Marine Fishery Development and Climate Change

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Marine Fishery development

- Marine fisheries have very important roles for food supply, food security and income generation in India.
- About one million people work directly in this sector, producing 3.1 million tonnes annually.
- The value of the marine fish landings have been estimated at Rs. 36,964 crores in 2010 and India has earned a foreign exchange of Rs. 10,000 crores through the export of 6 lakh tonnes of sea food products.
- The fisheries sector, presently contributes around one percent to the GDP and 4.72 percent to Agricultural GDP of our country (Sathiadhas *et al*., 2012).

Table1: Profile of marine fisheries in India (source: CMFRI, 2010)

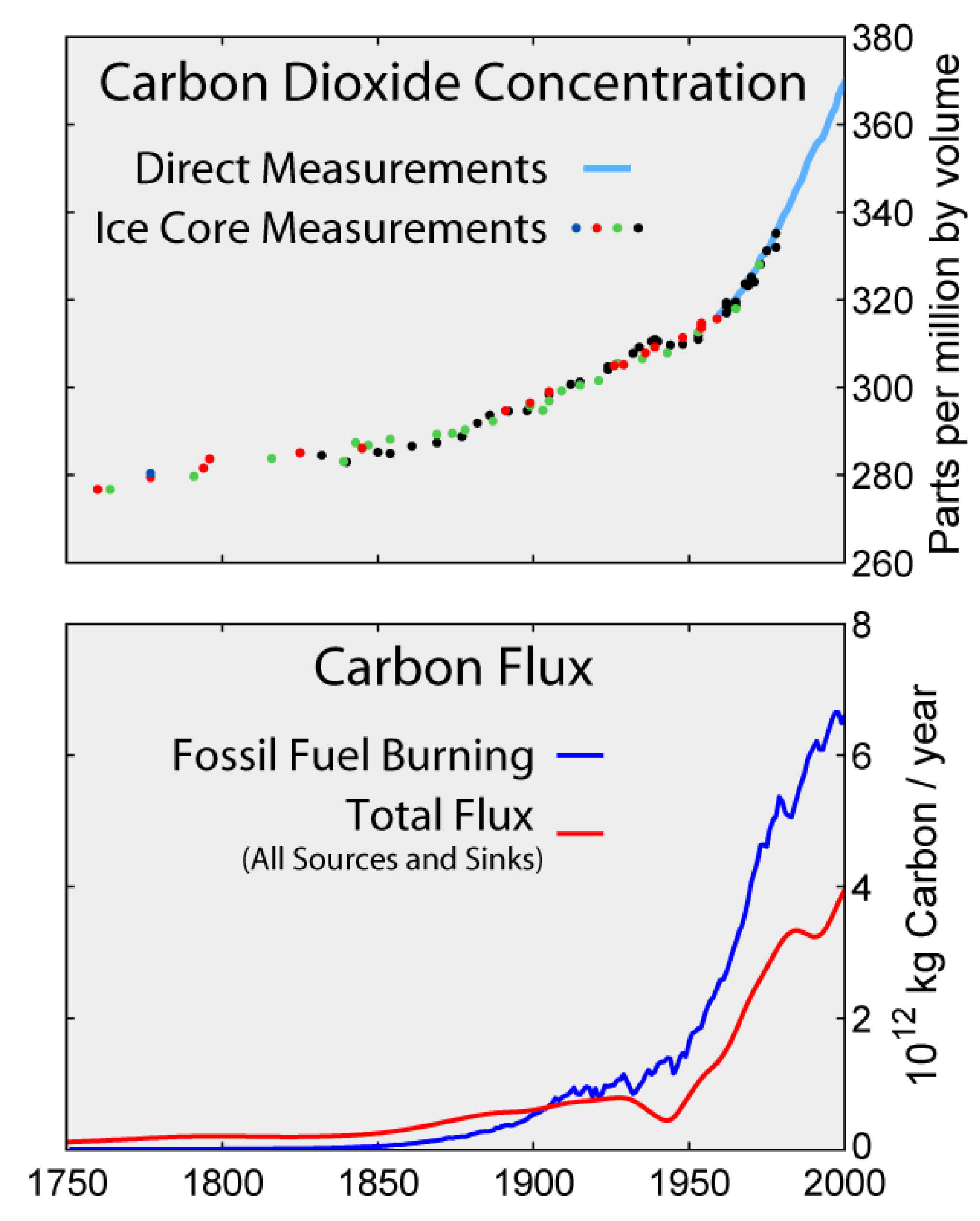
Component	Profile
Physical Component	
Coastline length (km)	8129
Exclusive Economic Zone (million km^2)	2.02
Continental shelf area (million km^2)	0.50
Area within 50m depth (million km^2)	0.18
Human Component	
Marine fisher population (million)	4.0
Active fisher population (million)	1.5
Infrastructure Component	
Landing centres	1511
Mechanized vessels	72559
Motorized vessels	71313
Non-motorized vessels	50618
Fish Catches	
Annual landings (2010) (million t)	3.07
Potential yield (million t)	3.92

Climate Change

- Concerns on global warming have been with us now for more than a decade. The global warming that is widely expected to occur over this century will not be confined to the atmosphere; the oceans would also get warmer.
- Over the next 50 years, sea surface temperature in the Indian seas is expected to rise by 1 to 3. The oceans are predicted to acidify, become more saline, and the sea level will rise, and currents may change. It has been recognised that it will have consequences, both benign and disadvantageous, on fisheries.
- The effects of environmental change on fisheries are likely, therefore, to be severe. Such changes are likely to affect fish migrations and habitat, augmenting fish stocks in some places and decreasing them in others, perhaps causing stocks to be displaced permanently to new habitats.

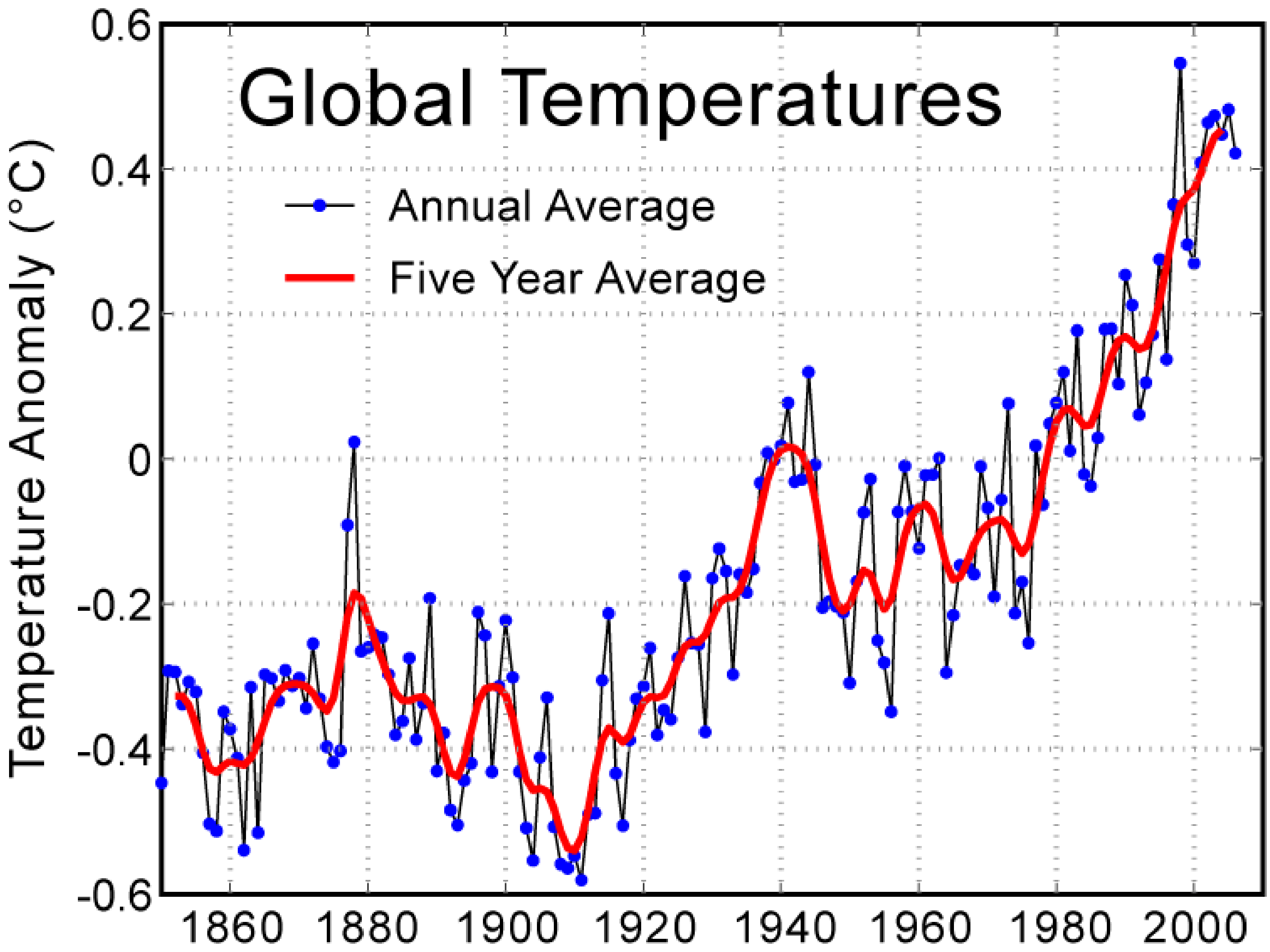
Causal factor for climate change

- CO_2 emission in the atmosphere has increased from 275 ppm in 1750 to 383 ppm in 2005.
- At the present trend, it may reach 450 ppm by 2030.
- Co_2 concentration of 550 ppm may be irreversible, and is threshold for several life processes.



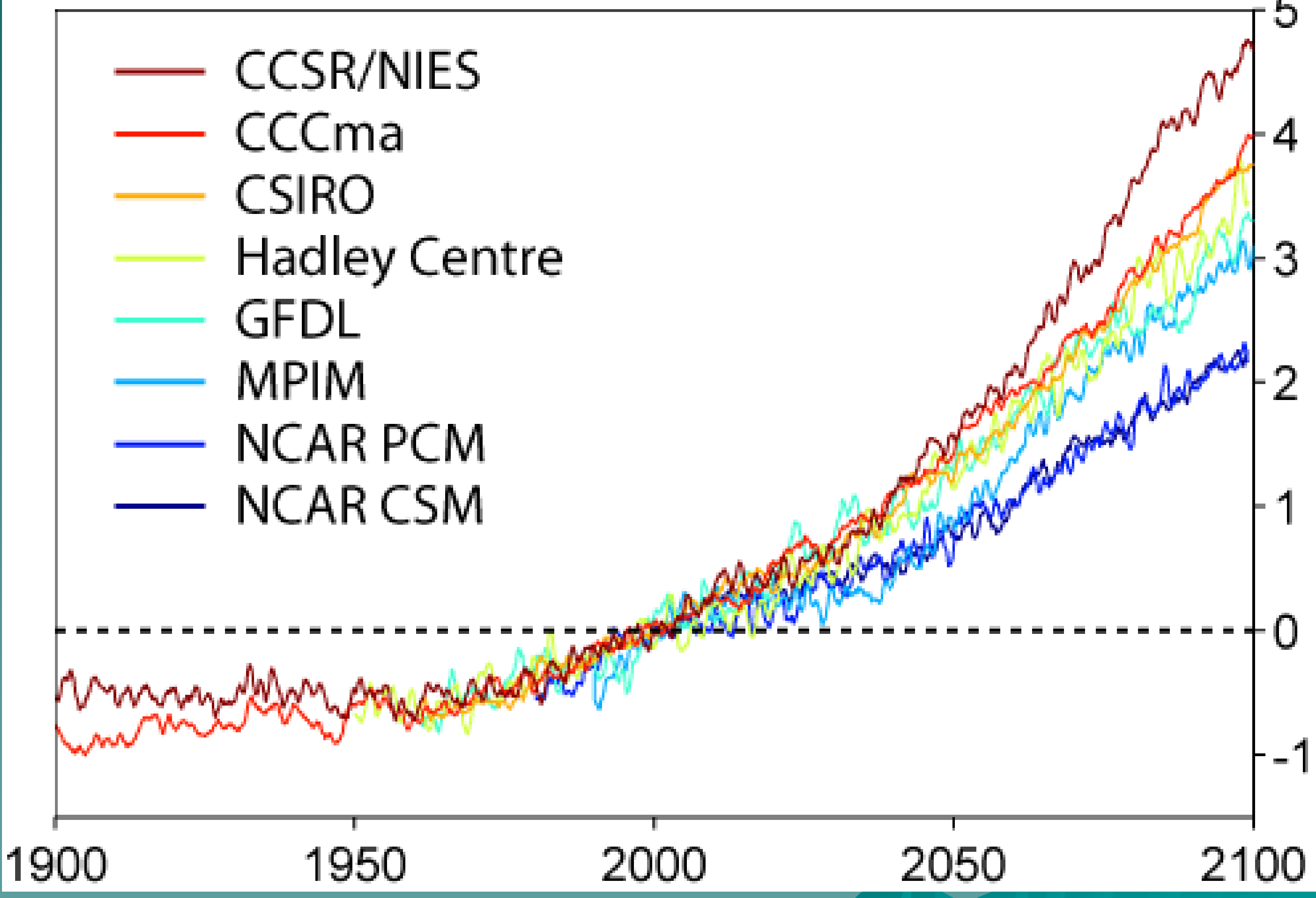
Climate Change in the Oceans: *Rise in Sea Temperature*

- The global average air temperature rose 0.74°C during the 100 year period ending in 2005.
- If the trend continues, the atmospheric temperature will increase by 2.2 to 4.8º C by 2100.
- Seawater mean temperature increased 0.06º C in the last 50 years.
- Increase is not even: upper 300 m of the oceans increased by 0.31º C.
- The mean sea surface temperature in the Indian Seas warmed by 0.2º C in the last 45 years.

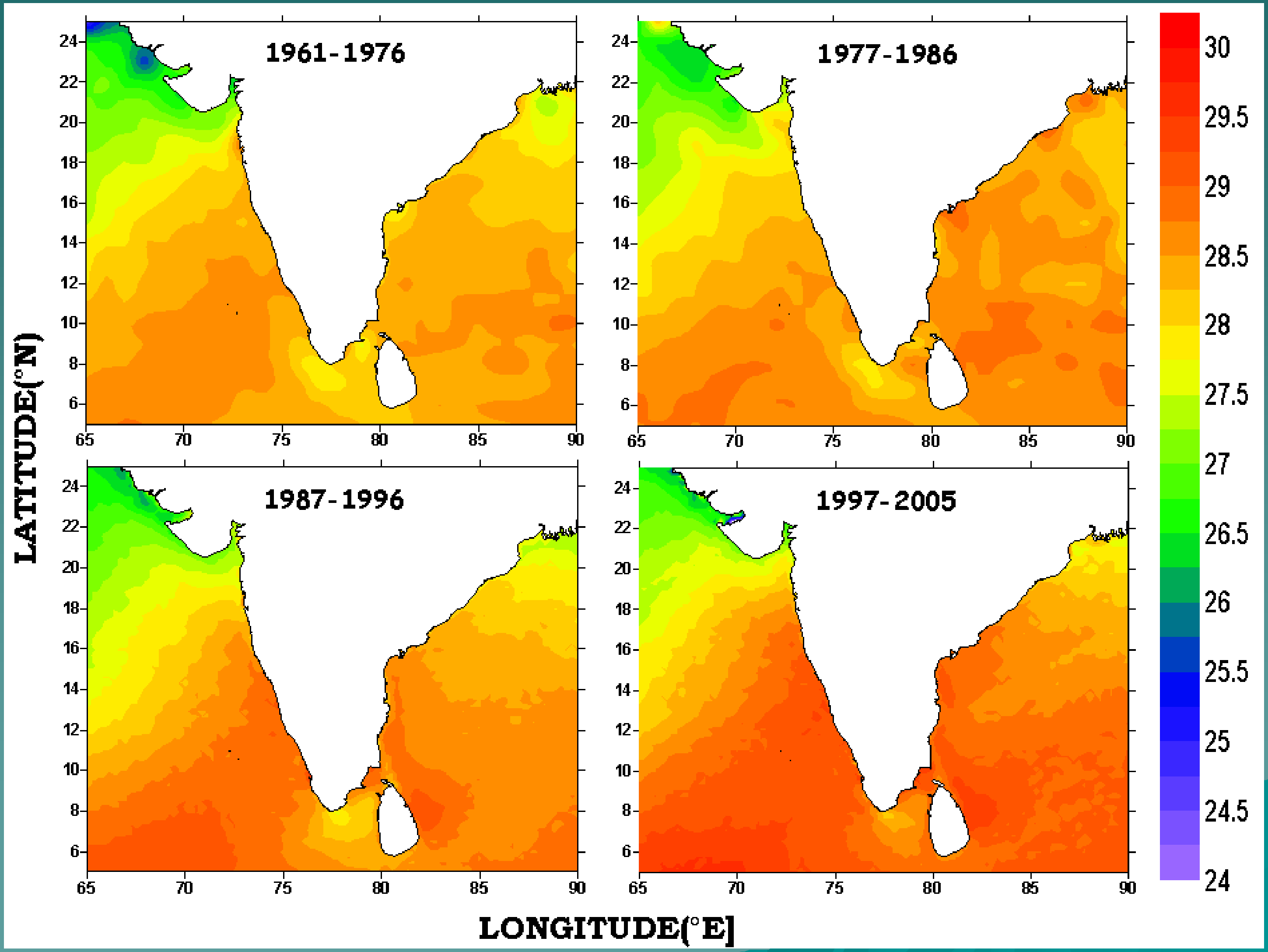


Global Temperatures
Annual Average
Five Year Average
Temperature Anomaly (°C)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
1860
1880
1900
1920
1940
1960
1980
2000

Global Warming Projections



Rise in Sea Surface Temperature in the Indian Seas



Climate Change in the Oceans: *Rise in Acidity*

- When CO_2 enters the oceans, it reacts with seawater to form carbonic acid, producing hydrogen ions, which cause the acidity of the seawater to increase.
- In the last 250 years, the concentration of H+ ions in seawater has increased by 30%, equating to a fall in pH by 0.1 unit.
- Continued rises in the concentration of atmospheric CO2 will lead to a global surface water pH reduction of up to 0.4 units by 2100.

Climate Change in the Oceans: *Rise in Sea Level*

- Sea level will increase due to seawater warming, which causes thermal expansion of ocean water (responsible for 70% of the increase); and melting of glaciers and ice sheets of polar regions (30% of the increase)
- Sea level is expected to rise by 9 to 30 cm by 2050 and by 30 to 90 cm by 2100.
- A 25 cm rise would displace large number of people from the Ganges delta, and drown Maldives.

Coral Bleaching

- **Coral bleaching results when the symbiotic zooxanthellae (single-celled algae) are expelled from the host coral organisms due to stress; may lead to mortality of corals depending upon the intensity of bleaching**

Degree Heating Week

- Degree Heating Weeks (DHWs) indicate the accumulation of thermal stress that coral reefs have experienced over the past 12 weeks. One DHW is equivalent to one week of sea surface temperatures one degree Celsius greater than the expected summertime maximum. Two DHWs are equivalent to two weeks at one degree above the expected summertime maximum OR one week of two degrees above the expected summertime maximum.

Satellite bleaching alerts

- There are five status levels: No Stress, Bleaching Watch, Bleaching Warning, Bleaching Alert Level 1, and Bleaching Alert Level 2. These levels are defined in terms of the CRW **HotSpot** and **Degree Heating Weeks (DHW)** products:

No Stress	HotSpot ≤ 0
Bleaching Watch	0 < HotSpot < 1
Bleaching Warning	1 ≤ HotSpot and 0 < DHW < 4
Bleaching Alert Level 1	1 ≤ HotSpot and 4 ≤ DHW < 8
Bleaching Alert Level 2	1 ≤ HotSpot and DHW ≥ 8

Temperature stress and bleaching

El Nino event
Green house gases

Causes of Coral Bleaching

Factors	Mechanism	Effects
Acidification	Lowering of pH and carbonate ion concentration	Calcification rates reduce
Temperature	Sea surface temperature increase due to greenhouse effect	Coral bleaching
Sea level	Rise in sea level because of warming	Coastal flooding, input of sediments
Storm	Increase in storm frequency & intensity	Species decline or shift
Dust	Iron dust enhances phytoplankton and macroalgal growth; transport of pathogens	Light penetration decrease, macroalgae compete with corals for space

Projected demise of coral reefs in the Indian Seas

Region	Decline starts	Remnant
Andaman	2030-2040	2050-2060
Nicobar	2020-2030	2050-2060
Lakshadweep	2020-2030	2030-2040
Gulf of Mannar	2030-2040	2050-2060
Gulf of Kachchh	2030- 2040	2060-2070

Research Projects at CMFRI in relation to climate change

Projects completed

- Impact, adaptation and vulnerability of Indian marine fisheries to climate change – ICAR Network Project

  (2007-2012).

- Carbon sequestration potential of Indian seaweeds – In-house research Project

  (April 2010 to March 2012).

On-going Project

- **National Initiative on climate resilient agriculture (NICRA) (April 2011 onwards & continuing)**

The main focal areas in this project include:

- Studies on the trends in marine capture fisheries, changes in biology and distribution pattern of fishes in relation to changing climate.

- Studies on climate resilient species suitable for mariculture as a step towards adaptive measures.

- Technology demonstration for the benefit of coastal communities in order to harness the benefits of climate change

Institutions involved:

Since the NICRA project is a national initiative of ICAR, many agriculture, animal science and fishery Institutes of ICAR are involved.

Fisheries and Climate

1. Climate affects fisheries
2. Climate affects biodiversity
3. Fisheries affect biodiversity

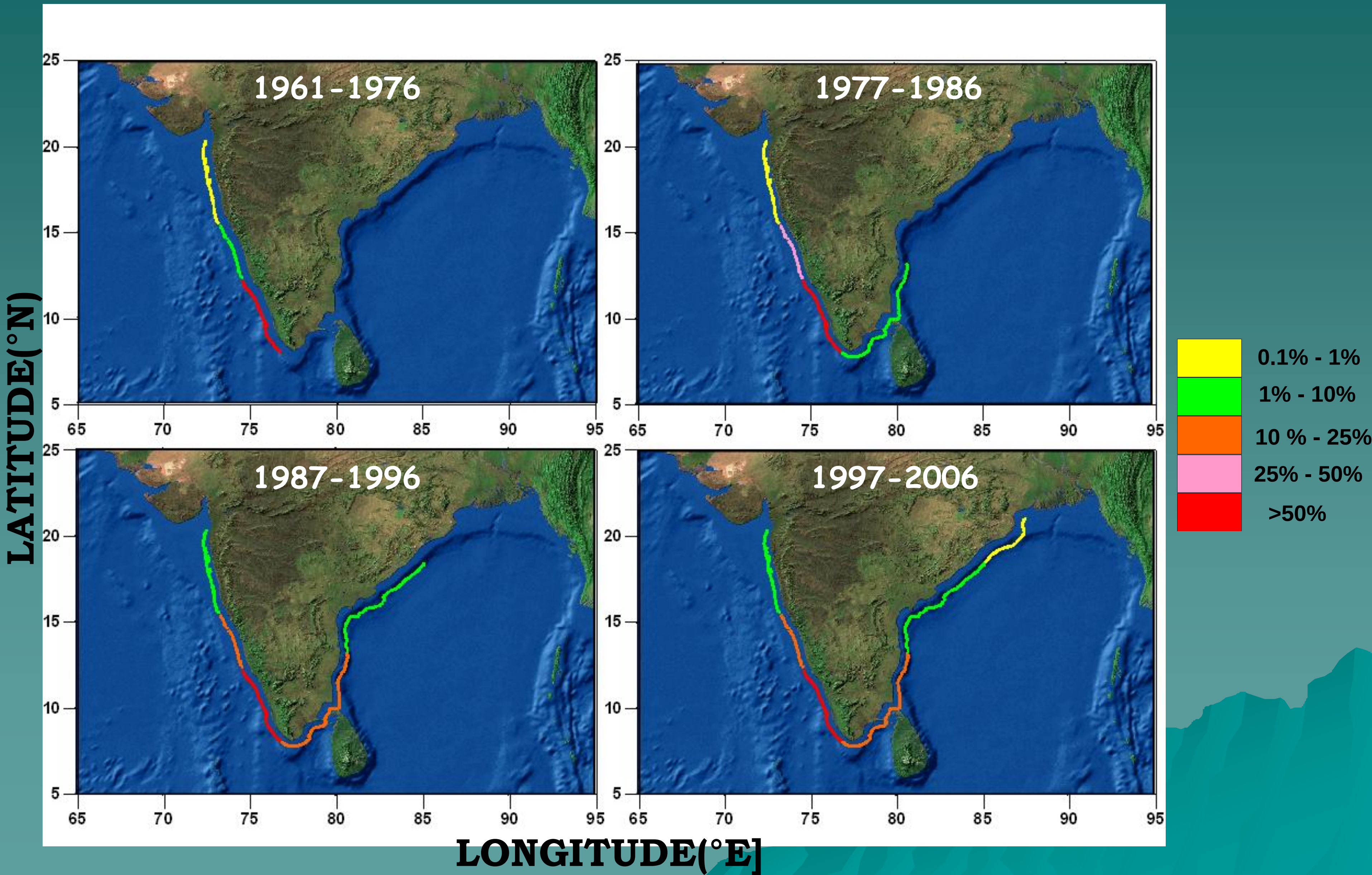
- *Fishing has a bigger effect on biodiversity than does climate change*
- *Our time series of changes in fish populations mainly come from fisheries*

Changes in Distribution and Phenology

- *Category 1: Shift in latitudinal distribution*
- *Category 2: Extension of distributional boundary*
- *Category 3: No shift/extension of boundary, but change in biomass*
- *Category 4: Shift in depth of occurrence*
- *Category 5: Spatial shift in spawning*
- *Category 6: Temporal shift in spawning*

Extension of northern boundary of oil sardine

(the colored lines indicate percentage of All India oil sardine production)



Distributional Changes

- With warming of the sea, the fish is able to find temperature to its preference in the northern latitudes and eastern longitudes, thereby extending the distributional boundaries and establishing fisheries in larger coastal areas.
- It is expected that the abundance may increase along Gujarat and West Bengal coasts in the coming years assuming further increase in sea temperature.
- These distributional shifts are expected to result in drastic changes in species mix and ecosystem structures and functions.
- Will this trend pave the way for species replacement?

Shift/extension of depth of occurrence

The Indian mackerel, *Rastrelliger kanagurta*, the second important resource contributing 7.9% of total landings for 2010 in addition to extension of its northern boundary, is found to descend to deeper waters in the last two decades. The fish normally occupies surface and subsurface waters. During 1985-1989, only 2% of mackerel catch was from bottom trawlers, and the rest of the catch was contributed by pelagic gear such as drift gillnet. During 2003-2010, it is estimated that 15% of mackerel catch is contributed by bottom trawlers along the Indian coast. The Indian trawlers operate at a depth ranging from 20m to 80m by employing high opening trawlers. In the last 25 years, the specifications of trawlnet such as mouth opening, headrope length, otterboard and mesh size have not been modified, and hence the increase in the contribution of trawlers to the mackerel catch is not gear-related. As the surface waters are also warming up, it appears that the mackerel, being a tropical fish, has extended its veridical boundary to deeper waters.

Phenological changes

- The phenology of species, *i. e.*, the sequence and timing of events – growth, maturation, reproduction – in their life cycle, is affected.
- The peak spawning season of threadfin breams off Chennai is found to shift from warmer months of April & May towards relatively cooler months of January & February
- The shift in the timings of maturation and reproduction may cause mismatches between the production of planktonic propagules in one part, and the usual patterns of coastal circulation or the availability of appropriate food items in the other.

Phenological changes

- The threadfin breams *Nemipterus japonicas* and *N.mesoprion* are distributed along the entire Indian coast at depths ranging from 10 to 100 m. They are short-lived (longevity: about 3 years), fast growing, highly fecund (annual egg production around 0.2 million per adult female) and medium-sized fishes (maximum length: 35 cm). Data on the number of female spawners collected every month off Chennai (south-east coast of India) from 1981 to 2010 indicated wide monthly fluctuations. However, a trend in the shifting of spawning season from warmer (April-September) to cooler months (October-March) was discernible. Whereas 35.3% of the spawners of *N.japonicus* occurred during warm months, the number of spawners gradually reduced and only 5.0% of the spawners occurred during the same season. A similar trend was observed in *N.mesoprion too*. The present occurrence of spawners of the two species linearly decreased with increasing temperature during April-September, but increased with increasing temperature during October-March over the time scale.

Options for fisheries and aquaculture sector for adaptation

Tackling overfishing

- Options for adaptation are limited, but they do exist. The impact of climate change depends on the magnitude of change, and on the sensitivity of particular species or ecosystems (Brander 2008).
- Fish populations are facing the familiar problems of overfishing, pollution and habitat degradation.
- Food and Agriculture Organization has estimated that about 25% of all fish stocks are overexploited and 50% are fully exploited (FAO 2007).
- Reduction of fishing effort will benefit in relation to adaptation of fish stocks and marine ecosystems to climate impacts; and mitigation by reducing greenhouse gas emissions. Hence, some of the most effective actions which we can be taken to tackle climate impacts are to deal with the old familiar problems such as overfishing (Brander 2008) and adapt Code of Conduct for Responsible Fisheries (FAO 2007).

Cultivation of sea plants

- Sea plants are excellent carbon sequestration agents and many of them sequester at a rate better than their terrestrial counterparts (Zon 2005).
- CO_2 sequestration by the common sea plants such as the red algae *Gracilaria corticata* and *G.edulis*, brown alga *Sargassum polycystum* and the green alga *Ulva lactuca* has been qualified in laboratory studies in India by Kaladharan *et al.* (2008).
- The seaweed *Kappaphycus alvarezii* has been collected and experiments are in progress. Initial results suggest that the seaweed has good carbon sequestration potential (CMFRI, 2010).

Studied the carbon fixing efficiency of two macrophytes – Red alga *Kappaphycus alvarezii* and brown alga *Padina* sp.

Stock of *Kappaphycus alvarezii*

Padina sp.

CO2 utilization by *Kappaphycus*

- In *K. alvarezii*, when the CO_2 levels in the medium was increased from 10 to 50 ppm, the utilization gradually increased to 32 ppm.
- With further increase in concentration (very high levels), the utilization was 90 ppm at a level of 185 ppm of CO2 in the medium.
- Thus, Kappaphycus is able to increase the utilization of CO2 upto a level of 185 ppm CO2 in the medium.

CO2 utilization by Padina

- The CO_2 utilization increased with increasing concentration and the utilization was 100% at 2, 10, 20, 30, 40 & 50 ppm CO_2 levels in the medium.

- At very high concentration of 230 and 370ppm, the utilization remained stable at 140ppm; indicating that no increase in utilization would be possible with further increase of CO_2 in the medium.

- Thus, Padina is able to increase utilization of CO_2 upto 230 ppm CO_2 level in the medium.

- Studies indicate that seaweeds are excellent source for fixing high levels of CO_2.
- The current CO_2 concentration in the atmosphere is 373 ppm. Experiments have been conducted with this value as the maximum reference point.
- Kappaphycus is able to increase utilization of CO_2 upto 185 ppm concentration and Padina upto 230 ppm concentration.
- However, the CO_2 utilization efficiency is maximum at a low concentration of 50 ppm and decreases beyond this concentration.
- The highest gross and net production of these two species were also at a low concentration of 20 ppm.

- Padina appears to be a better carbon sequestrating plant compared to Kappaphycus.
- This preliminary study has provided important clues on the carbon sequestration potential of seaweeds.
- These data will be useful for future research on estimating CO_2 potential of Indian seaweeds.
- Direct *in situ* measurements on CO_2 utilization - if made in Kappaphycus farms in Mandapam area -will be useful to validate the results.

Cultivation of halophytes

- In coastal areas and mudflats near the sea, where the salinity does not allow farming of the usual food crops, plants that grow and flourish those conditions are advocated.

- One such plant is the sea asparagus, *Salicornia.* The plant grows well with maximum yields in hot climates if the seeds are sown in cool season so as to reach maturity during the hot months

Concerns & Adaptive mechanisms

Uncertainties in fish availability and supply

- Adapt Code of Conduct for Responsible Fisheries
- Develop knowledge-base for climate change impact of fisheries and aquaculture
- Predict medium and long term probabilistic production
- Assess the adaptation capacity, resilience and vulnerability of marine production systems
- Adjust fishing fleet and infrastructure capacity

New challenges for risk assessment

- Consider increasing frequency of extreme weather events
- Consider past management practices to evolve robust adaptation systems
- Identify and address the vulnerability of specific communities; consider gender and equity issues.

Complexities of climate change interactions into governance of frameworks to meet food security objectives

- Recognition of climate-related processes, and their interaction with others

- Action plans at national/regional level based on (a) Code of Conduct for Responsible Fisheries; (b) Integrated ecosystem-based fisheries and aquaculture management plans (c) framework for expansion of aquaculture (d) linkage among cross-sectoral policy framework such as insurance, agriculture, rural development and trade

Fisheries and aquaculture may be more vulnerable in conflicts with other sectors

- Action plans should involve not only fisheries institutions/departments, but also those for national development planning and finance
- Sharing and exchange of information with other sectors
- Existing management plans for fisheries need to be reviewed by considering climate change

Financing climate change adaptation and mitigation measures

- Fishermen, fish farmers, processors, traders and exporters should increase self protection through financial mechanisms
- Improving equity and economic access such as microcredit should be linked to adaptation responses
- Investment of infrastructure such as construction of fishing harbor, should consider climate change
- Financial allocation in national budget for risk reduction and prevention practices such as early warning systems and disaster recovery programmes and for relocation of villages from low lying area
- Fiscal incentive for reducing the sector's carbon footprint and other mitigation and adaptation options
- Full potential of existing financial mechanisms has to adapt and mitigate the issue of climate change.

Conclusion

In the context of climate change, the primary challenge to the fisheries and aquaculture sector will be to ensure food supply, enhance nutritional security, and improve livelihood and economic output, and ecosystem safety. These objectives call for identifying and addressing the concerns arising out of climate change; evolve adaptive mechanisms and implement action across all stakeholders at national, regional and international levels. In response to shifting fish population and species, the fishing sector may have to respond with the right types of craft and gear combinations, on-board processing equipments etc. Governments should consider establishing Weather Watch Groups and decision support systems on a regional basis. Allocating research funds to analyze the impacts and establishing institutional mechanisms to enable the sector are also important. The relevance of active regional and international participation and collaboration to exchange information and ideas is being felt now as never before.

THANK YOU