Impact of Climate Change on Marine Biodiversity

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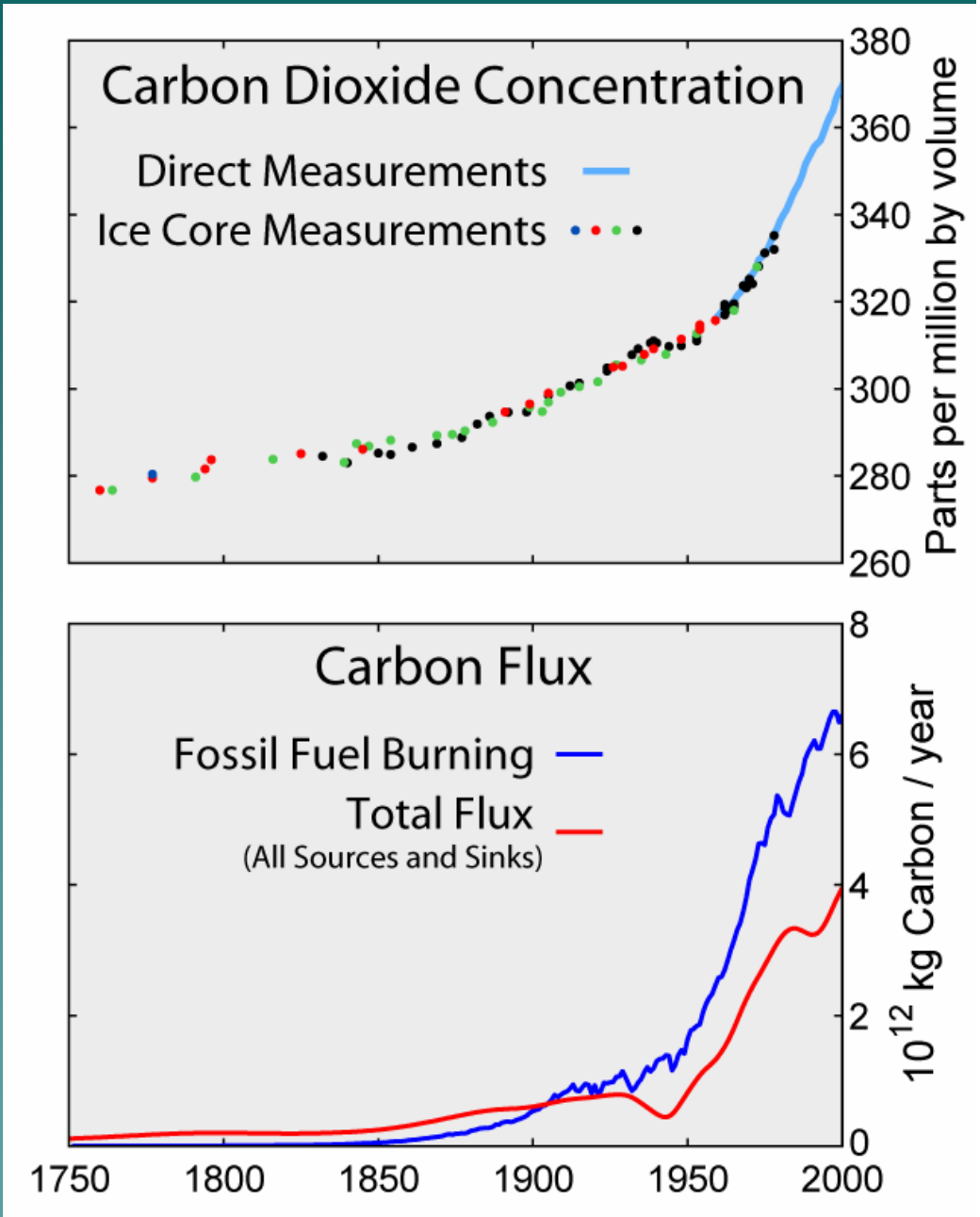
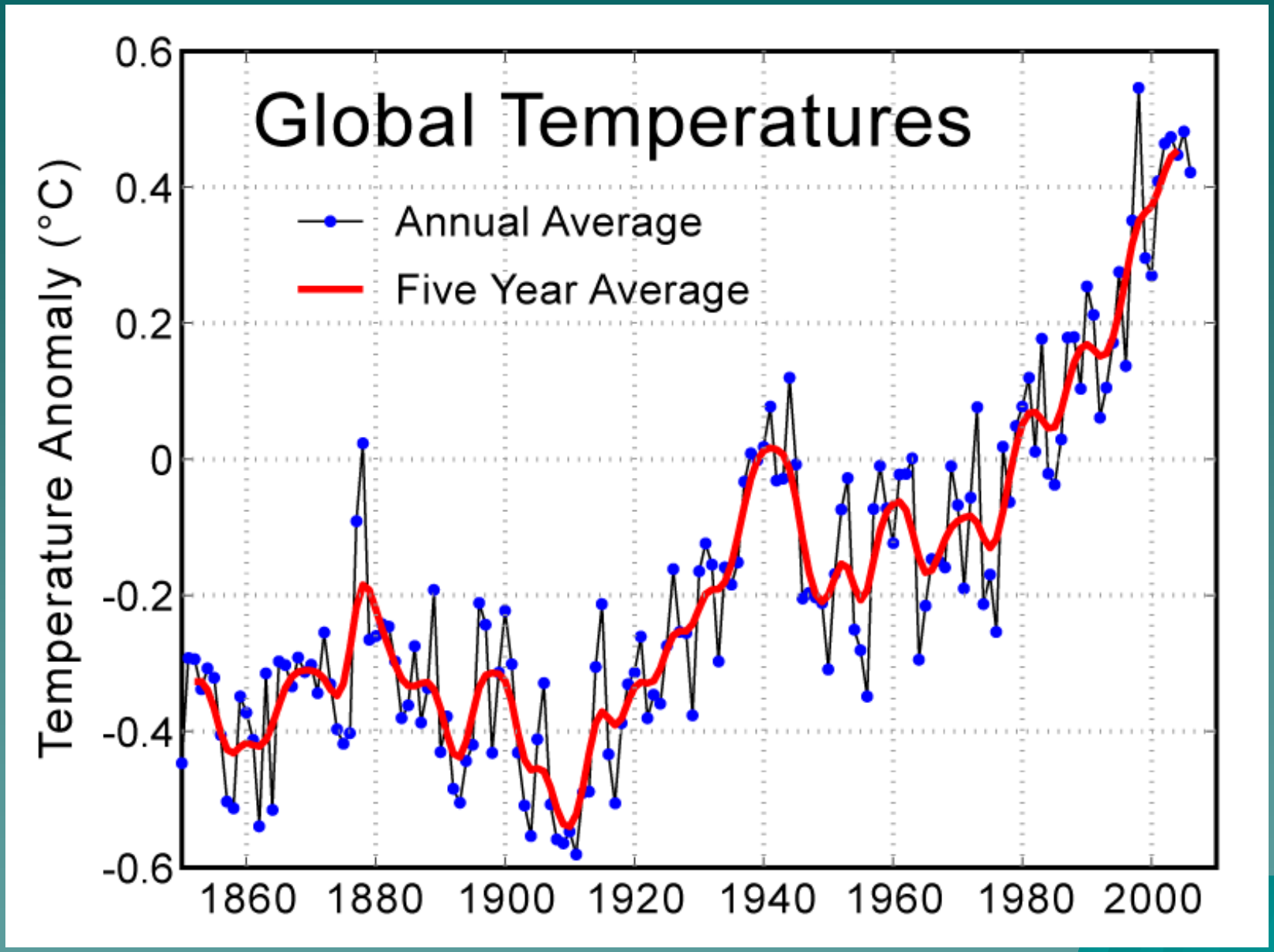
Causal factor for climate change

- 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.

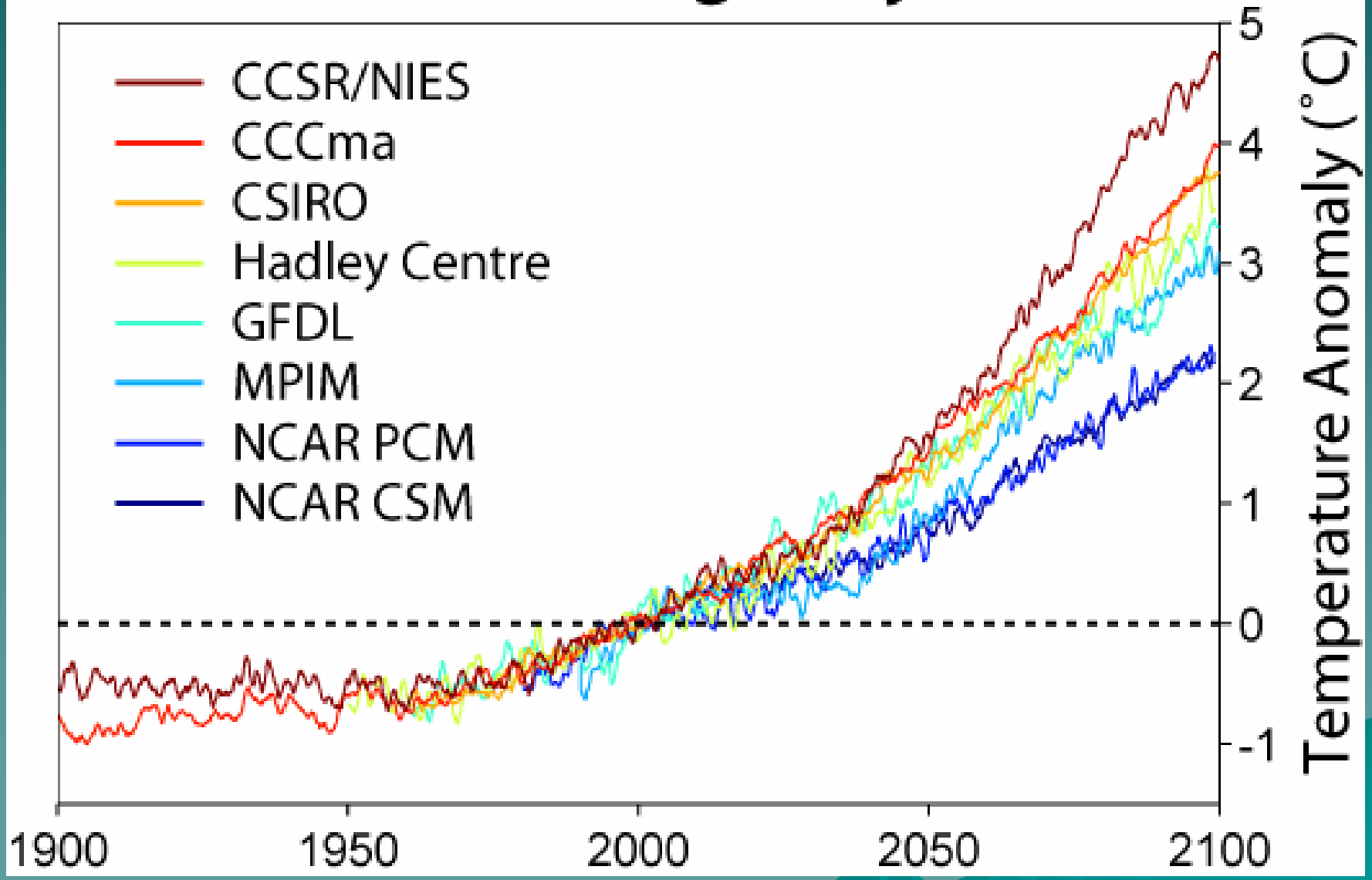


Climate Change in the Oceans: *Rise in Sea Temperature*

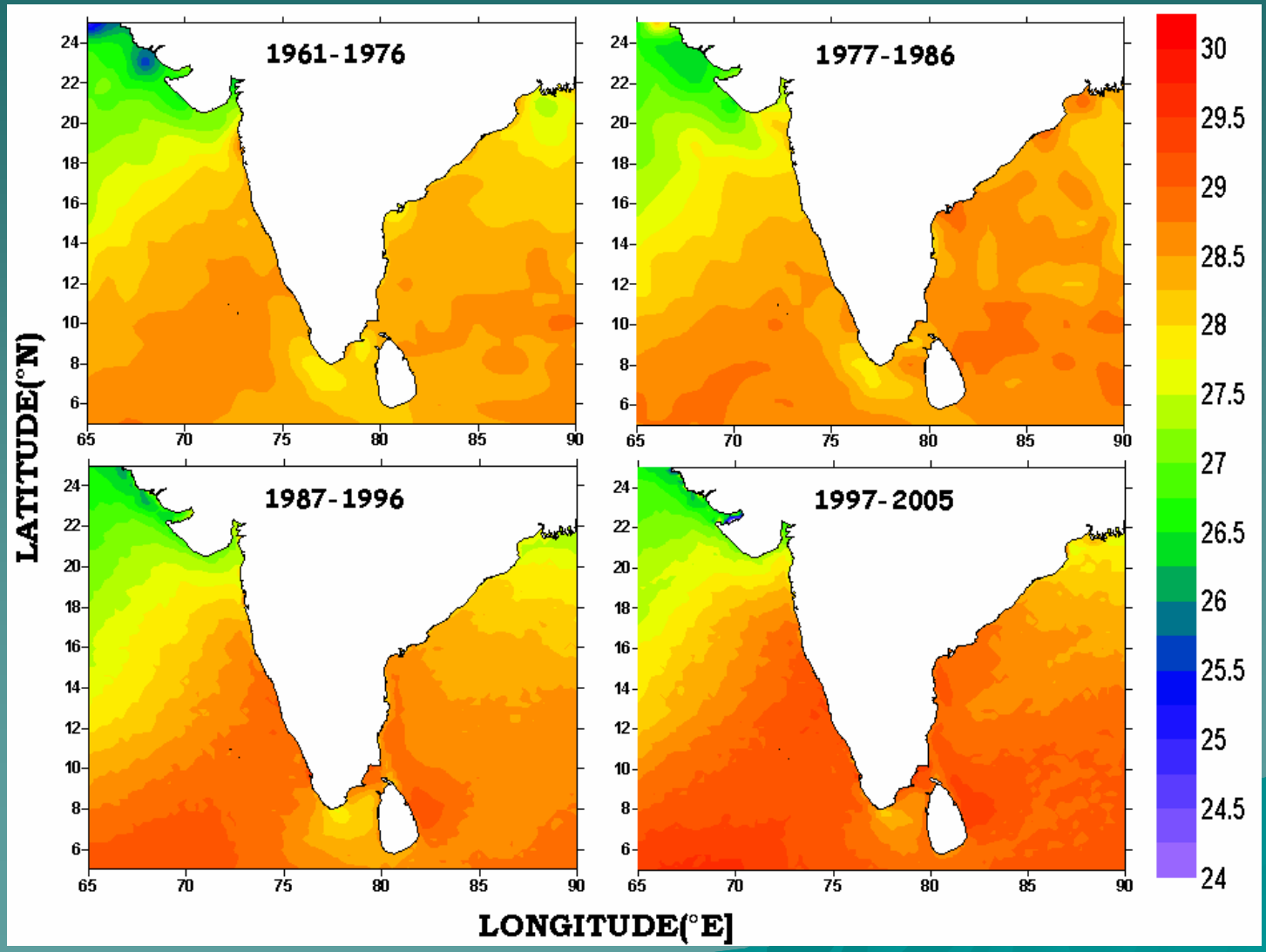
- The global average air temperature rose 0.74°C during the 100 year period ending in 2005.
- If the trend continues, the atmospheric temperature will increase by 2.2 to 4.8^{o} C by 2100.
- Seawater mean temperature increased 0.06^{o} C in the last 50 years.
- Increase is not even: upper 300 m of the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

Effects of climate on biodiversity

What do we mean by loss of biodiversity?

- species extinction
- stock extinction
- change in (relative) abundance
- changes in distribution

These changes may sound trivial, but…

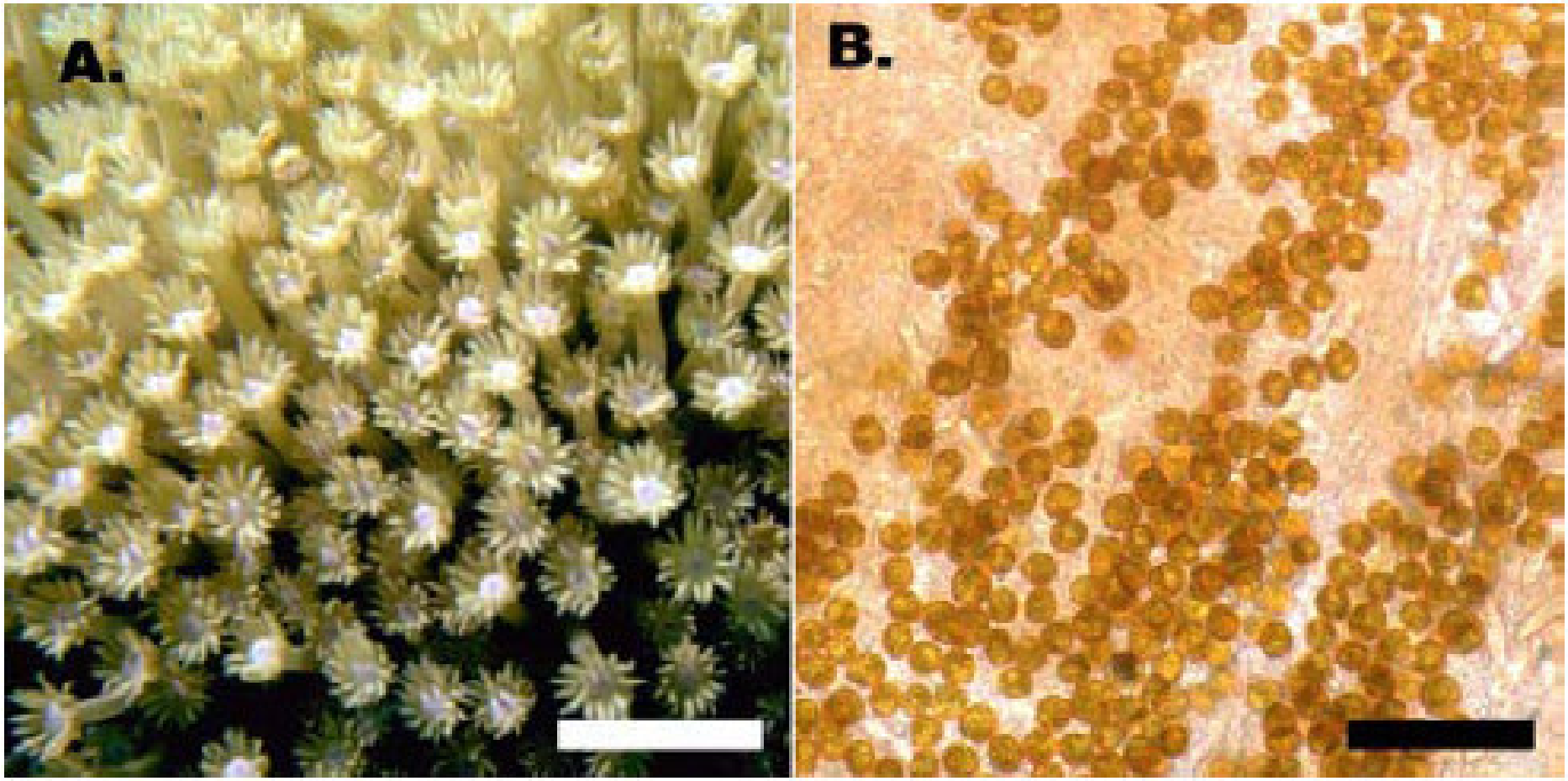
- Marine invertebrates are among the organisms most sensitive to CO_2 accumulation, especially those with a hypometabolic mode of life and heavily calcified.
- Echinoderms, crustaceans and molluscs are found to be very sensitive to acidity.
- Early life stages with an incomplete development of physiological capacities may be the most sensitive. Thereby, reduced reproductive success may be one of the key effect of climate change.
- The main impact of fluctuating climate on intertidal ecosystems would be through changes in sea level and temperature, and exposure to warmer environment during low tide.

Immediate effect is on the CORALS

Coral Bleaching

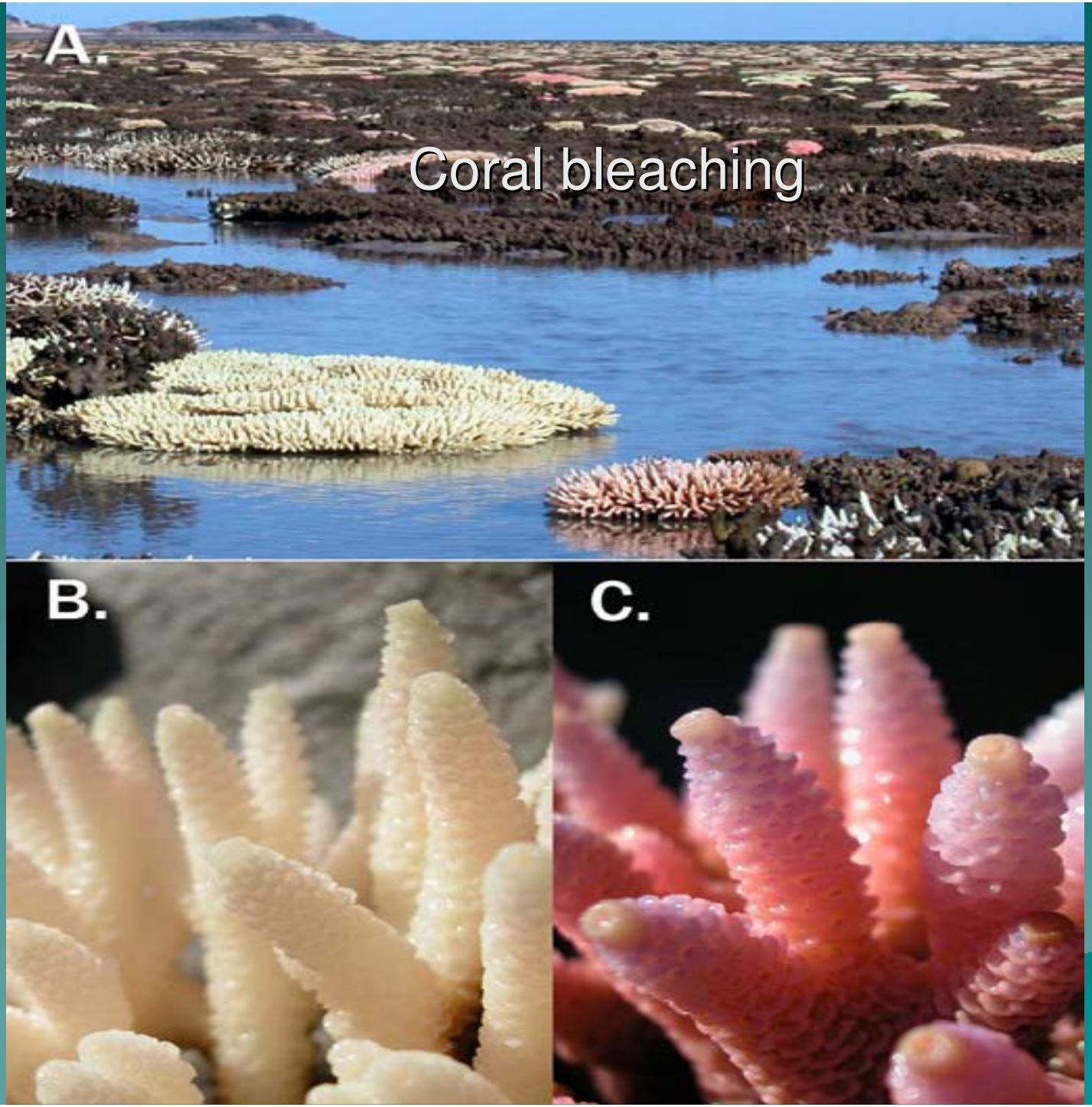
- **Coral bleaching results when the symbiotic zooxanthellae (single-celled algae) are expelled from the host coral organisms due to stress; may lead to mortality of corals depending upon the intensity of bleaching**

Polyps Zooxanthellae



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


A.
Coral bleaching
B.
C.

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

Vulnerability of sea turtles

- Olive ridley mass-nest along the Orissa coast during December – March every year (3 to 6 lakh turtles nest in a year).
- Sex of hatchlings determined by soil temperature at the time of incubation.
- Those hatching out at < 27°C are males; at > 27°C are females.

Climate and Fisheries

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*

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?

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.

IUCN: 1998 Red Data Book

Extinct: Species not located in the wild for the last 50 years

Endangered: Taxa in danger of extinction & survival unlikely if causal factors continue operating

Vulnerable: Likely to move into endangered category in the near future

- Over fishing
- Extensive destruction of habitat
- Environmental disturbance

Rare: Taxa not at present endangered or vulnerable but at risk

Existing CITES criteria for listing in Appendix I

1. Small population size (< 5,000 individuals)
2. Restricted area of distribution (10,000 km^2)
3. Decline in numbers
4. Likely to satisfy one of 1-3 within the next 5 years

There are severe limitations of the existing CITES listing criteria and guidelines if applied to exploited fish stocks

There may be several misses and numerous false alarms

Life history characteristics are very important

Greatest relevance to the risk of extinction is population resilience;

ability to rebound after perturbations;

ability to sustain exploitation

Small population size (< 5,000 individuals)

- applicable to sessile and low productivity species;

- for exploited fish stocks, the number of individuals associated with the risk of extinction could range from <1000 (e.g. low productivity species) to > 1 million (e.g. highly productive small pelagics)

Restricted area of distribution (10,000 km^2)

- applicable for certain reef fish, sessile species;

- but is too large to protect several small pelagics, invertebrates including corals

- no numeric guideline is universally applicable

Historical decline if any, in area of distribution should be used

Analysis should be on a case-by-case basis

Decline in numbers

Population decline criterion is the most widely applicable for exploited fish stocks

Historical extent of decline should be considered

5% - 30% decline from the reference baseline is appropriate for listing

Productivity is a complex function of fecundity, growth rate, natural mortality, age at maturity and longevity.

More productive species have greater ability to rebound from low numbers; they can take advantage of situations

Low productive species, if depleted, spend longer periods at low population size; they are exposed to greater risk to depensatory factors

CONCLUSION

- CLIMATE CHANGE IS A DEPENSATORY FACTOR THAT EXACERBATES THE CURRENT THREATS TO BIODIVERSITY.
- MANAGING BIODIVERSITY WILL BECOME FAR MORE CONTENTIOUS BECAUSE THE FAUNA AND FLORA WILL CHANGE IN UNEXPECTED WAYS.
- The ability to preserve marine biodiversity will rest on a mechanistic understanding of the interactions between global change events and localized disturbances.