Climate Change and Its Impacts on Marine Organisms and Ecosystems

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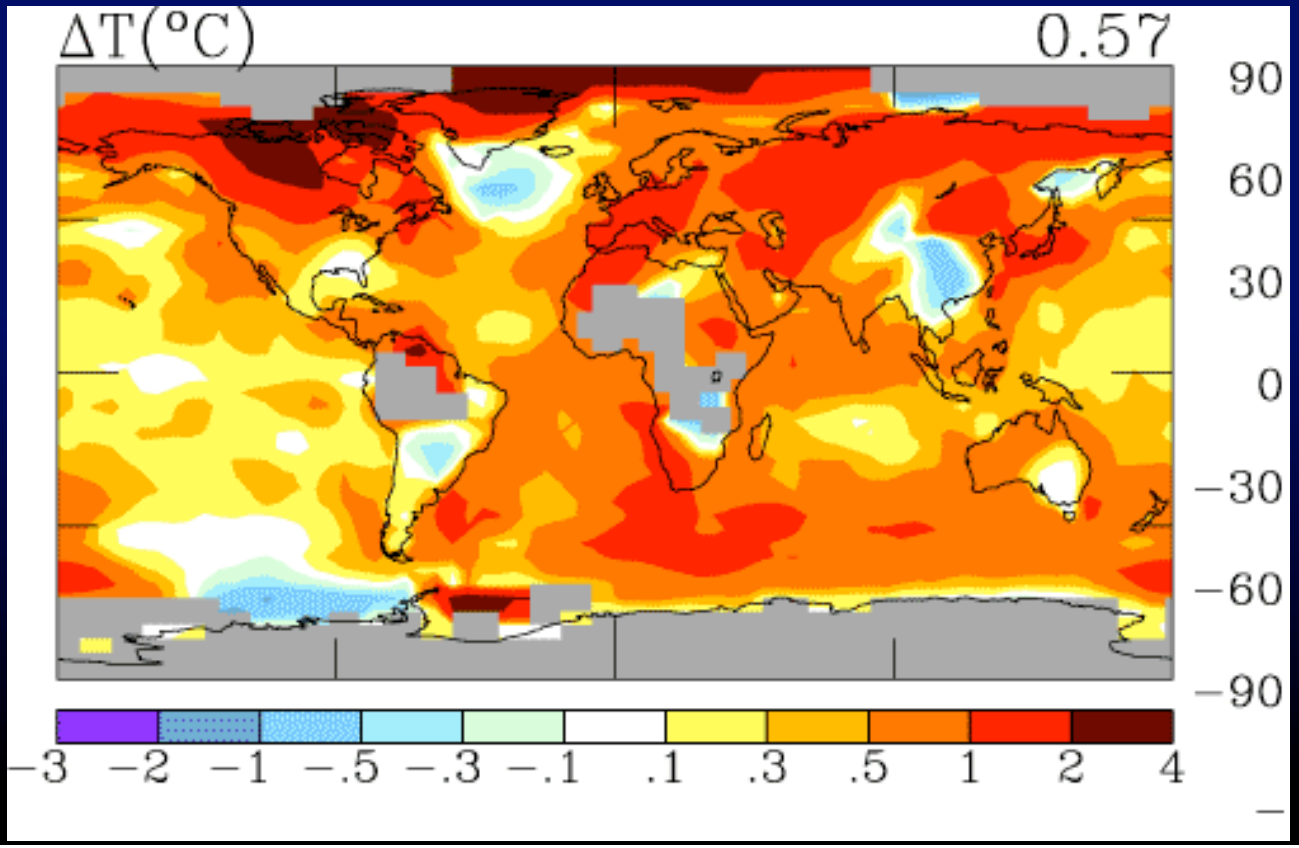
Effects of Climate Change on the Ocean

- Ocean warming
- Ocean acidification
- Sea level rise
- ENSO – El Niño Southern Oscillation
- Disease
- Changes in ocean circulation patterns

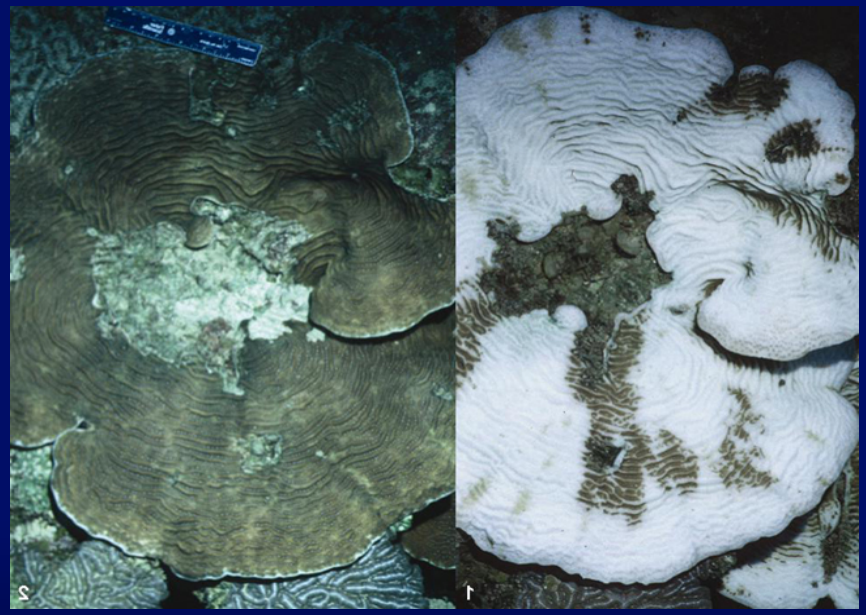
Ocean Warming



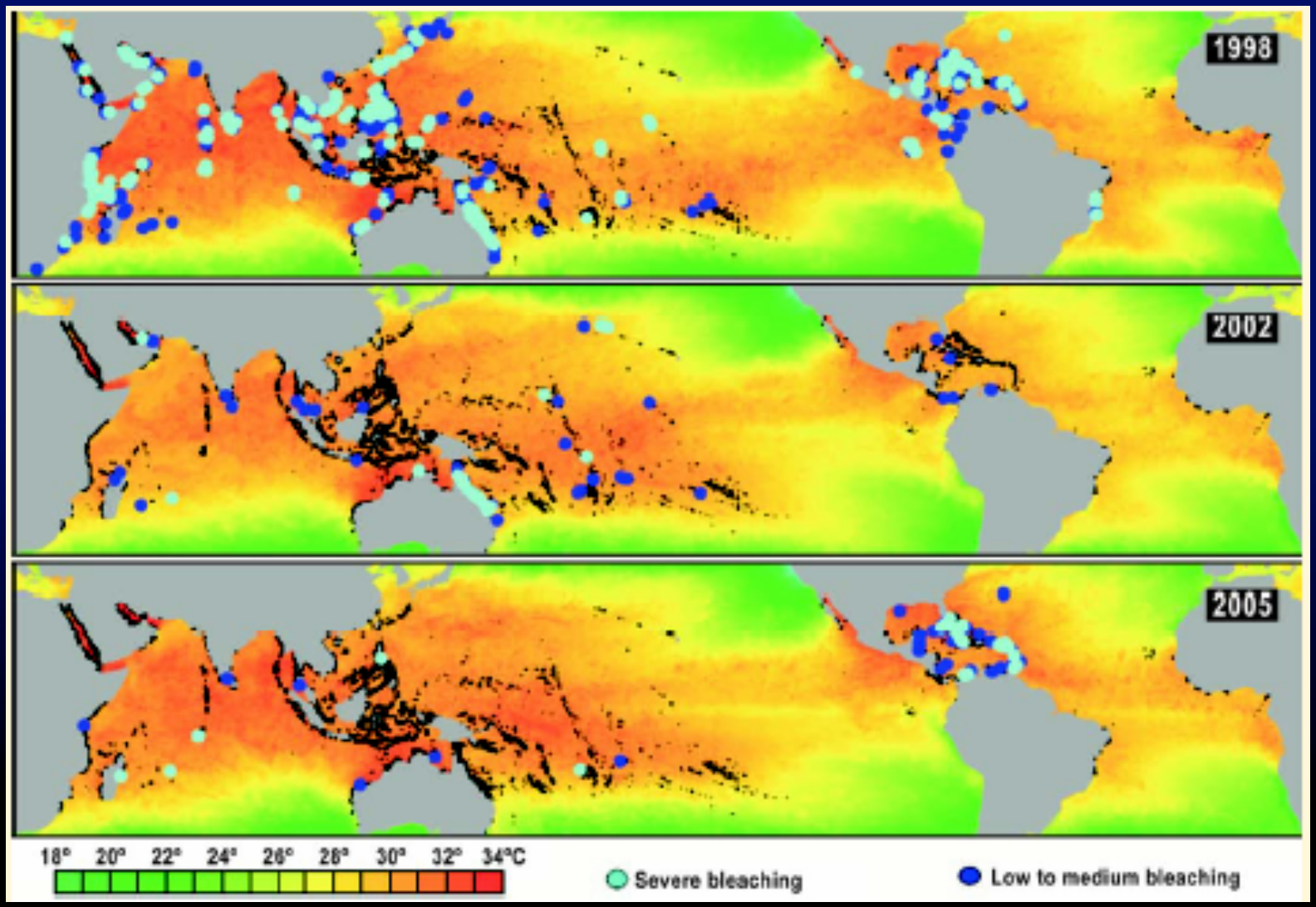
Observed 1880-2002 Ts change based on adjusted meteorological station data over land and sea Ts data for the ocean. (Hansen and Nazarenko, 2003, Figure 3)

Who is the *poster child* for climate change impacts?

Ocean Warming and Coral Bleaching



Coral bleaching can be widespread



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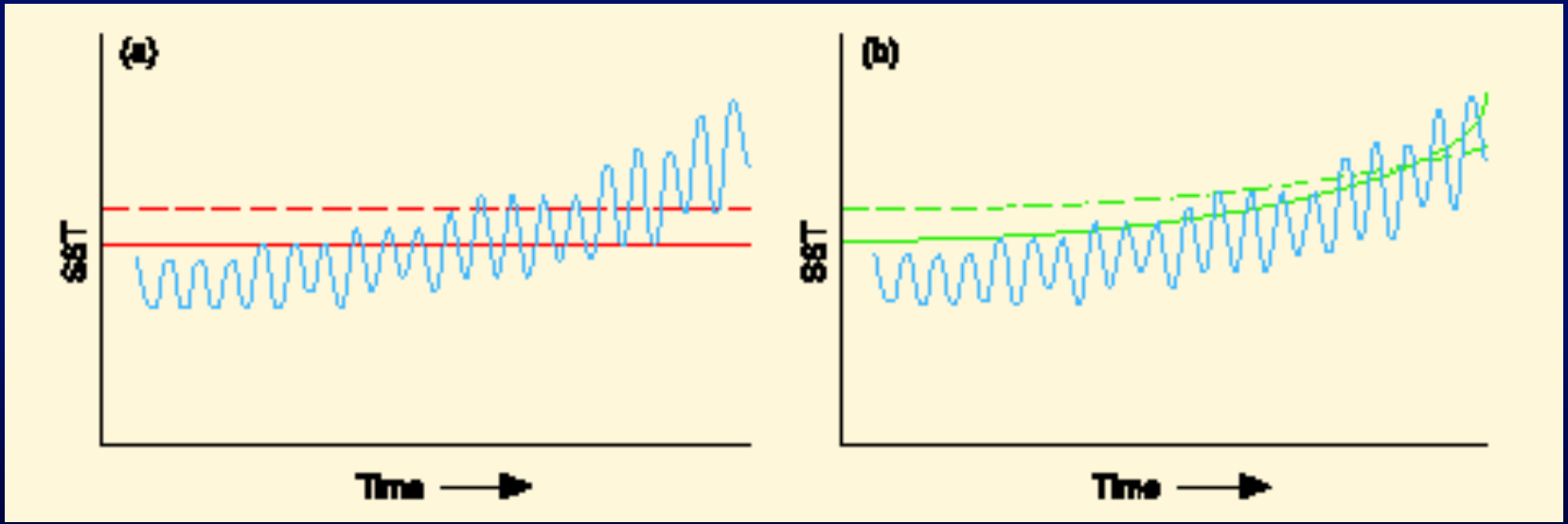
Can Corals Adapt?

Invariant model

Adapting model



Blue line = sea surface ºC

Solid red line = invariant 1 ºC threshold for bleaching

Dashed red line = invariant 2 ºC threshold for mortality

Solid green line = elevating threshold for bleaching

Dashed green line = elevating threshold for mortality

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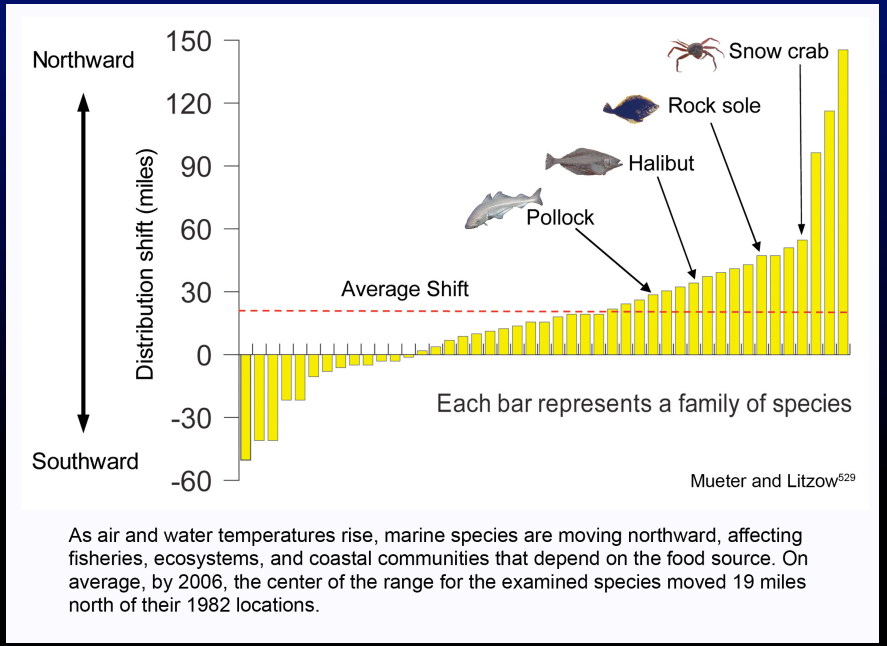
Organism Range or Distribution Shift

- Organisms may shift range in response to changing conditions
- Organisms may expand range as favorable conditions increase
- Organisms may contract range as favorable conditions decrease
- Implications for invasive species
- Implications for biodiversity
- Implications for fisheries

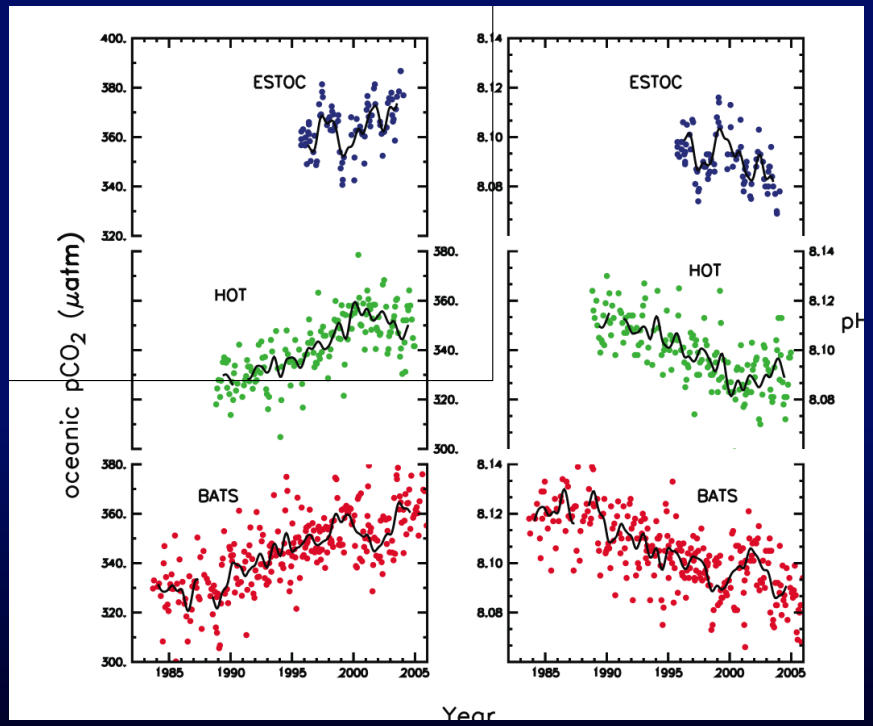


As air and water temperatures rise, marine species are moving northward, affecting fisheries, ecosystems, and coastal communities that depend on the food source. On average, by 2006, the center of the range for the examined species moved 19 miles north of their 1982 locations.

Ocean Acidification

CO_2 Causes Acidification

Increased atmospheric CO_2 ⇒ increased oceanic pCO_2 ⇒ lower pH



Measured or calculated pCO_2 & pH at:

- ESTOC = European Station for Time-series in the Ocean
- HOT = Hawaii Ocean Time-series
- BATS = Bermuda Atlantic Time-series Study

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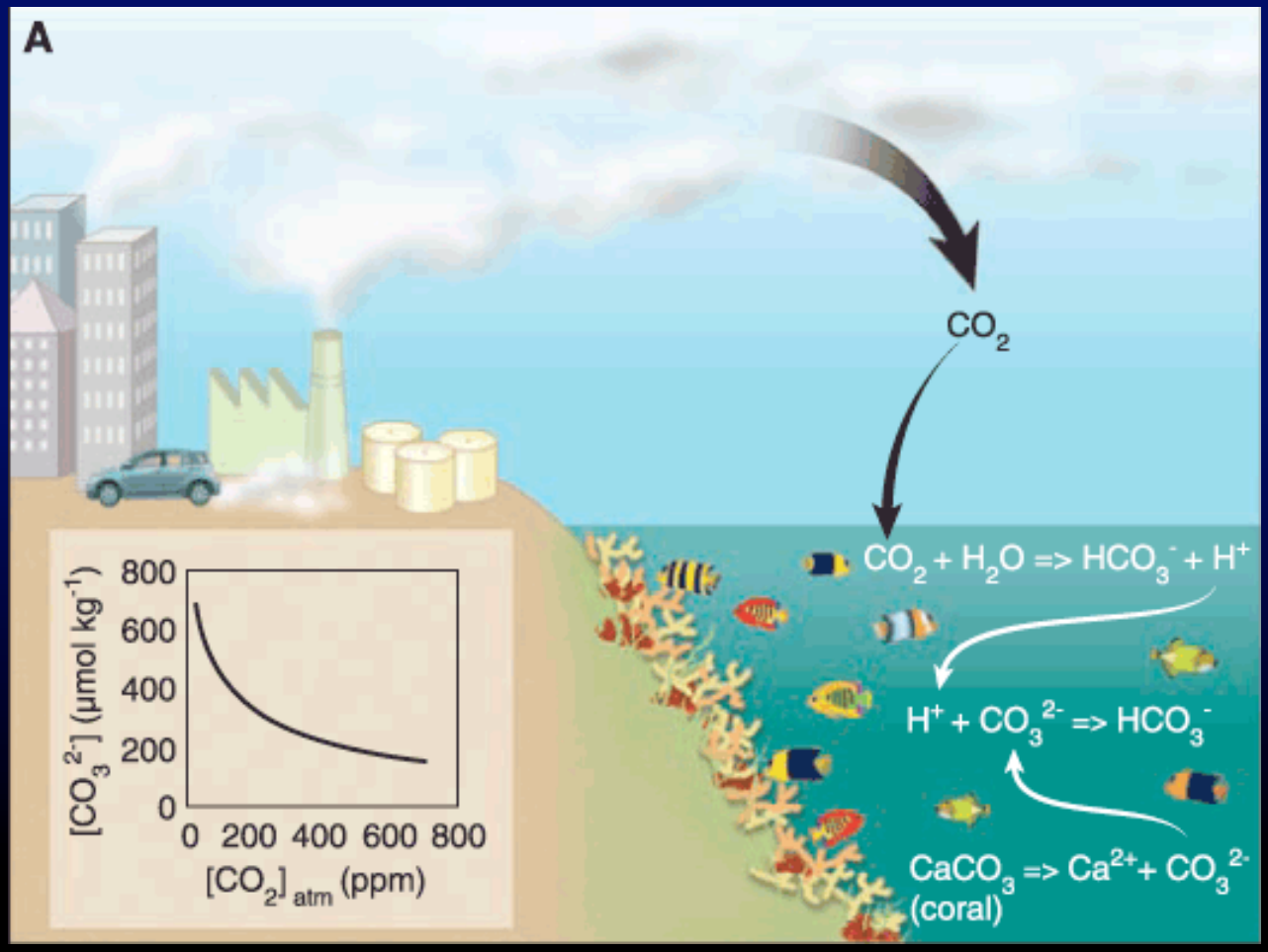
CO_2 Causes Acidification – How it Works

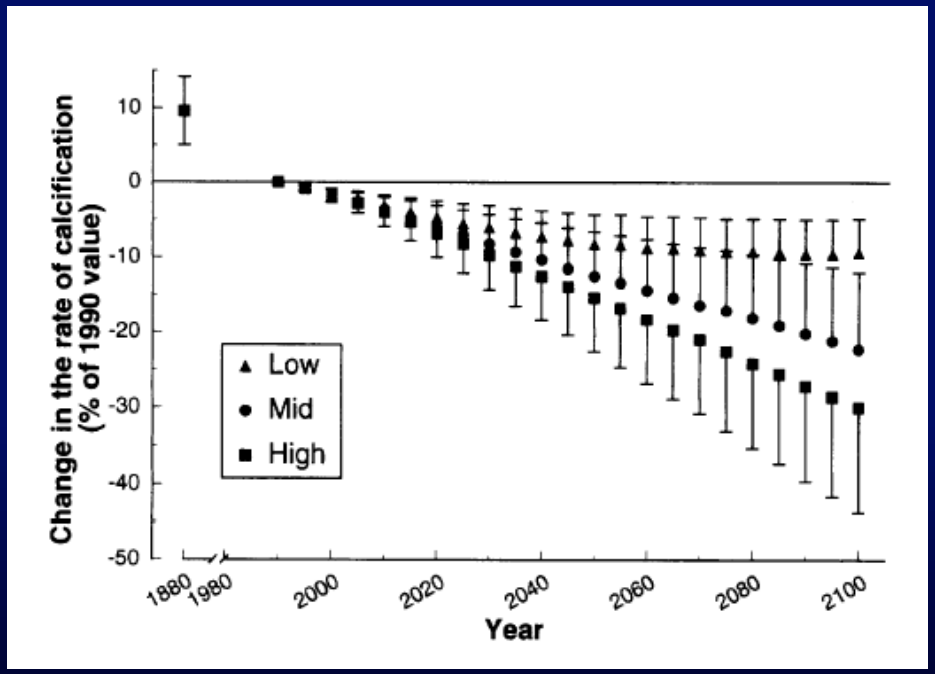
$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^- \rightleftharpoons 2H^+ + CO_3^{2-}$$



From Hoegh-Guldberg et al. 2007

Acidification Alters Calcification

- Mean calcification rate predicted to decrease up to 30% relative to 1990
  (3 IPCC scenarios)



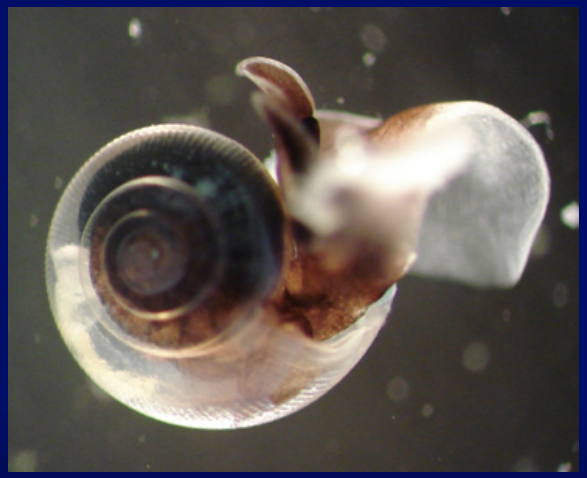
Gattuso, *et al*. 1999. American Zoologist 39: 160–183

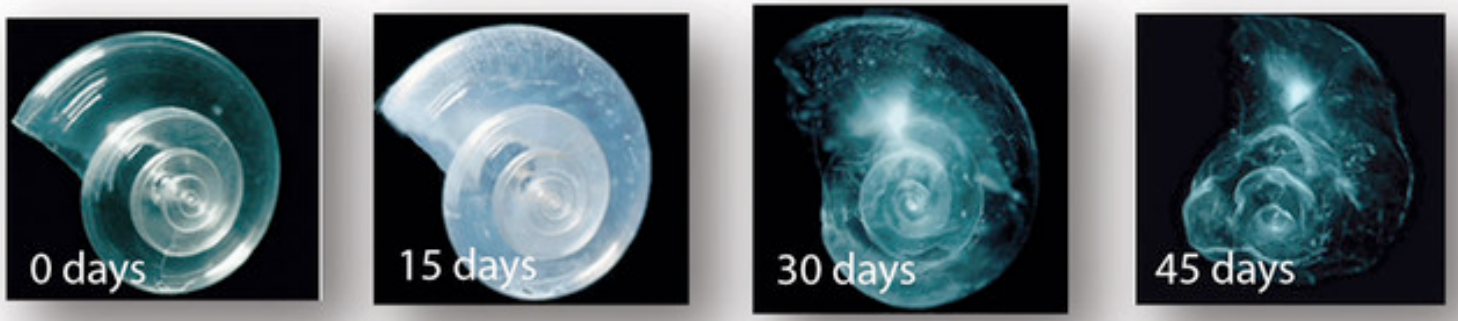
Consequences of Decreased Calcification

- Affects corals and calcareous algae = reef builders
- Reefs become less robust and grow slower
- Weaker & slower growing reefs may be lost
  - accretion < erosion and dissolution
    (low pH promotes dissolution)
  - regrowth < cumulative loss to storms
    (increased frequency of storms increases loss)
- Lose structure = broader effects in ecosystem

Decreased Calcification/Dissolution also Affects:

Pteropods





Shell fate after 45d in acidified water projected for 2100

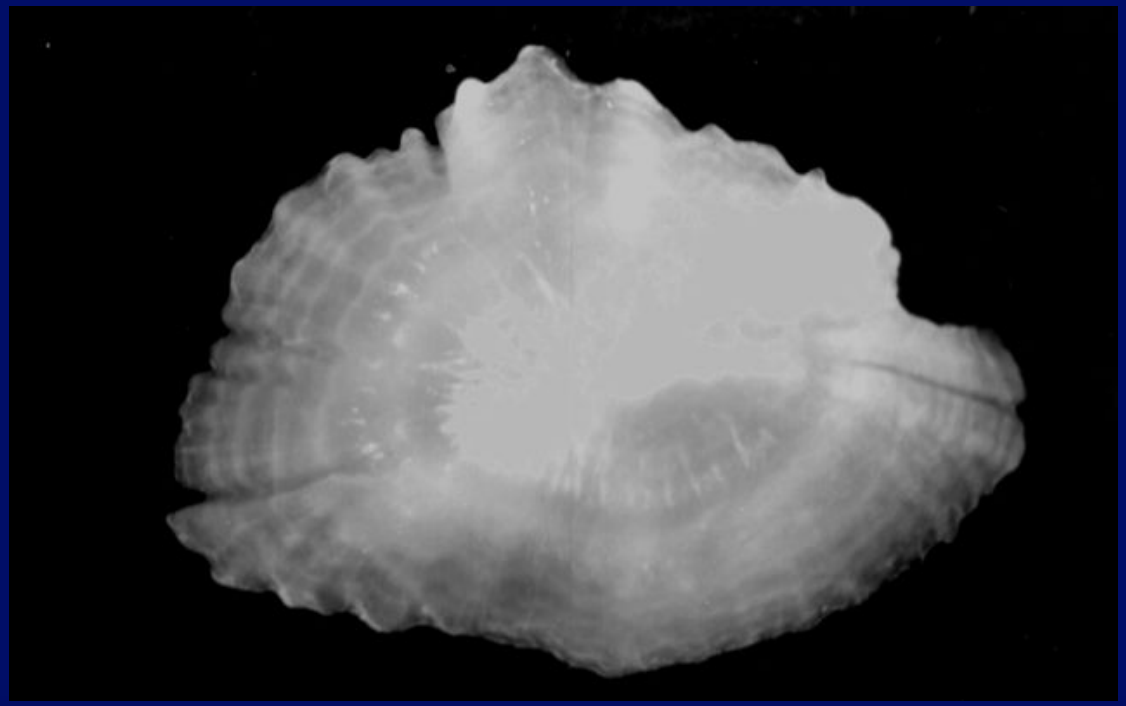
National Geographic

Decreased Calcification/Dissolution also Affects:

Image credit:
Universitat Autonoma de Barcelona

Coccolithophores

Coccolithophore bloom in English Channel
(Image credit Wilson and Groom)



…and Fish ?

(excuse me, what was that you said?)

PNAS

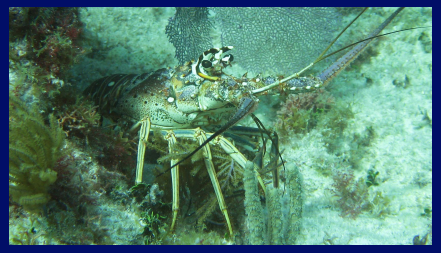
Ocean acidification impairs olfactory discrimination and homing ability of a marine fish

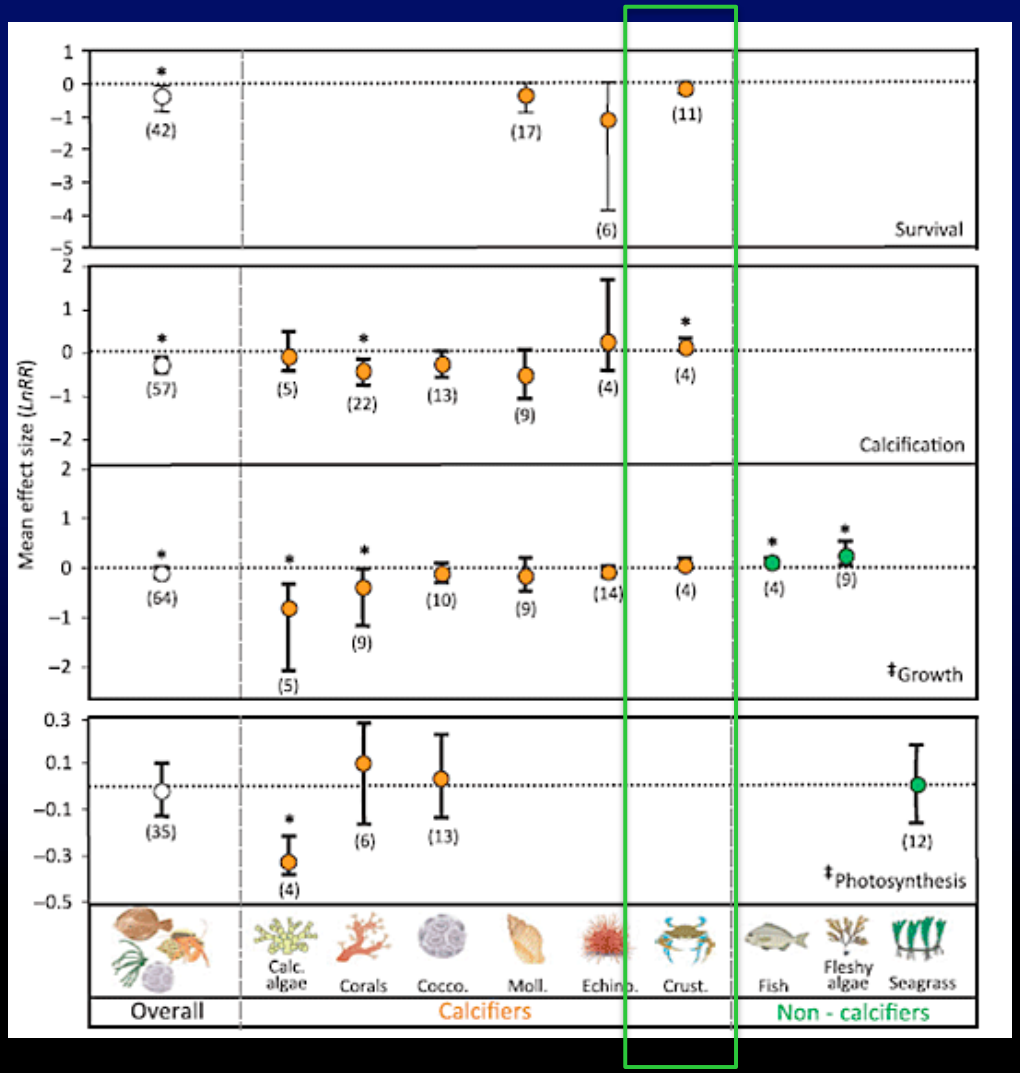
Philip L. Munday[a,b,1], Danielle L. Dixson[a,b], Jennifer M. Donelson[a,b], Geoffrey P. Jones[a,b], Morgan S. Pratchett[a], Galina V. Devitsina[c], and Kjell B. Døving[d]

[a]Australian Research Council Centre of Excellence for Coral Reef Studies, [b]School of Marine and Tropical Biology, James Cook University, Townsville, QLD 4811, Australia; [c]Ichthyology Department, Faculty of Biology, Moscow MV Lomonosov State University, Moscow 119992, Russia; and [d]Physiology Program, Institute of Molecular Bioscience, University of Oslo, N-0316 Oslo, Norway

Edited by David M. Karl, University of Hawaii, Honolulu, HI, and approved December 29, 2008 (received for review October 6, 2008)

…and of course crunchy calcified crustaceans…WAIT not so fast!



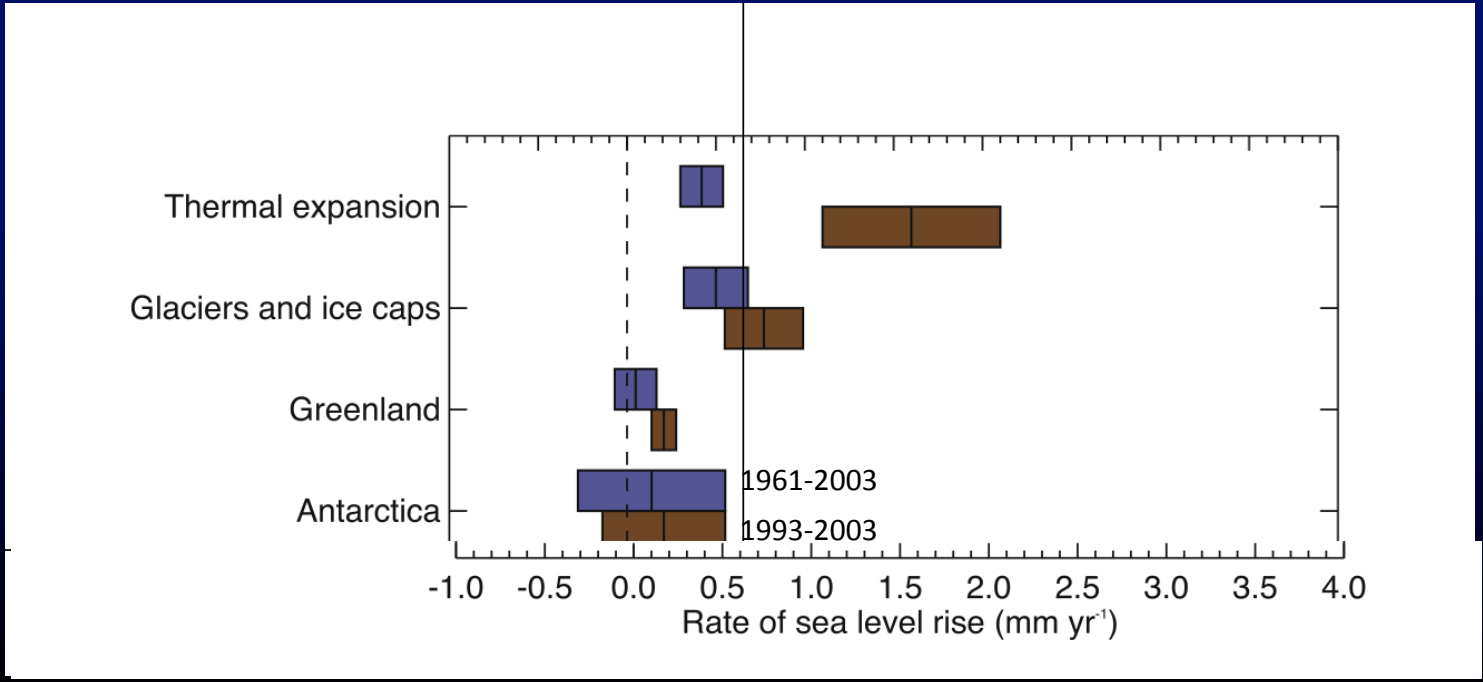


(Kroeker et al. Ecology Letters 2010)

Sea Level Rise

Increased °C Causes Sea Level Rise

- Warm sea water expands (thermal expansion)
- Ice melts



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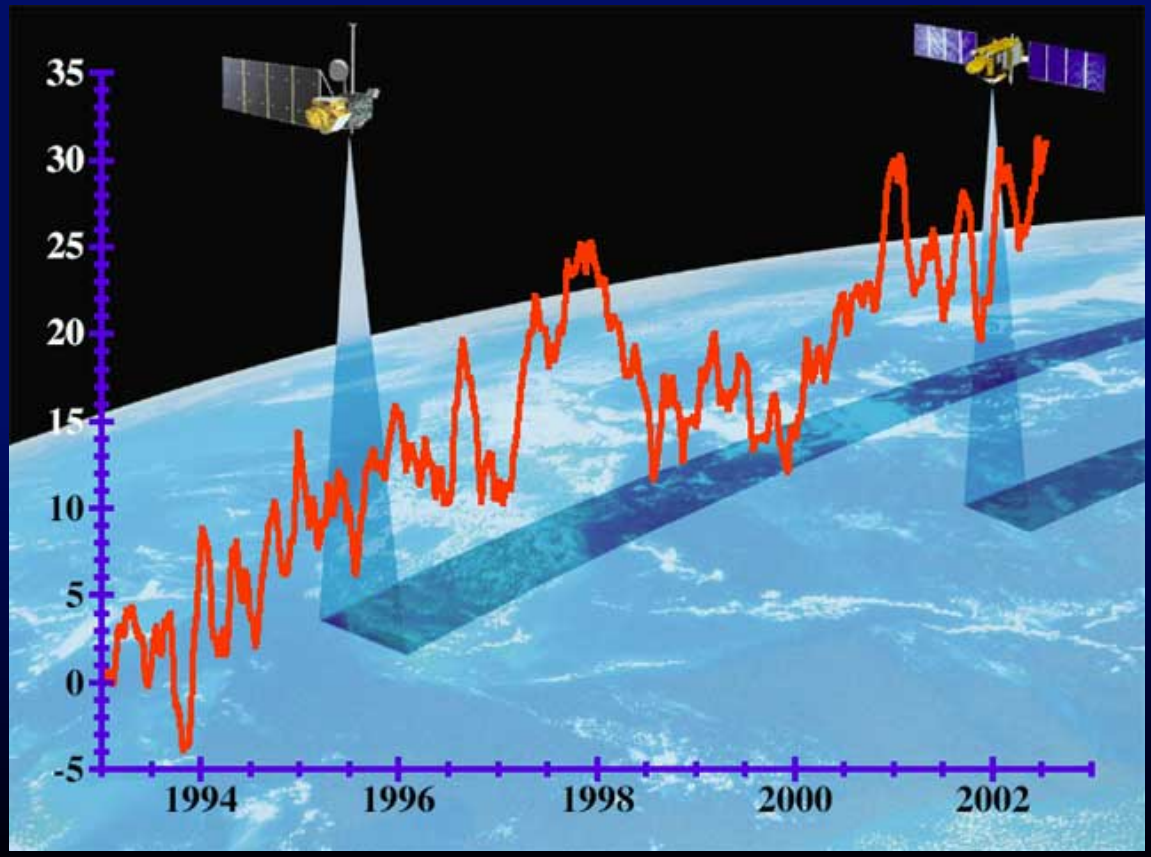
Sea Level is Rising



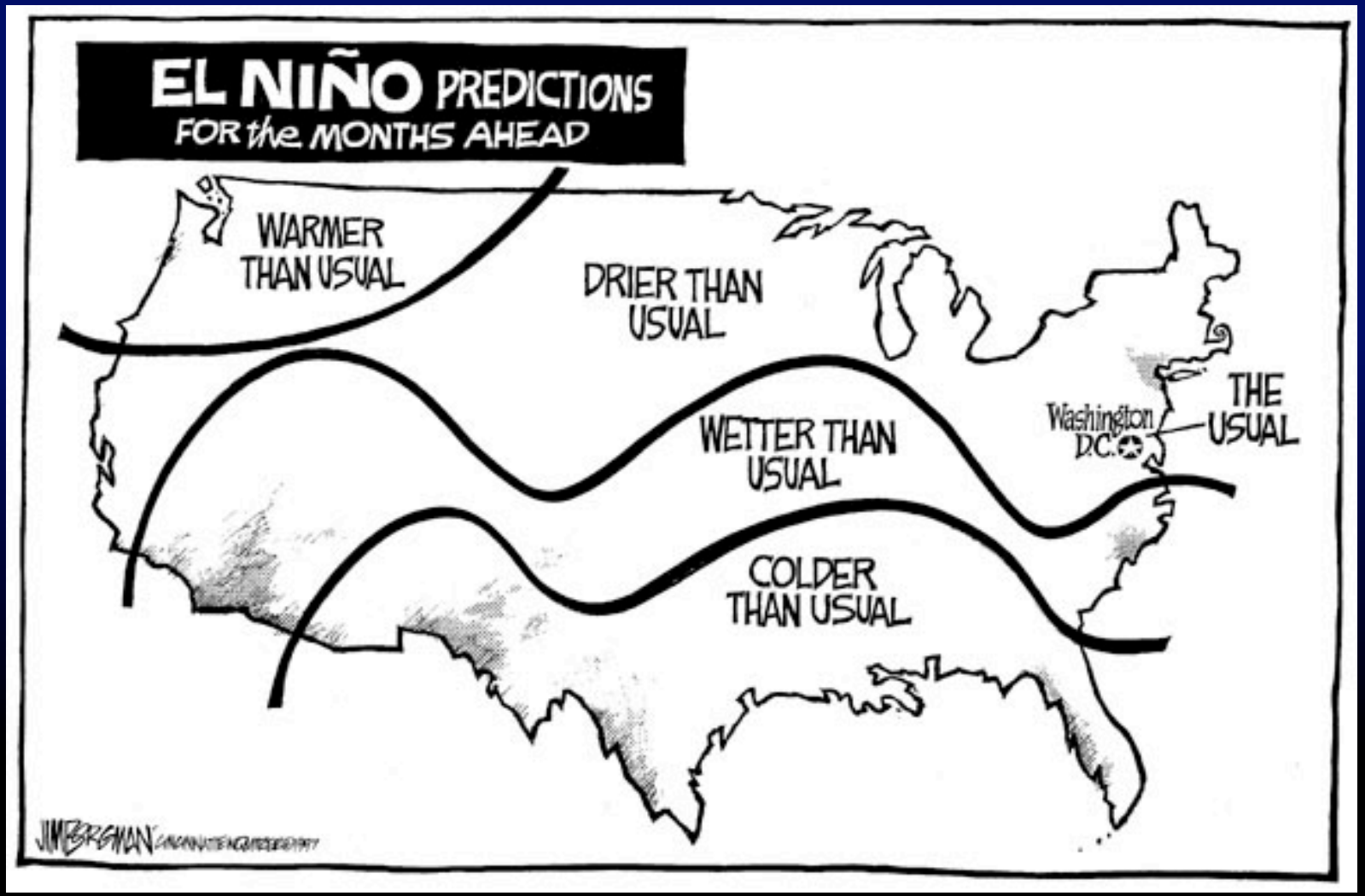
Since 1992, global sea level has risen at a rate of about 2.8 mm per year

NASA

Effects of Sea Level Rise

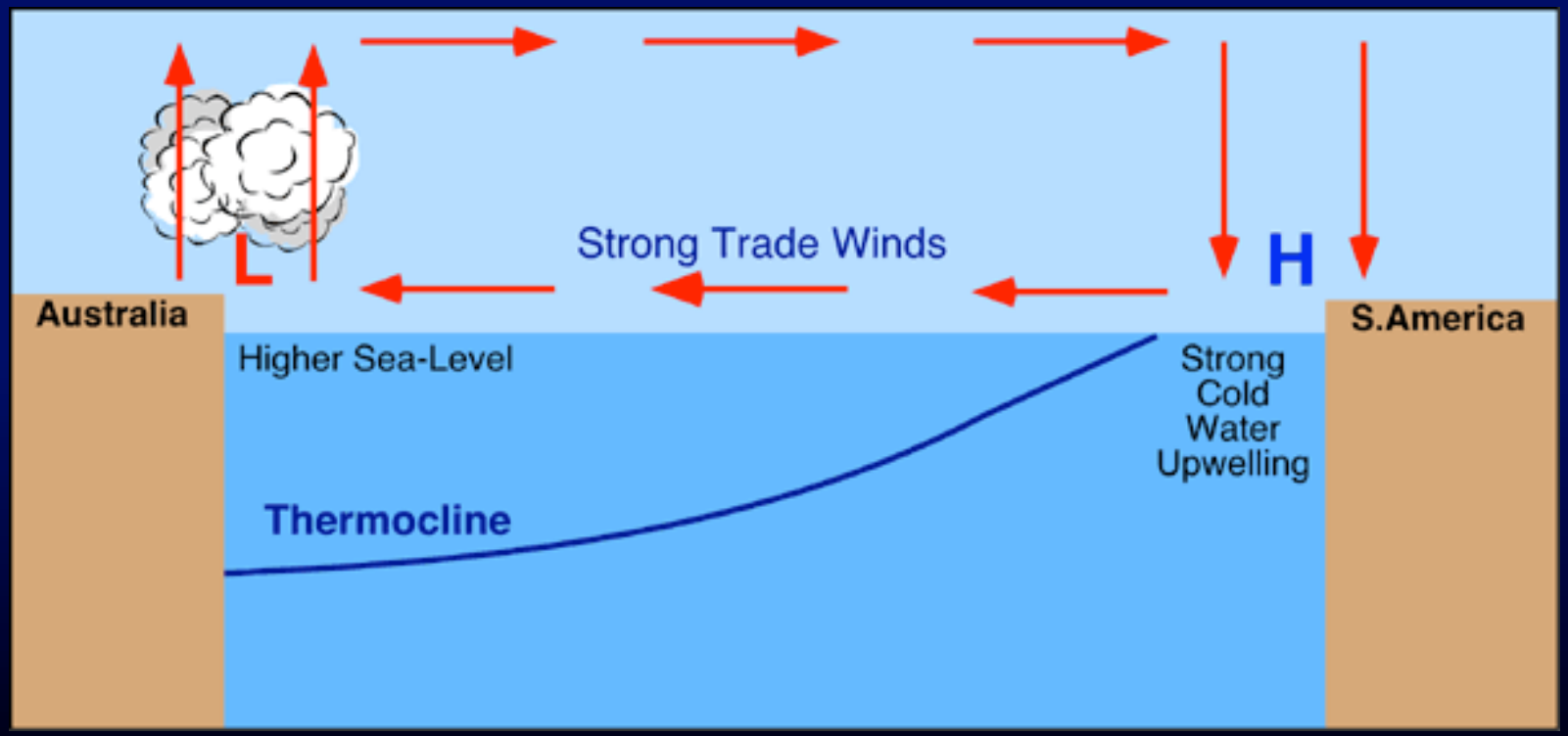
- Lost wetlands (marshes, estuaries, etc.)
- Decreased light for corals and seagrass (significant?)
- Altered ocean currents
- Increased connectivity between ocean basins
- Vertical coral reef growth? (a good thing)

EL Niño!


EL NIÑO PREDICTIONS
FOR the MONTHS AHEAD
WARMER THAN USUAL
DRIER THAN USUAL
WETTER THAN USUAL
COLDER THAN USUAL
Washington D.C.
THE USUAL
JIM BERGMAN

El Nino Southern Oscillation (ENSO)

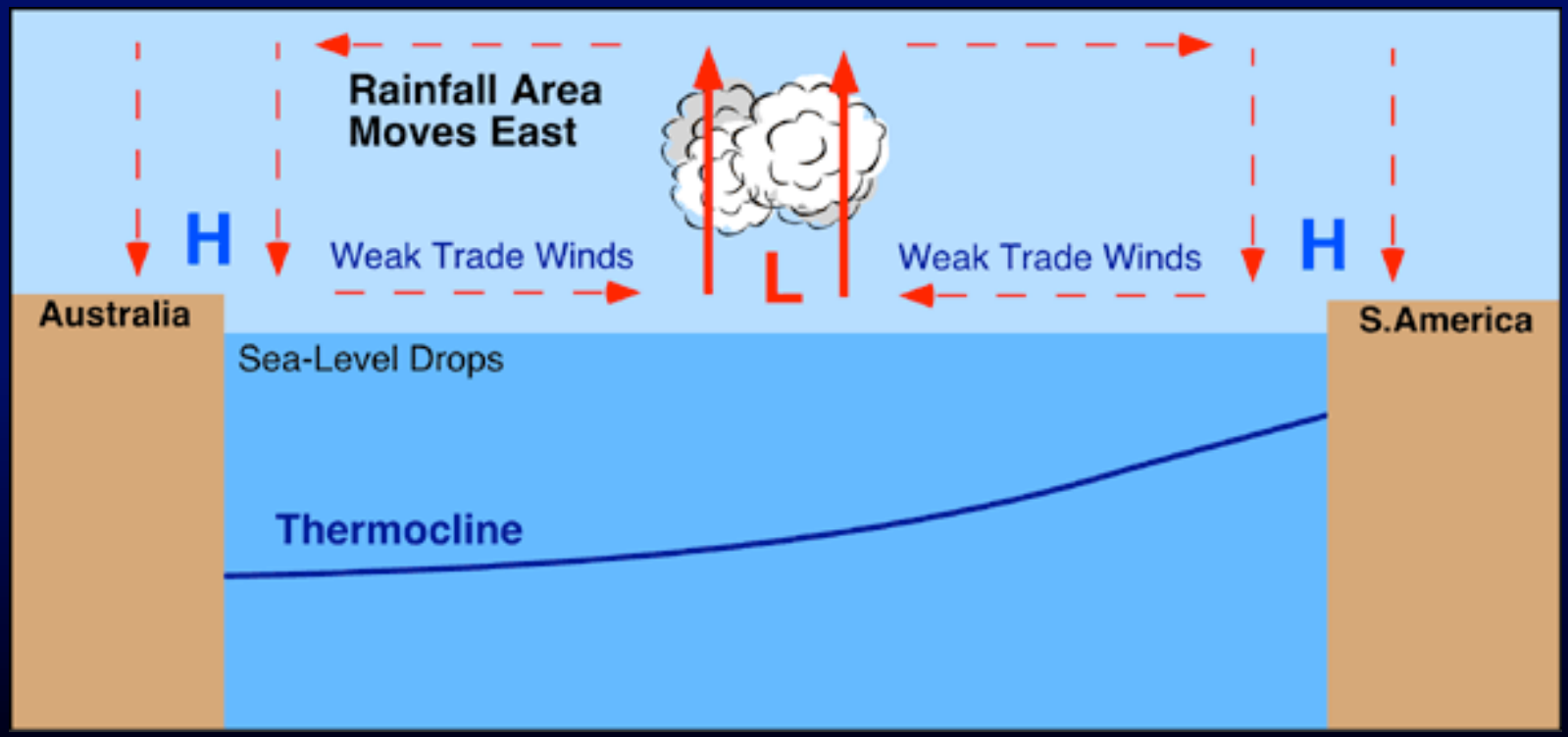
Normal conditions



Physicalgeography.net

El Nino Southern Oscillation (ENSO)

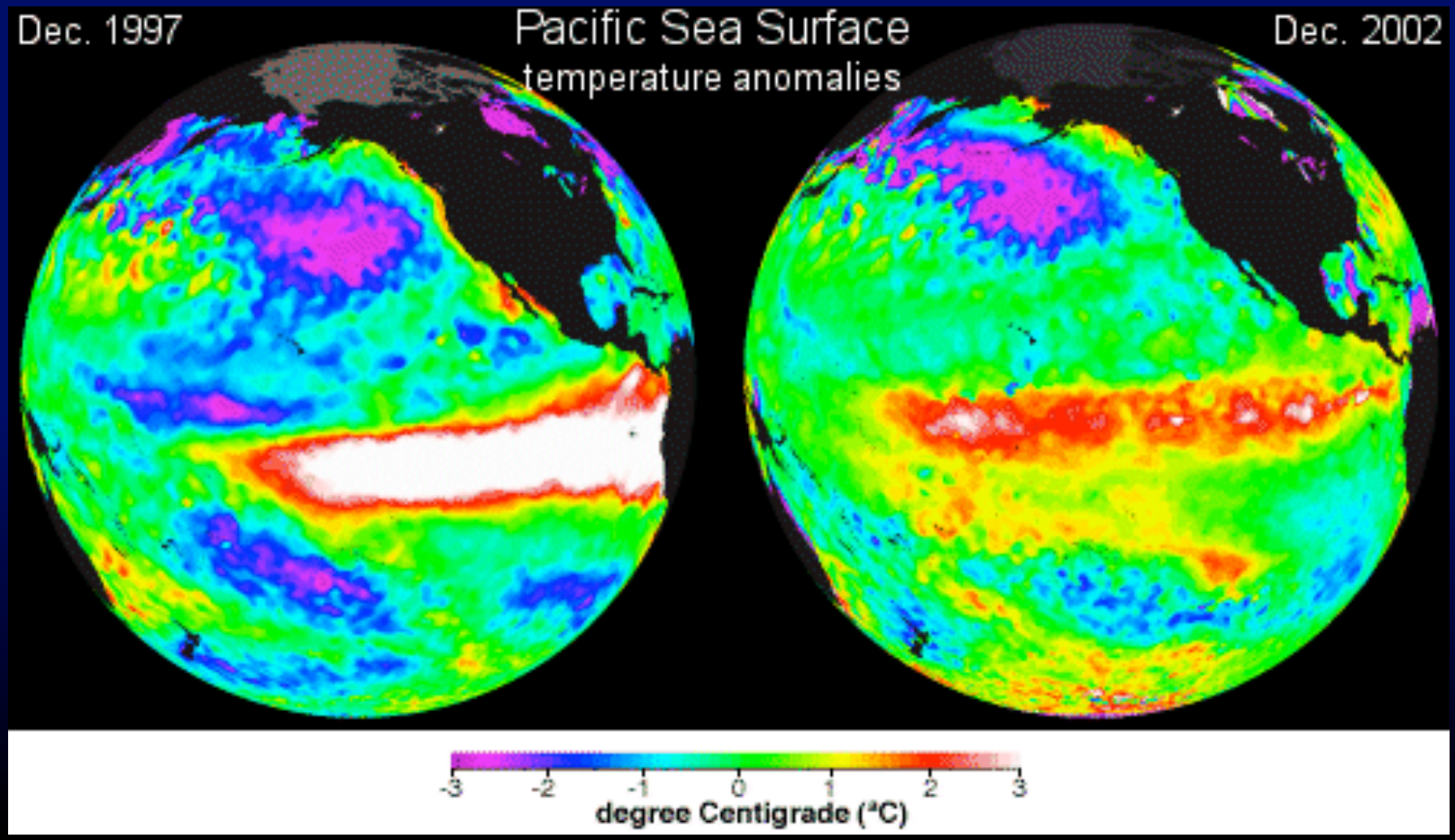
El Niño conditions



Physicalgeography.net

Isn't there a La Nina?

Strong El Nino in 1997



So, its always happened, right?

Yes, but its complicated…

Cobb et al. 2013 Science

- Some researchers have made connections in data trends that support idea of more frequent El Niño events.
- Recently, researchers measured oxygen isotopes in coral cores and found that the ENSO has been more variable and more intense in 20th century
- BUT, also in 17th C when there was not global warming
- Jury may still be out

Consequences?

But of course!

- Hot water = lots of bleaching!
- Altered winds = changes in ocean mixing and currents = effects on food webs
- Altered weather patterns such as increased or decreased rainfall = altered salinity or run-off

How about Marine Diseases??

Climate Change and Disease

Does warmer necessarily mean more disease?

Maybe…*maybe not*

Increase

- **Increasing temperature could increase disease if hosts are more susceptible infection**
  - Green turtle fibropapilloma tumors grow rapidly in summer
  - Bleaching and subsequent white syndrome in Pacific corals
- **Disease may increase if increased temperature is more favorable to pathogen**
  - Bacterial infection of soft corals in Mediterranean
- **Both factors may act synergistically**

Climate Change and Disease

Decrease

- **Disease may decrease if temperature impacts parasites more the host**
- **If host population decreases it may reduce transmission**
- **Decrease in biodiversity could decrease number of pathogens**

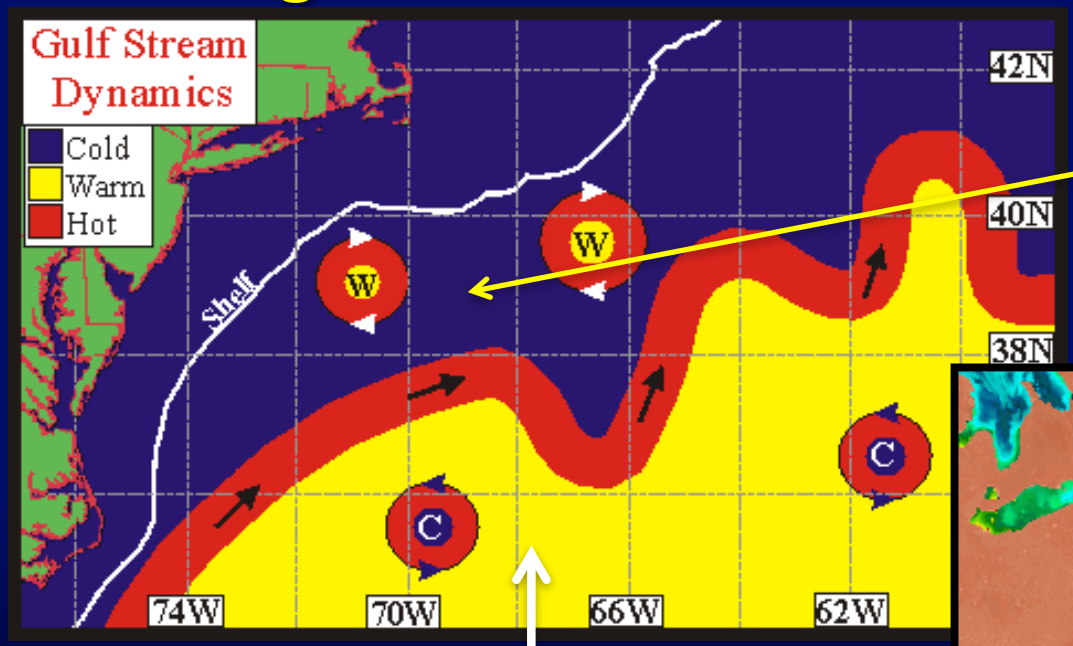
Neither (increase?)

- **Range shifts**
  - geographic range of the oyster parasite *Perkinsus marinus* extended 500 km north due to increase in winter temp
- **Increase in suitable habitat may not shift or increase range**
  -may be limited by dispersal barriers, competition and predation, intermediate host availability

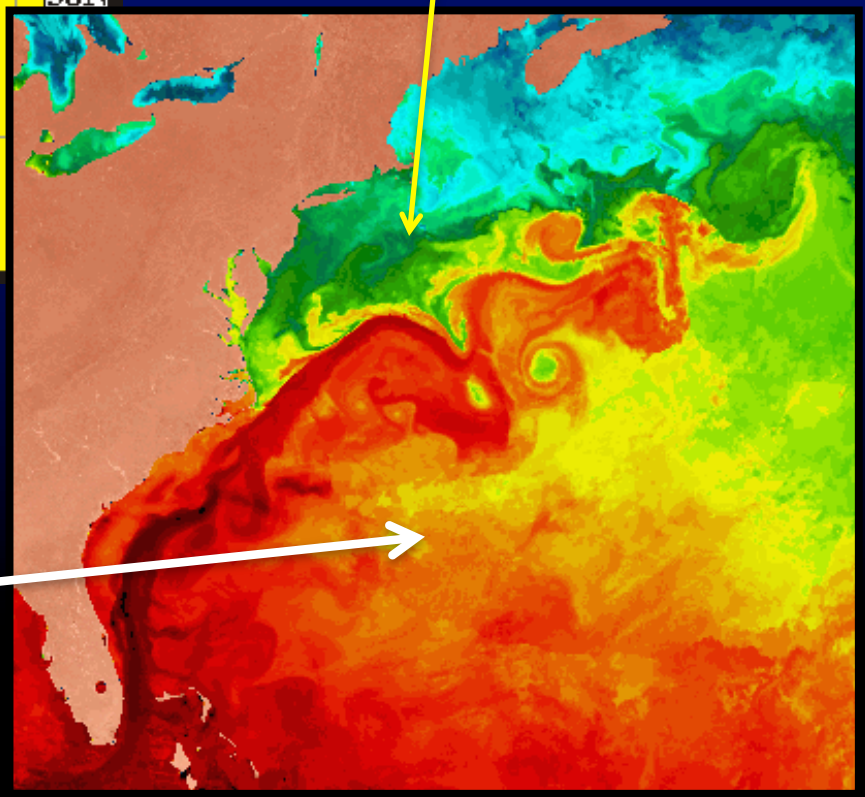
Ocean Circulation Changes?

Ocean Weather Resource Center

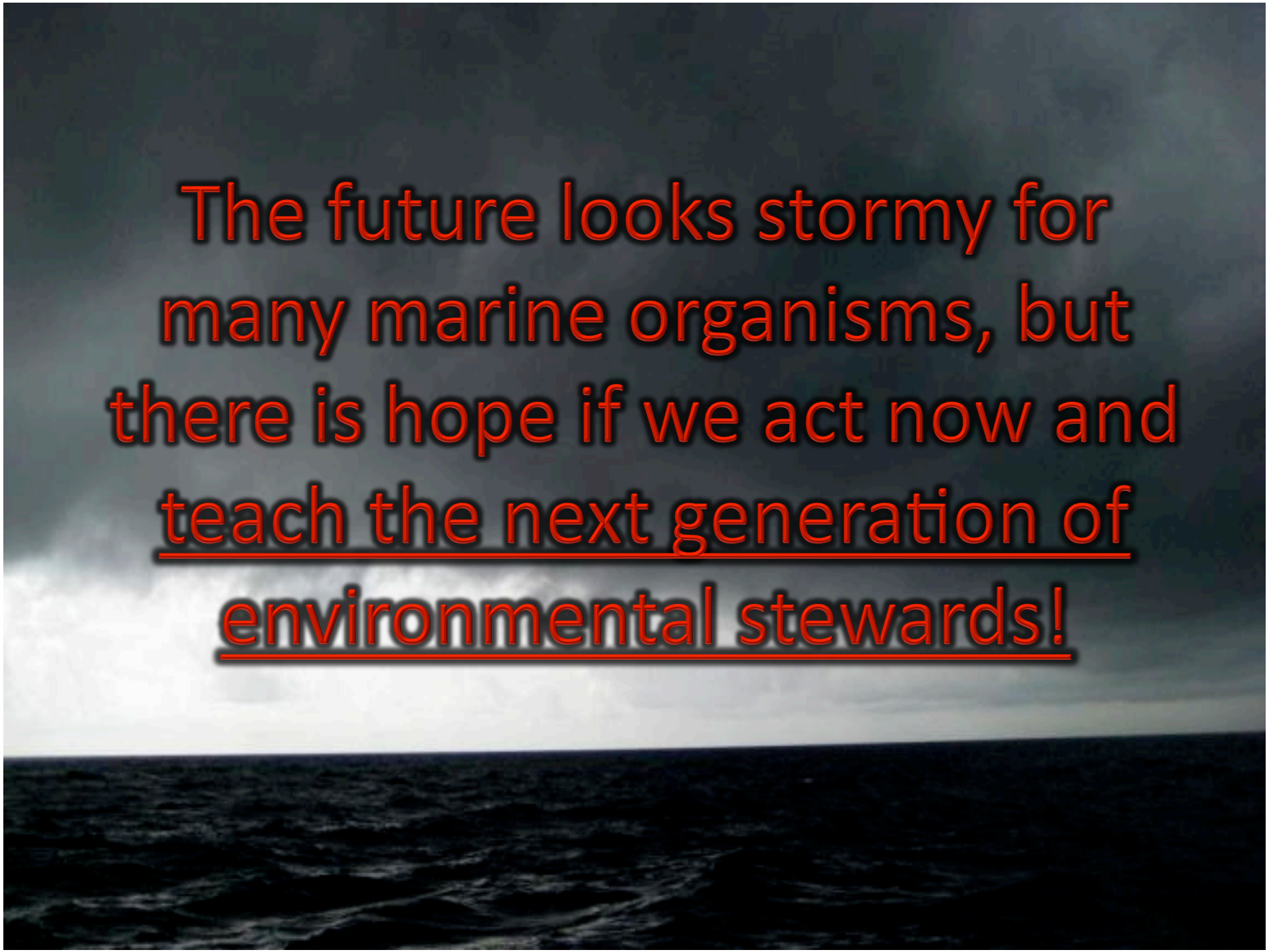
Currents are linked to the Climate, so if they Change the Climate will Change (and vice versa)



Nutrient rich, cold continental slope water

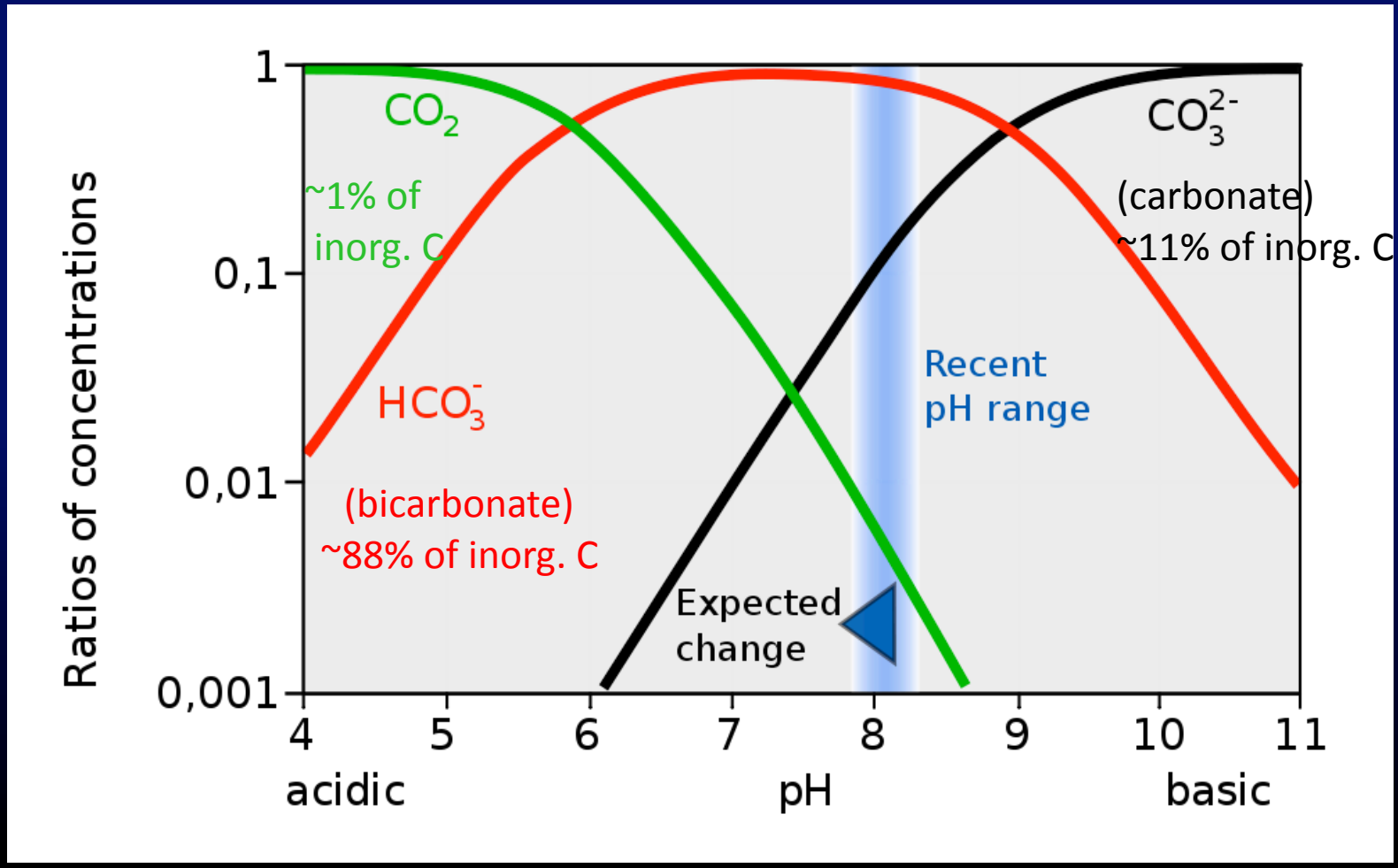


Warm, nutrient poor Sargasso Sea water

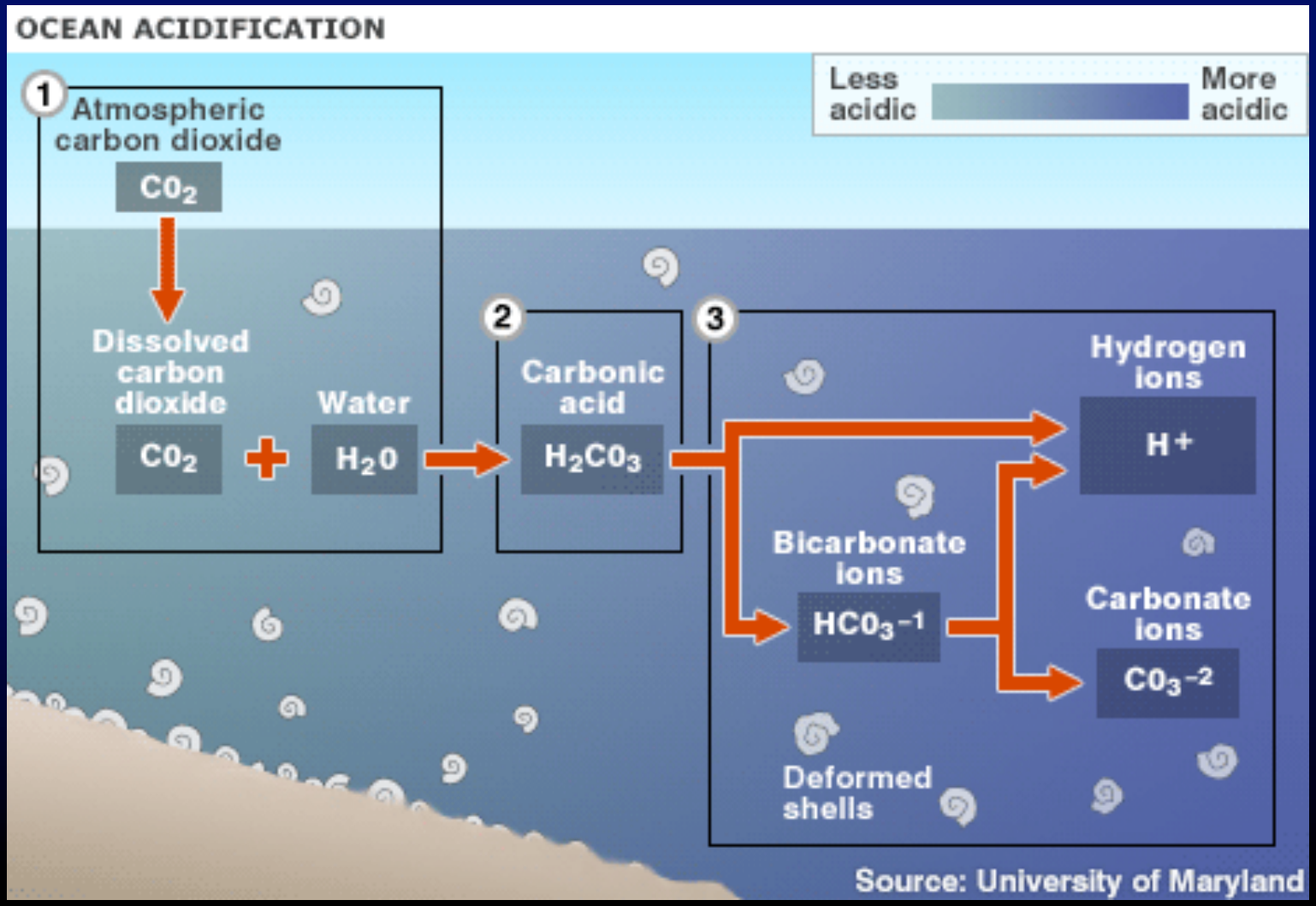

The future looks stormy for many marine organisms, but there is hope if we act now and teach the next generation of environmental stewards!


Thanks!

CO_2 Causes Acidification – How it Works



http://www.yaleclimatemediaforum.org/2008/06/covering-ocean-acidification-chemistry-and-considerations/


OCEAN ACIDIFICATION
Less acidic
More acidic
1
Atmospheric carbon dioxide
CO_2
Dissolved carbon dioxide
CO_2
Water
H_2O
2
Carbonic acid
H_2CO_3
3
Hydrogen ions
H^+
Bicarbonate ions
HCO_3^{-1}
Carbonate ions
CO_3^{-2}
Deformed shells
Source: University of Maryland