipoda, Isopoda, Tanaidacea, Polychaeta, and Polyplacophora.
- The present study shows that the seaweed farming area supports a high density of macrofaunal population.

Progress of work undertaken by ICAR- CMFRI

The inter-institutional project funded by Department of Fisheries, GoI under centre sector scheme of PMMSY was sanctioned to NCSCM, ICAR-CMFRI & CSIR-CMCRI, where NCSCM is the nodal agency. The technical programme of ICAR-CMFRI is to be executed at ICAR-Mandapam Regional Centre of CMFRI and ICAR-Tuticorin Regional Station of CMFRI. The ICAR-CMFRI will be undertaking the trial in a participatory mode by involving local fishers from identified two sites in Ramanathapuram district, i.e., Nochiurani & Seeniappadharga and one site in Tuticorin district i.e., Vellapatti. According to the terms of reference, the study was planned to be undertaken to understand the exact impact of seaweed cultivation (original proposal was very clear in indicating the cultivation of *Kappaphycus alvarezii*) on corals and seagrass by collecting the data for 5 cycles in the coast of Tamil Nadu, around Gulf of Mannar and Palk Bay in a span of one year. As the permission was denied for conducting the study with *Kappaphycus alvarezii* the following actions were taken by ICAR-CMFRI.

Observations by ICAR- CMFRI on the permission obtained from Principal Chief Conservator of Forest & Chief Wildlife Warden, Tamil Nadu for conducting joint study was communicated to NCSCM and NITI Aayog.

- It was communicated that if the non-native species is not included in the farming, then the purpose of the study will not be fulfilled.
- The cultivation of native seaweeds as indicated by the PCCF&CWLW was decided to be initiated by ICAR-CMFRI at the identified locations in Gulf of Mannar.
- While the cultivation is in progress, efforts to persuade the Tamil Nadu Forest Department and emphasize the importance of cultivating *K. alvarezii* as per the original proposal may be undertaken.
- It was requested to carry out the joint study only for the native species and should not include non-native species as per the permission granted by the State Chief Wildlife Warden.

VII. Long Term Monitoring Plan for the Ecosystem based Conservation Management for Bhitarkanika Conservation Area Phase –II

Introduction

Bhitarkanika Conservation Area known for its salt water crocodile (Crocodylus porosus) population is a rich, lush green, vibrant ecosystem lying in the estuarine region of Brahmani, Dhamra and Baitarani rivers in the north-eastern corner of Kendrapara District, *Odisha, and East coast of India*. It covers an area of 2731.92 km2. Bhitarkanika Conservation Area encompasses Bhitarkanika Wildlife Sanctuary, Bhitarkanika National Park, Gahirmatha Marine Sanctuary, Critically Vulnerable Coastal Areas and the Eco-Sensitive Zone *(figure 1)*. The Government of Odisha declared this area as a sanctuary in 1975 to better protect the habitat. Later, the core area (145 km2) of the sanctuary was declared a national park in 1998. The entire mangrove area is a conglomerate of 13 proposed reserve forests (PRF), 12 protected forests (PF) and a newly formed island. Due to its rich diversity of flora and fauna, this mangrove area was declared a Ramsar site (No. 1205), a wetland of international importance, on August 19, 2002. The peripheral areas in the buffer zones have numerous ornithologically important wetlands and are listed as IN 310 (A1, A4i) un*der Important Bird Areas (IBA).*

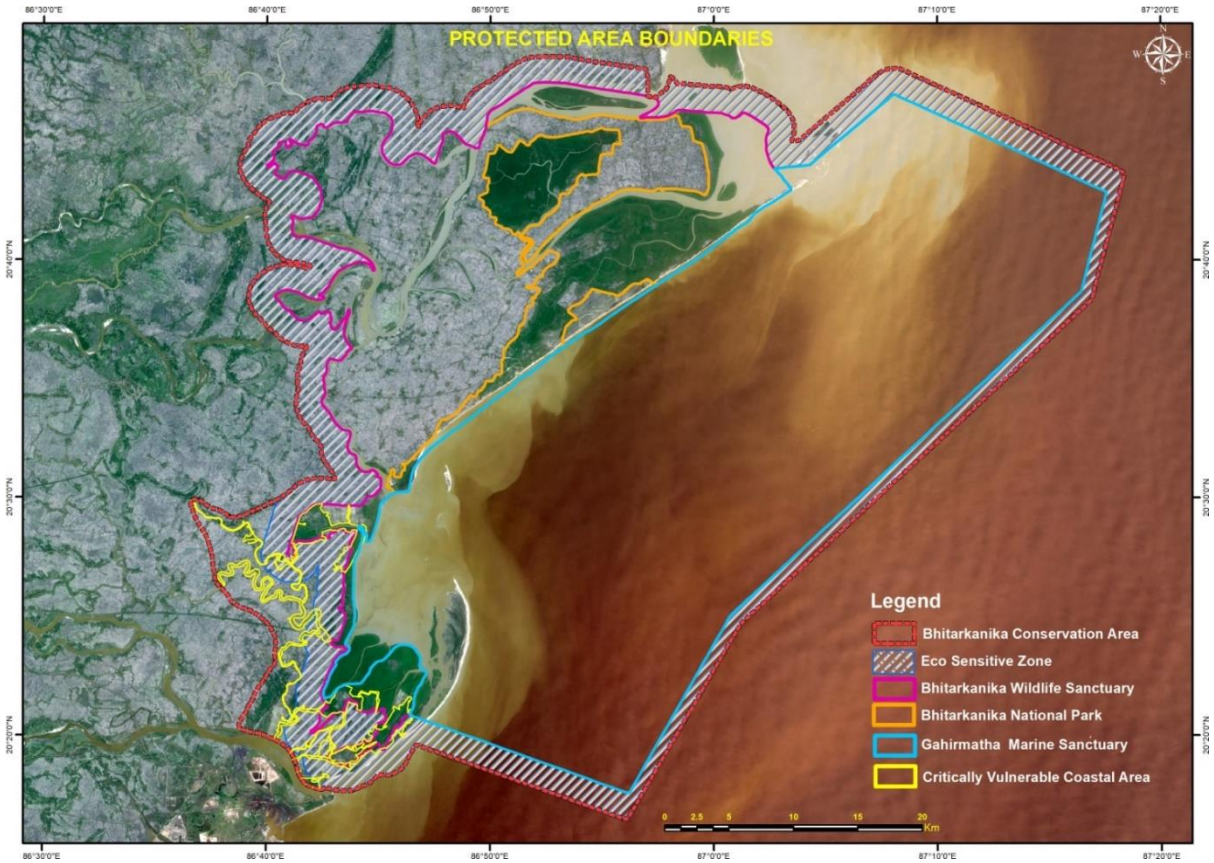

Figure 1: Boundary of Bhitarkanika conservation area

The unique biodiversity of Bhitarkanika warrants a high conservation priority. Although, the protection and the effort for conservation of species by the Forest Department, Odisha are adequate, a comprehensive ecosystem-based approach to strengthen the current conservation measures is important. Considering the possible impact of climate change, increasing human interventions and the conservation priority for Bhitarkanika ecosystem, National Centre for Sustainable Coastal Management (NCSCM) has been carrying out a long-term study jointly with Wildlife Wing of Forest Department, Government of Odisha, funded by the JICA assisted (OFSDP-II) Project, to develop an ecosystem-based management programme. Monthly samplings were carried out during the 'Phase-I' of the project to achieve the goal of establishing a credible baseline for various parameters. Based on the finding/gaps in the outcome and execution of the 'Phase-I'; a quarterly sampling and monitoring plan was adopted during the 'Phase-II' of the BCA project.

Objectives

In view of the expert suggestions and recommendations, received during the project review meeting for 'Phase-I' regarding augmentation of environmental and ecological monitoring of BCA; the following objectives were set for execution of the BCA 'Phase-II'.

1. Environmental and Ecological Monitoring
2. Environmental Monitoring of microplastics in BCA
3. Assessment of eco-flows to the BCA
4. Biodiversity Assessment
5. Ecosystem Goods and Services
6. Significance of BCA mangroves in climate mitigation
7. Ecosystem Health Report Card 2022 for BCA
8. Capacity Building

Study Sites

To create a long-term database for physical, chemical and biological variables from the Bhitarkanika Conservation Area (BCA), an elaborate sampling plan has been adopted. Sampling was carried out between April 2021 to March 2022.

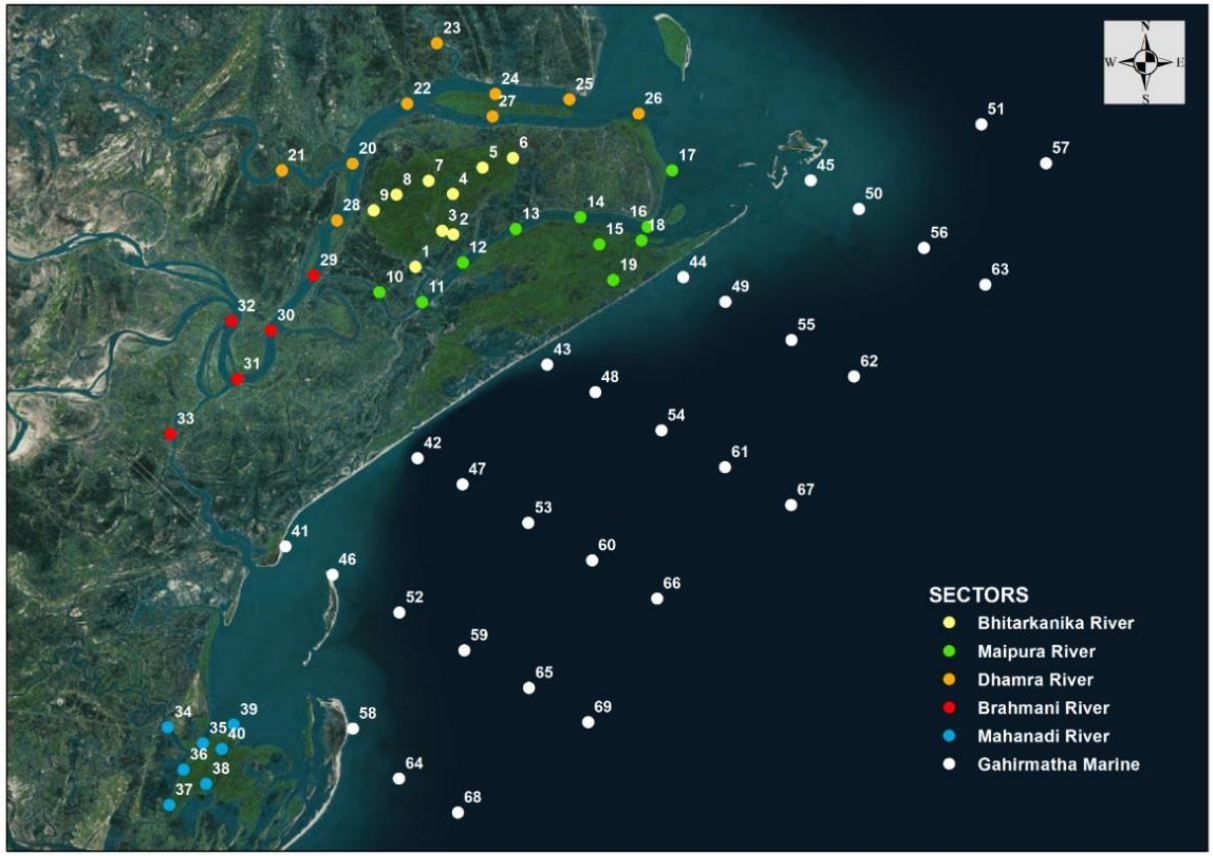

Figure 2: Sampling stations for long term monitoring from BCA

Surface water, sediment and biota samples were collected from fixed geographical locations of BCAs (Figure 1). Due to the observed spatial heterogeneity, BCA waters is segmented into five sectors i) Bhitarkanika ii) Maipura iii) Dhamra iv) Brahmani v) Mahanadi () and further into three seasons i) Pre-monsoon (February-May), ii) Monsoon (June-September, iii) Post-monsoon (October-January) for better evaluation of ecosystem health. Due to Covid -19 pandemic situation in 2021, the monthly surveys got impacted and few months sampling were missed out. Apart from these 29 stations from Gahirmatha amrine area were also selected and assessed during January 2022.

Methods

- Assessment of Estuarine Trophic Status (ASSETS) is considered as a reliable tool to address the eutrophication status in estuarine systems. The model quantifies overall Human Influence, and Overall Eutrophic Conditions and Future Outlook to rank the system.
- Trophic index (TRIX) is an eutrophication index to characterize the trophic state of marine waters.
- Installation of an Automatic Weather Station (AWS) in Dangmal transmitted weather data in real-time basis to three locations i) NCSCM Lab; ii) Dangmal Field Lab
- Quantitative enumeration of phytoplankton, zooplankton and benthic fauna using plankton net and grab samples.
- Sediment collected using core sampler and analysed for particle size distribution, organic matter, major nutrients, heavy metals and pesticides
- Amount of suspended Particulate Matter (PM10, PM2.5) determined using High volume air sampler.
- Determination of Noxious gases (like, SO2, NOx) affecting the mangrove ecosystem using improved West and Gaeke method for SO2 and Jacob and Hochheiser Method for NOx.
- Identify Source and transport pathway of noxious gases using NOAA HYSPLIT Trajectory model
- Microplastic samples were subjected to wet peroxide oxidation (WPO) in the presence of a Fe(II) catalyst to digest labile organic matter. The plastic debris remains unaltered. The WPO mixture is subjected to density separation in NaCl (aq) to isolate the plastic debris through flotation. The floating solids are separated from the denser undigested mineral components using a density separator. The floating plastic debris will be collected in a density separator using a custom 0.3-mm filter, air-dried, and plastic material is removed and weighed to determine the concentration of microplastics.
- Bathymetry survey undertaken along major creeks of the BCA. DGPS positioning system and Single Beam Echo sounder system was used for carrying out the bathymetry survey, from the mouth to the interior of the creeks with the depth contour at 30 m spacing. The raw water depth is reduced to chart datum (CD) using predicted tide at the survey area. The navigation data from the DGPS will be logged continuously and monitored using the Starfix navigation suite
- Human-crocodile-conflict (HCC) dynamics: Using population viability analysis (Vortex version 10.5.0.0) to investigate how the SWC population in a marine protected area: (a) behaves in the presence and absence of an ongoing species recovery strategy, (b) responds to changes in specific demographic and environmental parameters, and (c) varies in response to a notional management intervention.

Key results

Water Quality

- Salinity in the BCA waters varied from fresh water (0.04) to seawater (32.8) conditions. Significant variation ($p<0.05$) in salinity was noticed among all sectors and seasons. Seasonal and spatial changes in salinity occur primarily in response to changes in freshwater inflow from the Brahmani and Baitarani rivers. The pH in the surface waters of the BCA were in the range of 6.66 to 8.03 with lower pH values showed during monsoon. Among the sectors the DO saturation varied as follows Maipura **>** Brahmani **>** Dhamra **>** Mahanadi **>** Bhitarkanika. In general, BCA waters accounts for the non-chlorophyll suspended matter as dominant fraction in TSS; as strong tidal hydrodynamics plays a key role in the suspended sediments concentrations as observed in meso- and macro-tidal estuaries.
- Bhitarkanika waters recorded higher DIN values, as most of the DIN as nitrate comes through runoff and flushing from the watershed area. In DIN, the contribution from each fraction varies as follows nitrite < ammonium < nitrate. Among the seasons, DIN was observed to be higher during monsoon followed by pre-monsoon and post-monsoon. No significant variation for DIP were noted between different sectors in Bhitarkanika region. Relatively higher DIP concentration from the Mahanadi mangroves were noted with respect to Bhitarkanika mangrove waters. DSi concentrations were observed lower during pre-monsoon and higher in monsoon point out that intrusion of silicate through the river. Nutrient distribution at different sectors during different seasons clearly specifies that apart from the riverine/marine sources, internal cycling mechanisms, water sediment interaction and influence by mangrove litter processes regulate the nutrient chemistry in BCA.
- The concentration of major ions in the BCA waters are Na**>**Mg**>**SO4**>**Ca**>**K**>**HCO3 **>**CO3. Among the seasons, major ions dominate during pre-monsoon and diminish during monsoon. Significant ($p<0.05$) spatial and seasonal variations were noticed for all major ions in BCA waters during this entire annual cycle.
- Salinity variation among the surface waters of Gahirmatha is relatively larger than the variation noted among bottom waters. As observed in the salinity stratification layers the DO values noted in the bottom waters of Gahirmatha area are also lower as usual, due to less diffusion. Both DIN and DIP values showed higher values in the southern part compared to the northern part of

Gahirmatha waters; this might be due to the influence from Paradip port activities. All the N fractions along with DIN and DIP in the bottom waters are relatively higher compared to the surface waters. Contrast to the other nutrients DSi showed higher values at the surface than bottom waters. Elevated concentrations of major ions (Na, K, Ca, Mg, SO4) observed in entire coast except near Mahanadi area. Overall, major ions in the Gahirmatha waters follow the conservative nature.

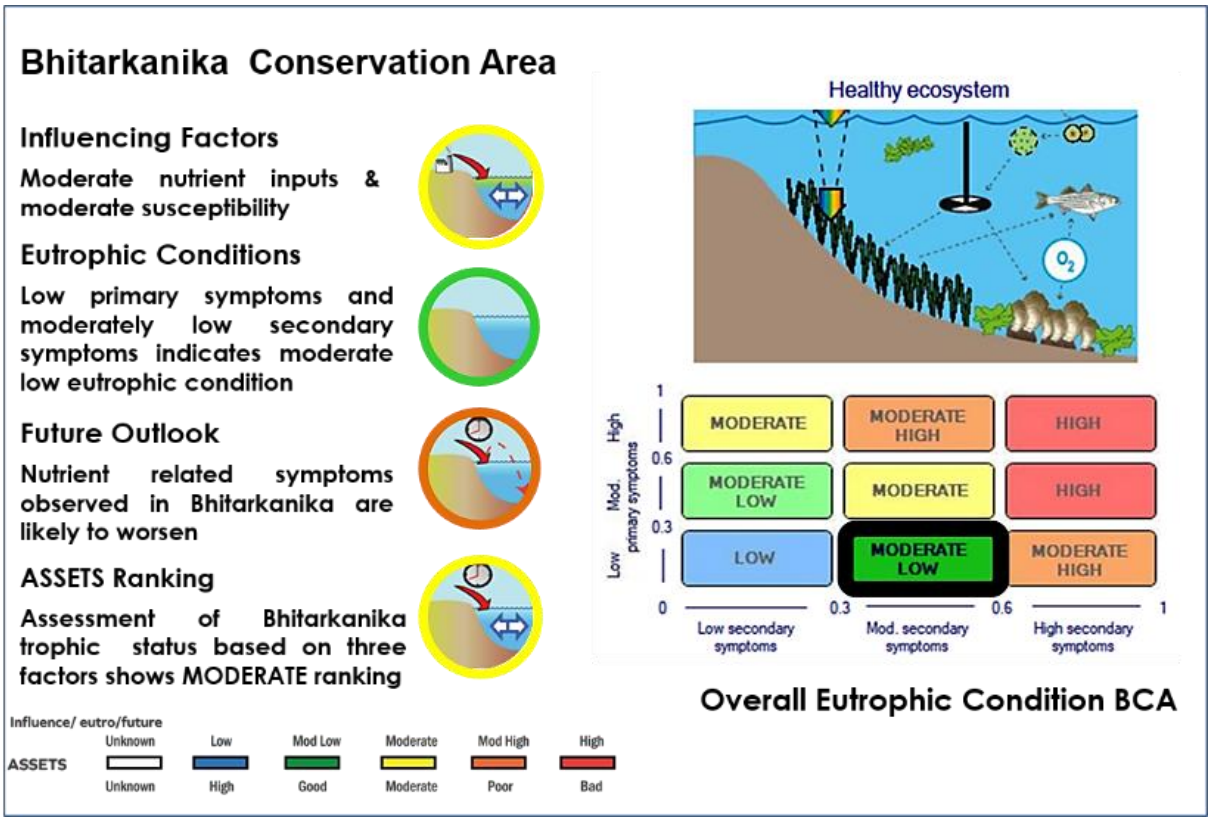

Figure 3: Trophic Status of Bhitarkanika Mangroves using ASSETS model

Hydrodynamic Environment

Coastal processes data such as bathymetry, tides, currents, and sediments have been surveyed and collected over the Bhitarkanika region during February and March 2022. The bathymetry of the Bhitarkanika region is shown in Figure 4, clearly indicating highly variable bathymetry in the creeks and at the mouth of the region. The bathymetry is varied between 0.4 m and 20.5 m in and around the Bhitarkanika region. The creek, which channels through the mangrove region, has a bathymetry that varies between 0.4 and 12 meters of depth and is highly silted in a few regions due to bank erosion and river sediments. The surveyed bathymetry data is very useful for the deployment of real-time monitoring buoys to observe the seasonal and annual variations of the water environment and water quality parameters in the Bhitarkanika region. In addition, this data is very useful for designing the bank erosion protection measures to maintain the creek tidal flow conditions.

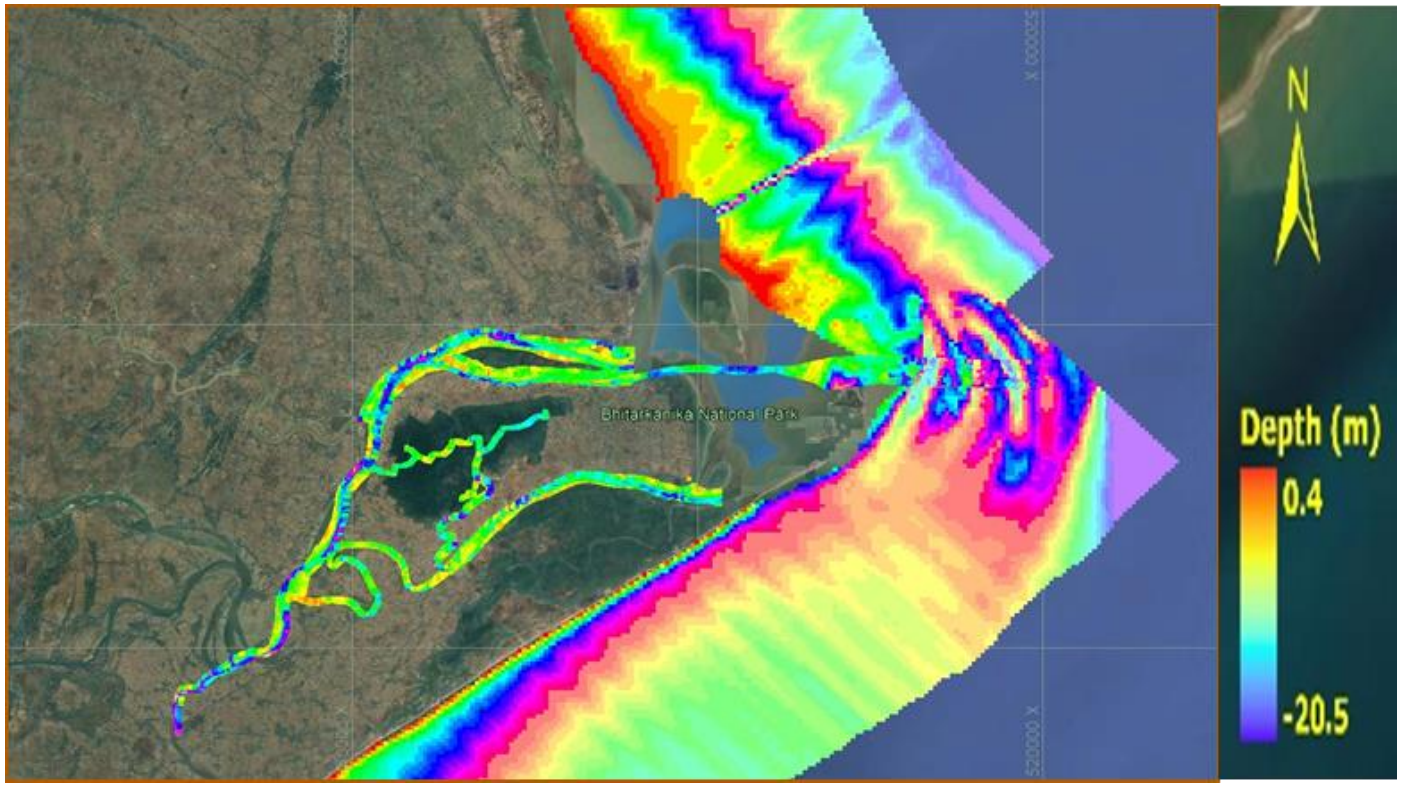

Figure 4: bathymetry in the creeks and coastal regions of the Bhitarkanika

Along with the bathymetry survey, oceanographic instruments have been deployed at various locations in and around the Bhitarkanika region during the same period as above to measure the tides, currents, and river discharge to understand the tidal flow environment and fluctuations in the river discharge (Figure 5). The tidal amplitude is varied between -1.35m and 1.35 m and high in the narrow creek region. The maximum tidal currents varied between 80 cm/s and 120 cm/sec; however, they are maximum at the Bramhani River confluence and Kola region due to the additional flow from the river along the tidal currents and the narrow creek at the Kola. The surveyed oceanographic parameters are very helpful to understand the future projections of the hydrodynamic flows and nutrient dynamics in this region.

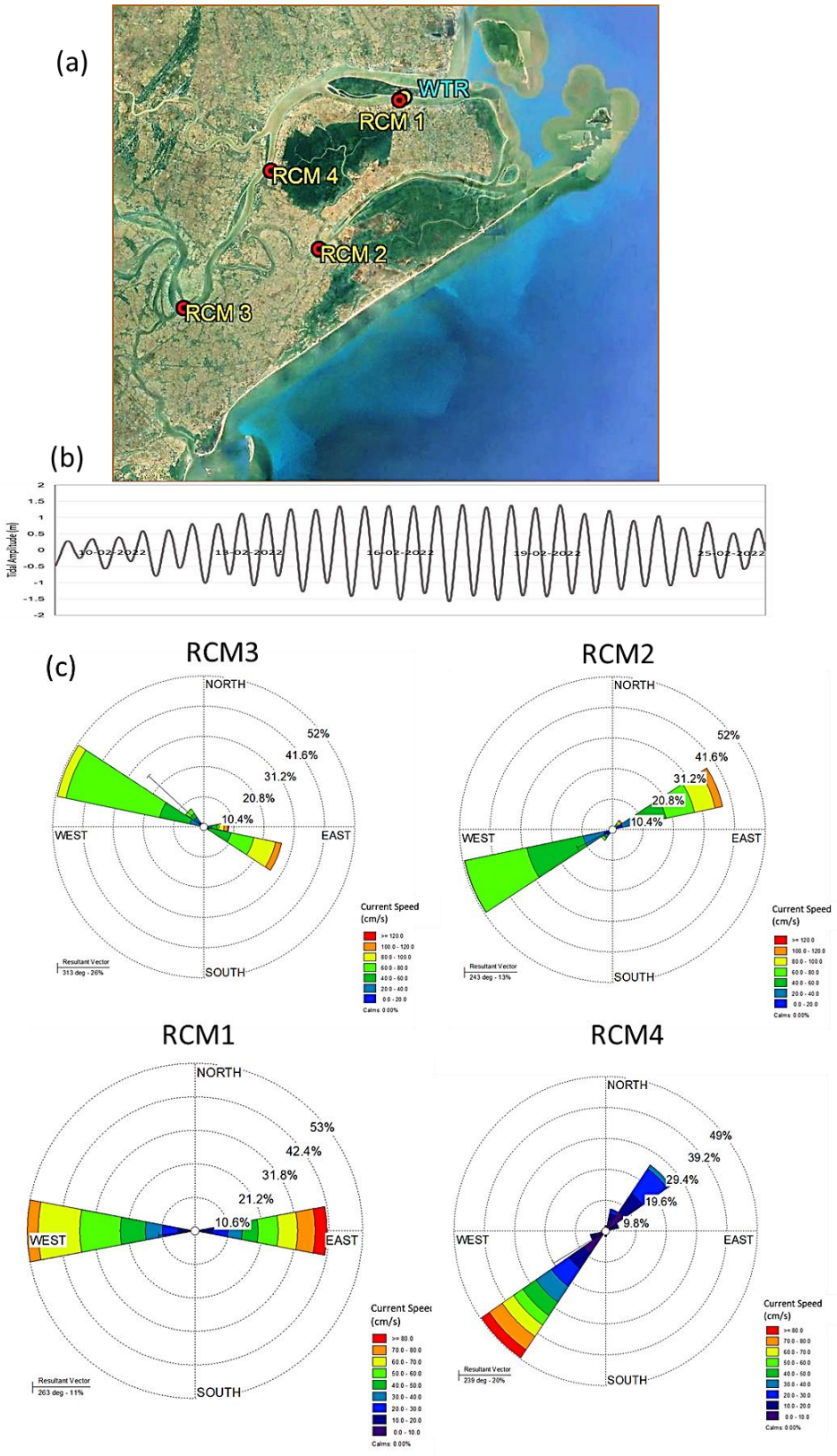

Figure 5: (a) deployed locations of the oceanographic instruments; (b) tidal amplitude at the Kalibhanjadia; (c) tidal currents at four locations of Bhitarkanika region.

Benthic habitat

Sediment sampling for benthos was carried out in the subtidal region of selected stations by operating a motorized fibre boat and collected using a stainless steel Van Veen sediment grab sampler (with sampling area - 340 cm^2).

Macrofauna: 13 higher taxa, represented with a total of 79 individual species belonging to 53 genera of macrofauna were recorded. Polychaeta, Isopoda, Amphipoda, Tanaidacea, Bivalvia, Gastropoda, and others (Cumacea, Ostracoda and Decapoda Nemertea, Sipuncula, Ophiuroidea, and Hydroids) were the major taxa identified. Of these, Polychaeta was observed to be the dominant group in terms of diversity, represented with a total 32 species. Amphipoda was the next dominant groups with a total representation of 18 species. The numerically most abundant macrofaunal species was *Parapsuedes* sp. belonging to Tanaidacea. In Polychaeta, *Nephtys* sp. and *Lumbrinereis* sp. were numerically abundant.

The percentage compositions of macro benthos based on total abundance data in BCA area during the year 2022 reveal Polychaeta to be the dominant group contributing about 43% of the total macrobenthic density. Tanaidacea represented with a single species was the next major dominant group with contribution of 29% to the total macrofaunal density, followed by Amphipoda contributing 15%, other taxa 6%, Bivalvia 4%, Isopoda 2% and Gastropoda 1%. The population density of macrobenthic community was found to vary between 214 to 2019 ind/m^2. The maximum density was recorded at Bhitarkanika during April 2021 and min density at Dhamra during September 2021. The species richness varied from 2.35 to 7.75, with minimum value found during March 2021 at Brahmani and max during April 2021 at Bhitarkanika. The species evenness value varied from 0.48 to 0.93 with min value recorded during August 2021 at Bhitarkanika and max during August 2021 at Maipura.

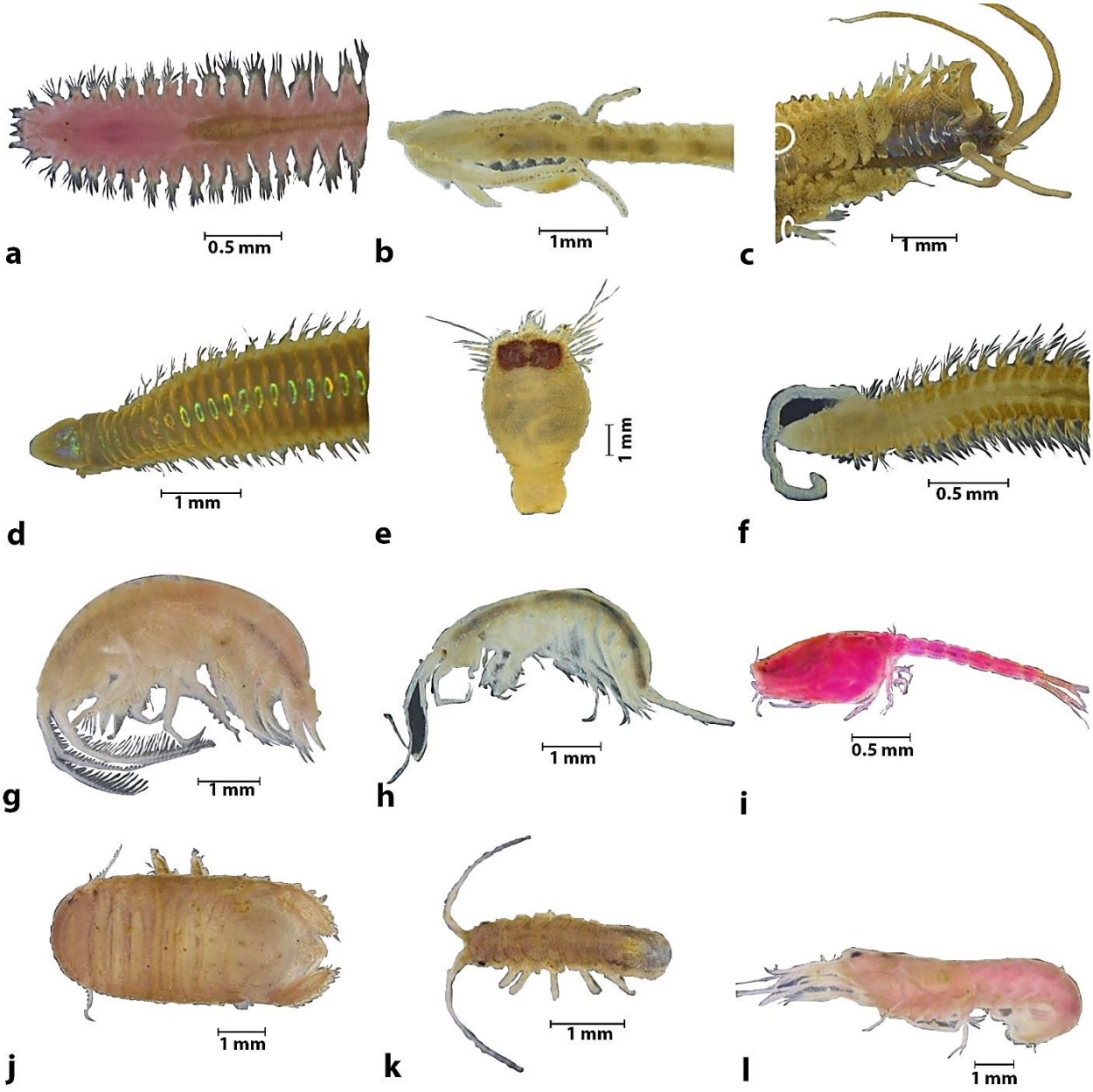

Plate 1: *Benthic macrofaunal species identified from Bhitarkanika Conservation Area.* ***A-L:*** ***a.*** *Nephtys sp.,* ***b.*** *Prionospio sp.,* ***c.*** *Diopatra sp.,* ***d.*** *Lumbrinereis sp.,* ***e.*** *Sternapsis scutata,* ***f.*** *Cossura sp.,* ***g.*** *Byblis sp.,* ***h.*** *Melita sp.,* ***i.*** *Cumacea,* ***j.*** *Flabellifera,* ***k.*** *Idotea sp.,* ***l.*** *Decapod.*

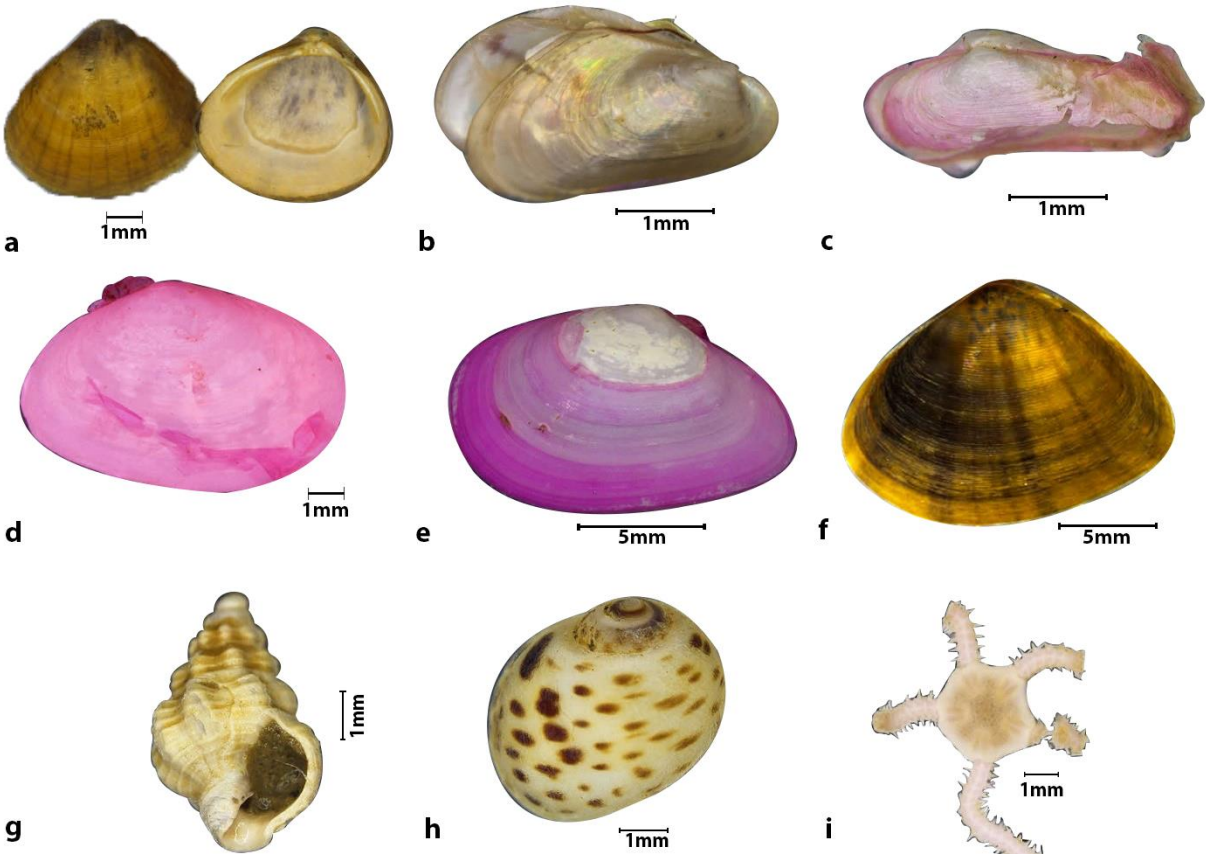

Plate 2: *Benthic macrofaunal species (Bivalves & Echinoderms) identified from Bhitarkanika Conservation Area* ***A-I****:* ***a.*** *Marcia opima,* ***b.*** *Modiolus metcalfei,* ***c.*** *Pholas orientalis,* ***d.*** *Scissulina dispar,* ***e.*** *Tellina versicolor,* ***f.*** *Meretrix casta,* ***g.*** *Cerithium scabridum,* ***h.*** *Natica tigrina,* ***i.*** *Brittle star.*

Meiofauna: 8 higher taxa, with a total number of 35 genera and 46 species belonging to 31 families of meiofauna were recorded from Bhitarkanika conservation area (Annexure 1). Of these, nematodes were found to be the dominant group with 32 species. The foraminifera, benthic diatoms, ostracod, benthic ciliates, copepoda, tubulinea, turbellaria and kinorhyncha were observed as the next dominant groups in terms of abundance with 25, 17, 11, 7, 5, 2, 1 and 1 species respectively. The percentage compositions of meiobenthos based on total abundance data in BCA area during the year 2022. Nematodes were found to be the dominant group by constituting 35% of the total meiobenthic organisms. Foraminifera were the next dominant group,

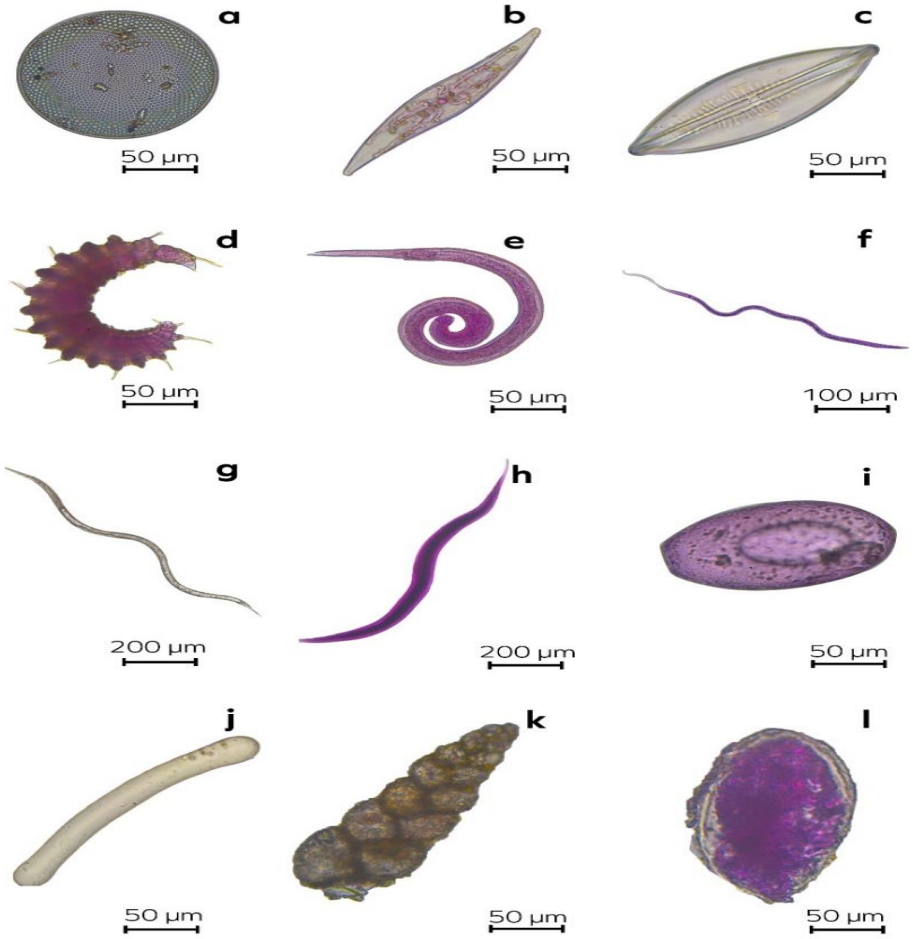

Plate 3: *Benthic meiofaunal species identified from Bhitarkanika Conservation Area* ***A-l:*** ***a.*** *Aulacodiscus sp.,* ***b.*** *Gyrosigma sp.,* ***c.*** *Navicula sp.* ***d.*** *Desmoscolex sp.,* ***e.*** *Desmodora sp.,* ***f.*** *Halalaimus sp.,* ***g.*** *Oxystomina sp.,* ***h.*** *Daptonema sp.,* ***i.*** *Allogromiid sp.,* ***j.*** *Parafissurina botelliformis,* ***k.*** *Bolivina sp. and* ***l.*** *Psammophaga sp.*

VIII. South Asia Nitrogen Hub Project (UKRI-GCRF, UK - 2021-2024)

Introduction

Coastal vegetation including mangroves, marshes and seagrasses are well known for their concurrent contribution to the regional nutrient cycle, water column productivity and to the global carbon sink (Macreadie, 2019). In tropical and sub-tropical conditions, mangroves are very important links between land and ocean and contribute to a large quantity of sediments and particulate organic matter (POM) to the ocean. For instance, the worldwide extent of total mangrove surface area is only 0.5%, yet they account for 10 - 15% to coastal sediment organic carbon and export to 10-11% of particulate carbon to the oceans (Alongi, 2014). Indian mangroves with total cover of 5403 km^2 represent 3.3% of global mangroves and about 56% of global mangrove species (Ragavan et al., 2019). The east and west coast of India cover 56% and 32% of the total mangrove cover of the country (Purvaja et al., 2018). It is estimated that Indian mangroves transport about 0.58 Tg C as POC and 0.04 Tg N as PN per annum into the northern Indian Ocean (Ray et al., 2018).

Two marine basins such as Bay of Bengal and Arabian Sea in the northern Indian Ocean, there is a significant difference in the input of dissolved inorganic nitrogen (DIN) through river fluxes to fresh production (Singh and Ramesh, 2011). The east coast rivers transport about 9 Tg N/yr, with the Ganges alone accounting for more than half (5 Tg N/yr), whereas the west coast rivers transport 4.3 Tg N/yr. The net anthropogenic nitrogen input (NANI) for India is estimated to be 4616 kg N/km/yr with the highest contribution from fertilizer N application (3322 kg N/km/yr) followed by agricultural N fixation (1098 kg N/km/yr), atmospheric deposition of oxidized N (390 kg N/km/yr) and N in net food and feed imports (-193 kg N/km/yr) (Swaney et al., 2015).

Among the nine major Indian watersheds, Ganges shows the highest NANI value overall (6955 kg N/km/yr) and Brahmaputra shows the lowest NANI (2223 kg N/km/yr) (Swaney et al., 2015). The vast majority of riverine DIN flux (81 percent in the Arabian Sea and 96 percent in the Bay of Bengal) is absorbed in river courses or in estuaries rather than being transferred to the coastal ocean (Singh and Ramesh, 2011). During the southwest monsoon, export DIN fluxes from Indian monsoonal estuaries along the west coast revealed 4 times higher N (607.1 ± 700.7 kg N/km^2/yr) than the east coast monsoonal estuaries (160.9 ± 369.0 kg N/km^2/yr), standardized by catchment area (Krishna et al., 2016). During dry and rainy periods (each of 6 months), the weighted net annual emission of N_2O from Indian estuaries is 0.71×10^{-3} and 0.46×10^{-3} Tg N_2O, respectively, and the yearly emission is 0.0006 Tg N_2O y^{-1} covering 0.027×10^6 km^2 of area (Rao and Sarma, 2013).

During the rainy and dry seasons, the Indian estuaries show a wide range of N_2O saturation levels, ranging from 70 to 631 percent and 75 to 567 percent, respectively. In Indian estuaries, the yearly mean N_2O saturation is 204 ± 137%. During the wet and dry seasons, the mean N_2O flux from Indian estuaries is 1.07 and 1.65 µmol N_2O/m^2/day, respectively, with an annual mean of 1.34 µmol N_2O/m^2/day. In comparison to world estuaries, the Indian estuaries have low N_2O saturation and fluxes due to mean low DIN concentrations and nitrification rates. Despite the large

amounts of nitrogen and phosphorus artificial fertilizers used in India, which are projected to end up in estuaries, they are hardly altered within the estuary due to high flushing rates during the rainy season (Rao and Sarma, 2013). The average flushing period for Indian estuaries is 10 days, compared to >40 days for European and American estuaries (Sarma et al., 2012). As a result, microbes are unable to efficiently oxidize ammonium, resulting in low nitrification rates in Indian estuaries. Furthermore, because there are less human settlements along the banks of Indian estuaries, domestic and industrial pollution is reduced. As a result, Indian estuaries emit less N_2O into the atmosphere than those found elsewhere. (Rao and Sarma, 2013).

Coral reefs are highly threatened by eutrophication, which can both predispose and prevent recovery following temperature-driven coral bleaching' (e.g., the 2016 event led to >95% coral death in some areas). Technology deployment by UK and India will allow investigation of historical change and source attribution using 15N techniques, while sharing reef monitoring protocols (inc. coral recruitment, predation). Comparison of uninhabited/populated atolls, supported by data on herbivorous fish stocks (inc. Laccadive, Andaman & Nicobar) in the context of ocean acidity, will help inform how much agricultural and waste-water measures could aid coral recovery. The comparison of the forest epiphyte and coral symbioses will inform both biological understanding and societal perceptions of 'value' in comparison to other key threats.

Objectives

- Review and Identification of Best management practices
- Identify long list and short list of BMPs for farmers relevant for nitrogen management
- To quantify how much eutrophication predisposes reefs to CORAL BLEACHING and prevents recovery, sharing observational capability to improve understanding and inform mitigation strategies.
- To assess the relative contributions of SOIL, FRESHWATER and MARINE N POLLUTION to human and ecosystem health
- Predicting the impact of the N flows on the coastal waters

Study sites

Southeast Asia has been considered the study region to understand the best management practices and to prepare a list of the best management plans for farmers relevant to nitrogen management. The Indian peninsula intersects the north Indian Ocean into the Bay of Bengal (east coast) and the Arabian Sea (west coast). The west coast has a steep continental shelf and lacks major deltas and rivers and is dominated by sandy and rocky substratum, whereas the shallower east coast is characterized by major deltas and large estuarine systems. Major mangrove ecosystems from four coastal states along east coast and three coastal states along west coast were identified to understand the particulate organic matter dynamics (Figure 1).

Site specific areas such as Lakshadweep and the Maldives' coral reef areas are considered to assess the impact of nitrogen flow on the ecosystems and the health of human beings. In addition, the present study, we considered three deltaic systems such as the Ganges Delta, the Mahanadi Delta, and the Godavari Delta along the east

coast of India to quantify the ammonia concentration to enter into the coastal waters when it transferred from the riverine systems to the coastal waters through the estuaries (Figure 2 and 3). These three deltaic systems are dominated by the monsoonal river discharge and contribute the major quantity of the nitrogen compared to the other systems along the Indian coast.

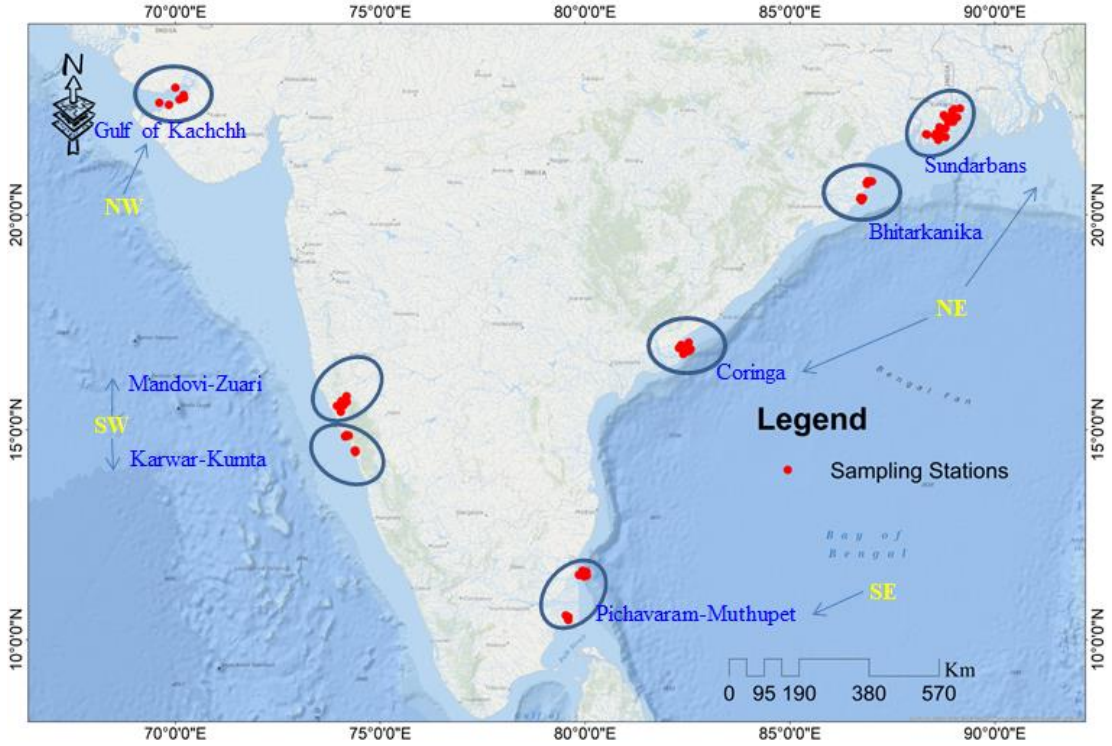

Figure 1: Map of the studied mangrove ecosystems along the east coast (Sundarbans, Bhitarkanika, Coringa and Pichavaram and Muthupet) and west coast (Gulf of Kachchh, Mandovi and Zuari, and Karwar and Kumta) of India.

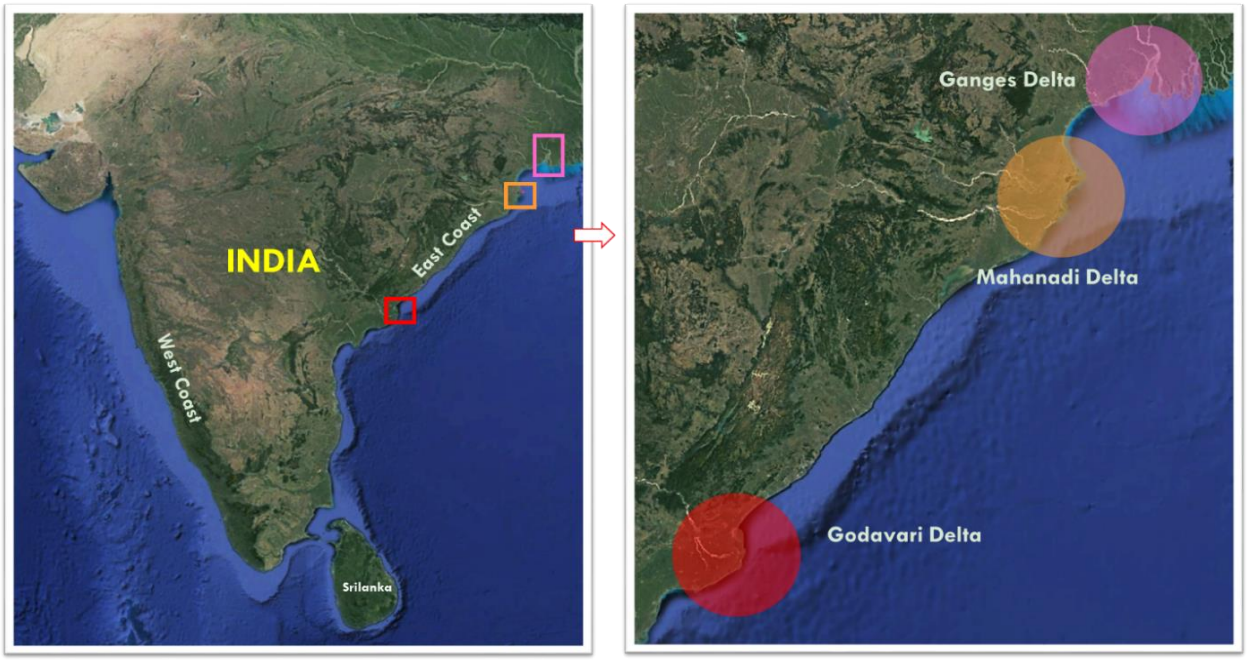

Figure 2: study area to understand the impact of N flow along the Indian coast.

Figure 3: study areas for the coastal estuarine modeling along the east coast of India

Methods

Surface water samples were collected from seven major mangrove ecosystems of India, during the dry period (from December 2016 to March 2017) (Figure 1). Based on the areal extent and accessibility, duplicate water samples along the salinity gradient were collected from the mangrove waters along the north east [NE; Sundarbans (21 locations) in West Bengal; Bhitarkanika, (17 locations) in Odisha; Coringa (11 locations) in Andhra Pradesh], south east [SE; Pichavaram-Muthupet (11 locations) in Tamil Nadu], south west [SW; Mandovi-Zuari (17 locations) in Goa, Karwar-Kumta (14 locations) in Karnataka] and north west [NW; selected locations of Gulf of Kachchh (7 locations) in Gujarat] coast of India. Samples for DOC in glass bottles and POC in amber coloured tarson bottles were collected) and preserved in dark at 4°C. In-situ measurements of water quality (Temperature, Salinity, pH and Chlorophyll-a (Chl-*a*) were carried out using a pre-calibrated water quality probe (HYDROLAB).

Analysis of nutrients was carried on filtered water samples following the standard spectrophotometric procedures (Grasshoff et al., 1999). The analytical precision of nitrate + nitrite (NO3+NO2), ammonium, phosphate and silicate were ±0.02, ±0.02, ±0.01 and ±0.02 µM, respectively. SPM was measured as the weight of material retained on 0.2 µm polycarbonate filter (Millipore) after passing 250 ml of water followed by oven drying for 24 hours (60oC). Concentrations of DOC was measured after the water samples were filtered through pre-combusted 0.7 µm GF/F filters, using TOC analyser (Elementar Vario TOC Cube) following high temperature catalytic oxidation method.

ANOVA was performed separately for the samples collected along the east and west coast, to analyse the spatial variations in dissolved nutrients, SPM, POC, PON and POC/PON among the selected mangrove waters. Tukey post hoc multiple comparison test was performed to identify the difference among sample groups. Stepwise multiple regression analysis with backward elimination technique was applied to explain the variability and to identify the major predictors of DOC/POC ratios for each of the studied mangrove ecosystems along the Indian coast. ANOVA and stepwise multiple

regression analysis were performed using the MiniTab 16 software, and all plots were created using Grapher (version 5.0), and Microsoft excel.

The integrated coupled modeling system, which is the combination of a hydrodynamic model and an Eco-Lab nutrient model, has been configured over the two deltaic systems, and simulations have been carried out for the Hooghly estuary and the Bhitarkanika estuary during the dry seasons of the years 2018 and 2022 to estimate the ammonia concentrations from the river front to the mouth of both the estuaries at various locations (Figure 4). It uses this as an accurate input concentration of ammonia for the marine models. It also explained the bio-geophysical processes in the estuarine region of the deltaic riverine systems.

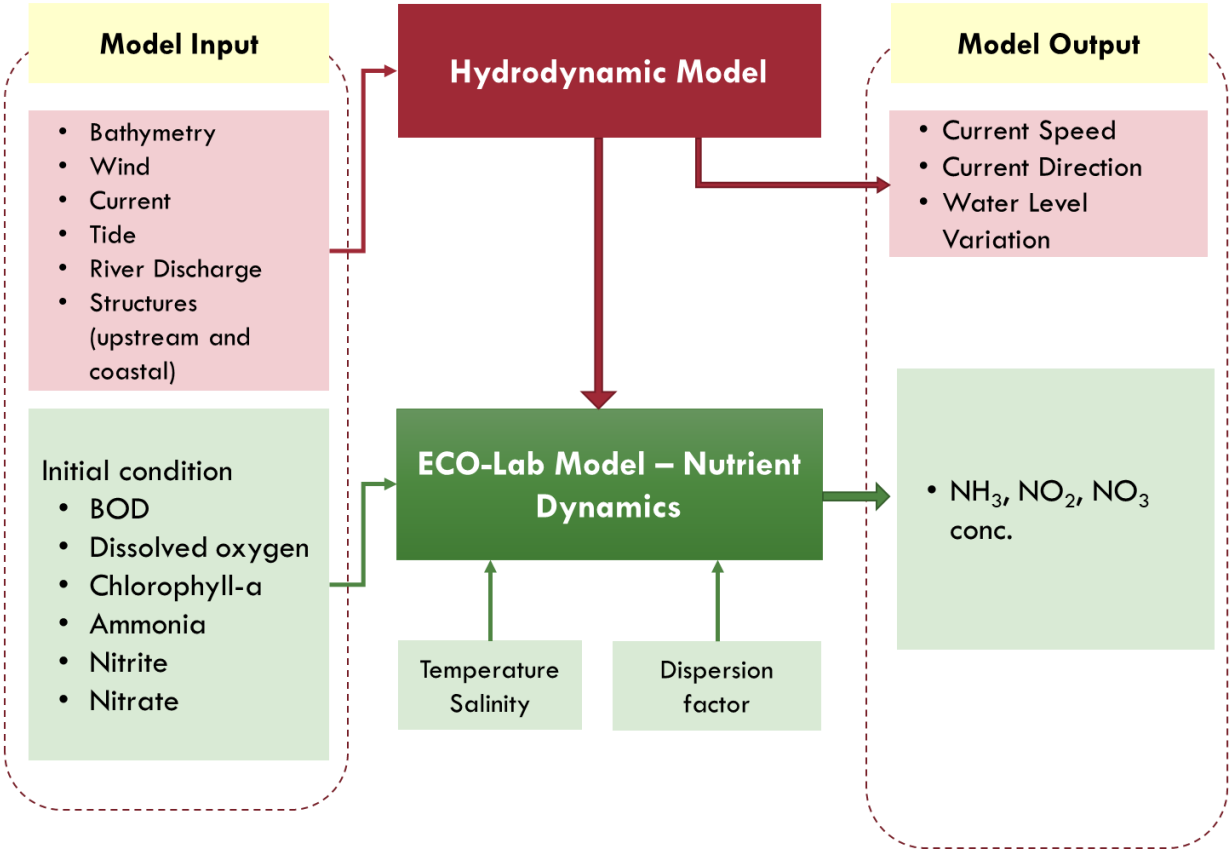

Figure 4: Integrated coupled modelling system to simulate and estimate the ammonia concentration at the estuarine mouths over three deltaic systems such as Ganges, Mahanadi and Godavari.

Key Results

South Asia N scenario description

Net anthropogenic nitrogen inputs (NANI) has emerged as a useful technique for assessing the impact of human activities on the nitrogen cycle process in watersheds, opening up new avenues for research into nitrogen flux responses. NANI makes it simple for policymakers to identify the key anthropogenic N sources in a region and, as a result, to assist them set management priorities. Efforts were performed in this endeavor to assess nitrogen inputs from anthropogenic activities in Pulicat watershed.

NANI is a nitrogen budgeting method that considers nitrogen inputs from the atmosphere, chemical fertilizer application, agricultural nitrogen fixation, and net nitrogen import in food and feed (NFF) (Howarth et al., 2006). The Pulicat watershed (the subject of this case study) is split between two coastal Indian states, with 26% in Tamil Nadu (Thiruvallur district) and the remaining 74% in Andhra Pradesh (Nellore and Chittoor district). The release of domestic and municipal sewage, fertilizers from agricultural fields, and aquaculture ponds placed along the lagoon's shore are the main sources of nitrogen in Pulicat Lagoon.

The Arani and Kalangi rivers drain into the lagoon on a regular basis, carrying with them land-based fertilizers and agricultural runoff. Overfishing, habitat fragmentation, pollution from chemical fertilizers, and thermal power plants have all contributed to the lagoon becoming a victim of numerous environmental stressors in recent decades. In general, nitrogen inputs to the Pulicat watershed were 3873 kg N/km^2/yr (75.7%) from fertilizer N application, 957 kg N/km^2/yr (18.7%) from agricultural nitrogen fixation, 373 kg N/km^2/yr (7.3%) from atmospheric deposition, and -84 kg N/km^2/yr (-1.7%) from NFF. The estimated NANI values for the Pulicat watershed (5119 kg N/km^2/yr) are close to those for the Godavari (4181 kg N/km^2/yr), Krishna (5191 kg N/km^2/yr), and Cauvery (5913 kg N/km^2/yr) river basins in South India**Error! Bookmark not defined.**. The Pulicat watershed's NANI is likewise comparable to data from the northeastern United States (560 to 4500 kg N/km^2/yr)^2 and Europe (<1000 to over 20,000 kg N/km^2/yr) (Billen et al., 2011).

Overall, fertilizer, atmospheric fixation, particularly in crop fields, and animals in the form of food and its products account for the majority of anthropogenic N input in the Pulicat watershed. Some of it is deposited in the soil, and the excess N is leached and flows into rivers and streams. NANI has a direct impact on the export of nitrogen to coastal waterbodies, resulting in environmental problems. In the pre-monsoon period, the riverine export flux of DIN for the lagoon was predicted to be 191 x 103 kg/yr. The annual average N flow from the rivers to Pulicat is calculated to be 574 x 103 kg/yr, assuming a five-fold increase in DIN flux during monsoon as observed in other east coast rivers.

The entire export flux of dissolved N through rivers is predicted to be 1723 x 103 kg/yr, with organic N accounting for approximately 75% of total TDN. This export value was about 10% higher than the Pulicat Lagoon's estimated N inputs in NANI (5119 kg N/km^2/yr of N). In the Pulicat watershed, anthropogenic N inputs from fertilizer predominate, reflecting the pressures of agricultural growth. In comparison to the other two districts, fertilizer use is notably high in the agricultural sections of the Nellore district. Excess nitrogen is a major available source of N to rivers and coastal seas, despite crop production and uptake of N from fertilizer application. The NANI from land sources into the Pulicat watershed was dominant because the rice planting area in this region made up a large portion of the entire planting area in the Pulicat region. In the rice planting system, the fertilizer N input was significantly higher, and the loss was likewise relatively high.

Review and identification of best management practices

Nitrogen losses from the cultivated field can be reduced by using appropriate technologies and practices to increase the availability of nitrogen for plant use, improve crop N absorption capacity, and match nutrient inputs to agronomic needs. For the betterment of the environment, ecological, and economic status, nitrogen usage efficiency (NUE), or the efficiency with which plants consume and retain nitrogen in the soil, becomes a crucial issue for the agriculture sector in the Pulicat watershed area. Improved NUE has the ability to boost yields and earnings while having minimal negative environmental consequences. Implementing best management practices (BMPs) that lead to increased recycling within the system is required to achieve nitrogen use efficiency (NUE) in crop production. Even under well-managed conditions, nitrogen utilization efficiency in the rice fields of the Pulicat watershed is predicted to be less than 40%. To achieve a greater fertilizer usage efficiency, it is advised that fertilizer ingredients with a higher NUE than urea be encouraged.

Promoting the zero budget natural faming (ZBNF) technique, which requires less water, could be a long-term option for reducing nitrogen loss in agriculture. Techniques such as proper fertilizer delivery based on acreage, organic fertilizing, and fertilizing process improvements could increase crop output while lowering N inputs. Micro-irrigation, sprinkler irrigation, straw mulching, and other techniques can help increase crop yield. Using appropriate nitrification inhibitors or urease inhibitors, as well as neem coated urea and smart crop rotation, could significantly improve NUE.

Role of eutrophication in exacerbating coral bleaching and coastal impacts

Coral bleaching was observed due to rise in SST prior to the onset of monsoon (May 2022) at Palk Bay and the Gulf of Mannar was observed. Most of the bleached corals recovered after the onset of monsoon when water temperature became optimal (Figure 5). Coral reef monitoring was carried out during the month of February 2023 at two sites in the Gulf of Mannar and the Palk Bay as per the mandate of the project. Due to lack of visibility LIT survey was not possible in the previous months. Turbidity and algal bloom were the two major obstacles to carry out reef monitoring during the monsoon and post-monsoon season.

Degraded state of reef in both the surveyed sites were recorded and also phase shift was evident as live coral cover was very low and macroalgae seemed dominant (Table 1 and 2). Diversity and abundance of macroalgae and sponge were much higher and noteworthy at Palk Bay. Hence, high degree of competition with live corals was observed. Lack of reef fishes and other herbivores in the surveyed reef areas were noted during the survey. This might be due to overfishing in the shallow water reef areas adjacent to the shores.

Table 1: Percentage benthic cover at Ervadi, Gulf of Mannar

Live coral	**11.92**
Dead Coral	20.77
Macroalgae	24.97
Rubble	37.68

Sand	4.67

Figure 5: Bleached and unbleached colonies of *Porites* sp.

Algal bloom (*Noctiluca* sp.) due to eutrophication (September & October, 2022) was recorded at the reef areas in Ervadi, Gulf of Mannar. Fish mortality was noted due to the harmful algal bloom (Figure 6).

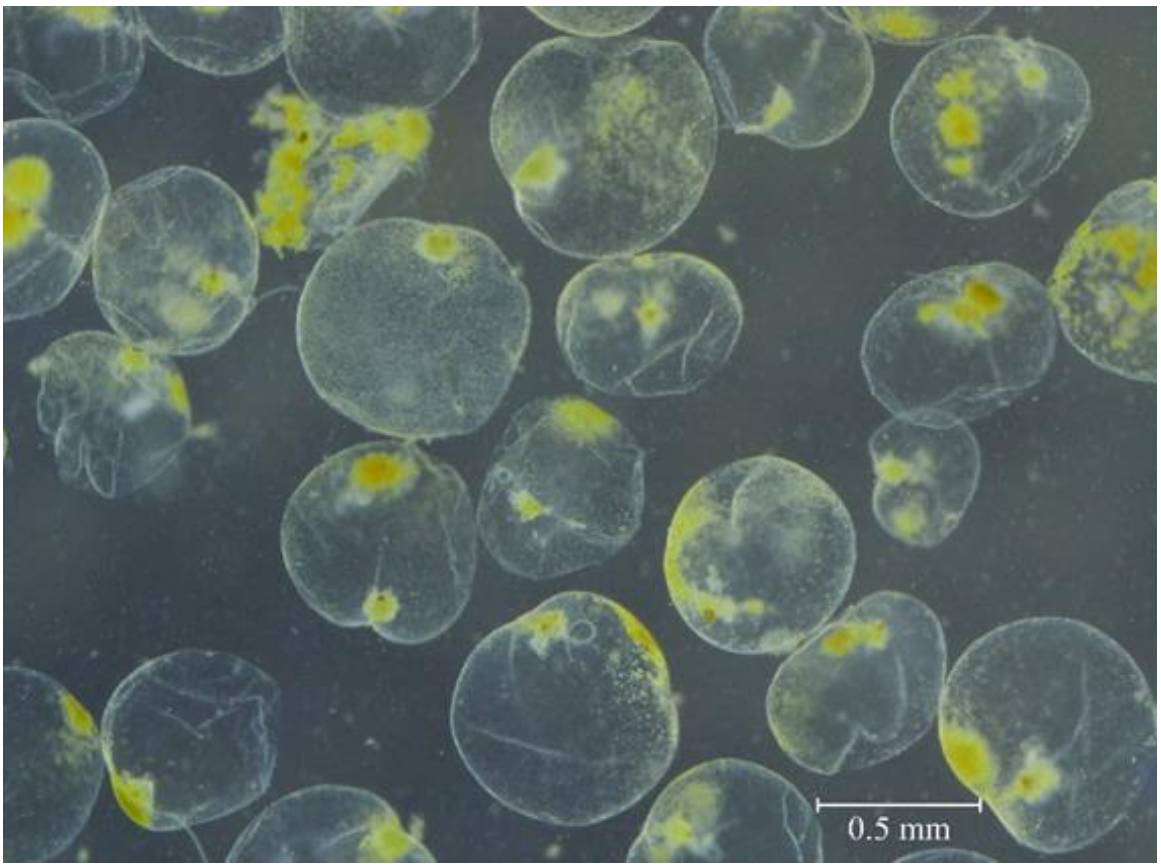

Figure 6: *Noctiluca* sp. as observed in the collected algal bloom samples

Table 2: Percentage benthic cover at Thonithurai, Palk Bay

Live coral	**10.33**
Dead coral	6.28
Macroalgae	29.40
Rubble	35.60
Sponge	18.08
Others	0.30

Distribution and dynamics of particulate organic matter in Indian mangroves

Indian mangrove systems displayed a wide range of hydrological conditions during the non-monsoon season. During the study surface water temperature varied between 25.52 and 33.76 ºC (mean, 30.04±2.31ºC) (Table 2). Salinity ranged from 9 to 42.0 and considerably higher mean salinity was recorded in the west coast mangroves (29.7±10.9) compared to the east coast mangroves (20.7±8.7) (Figure 2a). The lower mean salinity in the mangrove waters of east coast could be attributed to the consistent discharge from the perennial rivers of east coast, even in non-monsoonal periods (Rudra, 2014).

The concentrations of the DIN ranged from 5.54-318 µM (mean 94.4±82.5) and was higher than the concentrations reported earlier from the Indian mangroves (55.7±107 µM). These values were consistent with global ranges reported from mangrove waters (27.3-339.2 µM). The range of DIP and DISi varied from 0.03-35.9 µM (3.4±7.8) and 0.8-1308 µM (125±197), respectively and were lower than previously reported values from Indian mangrove waters (8.57±6.13µM and 194±132 µM; Rao et al., 2018). Significantly higher concentrations ($p<0.001$) of dissolved ammonium (NH_4^+) (203±6.9 µM) and DIP (29.8±5.5 µM) were, recorded from NW mangroves, relative to other Indian mangrove waters. The mean N/P and Si/N ratios in these mangrove waters were found to be ~126±313 and 1.98±1.57, respectively. The ratios of dissolved inorganic nutrients indicated a deficiency in dissolved phosphorus relative to dissolved nitrogen in Indian mangrove waters. The mean dissolved inorganic N/P and Si/N ratios along the east (153±51.1 and 2.0±0.14, respectively) and west (86±11 and 2.1±0.39, respectively) coast of India indicated higher enrichment of DIN with respect to DIP for the east coast relative to west coast.

Suspended particulate matter (SPM) is a key component of coastal food web and a key variable of nutrient budgets. It varied from 44.4 to 290 mg l^{-1} (122±55.5 mg l^{-1}) in the Indian mangrove waters during the study period. These values were higher than those reported earlier from Indian mangroves (88.6±12.4 mg l^{-1}) and lower than Iranian mangroves (344±180 mg l^{-1}). Mean SPM concentrations were about~1.6 folds higher in west coast than east coast of India. Further, the SPM concentrations of NW (170±24) were highest compared to other mangrove systems and were attributed to sediment resuspension caused by high tidal amplitude at NW region. The phytoplankton biomass, in terms of Chl-*a* varied between 1.1 and 28.0 mg m^{-3} in Indian mangroves and it was consistent to earlier reports. The mean concentration of Chl-a during study period was relatively higher in the west coast (9.5±1.4 mg m^{-3}) than the

east coast (6.1±0.8 mg m^{-3}). These spatial variations in Chl-a were consistent with dissolved oxygen saturation which varied between 61.9 and 131%, with the mean saturation of 85.1± 12.5% (east coast) and 94.2± 16.7% (west coast) in the mangrove waters (Figure 7).

Coastal acidification and deoxygenation, inextricably associated through the process of heterotrophic respiration, could occur at extreme levels when the coastal zone receives a large quantity of natural/anthropogenic nutrient and organic matters. Considerably, high abundance of dissolved nutrient (dissolved inorganic nitrogen in particular) in Coringa waters along the NE coast and in Gulf of Kachchh along the NW coast, clearly indicated the influence of intense anthropogenic activities in these mangrove waters. Low mean pH (pH < 7.7; except Sundarban waters) and persistence of DO under-saturation (except Karwar and Kumta waters) in most of these mangroves revealed the dominance of heterotrophic respiration and depletion of dissolved O_2 in the water column. Intensification of land based sources of contaminants and organic matter could further deteriorate the mangrove water quality and reduce the growth and survival of early-life stage aquatic organisms in this unique intertidal environment.

Mangrove ecosystems along Indian coast, substantially contributes to the organic carbon pool across the intertidal landscape, with spatial variations caused by variable contribution of primary producers and anthropogenic activities along the coast. Present study revealed that POC and PN present in SPM of the mangrove waters along east coast were almost two times higher than those of the west coast of India. POC and PN were strongly correlated in all mangrove waters indicating their identical origin (i.e., particulate organic matter) in the individual ecosystems, during non-monsoon period. It was evident that mangrove litter, marine phytoplankton and marine sediment form the dominant POC pool for the Indian mangrove ecosystems.

Presence of dissolved oxygen and resistance to microbial decomposition of organic carbon generated from multiple sources, primarily determines their stability and transformation in the mangrove water columns. In particular, high DOC concentrations and DOC/POC ratios in the mangrove waters of Coringa indicated rapid transformation of organic carbon from particulate to more labile dissolved forms. Any alteration in local geomorphic settings in the coastal areas or changes in particle transport from the upstream areas may affect the production, storage and fluxes of carbon within the mangrove ecosystems and the subsequent export to the adjacent coastal waters.

Further, ecological changes (crab burrowing activity, primary production litter fall etc.) caused by various environmental factors (temperature, rainfall, detrital outwelling, coastal currents etc.) likely to have significant impact on the transformation and export of to the adjacent coastal waters. Conservation and restoration of intertidal landscape, characterized with healthy mangrove vegetation, is therefore critical to sustain ecological balance in coastal environment. Detailed studies on the origin and fate of different forms of carbon together with quantification of anthropogenic inputs and tidal fluxes will help to elucidate their functional role in mangrove carbon cycle along the Indian coast.

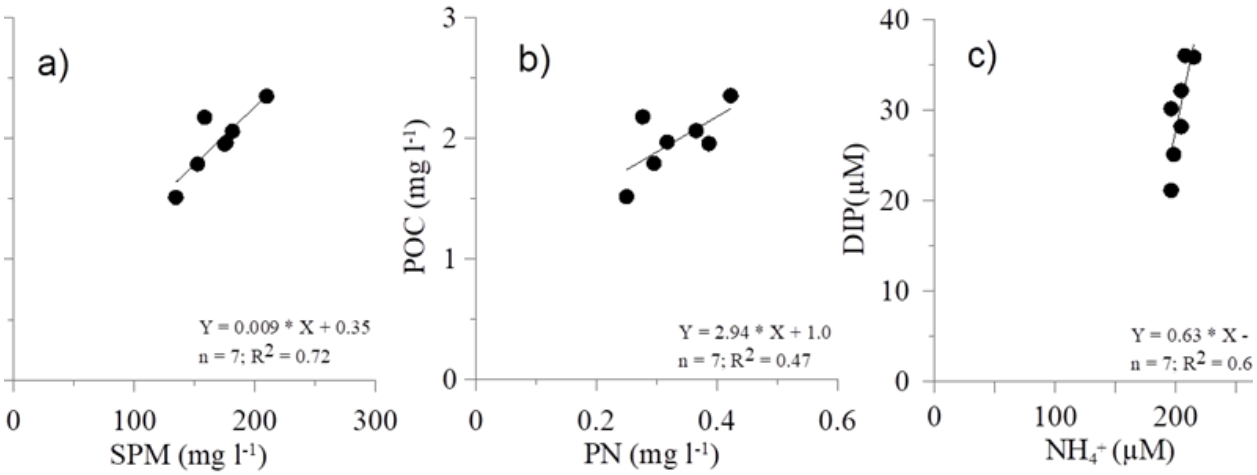

Figure 7: Correlations between a) SPM and POC; b) POC and PN; c) DIP and NH_4^+; d) Chl-a and SPM of Gulf of Kachchh, mangroves

Simulation of N flows using estuarine model

An estuarine model was simulated over the Hooghly estuary using bathymetry, tides, and river discharge with input of nutrient concentrations such as nitrate, nitrite, and ammonia during the dry season of 2018 (Figure 8). The model predictions clearly showed that the NO2 concentration changed from the river front to the mouth of the estuary by about 70.2% compared to the source concentration. The nitrate concentration (NO3) changed to negative from the river to the estuary mouth by about 27.3%, and finally, the ammonia concentration (NH4) changed by about 47.8% from the river front to the estuarine mouth (Table 3). The model simulations clearly indicate that the source concentration is highly undergone to the biogeochemical processes in the estuary and causes an increase in the concentrations of NO2 and NH4 while decreasing the concentration of NO2. The model predictions have to be reassessed to understand the vitality of the biogeophysical processes in the estuarine regions.

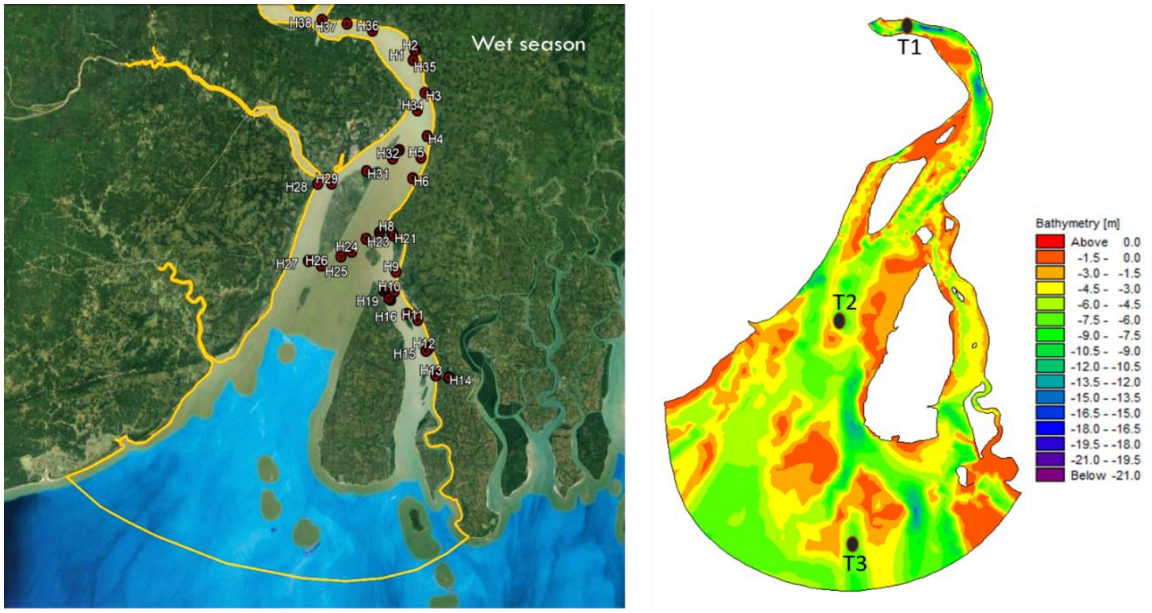

Figure 8: Study domain of the Hooghly Estuary with bathymetry

Table 3: variation of N concentrations in the estuary of the Hooghly

T1	Estuary Head
T2	Mid Estuary
T3	Estuary Mouth

Nutrients	Locations	AVG Conc.(mg/l)	Percentage Change (%) in concentration
NO_2	T1	0.008	
	T2	0.0209	
	T3	0.013	70.2
NO_3	T1	0.865	
	T2	0.355	
	T3	0.096	-27.3
NH_4	T1	0.091	
	T2	0.444	
	T3	0.225	47.8

Hydrodynamic Environment in and around the Bhitarkanika Region

Coastal processes data such as bathymetry, tides, currents, and sediments have been surveyed and collected over the Bhitarkanika region during February and March 2022. The bathymetry of the Bhitarkanika region is shown in Figure 9, clearly indicating highly variable bathymetry in the creeks and at the mouth of the region. The bathymetry is varied between 0.4 m and 20.5 m in and around the Bhitarkanika region. The creek, which channels through the mangrove region, has a bathymetry that varies between 0.4 and 12 meters of depth and is highly silted in a few regions due to bank erosion and river sediments. The surveyed bathymetry data is very useful for the deployment of real-time monitoring buoys to observe the seasonal and annual variations of the water environment and water quality parameters in the Bhitarkanika region. In addition, this data is very useful for designing the bank erosion protection measures to maintain the creek tidal flow conditions.

Along with the bathymetry survey, oceanographic instruments have been deployed at various locations in and around the Bhitarkanika region during the same period as above to measure the tides, currents, and river discharge to understand the tidal flow environment and fluctuations in the river discharge (Figure 10). The tidal amplitude is varied between -1.35m and 1.35 m and high in the narrow creek region. The maximum tidal currents varied between 80 cm/s and 120 cm/sec; however, they are maximum at the Brahmani River confluence and Kola region due to the additional flow from the river along the tidal currents and the narrow creek at the Kola. The surveyed oceanographic parameters are very helpful to understand the future projections of the hydrodynamic flows and nutrient dynamics in this region.

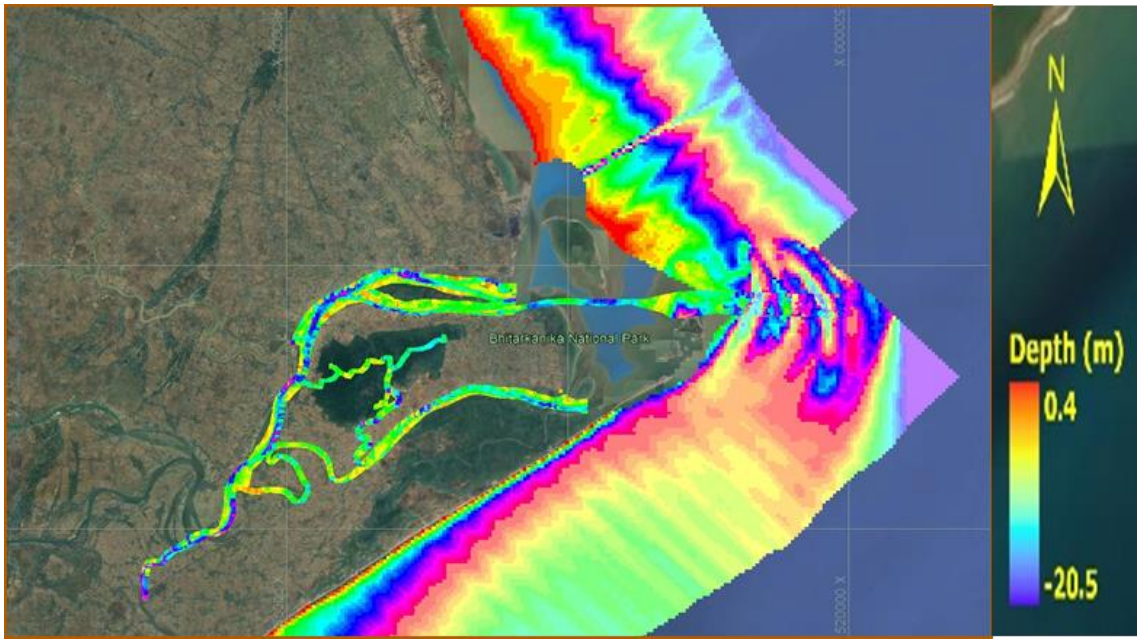

Figure 9: Bathymetry in the creeks and coastal regions of the Bhitarkanika

Significant Outcomes

- In the pre-monsoon period, the riverine export flux of DIN for the lagoon was predicted to be 191 x 10^3 kg/yr. The annual average N flow from the rivers to Pulicat is calculated to be 574 x 10^3 kg/yr, assuming a five-fold increase in DIN flux during monsoon as observed in other east coast rivers. The entire export flux of dissolved N through rivers is predicted to be 1723 x 10^3 kg/yr, with organic N accounting for approximately 75% of total TDN. This export value was about 10% higher than the Pulicat Lagoon's estimated N inputs in NANI (5119 kg N/km^2/yr of N).

- In the Pulicat watershed, anthropogenic N inputs from fertilizer predominate, reflecting the pressures of agricultural growth. In comparison to the other two districts, fertilizer use is notably high in the agricultural sections of the Nellore district. Excess nitrogen is a major available source of N to rivers and coastal seas, despite crop production and uptake of N from fertilizer application.

- For the Pulicat watershed, it is proposed that high-yielding, water-efficient agricultural varieties be promoted. Genetic interventions could help some crops improve their nitrogen recovery or use efficiency.

- The application of the leaf color sensing technique – which is used to detect nutrient deficit in plants – has the potential to reduce nitrogen fertilizer use on farms by 10%–15%.

- This technology, together with the use of urease inhibitors when utilizing urea-based fertilizers and better management of manure, wastes, and crop residues, might result in a 20–25 percent increase in India's NUE by 2030. In the Pulicat watershed, these approaches should be favored over synthetic symbioses and synthetic nitrogen fixation.

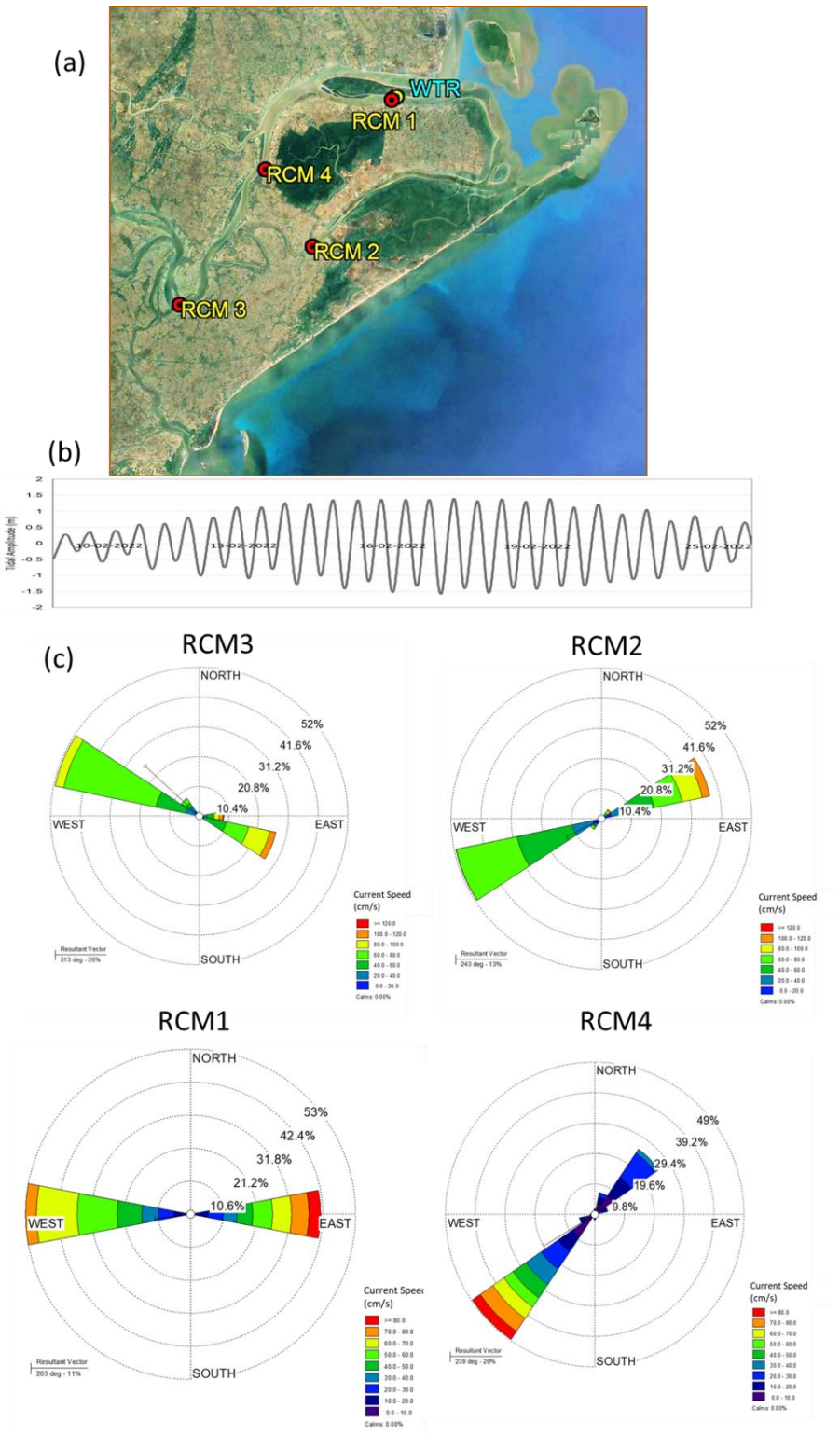

Figure 10: (a) deployed locations of the oceanographic instruments; (b) tidal amplitude at the Kalibhanjadia; (c) tidal currents at four locations of Bhitarkanika region.

- Most of the bleached corals recovered after the onset of monsoon when water temperature became optimal in the Palk Bay and Gulf of Mannar.

- Degraded state of reef in both the surveyed sites were recorded and also phase shift was evident as live coral cover was very low and macroalgae seemed dominant
- The POC and PN present in SPM of the mangrove waters along east coast were almost two times higher than those of the west coast of India.
- In particular, high DOC concentrations and DOC/POC ratios in the mangrove waters of Coringa indicated rapid transformation of organic carbon from particulate to more labile dissolved forms. Any alteration in local geomorphic settings in the coastal areas or changes in particle transport from the upstream areas may affect the production, storage and fluxes of carbon within the mangrove ecosystems and the subsequent export to the adjacent coastal waters.
- Estuarine model predictions clearly indicate that the source concentration is highly changed due to the biogeochemical processes in the estuary and causes an increase in the concentrations of NO_2 and NH_4 while decreasing the concentration of NO_2.
- The surveyed oceanographic parameters are very helpful to understand the future projections of the hydrodynamic flows and nutrient dynamics in this region.

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IX. Circular Economy Solution preventing Marine Litter in three Ecosystems (2022-2024)

Background

Plastic waste is one of the most significant pollutants in the oceans from India, where approximately 600,000 tonnes is washed into the oceans annually. Hence, reducing plastic consumption and waste along the value chain is of urgent importance. It is estimated that about 9 million tonnes of plastic waste are generated every year. Despite positive developments in India's plastic waste management strategy, Extended Producer Responsibility (EPR) is facing serious challenges, including a general lack of awareness among key stakeholders and a lack of capacity on municipal levels to collect low-value waste. Moreover, there are gaps in data about waste volumes and the types of packaging that are disposed of, making EPR schemes difficult to implement. Additionally, the effectiveness of single-use plastic bans and EPR systems remains to be seen, as well as the possible reduction in waste that might result.

The German Federal Ministry for Environment, Nature Conservation and Nuclear Safety (BMU) and Ministry of Environment, Forests and Climate Change (MoEFCC), Government of India have launched a collaborative project. In coordination with the MoEFCC, CES will demonstrate a range of technological approaches for tracking and monitoring waste in marine ecosystems. Additionally, the project will utilize EPR to reduce, reuse, and recycle plastics, involving such actors as recyclers, packaging manufacturers, and informal waste collectors. Through EPR, incentives could be offered to households, for instance, so that they separate waste at the source or return packaging items such as plastic bottles by introducing deposit schemes. Product design could also be positively influenced by EPR in terms of recyclability and reusability.

The selection of partner states (Kerala, Tamil Nadu and Uttar Pradesh) and ecosystems (coastal areas of Kerala and Tamil Nadu) and the type of activities were proposed by GIZ and MoEFCC. The selection was based on criteria such as ecosystem relevance, economic development, progress in plastic waste management and EPR, and current public and private sector capabilities. The two coastal states of Kerala and Tamil Nadu own a large portion of India's coastline. Both the backwaters of Kerala and the coastline of Tamil Nadu are severely affected by marine litter.

Rationale and Objective

This project aims to provide technical assistance, capacity building, institutional support, and accompanying services to assist in implementing the commitment to prevent marine litter and microplastics. The project aims as diverse as tracking, monitoring, and demonstrating technologies for reducing plastic waste, reusing, and

recycling it, and supporting the national framework for Environmental Protection in India. In addition to the project's target locations, the project results can be adapted, replicated and transferred to other regions. As well, the initiative will be aligned with the overarching government initiatives "Digital India" and "Make in India". The solutions will be developed in close cooperation with the private sector, which will prevent any backlash and ensure that the industry (recycling) is accepted and owned. The project supports discussions with national and international stakeholders, development of knowledge products (e.g., policy briefs, plastic credit trading guides), and business-to-business (B2B) partnerships on sustainable packaging material selection and product eco-design that inform the national EPR framework. Regular coordination is necessary between the MoEFCC on the two marine litter projects (CES and CCP).

Project Objective

The following five major objectives have been identified for the proposed project.

1. Riverine/Lake/Marine leakages and transport of plastics is monitored to assess the sources of microplastics and hotspots are identified in the three locations
2. Mapping of site-specific distribution of plastics, microplastics and litter in riverine systems to enable Decision Support System (DSS)
3. The training and capacity building for tracking leakage of litter in coastal and riverine ecosystems using digital tools
4. Technological solutions for litter management are identified and demonstrated in riverine and marine ecosystems in the states of Kerala, Tamil Nadu and Uttar Pradesh
5. Creating an evidence-based reference for project implementation at partner state

CES-ML Study sites India

Tamil Nadu: Greater Chennai Corporation

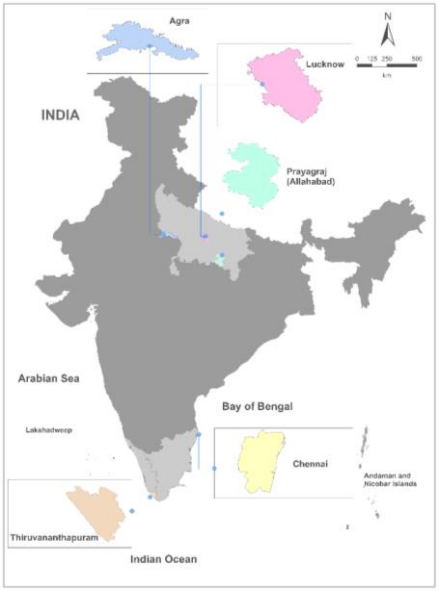
- Chennai coast
- Adyar and Cooum Rivers
- Buckingham Canal

Kerala: Thiruvananthapuram Municipal Corporation

- Coastal wards of Thiruvananthapuram
- Neyyar and Karamana Rivers
- Vellayani and Akkulam Lake
- Parvathi Puthannar Canal

Uttar Pradesh

- Lucknow Municipal Corporation
- Prayagraj Municipal Corporation
- Agra Municipal Corporation



Methodology

Quantification and typology of marine litter in coastal and riverine areas

Marine litter samples were collected in three ecosystems. It would be two transects of measurement covering a 500 m^2 area per site. They have a dimension of 100 m long and 5 m wide, respectively. Every survey was concluded with a weigh-in and a count of the litter collected. The NOAA Technical Memorandum and type (hard plastic, foam, foil, linen, etc.) were used to classify macro items based on their functional origin (e.g., plastic, glass, metals, rubber, cloth/fabric, etc.). Selected sites were classified based on their litter indices to improve litter management at unmanaged beaches.

Assessment of microplastics in surface water

Samples from coastal water and fresh water (rivers and lakes) were collected using a boat equipped with a manta trawl net (0.300 mm mesh size; opening dimensions of 30 x 15 cm) (Hydro-Bios, Germany) hauled horizontally for 20 min at the speed of 2–3 knots. Immediately after sampling, coarse non-plastic materials (various organic or inorganic materials) were sorted visually and removed. Sieve analysis of microplastic size classes were carried out using a dense seawater solution (concentrated with NaCl; 120 g/L). Finally, the filter membranes were collected in a sealed Petri dish and air-dried for 24 hours for further quantitative and qualitative analysis, and microplastic abundances were expressed as particles per cubic meter (particles/m^3)[3].

Surface water samples from the canal were collected using a Niskin sampler. The collected surface water were filtered through <100 µm stainless steel sieve. Then, the filtrates were treated with 30% H_2O_2 at 60 °C for 72 hours to digest organic matter, including biological and other biological materials. Subsequently, 100 ml of saline solution (120 g/l NaCl) were be added to the sample container and stirred by hand for 15 min. Finally, the filter membranes were collected in a sealed Petri dish and air-dried for 24 hours for further quantitative and qualitative analysis. Microplastic abundances were expressed as particles per litre (particles/L).

Assessment of microplastics in surface and core sediments

Surface and core sediments were collected using van veen grab and sediment corer respectively. Briefly, dry all sediment samples to a constant weight at 60 °C for 72 h. Add 100 mL of saturated Nacl solution to separate microplastics from 20 g of sediment by density flotation. The sediment is then sieved using a sieve of mesh size <100 µm. To reduce the interference of organic impurities in subsequent experiments, 30 mL of H_2O_2 (30%) were added to the supernatant to dissolve the biogenic matter. After

[3] Robin R.S, et al., 2020. Holistic assessment of microplastics in various coastal environmental matrices, southwest coast of India. Science of the Total Environment. 703, 134947.

digestion, transfer the supernatant to a polycarbonate membrane filter (1 µm pore size) under vacuum filtration. Finally, the filter membranes were collected in a sealed Petri dish and air-dried for 24 hours for further quantitative and qualitative analysis[4]. Microplastic abundances were expressed as particles per kilogram (particles/Kg).

Sampling and analysis of microplastics from beach sediments

Beach sediments were collected by the quadrat and size fraction sieving methods[5]. Sediment samples were collected from 1x1 m quadrat using a stainless steel scoop up to a depth of 5 cm. All the samples can be stored in pre-cleansed stainless-steel containers of approximately 15 L until sieve analysis. In order to separate different size fractions of microplastics, 10 L of filtered (0.45 µm Whatman glass fibre) seawater were added to each container and can be stirred for 10 min. This was followed by size-fraction wet sieving to separate the sediment and plastic into different size fractions. Isolated microplastics were placed on a glass Petri plate and allowed to dry in the shade for further analysis. Microplastic abundances were expressed as particles per sq. metre (particles/m^2).

Microplastics in ambient air

Ambient air sampling was carried out for PM_{10} and $PM_{2.5}$ by using Respirable Dust Sampler and Ambient Fine Dust Sampler, respectively, at 2 locations around the landfill sites. The air sampling was performed by following the standard protocols (IS 5182 Part-23: 2006; IS 5182 Part-24: 2019) and the filter papers were stored for further processes. In the laboratory, the filter papers were directly assessed for microplastics based on microscopic identification using a stereomicroscope (SMZ 25; zoom range: 0.63x - 15.75x) equipped with a digital camera. Particles with uniform thickness, homogeneous colour and nonorganic surface are classified as microplastics.

Key Results

Greater Chennai Corporation

Distribution and typology of marine litter

Marine litter was surveyed along the beaches of Chennai coast during January 2022. The mean abundance of marine litter in the study area was 0.69 ± 0.71 items/m^2, ranging between 0.17 and 2.03 items/m^2. In terms of weight, litter along the beaches varied between 0.69 and 12.70 g/m^2 with a mean of 4.12 ± 4.96 g/m^2 (Figure 1). Different types of marine litter were present at all sampling sites. Of the beaches examined, Cooum river mouth had the highest marine litter abundance of 2.03 items/m^2 with a corresponding weight of 12.70 g/m^2, followed by Adyar river mouth

[4] Strady E, et al., 2021. Baseline assessment of microplastic concentrations in marine and freshwater environments of a developing Southeast Asian country, Viet Nam. Marine Pollution Bulletin. 162, 111870.
[5] Karthik R, et al., 2018. Microplastics along the beaches of southeast coast of India. Science of the Total Environment. 645, 1388-1399.

with 1.72 items/m^2. In contrast, Kovalam beach had the lowest abundance (0.19 items/m^2) and weight (0.69 g/m^2).Among the studied beaches, 85 different types of marine litter were observed and these were classified into 10 major categories; plastic (39 types), rubber (4 types), cloth (5 types), Paper/Cardboard (7 types), Wood (4 types), metal (8 types), glass (4 types), Pottery/Ceramics (2 types), Sanitary waste (7 types) and medical (5 types). Only representative sub-samples from the total number of plastic litter were chosen at random for the chemical composition study. Of which 156 particles analysed, 38 particles were identified as PP, followed by PEHD (32), PEC (20), PS (14) and others (52).

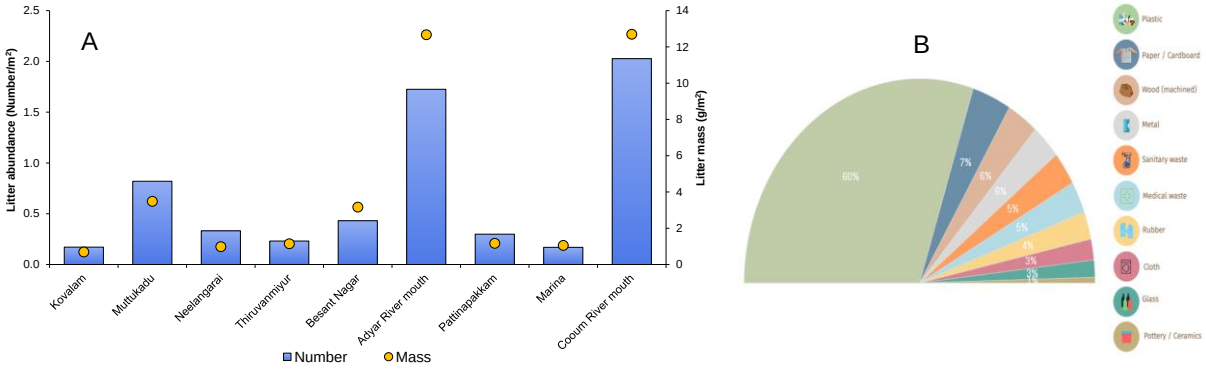


Figure 1. Abundance and distribution of marine litter (A) across nine beaches. (B) Percentage composition based on the total of litter items belonging to different categories

The cleanliness of the 9 beaches that were surveyed was evaluated and assigned to one of the BQI categories. In line with General Index (GI), 3 beaches (33.3%) were rated as "clean", 3 beaches as “moderate cleanliness” (33.3%), 1 beach as "low cleanliness" (11.1%), and 2 beaches as "very low cleanliness" (22.2%). According to Clean Coast Index (CCI), 4 of the beaches surveyed (45%) were graded as "clean", while 2 beaches were classified as (22%) "very low cleanliness".

Microplastics survey along the Chennai Corporation

Microplastics in the beach sediments

The MP abundance in beach sediment of Chennai coast ranges from 31 to 193 particles/m^2, with a mean of 81 ± 52.7 particles/m^2. The chemical composition of microplastic particles from all examined samples clearly shows the dominating presence of polyethylene (PE) (35.5%) followed by polypropylene (PP) (23%), polyamide (PA) (10.5%) and other types of polymers. In this study, the highest concentration of microplastic was found on Cooum River mouth beach, followed by Adyar River mouth and the lowest on Thiruvanmiyur beach (Figure 2).

Microplastics in the surface water

A total of 16 samples, including samples of landfill leachate and river water, were collected. Abundance in the water sample ranged from 0.8 to 32.1 items/L, with an average abundance of 12.1 ± 10.2 items/L (Figure 3). In water samples, the Cowl

Bazar (32.1 items/L) and Perungudi Landfill (32.1 items/L) sites showed maximum abundance in the water samples. This microplastic content in surface waters may come from dump sites and urban areas. The MP abundance in surface water of Chennai region ranges from 1.3 to 5.2 particles/m^3, with a mean of 3.3 ± 2.0 particles/m^3 (Figure 3). The highest concentration of microplastic was found on Ennore River mouth, followed by Broken Bridge and the lowest on Muttukadu. The chemical composition of microplastic particles from all examined samples clearly shows the dominating presence of polyethylene high-density (HDPE) (45%) followed by polypropylene (PP) (18%) and other types of polymers.

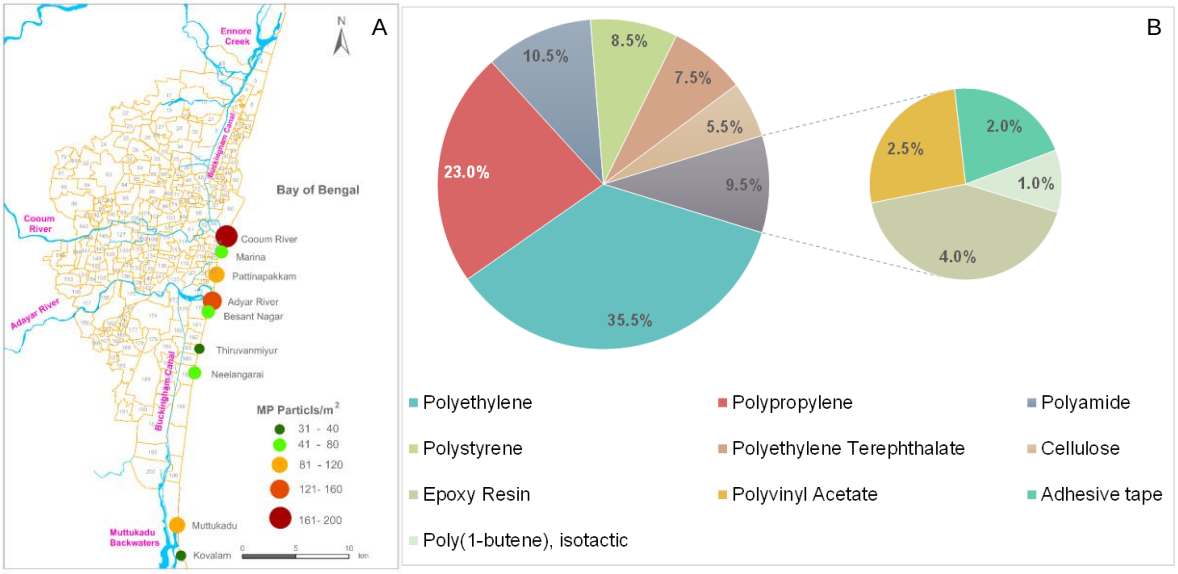


Figure 2. A) Abundance and distribution of microplastics. B) Chemical composition of microplastics in beach sediment

Riverine fluxes of Microplastic

The out fluxes of litter from rivers to sea were calculated by multiplying the river discharge by the exchange rates of litter concentration at the boundaries (river to sea). The final flux of litter from rivers was expressed as particles/day. Among the three rivers, the Ennore creek mouth recorded the maximum flux of 24.2 (106 particles/day) followed by Muttukadu 1.2 (106 particles/day) (Figure 3).

Microplastics in ambient air

The mean of microplastic particles/m^3 of air in Kodungaiyur was 0.56 for PM_{10} and 0.71 for $PM_{2.5}$, respectively. The mean of microplastic particles/m^3 of air in Perungudi was 0.44 for PM_{10} and 1.58 for $PM_{2.5}$, respectively.

Plastic leakage hotspot identification-GCC

Hotspots, or plastic litter accumulation sites, can be identified by comparing the amount of litter at different locations. Coastal cities and urbanized areas are key hotspots of plastic leakage, along with cities along river systems, which ultimately carry plastic waste and sewage pollution to the ocean. The sampling campaign was

conducted for hotspot identification in January 2022 at 20 sites along the Greater Chennai Corporation. Based on the visual inspection, plastic litter hotspots were identified. Many hotspots could be seen in the Buckingham canals, Adyar and Cooum river mouth and Market area. Hotspots were also seen on Cowl Bazar (Airport backside), Velachery Railway Station and Pattinapakkam Beach (Figure 4).

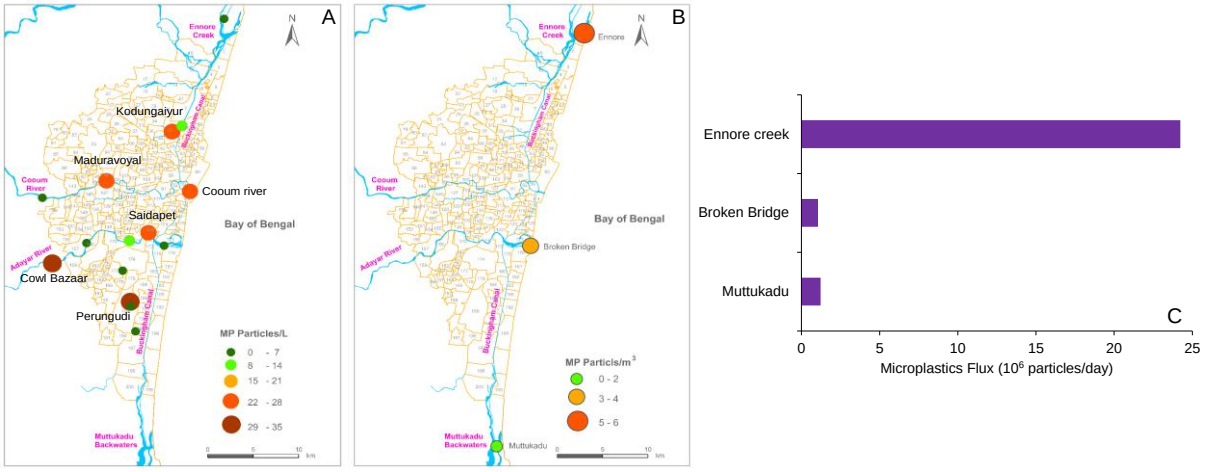


Figure 3. A) Abundance and distribution of microplastic particles found in surface water along Chennai coast. B) Microplastic river flux

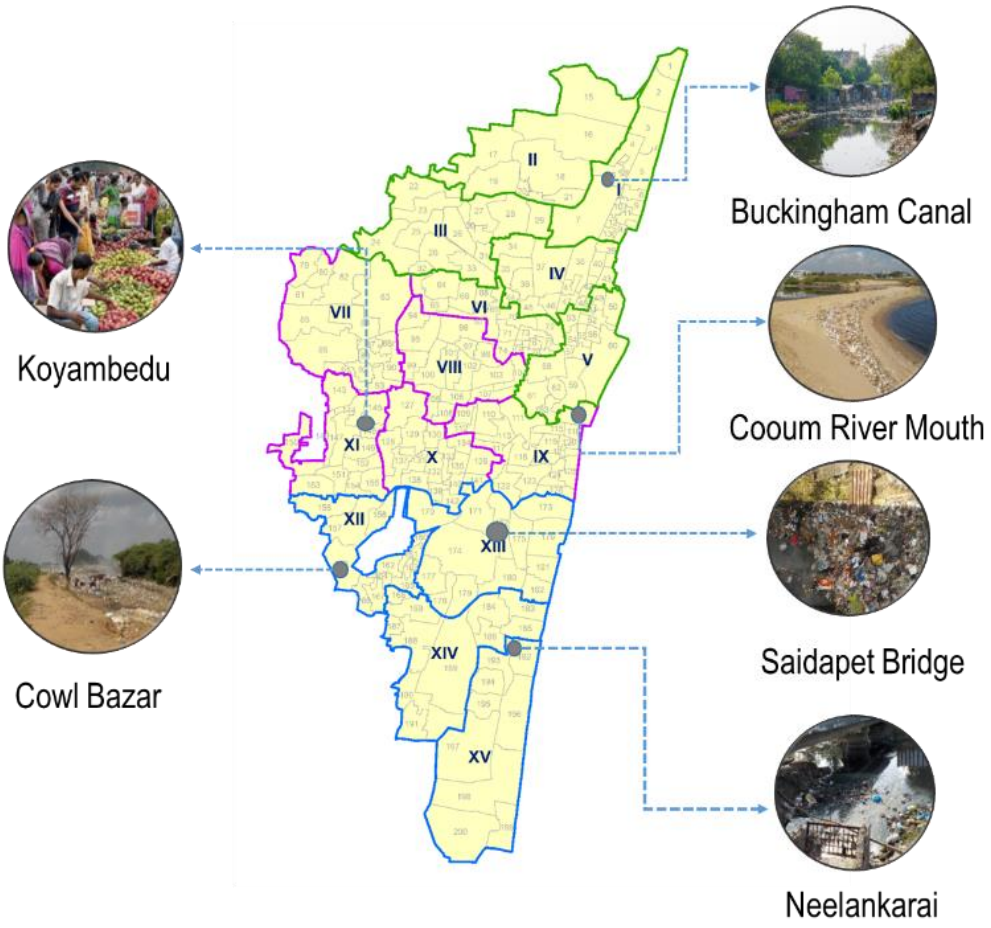


Figure 4. Major plastic leakage hotspots identified from the Greater Chennai Corporation

Thiruvananthapuram Municipal Corporation

Distribution and typology of marine litter

Marine litter was surveyed along the beaches of Thiruvananthapuram coast during April 2022. The mean abundance of marine litter in the study area was 1.97 ± 1.15 items/m^2, ranging between 0.46 and 4.10 items/m^2. In terms of weight, litter along the beaches varied between 2.91 and 49.10 g/m^2 with a mean of 17.54 ± 13.24 g/m^2. Different types of marine litter were present at all sampling sites. Of the beaches examined, Bheemapally Beach had the highest marine litter abundance of 4.10 items/m^2 followed by Veli beach with 3.51 items/m^2. In contrast, Kovalam beach had the lowest abundance (0.46 items/m^2).

Among the studied beaches, 83 different types of marine litter were observed and these were classified into 10 major categories; plastic (38 types), rubber (4 types), cloth (4 types), Paper/Cardboard (7 types), Wood (3 types), metal (9 types), glass (4 types), Pottery/Ceramics (2 types), Sanitary waste (7 types) and medical (5 types). The cleanliness of the 11 beaches that were surveyed was evaluated and assigned to one of the BQI categories. Among the beaches surveyed, Kovalam Beach was in good condition, while other beaches required litter management strategies.

Microplastics survey along the Thiruvananthapuram Corporation

Microplastics in the beach sediments

The MP abundance in beach sediment of Thiruvananthapuram coast ranges from 158 to 4398 particles/m^2, with a mean of 1107 ± 1172 particles/m^2. In this study, Vizhinjam and Bheemapally beaches have higher concentrations of microplastic and potential sources of these plastics include increased fishing activity, lack of cleanliness and dumping. On the other hand, Kovalam beach has the lowest concentration of microplastics due to regular clean-up activities carried out.

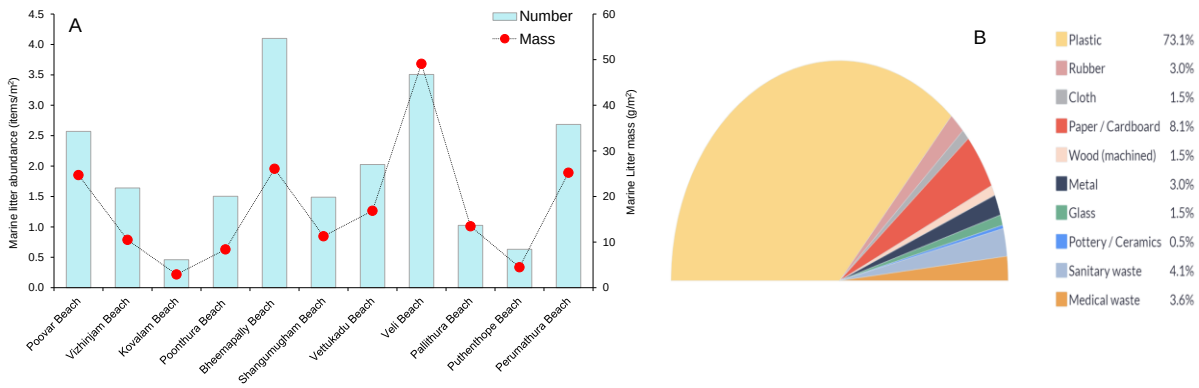


Figure 5. Abundance and distribution of marine litter (A) across 11 beaches. (B) Percentage composition based on the total of litter items belonging to different categories

Microplastics in the surface water

Abundance in the coastal water sample ranged from 1.2 to 8.3 items/L, with an average abundance of 3.8 ± 2.4 items/L. In coastal water samples, the Puthenthope (8.3 items/L) and Poonthura Beach (7.2 items/L) sites showed maximum abundance in the water samples. Abundance in the fresh water sample ranged from 0.7 to 28.4 items/L, with an average abundance of 9.2 ± 7.4 items/L. In fresh water samples, the Chakka Bridge (Parvathy Puthanar canal) and Killipalam Bridge (Killi River) sites showed maximum abundance in the water samples. The MP abundance in surface water of Thiruvananthapuram region ranges from 3.4 to 8.4 particles/m^3, with a mean of 6.1 ± 2.5 particles/m^3. In this study, the highest concentration of microplastic was found on Muthalapozhi, followed by Akkulam Lake and the lowest on Poovar.

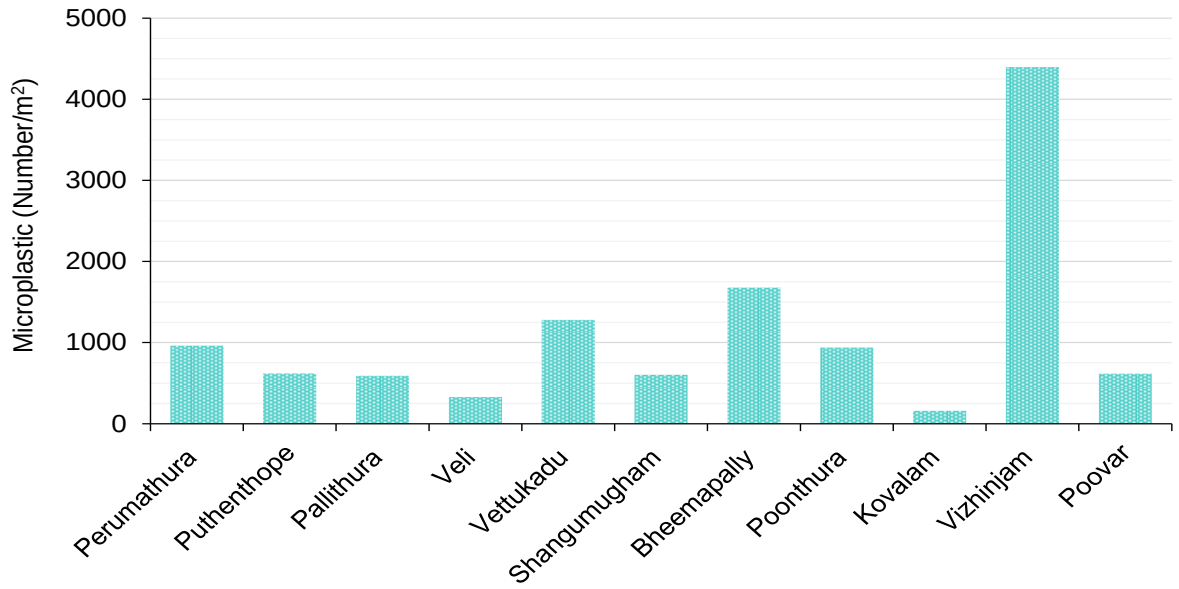


Figure 6. Abundance and distribution of microplastics in beach sediment

Riverine fluxes of Microplastics

Among the three rivers, the Vamanapuram River (Muthalapozhi Estuary) recorded the maximum flux of 74.7 (106 particles/day), consistent with river discharge. This could be attributed to high river discharge and tidal currents in the estuary.

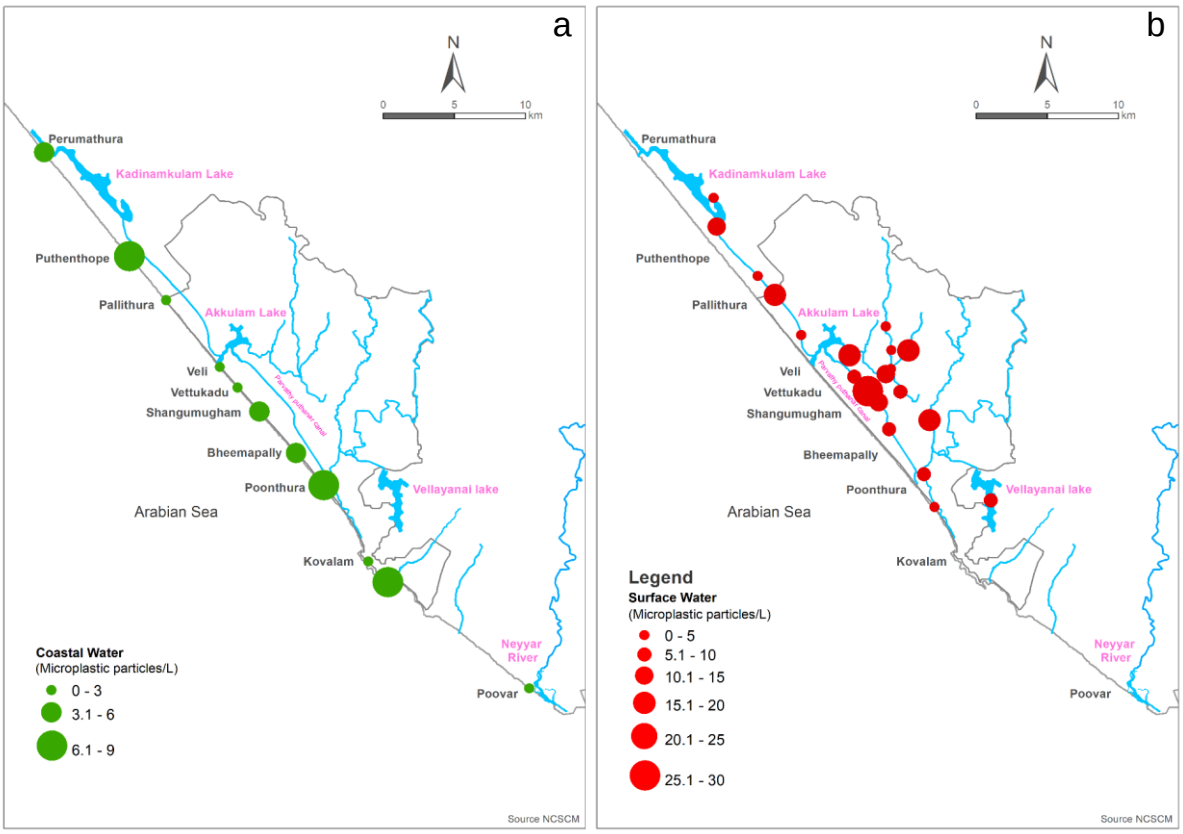


Figure 7. a) Abundance and distribution of microplastic particles found in a) coastal water and b) freshwater along the Thiruvananthapuram Corporation.

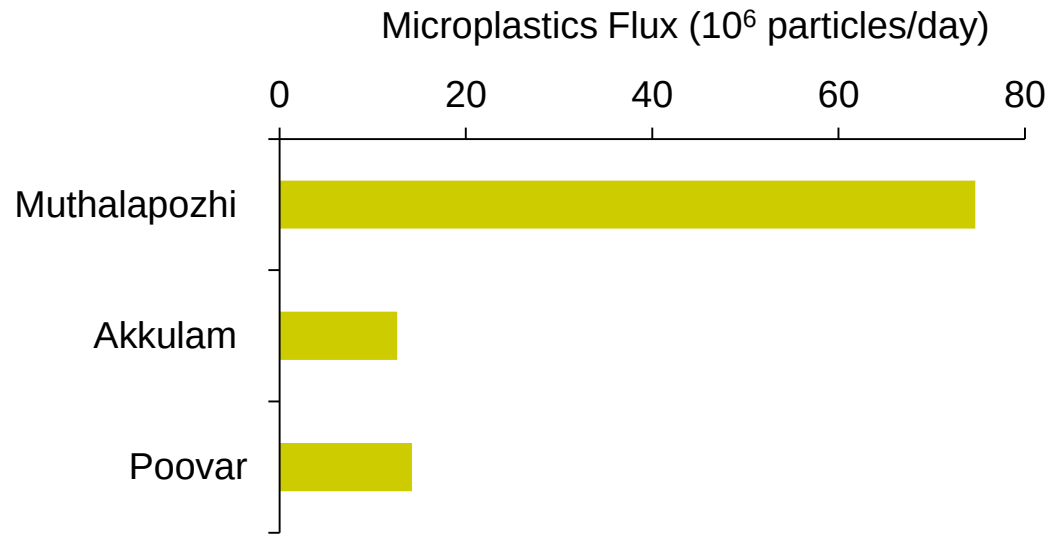


Figure 8. Microplastic river flux

Plastic leakage hotspot identification

Based on the visual inspection, plastic litter hotspots were identified. The major plastic litter hotspots for the Thiruvananthapuram Corporation has been marked in the maps as Figure 8. Many hotspots could be seen in the Parvathy Puthanar canal, Amiyazhanchan Thodu, Killi River, Bheemapally, Vizhinjam beach, Chalai market and Akkulam Lake.

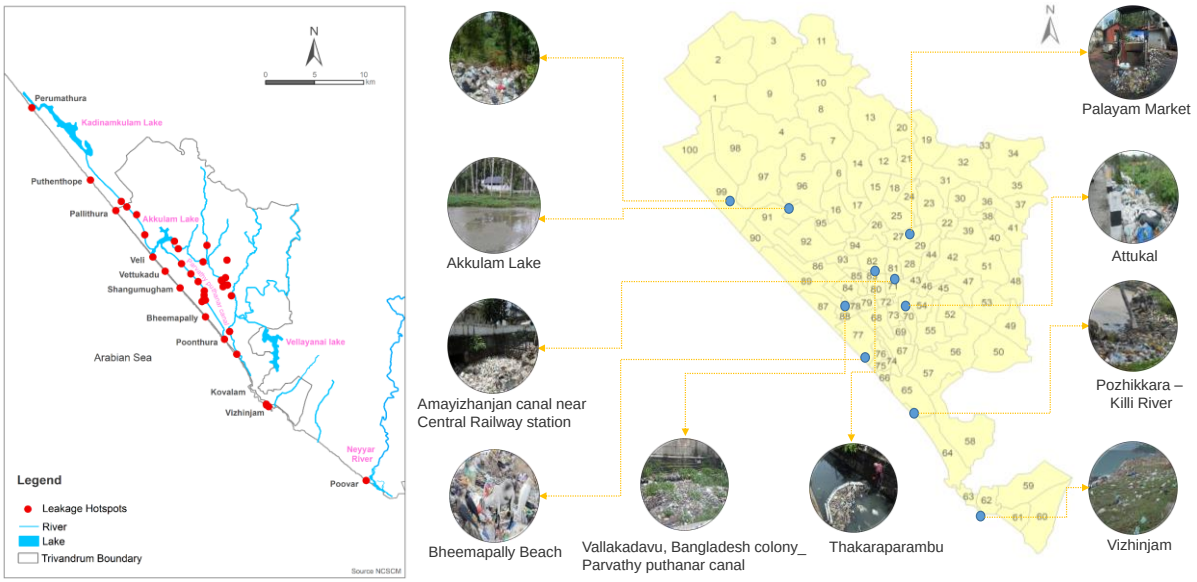


Figure 8. Major plastic leakage hotspots identified from the Thiruvananthapuram Corporation.

Lucknow Municipal Corporation

Microplastics in the surface water

The MP abundance in fresh water of Lucknow region ranges from 6.5 to 112 particles/L, with a mean of 28 ± 25.8 particles/L. In this study, the highest concentration of microplastic was found on STP, followed by Gomti River-4 and the lowest on Canal B4 (Figure 9).

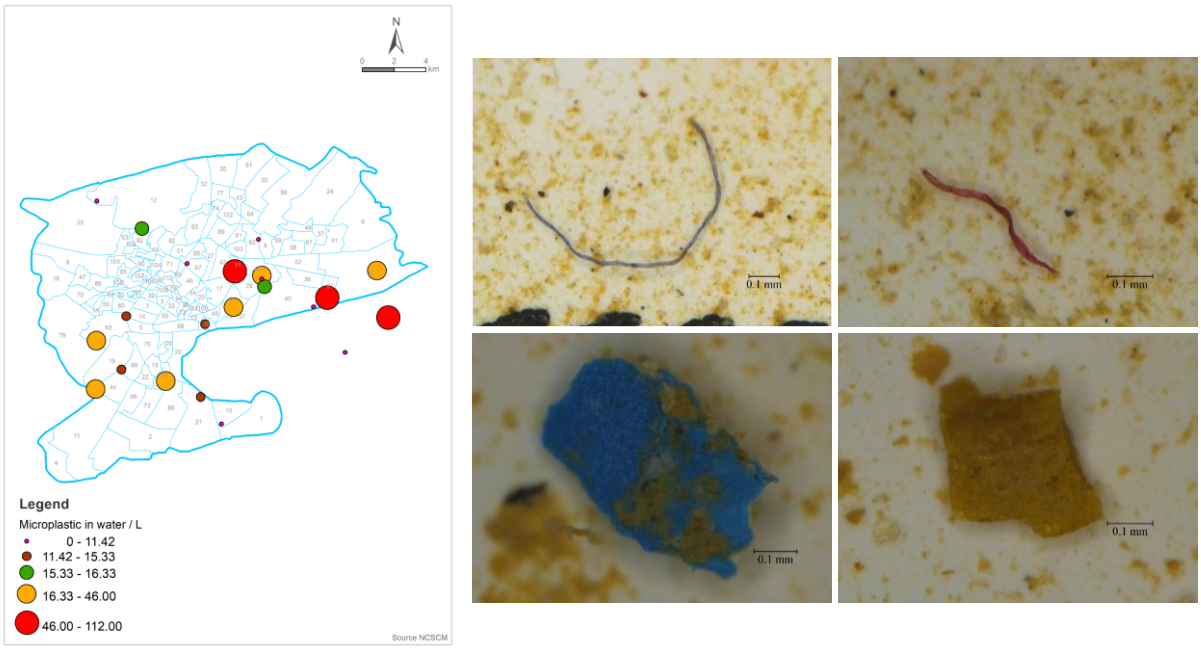


Figure 9. Abundance and distribution of microplastic in surface water and Stereomicroscopic images of different types of microplastic particles found in the water samples of Lucknow Corporation.

Microplastics in the surface sediment

The MP abundance in surface sediment of Lucknow region ranges from 1 to 7.1 particles/g, with a mean of 2.2 ± 1.5 particles/g. In this study, the highest concentration of microplastic was found on STP, followed by Gomti River-4 and the lowest on Gomti River-4 (Figure 10).

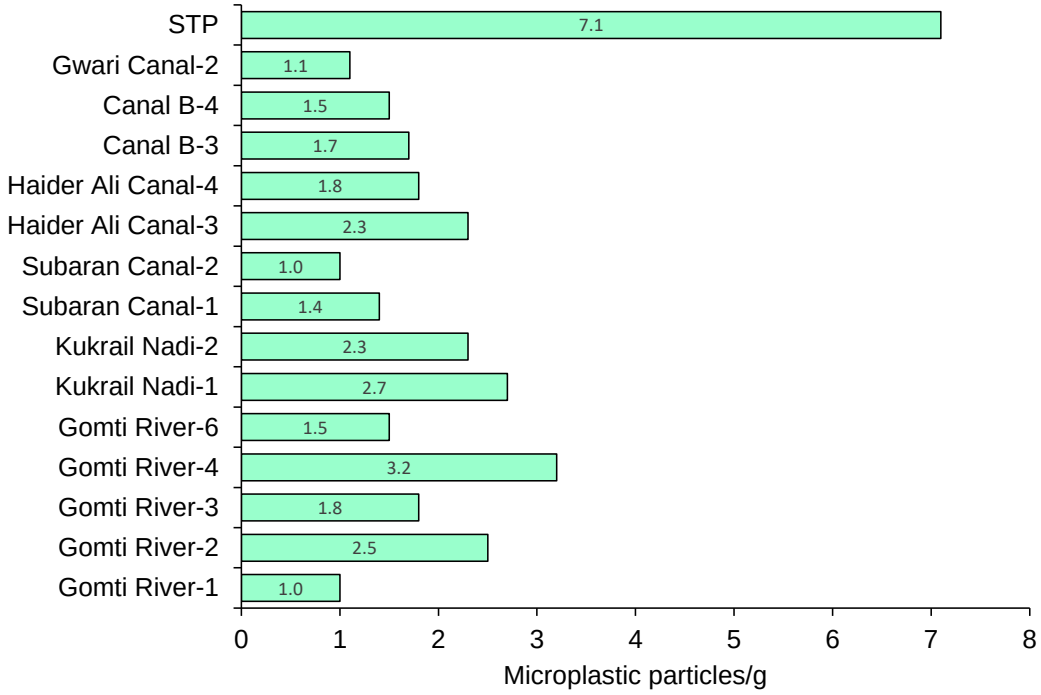


Figure 10. Abundance and distribution of microplastic in surface sediment (river, canal & STP) of Lucknow Corporation

Significant outcomes

Key findings: Greater Chennai Corporation

- The highest abundance of marine litter was measured in the Cooum river mouth followed by Adyar river mouth on the Chennai coast. The number of items on Kovalam beach was less than on other beaches
- Plastic is the most common item, accounting for 59.9% of all items on surveyed beaches
- 38 chemical types of marine litter were identified
- According to General index, 3 beaches were rated as "clean", 3 beaches as “moderate cleanliness”
- In line with Clean coast index, 4 of the beaches surveyed were graded as "clean", while 2 beaches were classified as "very low cleanliness"
- The highest concentration of microplastics in beach sediment was found at the Cooum River mouth beach, followed by the Adyar River mouth and the lowest at Thiruvanmiyur beach
- The dominating presence of polyethylene (PE) followed by polypropylene (PP), and polyamide (PA) was observed

- Riverine microplastic flux were measured along the beaches of the Chennai coast. Ennore creek mouth recorded the maximum flux followed by Muttukadu
- The major plastic litter hotspots for the Greater Chennai Corporation has been identified.

Key findings: Thiruvananthapuram Municipal Corporation

- Of the beaches examined, Bheemapally beach had the highest marine litter abundance followed by Veli beach. In contrast, Kovalam beach had the lowest abundance
- Plastic is the most common item, accounting for 73.1% of all items on surveyed beaches
- According to General index, 9 beaches were rated as "very low cleanliness", 2 beaches as “low cleanliness”.
- According to CCI, the beaches surveyed, Kovalam beach was in clean condition, while other beaches required litter management strategies.
- The highest concentration of microplastics in beach sediment was found at the Vizhinjam beach, followed by the Bheemapally beach and the lowest at Kovalam
- The highest concentration of microplastics in coastal water was found at the Puthenthope beach, followed by the Bheemapally beach
- In fresh water samples, the Chakka Bridge (Parvathy puthanar canal) and Killipalam Bridge (Killi River) sites showed maximum abundance in the water samples
- Among the three rivers, the Vamanapuram River (Muthalapozhi Estuary) recorded the maximum flux. This could be attributed to high river discharge and tidal currents in the estuary
- Many hotspots could be seen in the Parvathy puthanar canal (Vallakadavu, Bangladesh colony), Amiyazhanchan Thodu (Pattoor, Thakaraparambu), Killi River (Pozhikkara), Bheemapally beach, Vizhinjam beach, Chalai market and Akkulam Lake

Key findings: Lucknow Municipal Corporation

- The highest concentration of microplastics in both surface water and sediment samples was found on STP, followed by Gomti River-4.

X. Linking the Land-based Activities with Ecosystem Dynamics of Pulicat Lagoon in India

Pulicat lagoon is the second largest brackish water lagoon in India after Chilika. It is shared between two states i.e. 1/3rd in Tamil Nadu and 2/3rd in Andhra Pradesh. Due to deltaic deposits, the lagoon is extensively shallow, averaging ~1.5 m, ranging between 0.5 and 6 m respectively. The lagoon at its southern end near the Pulicat town, opens into the Bay of Bengal by a narrow pass (bar-mouth) into the sea. The Buckingham Canal runs parallel on the eastern side between the Bay of Bengal and the lagoon, along the narrow sand-bar (Sriharikota Island) and joins near Annamalaichery in the south. The Lagoon acts as buffer to retain the accumulated flood water till the flood water is discharged gradually to the sea during the monsoon period and cyclones.

The lagoon behaves like a positive estuary during monsoon when the fresh water influx is greater and during summer, due to high evaporation, low run-off and precipitation, it is a negative estuary. Due to such wide changes in the salinity regime, biodiversity of Pulicat lagoon is dominated by highly resistant and resilient flora and fauna. Despite the ecosystem services that it provides, the lagoon has been particularly affected by strong anthropogenic pressures in the resent years. Land reclamation and transformations derived from agriculture and tourism, including excessive nutrient inputs and overfishing, are common problems. At the same time, at a larger scale, they are also affected by slower but durable changes, such as global climate change.

The overall goal of this study was to identify potential options for agricultural management surrounding Pulicat Lagoon to reduce greenhouse gas emission, nutrient loads and lessen future bloom events in the Lagoon. The existing agricultural practices (selective classes), soil mineralization and net N loss around the Lagoon were assessed for prioritizing Crop Management to increase Nitrogen Use Efficiency (NUE) and restricting Cultural Eutrophication in Pulicat Lagoon. The study has been conceptualized in following objectives:

- Assessment of decadal land use changes for assessing areas conversion which may have influenced nitrogen retention, release and losses Identification of key geomorphological features and areas with anthropogenic activities, which may act/ influence nitrogen behaviour in Pulicat
- Quantification of land-based sources and sea-based sources of nitrogen
- Assessment of nitrogen use efficiency for Pulicat lagoon.
- Preparation of report card for Pulicat Lagoon

Activity 1 - Analysis of Land use and Land cover around Pulicat lagoon

The land use/land cover pattern of a region is an outcome of natural and socio-economic factors and their utilization by man in time and space. Preliminary satellite image classification (multi-temporal) and band composite images were used to identify the major land use classes to be surveyed. Field data was collected during the dry season to round verification of major land use classes around the lagoon. Temporal changes in LULC types within Pulicat watershed was used to assess the changing environmental pressure on the lagoon. Agriculture is the primary occupation in the area considered. The spatial extent of crop land is 1723.13 km^2 which is ~30% of the total area in 2020 (Figure 1). Major crops cultivated in the area includes paddy and groundnut besides pulses such as Red gram, Bengal gram and Green gram. The study revealed that the lagoon reduces in its spatial extent from 684.55 km^2 to 692.12 km^2 from 2010 to 2020, especially due to the increased siltation in the lagoon as mudflats and sandy areas. Total land area under agriculture decreased from 1632.75 km^2 (2010) to 1472.90 km^2 (2020), primarily due to the expansion in settlement and industrial activities. Settlement with vegetation increased from 264.86 km^2 (2010) to 285.07km^2 (2020). The anthropogenic features such as aquaponds (27.76 km^2) exhibited a remarkable increase between 2010 and 2020.

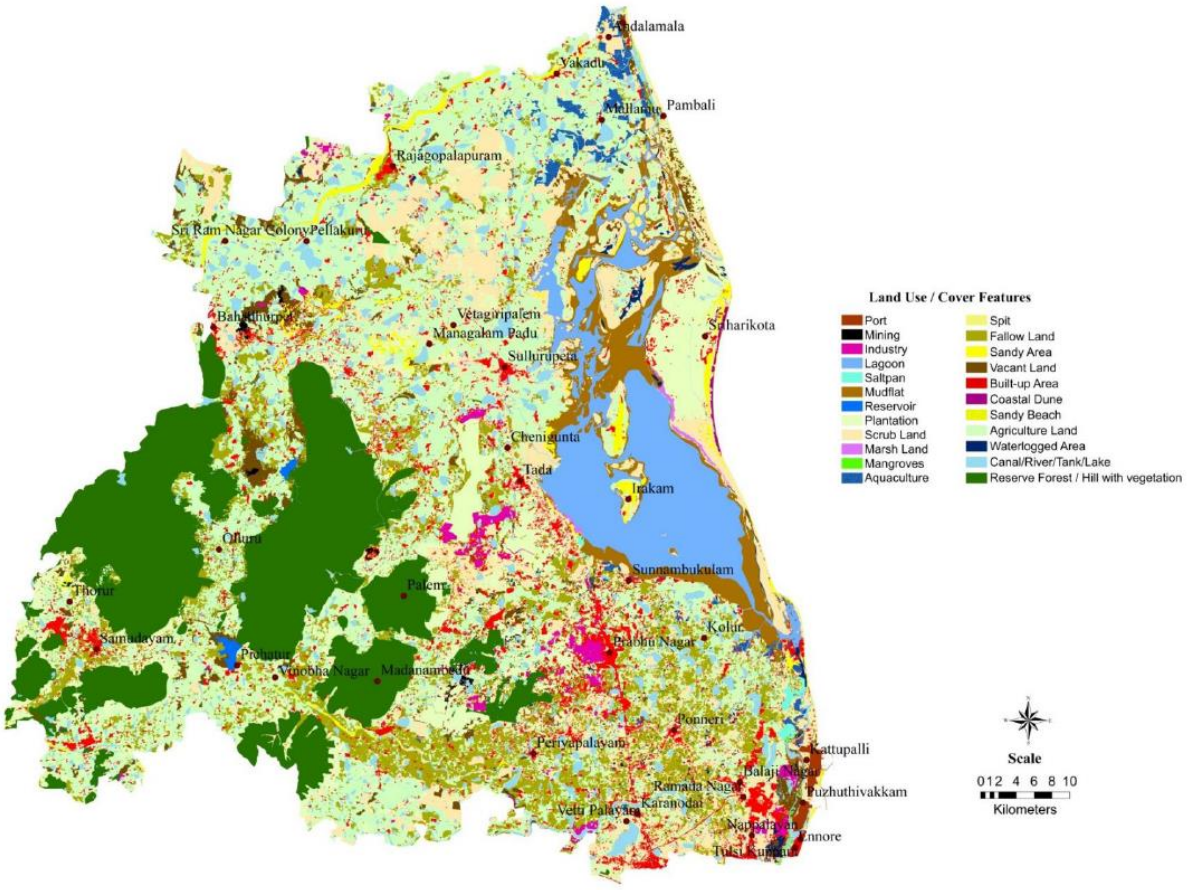


Figure 1: Land use/cover in and around the Pulicat Lagoon in 2020

Activity 2 – Major Land use practices and sources of nitrogen to the Pulicat lagoon

Sources of nutrients to Pulicat lagoon

The sources (point and non-point sources) of nitrogen were quantified and a linkage with land use land cover was established. It was assumed that different land use pattern and management practices may have variable influence on the soil mineralization process in and around Pulicat Lagoon and accordingly influence the nitrogen mineralization and transformation. In order to understand the availability of biologically active parameters and associated nitrogen availability, analytical experiments were carried out.

The study revealed that Agriculture is the major land use type followed by Reserved Forest, Scrub Land, Fallow Land, Plantation, Lagoon and Built-up Area. It is reported that increase in people's involvement in fishing caused insufficient catch in this area. Occurrence of frequent algal bloom in the Northern sector of Pulicat lagoon are also reported. It is noticed that drainage system in the surrounding villages acts as the major source of anthropogenic nutrient input to the lagoon water. The fish processing waste are mostly thrown in the lagoon which often caused pollution along the landward periphery of lagoon. Inorganic and organic pollutants from the aquaculture farms surrounding the lagoon also influence environmental conditions of the lagoon. However, a few organic aquaculture farms utilize agriculture by-products, animal manure, plant meals, beneficial bacteria and animal meal as feeds for the fishes. The sludge released from these aquaculture ponds is used to fertilize the agriculture field.

Water, salt and non-conservative nutrient budgets for Pulicat Lagoon

The overall freshwater discharge into the lagoon from rivers was 3.04×10^6 m^3 d^{-1}. The shallow lagoon is highly turbid with moderately high nutrient concentrations in the dry season. Riverine flux of DIN for the lagoon was estimated to be 37.46×10^3 mol d^{-1}. During non-monsoon season the lagoon acts as net source for inorganic nitrogen DIN (ΔDIN to the coastal waters (8.10×10^3 mol d^{-1}). During non-monsoon season the lagoon acts as net source for inorganic nitrogen DIP (ΔDIP) to the coastal waters (4.32×10^3 mol d^{-1}). The molar ratios of DIN/DIP were consistently <16, indicating the enrichment of DIP in all the sectors of the lagoon. High dissolved ammonium concentrations indicated the significant influence of untreated wastewater from different land use classes of Pulicat watershed. Mean residence time for water (τ), N (DIN τ) and P (DIP τ) were 111, 144 and 121 days respectively in the lagoon.

Trophic state of the lagoon (TSI)

The Pulicat lagoon appeared to be moderately net heterotrophy as the calculated net ecosystem metabolism (NEM) p-r was -0.58 mmol m^{-2} d^{-1} during pre-monsoon. Nfix-denit was calculated as -0.06 mmol m^{-2} d^{-1} depicted that the lagoon acted as net denitrification during pre-monsoon. The weighted arithmetic mean of TSI (TSI mean) computed from SD, Chl-a, TN and TP revealed that the northern sector of the lagoon

is eutrophic (TSI ranged from 40--49) whereas the southern and central sector was mesotrophic in nature (TSI ranged from 50-70). Extremely high nutrient concentrations (hypertrophic state) in some of partially isolated water bodies within the northern sector of the lagoon indicated deterioration of water quality. The study revealed that Future increase in algal biomass supported by enriched nutrient conditions could facilitate decay of seagrass bed in the central and southern sector of the lagoon.

From the present study, it can be concluded that the trophic state of the lagoon was primarily controlled by the combined effect of turbidity and phosphorous availability during non-monsoon season. Spatially, northern sector showed higher nutrient enrichment primarily influenced by agricultural runoff from Pulicat Watershed. Slightest perturbation in the lagoon water quality, due to the alteration in precipitation, wind, pollution source, etc., can modify these trophic states of different sectors. Higher algal densities supported by enriched nutrient conditions might also facilitate decay of seagrass bed in the central and southern sector of the lagoon. The TSI can be a valuable tool for monitoring lagoon eutrophication and also as a simple but effective scientific technique for ecosystem investigations. However, a more complete picture of the lagoon trophic state can be achieved only by simultaneously applying multiple indicators (including physical, chemical, and biological) at a larger time span.

Activity 3 - Nitrogen Use efficiency (NUE)

NUE can be defined as the ratio of grain yield (Gw) per unit of available N (Ns) in the soil, including the present residual soil N and fertilizer N. NUE is a function of soil texture, climate conditions, interactions between soil and bacterial processes and the nature of organic and inorganic N sources which is not included in any of the following formulas[6].

$$\mathbf{NUE = Nitrogen\ exported\ from\ field\ into\ crops / Nitrogen\ applied}$$

The estimated NUE values in different types of agriculture practices within the Pulicat watershed were used to recommend the possible N management strategies. Enhanced NUE can be achieved by introducing various changes in the type of N fertilizer, amount, timing and application method. It is assumed that different land use pattern and management practices may have variable influence on the soil mineralization process in and around Pulicat Lagoon. Hence, in order to understand the availability of biologically active parameters and greenhouse gas emission potentials from the sediments, a detailed study focusing on the in-situ mineralization experiment was carried out.

[6] Hirel B, Le Gouis J, Ney B, Gallais A. The challenge of improving nitrogen use efficiency in crop plants: towards a more central role for genetic variability and quantitative genetics within integrated approaches. Journal of Experimental Botany 2007; 58:2369–87

The incubation experiment (up to 30 days) was conducted at a fixed temperature to understand net greenhouse gas emission, mineralization rate from different land uses within the Pulicat watershed. The experimental output was used to recommend better land use practices with in the watershed.

Nitrogen use efficiency was estimated for both the agriculture plots, using the information on the total harvest from each plot and the control plot (harvest without any fertilizer application). Assuming the nitrogen application of 70 kgN/acre and the yield of 2028 kg with the grain nitrogen content of 2%. NUE is estimated to 37% with a nitrogen uptake of 41 kg/acre. It is found that the nitrogen use efficiency in the rice field of the Pulicat watershed is hardly 40%, even under well managed conditions. It is recommended that fertilizer materials that are better in terms of NUE than urea should be promoted to get a higher fertilizer use efficiency.

Table 1: Total harvest and NUE between the different agricultural practices applied

Agriculture practice	Applied N (kg/ac)	Grain Yield (kg/ac)	Grain N (%)	N uptake (kg/ac)	Fertilizer recovery (NUE), %
Zero plot (control)	0	800	1.8	14.4	
Best management Practice (BMP)	70	2028	2	40.56	37%
Traditional	94	2028	2.1	42.49	30%

The study revealed that inorganic N fertilizer and urea constitute the largest fractions of the total fertilizers used in huge amount in the Pulicat watershed. There is an urgent need to reduce overall nitrogen losses from agriculture, which includes loss of NH_3, N_2O, NO, and N_2 through direct emissions, as well as nitrate and other forms of nitrogen through leaching. Each of these losses is driven by different processes. The NUE for traditional paddy practices was estimated as 30% in the Pulicat watershed. The NUE for paddy cultivation, following the recommendation of Best Management Practices was estimated as 37% from the NCSCM field plot (**Table 1).**

Scarcity of water for irrigation, intrusion of salt water in soil were found to be the major issues beside the application of excess nutrients to the agriculture field. Promotion of ZBNF technique with reduced water requirement could be a sustainable solution to reduce N loss in the agriculture. Micro-irrigation, sprinkler irrigation, use of straw mulch etc. can improve the crop harvest. Use of suitable nitrification inhibitors or urease inhibitors, in addition to the application of neem coated urea and strategic crop rotation could substantially enhance NUE. There is limited knowledge and awareness of the available BMPs and strategies to reduce N loss in agriculture among the farmers of Pulicat watershed.

Policy recommendation

1) Promotion of high-yielding water-efficient crop varieties is recommended for the Pulicat watershed area. Improvement in N recovery or N utilization efficiency of some crops may be made through genetic interventions.

2) Adoption of best crop management practices (BMP's), such as the
   i. use of recommended rate of quality seed;
   ii. Timely sowing/transplanting;
   iii. Efficient water management (micro-irrigation, sprinkler irrigation, straw mulch etc.),
   iv. Weed management and
   v. pest management

3) Introduction of site-specific N management –
   i. prescriptive (before planting), and
   ii. Corrective (using in-season diagnostic tools) or both based on the availability of other resources.

4) Application of balanced NPK and adequate amount of deficient secondary and micronutrient(s) are recommended to allow optimum utilization of available N.

5) The use of leaf colour sensing technique – used for identifying a nutrient deficiency in plants shows great potential to reduce nitrogen fertilizer use on farm by 10–15%.

6) Promotion of highly efficient fertilizer products, biochar etc. that better synchronize N release and crop N demand (e.g., slow and controlled-release fertilizers, such as the use of neem-coated urea/ urea super-granules/ innovative N fertilizers, and nano-fertilizers, etc.) are essential.

7) Decision support systems: Based on agroclimatic, edaphic and other resource availability computer-based models or simple field assessment tools and interpretation aids (mobile app-based) may be promoted among the farmers.

8) Mass awareness about the importance of soil testing and balanced and integrated fertilizers application needs to be promoted.

9) Integrated site-specific approach, involving agronomic best management practices and innovative cost-effective N fertilizers have the potential to enhance the use efficiency of N and reducing its uses in Indian farming.

Activity 4 - Nutrient management & Spatial planning using report cards

Watershed management strategies are often introduced in an attempt to reduce pollution loads received by coastal lagoon. Seasonal monitoring programs within the Pulicat watershed typically consist of samples collection from the two major rivers, lagoon and coastal waters. The Net Anthropogenic Nitrogen Inputs (NANI) and

Phosphorus Inputs (NAPI) models[7] were used to estimate of anthropogenic net nutrient fluxes across its boundaries, and is thus a measure of the effect of human activity on the regional nutrient cycle. These watershed models account for the fluxes of atmospheric N deposition, fertilizer N application, agricultural N fixation, and net food and feed imports, each of which represents a potentially important source of nitrogen in watersheds (Figure 2).

Nitrogen mineralization is principally controlled by the microbes present in the soil. The saline soil of the Pulicat watershed indicated the presence of salt tolerant microbes. Hence, it can be anticipated that salinity could not cause any change on the microbial population that was involved in nitrogen mineralization processes.

In the agriculture field of the Pulicat watershed, the rate of nitrogen mineralization was found to be 0.29±0.08 µg N g^{-1} dry wt of soil day^{-1}. Sediment collected from the aquaculture sector showed a nitrogen mineralization rate of 1.51±0.49 µg N g^{-1} dry wt of soil day^{-1}. Comparatively higher nitrogen mineralization rate in the aquaculture sediment might be due to its more moisture content. It was reported earlier that the moisture content of sediment had a positive influence on nitrogen mineralization rate. Increased nitrogen mineralization rate in the aquaculture sector provides a huge amount of available nitrogen to the algal community causing algal bloom along with depletion of oxygen level in the associated aquatic environment.

A positive correlation was found between nitrogen mineralization rates and soil C:N ratio [nitrogen mineralization rate = 0.11 C:N) – 0.64; R2=0.23], suggested nitrogen mineralization rate was accelerated by the increased C:N ratio. The average C;N ratio found from the different regions of the Pulicat watershed area suggested quick removal of nitrogen through nitrogen mineralization. Nitrogen retention capacity of those different regions became necessary to be measured for overall monitoring of nitrogen use efficiency of the soil of the selected regions.

Key observation

1. Fertilizer and manure should be applied beneath a few cm of the soil surface (anoxic depth) to hinder the process of nitrogen mineralization and nitrogen loss from the soil of the Pulicat watershed.
2. Nitrogen mineralization rate in the cultivation field should be controlled by minimizing the use of inorganic nitrogenous fertilizers in the cultivation fields as they add NH_4^+ and NO_3^- ions to the environment at a rapid rate.

[7] Gao, W., Gao, B., Yan, C. A. and Liu, Y. 2016. Anthropogenic nitrogen and phosphorus input evolution and lake water environment response in Poyang Lake Basin. J. Journal of Environmental Science, 36(9): 3137-3145

3. Organic nitrogenous fertilizer or manure can be applied to delay the quick release of dissolved nitrogenous ion to control overgrowth of algae in the aquatic environment.
4. NANI in Pulicat watershed reveals the largest N component was Fertilizer (75.6%) followed by Agricultural Nitrogen fixation (18.7%) and Atmospheric N deposition (7.3%).

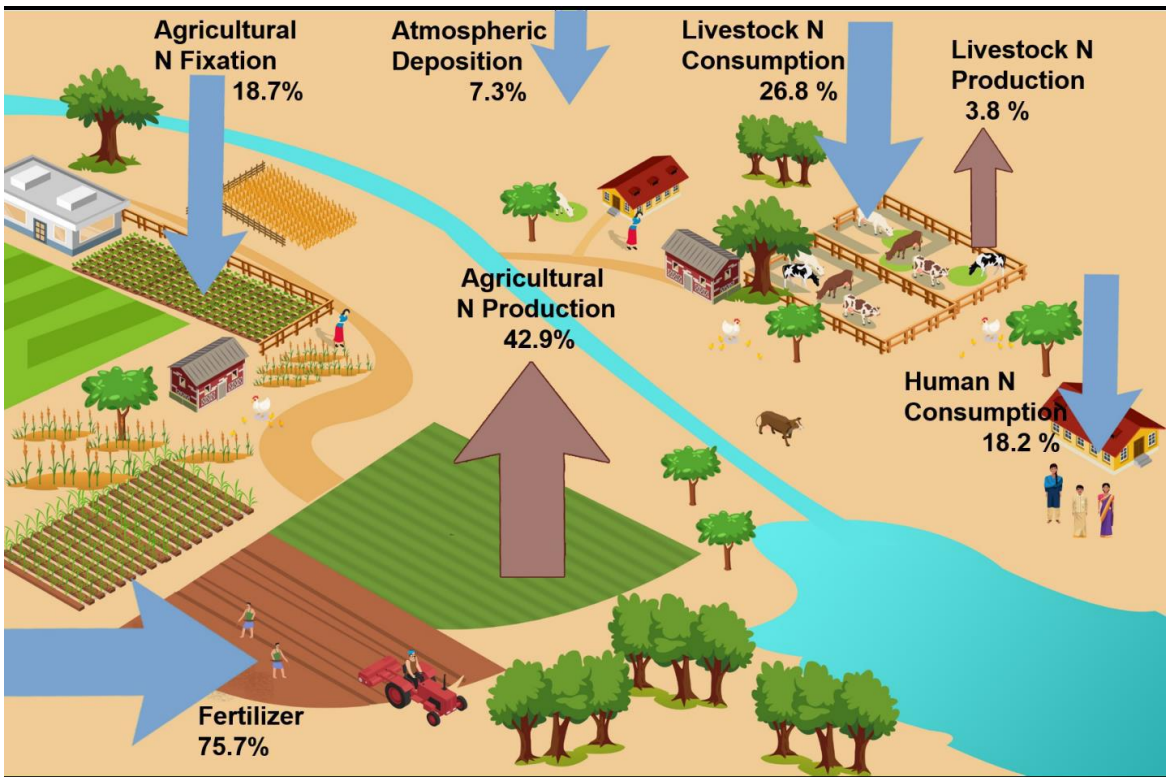


Figure 2. Contribution by different components on NANI in Pulicat watershed

5. NFF from the Pulicat watershed is slightly negative (-1.6%) indicating an excess of production over consumption.
6. Agricultural production is dominant in Pulicat watershed, shows the role of N inputs from various process due to agricultural activities.
7. Paddy fields are the principal source of nitrogen fixation due to the large cultivation area and rapid plant uptake.
8. Spatial difference of NANI and its components were evident among the sub-basins due to its varying population distributions and agricultural pressures.
9. Riverine N export was not correlated with NANI inputs, as lack of proper riverine N flux and non-inclusion of some controlling factors like denitrification etc.
10. Implementing best management practices by reducing fertilizer consumption without dramatic decreases in crop production could be an effective method of improving the environment and decreasing NANI in Pulicat lagoon.

11. Biochar, a fine-grained, carbon-rich, a porous product, is the product of biomass pyrolysis and has been shown to reduce soil acidity, immobilize metals and thus ameliorate plant growth.
12. Considering the potential ability of biochar to promote N retention, co-application of high rates of biochar with excessive compost in the agriculture field could be very useful in the Pulicat watershed.
13. Results from Net anthropogenic nitrogen input (NANI) revealed that the inorganic fertilizer is the largest N component followed by Agricultural Nitrogen fixation and Atmospheric N deposition in Pulicat watershed.
14. Net Nitrogen in the food and feed (NFF) from the Pulicat watershed is slightly negative indicating an excess of production over consumption.
15. Rice is the dominant source of nitrogen fixation due to the large cultivation area of paddy fields.
16. Spatial difference of NANI and its components were evident among the sub-basins due to its varying population and agricultural pressures.
17. Reducing fertilizer consumption without dramatic decreases in crop production by implementing best management practices could be an effective method of improving the environment and decreasing NANI in Pulicat lagoon.

Lagoon Ecosystem Health Report Card and Nitrogen Report Card

Ecosystem Health Report Card – a tool for monitoring nutrient and overall health of the coastal ecosystem were used to understand the present environmental condition of the lagoon. It further demonstrate the effects of nutrient over enrichment due to land based activities in the lagoon basin on water quality, ecosystem services and the livelihoods of local population. In addition, detailed assessment of nitrogen stocks, pools and fluxes were presented a nitrogen report card for Pulicat lagoon indicating the areas which requires immediate and long term interventions. These report card provides a transparent, timely, and geographically detailed annual assessment of Pulicat lagoon using important indicators that are combined into a single overarching index of health. A multi-stakeholders workshop on Pulicat lagoon were organized to develop an integrated plan for the possible implementation of the report card approach on sustainable nutrient management.

The quality of coastal marine water is assessed from the observed data and by analysing the data for selected chemical and biological parameters. The data processed is used to obtain two important indices, viz., Water Quality Index and Shannon-Wiener Index. The Water Quality Index (http://www.eco-check.org) combines the water quality threshold scores (chlorophyll a, water clarity and dissolved oxygen) into a single overarching index. Good overall water quality is characterized by having high index scores (green). Poor overall water quality is characterized by having low index scores (orange and red). The Shannon-Wiener index is calculated from species diversity and species richness. The Shannon index, sometimes referred to, as the Shannon-Wiener Index or the Shannon-Weaver Index, is one of the several

diversity indices used to measure diversity in categorical data. It is simply the information entropy of distribution, treating species as symbols and their relative population sizes as the probability. Combining the two quality indices, the total ecosystem health is estimated.

Based on data availability and natural geographic divisions within the Pulicat lagoon, the Report Card presents results, divided into three sectors referred as:

1. Southern sector
2. Central sector
3. Northern sector

Ecosystem health grade was assigned for individual environmental variables recorded from Pulicat Lagon (Figure 4.4). Despite spatial variabilities, the overall Ecosystem Health of Pulicat Lagoon is found to be “Moderate”. Higher anthropogenic pressure and limited seawater mixing in the northern sector of the lagoon causes relatively poorer ecosystem health compared to other part of the lagoon. Sector wise ecosystem health grades of Pulicat Lagoon is provided in **Figure 3 and** Table 2. Sustainable land use practices and integrated lagoon management can improve the ecosystem health and restore the degraded ecosystems of the lagoon.

Grades are assigned + or – (e.g. B+ or B-) if attainment scores are within 4% of the cutoff between grades. For example, 77% would equate to C+; whereas 63% would equate to a D-.

Color Code	Indicator Attainment Score	Report Card Grade
	90 – 100%	A - Excellent
	80 – 90%	B - Good
	70 – 80%	C - Moderate
	60 – 70%	D - Poor
	0 – 60%	F – Very Poor

Key observation

1. Overall ecosystem health of Pulicat Lagoon is moderate, whereas Southern, Central & Northern sectors showed moderate, good and poor water quality condition, respectively.

2. Major concern is water clarity/transparency, as all throughout the sectors water is very turbid. Chlorophyll-a concentrations clearly shows that; the lagoon primary productivity is very poor.

3. Limited tidal flushing, siltation and shallow depth of the lagoon are the major driving factor, making the lagoon water highly turbid.

4. In terms of Nitrogen and Phosphorous load in the water, northern sector is highly affected, as this area is surrounded by agricultural fields.

Table 3: Summary of report card scores and assigned grades for the three sectors of Pulicat lagoon

		Sectors			Metric Score	Indicator Score	Category Score	Grade
Indicator	Metric	Southern	Central	Northern				
Fauna	Zooplankton (Simpson's Index 1-D)	65	56	74	65	65		
Water quality	pH	86	92	100	93	75	76	C+
	Dissolved Oxygen	100	100	71	90			
	Chlorophyll-a	14	42	43	33			
	Dissolved Inorganic Nitrogen	100	92	57	83			
	Dissolved Inorganic Phosphorus	86	100	43	76			
Flora	Phytoplankton (Simpson's Index 1-D)	91	89	87	89	89		
Overall regional score		78	77	75	MODERATE			
		C+	C+	C				

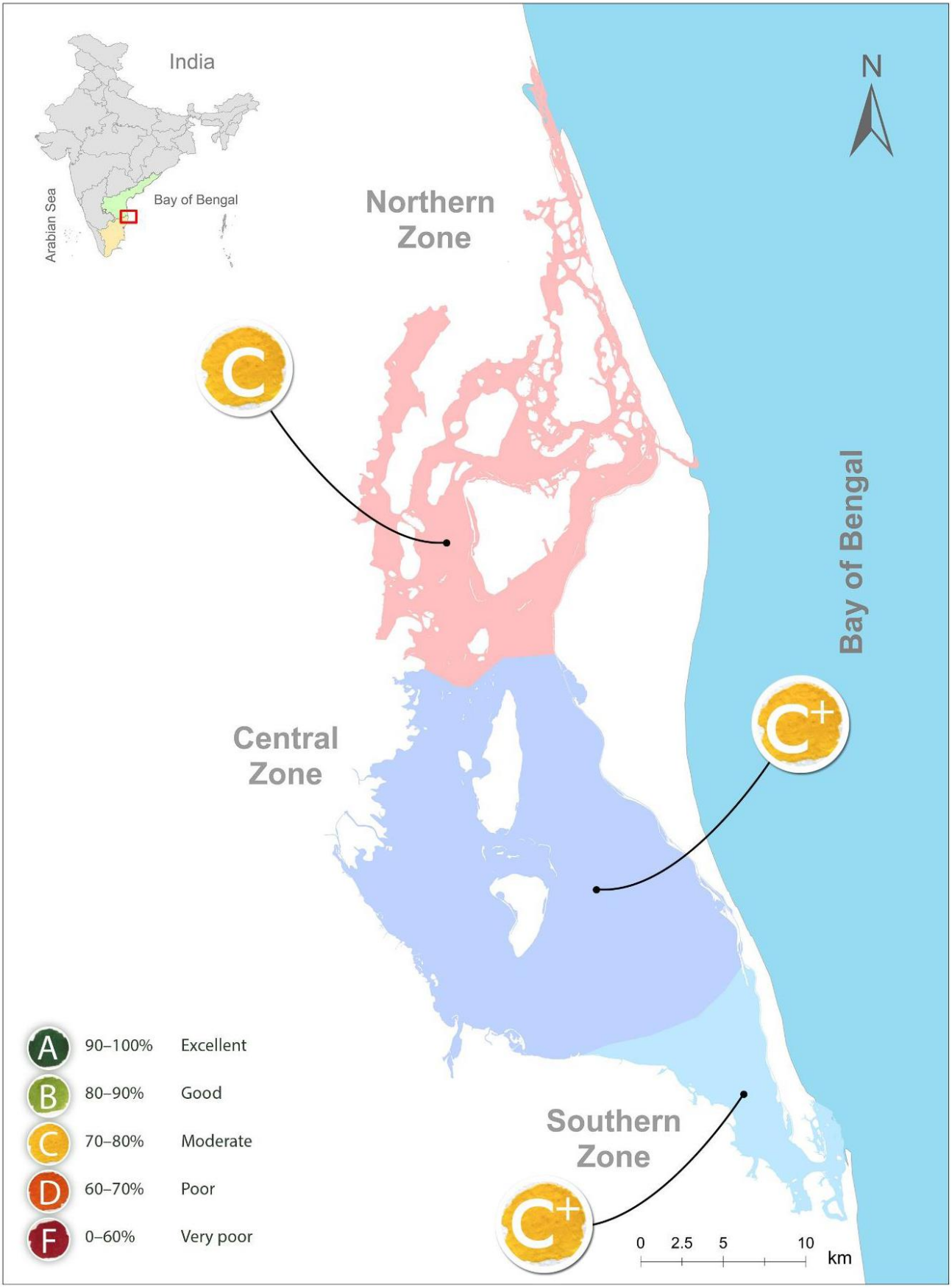


Figure 3: Sector wise ecosystem health grades of Pulicat Lagoon

Summary

Sustainable agricultural practices to enhance nutrient use efficiency and water use efficiency were recommended. Adopting organic farming activities and usage of fertilizers according to soil and crop requirement can reduce the fertilizer input in the lagoon. It is recommended that fertilizer materials that are better in terms of NUE than urea should be promoted to get a higher fertilizer use efficiency. In order to reduce agricultural water demand and loss of N, adequate use of organic manure and use of biofertilizers is recommended in an integrated nutrient management strategy should be followed. Promotion of highly efficient fertilizer products, biochar etc. that better synchronize N release and crop N demand (e.g., slow and controlled-release fertilizers, such as the use of neem-coated urea/ urea super-granules/ innovative N fertilizers, and nano-fertilizers, etc.) are essential. Implementing best management practices by reducing fertilizer consumption without dramatic decreases in crop production could be an effective method of improving the environment and decreasing Net anthropogenic nitrogen input (NANI) in Pulicat lagoon. Despite spatial variabilities, the overall Ecosystem Health of Pulicat Lagoon is found to be “Moderate”. Higher anthropogenic pressure and limited seawater mixing in the northern sector of the lagoon causes relatively poorer ecosystem health compared to other part of the lagoon. Sustainable land use practices and integrated lagoon management can improve the ecosystem health and restore the degraded ecosystems of the lagoon. Decision support systems: Based on agro-climatic, edaphic and other resource availability computer-based models or simple field assessment tools and interpretation aids (mobile app-based) may be promoted among the farmers. Lack of awareness and scientific knowledge in NUE agriculture is resulting in excessive nutrient loses from the field to the adjacent water bodies and eventually to the Pulicat lagoon. Mass awareness about the importance of soil testing and balanced and integrated fertilizers application needs to be promoted to reduce the anthropogenic pressure on the lagoon ecosystem.

5. Accreditation and Certification of NCSCM

NCSCM, is rated as a PLATINUM CERTIFIED LEED Building with 14 advanced multidisciplinary laboratories; 115 scientists and staff on contract; and received the following Certifications and Accreditations in the year 2021-2022:

(a) National Accreditation Board for Testing and Calibration Laboratories (NABL) – for “Testing” (Surveillance Audit – October 2021)

(b) ISO 9001 (Surveillance Audit – August 2021)

(c) ISO 45001 (Surveillance Audit – August 2021)

ISO 9001:2015

Certificate of Registration

This certificate has been awarded to

National Centre for Sustainable Coastal Management (NCSCM), Ministry of Environment, Forest and Climate Change

Anna University Campus, Chennai, Tamil Nadu, 600025, India

in recognition of the organization's Quality Management System which complies with

ISO 9001:2015

The scope of activities covered by this certificate is defined below

Please refer to the Appendix

Certificate Number:	Date of Issue: (Original)	Date of Issue:
112179/B/0001/UK/En	25 July 2020	25 July 2020
Issue No:	**Expiry Date:**	
1	24 July 2023	

Issued by: *On behalf of the Schemes Manager*

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If there is any doubt as to the authenticity of this certificate, please do not hesitate to contact the Head Office of the Group on info@urs-certification.com.
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Appendix to Certificate

To Provide Laboratory Testing of Chemical and Biological Material, Conduct Coastal Environmental Impact Assessments (CIA), Cumulative Environmental Impact Assessments (CEIA) and Research and Development Services through NCSCM Divisions, Laboratory Facilities and Infrastructure

Certificate Number:	Date of Issue: (Original)	Date of Issue:
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Issue No:	**Expiry Date:**	
1	24 July 2023	

0043

ISO 45001:2015

Certificate of Registration

This certificate has been awarded to

National Centre for Sustainable Coastal Management (NCSCM), Ministry of Environment, Forest and Climate Change

Anna University Campus, Chennai, Tamil Nadu, 600025, India

in recognition of the organization's Health and Safety Management System which complies with

ISO 45001:2018

The scope of activities covered by this certificate is defined below

Please refer to the Appendix

Certificate Number:	Date of Issue: (Original)	Date of Issue:
112179/A/0001/UK/En	25 July 2020	25 July 2020
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0043

NABL Certification

National Accreditation Board for Testing and Calibration Laboratories

NABL

CERTIFICATE OF ACCREDITATION

NATIONAL CENTRE FOR SUSTAINABLE COASTAL MANAGEMENT (NCSCM), MINISTRY OF ENVIRONMENT, FOREST AND CLIMATE CHANGE

has been assessed and accredited in accordance with the standard

ISO/IEC 17025:2017

"General Requirements for the Competence of Testing & Calibration Laboratories"

for its facilities at

NCSCM, MINISTRY OF ENVIRONMENT, FOREST AND CLIMATE CHANGE, CHENNAI, TAMIL NADU, INDIA

in the field of

TESTING

Certificate Number: TC-8975

Issue Date: 02/09/2020 Valid Until: 01/09/2022

This certificate remains valid for the Scope of Accreditation as specified in the annexure subject to continued satisfactory compliance to the above standard & the relevant requirements of NABL.
(To see the scope of accreditation of this laboratory, you may also visit NABL website www.nabl-india.org)

Name of Legal Identity : NATIONAL CENTRE FOR SUSTAINABLE COASTAL MANAGEMENT (NCSCM)

Signed for and on behalf of NABL

N. Venkateswaran
Chief Executive Officer

6. Knowledge dissemination and Capacity Building (Including virtual workshop, meetings and conferences)

Development of knowledge products during 2020-2021

NCSCM has undertaken many research studies pertaining to coastal as well as its resource management. The highlights from the finding of these studies were brought as research publications, technical reports, atlases, brochures etc. in order to sensitize the importance of coastal and marine environment.

a) Research Articles

S. No	Year	Details of the Publication
40	2022	Mamidala, H.P., Ganguly, D., Purvaja, R., Singh, G., Das, S., Rao, M.N., Ys, A.K., Arumugam, K. and Ramesh, R., 2023. Interspecific variations in leaf litter decomposition and nutrient release from tropical mangroves. Journal of Environmental Management, 328, p.116902. (Impact Factor: 8.91).
39	2022	Sachithanandam, V., Bonthu, S., Mageswaran, T., Singh, K.S., Vimala, J., Sridhar, R., Purvaja, R. and **Ramesh R**., 2022. Effect of hydrodynamic conditions on seagrass ecosystems during Cyclone Lehar in the South Andaman Islands, India. Ecohydrology & Hydrobiology. (Impact Factor: 2.957).
38	2022	Neethu, C.S., Saravanakumar, C., Purvaja, R., Robin, R.S. and **Ramesh R**., 2022. Arsenic resistance and horizontal gene transfer are associated with carbon and nitrogen enrichment in bacteria. Environmental Pollution, 311, p.119937. (Impact Factor: 9.988)
37	2022	Parthiban, A., Sachithanandam, V., Sarangapany, S., Misra, R., Muthukrishnan, P., Jeyakumar, T.C., Purvaja, R. and **Ramesh R**., 2022. Green synthesis of gold nanoparticles using quercetin biomolecule from mangrove plant, Ceriops tagal: Assessment of antiproliferative properties, cellular uptake and DFT studies. Journal of Molecular Structure, 1272, p.134167. (Impact Factor: 3.841)
36	2022	Rajakumari, S., Sundari, S., Kamatchi, G.A. and **Ramesh R**., 2022. Assessment of challenges to Radhapuram due to temporal coastal infrastructures using hybrid approach. Journal of Coastal Conservation, 26(5), pp.1-14. (Impact Factor: 2.098)
35	2022	Saravanakumar, C., Neethu, C.S., Purvaja, R., Sunantha, G., Robin, R.S. and **Ramesh R**., 2022. Networking and co-occurrence of virulent and multidrug resistant environmental bacteria in different aquatic systems: A gap in MDR-virulence transfer?. Science of The Total Environment, p.159221. (Impact Factor: 10.753)
34	2022	Balachandar, K., Viswanathan, C., Robin, R.S., Abhilash, K.R., Sankar, R., Samuel, V.D., Purvaja, R. and **Ramesh R**., 2022. Benthic foraminifera as an environmental proxy for pollutants along the coast of Chennai, India. Chemosphere, p.136824. (Impact Factor: 8.943)
33	2022	Rajakumari, S., Mahesh, R., Sarunjith, K.J. and **Ramesh R**., 2022. Volumetric change analysis of the Cauvery delta topography using radar remote sensing. The Egyptian Journal of Remote Sensing and Space Science, 25(3), pp.687-695. (Impact Factor: 6.393)
32	2022	Shah, H and Ramesh, R. (2022). Development-aligned mangrove conservation strategy for enhancement of Blue Economy: A successful model from Gujarat,

S. No	Year	Details of the Publication
		India. Estuarine and Coastal Shelf Science. https://doi.org/10.1016/j.ecss.2022.107929
31	2022	Bansal, S., Raghuram, N., Adhya, T.K., Rahman, M.M., Tshering, D., Dahal, K.R., Wakeel, A., Aminath, S., Safi, Z., Nissanka, S. and Pathak, H., …. and **Ramesh R**., Mark A.S. (2022). Long-term trends of direct nitrous oxide emission from fuel combustion in South Asia. *Environmental Research Letters*, *17*(4), p.045028. (Impact Factor: 6.793)
30	2022	Noufal, K.K., Sanjana, M.C., Latha, G. and Ramesh, R., 2022. Influence of internal wave induced sound speed variability on acoustic propagation in shallow waters of North West Bay of Bengal. *Applied Acoustics*, *194*, p.108778. (Impact Factor: 2.639).
29	2022	Rajakumari, S., Mahesh, R., Sarunjith, K.J. and Ramesh, R., 2022. Building spectral catalogue for salt marsh vegetation, hyperspectral and multispectral remote sensing. *Regional Studies in Marine Science*, p.102435. (Impact Factor: 1.624).
28	2022	Mamidala, H. P., Ganguly, D., Purvaja, R., Reddy, Y., Selvam, A. P., Singh, G Kakolee., Robin RS. **Ramesh R**., (2022). Distribution and dynamics of particulate organic matter in Indian mangroves during dry period. *Environmental Science and Pollution Research*, 1-12. (Impact factor: 4.306)
27	2022	Karthik R., Robin R.S., Purvaja R., Karthikeyan V., Subbareddy B., Balachandar K., Hariharan G., Ganguly D., Samuel V.D., Jinoj TPS. and **Ramesh R**. (2022). Microplastic pollution in fragile coastal ecosystems with special reference to the X-Press Pearl maritime disaster, southeast coast of India. *Environmental Pollution*, *305*, p.119297. (Impact Factor: 8.071)
26	2022	Hariharan G., Purvaja R., Anandavelu I., Robin R.S. and **Ramesh R**., (2022). Ingestion and toxic impacts of weathered polyethylene (wPE) microplastics and stress defensive responses in whiteleg shrimp (Penaeus vannamei). *Chemosphere*, *300*, p.134487. (Impact Factor: 7.086).
25	2022	Dev P.J., Geevarghese G.A., Purvaja R. and **Ramesh R**., (2022). Measurement of in-vivo spectral reflectance of bottom types: Implications for remote sensing of shallow waters. *Advances in Space Research*, *69*(12), pp.4240-4251. (Impact Factor: 2.152)
24	2022	Parthiban A., Sachithanandam V., Lalitha P., Elumalai D., Asha R.N., Jeyakumar TC., Muthukumaran J., Jain M., Jayabal K., Mageswaran T. Sridhar R., Purvaja R. and **Ramesh R**. (2022). Isolation and biological evaluation 7-hydroxy flavone from Avicennia officinalis L: insights from extensive in vitro, DFT, molecular docking and molecular dynamics simulation studies. *Journal of Biomolecular Structure and Dynamics*, 1-13. (Impact Factor 3.39)
23	2022	Singh K.S., Bonthu S., Bhaskaran P.K., Purvaja R. and **Ramesh R**., (2022). Impact of time step size on different cumulus parameterization schemes in the numerical simulation of a heavy rainfall event over Tamil Nadu, India. *Pure and Applied Geophysics*, *179*(1), 399-423. (Impact Factor: 2.335)
22	2022	Malakar B., Rajendran A.K., Govindasamy H., Kumar DSV., Gogoi NK., Purvaj R. and **Ramesh R**., (2022). Record of a Dugong Feeding Trail with a Note on Recent Dugong-Related Incidents Along the Coast of Tamil Nadu, India. *Aquatic Mammals*, *48*(1), 21-25. (Impact Factor: 1.382).
21	2021	Parthiban A., Sachithanandam V., Lalitha P., Muthukumaran J., Misra R., Jain M., Sridhar R., Mageswaran T., Purvaja R. and **Ramesh R**. (2021). Isolation, characterisation, anticancer and anti-oxidant activities of 2-methoxy mucic acid from Rhizophora apiculata: an in vitro and in silico studies. *Journal of Biomolecular Structure and Dynamics*, pp.1-13. (Impact Factor 3.39)

S. No	Year	Details of the Publication
20	2021	Rajakumari S., Meenambikai M., Divya V., Sarunjith KJ. **Ramesh R**., (2021). Morphological changes in alluvial and coastal plains of Kandaleru river, Andhra Pradesh using RS and GIS. *The Egyptian Journal of Remote Sensing and Space Science*. . (Impact Factor: 5.188).
19	2021	Lalitha P., Parthiban A., Sachithanandam V., Purvaja R., **Ramesh R**. (2021). Antibacterial and antioxidant potential of GC-MS analysis of crude ethyl acetate extract from the tropical mangrove plant *Avicennia officinalis L*. South African Journal of Botany, 142, 149-155. (Impact Factor: 2.315).
18	2021	Mahesh R., Sarunjith KJ., Rajakumari S., Muruganandam R., **Ramesh R**. (2021). Quality assessment of open sourced digital elevation models in southeast coast of India. The Egyptian Journal of Remote Sensing and Space Science. (Impact Factor: 5.188).
17	2021	Banerjee K., Saravanan C., Fernandes MC., Kannan V., Purvaja R., **Ramesh R**. (2021). Groundwater and Drinking Water Radon Concentrations in the Coastal and Interior Areas of Chennai Metro City and Its Impact on Public Health. Radiation Protection Dosimetry, 195(2), 83-91. (Impact Factor: 0.773).
16	2021	Raghuram N., Sutton MA., Jeffery R., Ramesh R., Adhya TK. (2021). From South Asia to the world: embracing the challenge of global sustainable nitrogen management. One Earth, 4(1), 22-27.
15	2021	Balasubramanian VK., Maran MIJ., Ramteke D., Vijaykumar DS., Rajendran AK., Purvaja R., **Ramesh R**. (2021). Environmental DNA reveals aquatic biodiversity of an urban backwater area, southeast coast of India. Marine Pollution Bulletin, 171, p.112786. (Impact Factor: 5.553).
14	2021	Jinoj T., Bonthu S., Robin RS., Babu KK., Arumugam K., Purvaja R., **Ramesh R**. (2021). Numerical modelling approach for the feasibility of shore protection measures along the coast of Kavaratti Island, Lakshadweep archipelago. Journal of Earth System Science, 130(3), 1-20. (Impact Factor: 1.423).
13	2021	Semanti P., Robin RS., Purvaja R., **Ramesh R**. (2021). Fatty acid signatures of sediment microbial community in the chronically polluted mangrove ecosystem. Marine Pollution Bulletin, 172, 112885. (Impact Factor: 5.553).
12	2021	Jha RK., Khan RJ., Parthiban A., Singh E., Jain M., Amera GM., Purvaja R., **Ramesh R**., Singh AK. (2021). Identifying the natural compound Catechin from tropical mangrove plants as a potential lead candidate against 3CLpro from SARS-CoV-2: An integrated in silico approach. Journal of Biomolecular Structure and Dynamics, 1-20.
11	2021	Rao MN., Ganguly D., Prasad MHK., Singh G., Purvaja R., Biswal M., **Ramesh R**. (2021). Interspecific variations in mangrove stem biomass: A potential storehouse of sequestered carbon. Regional Studies in Marine Science, 102044. (Impact Factor: 1.624).
10	2021	Robin RS., Purvaja R., Ganguly D., Hariharan G., Paneerselvam A., Sundari R. T., ... and **Ramesh R**. (2021). COVID-19 restrictions and their influences on ambient air, surface water and plastic waste in a coastal megacity, Chennai, India. Marine pollution bulletin, *171*, 112739. Impact Factor: 5.553).
9	2021	Gopi M., Jeevamani JJJ., Goutham, S, Nina T.S., Deepak Samuel V., Abhilash KR, Robin RS., Hariharan G., Muruganandam R., Krishnan P., Purvaja R., and **Ramesh R**. (2021). Status of Health and Conservation Classification of Tropical Coral Reefs In Lakshadweep Archipelago. Wetlands Ecology and Management. (Impact Factor: 1.376).
8	2021	Mugilarasan M., Karthik R., Purvaja R., Robin RS., Subbareddy B., Hariharan G., Rohan S., Jinoj TPS., Anandavelu I., Pugalenthi P. and **Ramesh R**., (2021). Spatiotemporal variations in anthropogenic marine litter pollution along the

S. No	Year	Details of the Publication
		northeast beaches of India. Environmental Pollution, p.116954. (Impact Factor: 8.071).
7	2021	Rajkumari S., Arun BM., Meenambikai M., Sarunjith KJ., **Ramesh R**. (2021). Mapping of water logged areas using SAR images to assess the impact of Tropical Cyclone Gaja in Nagapattinam district, Tamil Nadu using Remote Sensing and GIS. International Research Journal of Engineering and Technology. 8(2). 1008-1024.
6	2021	Mageswaran T., Sachithanandam V., Sridhar R., Mahapatra M., Purvaja R., and **Ramesh R**. (2021). Impact of sea level rise and shoreline changes in the tropical island ecosystem of Andaman and Nicobar region, India. Research Square. 1-22.
5	2021	**Ramesh R**., Purvaja R., Rajakumari S., Suganya GMD., Sarunjith K. J., and Senthil Vel A. (2021). Sediment cells and their dynamics along the coasts of India–A review. Journal of Coastal Conservation, 25(2), 1-14. (Impact Factor: 1.839).
4	2021	Reddy Y., Ganguly D., Singh G., Prasad MH., Paneer Selvam A., Banerjee K., Arumugam A, Purvaja R., and **Ramesh R** (2021). Assessment of bioavailable nitrogen and phosphorus content in the sediments of Indian mangroves. Environmental Science and Pollution Research, 1-19. India (Impact Factor: 4.223).
3	2021	Krishnan P., Abhilash KR. Sreeraj CR., Deepak Samuvel V., Purvaja R., Anand ., Mahapatra M., Sankar R., Raghuram R., and **Ramesh R**. (2021). Balancing livelihood enhancement and ecosystem conservation in seaweed farmed areas: A case study from Gulf of Mannar Biosphere Reserve, India. Ocean & Coastal Management. (Impact Factor: 3.284).
2	2021	Sachithanandam V., Lalitha P., Parthiban A., Jayaraman M., Monika Jain, Ranjita M., Mageswaran T., Sridhar R., Purvaja R., **Ramesh R**. (2021). A comprehensive in silico and in vitro studies on quinizarin: a promising phytochemical derived from *Rhizophora mucronata* Lam. Journal of biomolecular Structure & Dynamics. (Impact Factor: 3.392).
1	2021	Hariharan G., Purvaja R., Anandavelu I., Robin RS., and **Ramesh R**. (2021). Accumulation and ecotoxicological risk of weathered polyethylene (wPE) microplastics on green mussel (*Perna viridis*). Ecotoxicology and Environmental Safety, 208, 111765. (Impact Factor: 6.291).

b) Technical Reports

S. No	Year	Title of the report
6	2022	Long Term Monitoring Plan for the Ecosystem based Conservation Management for Bhitarkanika Conservation Area - 3nd Annual Report & Project Completion Report
5	2022	Linking the Land-based Activities with Ecosystem Dynamics of Pulicat Lagoon in India (UNEP, Nairobi; Yr2021)
4	2022	Safety Risk Assessment and Bathing Water Quality Testing in three Beaches of India
3	2021	National Coastal and Marine Spatial Plan: A framework and action plan
2	2021	The Assessment of Environmental Impact of proposed floating Solar Photo Voltaic Cells in Lagoon of Agatti and Kavaratti Island, Union Territory of Lakshadweep
1	2021	ENCORE - Project Preliminary Report and Detailed Project Reports for Coastal States of India

c) Factsheets & Brochures

- Bhitarkanika Conservation Area Report Card – 2: (Yr2020-Yr2021)

d) Atlas

- Awareness on Single Use Plastic Pollution

e) Capacity building

Number of Internships for the year 2021-2022	**4**
Number of Dissertation for the year 2021-2022	**10**

f) Other Research Revenue Generation Projects

EDC Group Projects

1. Preparation of Mangrove Conservation and Management Plan for Kerala Speed Rail Project
2. Environmental Monitoring of Phase II Development of Adani Krishnapatnam Port
3. Survey of 45 hectares area at Kasarkod Tonka in Honnavar Taluk of Uttar Kannada District of Karnataka on the issue of Turtle Nesting Ground.

	GROUP A	GROUP B	Total
COMPLETED	22	1	23
ONGOING/ PENDING	29	7	36
Total	**51**	**8**	**59**

g) Meetings/ Conferences/ Workshops (2021-2022)

Date	Title of Event	Organised by	Place
29th June 2022 to 3rd July 2022	Uttar Pradesh Plastic Waste Management Conclave - 2022	Department of Environment, Forest and Climate Change and Urban Development Department, Government of Uttar Pradesh in collaboration with GIZ India	Indira Gandhi Pratishthan, Lucknow
02nd February, 2022	World Wetland Day 2022	Tamil Nadu State Wetland Authority, Government of Tamil Nadu & National Centre for Sustainable Coastal Management (NCSCM)	Rosette convention centre,NCSCM, Chennai
26th January, 2022	Celebration of 73rd Republic day and Inauguration of Coastal Ecology Lab (BENTHOS)	NCSCM	NCSCM
26th January, 2022	Celebration of 73rd Republic day and Inauguration of Coastal Ecology Lab (BENTHOS)	NCSCM	NCSCM
01st November, 2021 to 3rd November, 2021	Sh. Jigmet Takpa, Joint Secretary @MoEFCC and National Project Director @SICOM and Sh. Sundeep, Additional Project Director @SICOM visited @NCSCM for interaction with scientists	NCSCM	NCSCM
30th October, 2021	An outreach activity was conducted by #NCSCM at Elliots Beach, Besant Nagar, Chennai as part of Vigilance Awareness Week 2021 on 30th November 2021.	NCSCM	Elliots Beach, Besant Nagar, Chennai
5th August, 2021	75th Independance day @NCSCM	NCSCM	NCSCM


TOP PREDATORS
HIGHER TROPHIC LEVEL
MID-TROPHIC LEVEL
LOWER TROPHIC LE
PRIMARY PRODUCERS


12
21 Century Polymers, North West, Delhi
POLYMER COMPOUNDS
FOR PACKAGING
11
SAAHAS- Zero Waste, Bangalore Karnataka
TOP PREDATORS
HIGHER TROPHIC LEVEL
MID-TROPHIC LEVEL
RECOVERY
RECYCLE
Convert materials to new products

World Wetland Day 2022

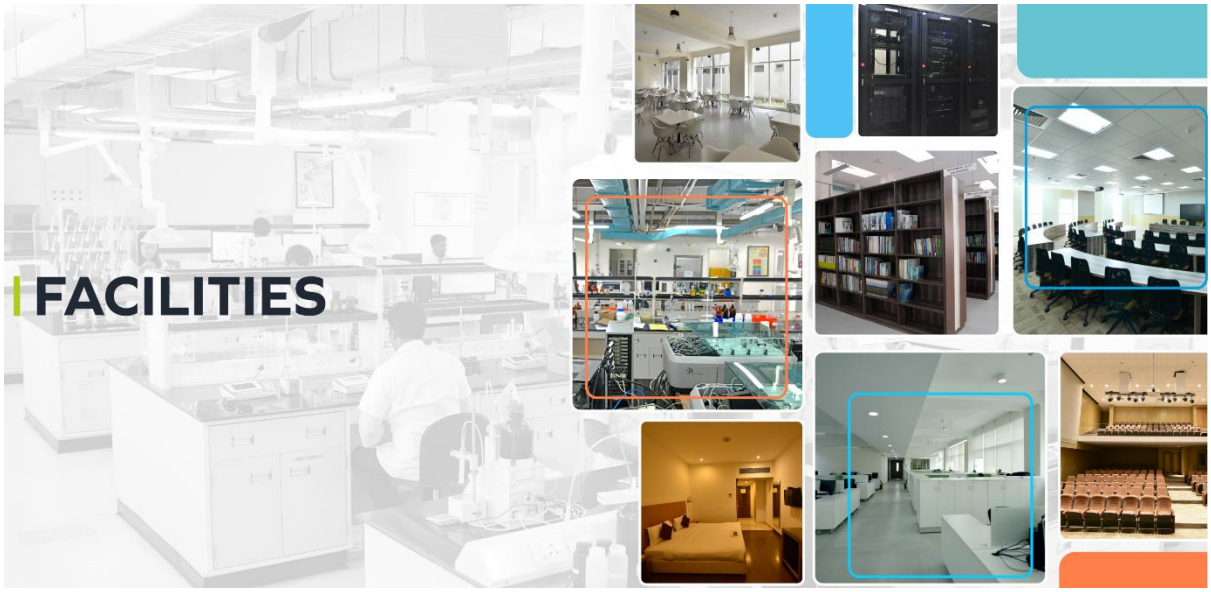
Celebration of 73rd Republic day and Inauguration of Coastal Ecology Lab (BENTHOS)

Sh. Jigmet Takpa, Joint Secretary @MoEFCC and National Project Director @SICOM and Sh. Sundeep, Additional Project Director @SICOM visited @NCSCM for interaction with scientists

An outreach activity was conducted by #NCSCM at Elliots Beach, Besant Nagar, Chennai as part of Vigilance Awareness Week 2021 on 30th November 2021

75th Independence day @NCSCM

Infrastructure



DELTA

The Auditorium

DELTA auditorium is the central important place to deliver professional seminars, conferences, presentations and important meetings apart from screening research oriented movies. The entire facility is fully air-conditioned with a dedicated power back-up. Delta auditorium has a seating configuration for 220 people with acoustic audio visual facilities. Other facilities includes video conferencing, Personnel assistance system, digital projection, and WiFi facilities. It has an excellent stage to be used for all common functions/events. Behind the stage, support and service room is also available.

ROSETTE

Convention Centre

Rosette hall is a well-furnished and very spacious fully air conditioned Conference Hall with state of the art audio, video facilities. It has a capacity to accommodate up to 70 participants. This premier space is designed for various lectures by Guest Speakers, Exhibitions, Seminars, programmes and conferences.

CLIFF

Visiting Scientist's Hostel

NCSCM offers well-designed spacious 2-storeyed Visiting Scientist's Hostel for the comfortable stay for the delegates, researchers and scientists. Cliff Visiting Scientist

Hostel has 13 AC rooms, consisting of 4 Suites and 9 Standard rooms. All the rooms are well-equipped with Television set, intercom, Hi speed Wi-Fi and other basic amenities.

For reservation email the downloaded application to traveldesk[at]ncscm[dot]org

Chlorophyll

The Café

NCSCM has air conditioned Cafeteria with modern facilities within its campus, which is open for staff, students and visitors. It has a seating capacity of 64 serves at a time. Healthy and hygienic food, meals and fresh fruit juices are available. Hard-working, well-trained staff ensures a prompt and environmentally sustainable services by using resources conscientiously.

Cafeteria is open for public from Monday to Saturday (9:00 AM to 6:30 PM).

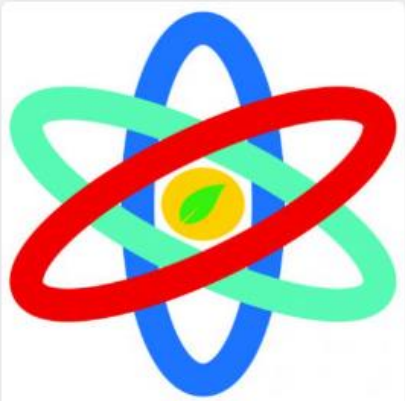
Library

ATHENAEUM

NCSCM library collection includes books, periodicals, newspapers, manuscripts, research films, maps, printed resources, manuscript, online databases, theses and ephemeral collections to support the scholarly and subject information needs of the researchers. Athenaeum has a reading hall with seating capacity of 36, and 85″ smart TV for displaying recent research works, research movies, underwater videos about different species and its habitat. The mezzanine floor has a dedicated e-library with Science Direct subscription. 16 touch screen personal computers are available. Dedicated library staff are present to provide assistance for issuing and returning of books. NCSCM invites all to visit the library in order to enjoy the wealth of printed resources available on our shelves.

SCIENTIFIC LABORATORIES

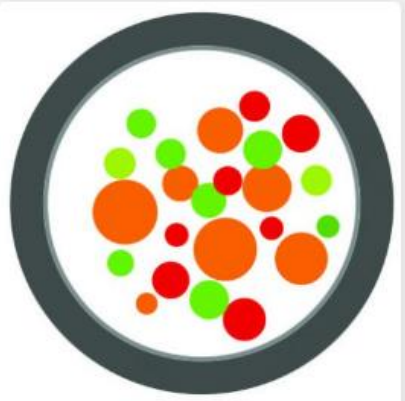
NCSCM laboratories are equipped with highly sophisticated equipment for specialized analyses. Several multi-disciplinary research studies are undertaken as part of the Integrated Coastal Zone Management Project and coastal ecosystem science for management. This state-of-the-art facility is used to further NCSCM research mandates and are open for use by researchers, students and for expanding the business plan of NCSCM.



Environmental Radiochemistry Lab

Coastal Biomonitoring Facility

Coastal Hydrogeochemistry Facility



Marine Microbiology Lab

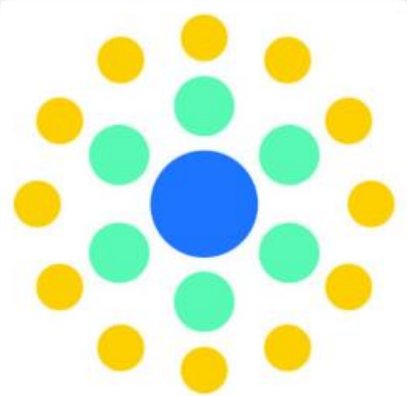
Persistent Organic Pollutant Research Lab

Climate Change Research Facility

Paleoclimate Reconstruction Lab

Beach Monitoring Lab

Marine Litter Research Lab



Advanced Imaging and Analytical Facility

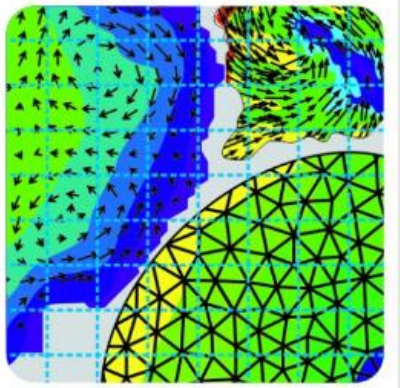
Marine Plankton Imaging Lab

Coastal Tropical Ecology Lab

Air Quality Monitoring Lab

Marine Biotechnology Lab

Field Equipment



Numerical Modeling Lab

7. Right to Information

RTI Annual Return Information System

Quaterly Return Form

Public Authority : National Centre for Sustainable Coastal Management (NCSCM)

Quarter : Ist Quarter (April-June)2021-2022

* Block I (Details about the requests and appeals)

			Progress during Quarter			
	Opening Balance as on begining of	No. of application received as transfer from other PAs u/s 6(3)	Received during the Quarter(including cases transferred to other PAs)	No. of Cases transfered to other PAs u/s 6(3)	Decisions Where requests/appeals rejected	Decisions Where requests/appeals replied
Requests	2	1	5	0	0	8
First Appeals	0	N/A	0	N/A	0	0
		Total no. Of CAPIOs designated 0		Total no. Of CPIOs designated 1		Total no. Of AAs designated 1

* Block II (Details about fees Collected,penalty imposed and disciplinary action taken)

Registration Fee Collected(in Rs.) u/s 7(1)	Addl. Fee Collected(in Rs.) u/s 7(3)	Penalty Amount Recovered(in Rs.) as directed by CIC u/s 20(1)	No. Of Cases where disciplinary action taken against any Officer u/s 20(2)
30	50	0	0

* Block III (Details Of various provisions of section 8 while rejecting the requested information)

No. Of times various provisions were invoked while rejecting requests

Relevant Sections Of RTI Act 2005

Section 8(i)										Section			
a	b	c	d	e	f	g	h	i	j	9	11	24	other
0	0	0	0	0	0	0	1	0	0	0	0	0	2

* Block IV (Details Regarding Mandatory Disclosures)

A. Is the Mandatory Disclosures under Sec. 4(1)(b) posted on the Website of Public Authority ?	Provide the detail/URL of webpage,where the disclosure is posted (max 150 chars)
Yes	www.ncscm.res.in
B. Last Date of updating of Mandatory disclosure under Section 4(1)b	2021-07-15
C. Has the Mandatory Disclosure been audited by third party as per DOPT vide OM No. 1/6/2011-IR dated 15-04-2013?	Provide the detail/URL of webpage,where the Audit report is posted (max 150 chars)
Yes	https://cic.gov.in/sites/default/files/Transparency%
D. Date of audit of Mandatory disclosures under Sec. 4(1)(b)(Format dd/mm/yyyy)	2018-11-12

RTI Annual Return Information System

Quaterly Return Form

Public Authority : National Centre for Sustainable Coastal Management (NCSCM)

Quarter : 2nd Quarter (July-Sept)2021-2022

* Block I (Details about the requests and appeals)

			Progress during Quarter			
	Opening Balance as on begining of	No. of application received as transfer from other PAs u/s 6(3)	Received during the Quarter(including cases transferred to other PAs)	No. of Cases transfered to other PAs u/s 6(3)	Decisions Where requests/appeals rejected	Decisions Where requests/appeals replied
Requests	0	1	9	2	0	7
First Appeals	0	N/A	0	N/A	0	0
		Total no. Of CAPIOs designated 0		Total no. Of CPIOs designated 1		Total no. Of AAs designated 1

* Block II (Details about fees Collected,penalty imposed and disciplinary action taken)

Registration Fee Collected(in Rs.) u/s 7(1)	Addl. Fee Collected(in Rs.) u/s 7(3)	Penalty Amount Recovered(in Rs.) as directed by CIC u/s 20(1)	No. Of Cases where disciplinary action taken against any Officer u/s 20(2)
130	0	0	0

* Block III (Details Of various provisions of section 8 while rejecting the requested information)

No. Of times various provisions were invoked while rejecting requests

Relevant Sections Of RTI Act 2005

Section 8(i)										Section			
a	b	c	d	e	f	g	h	i	j	9	11	24	other
0	0	0	0	0	0	0	0	0	1	0	0	0	1

* Block IV (Details Regarding Mandatory Disclosures)

A. Is the Mandatory Disclosures under Sec. 4(1)(b) posted on the Website of Public Authority ?	Provide the detail/URL of webpage,where the disclosure is posted (max 150 chars)
Yes	**www.ncscm.res.in**
B. Last Date of updating of Mandatory disclosure under Section 4(1)b	**2021-07-15**
C. Has the Mandatory Disclosure been audited by third party as per DOPT vide OM No. 1/6/2011-IR dated 15-04-2013?	Provide the detail/URL of webpage,where the Audit report is posted (max 150 chars)
Yes	**https://cic.gov.in/sites/default/files/Transparency%**
D. Date of audit of Mandatory disclosures under Sec. 4(1)(b)(Format dd/mm/yyyy)	**2018-11-12**

RTI Annual Return Information System

Quaterly Return Form

Public Authority : **National Centre for Sustainable Coastal Management (NCSCM)**

Quarter : **3rd Quarter (Oct-Dec)2021-2022**

* Block I (Details about the requests and appeals)

			Progress during Quarter			
	Opening Balance as on begining of	No. of application received as transfer from other PAs u/s 6(3)	Received during the Quarter(including cases transferred to other PAs)	No. of Cases transfered to other PAs u/s 6(3)	Decisions Where requests/appeals rejected	Decisions Where requests/appeals replied
Requests	1	14	11	1	0	21
First Appeals	0	N/A	4	N/A	0	4
		Total no. Of CAPIOs designated 0		Total no. Of CPIOs designated 1		Total no. Of AAs designated 1

* Block II (Details about fees Collected,penalty imposed and disciplinary action taken)

Registration Fee Collected(in Rs.) u/s 7(1)	Addl. Fee Collected(in Rs.) u/s 7(3)	Penalty Amount Recovered(in Rs.) as directed by CIC u/s 20(1)	No. Of Cases where disciplinary action taken against any Officer u/s 20(2)
20	0	0	0

* Block III (Details Of various provisions of section 8 while rejecting the requested information)

No. Of times various provisions were invoked while rejecting requests

Relevant Sections Of RTI Act 2005

Section 8(i)										Section			
a	b	c	d	e	f	g	h	i	j	9	11	24	other
13	0	0	0	0	0	0	21	0	1	0	0	0	2

* Block IV (Details Regarding Mandatory Disclosures)

A. Is the Mandatory Disclosures under Sec. 4(1)(b) posted on the Website of Public Authority ?	Provide the detail/URL of webpage,where the disclosure is posted (max 150 chars)
Yes	**www.ncscm.res.in**
B. Last Date of updating of Mandatory disclosure under Section 4(1)b	**2021-07-15**
C. Has the Mandatory Disclosure been audited by third party as per DOPT vide OM No. 1/6/2011-IR dated 15-04-2013?	Provide the detail/URL of webpage,where the Audit report is posted (max 150 chars)
Yes	**https://cic.gov.in/sites/default/files/Transparency%**
D. Date of audit of Mandatory disclosures under Sec. 4(1)(b)(Format dd/mm/yyyy)	**2018-11-12**

RTI Annual Return Information System

Quaterly Return Form

Public Authority : National Centre for Sustainable Coastal Management (NCSCM)

Quarter : 4th Quarter (Jan-Mar)2021-2022

* Block I (Details about the requests and appeals)

			Progress during Quarter			
	Opening Balance as on begining of	No. of application received as transfer from other PAs u/s 6(3)	Received during the Quarter(including cases transferred to other PAs)	No. of Cases transfered to other PAs u/s 6(3)	Decisions Where requests/appeals rejected	Decisions Where requests/appeals replied
Requests	4	0	7	1	0	10
First Appeals	0	N/A	0	N/A	0	0
		Total no. Of CAPIOs designated 0		Total no. Of CPIOs designated 1		Total no. Of AAs designated 1

* Block II (Details about fees Collected,penalty imposed and disciplinary action taken)

Registration Fee Collected(in Rs.) u/s 7(1)	Addl. Fee Collected(in Rs.) u/s 7(3)	Penalty Amount Recovered(in Rs.) as directed by CIC u/s 20(1)	No. Of Cases where disciplinary action taken against any Officer u/s 20(2)
0	0	0	0

* Block III (Details Of various provisions of section 8 while rejecting the requested information)

No. Of times various provisions were invoked while rejecting requests
Relevant Sections Of RTI Act 2005

Section 8(i)										Section			
a	b	c	d	e	f	g	h	i	j	9	11	24	other
1	0	0	0	0	0	0	2	0	0	0	0	0	4

* Block IV (Details Regarding Mandatory Disclosures)

A. Is the Mandatory Disclosures under Sec. 4(1)(b) posted on the Website of Public Authority ?	Provide the detail/URL of webpage,where the disclosure is posted (max 150 chars)
Yes	www.ncscm.res.in
B. Last Date of updating of Mandatory disclosure under Section 4(1)b	2021-07-15
C. Has the Mandatory Disclosure been audited by third party as per DOPT vide OM No. 1/6/2011-IR dated 15-04-2013?	Provide the detail/URL of webpage,where the Audit report is posted (max 150 chars)
Yes	https://cic.gov.in/sites/default/files/Transparency%
D. Date of audit of Mandatory disclosures under Sec. 4(1)(b)(Format dd/mm/yyyy)	2018-11-12

8. Audit Report (FY2021-2022)

K. RAMANAN & CO
Chartered Accountants

#778, D-Sector, 9th Street, Syndicate Bank Colony,
Anna Nagar West Extn, Chennai - 600 101.
Mob : +91-9840149391 | Ph : 044-48575362
E-mail : kramanan1949@gmail.com
Web : www.caramanan.com

Dt: 31.10.2022

To

The Director,

National Centre for Sustainable Coastal Management,

Anna University Campus,

Guindy,

Chennai-600025.

Dear Sir,

Sub: Statutory Audit for FY: 2021 - 22 - Management Report

In connection with our audit of the financial statements of the NCSCM Project for the Year ended 31st March 2022, we have familiarized ourselves with Project documents, the internal guidelines and circulars applicable during the period under audit. We also reviewed the business of the Project and evaluated the accounting systems and related internal controls of the Project in order to plan and perform our audit.

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

i) Lack of presence of Internal Audit Department:

The direct and ultimate responsibility for internal control always lies with management. The presence of Internal Audit Department will help in monitoring the effectiveness of the existing internal control processes and also newly introduced processes on a **regular and continuous basis** established by management which will help in **accomplishing its objectives** by bringing a systematic, disciplined approach to evaluate and improve the effectiveness of **risk management, control and governance processes**. Therefore, an Internal Audit Department becomes essential and needful.

ii) Mismatches of Fixed assets vs. Capital Account:-

As per the treatment of the prescribed accounting policy of the society, corpus fund-physical account of the society should be matched with the fixed assets acquired. However, for the past years, there is a mismatch to the extent of Rs.2,02,673/- the assets being short. We request the management to reconcile this difference.

iii) Settlement of Staff Advances (TA/DA &Contingency):

We would like to suggest for an introduction of a **policy** for settling of the advances made to various research and other personnel for their field trip visits. The advances given to employees is required to be settled before **an affixed deadline** (for ex: employees should submit appropriate vouchers/bills "within 7 days of completion of field visit" / "end of the financial year" whichever is earlier). This shall ensure the timely closure of the advances given by NCSCM to employees and also avoiding mishandling/misuse of organization funds in the hands of employees.

iv) Delay in Revenue Recognition of Projects undertaken by NCSCM:

There is a requirement of a **dedicated mechanism** for timely completion of Projects undertaken by NCSCM before the applicable deadline as decided in the first instance in the contract/agreement in order to avoid the delay for the following reasons:-

a) The recognition of Revenue in Income and Expenditure a/c is not delayed/deferred to next financial year.
b) The creation of Corpus in Balance Sheet is not delayed/deferred.

v) Existence of Contract extension agreement:

During the course of audit, it has been observed that few contracts are still continued without existence of appropriate **Contract Extension Agreement**. Hence, we hereby suggest that steps be taken to retrospectively enter into contract extension agreement for the aforesaid issue and proper measures to be placed to avoid such anomalies in the future.

vi) Unreconciled Deposits by Staff:

The numerous cash deposits were made by staff over a period of time in the past directly into the bank a/c of NCSCM amounts to Rs. 2,60,839/-. This is for "settlement of balances of TA/DA or Contingency advances". The centre is unable to trace and adjusted the same to the respective individual staff advance a/c due to unavailability of data (employee name, project against which remaining balance of advance sanctioned earlier is deposited) for adjustment of advance.

vii) Unreconciled Inter Unit Account:-

While consolidating all the accounts, Inter unit transfers/accounts should be reconciled and the balance should be nil. However, during the year end, there is an unreconciled balance aggregate of Rs.43,81,175.87/-. Management should take care in matching the entries.

viii) Status of Records:-

- Project books and records – up to date
- Accuracy of financial statements – Satisfactory
- Compliance of prescribed procedures – Satisfactory
- Status of Prior Audit recommendations:
    a) There was a loss of an asset called "Wave Rider Buoy" a few years ago. Insurance has rejected the claim. According to us, this cannot be shown as an existing asset and should be remove after appropriate approvals.
    b) The requirement for maintenance of an Asset Movement Register reported earlier is now successfully fulfilled.

ix) Statutory Liabilities:-

Statutory liability includes GST payable in revenue activity from the inception and it amounts to Rs.512.96 lakhs. The amounts paid against these amounts to Rs.517.19 lakhs and shown as Claims Receivable in Other Assets (Schedule 11-B-4).

This needs to be set off and tallied with ITC ledger and cash ledger in GST portal. The same is to be followed for other projects as well. Further it is necessary to adjust the asset and liability and the net figure be shown in the Balance Sheet.

x) State Bank of India:-

SBI account is being maintained for statutory payments. This account is a common account for all units. We find that a sum of Rs.30.61 lakhs is shown as a negative balance in SBI in ICZMP accounts, whereas there is no borrowings to that effect.

In order to avoid this, it is suggested to first transfer the required funds from either UBI or Yes Bank of ICZMP to SBI account.

xi) TDS:-

TDS claimed for the FY 2020-21 is Rs.63.11 lakhs in Income Tax return. In current assets, the amount claimed (as per books) is Rs.63.59 lakhs. Similarly, the Deferred Tax for the year as per the return and as per books is to be reconciled. The difference is Rs.12.82 lakhs.

The matters contained in the Management Report are intended solely for the information of The Project Management, for such timely consideration and action as Project Management may deem appropriate. They have all been considered by us in formulating the audit opinion expressed on the project financial statements in our audit report dated 31.10.2022 and they do not alter the opinion expressed in that audit report.

We wish to take this opportunity to thank Project Management for the courtesy and cooperation extended to us in the course of audit.

Yours Faithfully

CA.K.RAMANAN
M.No. 019177
For K.Ramanan & Co
Chartered Accountants
FRN No. 002926S

SCHEDULE 24 - Significant Accounting Policies and Notes forming part of Accounts for the year Ended 31.3.2022

A. Significant Accounting Policies:-

1. The accounts are prepared on the basis of historical cost. Grants and payments are accounted for on a "Cash basis".

2. Trust is having policy of not charging depreciation to Fixed Assets.

B. Notes to Accounts:-

Grants received is taken as a liability under NPMU Funds. This is levy spent for revenue and capital expenditure. The total of revenue and capital is transferred to Grant in Aid in the year end and shown as Income in Income and Expenditure Account.
The expenditure on capital account is shown as excess of income over expenditure and transferred to Corpus/ Capital Fund.

Signature to 1-24 schedule of the balance sheet

For K Ramanan & Co.
Chartered accountants

K Ramanan
M.No: 019177
Date: 27-10-2022
Place: Chennai

FORM OF FINANCIAL STATEMENTS (NON-PROFIT ORGANISATIONS)			
NATIONAL CENTRE FOR SUSTAINABLE COASTAL MANAGEMENT			
CONSOLIDATED BALANCE SHEET AS ON March 31, 2022			
FY 2021-2022			
		Amount (Rs)	
	Schedule	FY 2021-22	FY 2020-21
CORPUS/CAPTIAL FUND AND LIABILITIES			
CORPUS/CAPITAL FUND	1	₹ 1,64,35,06,526.07	₹ 1,40,44,07,317.84
RESERVES AND SURPLUS	2	₹ 0.00	₹ 18,17,98,126.88
1.Capital Reserve		₹ 0.00	₹ 0.00
As per last Account		₹ 0.00	₹ 0.00
Addition during the year		₹ 0.00	₹ 0.00
Less: Deductions during the year		₹ 0.00	₹ 0.00
2.Revaluation Reserve		₹ 0.00	₹ 0.00
As per last Account		₹ 0.00	₹ 0.00
Addition during the year		₹ 0.00	₹ 0.00
Less: Deductions during the year		₹ 0.00	₹ 0.00
3.Special Reserves:		₹ 0.00	₹ 0.00
As per last Account		₹ 0.00	₹ 0.00
Addition during the year		₹ 0.00	₹ 0.00
Less: Deductions during the year		₹ 0.00	₹ 0.00
4.General Reserve		₹ 0.00	₹ 18,17,98,126.88
As per last Account		₹ 0.00	₹ 0.00
Addition during the year		₹ 0.00	₹ 0.00
Less: Deductions during the year		₹ 0.00	₹ 0.00
EARMARKED/ENDOWMENT FUNDS	3	₹ 0.00	₹ 0.00
a) Opening balance of the funds		₹ 0.00	₹ 0.00
b) additons to the funds		₹ 0.00	₹ 0.00
i.Donations/grants		₹ 0.00	₹ 0.00
ii.Income from investments made on account of funds		₹ 0.00	₹ 0.00
iii.Other additions (specify nature)		₹ 0.00	₹ 0.00
TOTAL (a+b)		₹ 0.00	₹ 0.00
c) utilisation/expenditure towards objectives of funds		₹ 0.00	₹ 0.00
i.Capital Expenditure		₹ 0.00	₹ 0.00
-Fixed Assets		₹ 0.00	₹ 0.00
-Others		₹ 0.00	₹ 0.00
Total		₹ 0.00	₹ 0.00
ii.Revenue Expenditure		₹ 0.00	₹ 0.00
-Salaries, wages and allowances etc		₹ 0.00	₹ 0.00
-Rent		₹ 0.00	₹ 0.00
-Other administrative expenses		₹ 0.00	₹ 0.00
Total		₹ 0.00	₹ 0.00
Net Balance as at the year -end (a+b+c)		₹ 0.00	₹ 0.00
SECURED LOANS AND BORROWINGS	4	₹ 0.00	₹ 0.00
1.Central Government		₹ 0.00	₹ 0.00
2.State Government(specify)		₹ 0.00	₹ 0.00
3.Financial Institutions(a)term loan (b)interest accrued and due		₹ 0.00	₹ 0.00
4.Banks		₹ 0.00	₹ 0.00
5.Other institutions and agencies		₹ 0.00	₹ 0.00
6.Debentures and Bonds		₹ 0.00	₹ 0.00
7.Others (specify)		₹ 0.00	₹ 0.00
UNSECURED LOANS AND BORROWINGS	5	₹ 0.00	₹ 0.00
1.Central Government		₹ 0.00	₹ 0.00
2.State Government(specify)		₹ 0.00	₹ 0.00
3.Financial Institutions		₹ 0.00	₹ 0.00
4.Banks (a) Term Loans (b) other loans(specify)		₹ 0.00	₹ 0.00
5.Other institutions and agencies		₹ 0.00	₹ 0.00
6.Debentures and Bonds		₹ 0.00	₹ 0.00
7. Fixed Deposits		₹ 0.00	₹ 0.00
8.Others (specify)		₹ 0.00	₹ 0.00
DEFERRED CREDIT LIABILITIES	6	₹ 0.00	₹ 0.00
CURRENT LIABILITIES AND PROVISIONS		₹ 43,06,62,486.25	₹ 31,45,52,373.68
A.CURRENT LIABILITIES		₹ 40,90,83,075.09	₹ 29,25,34,721.68
1.Acceptances		₹ 0.00	₹ 0.00
2.Sundry Creditors (a) for goods (b) others		₹ 0.00	₹ 0.00
3.Advances received		₹ 32,20,13,343.91	₹ 23,06,96,122.18
4.Interest accrued but not due on(a) secured loan/borrowings, (b) unsecured loans/borrowings		₹ 0.00	₹ 0.00

K. RAMANAMAN
M.No. 019177
778, 8TH STREET,
ANNA NAGAR W.E.,
CHENNAI-101.
Chartered Accountants

K. Ramanaman

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

	Schedule	Amount (Rs) FY 2021-22	FY 2020-21
5.Statutory Liabilities	7	₹ 8,10,86,593.18	₹ 5,90,30,712.50
6.Other current Liabilities		₹ 59,83,138.00	₹ 28,07,887.00
B.PROVISIONS		**₹ 2,15,79,411.16**	**₹ 2,20,17,652.00**
1.For Taxation		₹ 0.00	₹ 0.00
2.Gratuity		₹ 0.00	₹ 0.00
3.superannuation /pension		₹ 0.00	₹ 2,15,16,266.00
4.Accumulated Leave Encashment		₹ 0.00	₹ 0.00
5.Trade Warranties/ claim		₹ 0.00	₹ 0.00
6.others (specify		₹ 2,15,79,411.16	₹ 5,01,386.00
TOTAL		**₹ 2,07,41,69,012.32**	**₹ 1,90,07,57,818.40**
ASSETS			
FIXED ASSETS	8	**₹ 1,40,73,80,032.84**	**₹ 1,40,42,04,644.84**
1. LAND		₹ 0.00	₹ 0.00
2.BUILDINGS		₹ 62,35,63,119.40	₹ 62,35,63,119.40
3.PLANT MACHINERY& EQUIPMENT		₹ 47,68,87,961.33	₹ 47,68,87,961.33
4.VEHICLES		₹ 28,86,557.00	₹ 28,86,557.00
5.FURNITURE, FIXTURES		₹ 20,04,965.00	₹ 19,21,565.00
6.OFFICE EQUIPMENT		₹ 68,99,669.00	₹ 68,99,669.00
7.COMPUTER/PERIPHERALS		₹ 26,49,31,758.00	₹ 26,18,39,770.00
8.ELECTRIC INSTALLATIONS		₹ 1,10,50,526.00	₹ 1,10,50,526.00
9.LIBRARY BOOKS		₹ 0.00	₹ 0.00
10.TUBEWELLS & W.SUPPLY		₹ 0.00	₹ 0.00
11.OHTER FIXED ASSETS		₹ 1,91,55,477.11	₹ 1,91,55,477.11
INVESTMENTS-FROM EARMARKED/ENDOWMENT FUNDS	9	**₹ 0.00**	**₹ 0.00**
1. In Government securities		₹ 0.00	₹ 0.00
2.Other approved securies		₹ 0.00	₹ 0.00
3.shares		₹ 0.00	₹ 0.00
4.Debentures and Bonds		₹ 0.00	₹ 0.00
5.Subsidiaries and joint ventures		₹ 0.00	₹ 0.00
6.Others (to be specified)		₹ 0.00	₹ 0.00
INVESTMENTS-OTHERS	10	**₹ 0.00**	**₹ 0.00**
1. In Government securities		₹ 0.00	₹ 0.00
2.Other approved securies		₹ 0.00	₹ 0.00
3.shares		₹ 0.00	₹ 0.00
4.Debentures and Bonds		₹ 0.00	₹ 0.00
5.Subsidiaries and joint ventures		₹ 0.00	₹ 0.00
6.Others (to be specified)		₹ 0.00	₹ 0.00
CURRENT ASSETS, LOANS, ADVANCES ETC	11	**₹ 66,67,88,979.48**	**₹ 49,65,53,173.56**
A.CURRENT ASSETS		**₹ 23,07,35,502.60**	**₹ 15,38,50,687.26**
1.Inventories		₹ 0.00	₹ 0.00
2.sundry Debtors		₹ 1,34,53,604.94	₹ 1,41,44,119.94
3.Cash Balance in Hand		₹ 4,033.00	₹ 4,033.00
4.Bank Balances		₹ 21,72,77,864.66	₹ 13,97,02,534.32
5.Post Office-savings accounts		₹ 0.00	₹ 0.00
B.LOANS , ADVANCES AND OTHER ASSETS		**₹ 43,60,53,476.88**	**₹ 34,27,02,486.30**
1.Loans		**₹ 2,10,27,030.74**	**₹ 2,24,27,276.38**
a-staff		₹ 0.00	₹ 0.00
b-other entities engaged in actvities/objectives similar to that of the entity		₹ 0.00	₹ 0.00
c-Others-Adv to staff-travel		₹ 2,10,27,030.74	₹ 2,24,27,276.38
2.Advances and other amounts recoverable in cash or in kind or for value to be received		**₹ 83,14,188.00**	**₹ 35,07,516.00**
a-on Capital Account		₹ 0.00	₹ 0.00
b-Prepayments		₹ 83,14,188.00	₹ 35,07,516.00
c-Others		₹ 0.00	₹ 0.00
3.Income Accrued		₹ 0.00	₹ 0.00
4.claims receivables		**₹ 40,67,12,258.14**	**₹ 31,67,67,693.92**
MISCELLANEOUS EXPENDITURE (to the extent not written off or adjusted)			₹ 0.00
TOTAL		**₹ 2,07,41,69,012.32**	**₹ 1,90,07,57,818.40**

K. RAMANAN & CO. Chartered Accountants
K. RAMANAN
M.No. 019177
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K. Ramanan

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

FORM OF FINANCIAL STATEMENTS (NON-PROFIT ORGANISATIONS)

NATIONAL CENTRE FOR SUSTAINABLE COASTAL MANAGEMENT

CONSOLIDATED INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED AS ON March 31,2022

FY 2021-22

	Schedule	Amount (Rs) FY 2021-22	Amount (Rs) FY 2020-21
INCOME			
INCOME FROM SALES/SERVICES	12	**₹ 7,37,31,096.00**	**₹ 13,04,44,352.80**
1.Income from Sales		₹ 0.00	₹ 0.00
2.Income from Services		₹ 7,37,31,096.00	₹ 13,04,44,352.80
GRANTS/SUBSIDIES	13	**₹ 16,02,70,763.70**	**₹ 31,42,58,150.25**
1.Central Government		₹ 0.00	₹ 0.00
2.State Government		₹ 0.00	₹ 0.00
3.Government Agencies		₹ 16,02,70,763.70	₹ 31,42,58,150.25
4.Institutions/welfare agencies		₹ 0.00	₹ 0.00
5.International organisations		₹ 0.00	₹ 0.00
6.Others(specify)		₹ 0.00	₹ 0.00
FEES/SUBSCRIPTIONS	14	**₹ 0.00**	**₹ 0.00**
1.Entrace Fees		₹ 0.00	₹ 0.00
2.Annual fees/ subscriptions		₹ 0.00	₹ 0.00
3.Seminar/program fees		₹ 0.00	₹ 0.00
4.consultancy fees		₹ 0.00	₹ 0.00
5.Others (specify)		₹ 0.00	₹ 0.00
INCOME FROM INVESTMENTS (INCOME ON INVEST FROM EARMARKED/ENDOW, FUNDS TRANSFERRED TO FUNDS)	15	**₹ 0.00**	**₹ 0.00**
1.Interest		₹ 0.00	₹ 0.00
2.Dividends		₹ 0.00	₹ 0.00
3.Rents		₹ 0.00	₹ 0.00
4.Others (specify)		₹ 0.00	₹ 0.00
INCOME FROM ROYALTY, PUBLICATION ETC	16	**₹ 0.00**	**₹ 0.00**
1.Income from royalty		₹ 0.00	₹ 0.00
2.Income from publications		₹ 0.00	₹ 0.00
3.Others (specify)		₹ 0.00	₹ 0.00
INTEREST EARNED	17	**₹ 47,34,868.00**	**₹ 77,75,829.00**
1 On term Deposit		₹ 0.00	₹ 0.00
2.On savings accounts		₹ 47,34,868.00	₹ 77,75,829.00
3.On loans		₹ 0.00	₹ 0.00
4.Interst onDebtors and other receivables		₹ 0.00	₹ 0.00
OTHER INCOME	18	**₹ 1,12,677.80**	**₹ 14,750.90**
1 Profit on sale/disposal of assets		₹ 0.00	₹ 0.00
2.Export incentives realised		₹ 0.00	₹ 0.00
3.Fees for Miscellaneous services		₹ 0.00	₹ 0.00
4.Miscellaneous Income		₹ 1,12,677.80	₹ 14,750.90
INCREASE/(DECREASE) IN STOCK OF FINISHED GOODS AND WORK-IN-PROGRESS	19	₹ 0.00	₹ 0.00
TOTAL(A)		**₹ 23,88,49,405.50**	**₹ 45,24,93,082.95**
EXPENDITURE		--	--
ESTABILLISHMENT EXPENSES	20	**₹ 11,14,61,138.00**	**₹ 12,72,50,320.00**
(a)Salaries and Wages		₹ 10,67,76,968.00	₹ 11,92,72,370.00
(b)Allowances and Bonus		₹ 0.00	₹ 0.00
(c)Contribution to Provident Fund		₹ 13,59,782.00	₹ 51,12,764.00
(d)Contribution to Other Fund (specify)		₹ 0.00	₹ 0.00
(e)Staff Welfare Expenses		₹ 33,24,388.00	₹ 28,65,186.00
(f)Expenses on Employees Retirement and Terminal Benefits		₹ 0.00	₹ 0.00
(g)Others (Specify)		₹ 0.00	₹ 0.00
OTHER ADMINISTRATIVE EXPENSES, ETC	21	**₹ 7,52,45,392.45**	**₹ 12,30,12,525.30**
a)Purchases		₹ 84,74,114.00	₹ 2,17,01,348.32
b)Labour and processing expenses		₹ 0.00	₹ 0.00
c)cartage and carriage inwards		₹ 0.00	₹ 0.00
d)Electricity and power		₹ 89,67,155.00	₹ 87,89,897.00
e)water charges		₹ 98,000.00	₹ 5,09,070.00
f)Insurance		₹ 8,88,109.00	₹ 8,95,970.00
g)Repairs & maintenance		₹ 2,40,75,512.12	₹ 3,95,61,129.92
h)Excise duty		₹ 0.00	₹ 0.00
i)Rent, Rates & Taxes		₹ 0.00	₹ 0.00
j)Vehicles Running and maintenance		₹ 0.00	₹ 0.00

K. RAMANAN & CO. Chartered Accountants
K. RAMANAN
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K. Ramanan

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

	Schedule	Amount (Rs) FY 2021-22	FY 2020-21
k)Postage, Telephone and communication charges		₹ 35,574.00	₹ 8,348.00
l)printing and stationery		₹ 7,15,470.00	₹ 31,67,562.00
m)Travelling and conveyance charges		₹ 68,81,542.50	₹ 95,01,546.62
n)Expenses on seminar/workshops		₹ 4,82,808.48	₹ 3,80,375.00
0)Subscription Expenses		₹ 0.00	₹ 0.00
p)Expenses on Fees		₹ 28,04,587.88	₹ 59,83,435.34
q)Auditors Remuneration		₹ 0.00	₹ 0.00
r)Hospitality Expenses		₹ 5,48,429.00	₹ 7,58,338.00
s)Professional Charges		₹ 0.00	₹ 0.00
t)Provision for Bad and Doubtful Debts/ Advances		₹ 0.00	₹ 0.00
u)Irrecoverable Balances Written-off		₹ 0.00	₹ 0.00
v)Packing Charges		₹ 0.00	₹ 0.00
w)Freight and Forwarding Expenses		₹ 0.00	₹ 0.00
x)Distribution Expenses		₹ 0.00	₹ 0.00
y)Advertisement and publicity		₹ 70,263.50	₹ 36,26,894.49
z)Others(Specify)		₹ 2,12,03,826.97	₹ 2,81,28,610.61
EXPENDITURE ON GRANTS, SUBSIDIES, ETC	22	₹ 0.00	₹ 0.00
a) Grants given to instutions/organisations		₹ 0.00	₹ 0.00
b) subsidies given to insituions/organisations		₹ 0.00	₹ 0.00
INTEREST	23	₹ 0.00	₹ 0.00
a) On fixed loans		₹ 0.00	₹ 0.00
b) On other loans (incl.bank charges)		₹ 0.00	₹ 0.00
c) Others(specify)		₹ 0.00	₹ 0.00
DEPRECIATION (NET TOTAL AT THE YEAR END-CORRESPONDING TO SCHEDULE 8)		₹ 0.00	₹ 0.00
TOTAL(B)		**₹ 18,67,06,530.45**	**₹ 25,02,62,845.30**
Balance being excess of Income Over Expenditure (A-B)		--	--
Transfer to Special Reserve (Specify each)		--	--
Transfer to/from General Reserve		--	--
BALANCE BEING SURPLUS(DEFICIT) CARRIED TO CORPUS/CAPITAL FUND		**₹ 5,21,42,875.05**	**₹ 20,22,30,237.65**

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NATIONAL CENTER FOR SUSTAINABLE COASTAL MANAGEMENT			
SCHEDULES FORMING PART OF CONSOLIDATED BALANCE SHEET AS AT 31/03/2022			
SCHEDULE 1- CORPUS/CAPITAL FUND			
BALANCE AT THE BEGINNING OF THE YEAR		₹	**1,58,62,05,444.72**
ADD:	**CONNTRIBUTION TOWARDS CORPUS/CAPITAL FUND**	₹	51,58,206.30
	NCSCM-ICZMP-ACITIVITES	₹	51,58,206.30
	NCSCM-ESA-ACTIVITIES	₹	-
	NCSCSM-EDC ACTIVITIES	₹	-
	NCSCM-USERS FEE	₹	-
	NCSCM-OGIA	₹	-
ADD:	**BALANCE OF NET INCOME/EXPENSES TRANSFERRED FROM THE INCOME & EXP A/C**	₹	**5,21,42,875.05**
	NCSCM-ICZMP-ACITIVITES	₹	-5,90,000.00
	NCSCM-ESA-ACTIVITIES	₹	-
	NCSCSM-EDC ACTIVITIES	₹	5,23,23,390.87
	NCSCM-USERS FEE	₹	84,027.18
	NCSCM-OGIA	₹	3,25,457.00
BALANCE AS AT THE YEAR END		₹	**1,64,35,06,526.07**

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SCHEDULES FORMING PART OF CONSOLIDATED BALANCE SHEET AS AT 31/03/2022		
SCHEDULE 2- RESERVE&SURPLUS-4-GENERAL RESEREVE		
BALANCE AT THE BEGINNING OF THE YEAR		₹ -
ADD:	**CONNTRIBUTION TOWARDS CORPUS/CAPITAL FUND**	₹ -
	NCSCM-ICZMP-ACITIVITES	₹ -
	NCSCM-ESA-ACTIVITIES	₹ -
	NCSCSM-EDC ACTIVITIES	₹ -
	NCSCM-USERS FEE	₹ -
	NCSCM-OGIA	₹ -
ADD:	**BALANCE OF NET INCOME/EXPENSES TRANSFERRED FROM THE INCOME & EXP A/C**	₹ -
	NCSCM-ICZMP-ACITIVITES	₹ -
	NCSCM-ESA-ACTIVITIES	₹ -
	NCSCSM-EDC ACTIVITIES	₹ -
	NCSCM-USERS FEE	₹ -
	NCSCM-OGIA	₹ -
BALANCE AS AT THE YEAR END		₹ -

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SCHEDULES FORMING PART OF CONSOLIDATED BALANCE SHEET AS AT 31/03/2022		
SCHEDULE 7 CURRENT LIABILITIES & PROVISIONS		
SCHEDULE	**ACCOUNTS**	**AMOUNT**
7-A-3	**CURRENT LIABILITIES-ADVANCE RECEIVED**	
	NCSCM-ICZMP-ACITIVITES	**₹2,27,55,537.95**
	NCSCM-ESA-ACTIVITIES	₹25,86,833.00
	NCSCSM-EDC ACTIVITIES	₹20,72,75,230.08
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹8,93,95,742.88
SUB TOTAL		**₹32,20,13,343.91**
7-A-5-B	**CURRENT LIABILITIES-STATUTORY LIABILITIES**	
	NCSCM-ICZMP-ACITIVITES	**₹42,38,002.00**
	NCSCM-ESA-ACTIVITIES	₹0.00
	NCSCSM-EDC ACTIVITIES	₹6,87,78,935.89
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹80,69,655.29
SUB TOTAL		**₹8,10,86,593.18**
7-A-6	**OTHER CURRENT LIABILITIES**	
	NCSCM-ICZMP-ACITIVITES	₹43,86,042.00
	NCSCM-ESA-ACTIVITIES	₹0.00
	NCSCSM-EDC ACTIVITIES	₹15,97,096.00
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹0.00
SUB TOTAL		**₹59,83,138.00**
7-B-3	**PROVISION-SUPERANNUATION/PENSION**	
	NCSCM-ICZMP-ACITIVITES	₹0.00
	NCSCM-ESA-ACTIVITIES	₹0.00
	NCSCSM-EDC ACTIVITIES	₹0.00
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹0.00
SUB TOTAL		**₹0.00**
7-B-6	**PROVISION-OTHERS**	
	NCSCM-ICZMP-ACITIVITES	₹1,01,107.00
	NCSCM-ESA-ACTIVITIES	₹0.00
	NCSCSM-EDC ACTIVITIES	₹2,14,71,609.00
	NCSCM-USERS FEE	₹6,695.16
	NCSCM-OGIA	₹0.00
SUB TOTAL		**₹2,15,79,411.16**

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SCHEDULES FORMING PART OF CONSOLIDATED BALANCE SHEET AS AT 31/03/2022		
SCHEDULE 8: FIXED ASSETS		
SCHEDULE	**ACCOUNTS**	**AMOUNT**
8-A-7	**COMPUTER/PERIPHERALS**	
	NCSCM-ICZMP-ACITIVITES	**₹21,66,72,603.00**
	NCSCM-ESA-ACTIVITIES	₹3,39,95,863.00
	NCSCSM-EDC ACTIVITIES	**₹58,22,867.00**
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹84,40,425.00
SUB TOTAL		**₹26,49,31,758.00**
8-A-2	**BUILDING**	
	NCSCM-ICZMP-ACITIVITES	**₹62,35,63,119.40**
	NCSCM-ESA-ACTIVITIES	₹0.00
	NCSCSM-EDC ACTIVITIES	₹0.00
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹0.00
		₹0.00
SUB TOTAL		**₹62,35,63,119.40**
8-A-3	**PLANT & MACHINERY& EQUIPMENTS**	
	NCSCM-ICZMP-ACITIVITES	**₹47,63,73,151.33**
	NCSCM-ESA-ACTIVITIES	₹4,29,110.00
	NCSCSM-EDC ACTIVITIES	**₹85,700.00**
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹0.00
SUB TOTAL		**₹47,68,87,961.33**
8-A-4	**VEHICLES**	
	NCSCM-ICZMP-ACITIVITES	**₹9,09,706.00**
	NCSCM-ESA-ACTIVITIES	₹0.00
	NCSCSM-EDC ACTIVITIES	**₹19,76,851.00**
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹0.00
SUB TOTAL		**₹28,86,557.00**
8-A-5	**FURNITURE&FIXTURE**	
	NCSCM-ICZMP-ACITIVITES	**₹20,04,965.00**
	NCSCM-ESA-ACTIVITIES	₹0.00
	NCSCSM-EDC ACTIVITIES	₹0.00
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹0.00
SUB TOTAL		**₹20,04,965.00**
8-A-6	**OFFICE EQUIPMENTS**	
	NCSCM-ICZMP-ACITIVITES	**₹68,99,669.00**
	NCSCM-ESA-ACTIVITIES	₹0.00
	NCSCSM-EDC ACTIVITIES	₹0.00
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹0.00
SUB TOTAL		**₹68,99,669.00**

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8-A-8	**ELECTRICAL INSTALLATION**	
	NCSCM-ICZMP-ACITIVITES	**₹66,16,667.00**
	NCSCM-ESA-ACTIVITIES	₹36,39,345.00
	NCSCSM-EDC ACTIVITIES	₹0.00
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹7,94,514.00
SUB TOTAL		**₹1,10,50,526.00**
8-A-11	**OTHER FIXED ASSETS**	
	NCSCM-ICZMP-ACITIVITES	**₹1,74,93,288.11**
	NCSCM-ESA-ACTIVITIES	₹15,88,991.00
	NCSCSM-EDC ACTIVITIES	₹0.00
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹73,198.00
SUB TOTAL		**₹1,91,55,477.11**

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SCHEDULE-11-CURRENT ASSETS LOAND AND ADVANCES		
11-A-2	SUNDRY DEBTOR	
	NCSCM-ICZMP-ACITIVITES	₹ 0.00
	NCSCM-ESA-ACTIVITIES	₹ 0.00
	NCSCSM-EDC ACTIVITIES	₹ 1,34,53,604.94
	NCSCM-USERS FEE	₹ 0.00
	NCSCM-OGIA	₹ 0.00
SUB TOTAL		₹ 1,34,53,604.94
11-A-3	CASH BALANCES IN HAND	
	NCSCM-ICZMP-ACITIVITES	₹4,033.00
	NCSCM-ESA-ACTIVITIES	₹0.00
	NCSCSM-EDC ACTIVITIES	₹0.00
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹0.00
SUB TOTAL		₹4,033.00
11-A-4A	DEPOSIT WITH SCHEDULE BANKS	
	NCSCM-ICZMP-ACITIVITES	₹44,95,230.83
	NCSCM-ESA-ACTIVITIES	₹76,920.05
	NCSCSM-EDC ACTIVITIES	₹11,54,84,016.98
	NCSCM-USERS FEE	₹11,25,275.17
	NCSCM-OGIA	₹9,60,96,421.63
SUB TOTAL		₹21,72,77,864.66
11-B-1-C	TRAVEL ADVANCE TO STAFF	
	NCSCM-ICZMP-ACITIVITES	₹5,70,235.16
	NCSCM-ESA-ACTIVITIES	₹0.00
	NCSCSM-EDC ACTIVITIES	₹1,98,91,665.00
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹5,65,130.58
SUB TOTAL		₹2,10,27,030.74
11-B-2B	ADV TO INSTITUTE	
	NCSCM-ICZMP-ACITIVITES	₹71,56,688.00
	NCSCM-ESA-ACTIVITIES	₹0.00
	NCSCSM-EDC ACTIVITIES	₹11,57,500.00
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹0.00
SUB TOTAL		₹83,14,188.00
11-B-4	CLAIMS RECEIVABLE	
	NCSCM-ICZMP-ACITIVITES	₹2,35,39,989.26
	NCSCM-ESA-ACTIVITIES	₹25,09,912.95
	NCSCSM-EDC ACTIVITIES	₹37,47,36,091.58
	NCSCM-USERS FEE	₹1,24,790.00
	NCSCM-OGIA	₹58,01,474.35
SUB TOTAL		₹40,67,12,258.14

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SCHEDULE-12-INCOME FROM SALES/SERVICES		
12-2-B	INCOME FROM PROFESSIONAL SERVICES	
	NCSCM-ICZMP-ACITIVITES	₹0.00
	NCSCM-ESA-ACTIVITIES	₹0.00
	NCSCSM-EDC ACTIVITIES	₹7,36,82,291.00
	NCSCM-USERS FEE	₹48,805.00
	NCSCM-OGIA	₹0.00
SUB TOTAL		₹7,37,31,096.00

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SCHEDULE- 13- GRANTS/SUBSIDIES		
13-3	GRANTS FROM GOVERNMENT AGENCIES	
	NCSCM-ICZMP-ACITIVITES	₹13,02,40,157.78
	NCSCM-ESA-ACTIVITIES	₹22,618.40
	NCSCSM-EDC ACTIVITIES	₹0.00
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹3,00,07,987.52
		₹0.00
SUB TOTAL		₹16,02,70,763.70

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SCHEDULE- 17- INTEREST EARNED		
17-2-A	NCSCM-ICZMP-ACITIVITES	₹8,556.00
	NCSCM-ESA-ACTIVITIES	₹0.00
	NCSCSM-EDC ACTIVITIES	₹44,64,074.00
	NCSCM-USERS FEE	₹36,778.00
	NCSCM-OGIA	₹2,25,460.00
SUB TOTAL		**₹47,34,868.00**

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SCHEDULE- 18- OTHER INCOME		
18-4	NCSCM-ICZMP-ACITIVITES	₹50,265.00
	NCSCM-ESA-ACTIVITIES	₹0.00
	NCSCSM-EDC ACTIVITIES	₹62,412.80
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹0.00
SUB TOTAL		**₹1,12,677.80**

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SCHEDULES FORMING PART OF CONSOLIDATED INCOME STATEMENT AS AT 31/03/2022		
SCHEDULE- 20		
20-A	**SALARIES & WAGES**	
	NCSCM-ICZMP-ACITIVITES	₹7,91,54,515.00
	NCSCM-ESA-ACTIVITIES	₹0.00
	NCSCSM-EDC ACTIVITIES	₹1,69,73,968.00
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹1,06,48,485.00
SUB TOTAL		**₹10,67,76,968.00**
20-C	**CONTRIBUTION TO PROVIDENT FUND**	
	NCSCM-ICZMP-ACITIVITES	₹13,59,782.00
	NCSCM-ESA-ACTIVITIES	₹0.00
	NCSCSM-EDC ACTIVITIES	₹0.00
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹0.00
SUB TOTAL		**₹13,59,782.00**
20-E	**STAFF WELFARE EXPENSES**	
	NCSCM-ICZMP-ACITIVITES	₹33,24,388.00
	NCSCM-ESA-ACTIVITIES	₹0.00
	NCSCSM-EDC ACTIVITIES	₹0.00
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹0.00
SUB TOTAL		**₹33,24,388.00**

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SCHEDULES FORMING PART OFCONSOLIDATED INCOME STATEMENT AS AT 31/03/2022		
SCHEDULE- 21		
21-A	PURCHASES	
	NCSCM-ICZMP-ACITIVITES	₹70,63,167.00
	NCSCM-ESA-ACTIVITIES	₹0.00
	NCSCSM-EDC ACTIVITIES	₹0.00
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹14,10,947.00
SUB TOTAL		₹84,74,114.00
21-D	ELECTRICITY & POWER	
	NCSCM-ICZMP-ACITIVITES	₹89,67,155.00
	NCSCM-ESA-ACTIVITIES	₹0.00
	NCSCSM-EDC ACTIVITIES	₹0.00
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹0.00
SUB TOTAL		₹89,67,155.00
21-E	WATER CHARGES	
	NCSCM-ICZMP-ACITIVITES	₹98,000.00
	NCSCM-ESA-ACTIVITIES	₹0.00
	NCSCSM-EDC ACTIVITIES	₹0.00
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹0.00
SUB TOTAL		₹98,000.00
21-F	INSURANCE	
	NCSCM-ICZMP-ACITIVITES	₹8,88,109.00
	NCSCM-ESA-ACTIVITIES	₹0.00
	NCSCSM-EDC ACTIVITIES	₹0.00
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹0.00
SUB TOTAL		₹8,88,109.00
21-G	REAPAIRS&MAINTENANCE	
	NCSCM-ICZMP-ACITIVITES	₹2,40,75,512.12
	NCSCM-ESA-ACTIVITIES	₹0.00
	NCSCSM-EDC ACTIVITIES	₹0.00
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹0.00
SUB TOTAL		₹2,40,75,512.12
21-K	POSTAGE,TELEPHONE&COMMUNICATE CHARGES	
	NCSCM-ICZMP-ACITIVITES	₹35,574.00
	NCSCM-ESA-ACTIVITIES	₹0.00
	NCSCSM-EDC ACTIVITIES	₹0.00
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹0.00
SUB TOTAL		₹35,574.00
21-L	PRINTING&STATIONERY	
	NCSCM-ICZMP-ACITIVITES	₹7,15,470.00
	NCSCM-ESA-ACTIVITIES	₹0.00
	NCSCSM-EDC ACTIVITIES	₹0.00
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹0.00
SUB TOTAL		₹7,15,470.00
21-M	TRAVELLING& CONVEYANCE EXPENSES	
	NCSCM-ICZMP-ACITIVITES	₹13,11,776.00
	NCSCM-ESA-ACTIVITIES	₹22,583.00
	NCSCSM-EDC ACTIVITIES	₹25,09,418.50
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹30,37,765.00
SUB TOTAL		₹68,81,542.50
21-N	EXPENSES ON SEMINAR/WORKSHOP	
	NCSCM-ICZMP-ACITIVITES	₹3,79,375.48

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	NCSCM-ESA-ACTIVITIES	₹0.00
	NCSCSM-EDC ACTIVITIES	₹0.00
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹1,03,433.00
SUB TOTAL		**₹4,82,808.48**
21-P	**EXPENSES & FEES**	
	NCSCM-ICZMP-ACITIVITES	₹28,04,587.88
	NCSCM-ESA-ACTIVITIES	₹0.00
	NCSCSM-EDC ACTIVITIES	₹0.00
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹0.00
SUB TOTAL		**₹28,04,587.88**
21-R	**HOSPITALITY EXPENSES**	
	NCSCM-ICZMP-ACITIVITES	₹5,48,429.00
	NCSCM-ESA-ACTIVITIES	₹0.00
	NCSCSM-EDC ACTIVITIES	₹0.00
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹0.00
SUB TOTAL		**₹5,48,429.00**
21-Y	**ADVERTISEMENT & PUBLICITY**	
	NCSCM-ICZMP-ACITIVITES	₹70,263.50
	NCSCM-ESA-ACTIVITIES	₹0.00
	NCSCSM-EDC ACTIVITIES	₹0.00
	NCSCM-USERS FEE	₹0.00
	NCSCM-OGIA	₹0.00
SUB TOTAL		**₹70,263.50**
21-Z	**OTHERS**	
	NCSCM-ICZMP-ACITIVITES	₹92,874.80
	NCSCM-ESA-ACTIVITIES	₹35.40
	NCSCSM-EDC ACTIVITIES	₹64,02,000.43
	NCSCM-USERS FEE	**₹1,555.82**
	NCSCM-OGIA	₹1,47,07,360.52
SUB TOTAL		**₹2,12,03,826.97**

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778, 9TH STREET,
ANNA NAGAR W.E.,
CHENNAI-101.
Chartered Accountants

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