Mapping and monitoring of Coral and Mangrove ecosystems of India using geospatial techniques

by

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Benefits of coral reef ecosystems

- Coral reefs are the most diverse of all marine ecosystems. They teem with life, with perhaps one-quarter of all ocean species depending on reefs for food and shelter.
- Coral reefs protect coastlines from storms and erosion, provide jobs for local communities, and offer opportunities for recreation.
- They are also are a source of food and new medicines.
- Over half a billion people depend on reefs for food, income, and protection.
- Fishing, diving, and snorkeling on and near reefs add hundreds of millions of dollars to local businesses.

What are the main threats to coral reefs:

Climate change: Corals cannot survive if the water temperature is too high. Climate change has already led to sharply increased rates of coral bleaching – killing vast areas of reef.

Overfishing: This affects the ecological balance of coral reef communities, warping the food chain and causing effects far beyond the directly overfished population.

Unsustainable coastal development: Tourist resorts and other coastal infrastructure have been built directly on top of reefs.

Pollution: Urban and industrial waste, plastics, sewage, agrochemicals, and oil pollution are poisoning reefs.

Sedimentation: Erosion caused by construction (along coasts), mining, logging, and farming is leading to increased sediment in rivers.

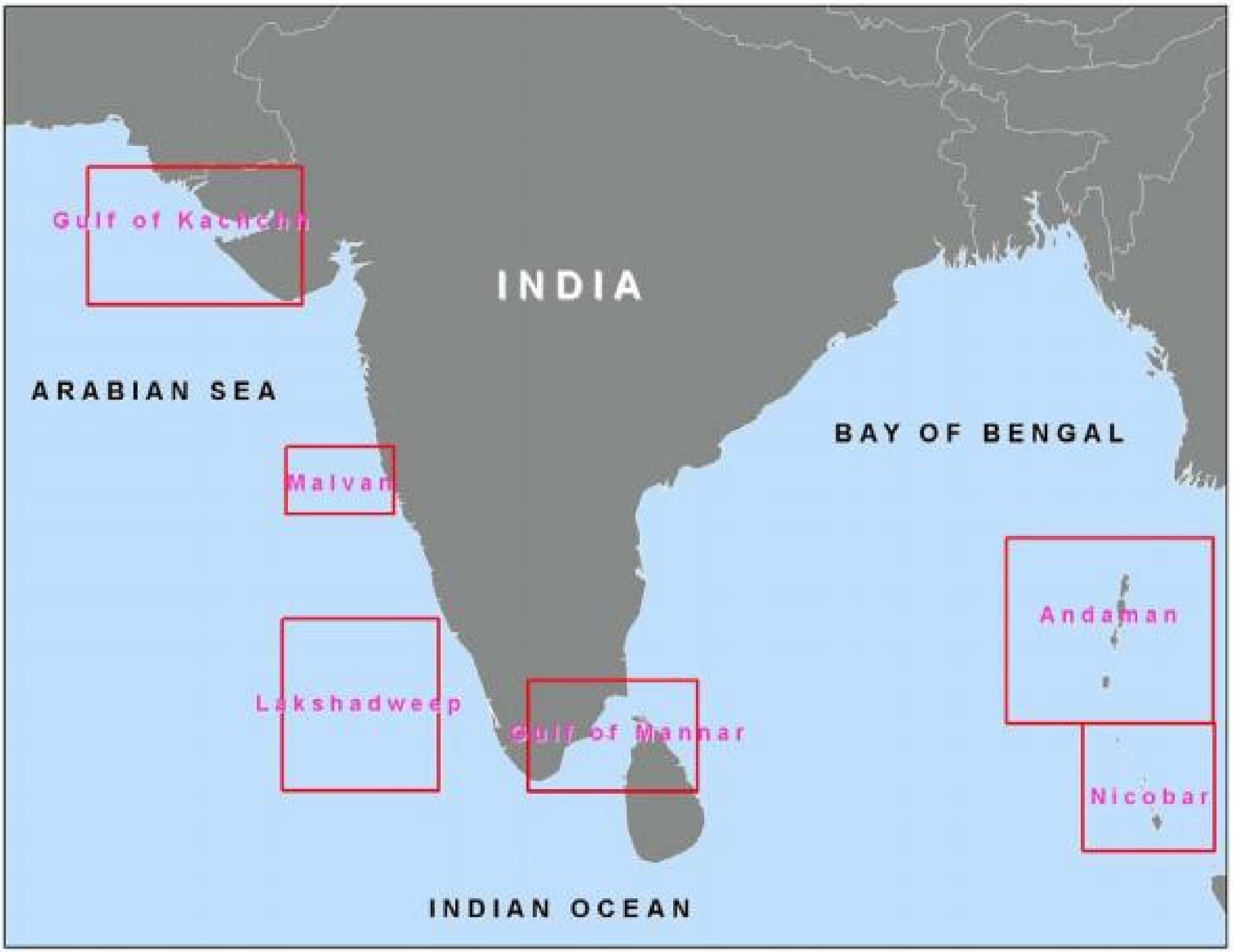
Destructive fishing practices: These include cyanide fishing, blast or dynamite fishing, bottom trawling, and Bottom-trawling is one of the greatest threats to cold-water coral reefs.

Careless Tourism: Careless boating, diving, snorkeling, and fishing, with people touching reefs, stirring up sediment, collecting coral, and dropping anchors on reefs.

Coral mining: Live coral is removed from reefs for use as bricks, road-fill, or cement for new buildings. Corals are also sold as souvenirs to tourists.

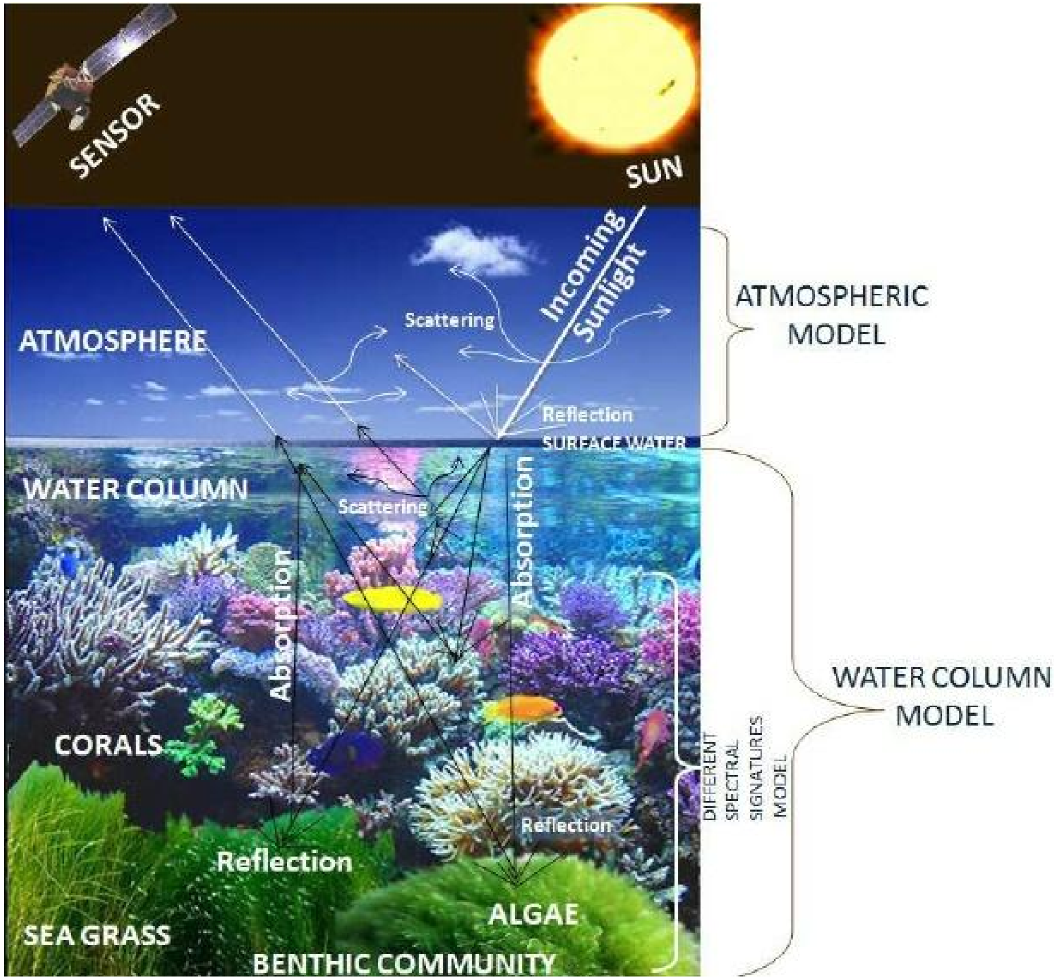
crown-of-thorns starfish: Parrotfish

Distribution of Coral reefs along the Indian coast:

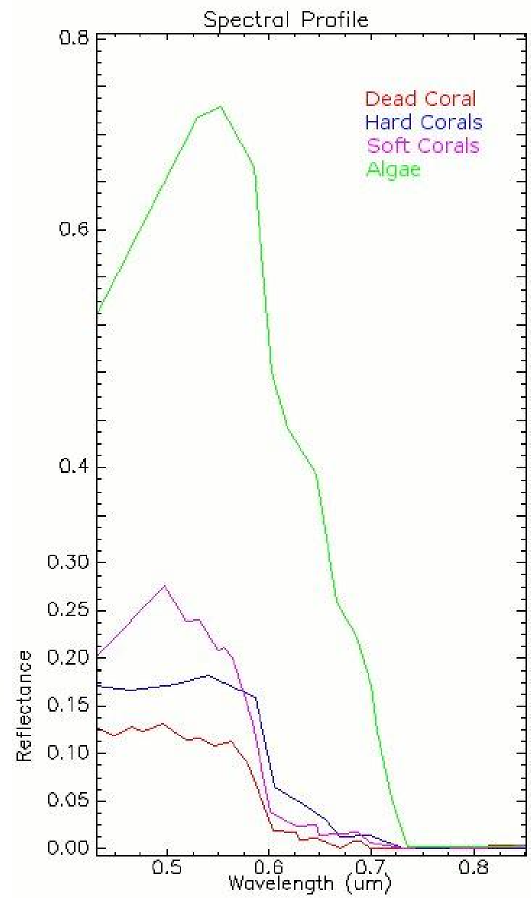


Predominantly Fringing and Atolls

Coral Reef Remote Sensing



Source: Contreras-Silva et al. 2012



Source: www.seos-project.eu

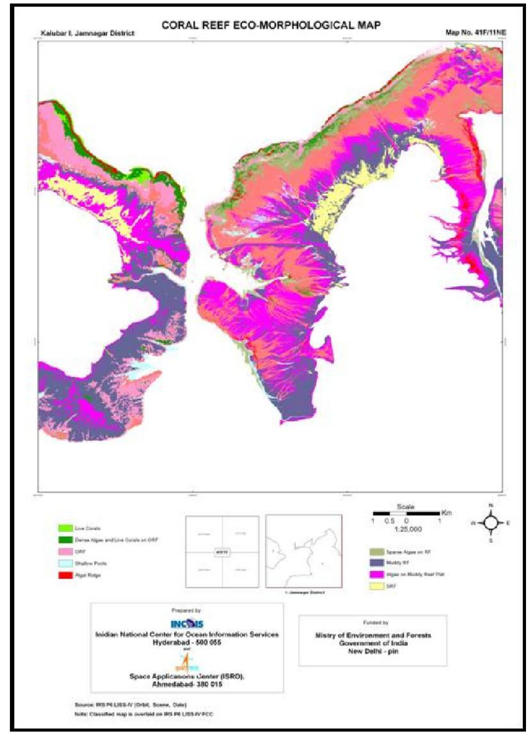
Eco-morphological Zonation of Coral Reef and Health Modeling

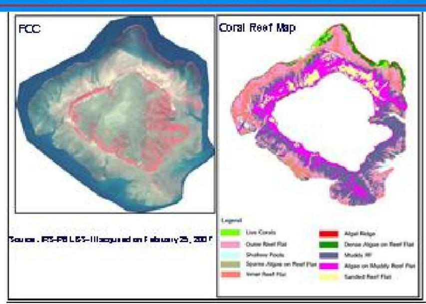
Objectives: Generation of the eco-morphological maps and Atlas on 1:25000 scales.

Methods

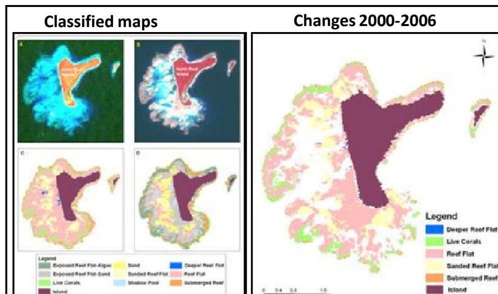
Eco-morphological Zonation

- Satellite data from IRS P6 LISS IV / III
- Pre classification steps (Image correction)
- Conversion of DN value to spectral radiance
- Habitat Classification based on Unsupervised (Pre-field map)
- Supervised classification based on Spectral difference and ground truth data
- Contextual editing → Final Coral Reef Zonation map
- Generation of Coral Atlas





Kalubar Island FCC and Classified map



The coral reef got exposed due to 26 December 2004 Sumatra earthquake.

Total area of 7.9 sq. km area exposed and degraded

Paper presented at *ISRS Symposium, Ahemedabad, India, 2008*

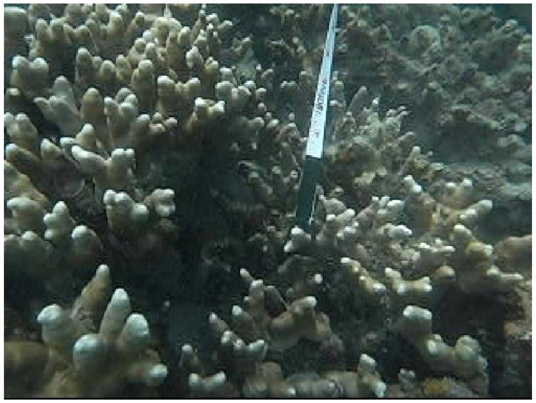
Field survey Methods

Transect Survey (LIT)

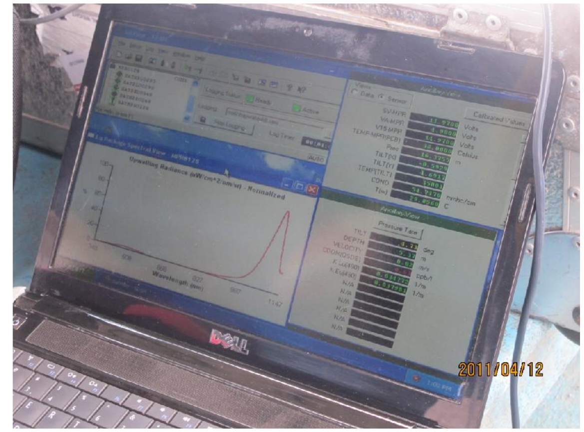
- Method : Parallel
- Depth : 5-20m
- Length : 30m
- No. of transects per site : 3

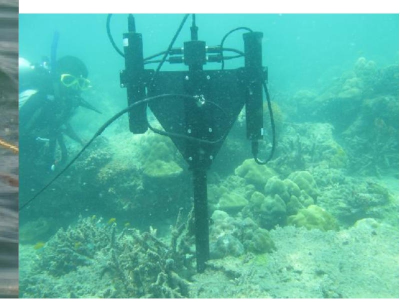
Video Transect

Underwater Visual Census (Colin et al., 2003)

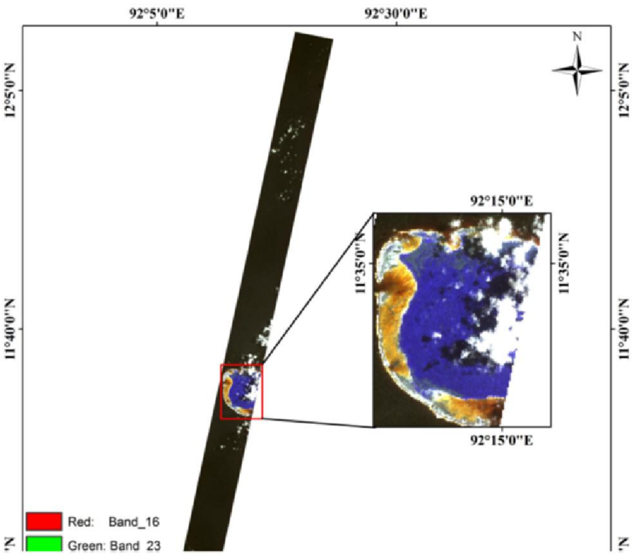


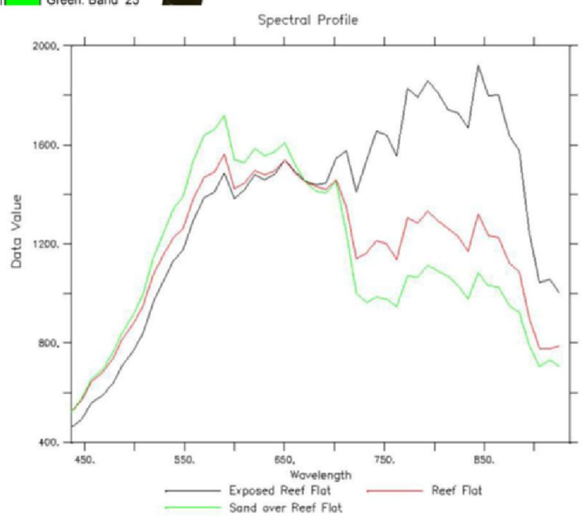
instrumentation/Gadgets - Survey





Mapping of coral reefs using hyperspectral remote sensing





Hyperion Image

↓

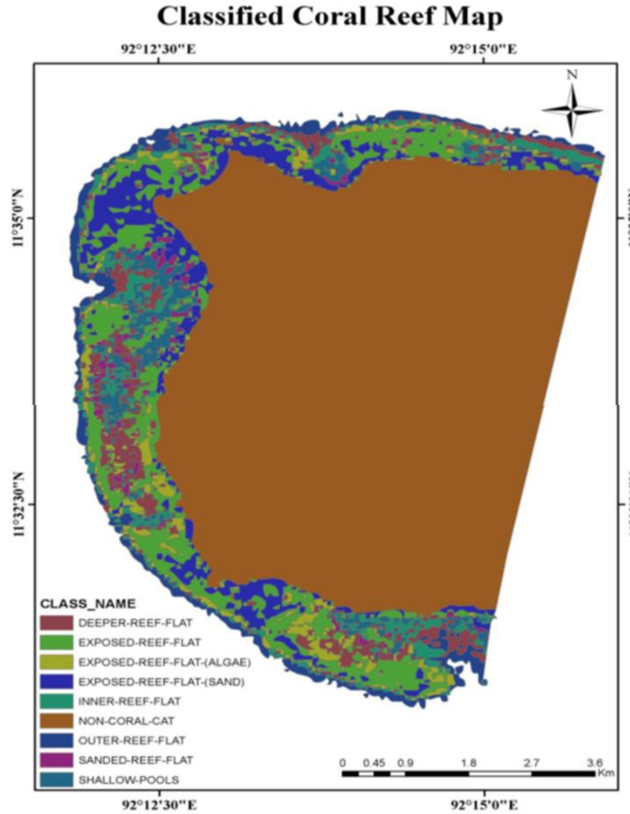
Atmospheric correction using FLAASH Algorithm

↓

Object Based Classification in Coral and Non-Coral classes

↓

Accuracy Assessment



- It demonstrates that 782.95 nm and 579.45 nm bands in the Hyperion data are suitable for separating coral and non-coral zone in the present study.
- Object Based Image Analysis (OBIA) technique to classify the Hyperion image which yielded 92.01% overall accuracy

Mohanty et al., 2016

Evaluation of various image classification techniques on Landsat to identify coral reefs

Uncorrected | Water corrected

Maximum Likelihood

Spectral Angular Mapper

Spectral Information Divergence

Support Vector Machine

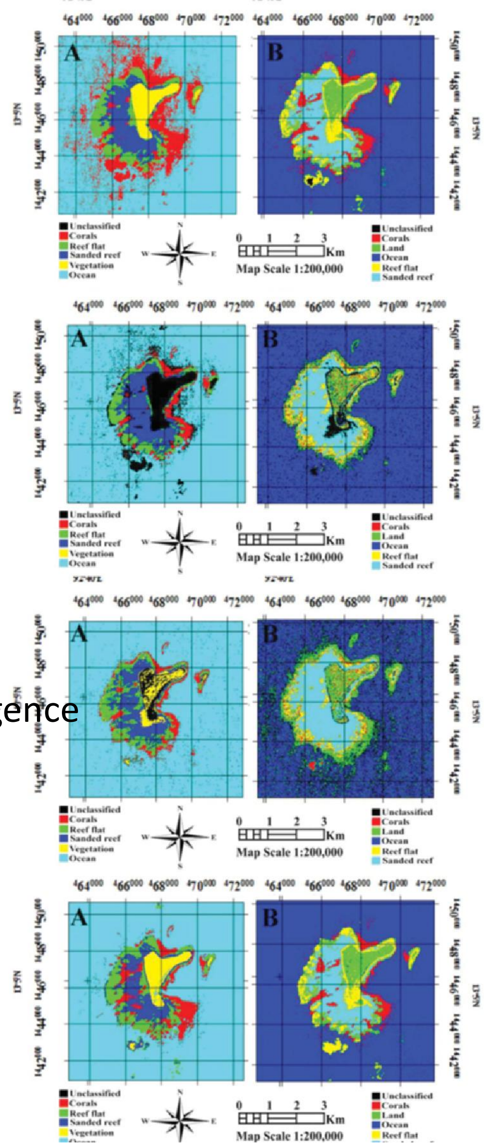


Table 1. Comparison of overall accuracy and Kappa coefficient of all classification before and after atmospheric and water column corrections.

Classification	Overall accuracy	Kappa coefficient
Maximum Likelihood	77.21%	0.6042
Spectral Angular Mapper	72.01%	0.4731
Spectral Information Divergence	62.47%	0.4386
Support Vector Machine	95.97%	0.9265
After atmospheric and water column correction		
Maximum Likelihood	93.36%	0.7952
Spectral Angular Mapper	89.84%	0.6869
Spectral Information Divergence	91.36%	0.7552
Support Vector Machine	99.94%	0.9984

Conclusions

This study clearly shows that MLC and SVM classification methods are preferable when classifying Landsat data for coral reef extraction.

The SVM method proved to be the best method in studying coral reef from multispectral Landsat ETM images, both in their statistical and classification results.

Tarun et al., 2013

Impacts of climate change on Corals

Heat content in the sea: causes thermal stress that contributes to coral bleaching and infectious disease.

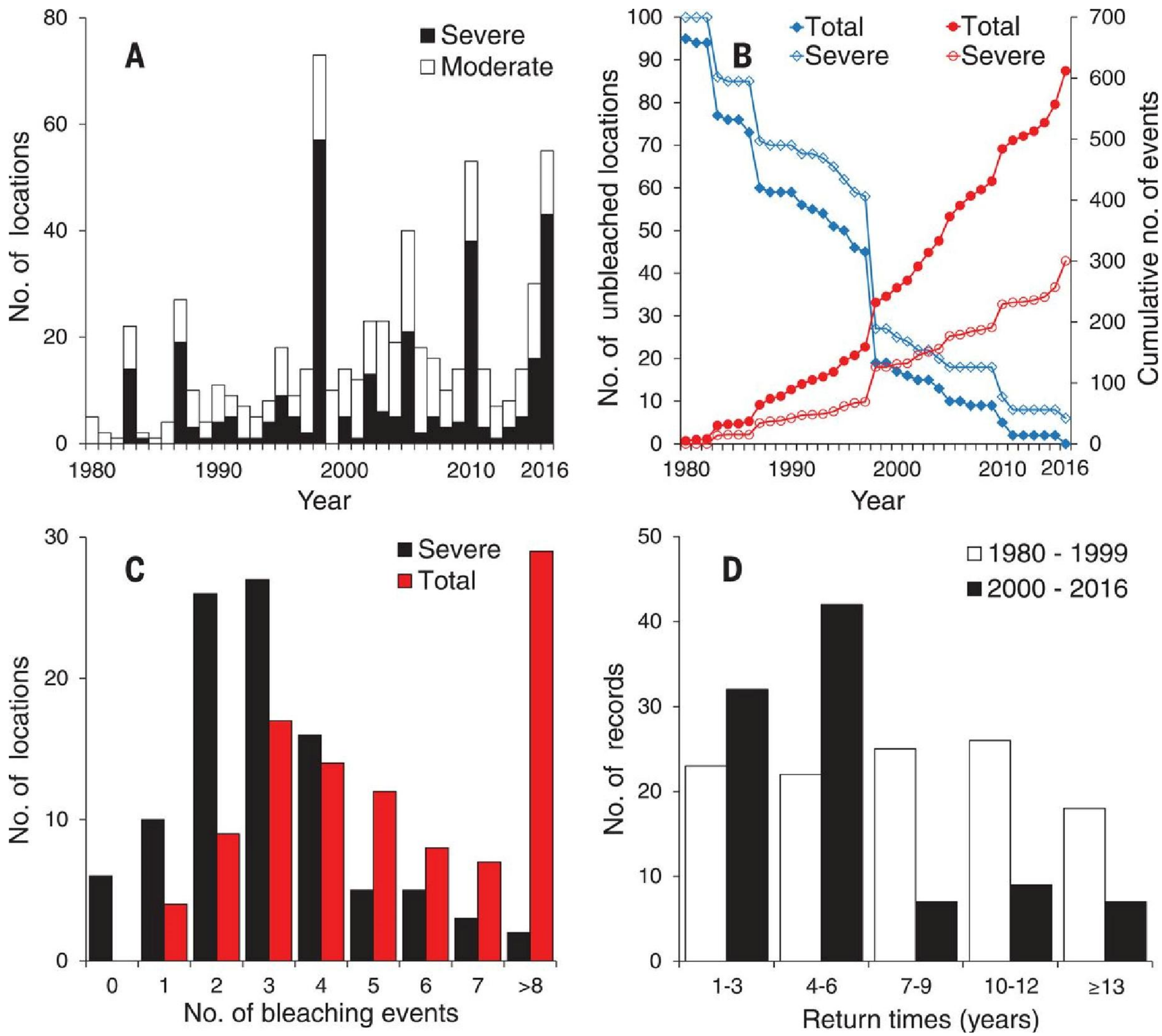
Sea level rise: may lead to increases in sedimentation for reefs located near land-based sources of sediment.

Heavy Precipitation: Sedimentation runoff can lead to the smothering of coral.

Altered ocean currents: leads to changes in connectivity and temperature regimes that contribute to a lack of food for corals and hamper the dispersal of coral larvae.

Ocean acidification (a result of increased CO2): Dissolved inorganic carbon in the sea causes a reduction in pH levels which decreases coral growth and structural integrity.

Temporal patterns of recurrent coral bleaching.



(A) Number of 100 pantropical locations that have bleached each year from 1980 to 2016. Black bars indicate severe bleaching affecting >30% of corals, and white bars depict moderate bleaching of <30% of corals.

(B) Cumulative number of severe and total bleaching events since 1980 (red; right axis) and the depletion of locations that remain free of any bleaching or severe bleaching over time (blue; left axis).

(C) Frequency distribution of the number of severe (black) and total bleaching events (red) per location.

(D) Frequency distribution of return times (number of years) between successive severe bleaching events from 1980 to 1999 (white bars) and 2000 to 2016 (black bars).

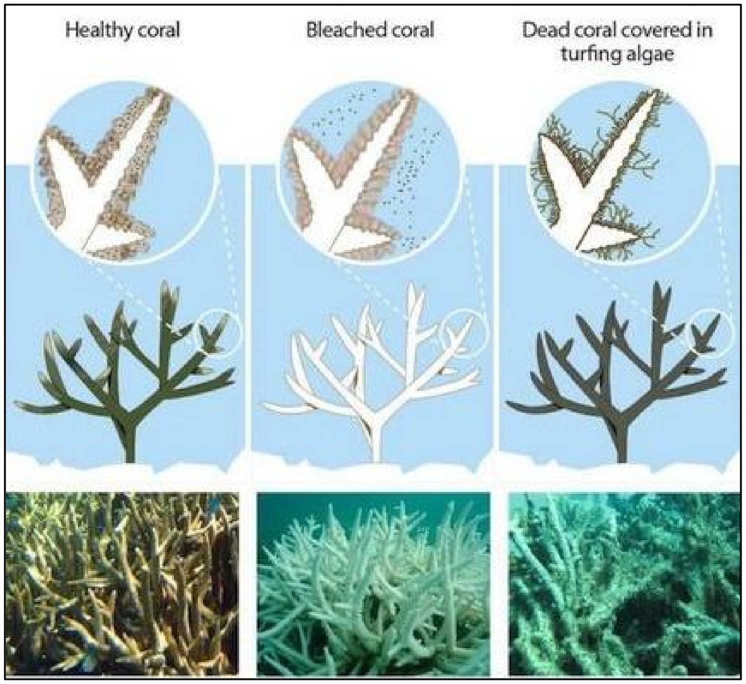
Hughes et al. 2018, Science,359:80-83

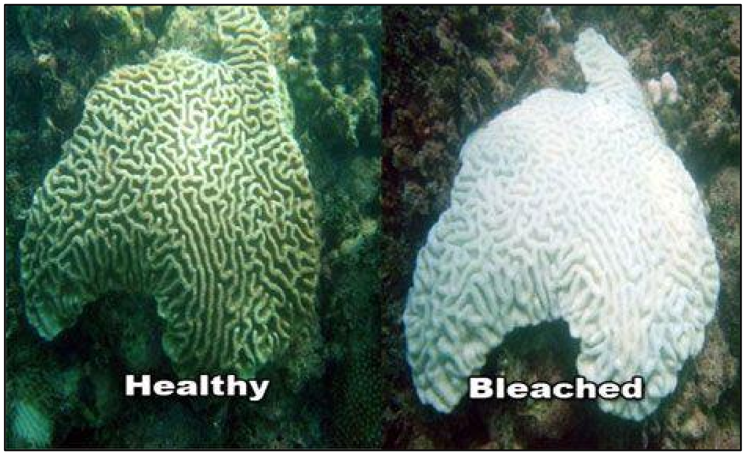
Coral Bleaching

Coral bleaching occurs when coral polyps expel algae that live inside their tissues during adverse environmental conditions.

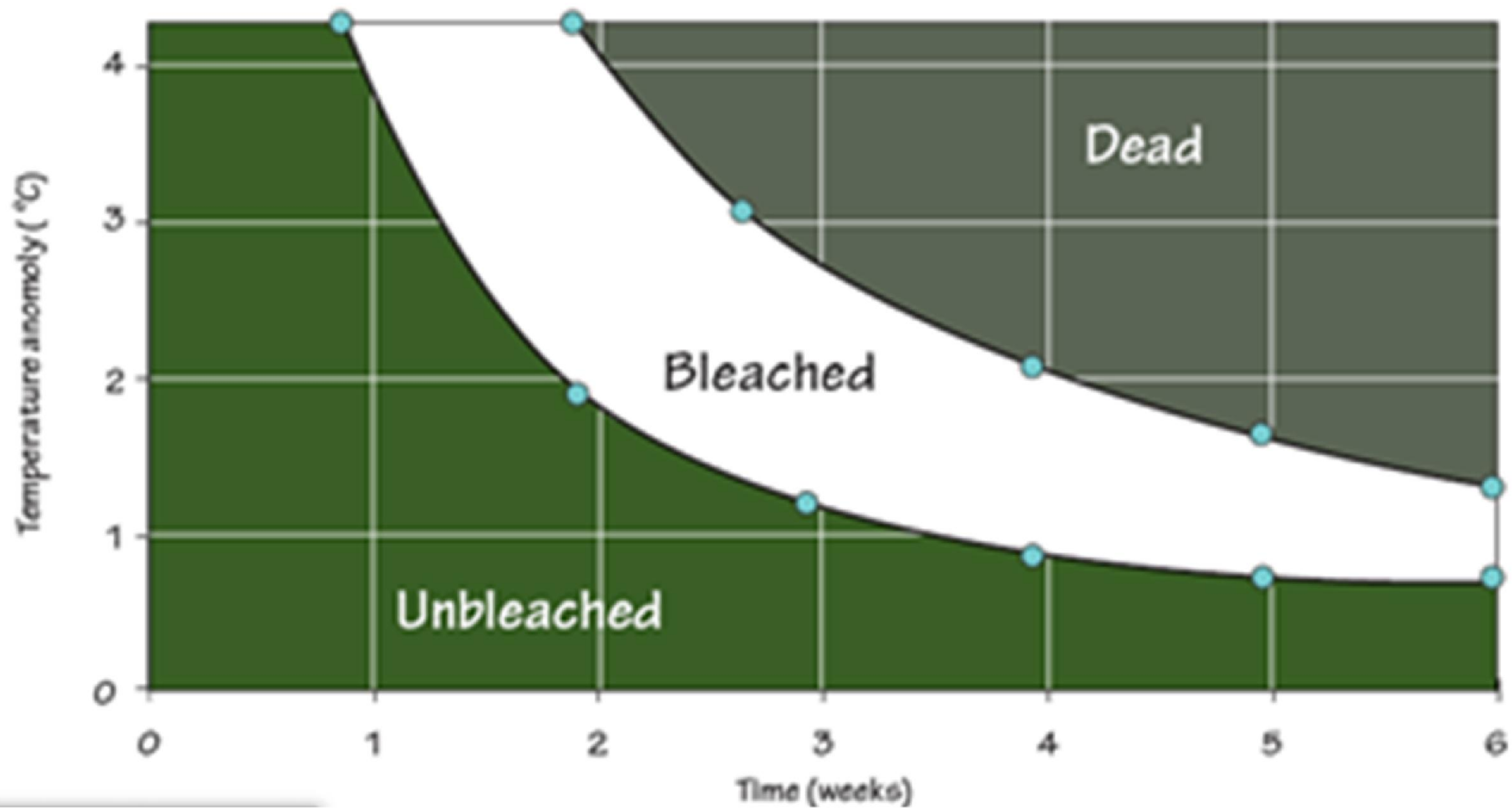
Causes for coral Bleaching:

- Temperature - Corals are very sensitive to changes in temperature. Water that warms only one degree Celsius can cause corals to bleach
- Sudden exposure of coral reef to atmosphere during low tide.
- Fresh water dilution storm generated precipitation and runoff can carry pollutants which cause coral bleaching.
- Eutrophication (when a body of water becomes overly enriched with minerals and nutrients which induce excessive growth of algae).





Relationship between intensity and duration of heat stress and risk/severity of mass bleaching



Satellite-based Coral Bleaching Mapping:

Inputs:

SST monthly climatology data

NOAA AVHRR SST data

HotSpot (°C) = SST – (MMM SST Climatology)

DHWs (°C-week) = 0.5 * ∑ preceding 24 bi-weekly HotSpots

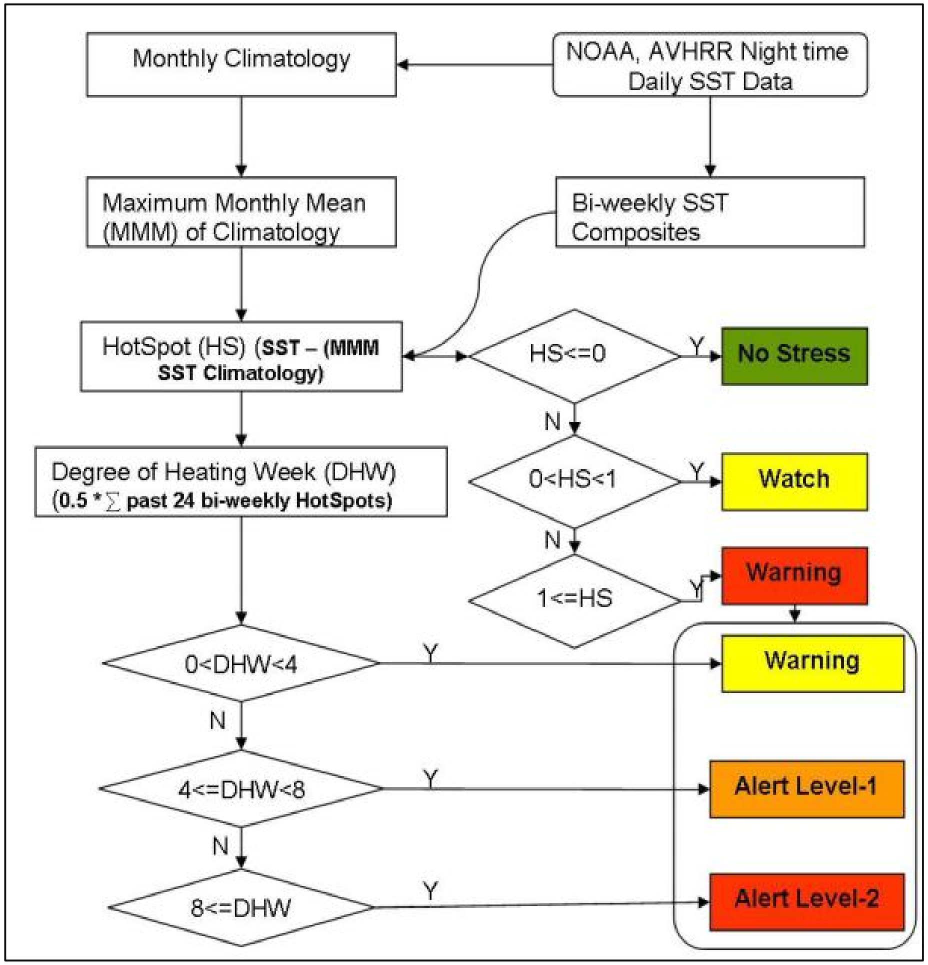
No stress: No thermal stress on the corals

Watch: Low thermal stress on the corals

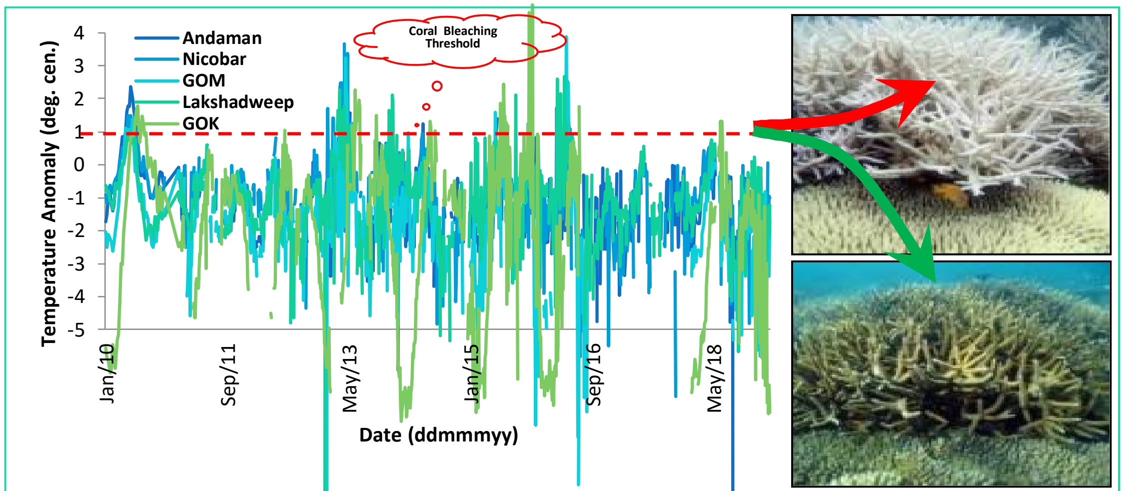
Warning: Thermal stress accumulated on corals

Alert Level1: Strong thermal stress on the corals, which may result in the partial bleaching

Alert Level2: Severe thermal stress on corals, which may result in widespread bleaching with likely coral mortality

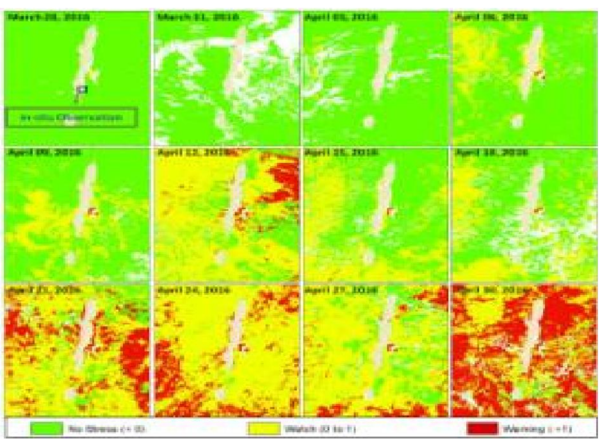


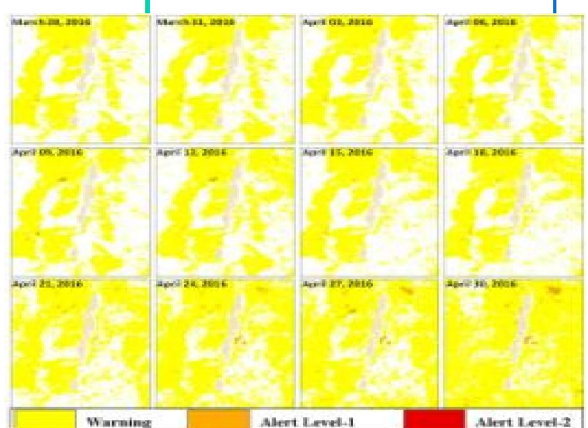
Coral Bleaching Alert System (CBAS) - A satellite derived SST based Service

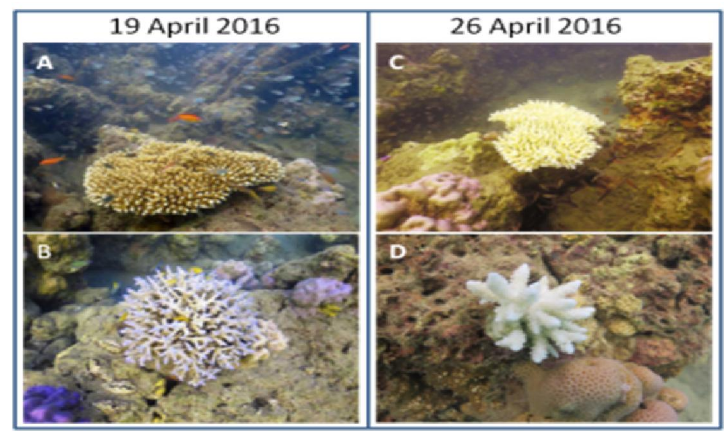


Service initiated since Feb 2011 and 122 advisories provided every year

Recent bleaching event was recorded during the April-May 2016 at Andaman validated with Field Data



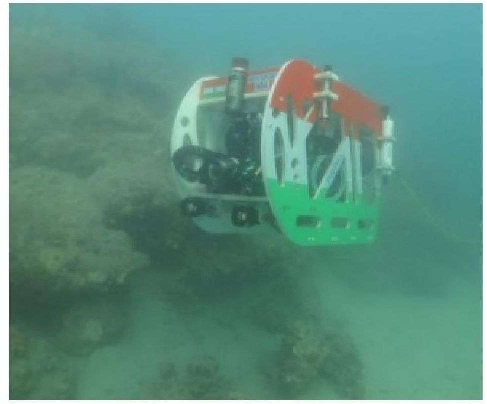




"Satellite based advisory service to predict thermal stress on an important coral ecosystem"

Validation of Coral Bleaching during April 2016 using ROV

Remotely Operated Vehicle

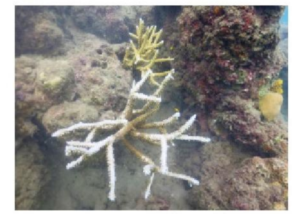


Vehicle under water

19 April 2016

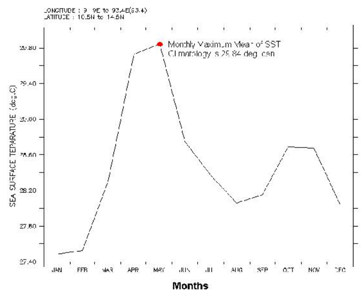
Status of Coral reef at North Bay on 19th April, 2016

26 April 2016

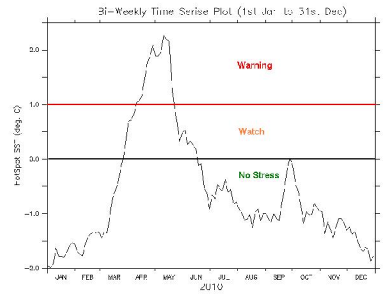


Bleaching Case Studies: April-June 2010 at Andaman

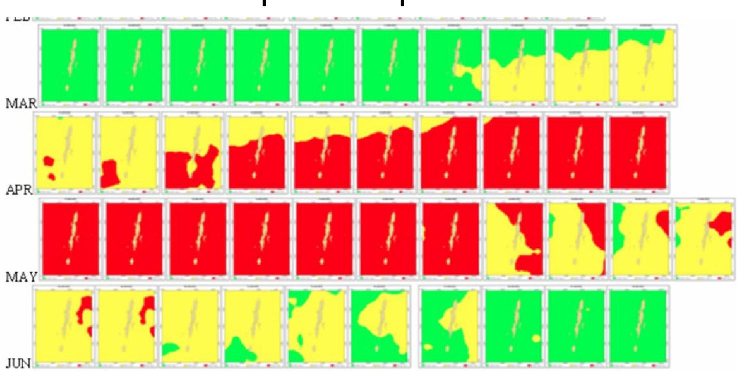
SST Climatology



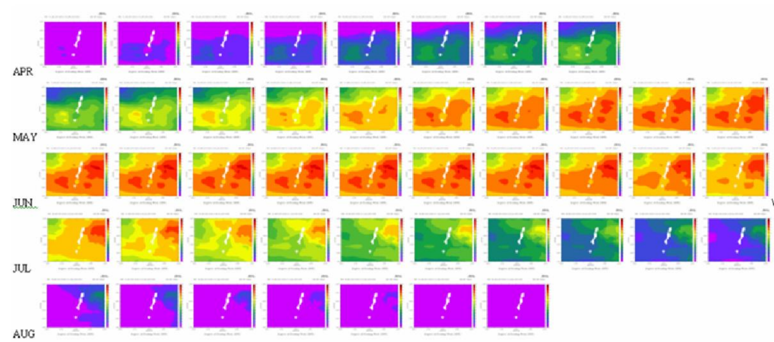
HS Time Series



HotSpot Composites

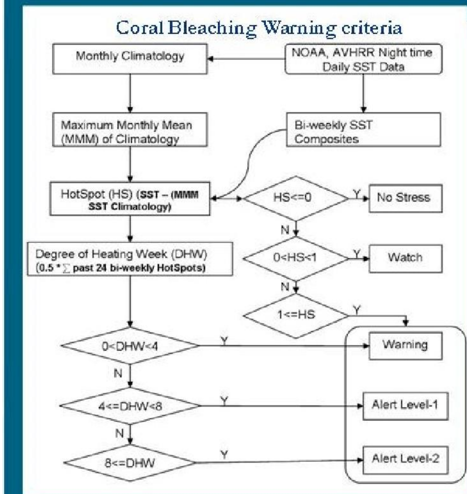


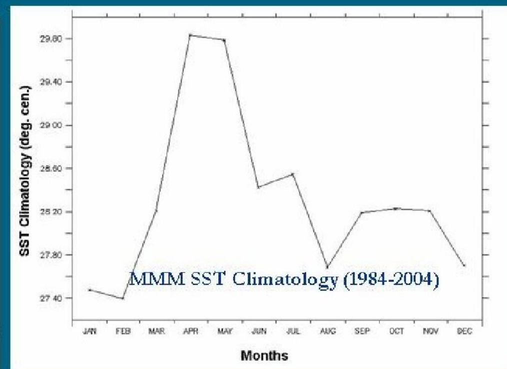
DHW Composites

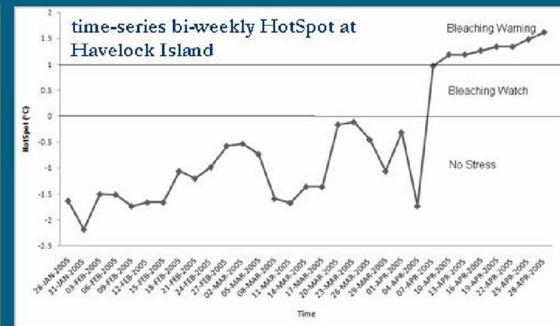


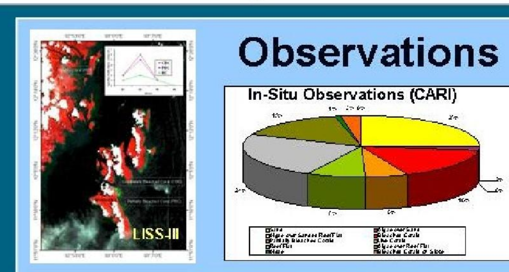
- A massive coral bleaching was depicted in Andaman during April-July 2010
- DHW shown the alert level-2 warning ie. Massive bleaching status
- The in-situ observations were depicted ~70-75% bleaching

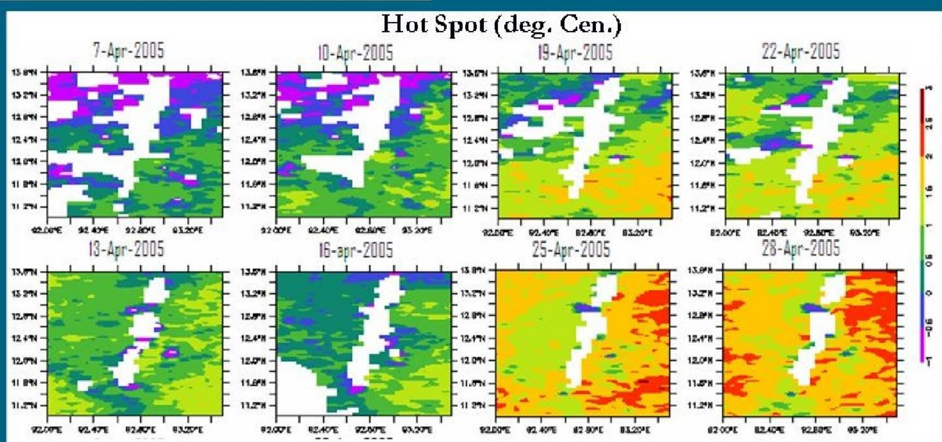
Bleaching Case Studies: April-May 2005 at Andaman

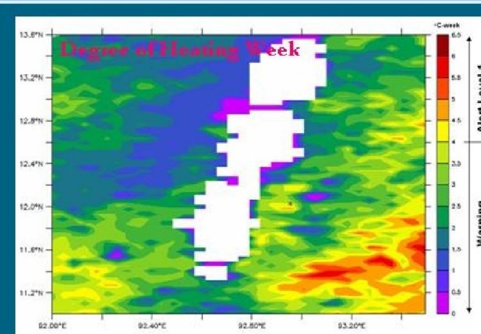












- The SST assessment depicted the coral bleaching with status “Alert Level1” was detected.
- The similar studies were planned for the other bleaching events in the Indian coral environs

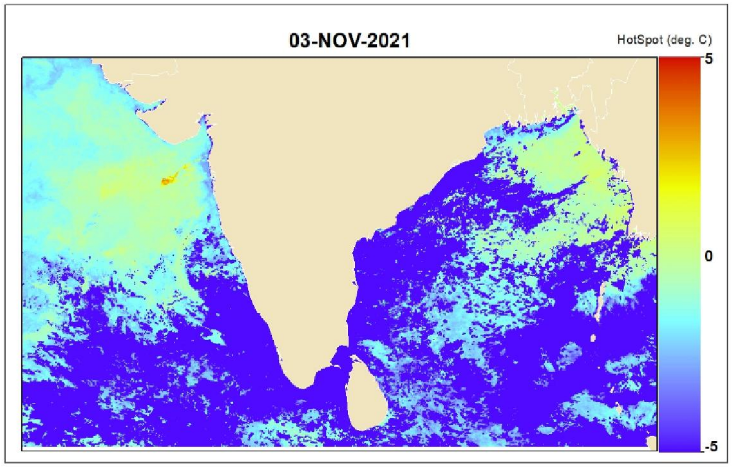
Coral Bleaching Alert System (CBAS)

The coral bleaching Alert System (CBAS), a service initiated from INCOIS since February 2011. This model uses the satellite derived Sea Surface Temperature (SST) in order to assess the thermal stress accumulated in the coral environs. This information yields in drawing the early signs of the intensity and spatial extents of coral bleaching. This methodology adopted from NOAA reef and tested for the earlier bleaching events of Indian coral environs. The service CBAS disseminated once in three days comprising the Hotspot, Degree of Heating Weeks and time series products.

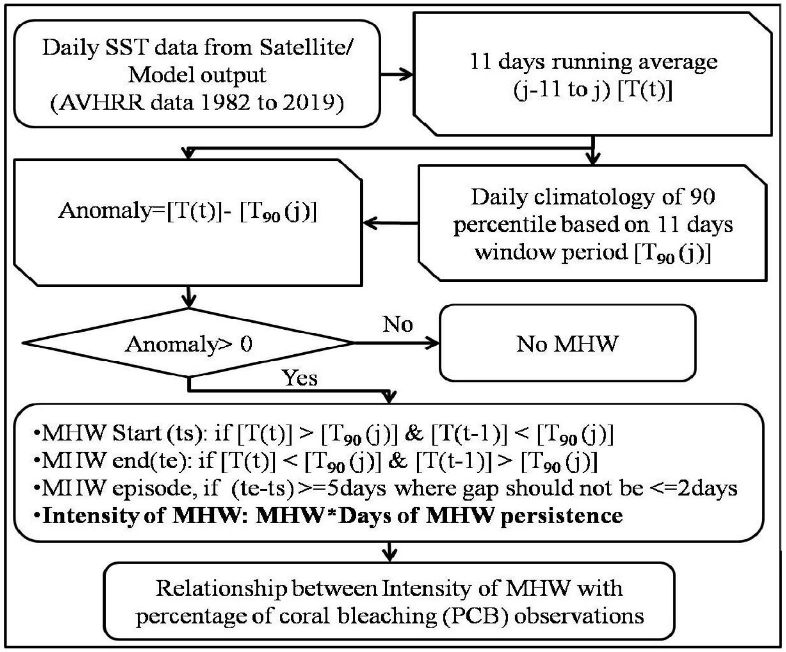
...Select Product... | ...Select Location... | ...Select Year... | Submit

Current Status

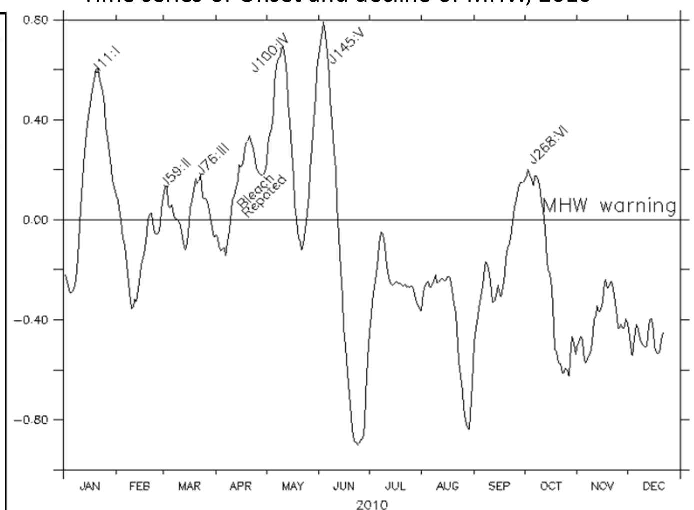
Area	HS	DHW
Andaman	No Stress	No threat
Gulf of Kutch	No Stress	No threat
Gulf of Mannar	No Stress	No threat
Lakshadweep	No Stress	No threat
Nicobar	No Stress	Not threat

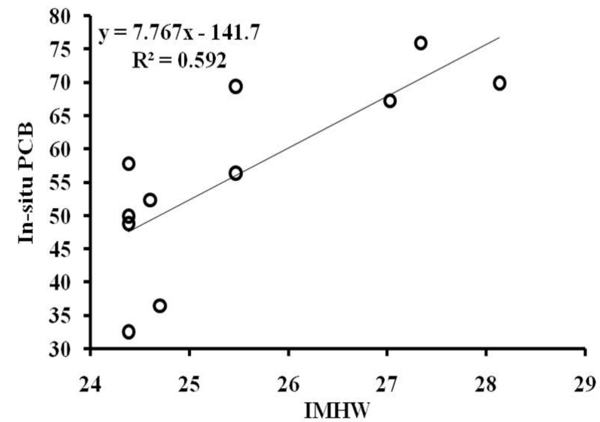


Persistence of Marine Heat Waves for coral bleaching and their spectral characteristics in Andaman Coral Reef

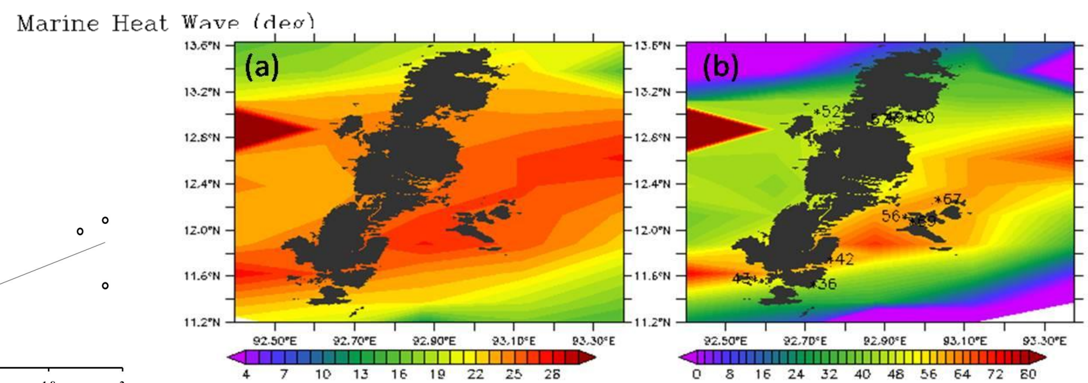


Time series of Onset and decline of MHW, 2010



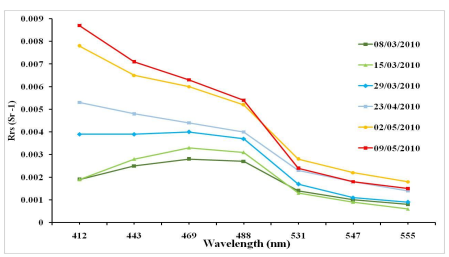


Scatter plot showing the Intensity of Marine Heat Wave (IMHW) plotted against observed percentage of Coral Bleaching (PCB).

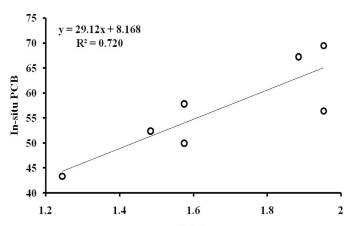


(a) Spatial patterns of Intensity of Marine Heat Wave (IMHW) during month of May, 2010 and (b) PCB computed empirically based on the equation2 along with In-situ observation bleaching percentage value at selected points (marked in value points).

MHW is an event that takes place when sea water of a particular area remains anomalously warmer for certain period (Scannell et al., 2016; Pearce, A. F. & Feng, M., 2013).



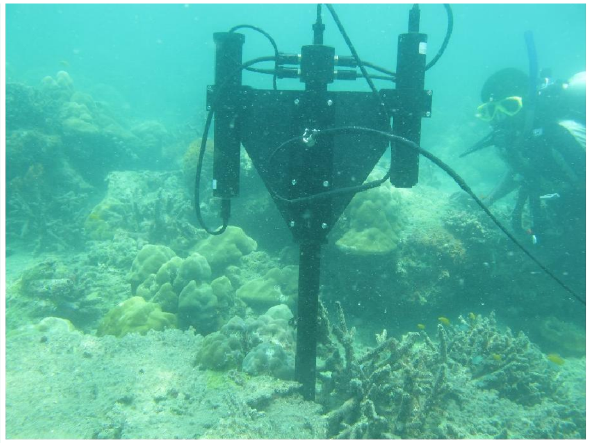
The spectral characteristics of remote sensing reflectance (Rrs) at coral reef region (corresponding to the Rrs Stations shown in figure1) during the period of coral bleaching starting from its onset in the last week of April, 2010.

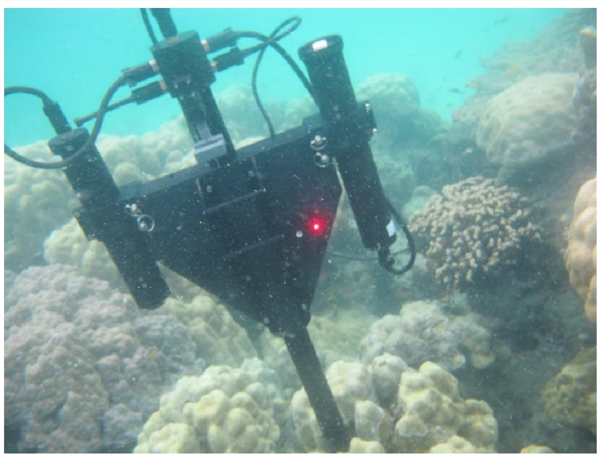


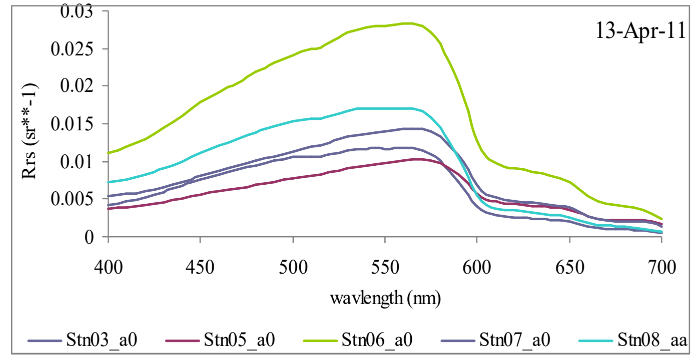
The scatter plots shows relationship between in-situ PCB against RB45

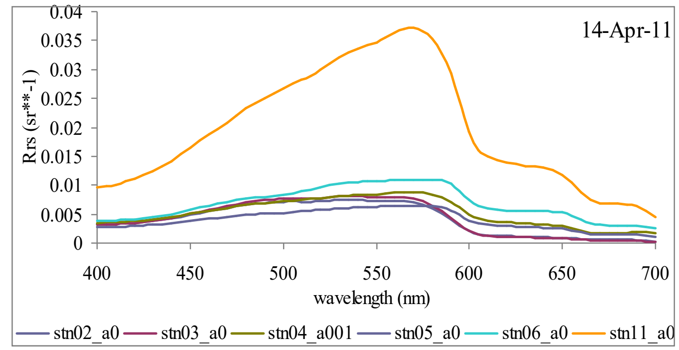
Mohanty et al., 2021

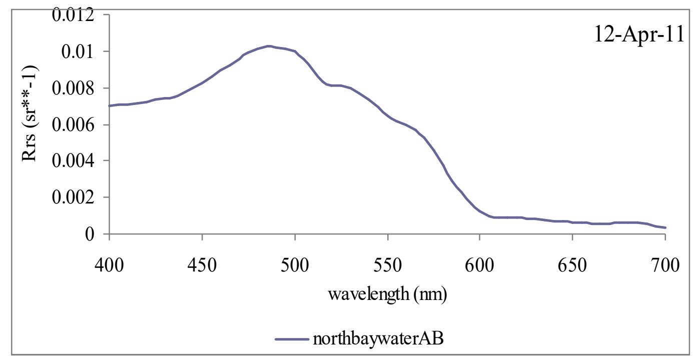
Optical Characterization of the coral reefs



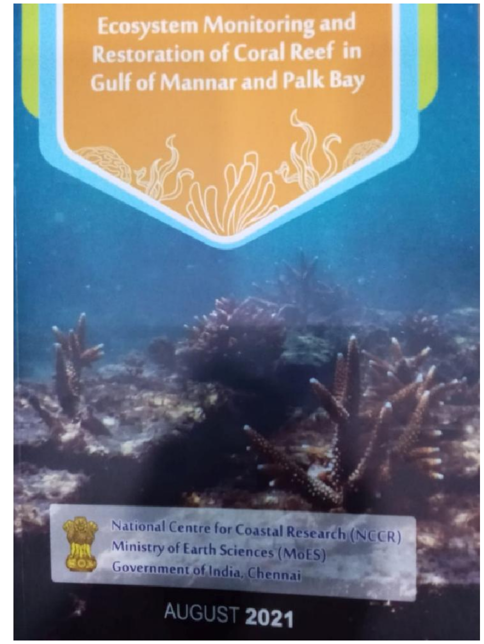








Coral Reef Restoration in the Gulf of Mannar and Palk Bay

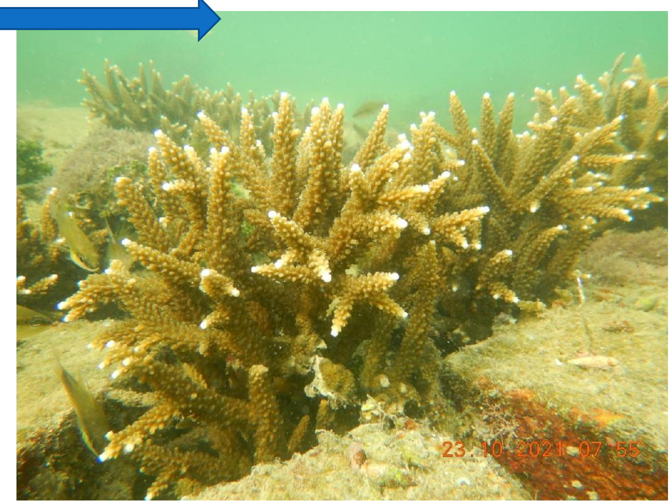


National Centre for Coastal Research has carried out extensive monitoring in the Gulf of Mannar and Palk bay

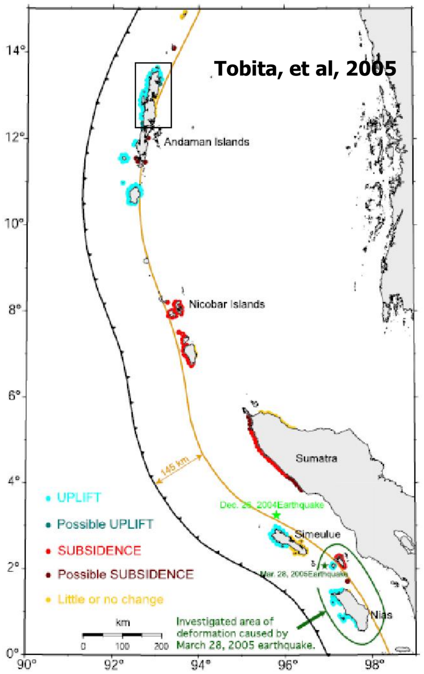
Restoration of coral reefs was taken up

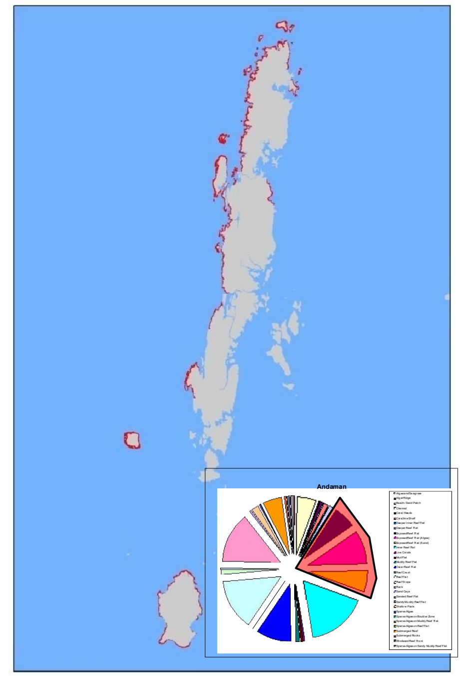
The growth of the coral reefs is shown in the images

Photo courtesy: NCCR, MoEAS



Spatio-temporal changes in the coral environs due to 2004 Sumatra Eq.





Mangroves

Mangrove is a brackish water flora that forms an important ecosystem in the coastal environment

Types of Mangrove Community

Riverine

Fringing mangrove

Over washed mangrove

Scrub or dwarf mangrove forests

Basin mangrove forests

Hammock mangrove

Threats Faced by Mangroves

Pollution

Clearing

Overharvesting

River changes

Climate change: Sea level rise, drought/floods, etc.

Shrimp farming

Tourism

Agriculture

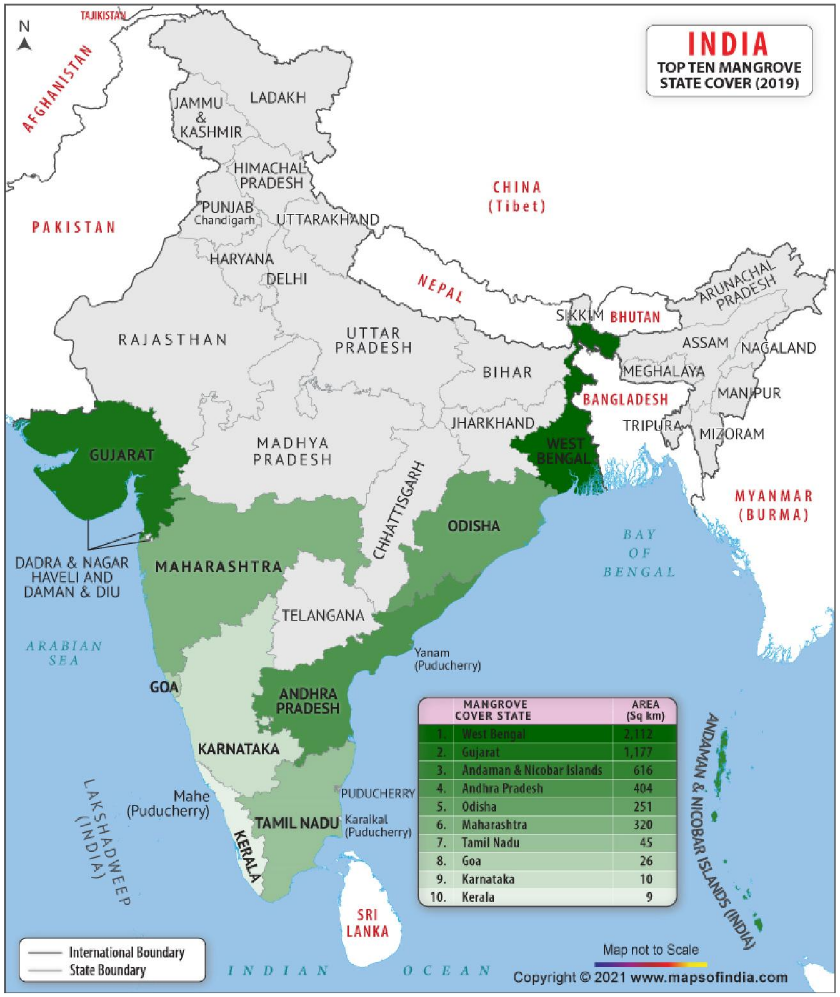
Charcoal and lumber industry

High saline water

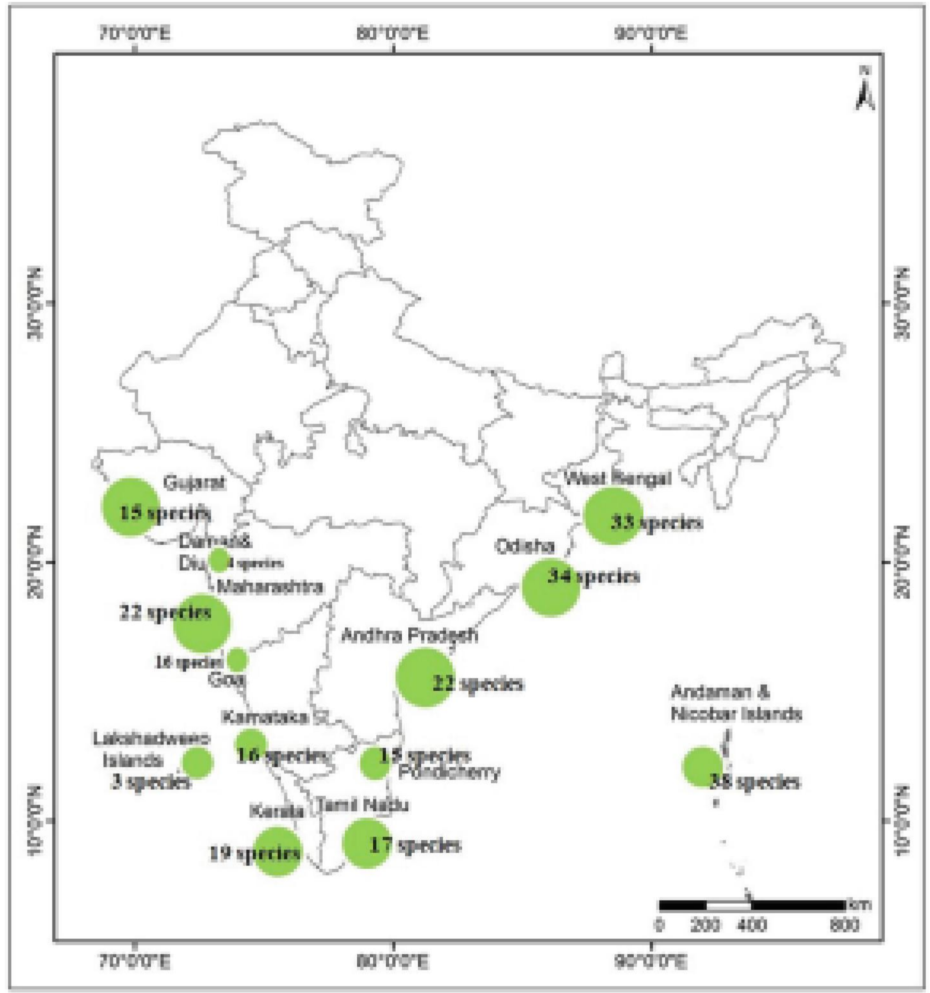
Importance of Mangroves

- Mangroves protect shore lines from damaging storm and hurricane winds, waves and floods.
- They act as carbon sink in coastal environment
- It can maintain water quality and clarity, filtering pollutants and trapping sediments originating from land.
- Mangroves are the nesting nursery and feeding grounds for mammals, reptiles countless unique plants and juvenile fishes etc.
- Good source of timber ,fuel and fodder
- Save the marine diversity which is fast diminishing.
- Secure economic livelihood of coastal communities
- They are rich in biodiversity.

Distribution of Mangrove forest in India



	MANGROVE COVER STATE	AREA (Sq km)
1.	West Bengal	2,112
2.	Gujarat	1,177
3.	Andaman & Nicobar Islands	616
4.	Andhra Pradesh	404
5.	Odisha	251
6.	Maharashtra	320
7.	Tamil Nadu	45
8.	Goa	26
9.	Karnataka	10
10.	Kerala	9



Mangrove cover change during 2019-2021

Table 3.2 Mangrove Cover Assessment 2021

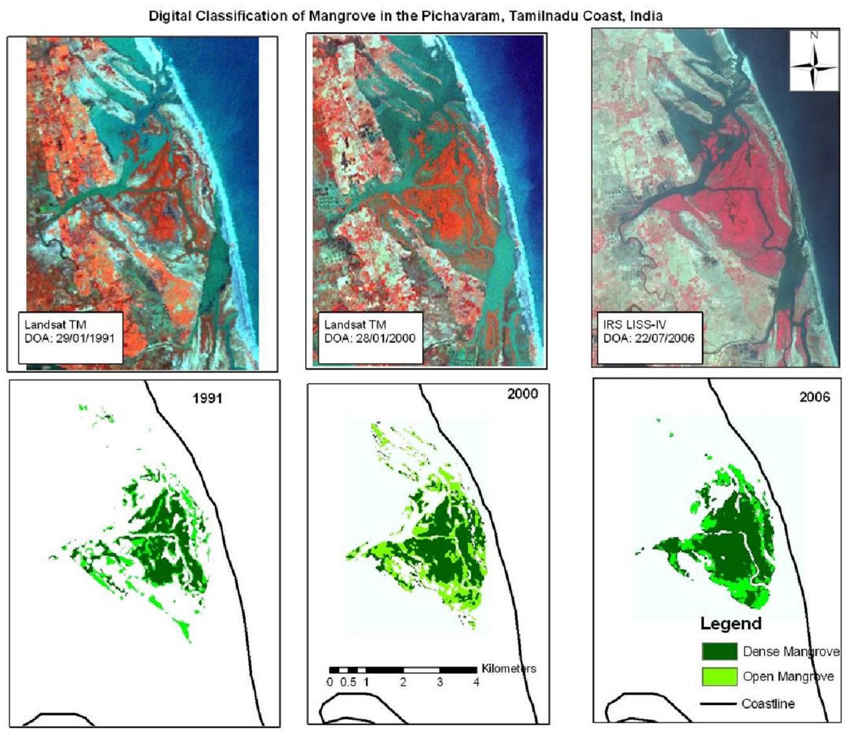
(in sq km)

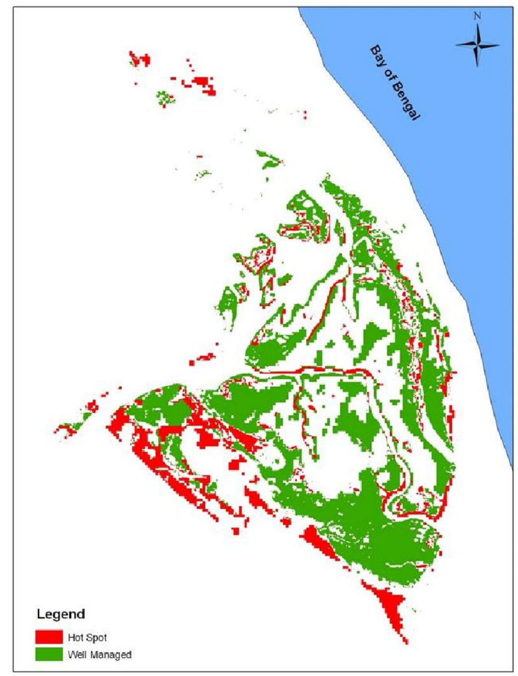
Sl. No.	State/UT	Very Dense Mangrove	Moderately Dense Mangrove	Open Mangrove	Total	Change with respect to ISFR 2019
1.	Andhra Pradesh	0	213	192	405	1
2.	Goa	0	21	6	27	1
3.	Gujarat	0	169	1,006	1,175	-2
4.	Karnataka	0	2	11	13	3
5.	Kerala	0	5	4	9	0
6.	Maharashtra	0	90	234	324	4
7.	Odisha	81	94	84	259	8
8.	Tamil Nadu	1	27	17	45	0
9.	West Bengal	994	692	428	2,114	2
10.	A&N Islands	399	168	49	616	0
11.	D&NH and Daman & Diu	0	0	3	3	0
12.	Puducherry	0	0	2	2	0
	Total	**1,475**	**1,481**	**2,036**	**4,992**	**17**

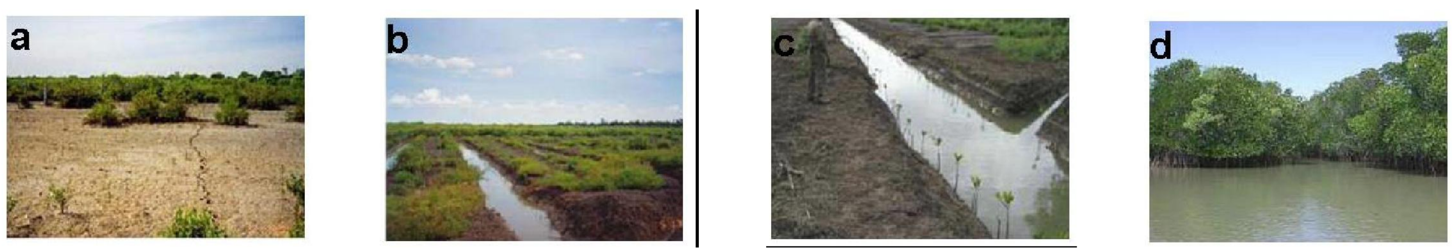
INDIA STATE FOREST REPORT 2021

Mangrove Mapping and Monitoring in Pichavaram

Case Study: Pichavaram Mangroves

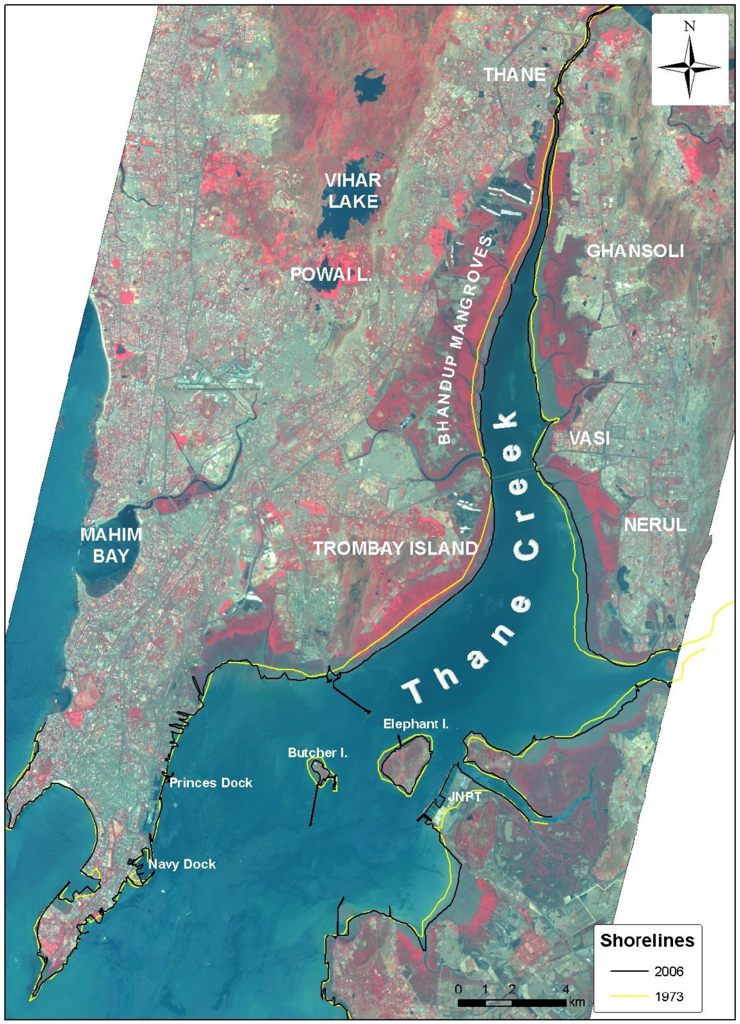


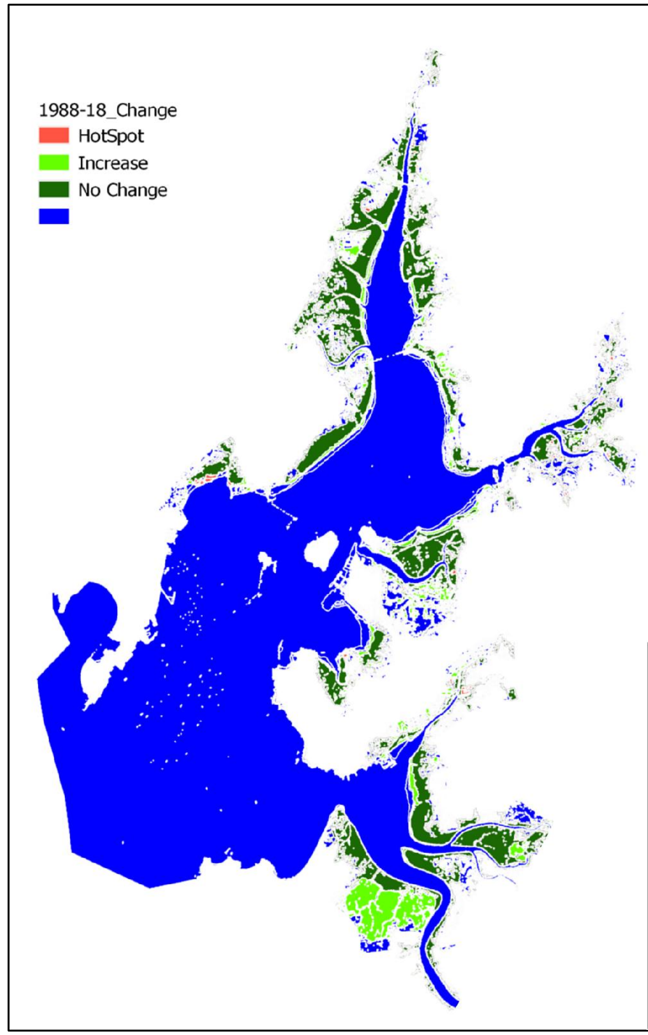


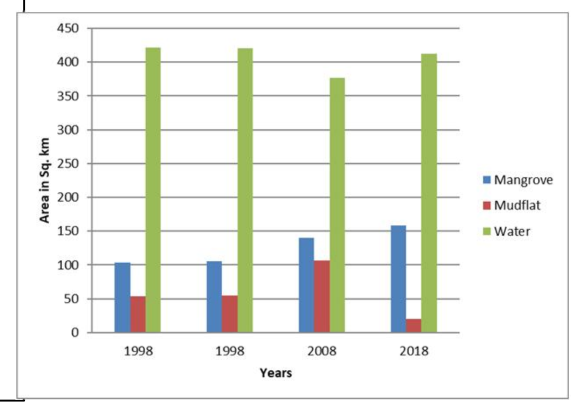


Kumar et al., 2011

Mangrove Mapping and Monitoring in Thane Creek



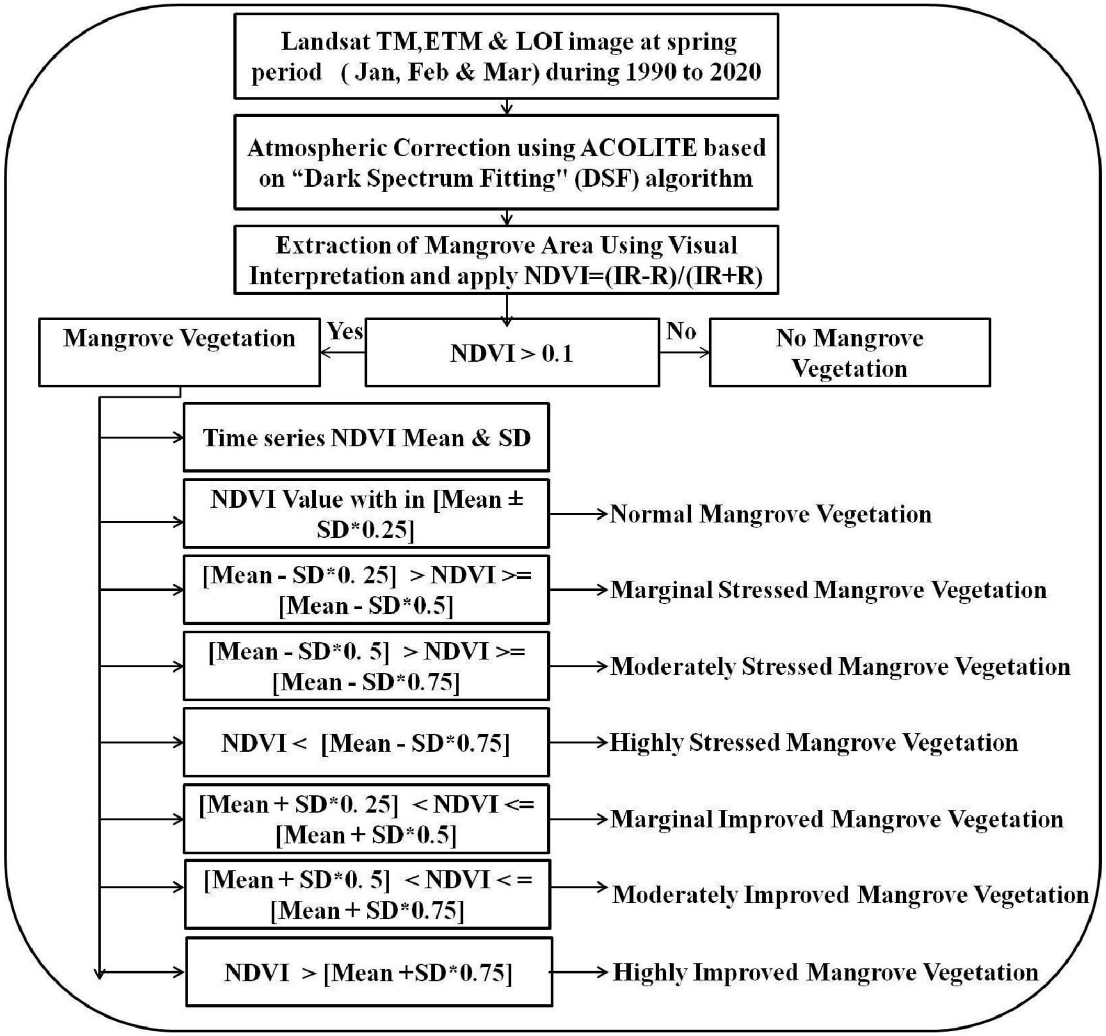


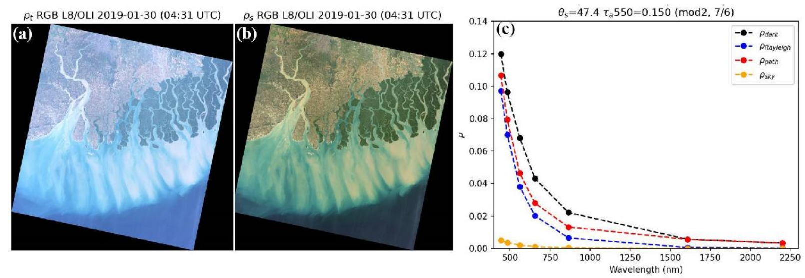


Climate Change impacts on Mangroves

- **The rise in sea level,**
- **The rise in atmospheric CO2,**
- **The rise in air and water temperature, and**
- **Variations in frequency and intensity of precipitation and storm patterns**

Spatio-temporal changes of Mangrove cover and its impact on bio-carbon flux along the West Bengal coast, Northeast coast of India

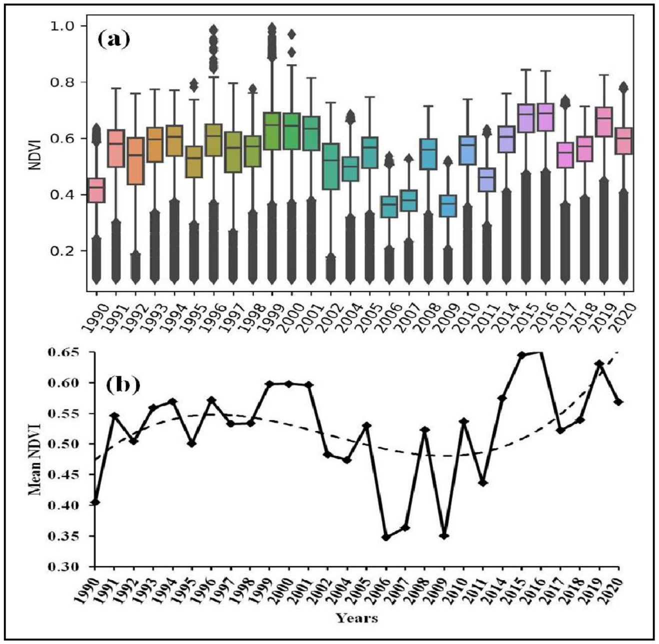




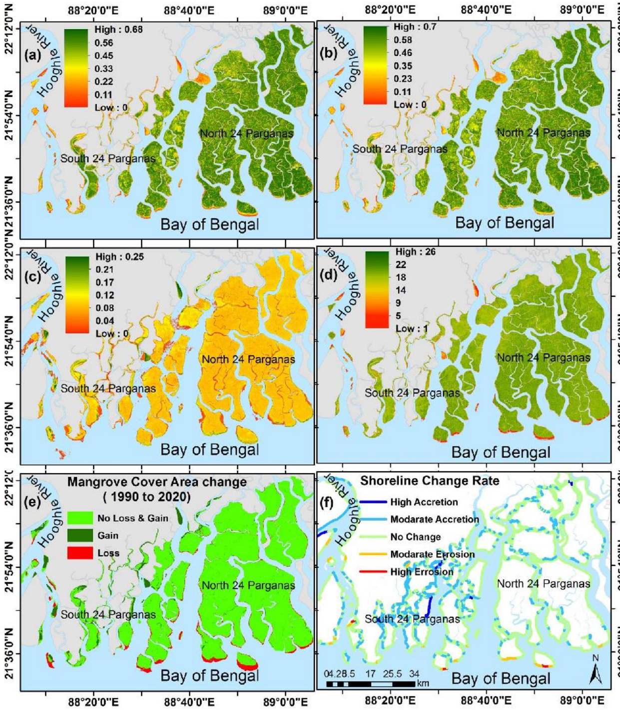
Spatio-temporal changes of Mangrove cover and its impact on bio-carbon flux along the West Bengal coast, Northeast coast of India

Objectives:

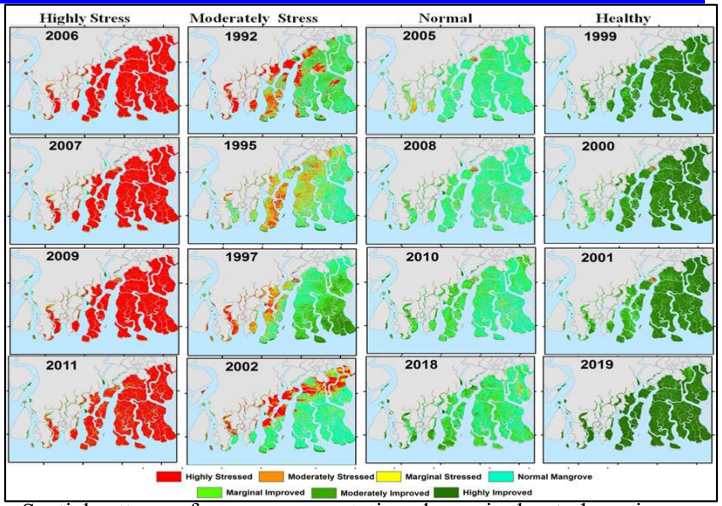
- Seasonal and non-seasonal Spatio-temporal distribution of Mangrove cover
- Seasonal bio-carbon carbon flux (Source & Sink)



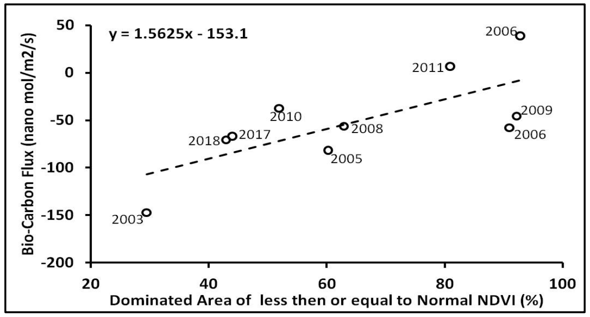
Whiskers chart shows (a) inter quartile range 25 (lower), 50 (middle) & 75 (upper) percentiles line in box and (b) line plot of mean NDVI with piece-wise linear trend over the study region during 1990-2020.



Spatial patterns of (a) NDVI mean climatology for spring season, (b) NDVI mean of the climatological normal (c) NDVI Standard Deviation and (d) number- frequency of data used to calculate NDVI normal as in b (e) change of mangrove cover area between 1990 to 2020 (f) shoreline change rate along the coast of the study region.



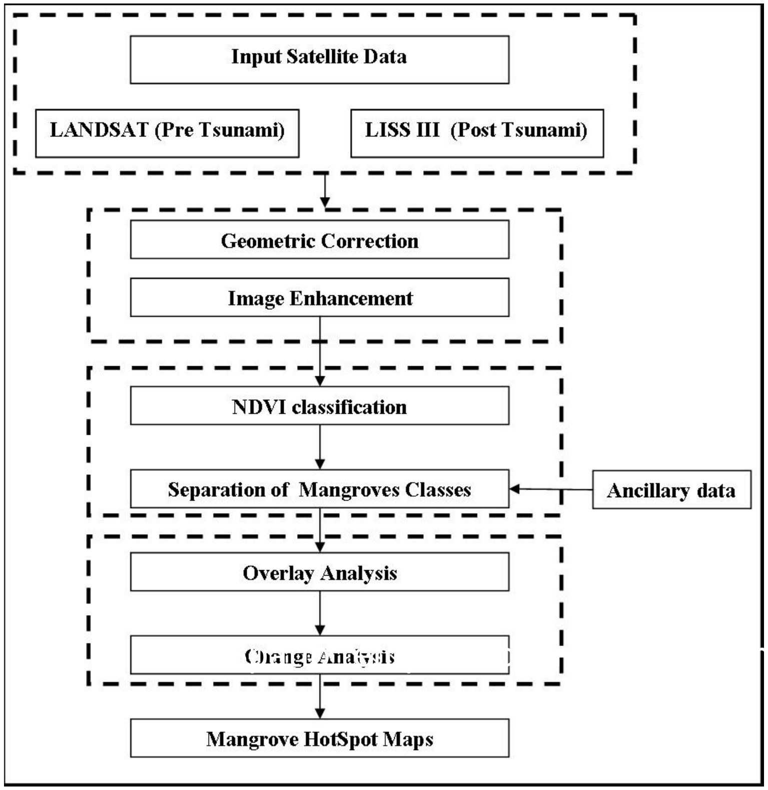
Spatial patterns of mangrove vegetation classes in the study region for selected years corresponding to dominant classes: highly Stress, moderately stress, normal and healthy conditions.

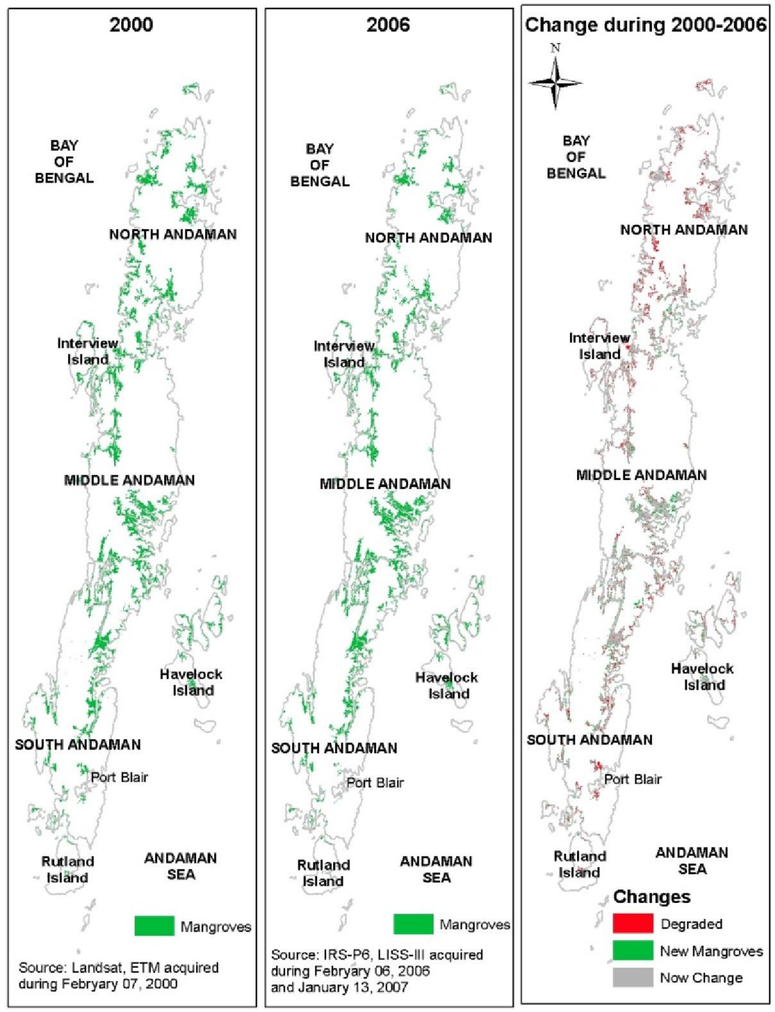


Relationships between Bio-carbon flux and increase in area (in percentage) being classified under ecological-stress for the years with dominant class being either normal or stress mangrove condition.

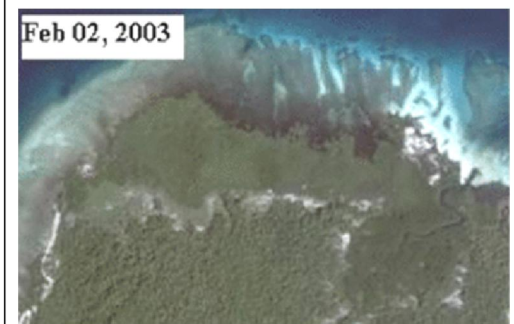
Mohanty et al., 2021

Spatio-temporal changes in the Mangrove environs due to 2004 Sumatra Eq.





Fall effect in the proximal end



Rise affect in the distal end

Total ~49.24 km^2 areas of mangroves were degraded during 2000-2006 in the Andaman coast.

Thank you