Sustainable Fisheries and Aquaculture: Impact of Climate Change and Mitigation Measures

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Climate Change

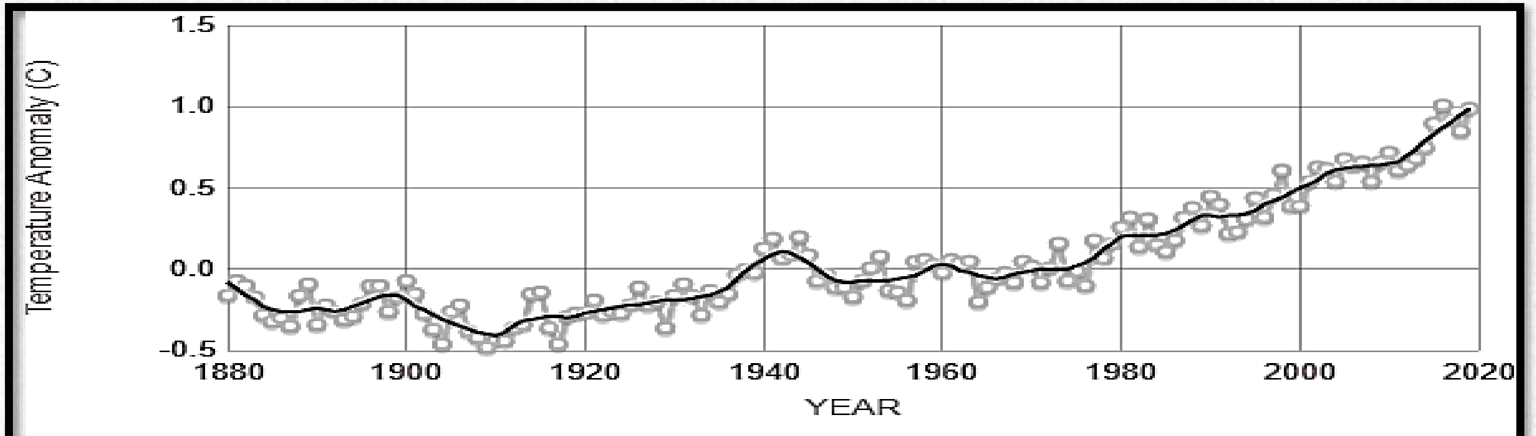
- Global mean sea surface temperature (SST) has increased since the pre-industrial era.

- The increase in SST has not been uniform in time or space, but there has been an average global increase of around 0.6°C over the last four decades.

- Climate change has been impacting the primary human requirement such as food, water and shelter. Frequent occurrences of natural disasters such as floods, droughts, cyclones, windstorms, heat waves etc., have been associated with the climate change.

- It is one of the most crucial challenge of the 21st century

- Natural disasters directly impact primary food producing agriculture and allied sectors creating food insecurity, potable water, sanitary and phytosanitary measures, health and environment.



Global temperatures from 1880 to 2020
(Source: Global Climate Change, NASA)

- In India, out of the 36 states/ Union Territories, 27 are vulnerable to natural disasters.

- India is one of the most victim-prone countries corroborate significant change in rainfall and temperature patterns which warn for more intense and frequent natural disasters in foreseeable future (Kothawale *et al*., 2010).

- Unprecedented heavy rains and resulting floods as happened in Kerala is one of the most recent effects of changing climate.

- The consequences of climate change phenomena are now visible everywhere including in animal farm industry (Lal and Harasawa, 2001)

- Fisheries and aquaculture is placed in an ambivalent situation with a great proportion of loss in the sector

Climate Change Impacts on Ocean

SST

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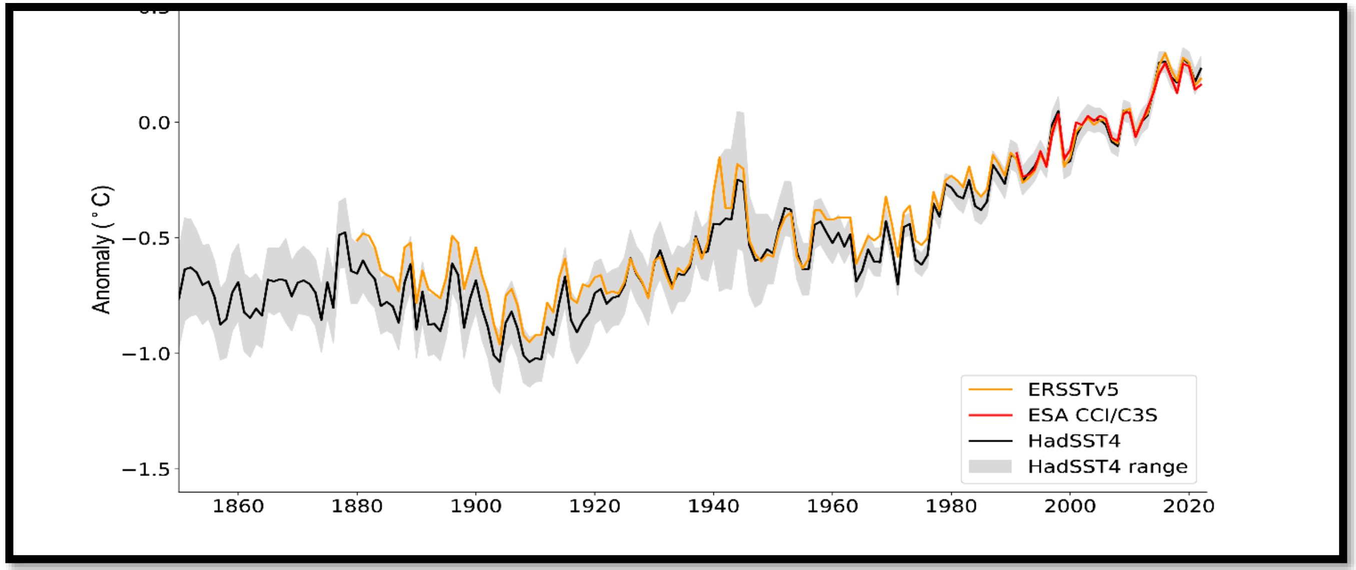
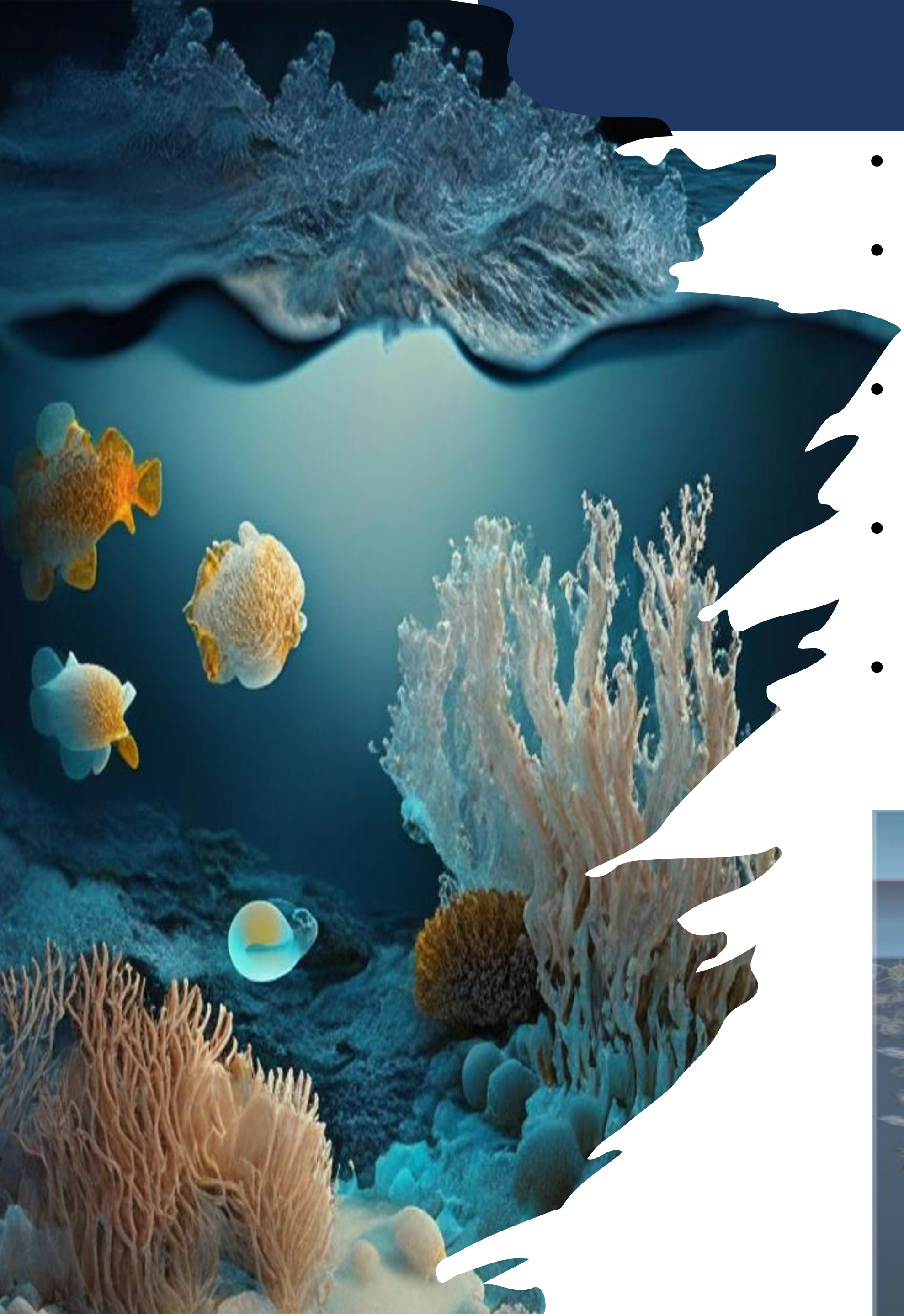


Source : climate.copernicus

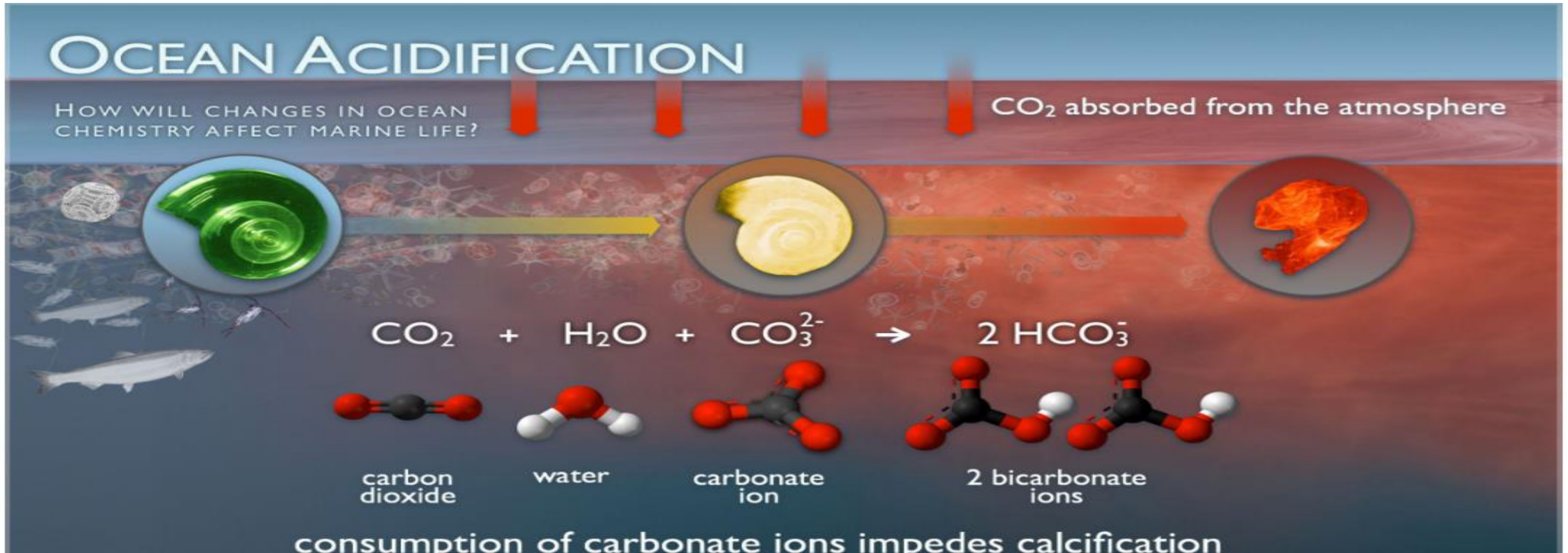
Source: NASA

Global Annual Temperature Anomaly

Ocean Acidification



- Ocean acidification is the reduction in the pH value of the Earth's ocean.
- Between 1751 and 2021, the average pH value of the ocean surface has decreased from approximately 8.25 to 8.14.
- Rising concentration of carbon dioxide in the atmosphere leads to more dissolution of CO2 in seawater which causes ocean acidification.
- Although warming and acidification are different phenomena, they interact to the detriment of marine ecosystems.
- Ocean acidification is a major threat to marine life as it increases the H^+ ions and reduces the availability of CO_3^{2-} ions detrimentally impacting the shelled and skeletal forming organisms including corals.



Coral Bleaching in Andaman Islands in 2010

(Contributed by collaborators at CARI, Port Blair)

1. **Bleaching in 2010 is higher than 1998**
   SST raised 2-3 deg C than 1998

2. Observed bleaching at Havelock Island (69.49%),
   South Button Island (67.28%),
   Nicolson Island (56.45%),
   Red Skin Island (43.39%),
   North Bay (41.65%) and
   Chidiyatapu (36.54%)

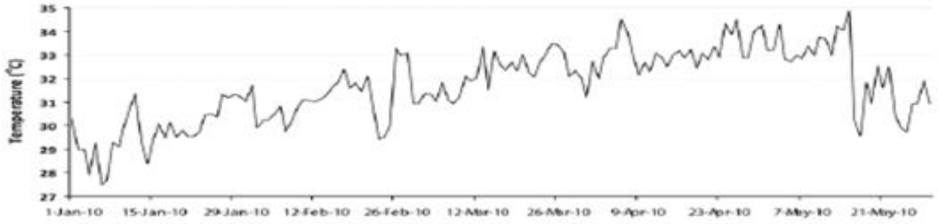


Fig. 1. Temporal variation in the maximum air temperature in Andaman

Branching coral
(*Acropora* spp)

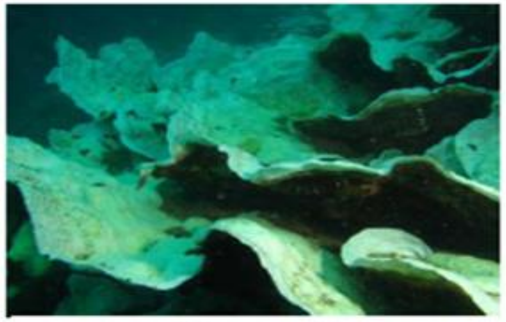
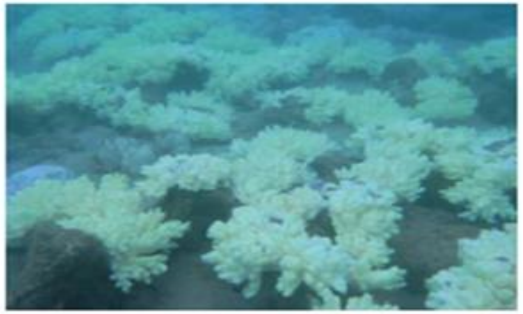


Plate coral
(*Echinopora lamellose*)

Massive coral
(*Porites solida*)



Partially bleached soft corals
(*Sinularia* sp)

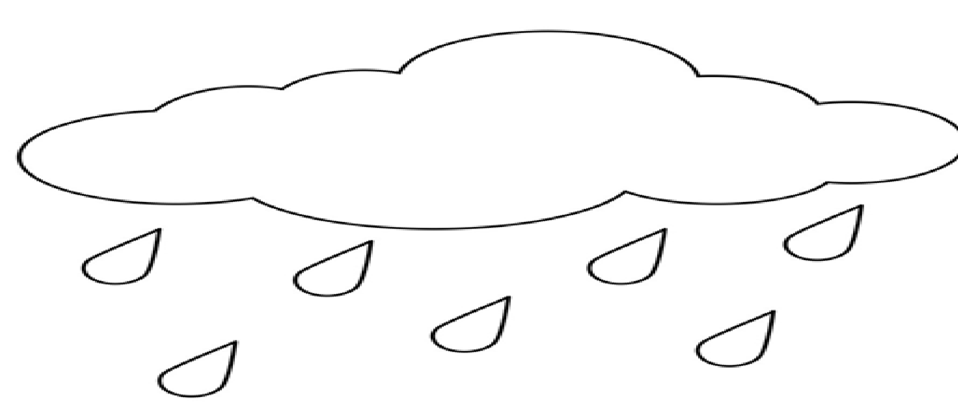
Bleached Sea anemone

Bleached Giant

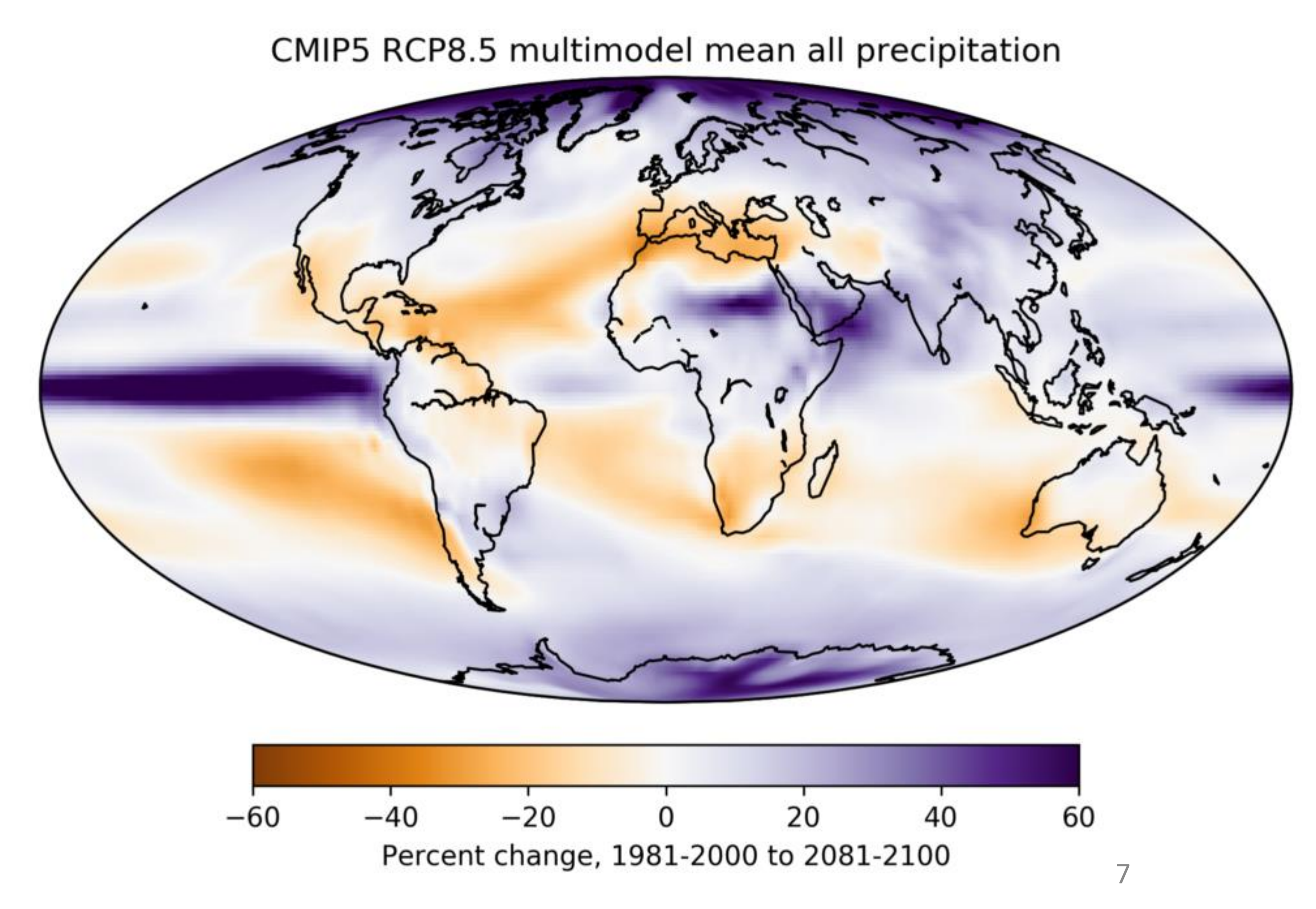
Withering Brittle stars

Field Observations around Coral Islands

Rainfall



- Intensified rainfall
- With warming, more water evaporates from oceans, lakes, and soils
- For every 1°C rise, the atmosphere holds 5% more water vapour
- Wet places will become wetter; dry places drier

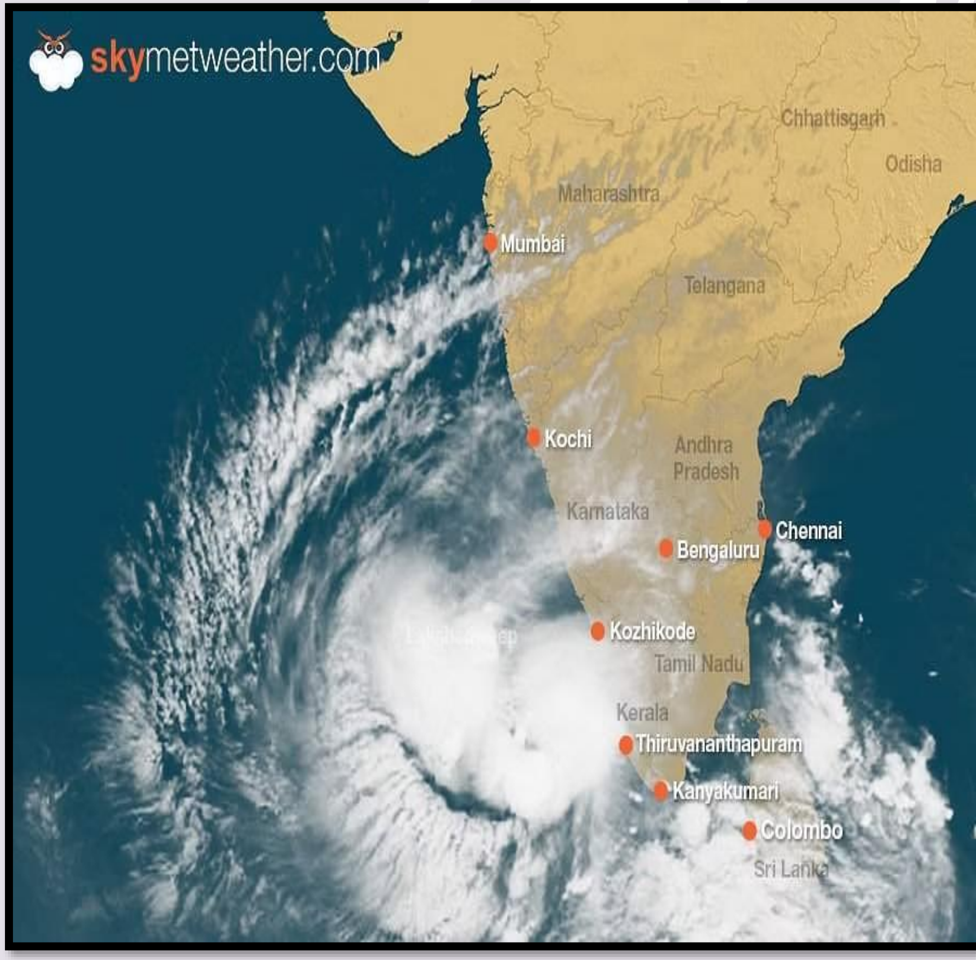


Cyclones

The World Meteorological Organization has reminded that climate change is expected to increase the proportion of major tropical cyclones worldwide, and to increase the heavy rainfall associated with these events

Direct Impact of Ockhi cyclone on the fishery- as reflected in the seasonal marine fish landings of Kerala

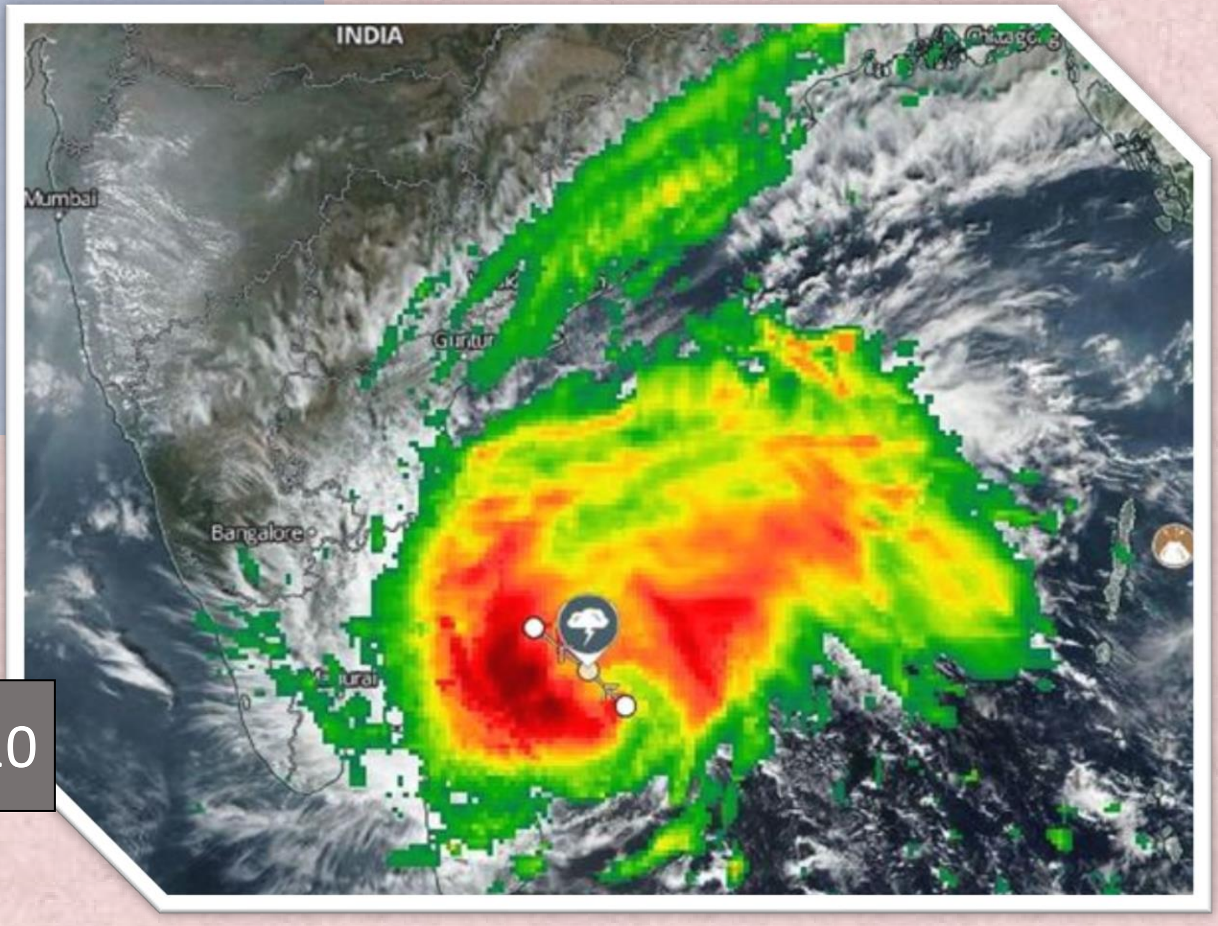
- Loss of effort in units -56,610 in 2017, which is 46% less compared to 2016
- Loss of effort in AFH - 5,70,495 which is 57% less than 2016
- Due to the loss of fishing days during Ockhi cyclone, the landings share during the above period reduced to 13.5% in 2017 from 22% in 2016
- The estimated loss during the above period was 35,465 t valued at Rs.585 cr. at landing center level and Rs.821 cr. at retail level



- Cyclone simulation results of HadRM2 for 2050s showed no significant change in the number of tropical cyclones.

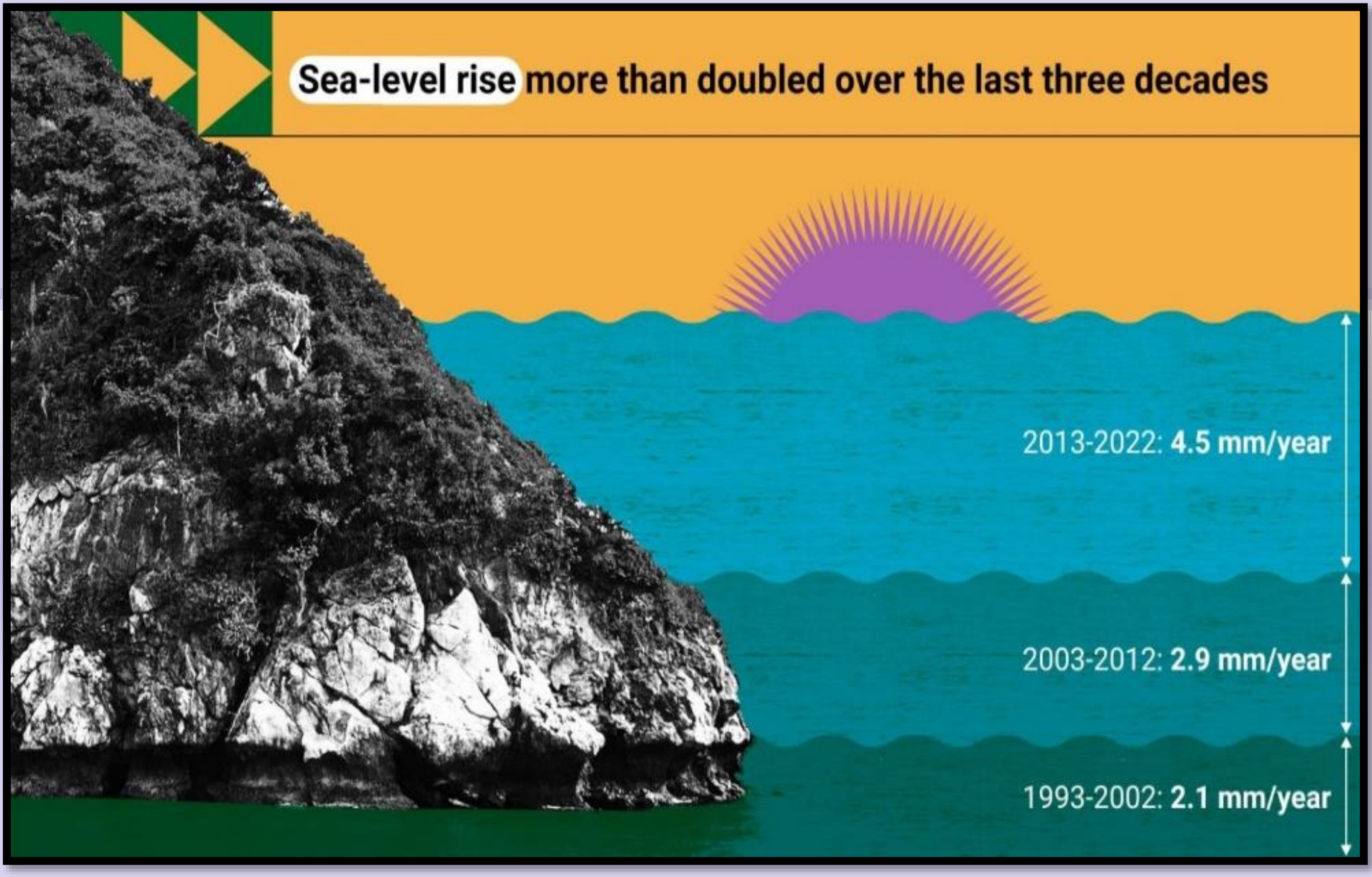
- However, the number of intense cyclones will increase.

- Frequency of cyclones with range of 100-120 km/h will be much higher



Cyclone Nivar off TN/Puducherry in November, 2020

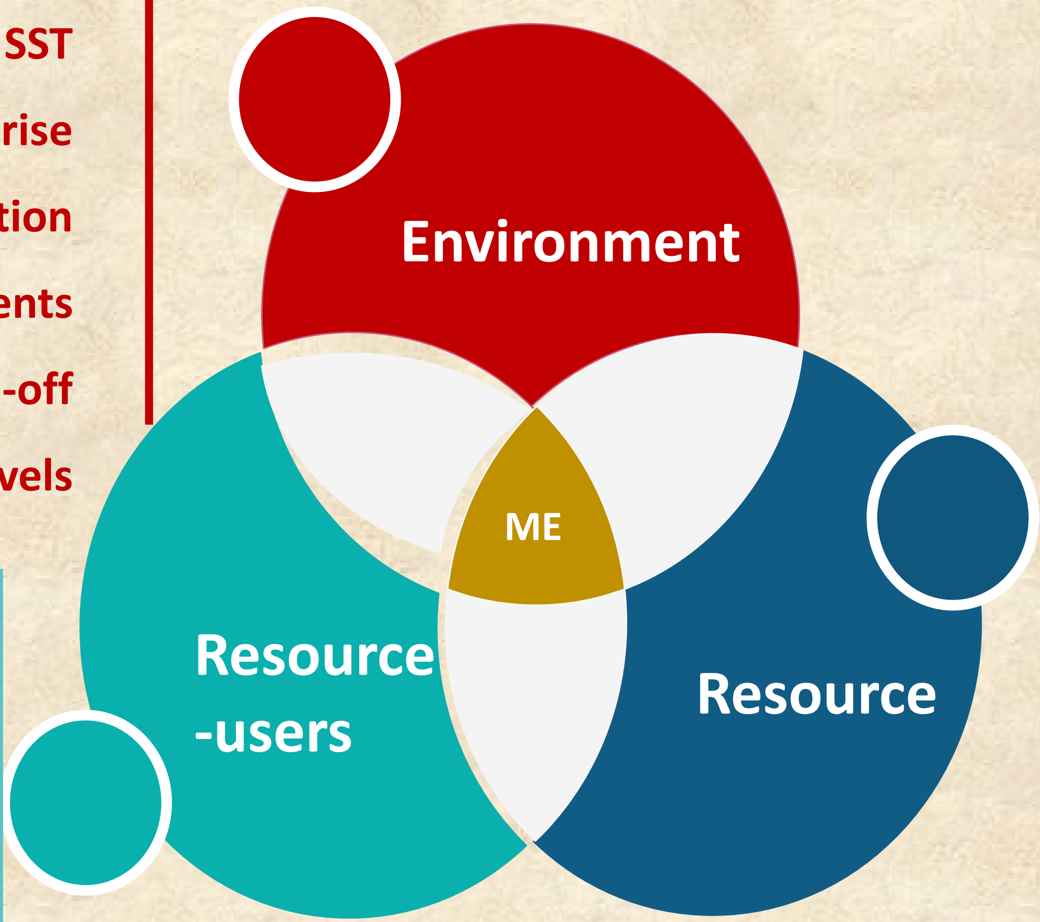
Sea Level Rise



Source: SUN - UK

Source: NASA

Marine Ecosystem and its components



Impact on physical environment

Increased SST

Sea-level rise

Ocean acidification

Extreme weather events

Changes in rainfall and river run-off

Reduction in Oxygen levels

Impact on fishers safety at sea and livelihoods

Migration

Loss of income

Loss of Property

Health problems

Debt and Unemployment

Impact on marine resources

Distributional shifts of shellfish and finfish

Change in ocean fish productivity

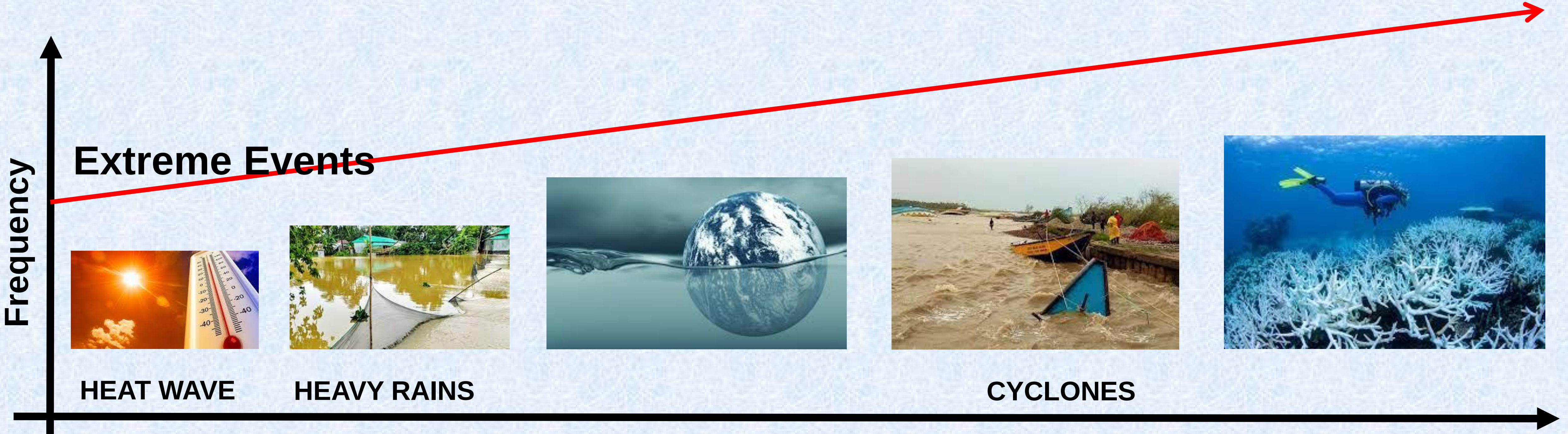
Coral reef habitat destruction

Changes in ocean fish productivity

Disappearance of coral reef ecosystems

Changing climate impacting aquaculture and fisheries

1. Temperature will cross 1.5^{o}C more than the mean in a decade and a half – increase in frequency, intensity & duration of marine heat waves.
2. Rainfall variability and intensity increasing – floods and droughts.
3. Sea level rising.
4. Cyclones are becoming fiercer & frequent.
5. Aquatic ecosystems, resources and resource-users are at stake.



Climate Change impact - Pathway

GHG accumulations

Biophysical changes

- **Temperature**
- **Acidification**
- **Currents**
- **Anoxia**
- **Rainfall**
- **Sea level rise**
- **Storm frequency & Intensity**

Impacts on aquatic life

Projected changes for India 2080-2100
(from base year 1975-2005)

Pathway	Atmospheric warming (° C)	Seawater warming (°C)	Annual rainfall increase (cm)	Sea level rise (m)
RCP 2.6	1.31 - 1.33	-	-	-
RCP 4.5	2.34 – 2.44	1.6	9.1 – 14.6	0.3 – 0.3
RCP 8.5	4.31 – 4.44	2.7	16.4 – 23.0	-

Representative Concentration Pathway (RCP) is a greenhouse gas concentration (not emissions) trajectory adopted by the IPCC. These represent the atmospheric concentrations of greenhouse gases and describe different climate futures, all of which are depending on the volume of greenhouse gases (GHG) emitted in the years to come. Now Socioeconomic components are added to the RCPs: such as new scenarios SSP1-1.9, SSP1-2.6, SSP 2-4.5 and SSP5-8.5.

Areas affected

Impacts

Production and Ecology

- Species composition production and yield
- Habitat distribution and seasonality
- Disease and other disruptions
- Coral bleaching
- Calcification

Fishing, aquaculture and post harvest actions

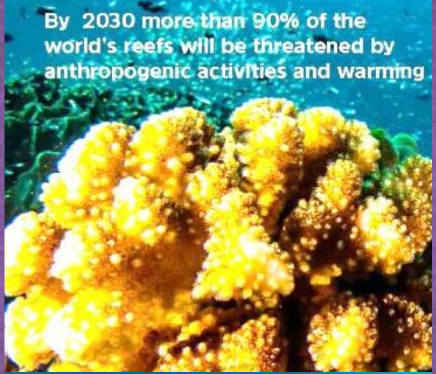
- Cost and efficiency
- Safety and Security
- Infrastructure security

Communities and Livelihoods

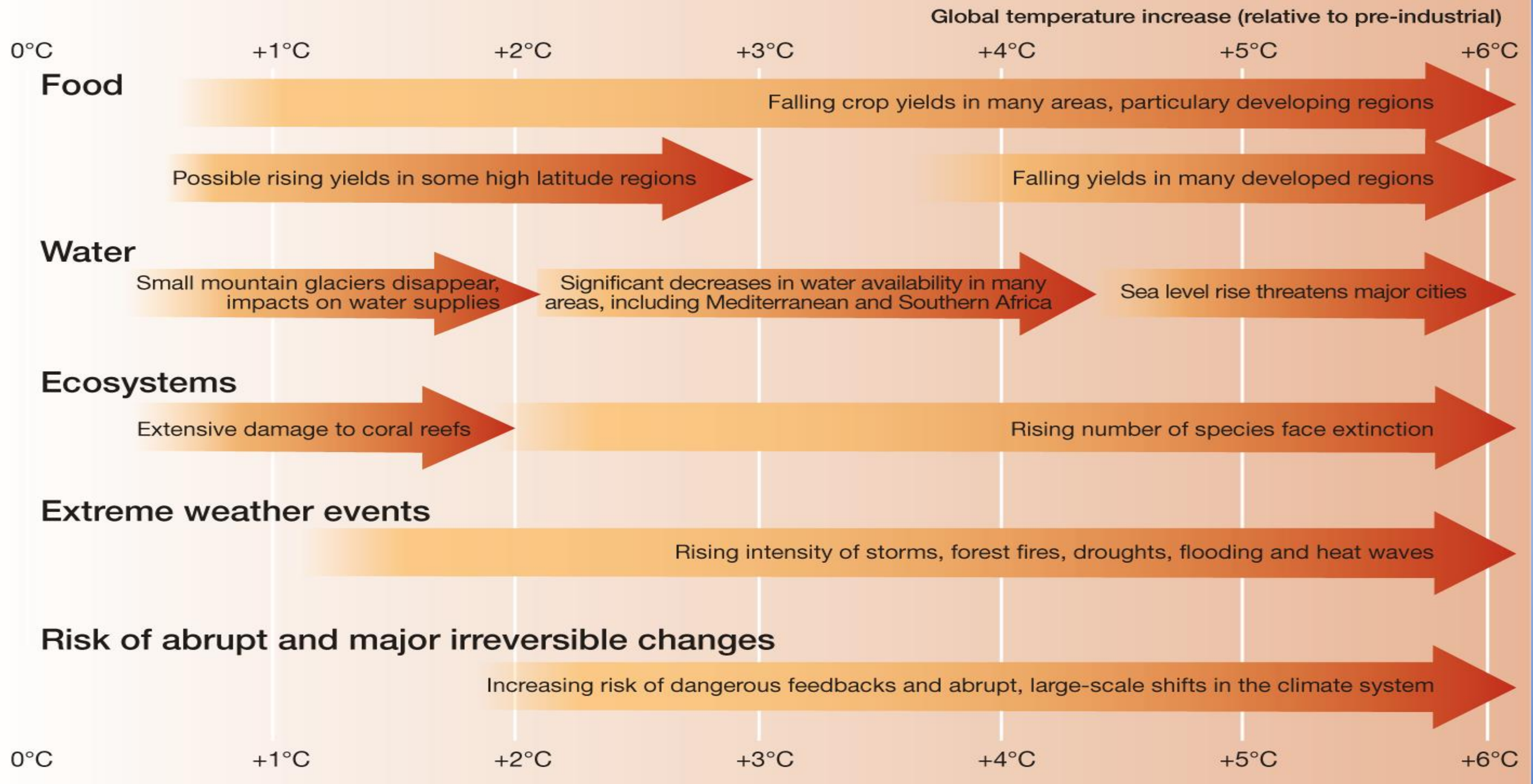
- Loss and damages to assets
- Risks to life and health
- Vulnerability and confidence
- Displacement and Conflicts

Society and Economy

Cost of migration and adaptations
Social and market impacts
Water and other resources



Projected impacts of climate change



Likely impacts on aquaculture farms

- Climate change will create physiological (survival, growth, disease), ecological (organic and inorganic cycles, ecosystem services) and operational (species and site selection, shrimp farms and sea cage technology) changes.
- As farms are located in shallow waters, solar radiation is likely to have an important influence on sea water temperature.
- Most problems involving heat will result in reduced water quality, oxygen levels, increased disease and associated diseases, and reduced feeding and growth performance rather than by directly exceeding the thermal tolerances of fish.

- The major threat would be cyclones and storm surges.
- It is predicted that the frequency and intensity of cyclones will increase. This will cause damage to farm properties and escape of stocks.
- In the case of sea cages, the cages may be drifted away.
- As abundance and distribution of wild fish stocks are affected, there will be changes in fisheries product price or through changes the supply and demand of resources such as availability of trash fish for feed and increase in feed price.
- Temperature changes will have an impact on the suitability of species for a given location.
- Increasing incidence of Harmful Algal Blooms is a cause for concern from the point of view of open sea cage farming.

Impact of Climatic Variations on Marine Fisheries

Impacted variables

- Rise in SST
- Changes in Salinity
- Decrease in pH
- Changes in rainfall patterns
- Frequency of storms / cyclones
- Changes in chlorophyll composition
- Rise in Sea level

Intermediate biophysical process

- Change in El Niño & La Niña ; change in current and water mass movement, density
- Ocean acidification
- Alters the hydrology of estuarine ecosystems
- Destruction of corals, vessels, fishing equipment and infrastructure on the coasts, Breaking of vertical stratification where coastal upwelling is absent.
- Inundation of coastal habitats such as mangroves, sea grass beds
- Inundation and physical impacts on coastal areas

Biological impacts

- Changes in distribution and abundance of species, phenology, growing and breeding seasons, feeding habits and deformities.
- Alters the nutrient composition, diatoms and planktons
- Alters critical habitats and community structure

Fisheries impacts

- Commercially important species may be replaced by low priced species
- Reduction in overall catch of marine fishes
- Affects the growth and catch rate of pelagic fishes
- Economic drain on fisherman
- Rehabilitation of fishermen into inland areas

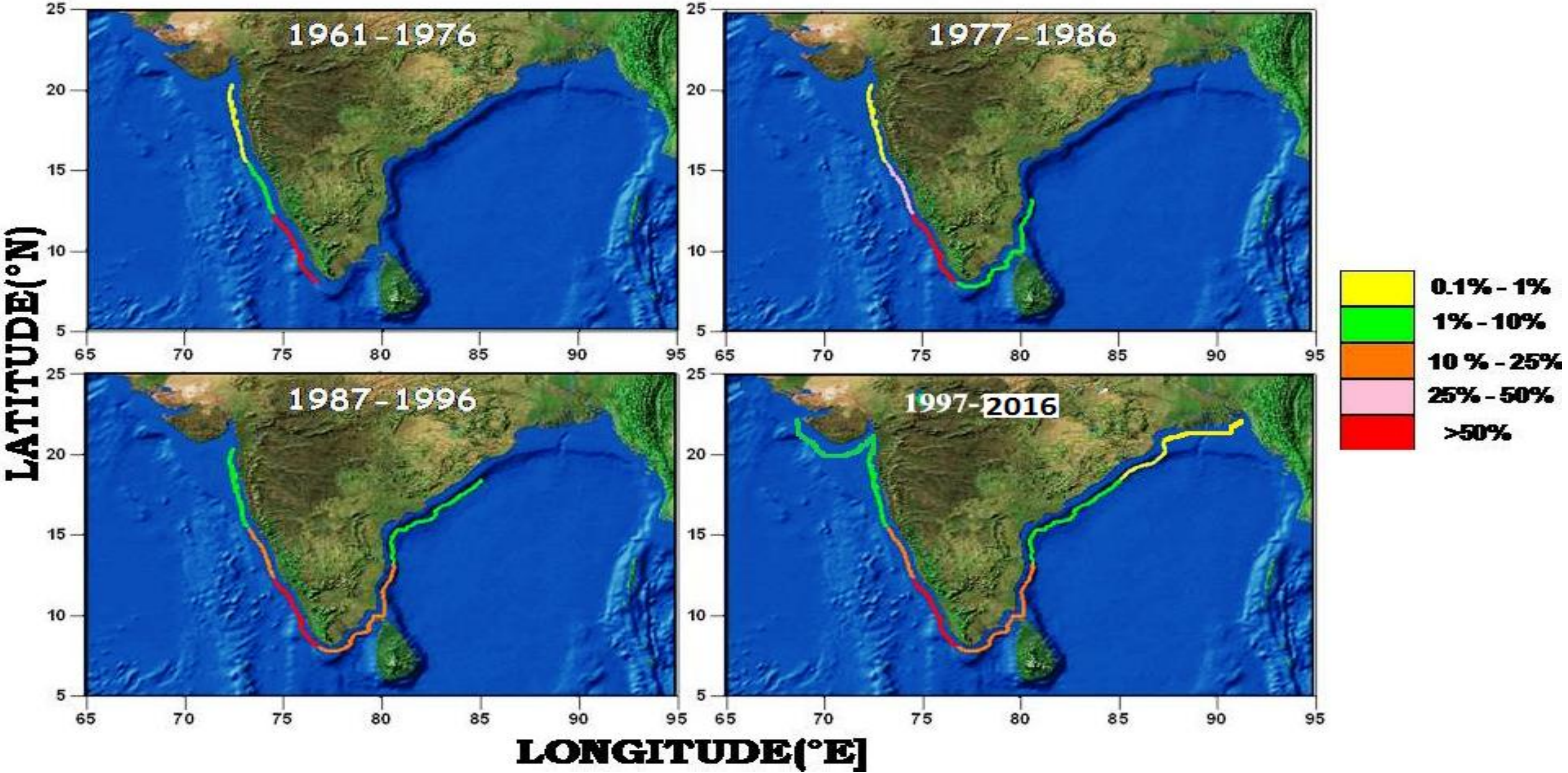
Marine fish

- **Distributional changes of small pelagics like oil sardine, Indian mackerel** *(evidences available for extension of distributional boundary towards northern latitudes)*
- **Phenological changes of a few species such as thread fin breams**

  (evidences available for changes in spawning season towards relatively cooler months)
- **Some species mature early in their life such as breams, mackerel** *(at smaller body size, producing smaller eggs)*
- **A few species grow faster than before such as anchovies, oil sardines, lesser sardines** *(indicating higher food requirement and faster turnover of generations)*

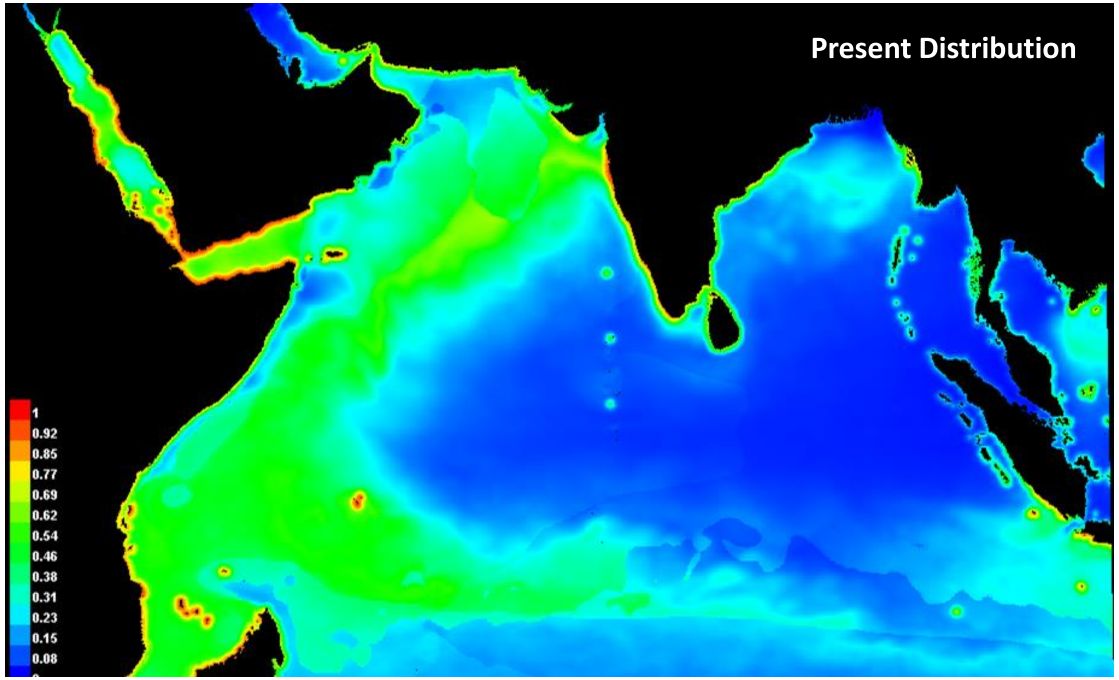
Extension of northern boundary of oil sardine

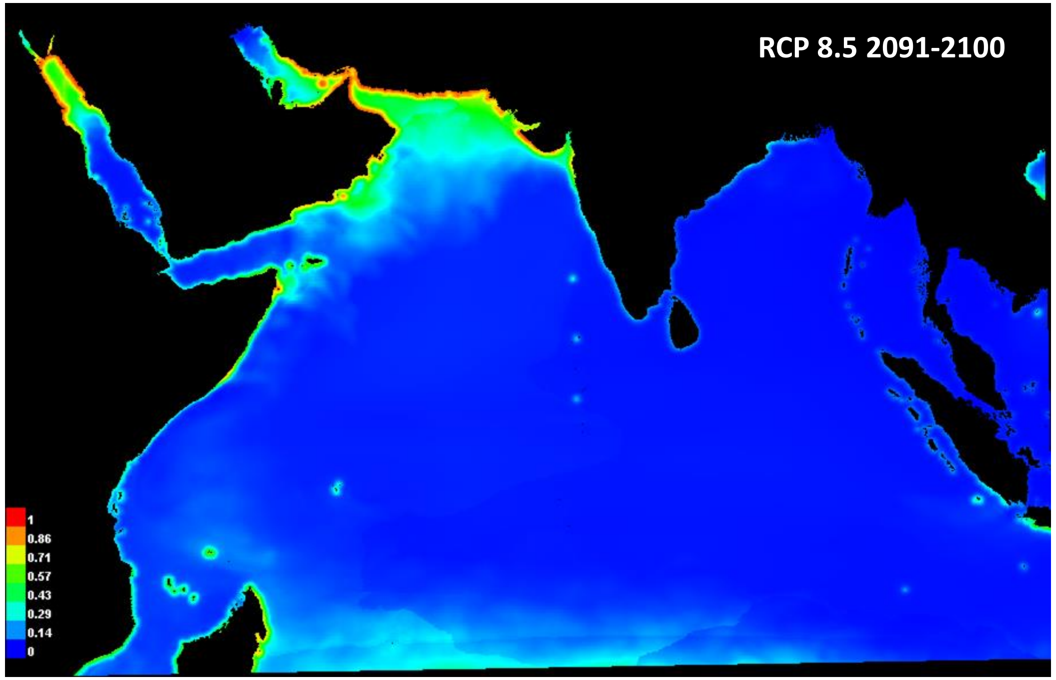
Colored line – percentage of all India Oil sardine Production



Predicted distribution of 34 commercially important marine fishes by 2100 in Northern Indian Ocean

- ✓ **Smaller Pelagics – reduced extent of distribution in RCP 8.5**
- ✓ **Vulnerable large pelagics – Northward extension of distribution**
- ✓ **Major Oceanic Tunas – Increased distributional pattern**





Current & Predicted distribution of Sphyrna zygaena (Linnaeus, 1758)

Adaptation framework for Marine Fisheries

Influencing parameters	Vulnerabilities	Adaptation Strategies
SST, Salinity, Sea Level Rise	Eco system damage- Mangrove, Coral reefs, seagrass beds	• Habitat mapping, monitoring and management • Coastal wetland management and scientific fish farming
SST, Rainfall, Chlorophyll, Wind pattern	Changes in distribution, abundance, phenology and trophodynamics of species	• Vulnerability assessment and monitoring of fisheries resources • Potential Fishing Zone Advisories • Mariculture of climate resilient species • Preventive health management
pH	Ocean Acidification	Seaweed farming and bioproducts development
SST	Reduction in fecundity/size	• Implementation of minimum legal size • Sustainable fisheries resource utilization
GHGs emissions	Increased C footprint in fishing operations	• Algal Biorefineries Integration • Harvesting solar energy from oceans
Wind pattern (Extreme events)	Income loss due to decline in catch and loss of fishing days	• Multivendor E-Commerce solutions for income improvement • Low cost fishing technologies development • Adoption to Integrated farming techniques
Sea Level Rise	Inundation and physical damages on coastal areas	• Enhancing preparedness of coastal population • Climate Resilient Coastal Village development

Reducing the impacts of climate change and other stressors on fish stocks

Expanding No-take Zones

Providing shelter to fish; restoring critical habitats

Regulating access to fishing grounds

Changing from open access to controlled access; reducing fishing pressure in coastal areas

Adopting Ecosystem Approach to Fisheries Management

Addressing multiple objectives; reducing impact of external stressors on natural stressors

Monitoring, Control and Surveillance (MCS) of fishing operations

- Use of fishing log books
- Boat movement tokens
- Colour coding of fishing boats
- Biometric cards to fishers
- Use of space technologies and IT tools

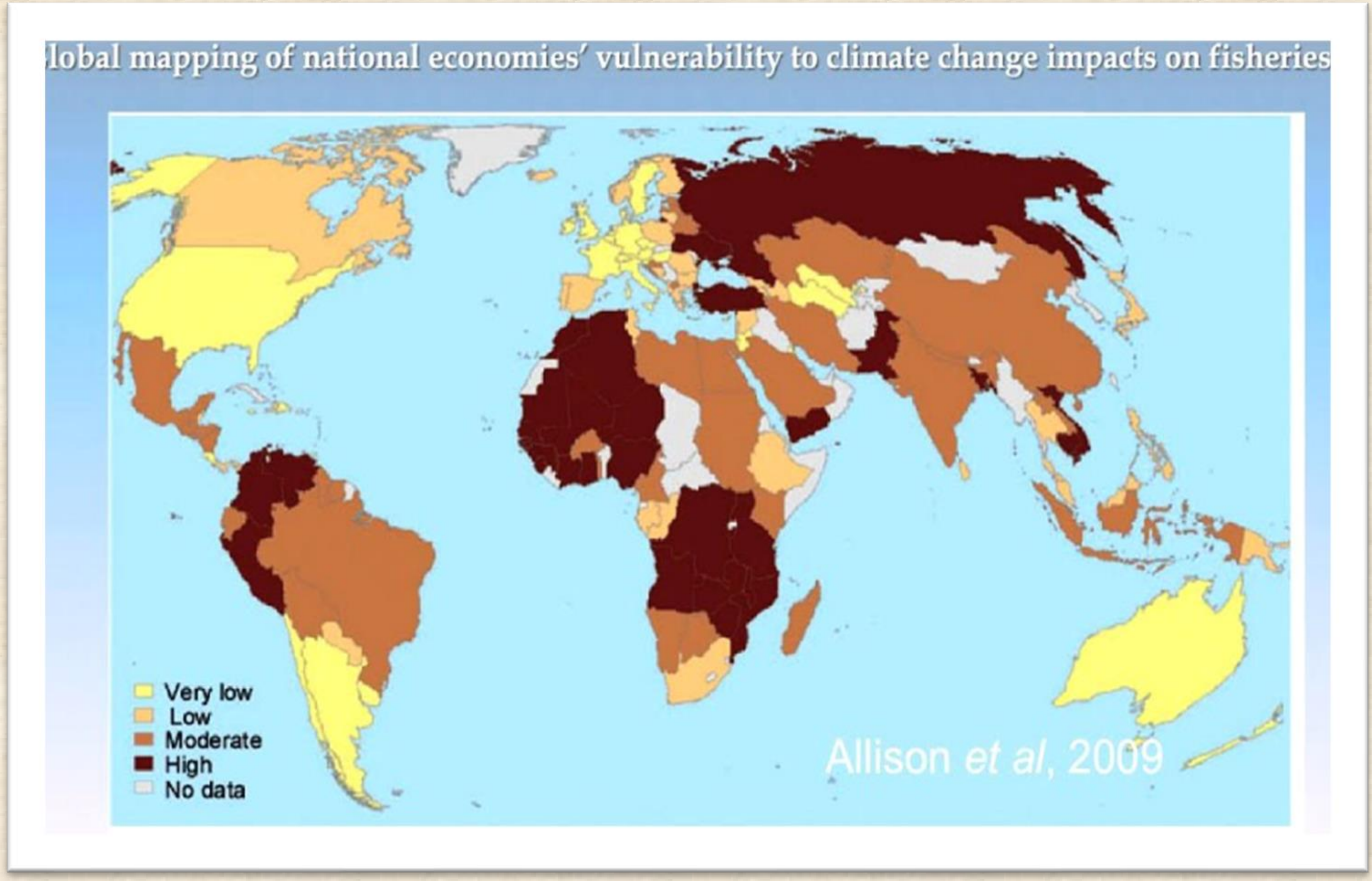
  - Vessel Monitoring System and Automatic Identification
  - Tracking the fishing boats by establishing High Frequency (HF) ground stations and HF sets on board the fishing boats

Enhancing economic benefits by improving value chain

Value realisation	• Reducing physical and quality loss: utilizing the catch fully; • Improvement in handling and preservation; • Need well-developed distribution channels and cold chain arrangements
Value addition	• Developing products to enhance nutritional and economic values; and shelf-life; • Needs better processing facilities; • Developing non-food, pharmaceutical & nutraceutical products
Value creation	• Creating new markets; • Certification, labelling and traceability of products; • Block chain approach

Impacts on Fisheries and Fishermen

- Susceptible fish species will disappear commercially
- Fish catch decline
- Economic drain on fishermen
- Cyclones, floods cause loss to lives & properties of coastal communities



Effects on fishing, communities, trade, value chain and economy

- Reduction/changes in fish catch
- Loss of fishing days
- Loss/damage to boats/gear
- Damage to coastal infrastructure
- Sea safety issues
- Effects on cost, trade & economic performance
- Compensation payment on losses

Reducing physical risks

- Coastal protection structures
- Temporary rehabilitation centres
- Insurance schemes
- Weather warning
- Post-disaster recovery
- Sea safety measures

Reducing the impacts of climate change on coastal communities

- Improving weather early warning system
- Promoting disaster risk management
- Improving safety-at-sea & shore
- Building capacity
- Raising awareness
- Financing adaptation and mitigation measures

Encouraging Green Fishing

- Following fuel efficiency norms by fishing boats (maintaining optimum speed, selecting fuel-efficient engines without excess horsepower, regular maintenance of vessel, etc)
- Using solar energy and wind energy in fishing boats and processing plants
- Following best fishing practices (reduce use of tow gear, larger mesh size, thinner twines, use of acoustic devices for fish finding)

Other mitigation measures:

Blue carbon (sequestering carbon in coastal vegetation like mangroves, seagrasses, seaweeds) – mass cultivation

Adaptation options

Climatic change element	Impacts on aquaculture	Adaptive measures
Warming	Rise above optimal range of tolerance of farmed species	Use better feeds, more care in handling, selective breeding and genetic improvements for higher temperature tolerance (and other related conditions)
	Increase in growth; higher production	Increase feed input; adjust harvest and market schedules
	Increase in eutrophication and upwelling; mortality of stock in open sea mariculture	Improve planning and siting to conform to CC predictions; establish regular monitoring and emergency procedures
	Increase virulence of dormant pathogens and expansion of new diseases	Focus management to reduce stress; set up biosecurity measures; monitor to reduce health risks; improve treatments, management strategies; make genetic improvements for higher resistance

Adaptation options

Climatic change element	Impacts on aquaculture	Adaptive measures
Warming	Limitations on fish meal and fish oil supplies/price	Identify fish meal and fish oil replacement; develop new forms of feed management, make genetic improvement for alternative feeds
	Increase of harmful algal blooms (HABs) in open sea farms	Improve monitoring and early warning systems
Storms and cyclones	Destruction of facilities; loss of stock; loss of business; mass scale escape with the potential to impact on biodiversity	Encourage uptake of individual/ cluster insurance; improve siting and design to minimize damage, loss and mass escapes; encourage use of indigenous species to minimize impacts on biodiversity, use non-reproducing stock in farming systems

Mitigation

- Relatively small global contributor, capture fisheries have a responsibility to limit GHG emissions as much as possible.

- **Eliminating inefficient fleet structures** (e.g. excessive capacity, over-fishing), improving fisheries management, **reducing post-harvest losses** and increasing waste recycling **will decrease the sectors' CO_2 emissions** and improve the aquatic ecosystems' ability to respond to external shocks.

- Other technical solutions to reduce fuel use might include **shifting towards static fishing** technologies and to more efficient vessels and gears.

- In some cases, **win-win** conditions could be identified, where reduced fuel-use strategies would link with reducing fishing effort, improving returns to vessels, safeguarding stocks and improving their resilience to climate change (FAO, 2008).

Mitigation options

Reduce fossil fuel consumption by fishing boat.

Mangrove protection & conservation to reduce sea erosion.

Energy efficient mechanism for propelling fishing boats.

Reduce fishing ground/area searching time by finding potential fishing zones.

As far as possible use of wind energy by having sail boats with appropriate engine facility.

Better preservation of fish to prevent spoilage by using ice and insulated boxes at sea.

Better marketing and cold chain facilities in up country places.

CMFRI developed various innovative climate resilient technologies

Farming of stress tolerant species (Silver pompano, Pearl spot) in ponds and small cages.

Low cost farming techniques (All weather mooring system for cages).

IMTA-Integrated Multi-Trophic Aquaculture (Seaweed, Cobia & Mussel).

Monoline seaweed culture method for better yield and profits.

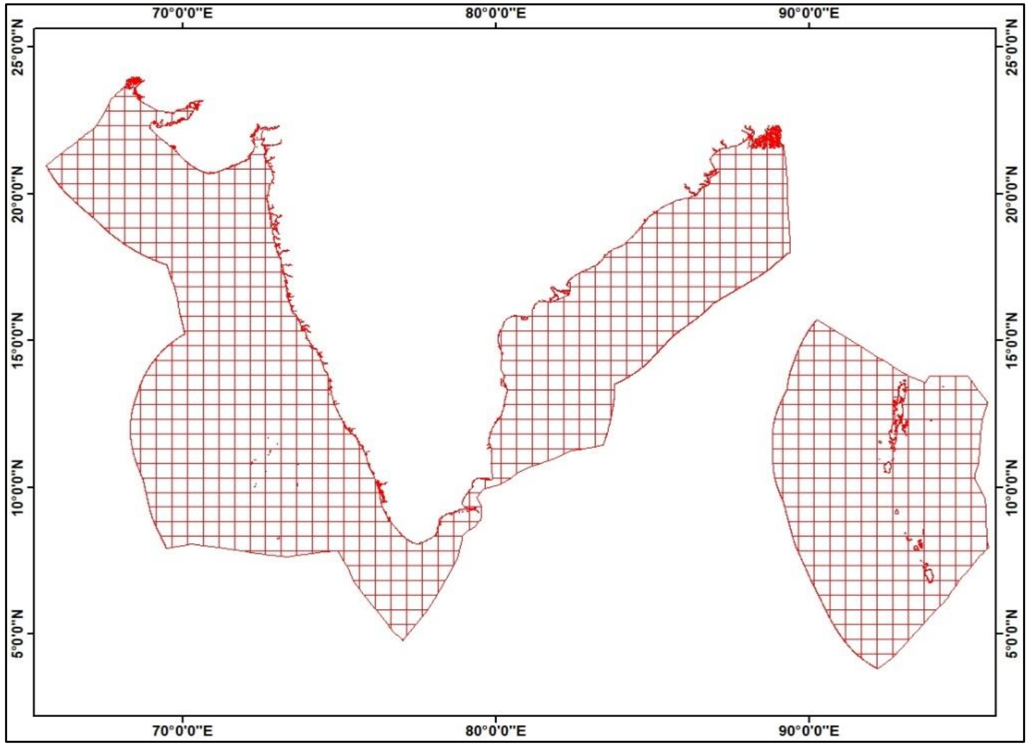
Technology development initiated for mariculture of Kappaphycus alvarezii using vegetative propagation to yield higher harvest and the technology has been attempted.

Paddy-Finfish farming in Pokkali fields.

Species distribution mapping for understanding the climate change related species shift in selected species

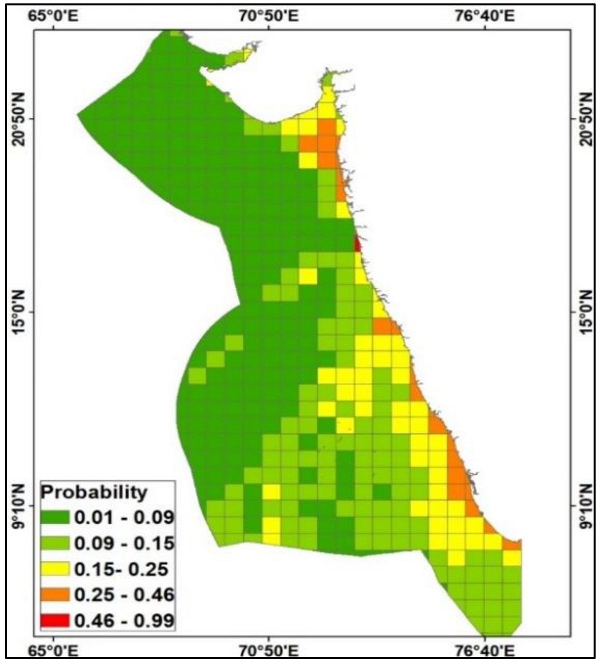
Resource: Anchovies

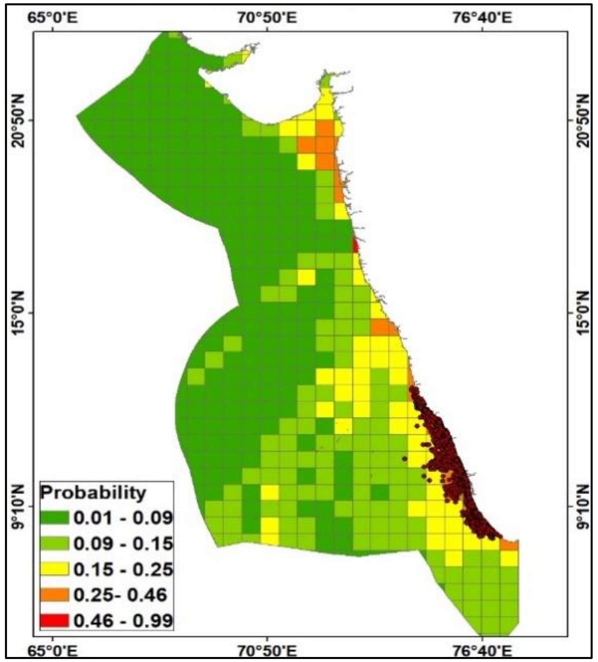
Species Distribution Models and Projections



0.5° x 0.5° grids generated for Indian EEZ

Total 951 grids





Preliminary studies on the species distribution and species shift initiated.
Collection of historic data from exploratory surveys before 1990s done was done
Decadal comparison of one major resource distribution done

Significant Climatic Variables in SDM: profile temp, CHL, SSS and DO

Carbon sequestration through seaweed cultivation

- Studies were conducted on the carbon sequestration potential of the seaweed Kappaphycus alvarezii.
- Specific rate of sequestration of CO_2 by the seaweed was estimated at 0.0187g/day

Integrated Multi-Trophic Aquaculture (IMTA)

- **Seaweed was farmed concurrently with cobia** in cages
- The demonstration yielded nearly double the amount that would be obtained from a similarly sized system used purely to cultivate seaweed.

Low cost cage construction

- Cages were developed using locally available materials like GI pipe and floated on fibre barrels.
- The low cost cage developed by CMFRI was demonstrated by making twelve low cost cages.
- This technology makes cage culture affordable to the common fishermen.
- The no of cages have increased from 12 to 700 now with the production expected to increase to 4 lakh tonnes from cage farming.

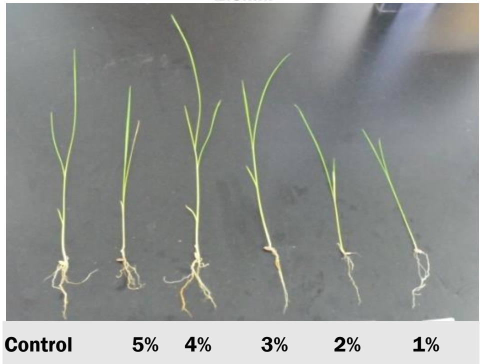
Climate Resilient Products from Seaweeds & Water Hyacinth

Enhancement of paddy, fish growth & Water Quality improvement was observed by Biochar Supplementation

Hydrolysate of Gracillaria, **Water hyacinth,** *Sargassum*

1.5mm

Biochar Based Feed



Paddy growth enhancement in biochar amended system

Enzyme

Seaweed & Water hyacinth were subjected to Solid State Fermentation using *Aspergillus brasiliensis* and *Phanerochaete chrysosporium* and enzyme harvested on 9th Day.

Biofuel

Seaweeds were subjected to pretreatment, hydrolysis and fermentation and crude bioethanol was detected.

Biochar

Produced from water hyacinth at 300^{O}C, 30 minutes in muffle furnace. Biochar produced from water hyacinth was tested as feed mixture and soil mixture.

Fish Feed

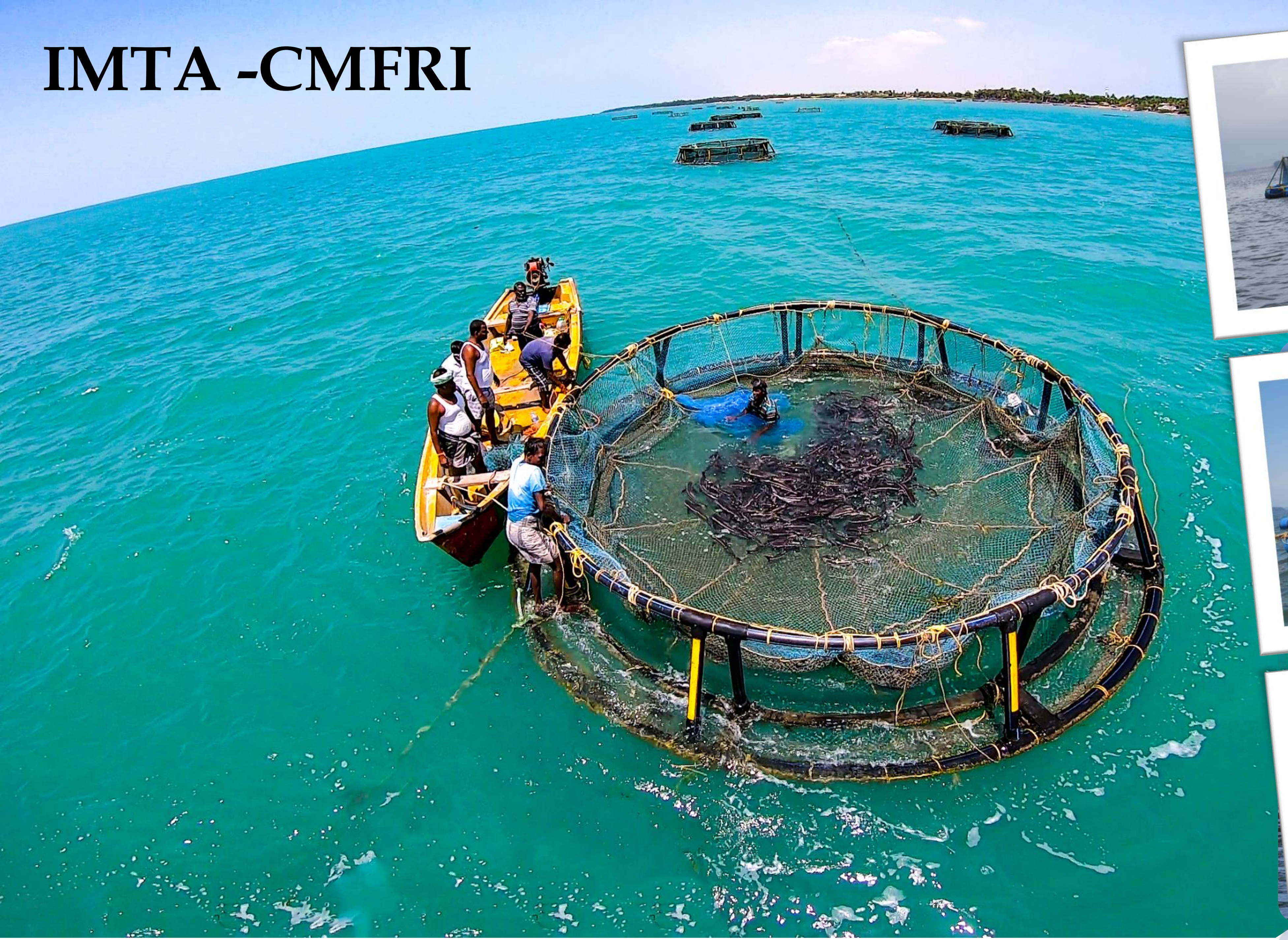
Formulation of Gift Tilapia feed were done with supplementation of 1 % Biochar and fish growth were observed.

- The pokkali paddy growth was found to be enhanced the most at 4% biochar addition
- The length and weight of fish (Tilapia) was found to increase at 1% biochar supplementation.
- Water Quality of the biochar amended (1%) system was found to be improved

Farming of sea weeds (Blue carbon initiative)

- Seaweeds could be feedstocks for biofuel production and thereby reduces the dependency on fossil fuel consumption.
- C sequestration ability of seaweed makes its large scale farming an option to combat ocean acidification.
- Bulk level conversion of seaweed residues into biochar which provides Carbon sequestration benefits along with agricultural applications.
- Manpower needed for the seaweed farming and processing can be met considerably from fishermen communities that are vulnerable to climate changes and thereby can enhance their livelihoods. Seaweed farming can be considered as a supplementary income source of livelihoods.

IMTA -CMFRI



India's carbon dioxide footprint from marine fisheries

ICAR-Central Marine Fisheries Research Institute (CMFRI) has estimated that the sector emits 1.32 tonne of CO_2 (carbon dioxide) to produce one tonne of fish, much lower than the global figure of more than 2t of carbon emission per tonne of fish.

Harvest phase (active fishing) in the country used more than 90% of the fuel used in the sector with annual CO_2 emissions from this phase being 4,934 million kg. "The country's carbon emission in marine fisheries at the national level is 16.3% lower than the global level"

Thank You