Ecological Impacts of Climate Change II:

Effects on Ocean Health

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Examples of Ocean Stessors

Overfishing

- unsustainable removal of organisms, particularly breeding stock

Pollution/sedimentation/eutrophication

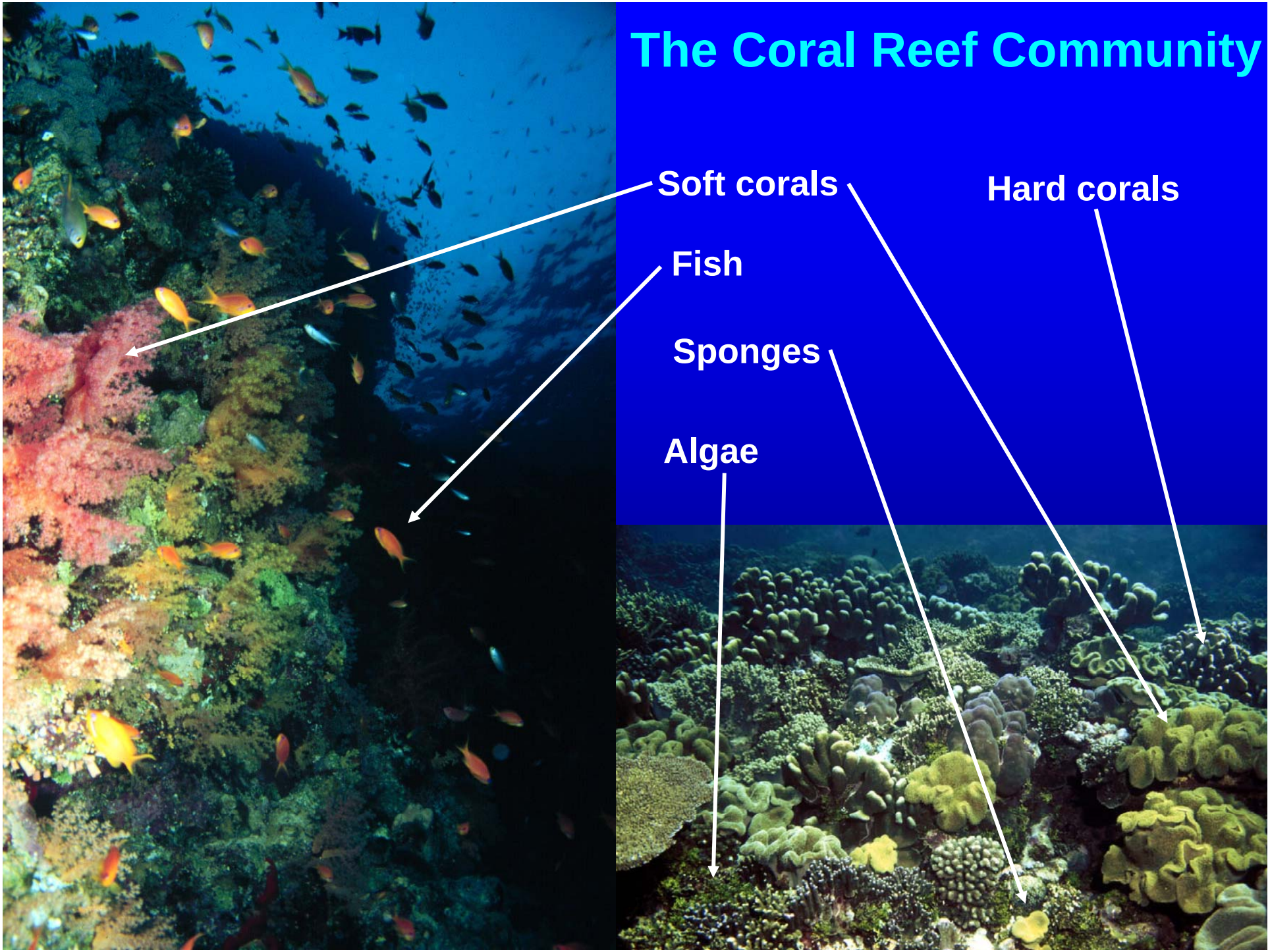
- 53% of population lives along coasts or rivers that drain into the sea
- runoff containing sediment, toxins, nutrients cause physiological stress, disease, blooms, mortality

Habitat modification

- destructive fishing methods
- coastal and watershed development impact estuaries, intertidal, mangrove and shallow sub-tidal habitats (e.g. seagrass beds)

These stressors reduce the resilience of species, communities and ecosystems to climate change effects.

The Coral Reef Community

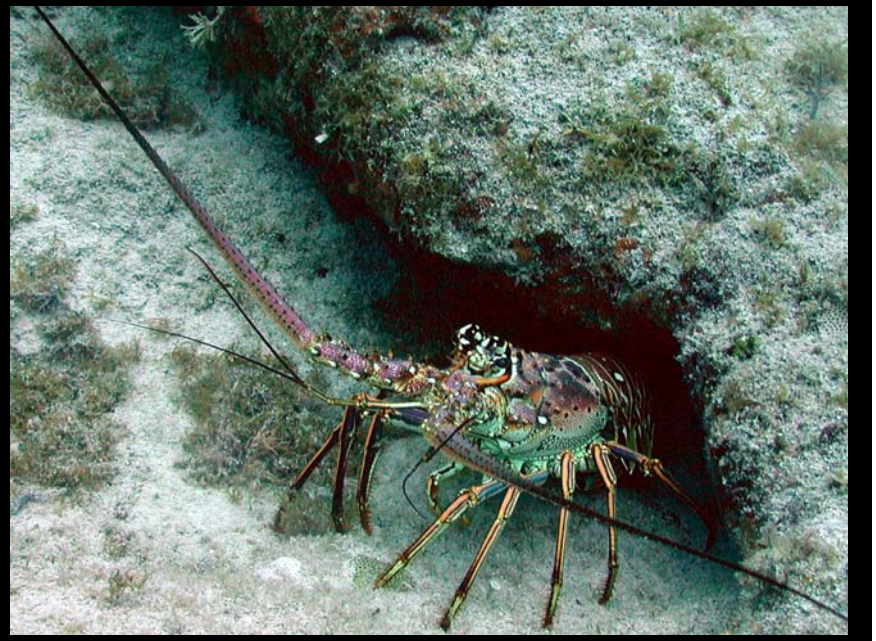


Corals

- Polyps form colony
- Limestone skeleton
- Energetically efficient
    - Symbiosis (algae =zooxanthellae)

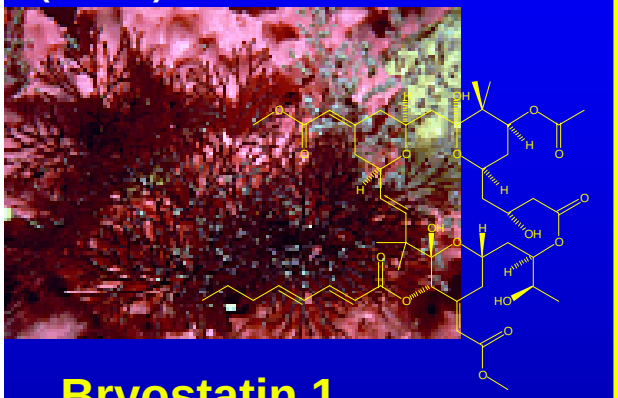
Why are coral reefs important?

Food and Other Products



Drugs from the Sea

Bugula neritina
(Pacific)



Bryostatin 1

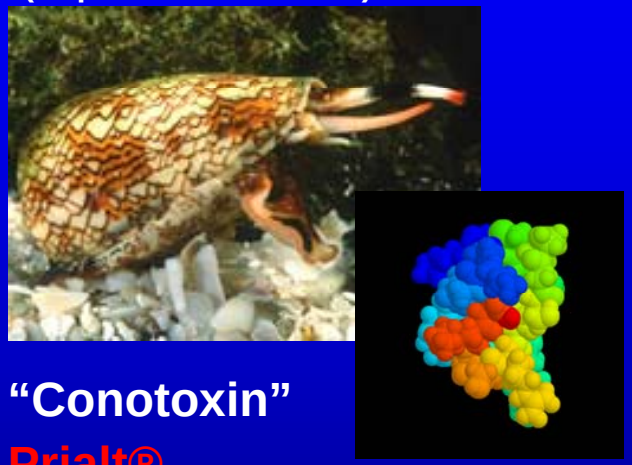
Phase II: cancer
(NCI-sponsored trials)

MOA: inhibitor of PKC tumor promotion

Uses: molecular probe (PKC activator), single agent drug Rx, dual agent drug Rx

Sustainability: mariculture, synthesis, symbiont fermentation/transgenics

Conus magnus
(tropical South Pacific)



"Conotoxin"

Prialt®
(licensed to Elan Pharmaceuticals)

MOA: specific blocker of Ca channels

Use: analgesic- 10,000x more potent than morphine, without side-effects

Sustainability: peptide synthesis (25 AA's)

Ecteinascidia turbinata
(tropical Caribbean)

Ecteinascidin 743

Phase II: cancer
(licensed to PharmaMar)

MOA: novel, but poorly understood

Use: single agent drug Rx- colon, melanoma, renal, lung, breast, ovarian

Sustainability: mariculture, synthesis

Polar Bears and Climate Change

- Females fast for 5-7 months in winter before emerging with cubs
- Depend on sea ice to hunt seals
- Declining sea ice:
  - decreased prey availability
  - increased energy spent swimming
- Polar Bear weight & number of cubs have declined by 15% over last two decades coincident with decline in sea ice extent

(Stirling et al. 1999 Arctic 52:294-306)

Major Climate Change Factors Affecting the Ocean

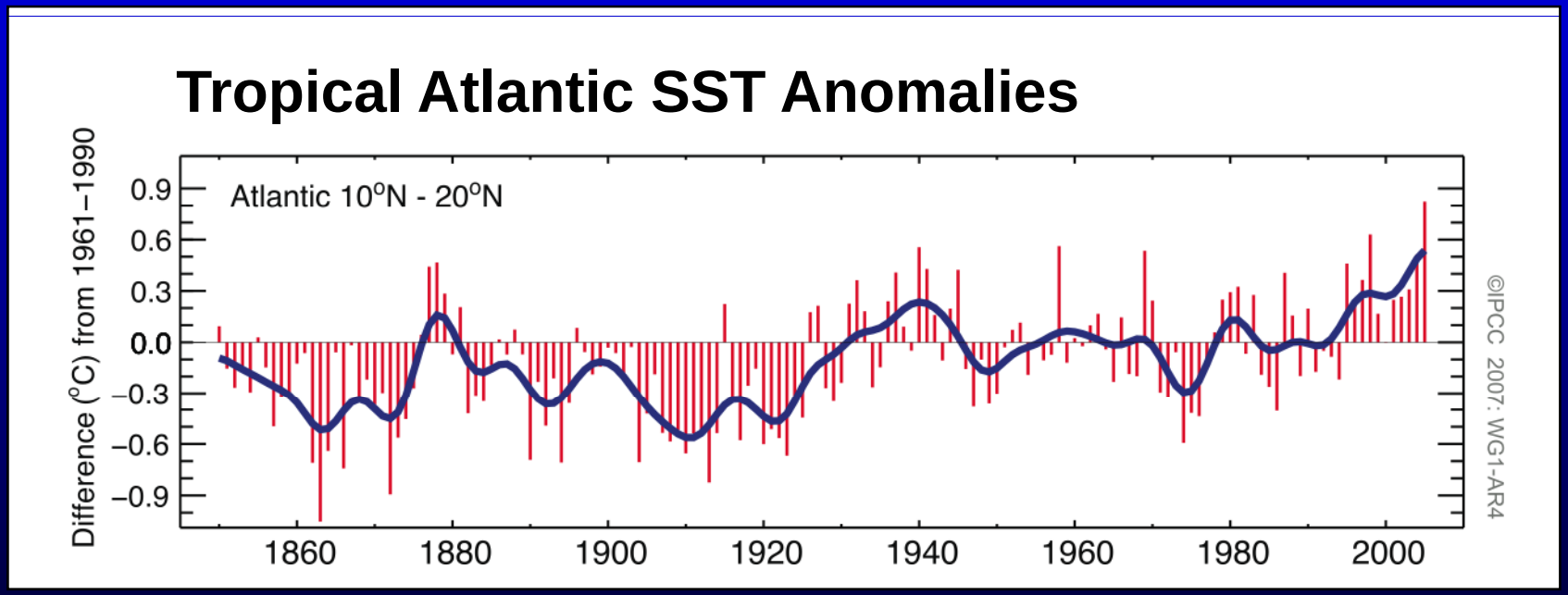
- Increasing seawater temperature
- Changing ocean chemistry
- Sea level rise
- Changes in extreme climate events
- Changes in ocean circulation

- Changes in terrestrial climate
- Changes in solar/UV irradiance
- Changes in pathogen distribution and virulence

- Interactions with non-climate stressors

Increasing seawater temperature

- Increased averages
- Increased extremes
- Not only surface, but deeper waters also affected



(IPCC 2007)

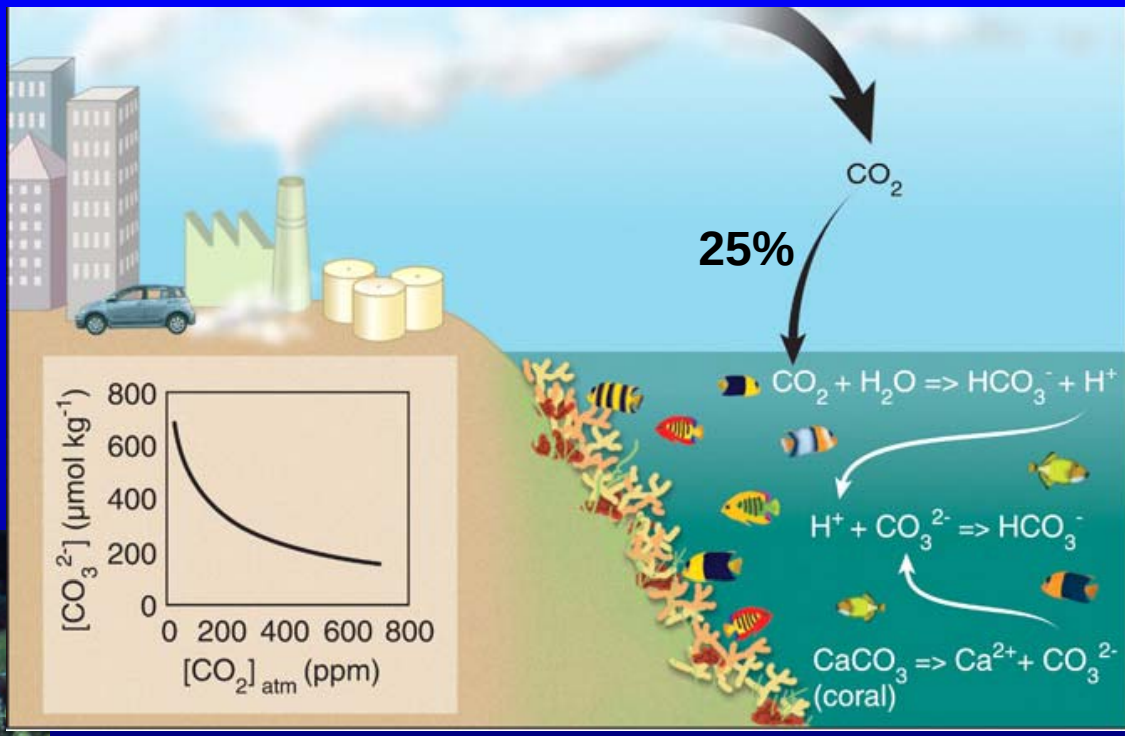
Increasing seawater temperature

- **What happens?**
  - Increased thermal stress = reduced resistance/resilience to other stressors (e.g., disease, competition, predation, pollution)
  - Species distributions limited by temperature (e.g. polar bears, corals) → range expansions/contractions, invasive species
  - Blooms of algae and jellyfish → effects on marine communities, fisheries and human health
  - Mass coral bleaching events (only 1-2°C) → dead reefs (affects tourism, commercial and subsistence fisheries, coastal protection)
- **Indirect effects**
  - Changes in cloud cover due to increased temperature cause changes in UV radiation that exacerbate temperature effects

Coral bleaching

Changing Ocean Chemistry

- Atmospheric CO_2 is absorbed by the ocean



(Hoegh-Guldberg et al. 2007 Science 318:1737-1742)

Changing Ocean Chemistry

- **What happens?**
  - **Decreased abilities of corals and other calcifying organisms (clams, oysters, mussels and other important fisheries species) to produce skeletons or shells, resulting in changes in marine food webs**
  - **Atm CO_2 now 380 ppm, expected to double by 2100**
  - **At 500 ppm atm CO_2, Erosion >> Deposition**

  - **Deep corals grow very slowly and if they can't calcify, there will be a reduction in deep reefs (70% by 2100) which are important habitats for fisheries species**

  - **Production of some carbon-limited species will increase (seagrasses, mangroves), but these will be offset by other stressors**

Sea Level Rise

- Sea level is rising an average of 2.6 mm/yr
- Increased volume mostly from ocean expansion due to increasing seawater temperature
- Melting of ice sheets also contributes to a lesser extent

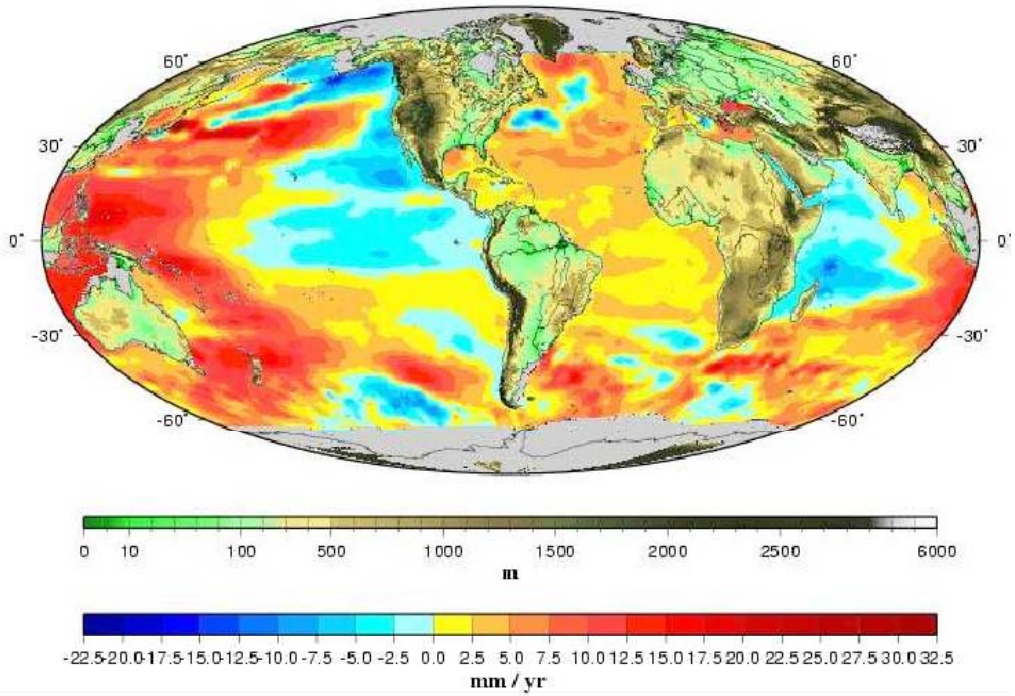


Figure 7. Sea level trends over 1993-2003 from the T/P mission.

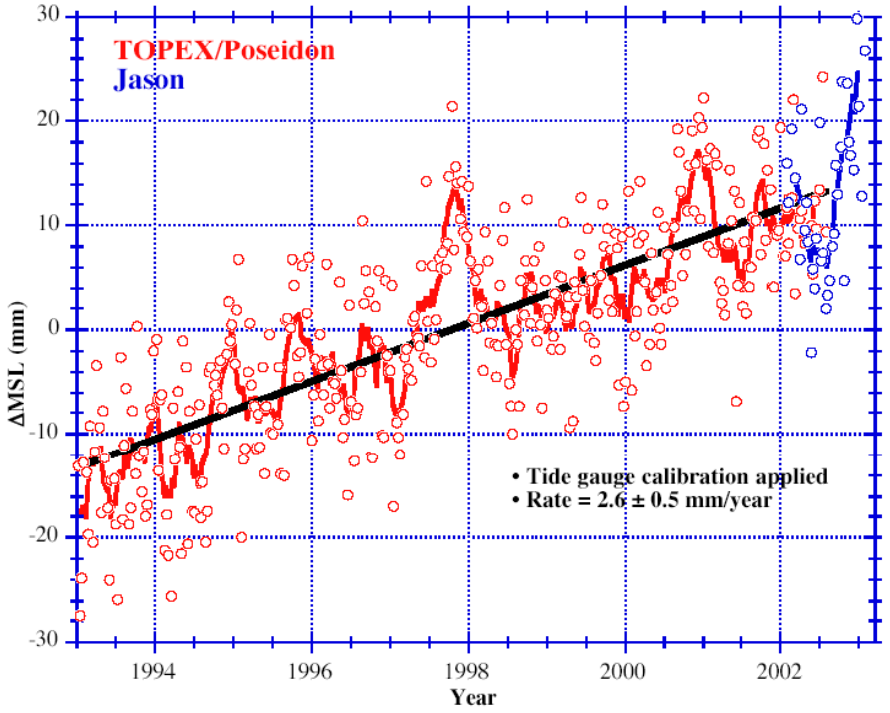


Figure 5. Global mean sea level variations from T/P and Jason.

(Cazenave and Nerem, 2004 Rev. Geophys 42)

Sea Level Rise

- **What happens?**
  - Flooded coastlines, wetlands, estuaries
  - Disappearance of shallow water and intertidal habitats
  - Coastal habitats can't shift to new shoreline due to coastal development
  - Loss of nursery grounds, nesting and feeding habitats of many organisms

  - Since 39% of world's population lives within 100 km of the ocean, this will have direct effects on their homes and livelihoods
  - Most extreme effects on island nations with low elevations
  - Coastal real estate will disappear
  - Economies relying on coastal fisheries and recreation will decline

  - Lessons from Hurricane Katrina and the Indian Ocean tsunami: these habitats are essential to protect the coastline from flooding

Coastal Protection

Changes in Extreme Climate Events

- **Increases in storm intensity**
- **Changes in storm paths**

- **What happens?**
  - **increased river volume, flooding, runoff (freshwater, sediment, pollutants, nutrients)**
  - **increased coastal erosion, especially beaches**
  - **destruction of salt marshes, seagrass beds, mangroves, and coral reefs**
  - **Harmful Algal Blooms result from runoff of sediment and nutrients, enhanced by elevated temperatures and solar radiation**

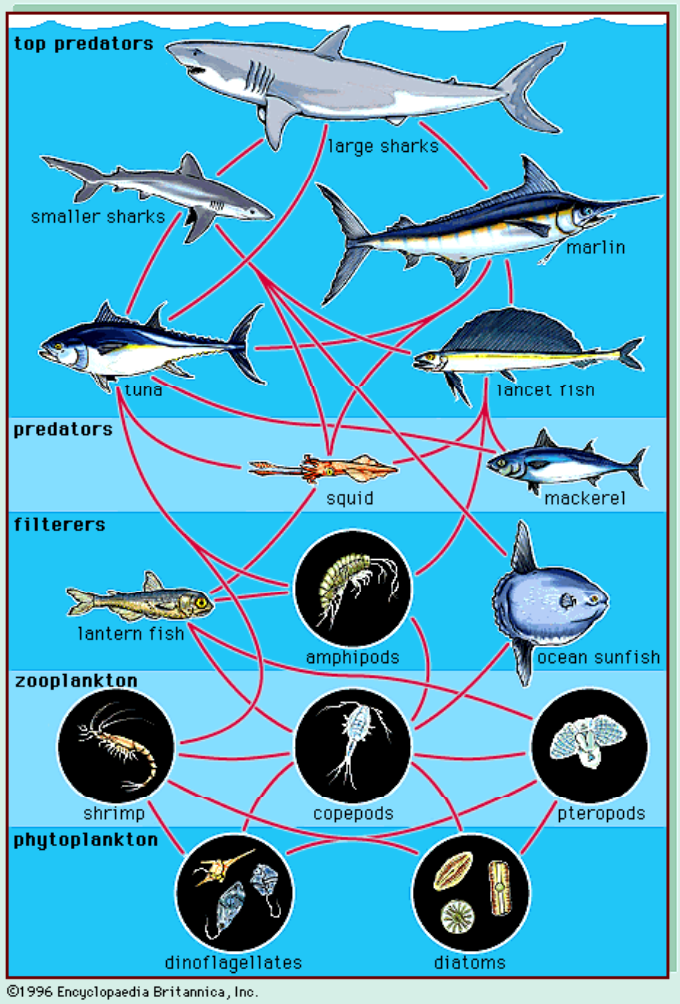
Harmful Algal Blooms

- Block sunlight and produce toxins
- Effects on health of marine communities, fish and shellfish
- Indirect effects on human health (ingestion of shellfish)
- Direct effects on human health (respiratory & dermatitis)

Changes in ocean circulation

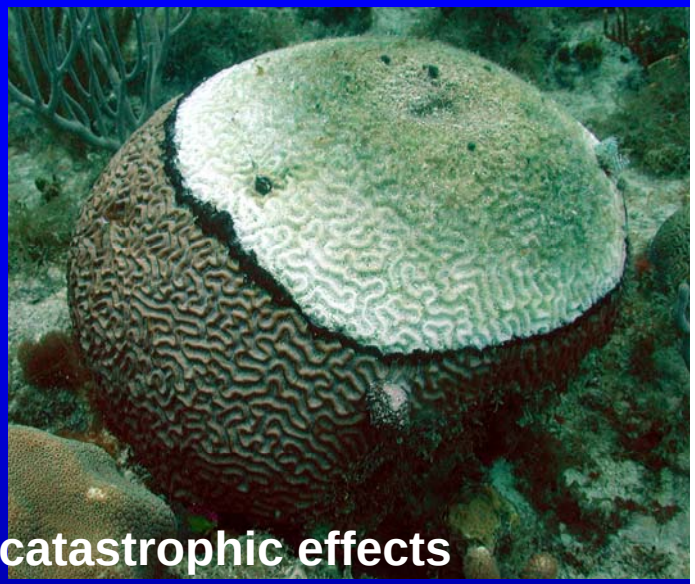
- **Changes in surface currents**
  - Due to warming and changes in winds
  - Affects larval dispersal and therefore population dynamics and distribution of species, including fisheries species
  - Invasive species
  - Pathogens

- **Changes in upwelling & stratification**
  - Due to warming and changes in winds
  - Upwelling brings cold nutrient-rich waters up to the surface, so this would change nutrient availability in surface waters
  - Changes in nutrients affect productivity of phytoplankton, with cascading effects higher up the food chain
  - Changes in food availability can have drastic changes on fisheries



Changes in pathogen distribution and virulence

- Changes in pathogen distribution
- Changes in pathogen virulence
- Changes in host resistance



What happens?

- Diseases more widespread, affecting more individuals and different species of hosts
- Disease outbreaks more common, with more catastrophic effects
- Newly emerging infectious diseases

Indirect interactions

- Desertification and dust storms transporting pathogens to new hosts

Summary

- Increasing seawater temperature
- Changing ocean chemistry
- Sea level rise
- Changes in extreme climate events
- Changes in ocean circulation & stratification
- Changes in pathogen distribution and virulence
- Interactions with non-climate stressors

- Many unknowns