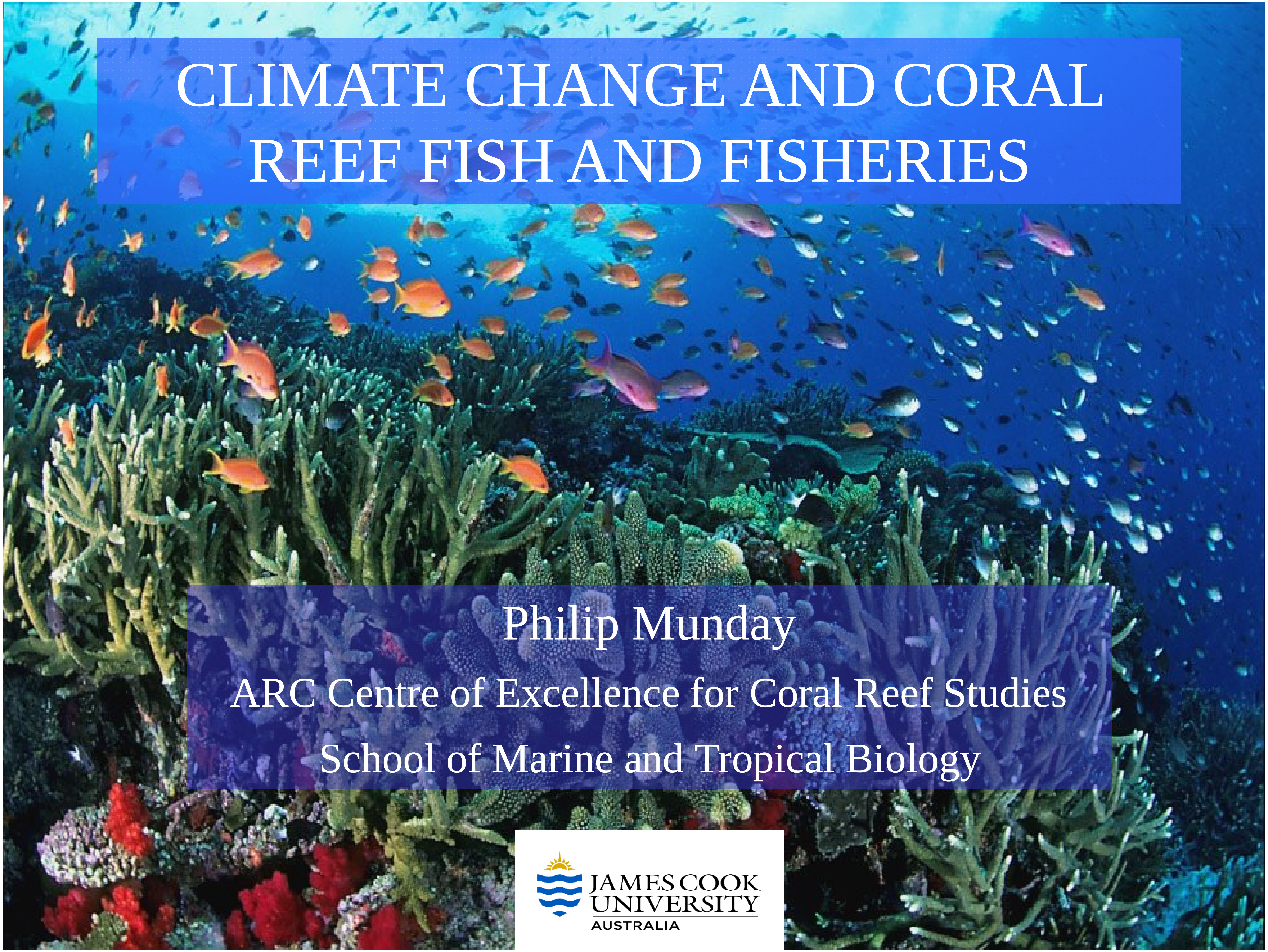

CLIMATE CHANGE AND CORAL REEF FISH AND FISHERIES

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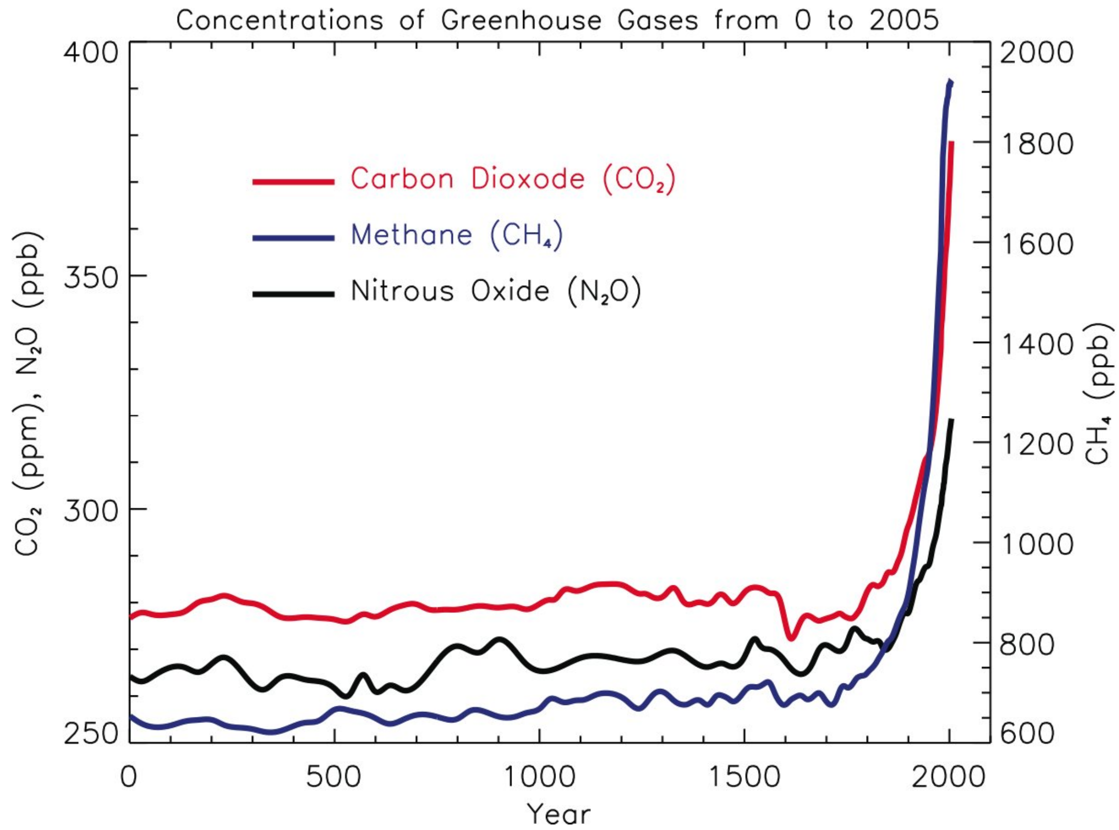
ARC Centre of Excellence for Coral Reef Studies

School of Marine and Tropical Biology

JAMES COOK UNIVERSITY
AUSTRALIA

Greenhouse gas concentrations

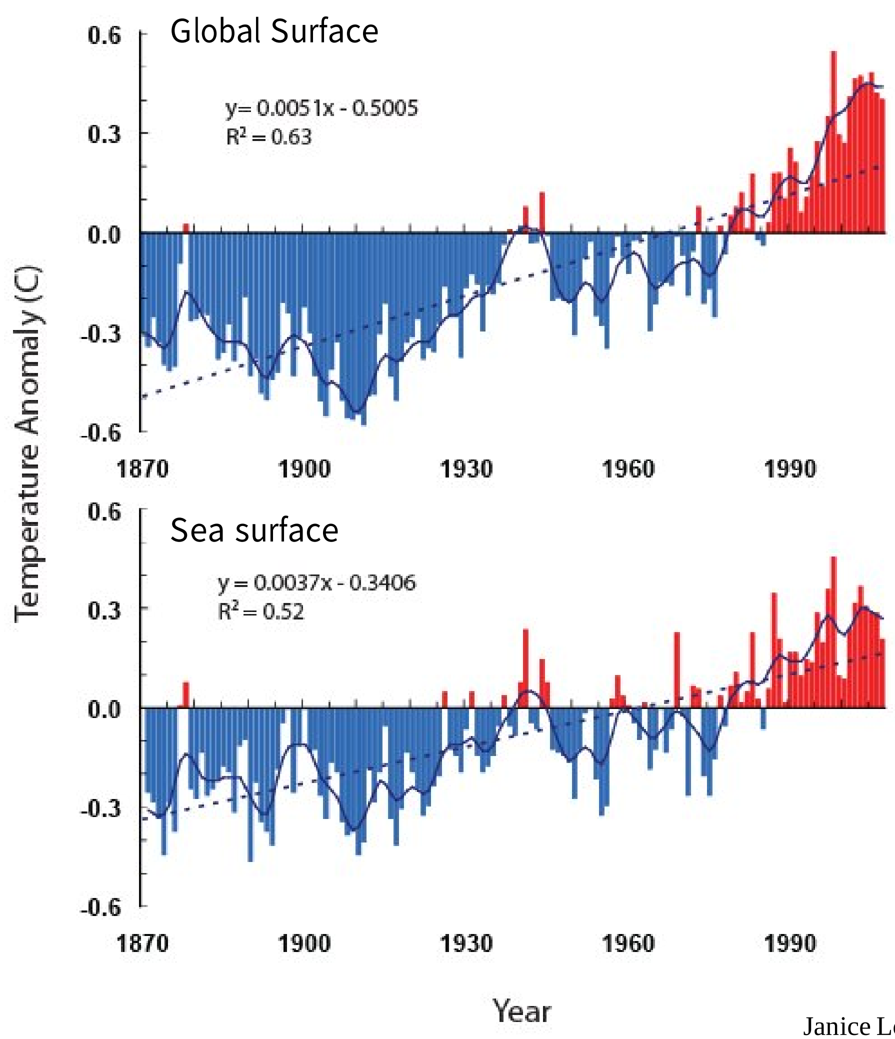
- CO_2 increased ~40% in 250 years
- 280ppm pre-industrial
- 390ppm now



IPCC 2007 Chapter 2 WGI FAQ2.1

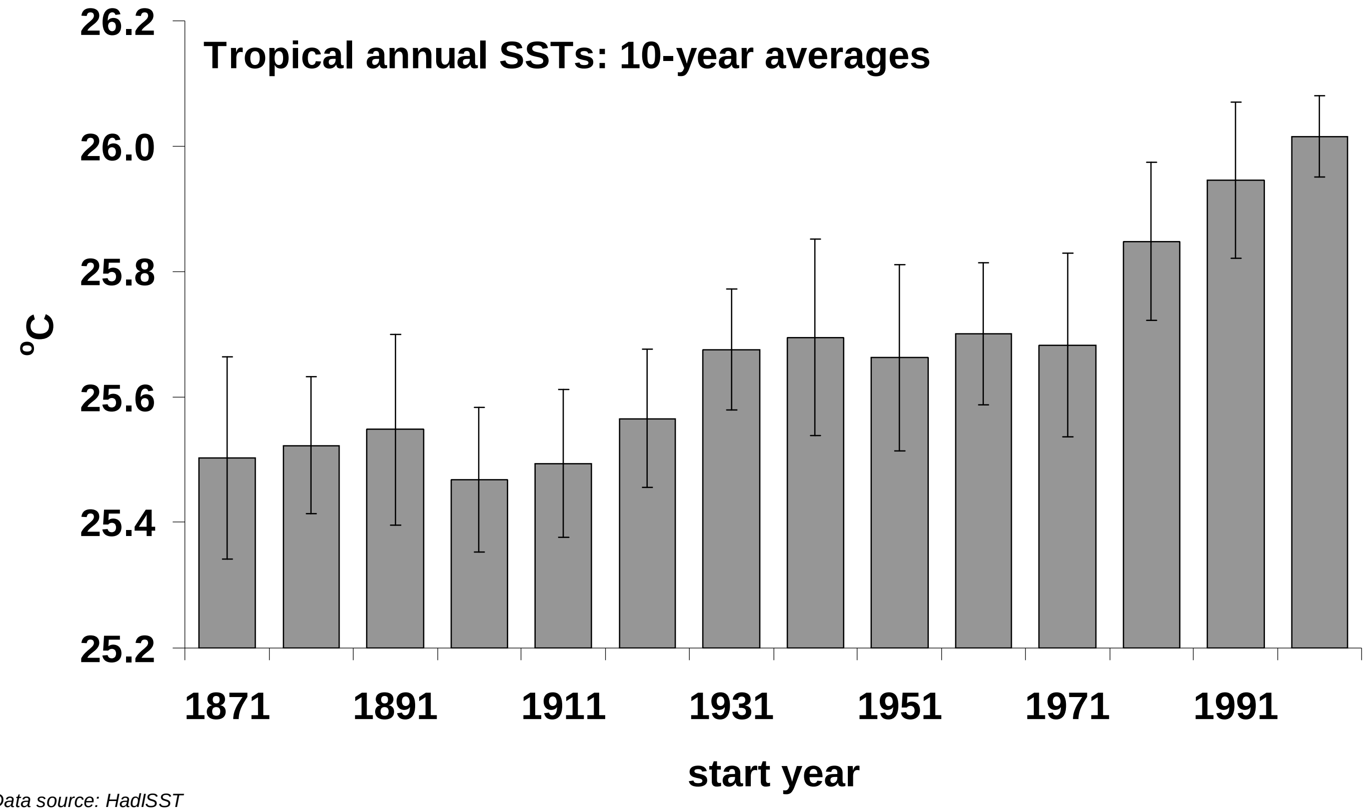
Enhanced Greenhouse Effect

- Average surface temperature highest for >1000 years
- Average ocean temperature increasing
- Tropical SST increased ~0.5C 1871-2007



Janice Lough AIMS

Last decade hottest on record



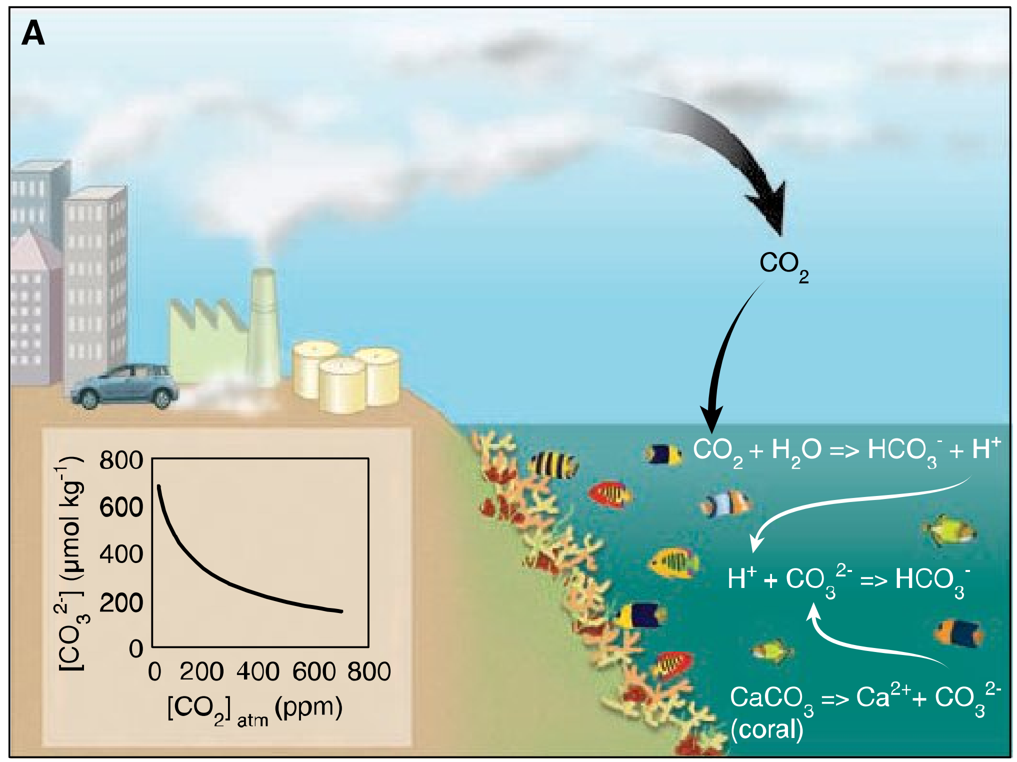
Data source: HadISST

Janice Lough AIMS

The other CO_2 problem

- Ocean acidification
- 30% of excess CO_2 absorbed by the ocean
- Ocean becomes more acidic and changes carbonate chemistry

↑ pCO2, carbonic acid, bicarbonate, H^+

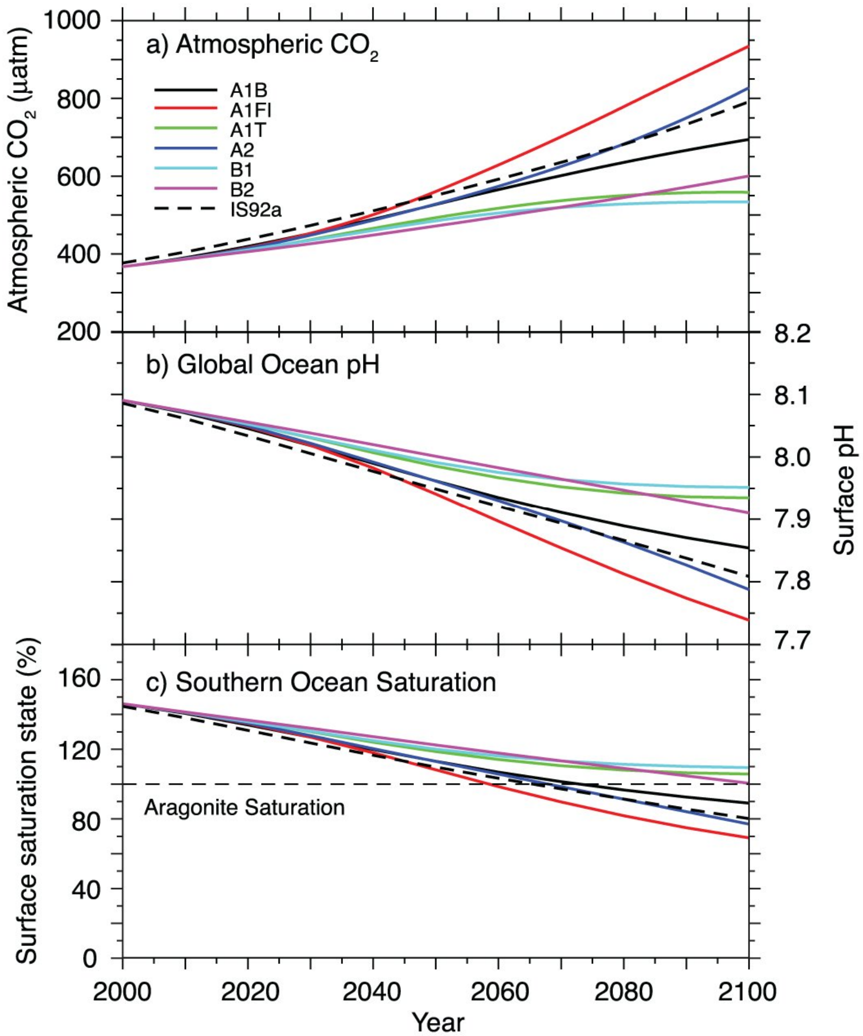


Hoegh-Guldburg et al. 2007

↓ carbonate, pH (-logH^+)

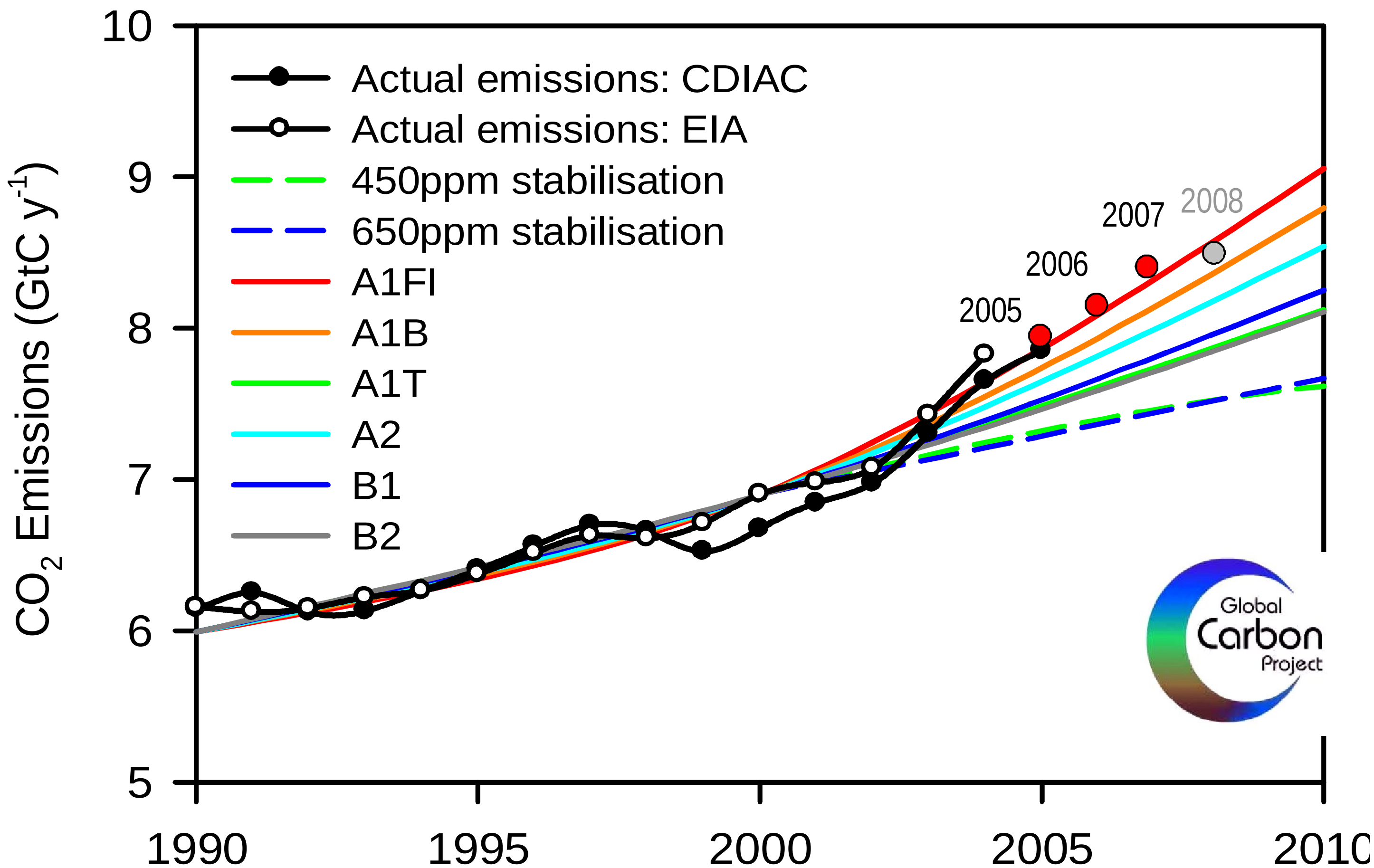
Projected CO_2 and ocean pH

- Ocean pH dropped 0.1 units since pre-industrial
- pH could drop another 0.3-0.4 units by 2100 depending on emissions
- Problem for marine calcifiers: corals, sea urchins, molluscs



IPCC 2007 Chapter 10 Global Climate Projections

Carbon dioxide emissions tracking high-end scenarios



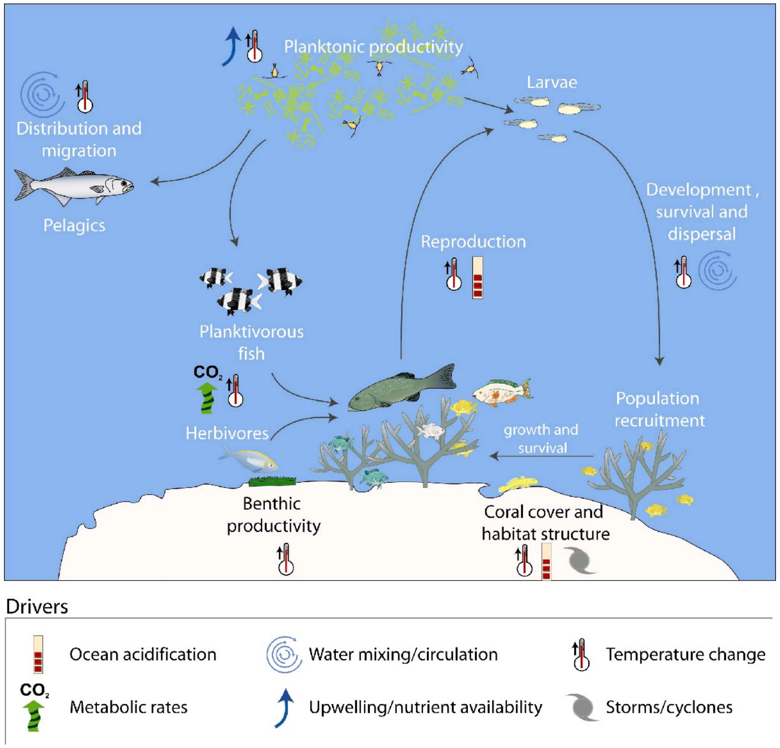
Raupach et al 2007, PNAS; Global Carbon Project 2009, Canadell June 2009

Projected climate changes by 2100

Global surface temperature	Increase 2-4^{o}C (6^{o}C)
Sea surface temperature	Increase 1-3^{o}C
Tropical storms	Stronger
Droughts and floods	More extremes
Sea level	Increase up to 0.6m
Ocean pH	Decrease 0.3-0.4 units

Impact on coral reef fishes

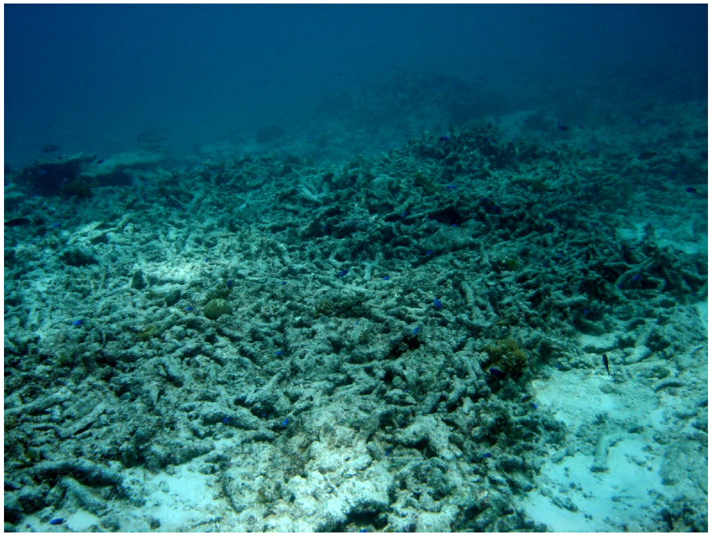
- Indirect: Habitat degradation
  - Diversity and abundance
  - Species composition
- Direct: Individual performance
  - Population sustainability
  - Population variability
  - Life histories (size & growth)
- Range shifts
- Productivity changes



Munday et al. 2008. Fish and Fisheries 9, 261-285

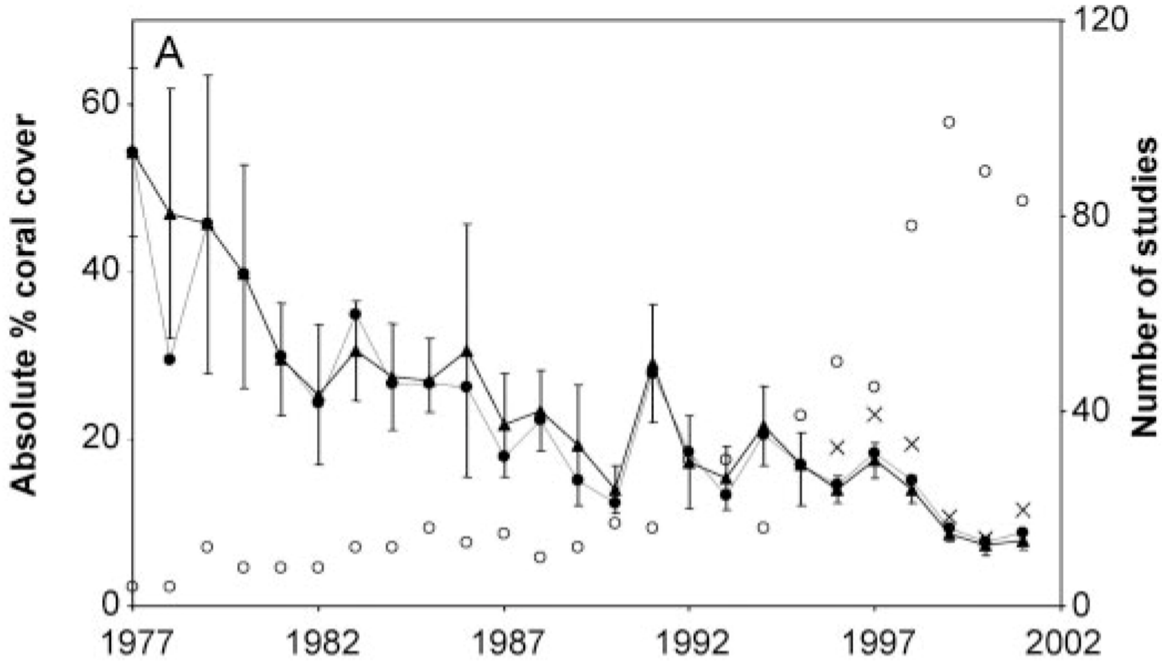
Climate change & habitat degradation

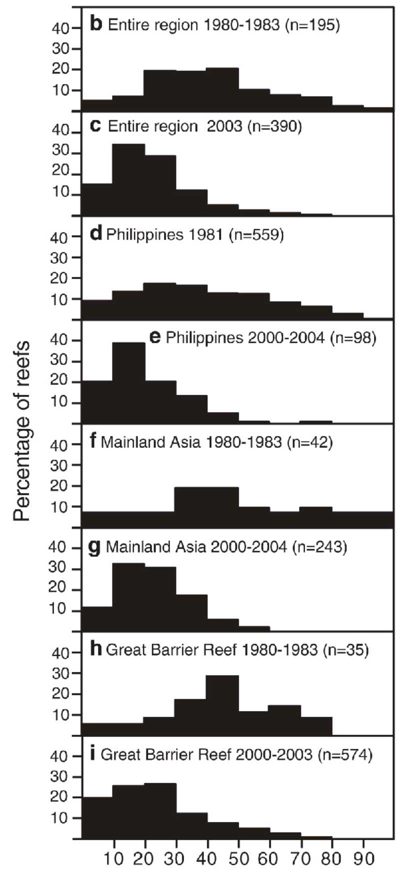
- Warming ocean
  - Mass coral bleaching
- Ocean acidification
  - Reduced calcification
- Stronger storms
  - More physical damage
- Loss of coral cover
- Shift in community composition - resilient species



Declining health of coral reefs

- Over 30% of world reefs seriously degraded
- Declining coral cover



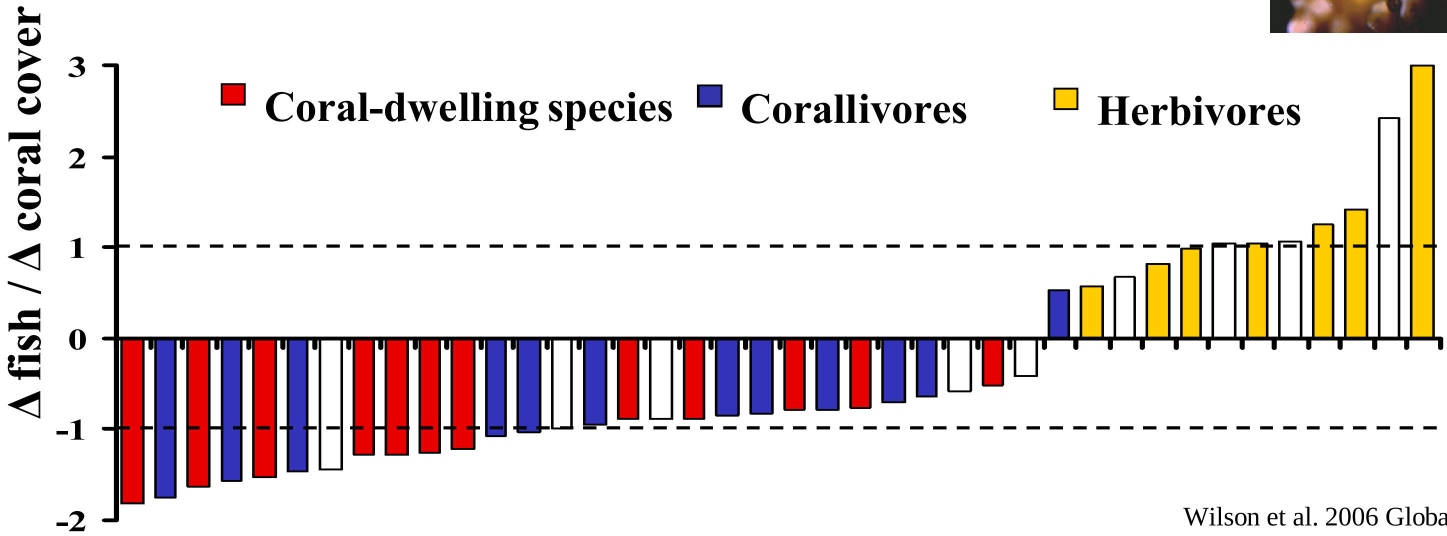


Gardner et al 2003 Science 301, 958-960

Bruno & Selig 2007 PLOSOne e711

Coral loss

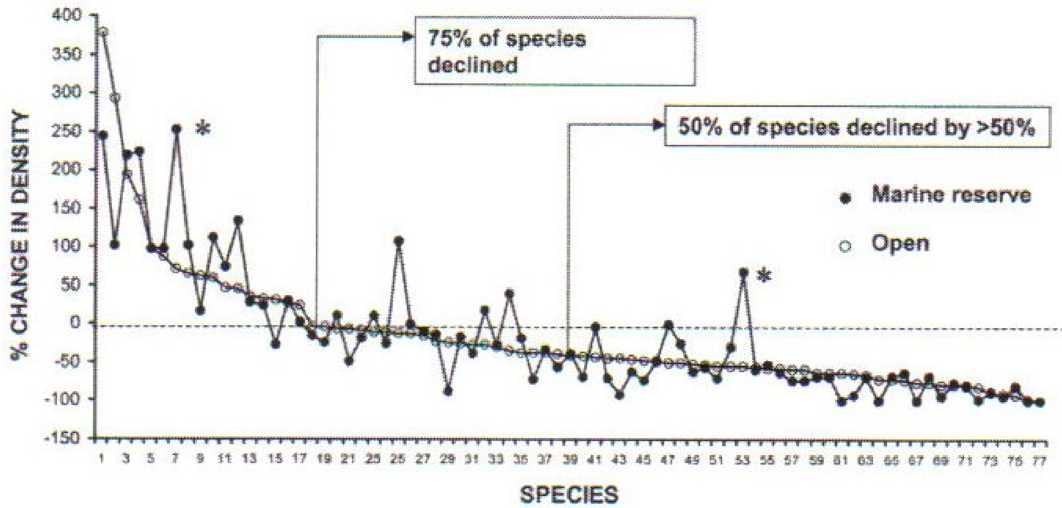
- 10 % of fishes are coral dependent
- Directly affected by coral loss



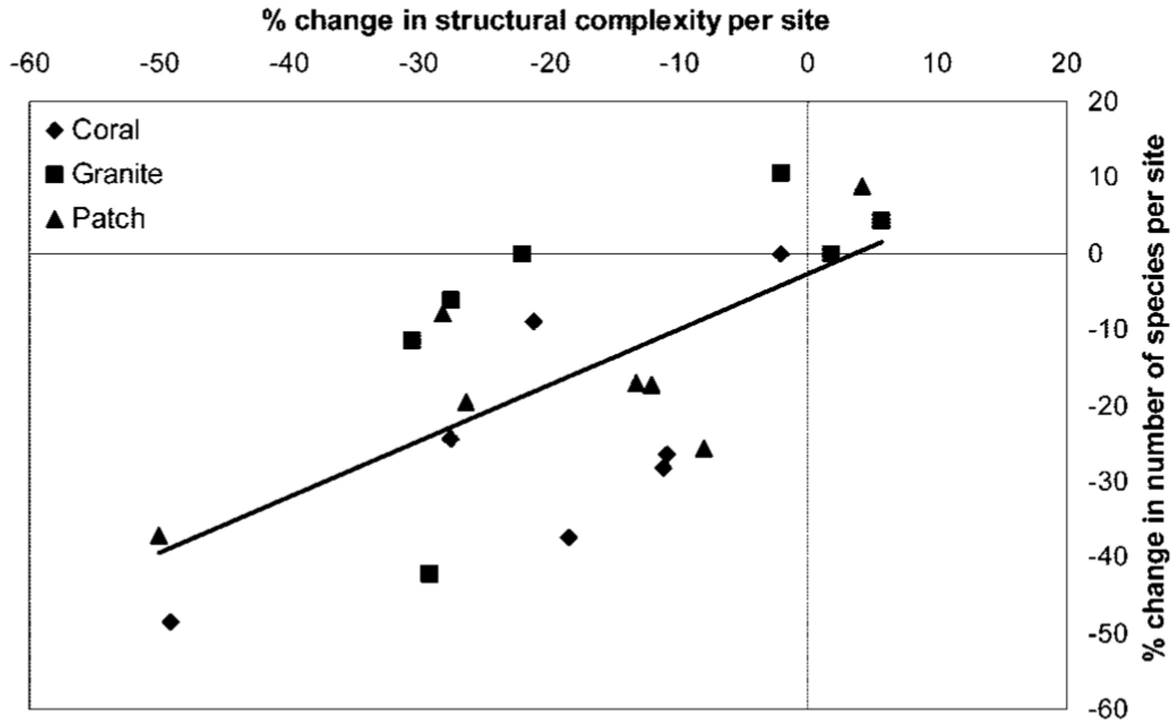
Wilson et al. 2006 Global Change Biology 12, 2220-2234

Coral loss

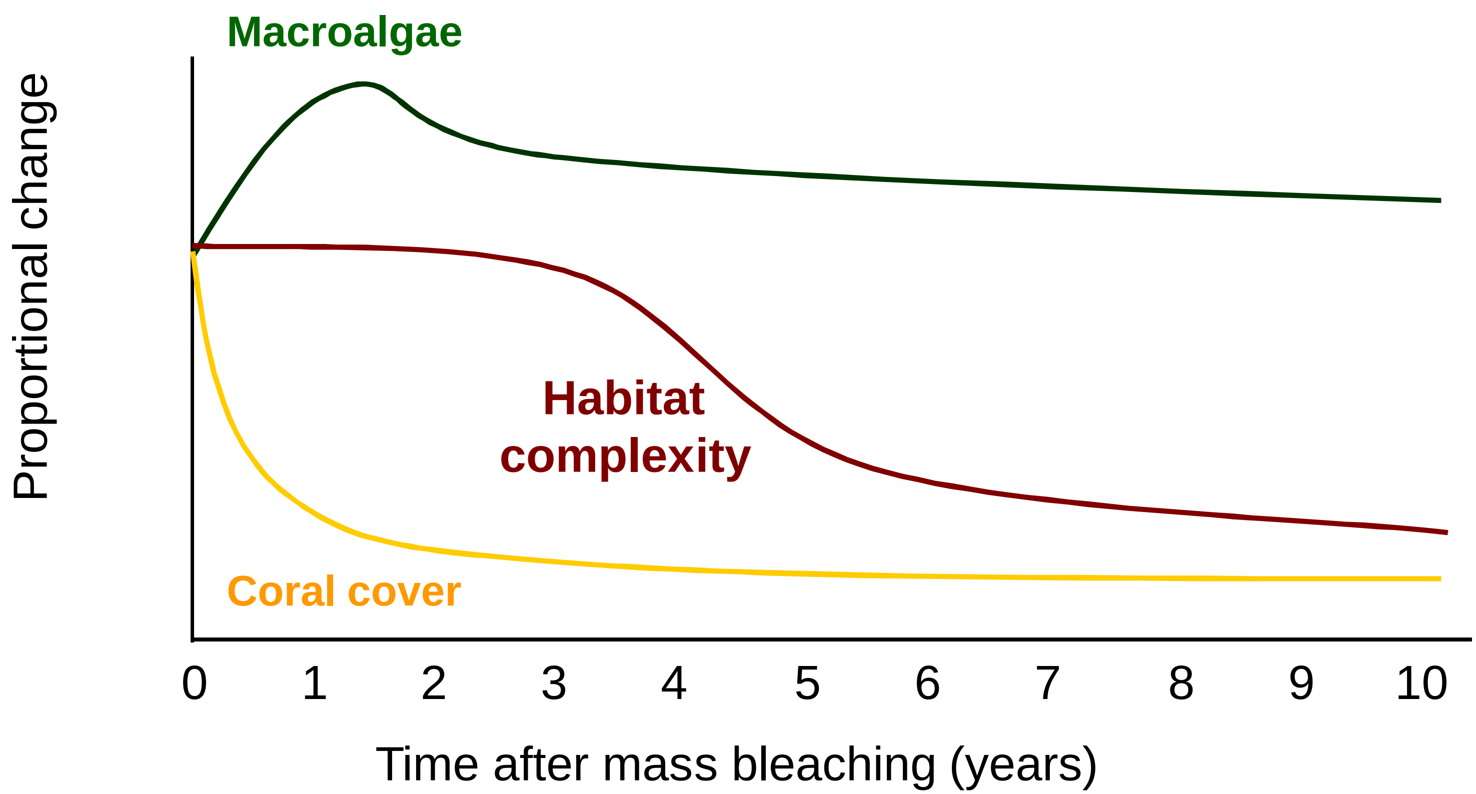
Jones et al. 2004. PNAS. 101: 8251-8253



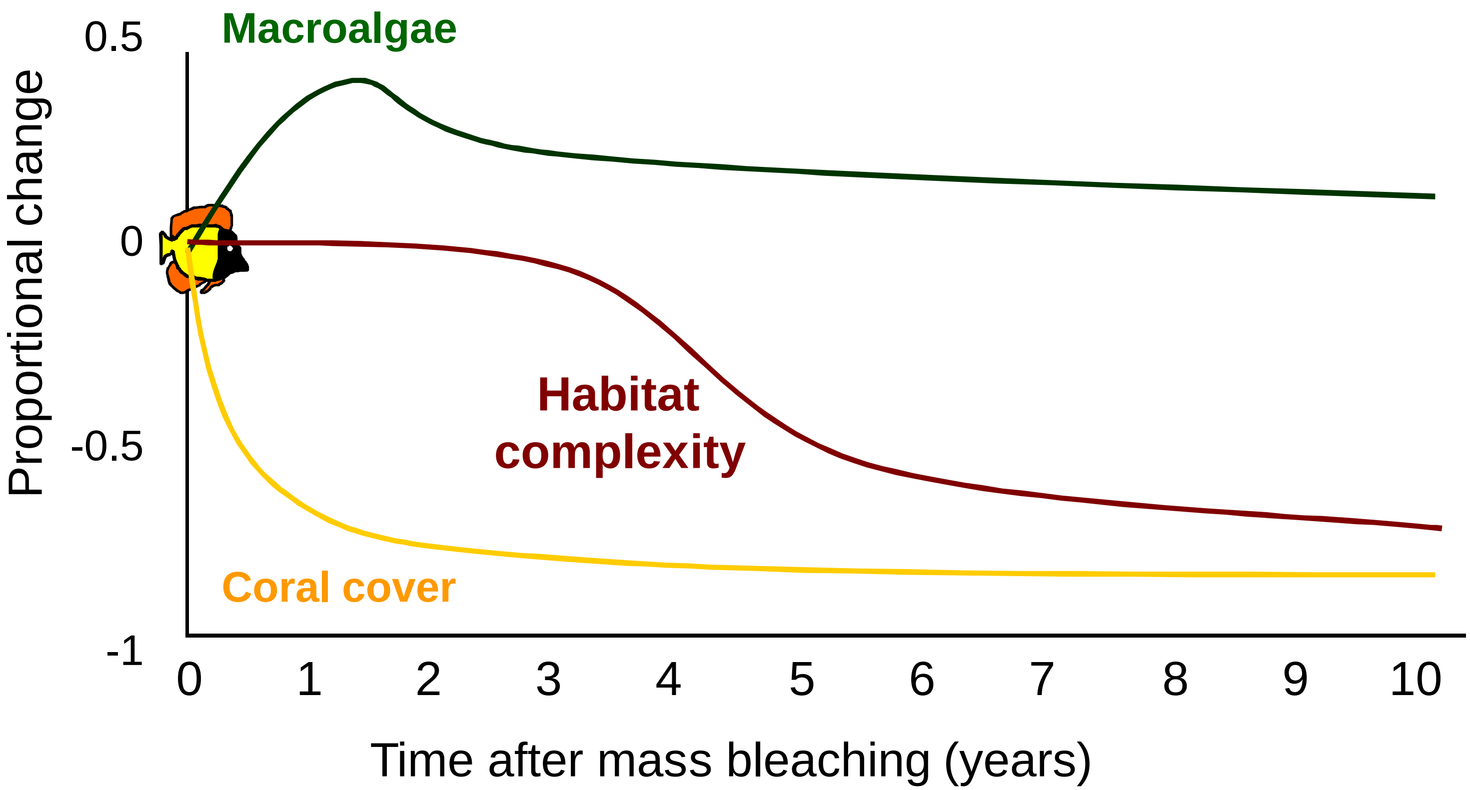
- But, 75% of species declined following coral decline
- 50% of species declined by >50%
- Small juveniles live in or near live coral



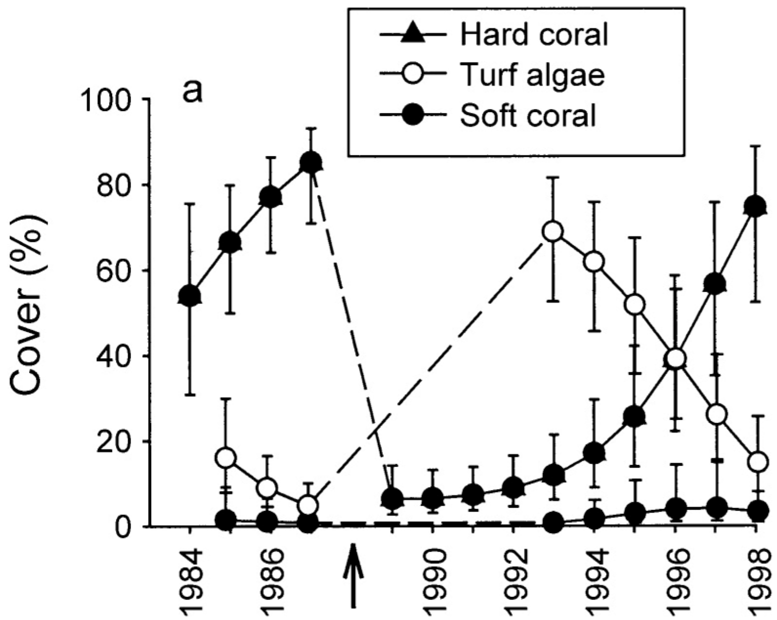
Graham et al. 2006 PNAS 103:8425

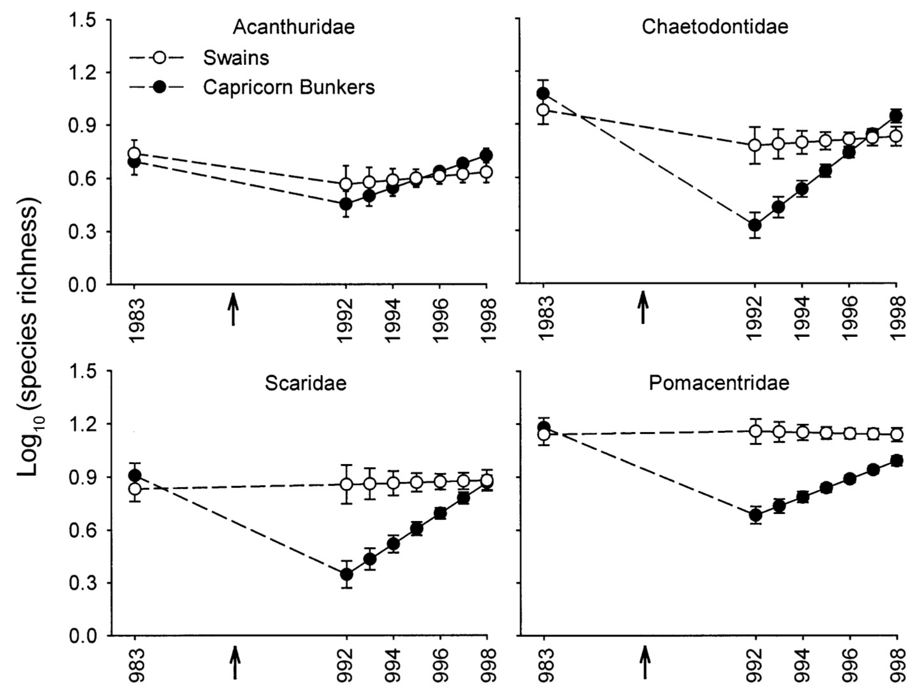


Macroalgae
Proportional change
Habitat complexity
Coral cover
0
1
2
3
4
5
6
7
8
9
10
Time after mass bleaching (years)


Macroalgae
Habitat complexity
Coral cover
Proportional change
0.5
0
-0.5
-1
0 1 2 3 4 5 6 7 8 9 10
Time after mass bleaching (years)

Resilience and recovery

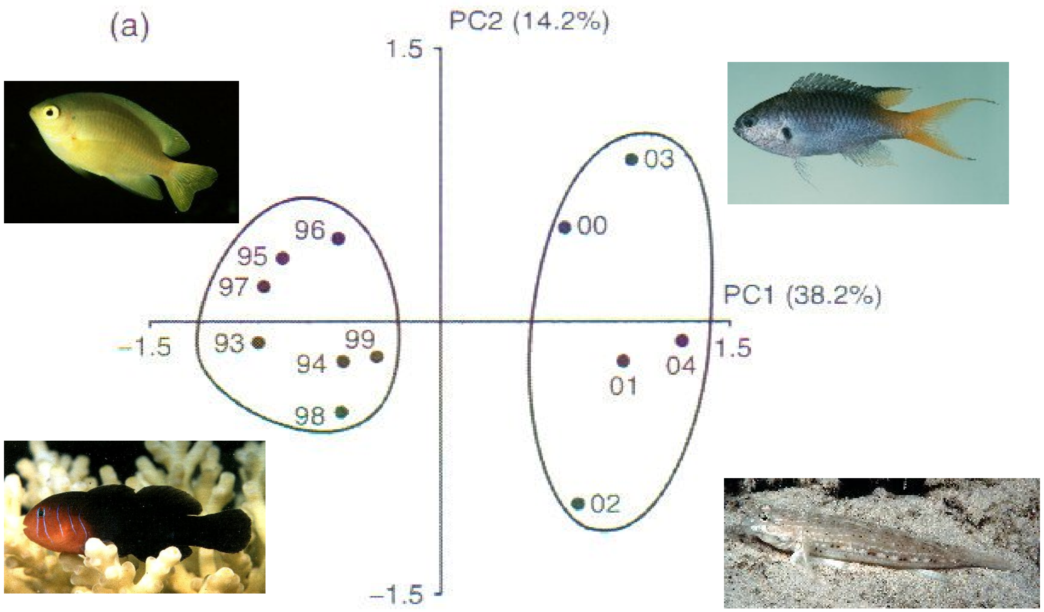


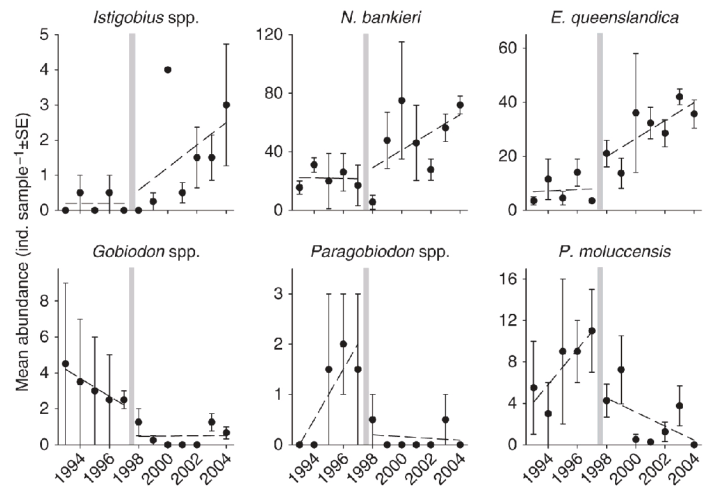


Coral cover and fish populations recovered over 8 years to near pre-disturbance abundances

Halford et al 2004. Ecology 85, 1892-1905

Regime shift





Post-bleaching regime shift on patch reefs

Fewer specialist and more generalist species

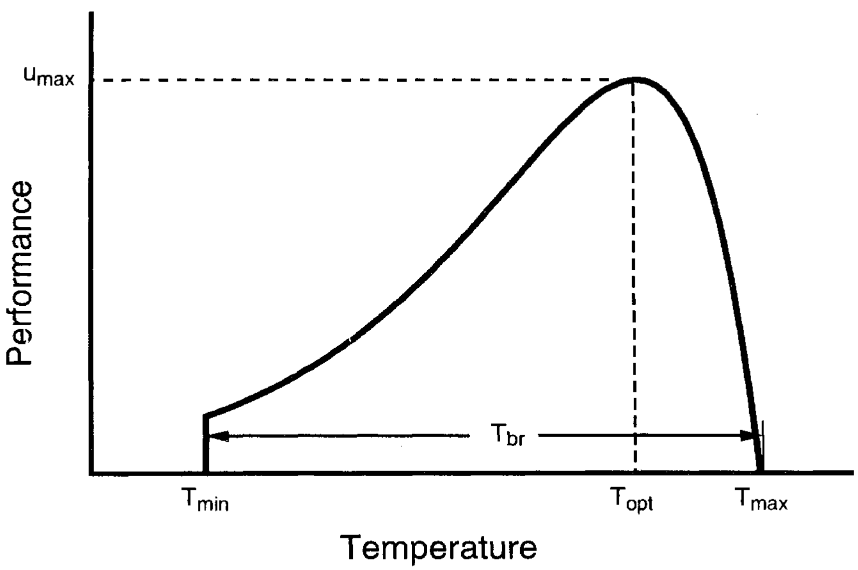
Bellwood et al 2006. Global Change Biology. 12: 1587-1594.

Coral loss and fish communities

- Depends on frequency and size of disturbances
  - recovery cycles
- Fewer species
  - coral dependent species lost first
- Lower abundances
  - loss of settlement habitat & shelter
- Changed fish communities
  - more generalists
  - Roving herbivores often increase in abundance (e.g. surgeonfishes). May be important in removing algae and facilitating reef recovery.
- Incomplete recovery and regimes shifts likely

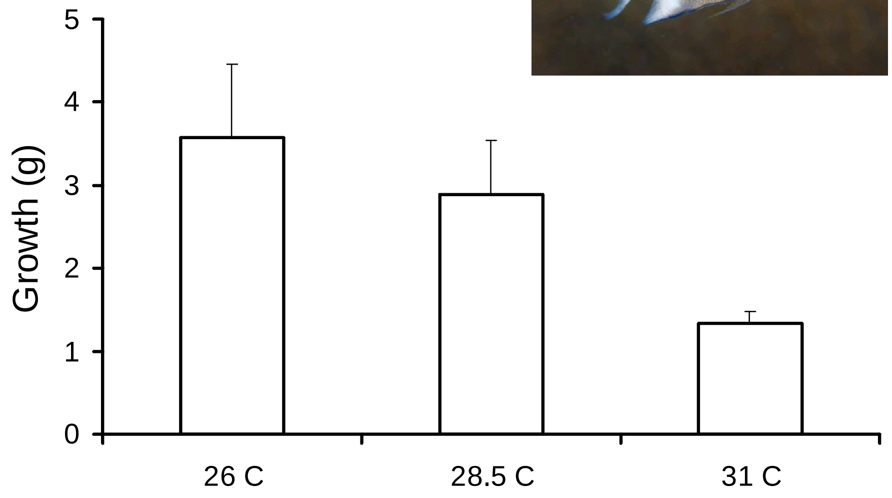
Direct Effects: Temperature

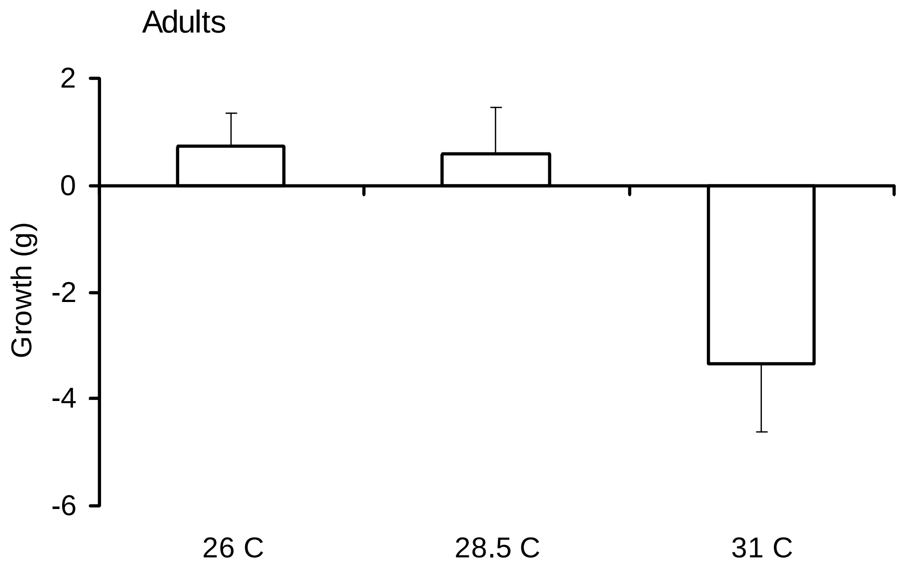
- Most reef fishes not living near lethal thermal limits
- Ectotherms - temperature affects physiological condition, development, growth rate, reproduction
- Tropical species sensitive to temperature change



Growth

- Reared at summer:
  - average 28.5ºC
  - minimum 26ºC
  - maximum 31ºC
- Lower growth at higher temperature
- Adults lost weight at 31ºC
- Already at thermal limits during summer

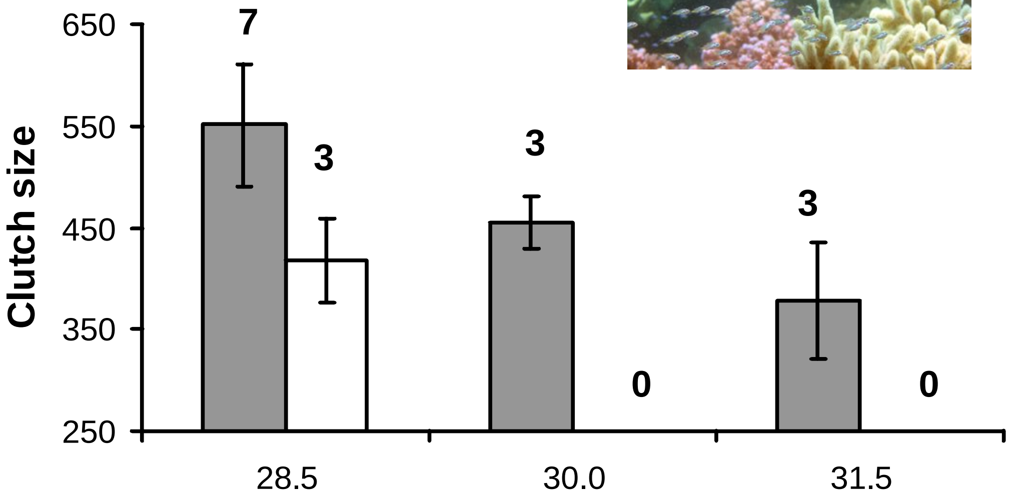


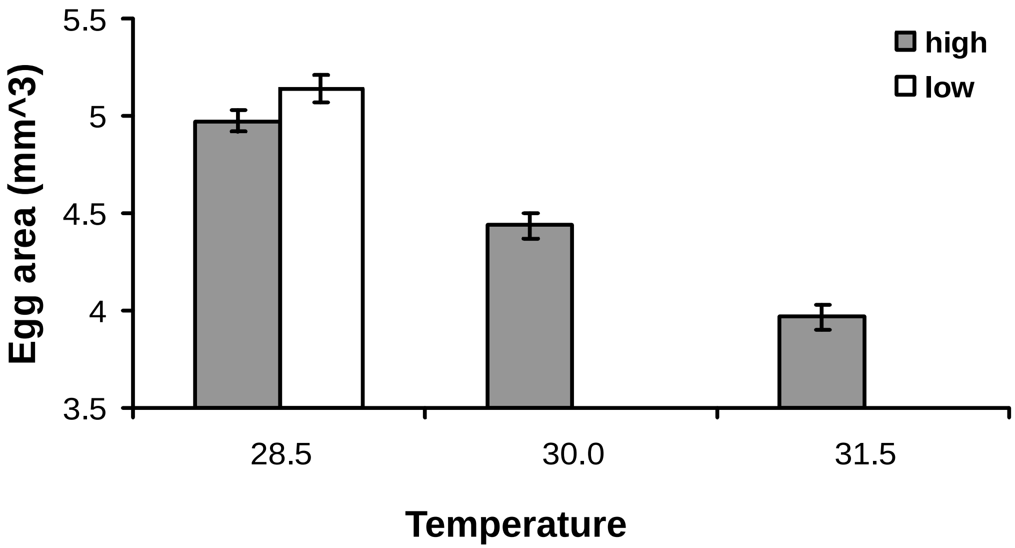


Munday et al. (2008) Coral Reefs. 27: 927-931.

Reproduction

- Reduced spawning
- Reduced clutch size
- Reduced egg size
- Reduced offspring size

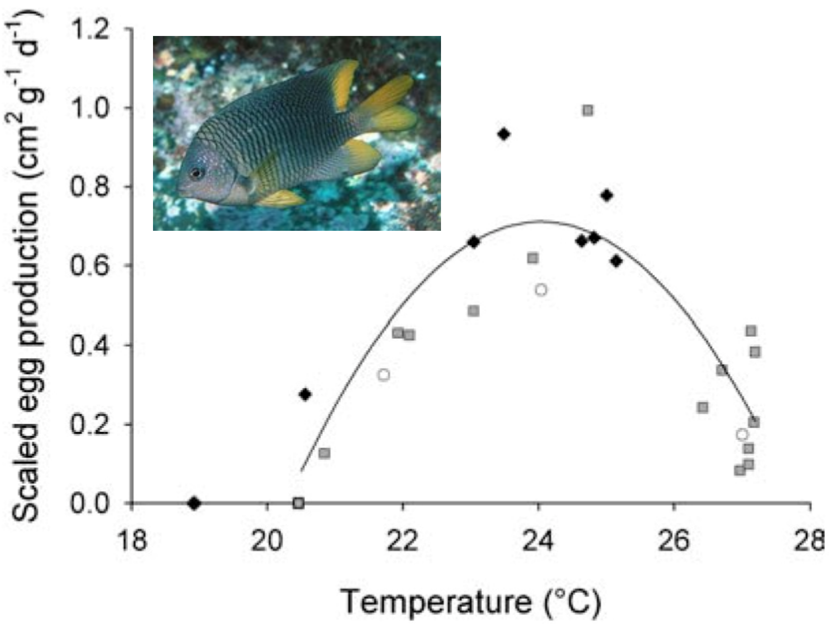




Donelson et al. 2010 MEPS In press

Reproduction

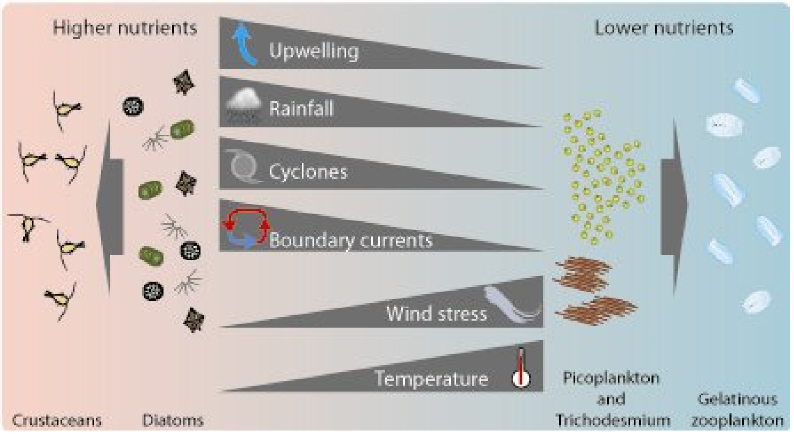
- Confined to narrow temperature range (5^{o}C)
- Breeding cued by temperature in some species - earlier breeding
- Reproductive output could be retarded
- Consequences for population replenishment

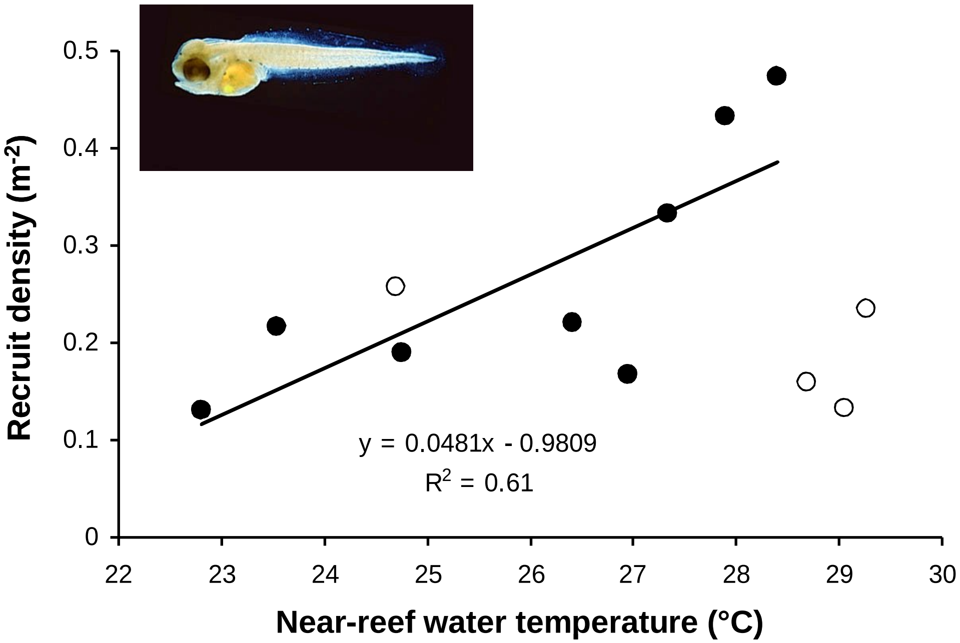


Ruttenberg 2005 Oecologia 145: 394-403

Larval survival

- Faster development = higher survival
- But, planktonic food supply affected by warmer water
- More extremes in number of larvae surviving to replenish adult populations
- Harder to manage fisheries

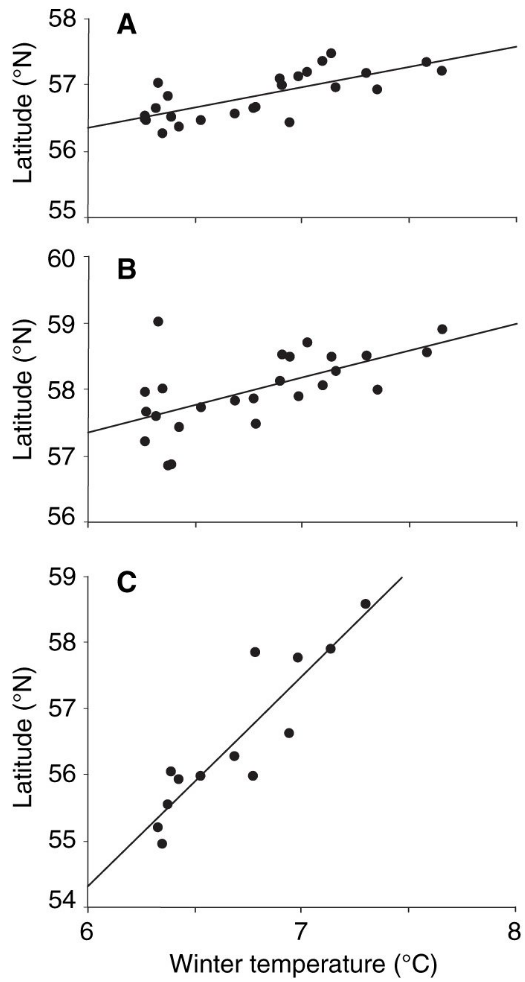




Sponaugle et al. MEPS 308, 1-15

Range shifts

- Widely recorded for temperate and polar fishes
- Tropical species being found at higher latitudes



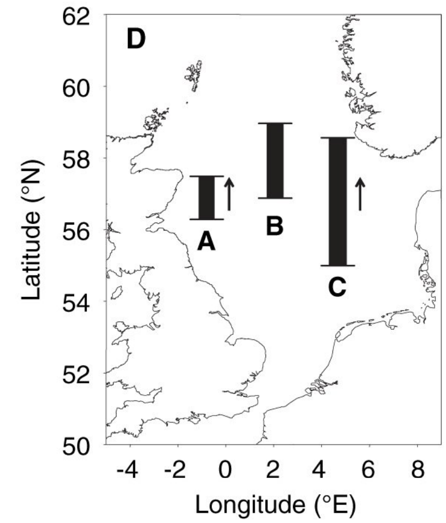


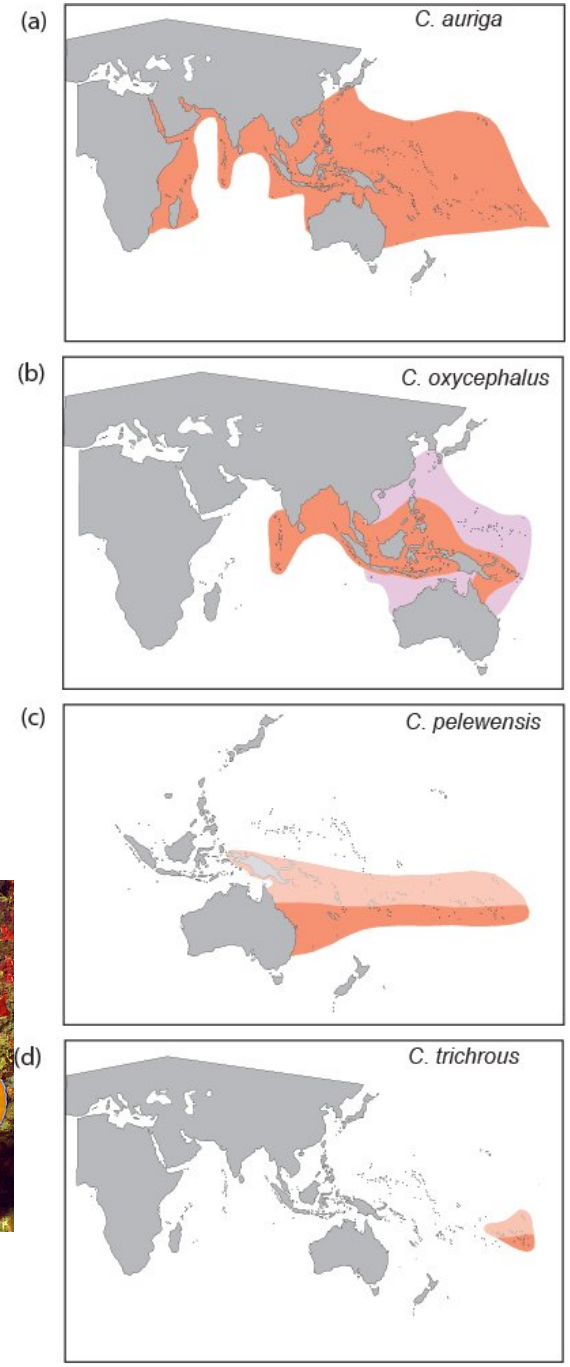
Fig. 1. Examples of North Sea fish distributions that have shifted north with climatic warming. Relationships between mean latitude and 5-year running mean winter bottom temperature for (**A**) cod, (**B**) anglerfish, and (**C**) snake blenny are shown. In (**D**), ranges of shifts in mean latitude are shown for (A), (B), and (C) within the North Sea. Bars on the map illustrate only shift ranges of mean latitudes, not longitudes. Arrows indicate where shifts have been significant over time, with the direction of movement. Regression details are in Table 1.

Perry et al. 2005 Science 308:1912-1915

Range shifts

- Increase or decrease
- Existing range
- Thermal tolerance

Munday et al. (2008). Fish and Fisheries 9 261-285



35%

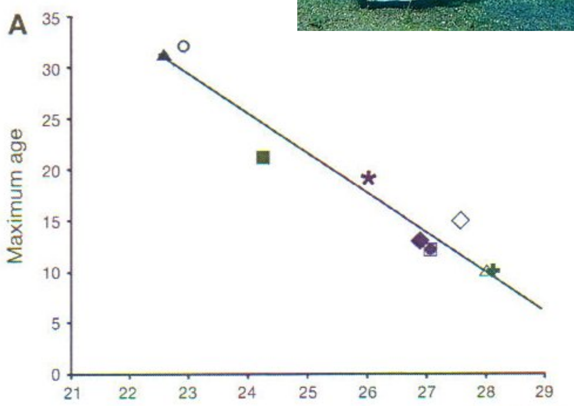
20%

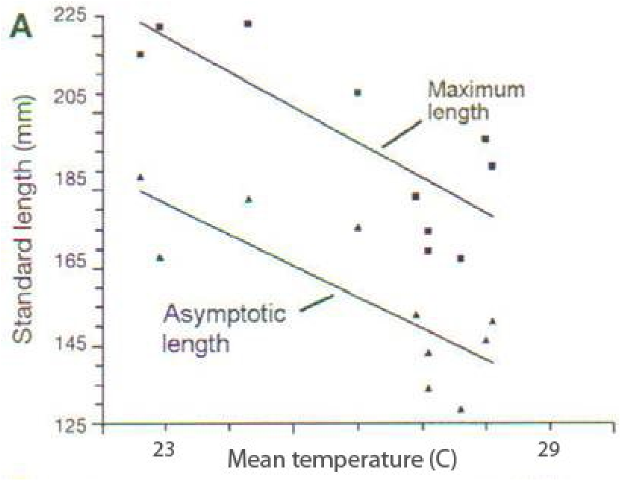
20%

25%

Life histories

- Correlated with temperature
- Populations in warmer water
    - shorter lived
    - smaller maximum size
    - earlier maturation
- Shifts in local populations
- Consideration for fished stocks
    - quotas and size limits





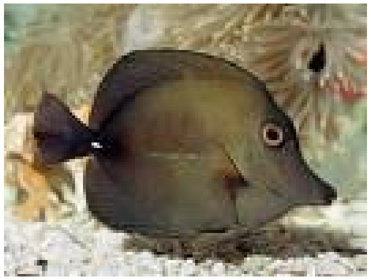
Robertson et al 2005 MEPS 295: 229-244

Temperature

- Effects on growth and reproduction
- Predict more variable larval supply - consequences for population dynamics
- Range shift as species track thermal preferences
- Habitat availability could limit high-latitude species
- Life-histories of local populations
- Long-term acclimation and adaptation??

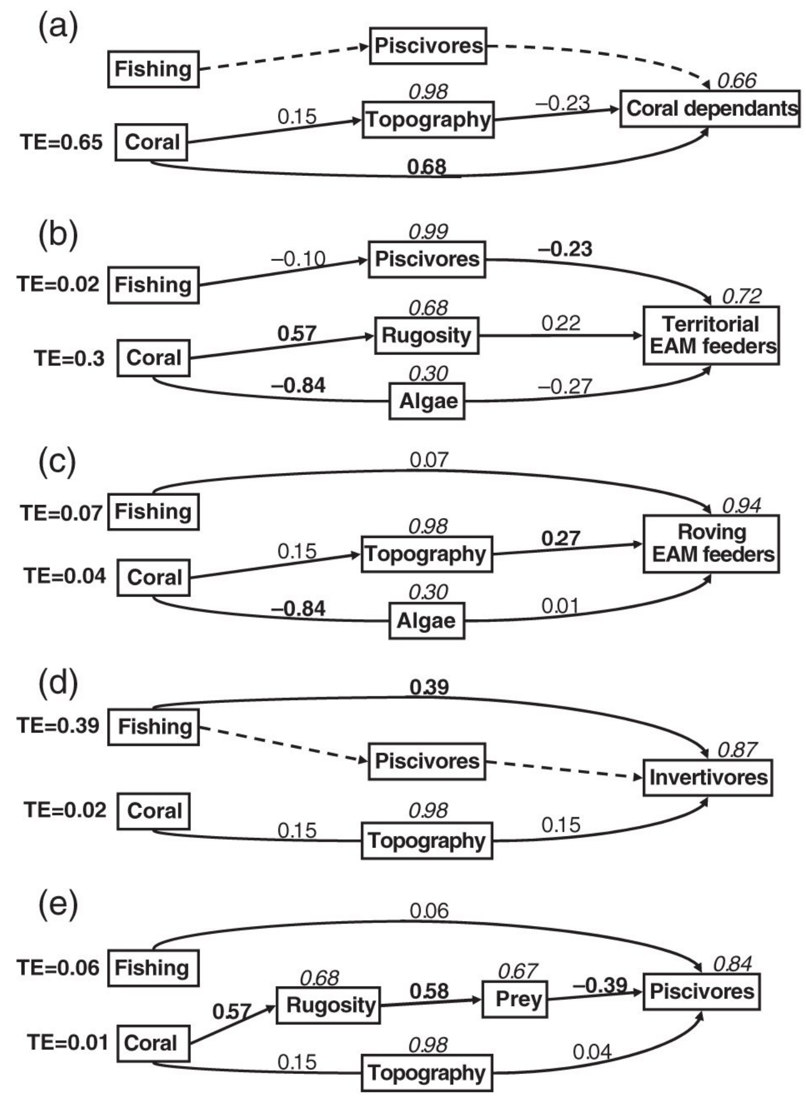
Acclimation and adaptation

- Many fishes have geographic ranges that span a large temperature gradient
- Potential for acclimation to increased temperature
- Genetic adaptation influenced by generation time
  - many small fishes live ~ 1 year
  - others live decades years



Climate change and fisheries

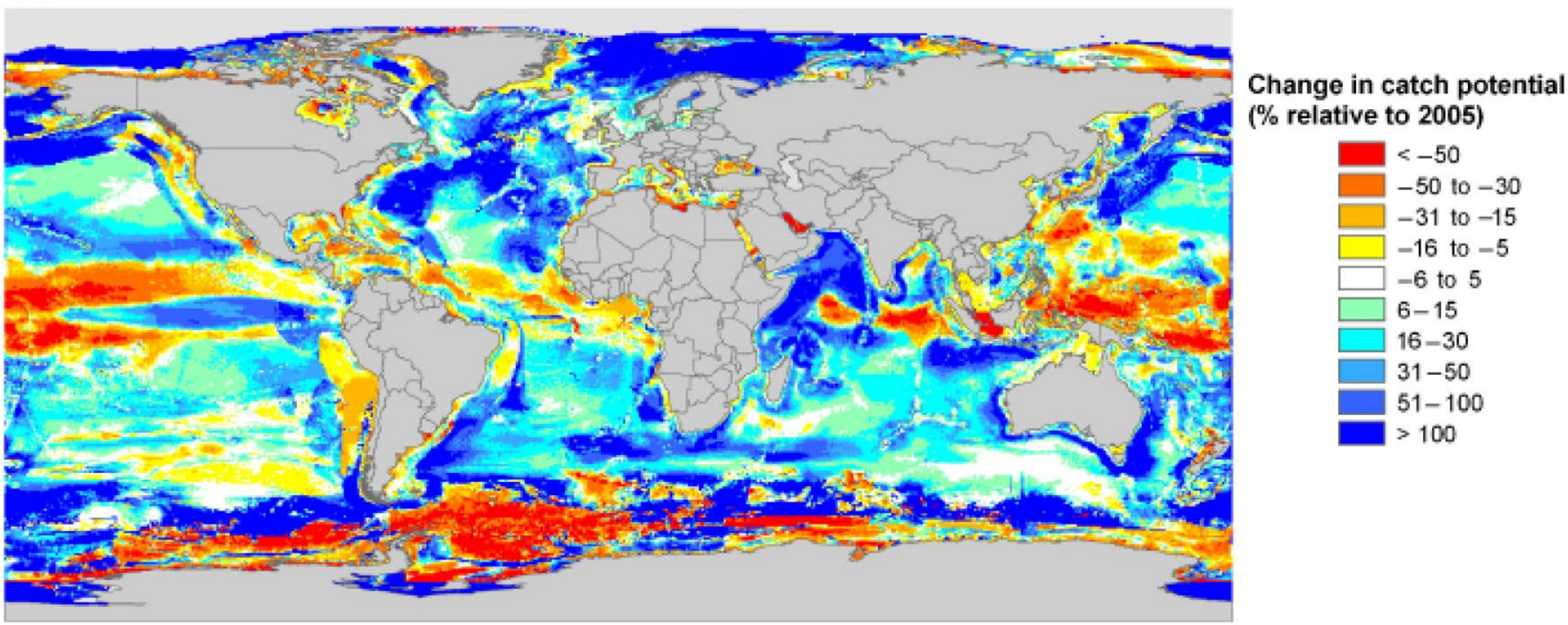
- Climate change will interact with fishing
- Habitat loss can have a similar magnitude of effect on abundance
- Larger species affected by reduced prey availability
- Climate change is an additional pressure for fished populations



Wilson et al. 2008. Global Change Biology 14, 2796-2809

Fisheries productivity

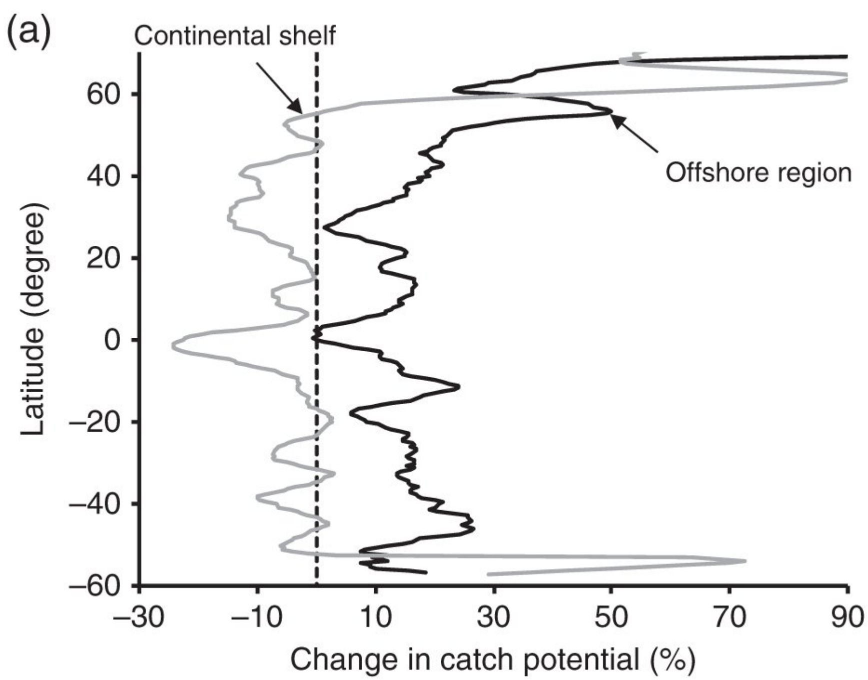
- Considered thermal tolerance, habitat availability, planktonic productivity to model fisheries productivity
- Increase in some areas decrease in other areas
- Estimate 40% reduction in tropics by 2055

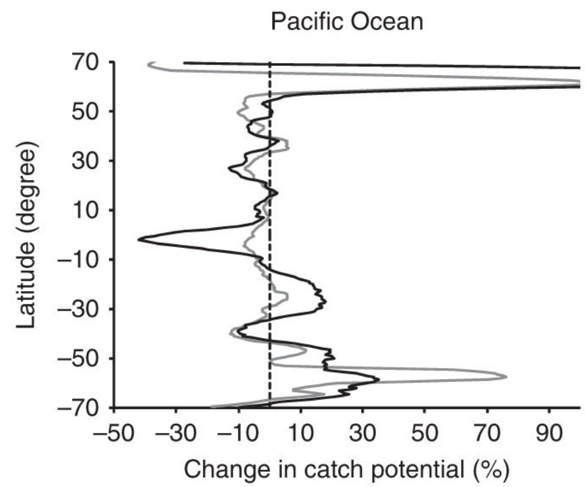


Cheung et al. 2010. Global Change Biology 16, 24-35

Fisheries productivity

- Greatest effects predicted on continental shelf
  – coral reefs
- Pacific region more strongly impacted

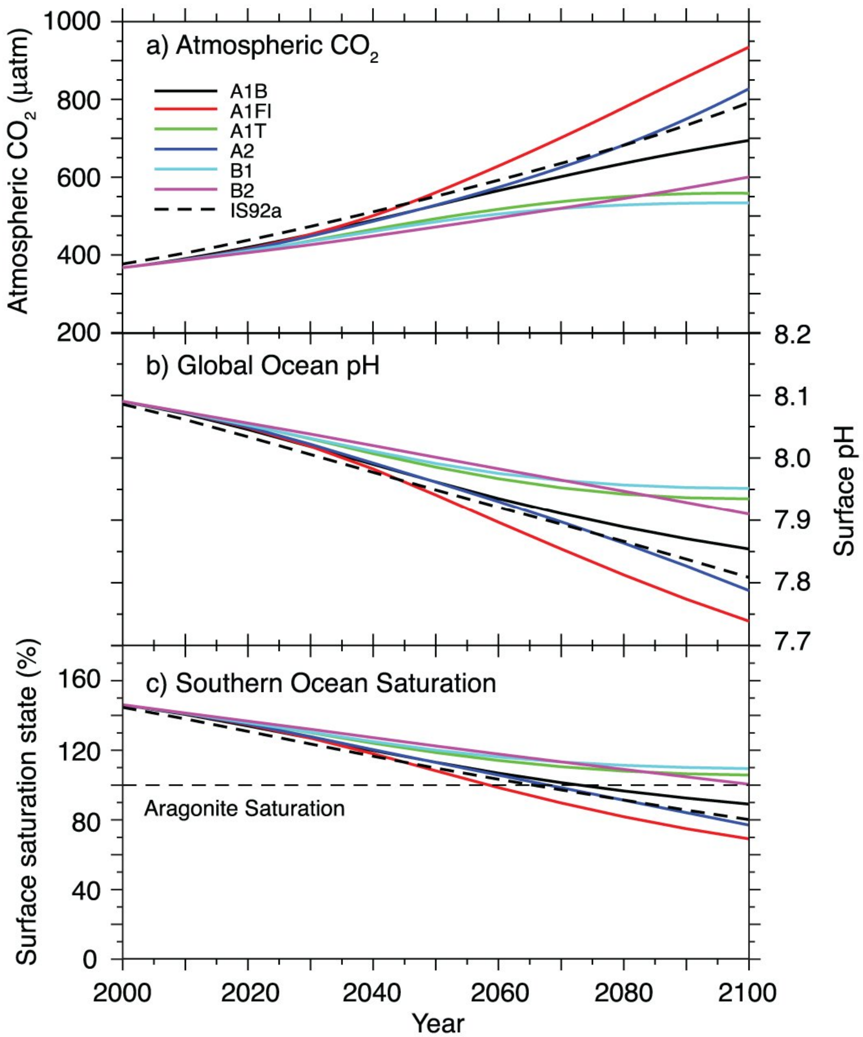




Cheung et al. 2010. Global Change Biology 16, 24-35

Ocean pH

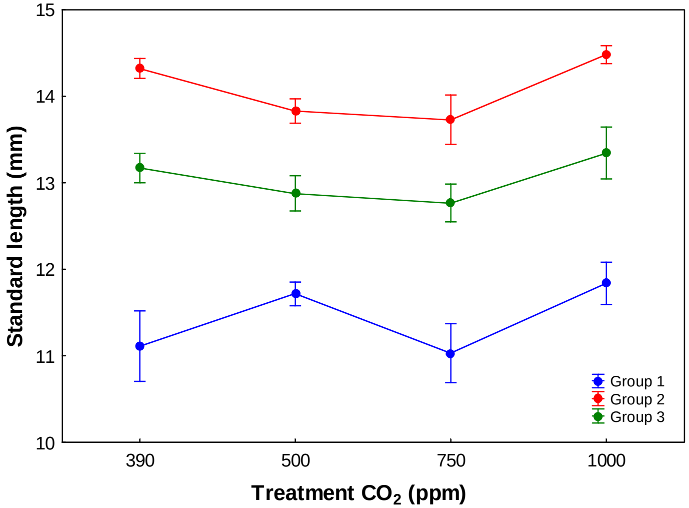
- So far only considered temperature
- pH 7.8 by 2100
- Problem for marine calcifiers: corals, sea urchins, bivalves, gastropods
- Important fisheries

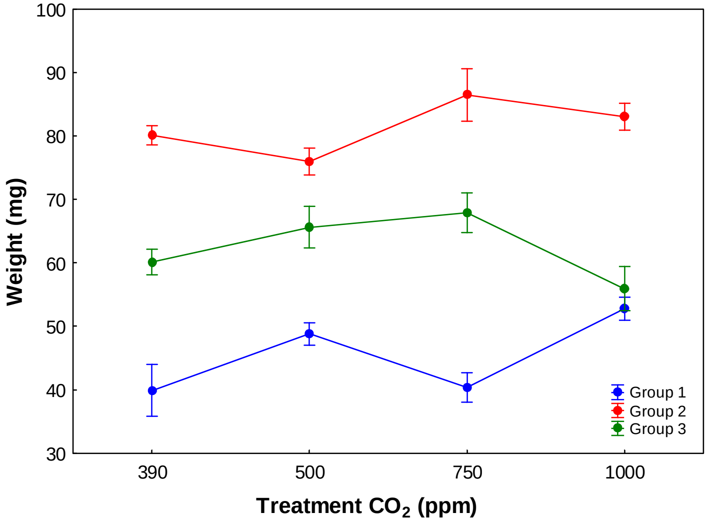


IPCC 2007 Chapter 10 Global Climate Projections

Good news!

- Most fish tolerate reduced pH
- No negative effects on:
  - Hatching success
  - Growth
  - Survival
  - Swimming ability

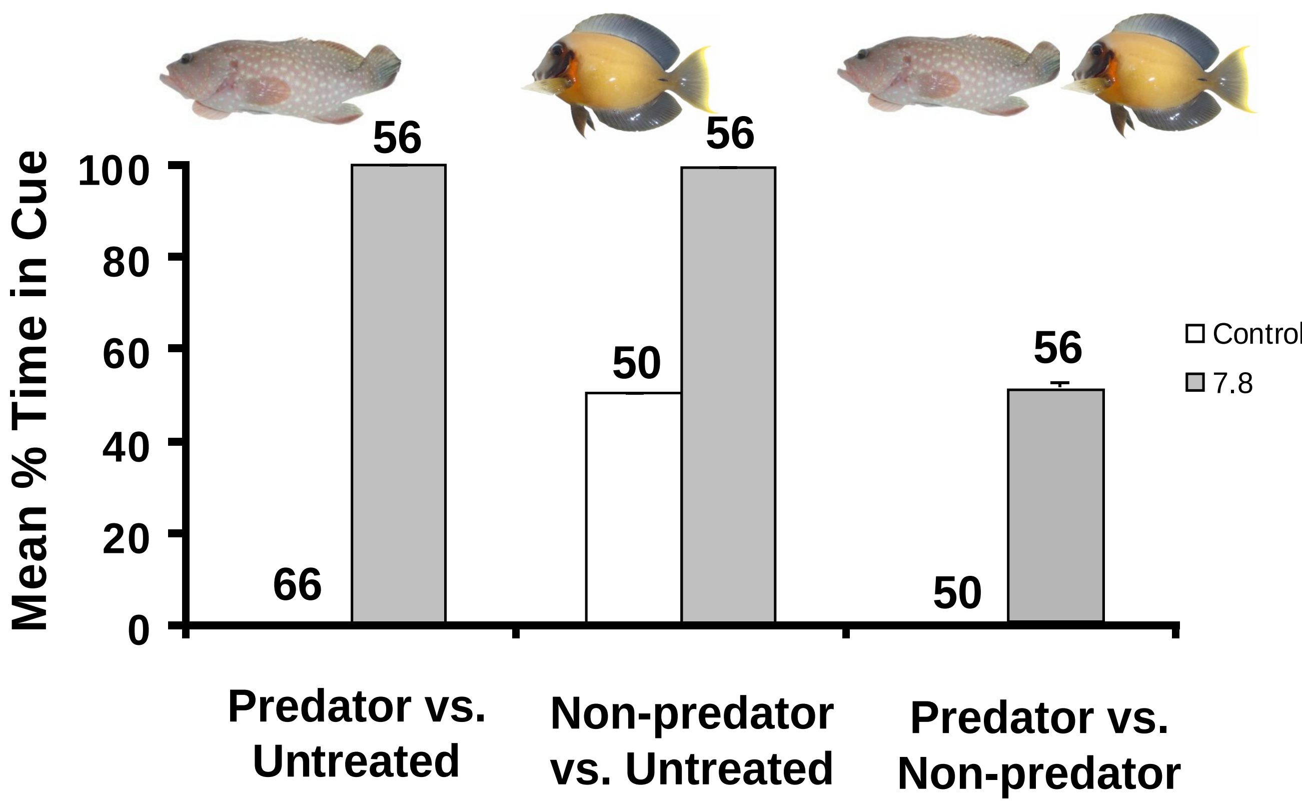




Munday et al. Proc R Soc B 2009. 276: 3275-3283

Bad news

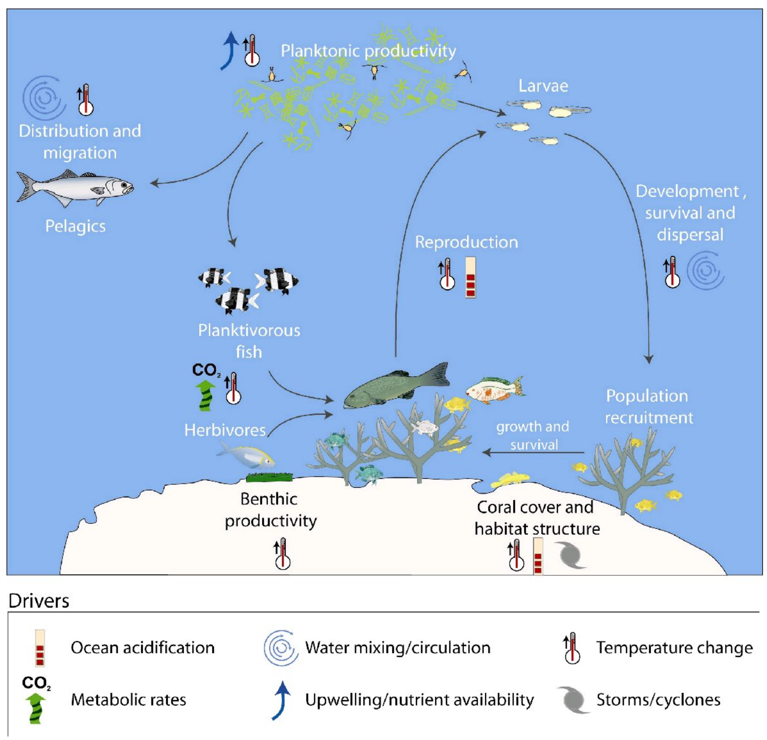
- Sense of smell disrupted by low pH
- Larvae use smell to locate adult habitat and avoid predators
- Attracted to sub-optimal habitat and predators



Dixson et al. 2010. Ecol Lett

Impact on coral reef fishes

Complex and difficult to predict!



Impact on coral reef fishes

- Habitat degradation
  - Decreased diversity and abundance
  - Changed species composition
- Individual performance
  - Increased population variability
  - Possible reproduction and recruitment failure
  - Life history shifts (size & growth)
- Range shifts
- Productivity changes – could be significant declines
  - Demands from human populations increasing

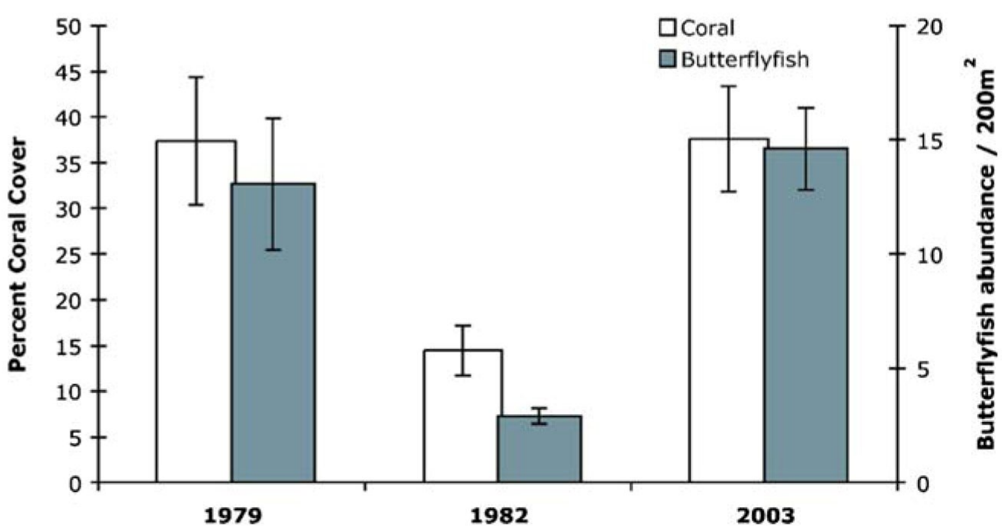
Management strategies

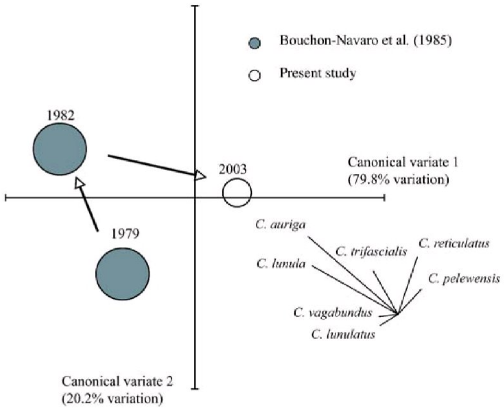
- Reduce CO_2 emissions
- Increase reef resilience
- Find ways to reduce harvest and reduce reliance on fisheries
- Safety margin to harvest levels to account for uncertainty
- Assist fishers adapt to change

Management strategies

- Pacific Islands climate change vulnerability assessment
- Published later this year

Recovery





Total abundance of coral and butterfly fishes in Moorea recovered, but community structure was different

Berumen & Pratchett 2006 Coral Reefs 25:647-653