The Impact of Climate Change on California's Marine Ecosystems: Beyond Sea Level Rise

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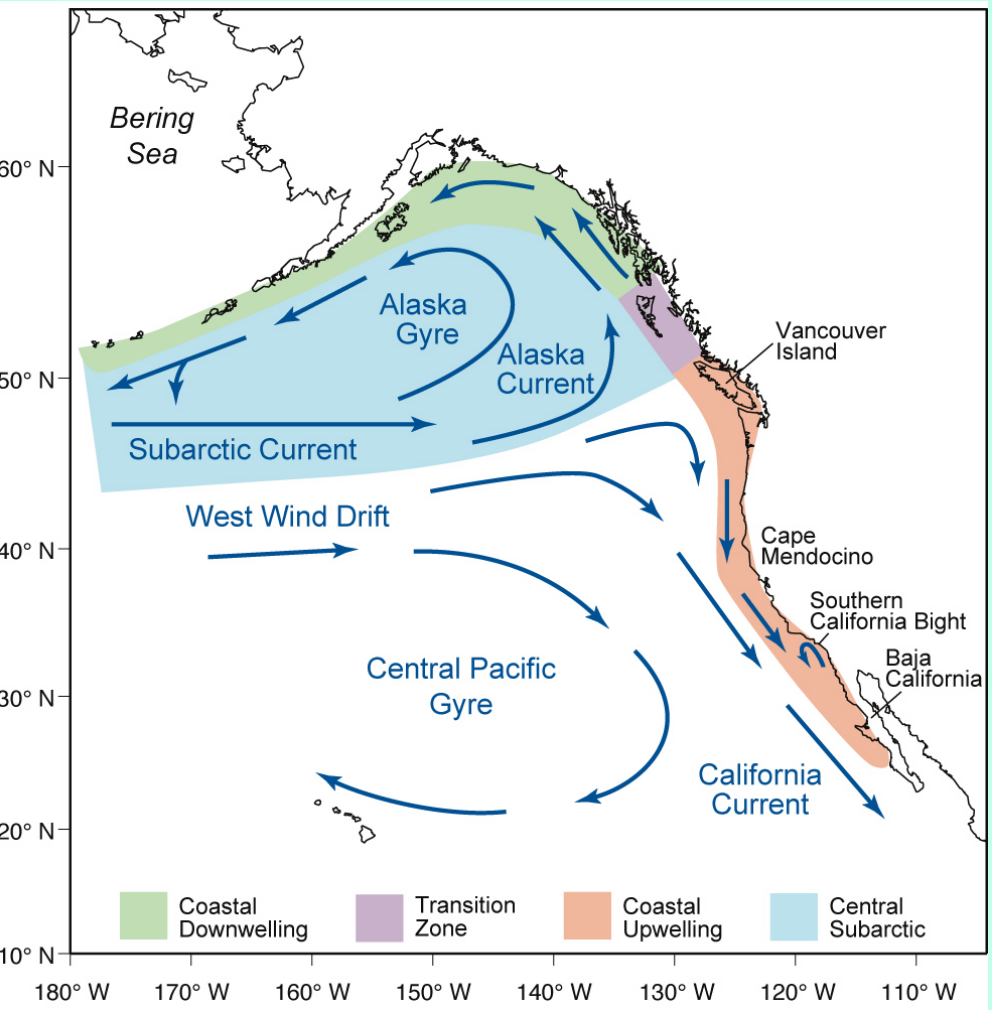
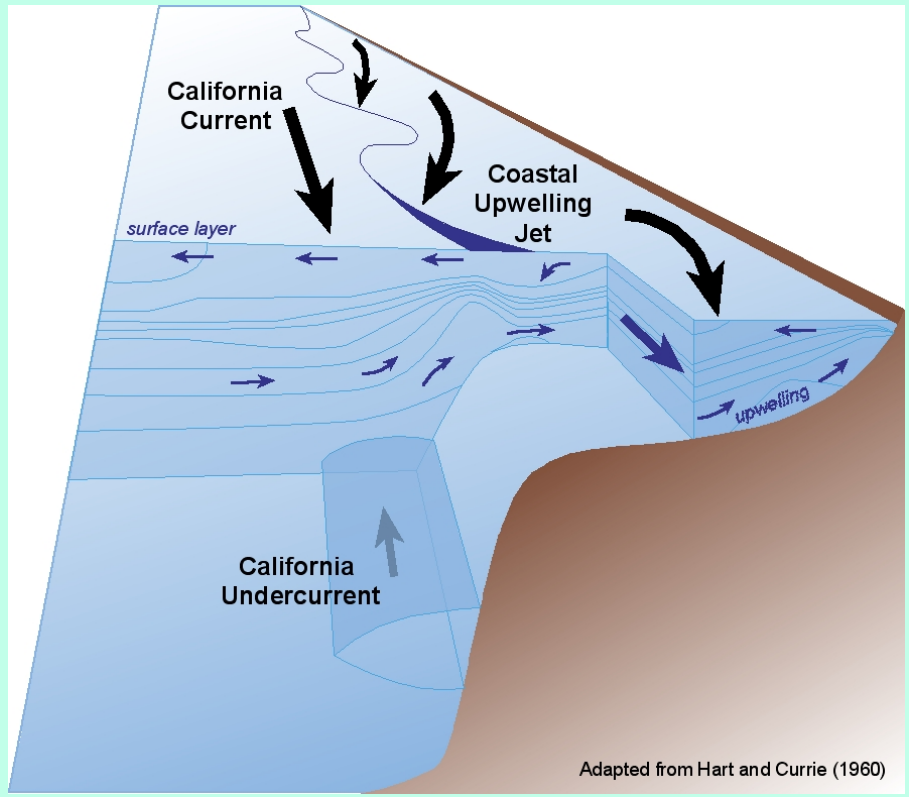
Climate Variability and the California Current Ecosystem: Key Questions

- ***What are the key environmental factors that shape ecosystem structure and productivity?***
- ***How are they are influenced by climate events and future climate scenarios?***
- ***How does the California Current respond to climate variability?***
- ***What are the primary ecological consequences of concern to California's economy and culture?***

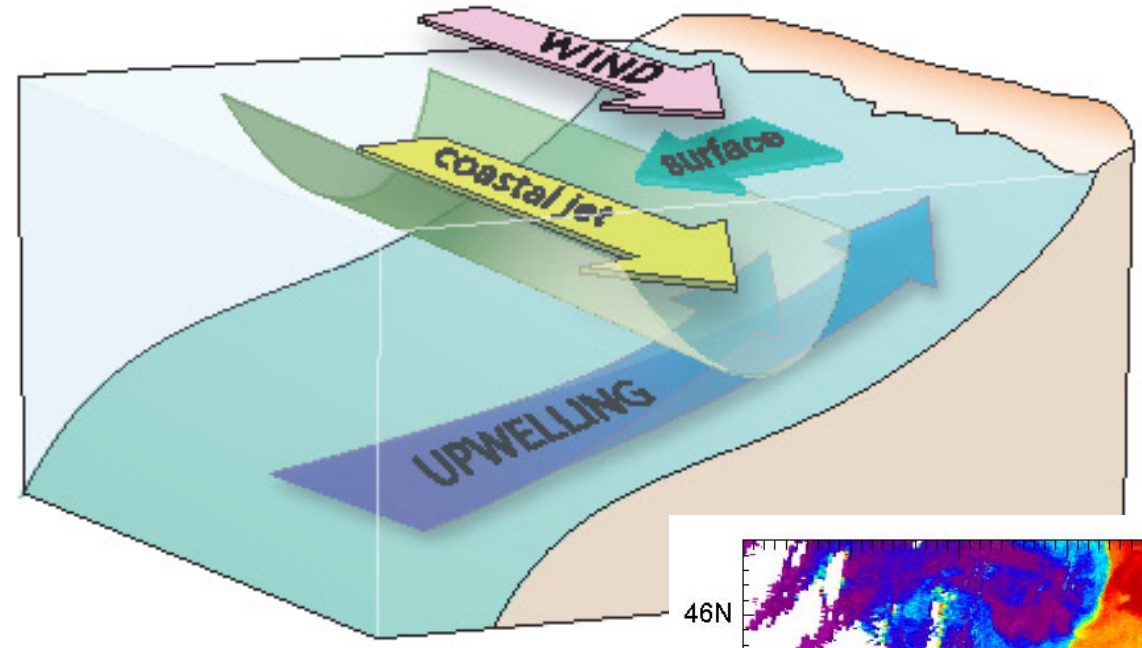
Large-Scale Circulation: The California Current, Part of the north Pacific Ocean Circulation





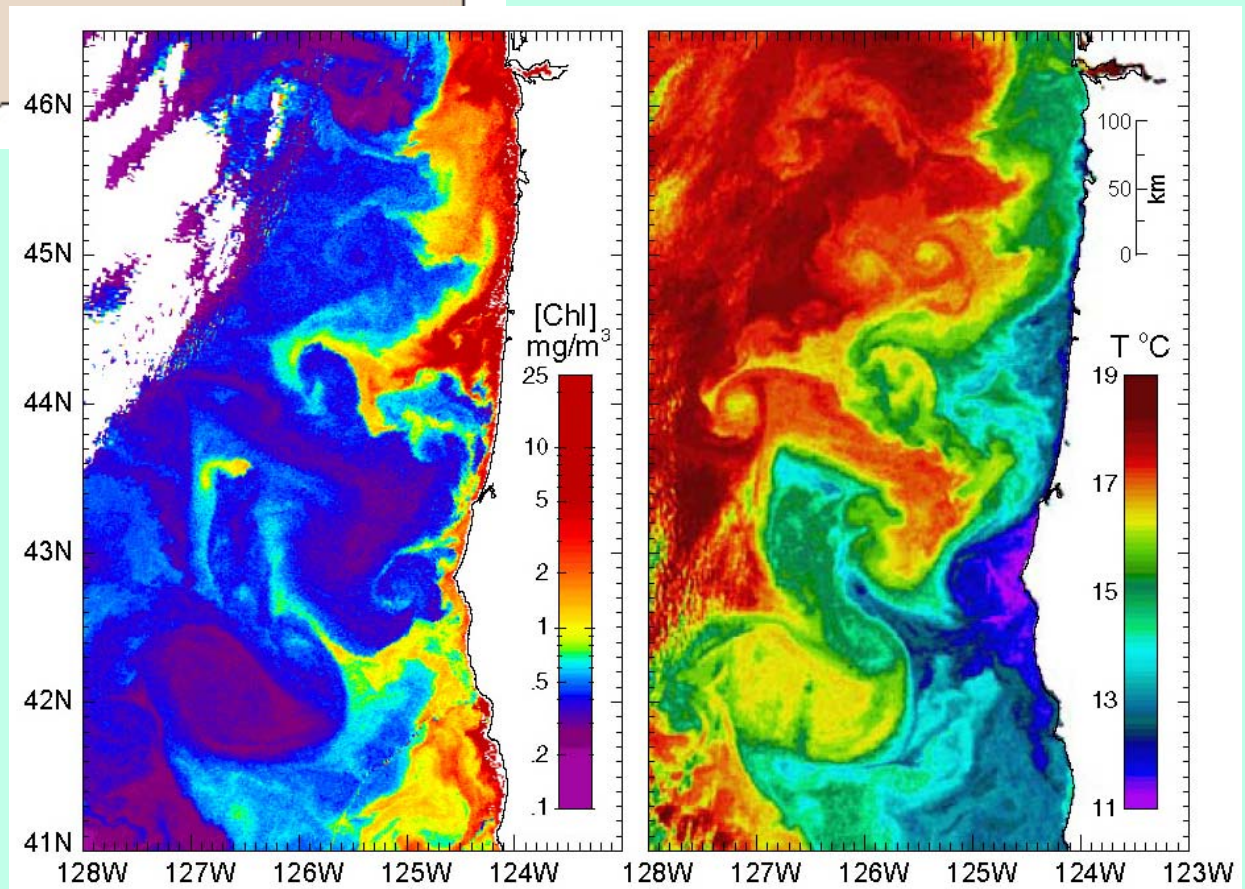
(from Jack Barth, OSU)

Coastal upwelling



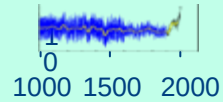
satellite chlorophyll and temperature

(from Jack Barth, OSU)

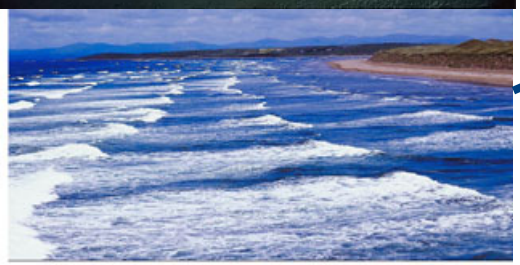


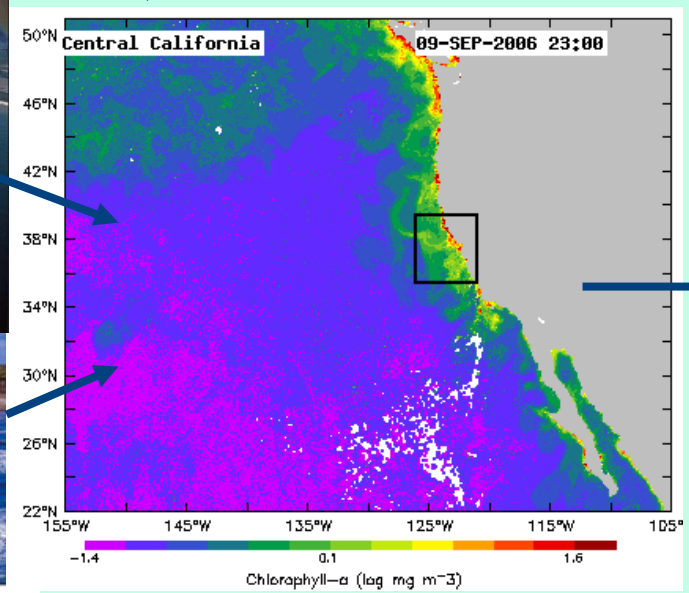
WHAT FACTORS SHAPE THE CALIFORNIA CURRENT ECOSYSTEM? "BOTTOM-UP"

- SEA LEVEL
- OCEAN TEMPERATURE/FRESHWATER
- CURRENTS & TRANSPORT
- STABILITY & FRONTS
- WATER QUALITY
- NUTRIENT AVAILABILITY
- FOOD TYPE & AVAILABILITY



"Bottom-up" Drivers

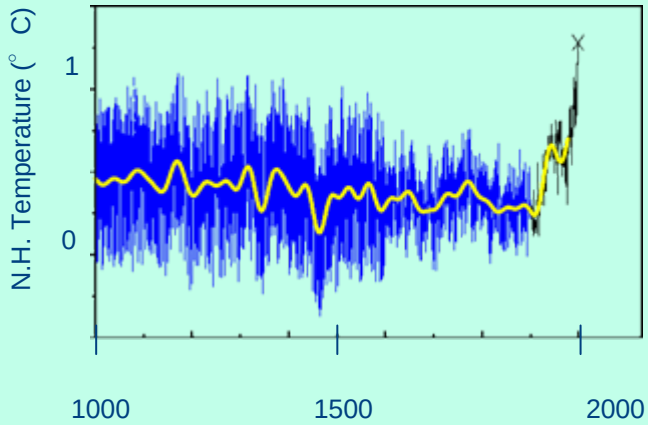


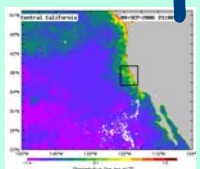


WHAT FACTORS SHAPE THE CALIFORNIA CURRENT ECOSYSTEM? "TOP-DOWN"

- PREDATION
- COMPETITION
- FISHING
- URBAN RUNOFF
- EXOTIC SPECIES INVASIONS

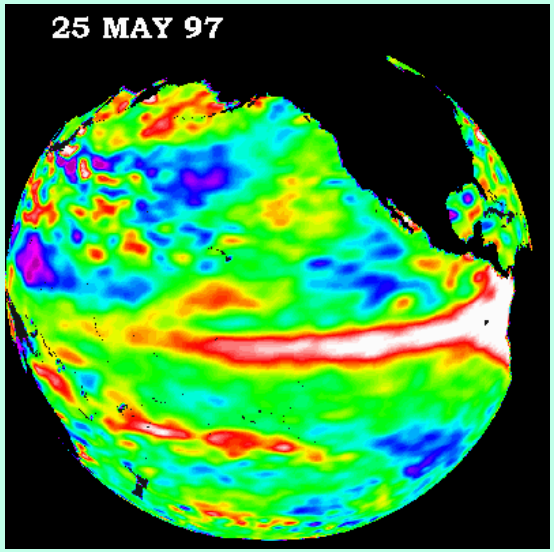
- CLIMATE EVENTS & CLIMATE CHANGE

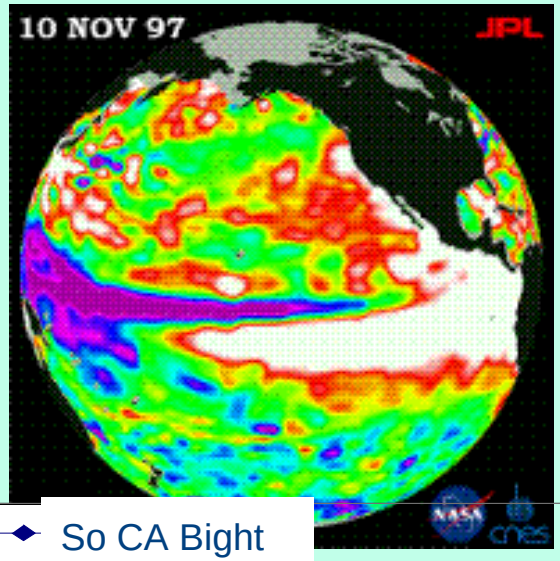




Top down & Human Drivers

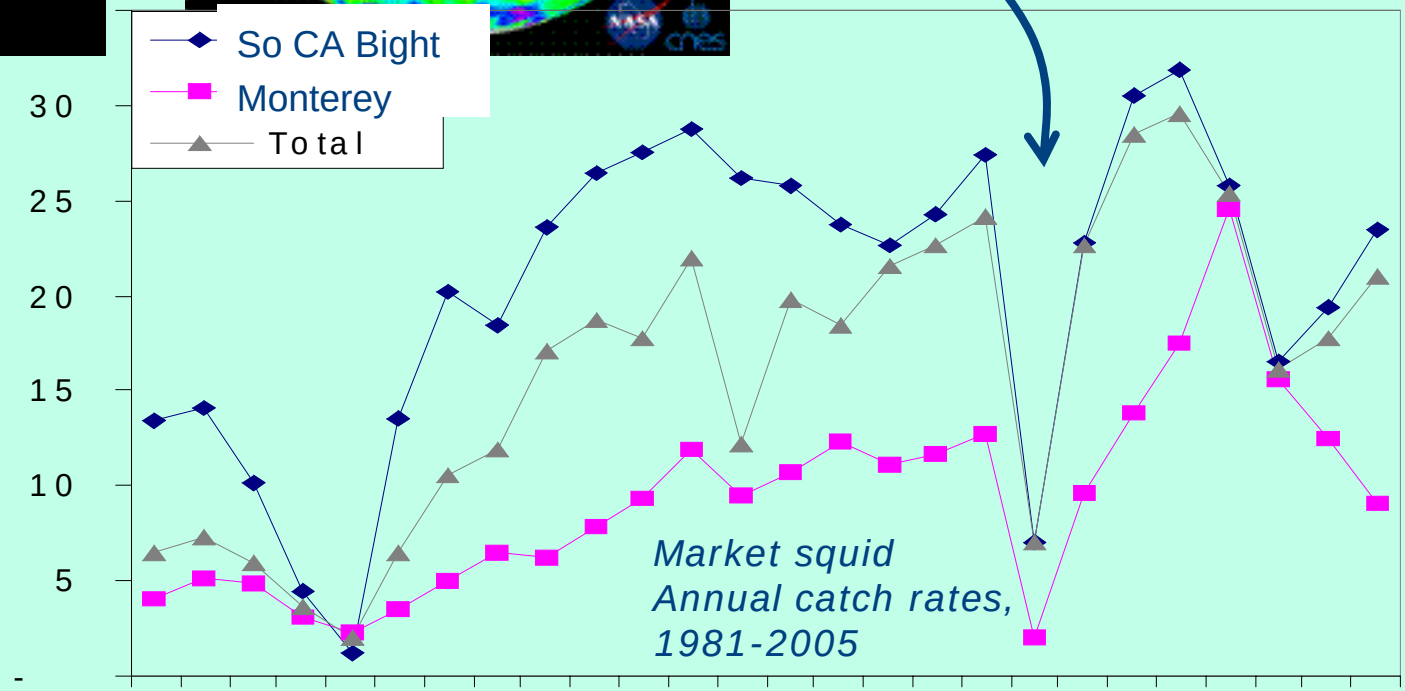
Interannual Variability Affects Fish Catch





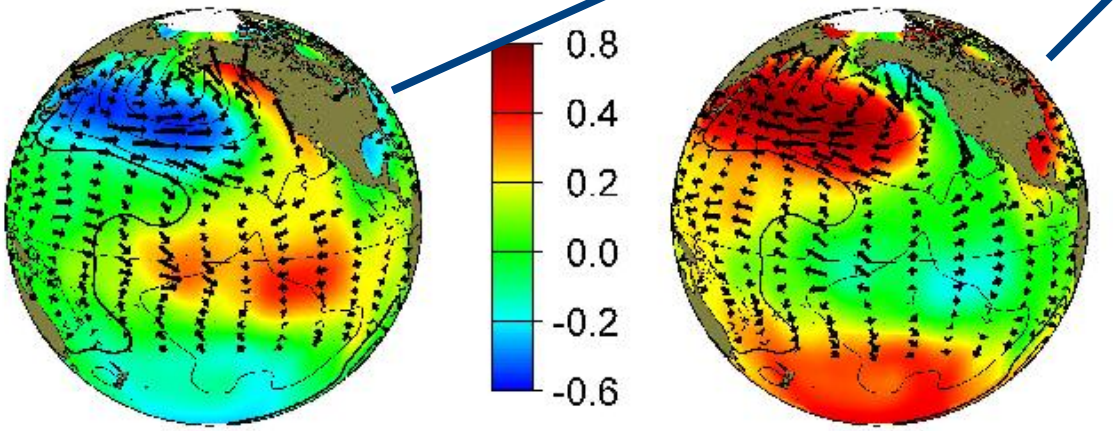
El Niño

(images from NASA)



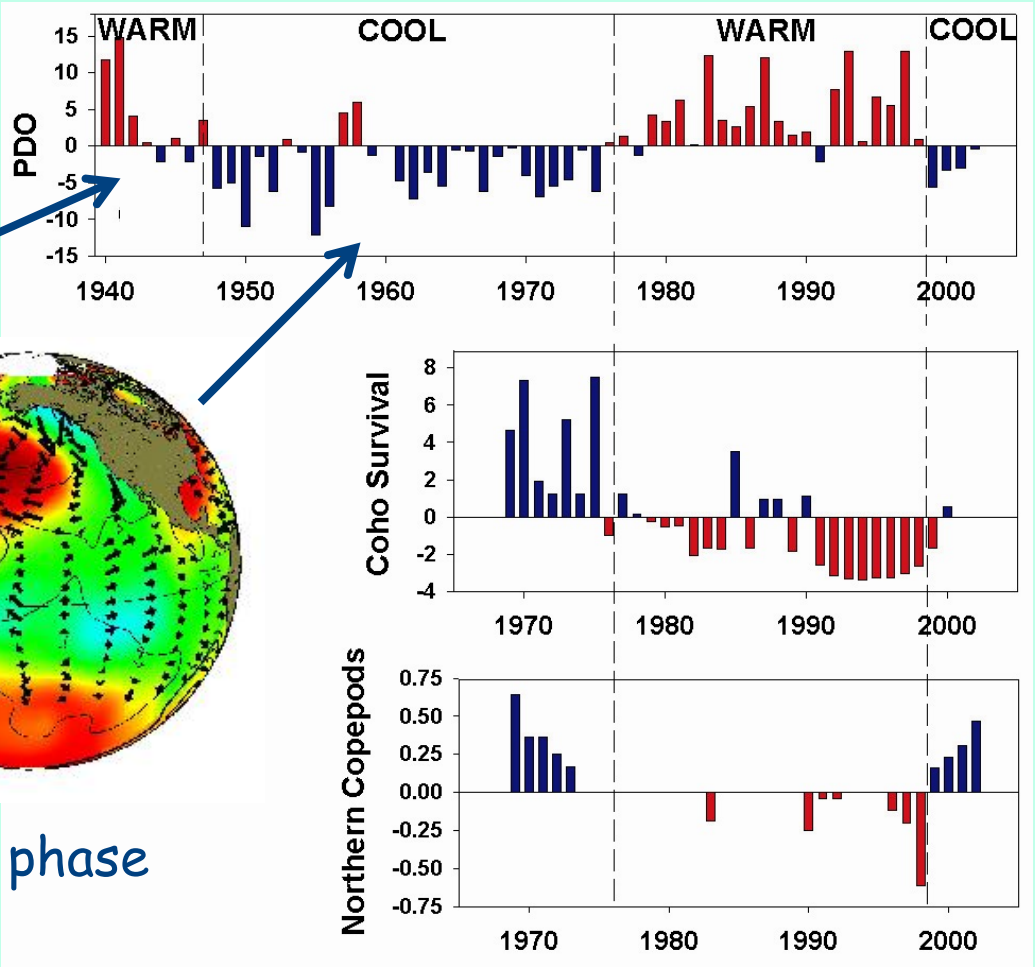
Interdecadal climate variability ("regime shifts") changes ecosystem structure and productivity

Pacific Decadal Oscillation



warm phase

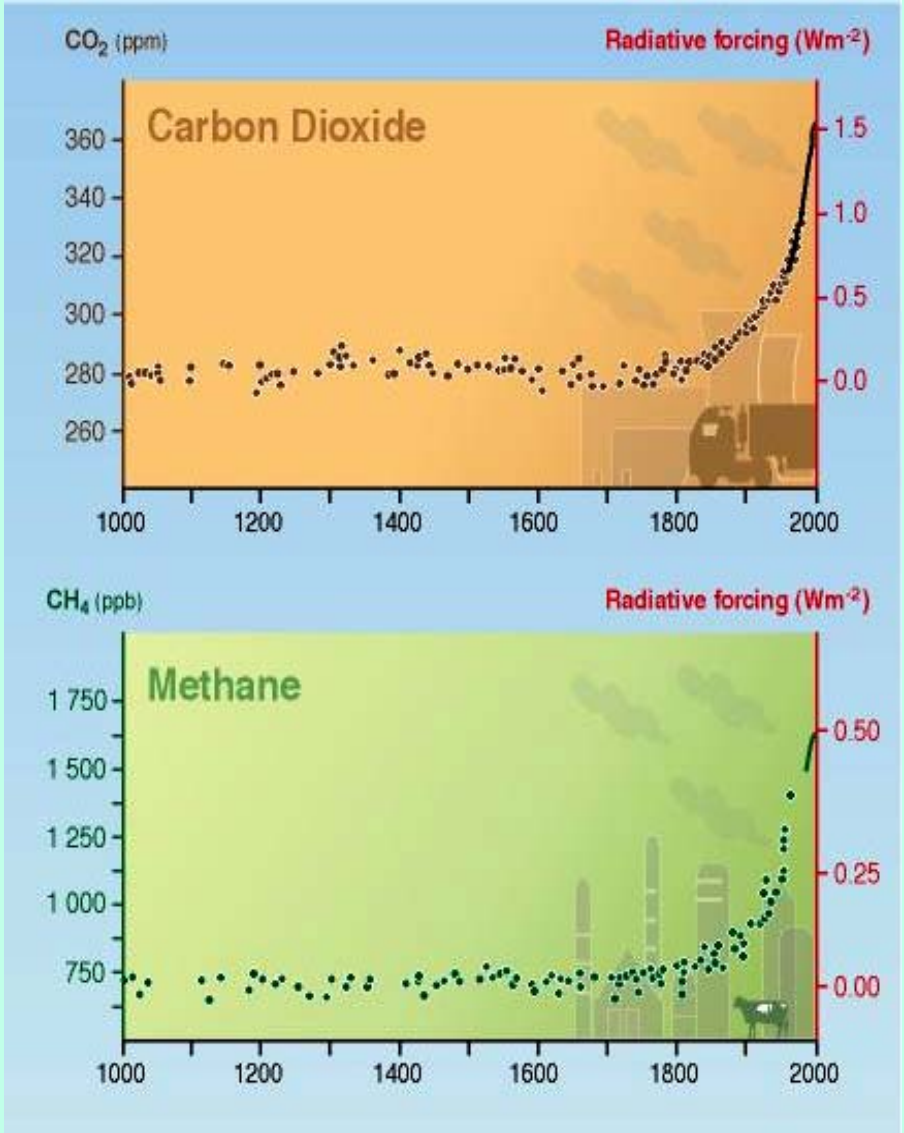
cool phase

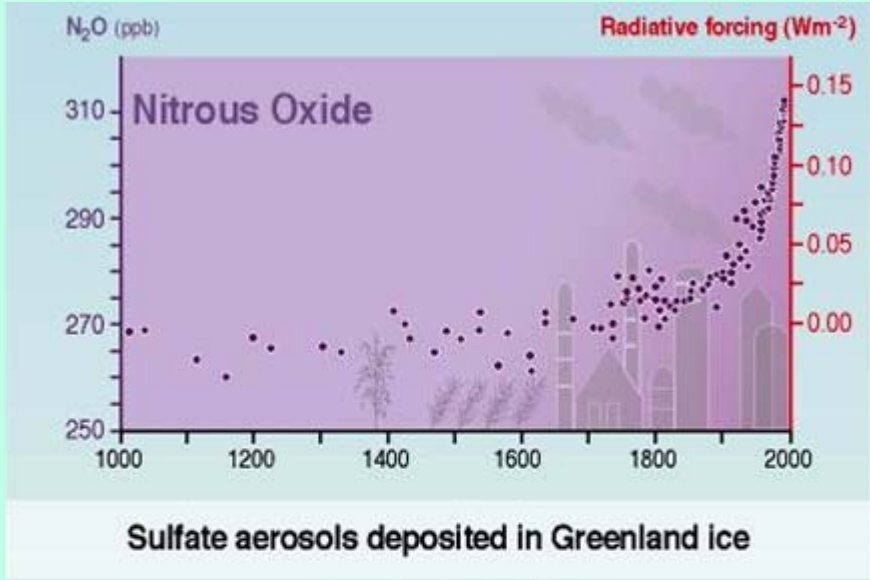


(from Nathan Mantua, U. Washington)

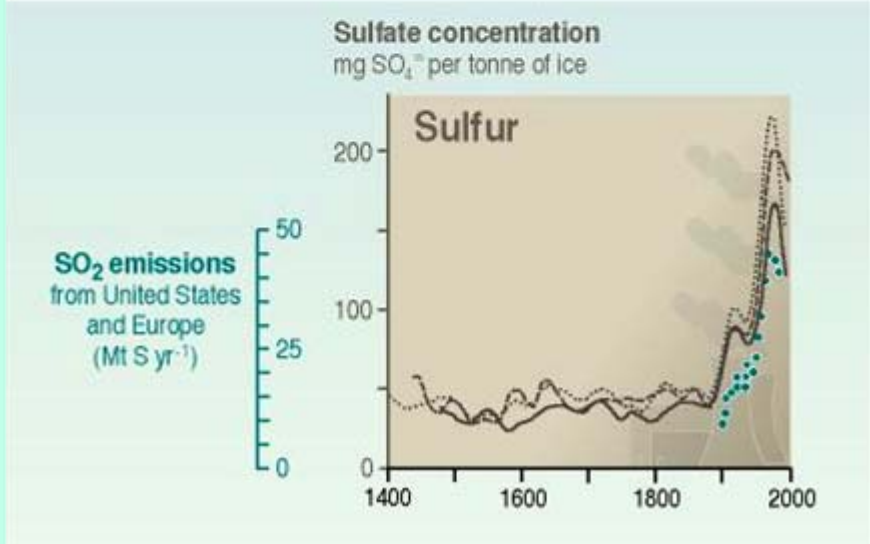
(from Peterson and Schwing, 2003)

Human activities have changed atmosphere composition since the pre- industrial era



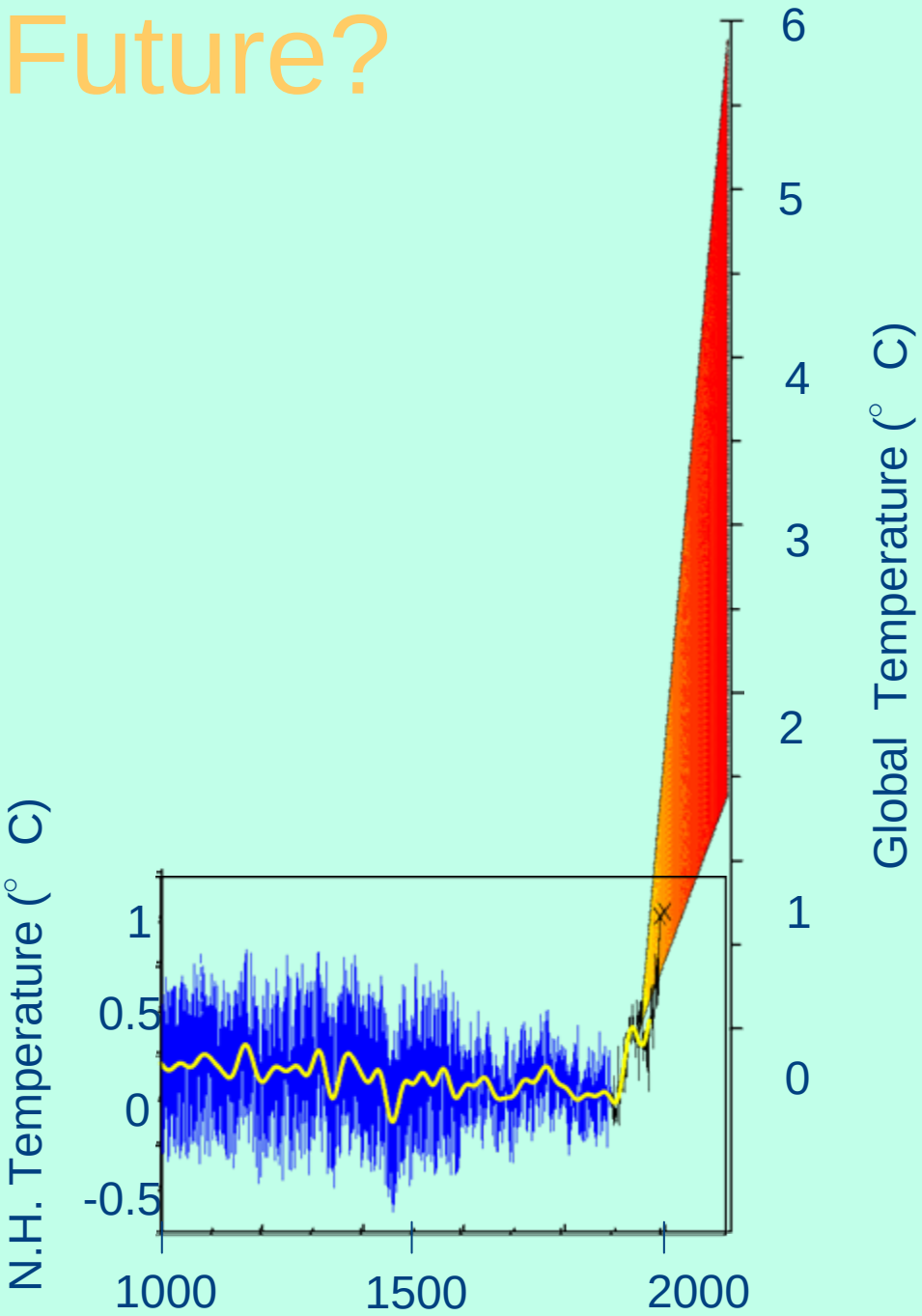


Sulfate aerosols deposited in Greenland ice



(from IPCC, 2006)

The Future?



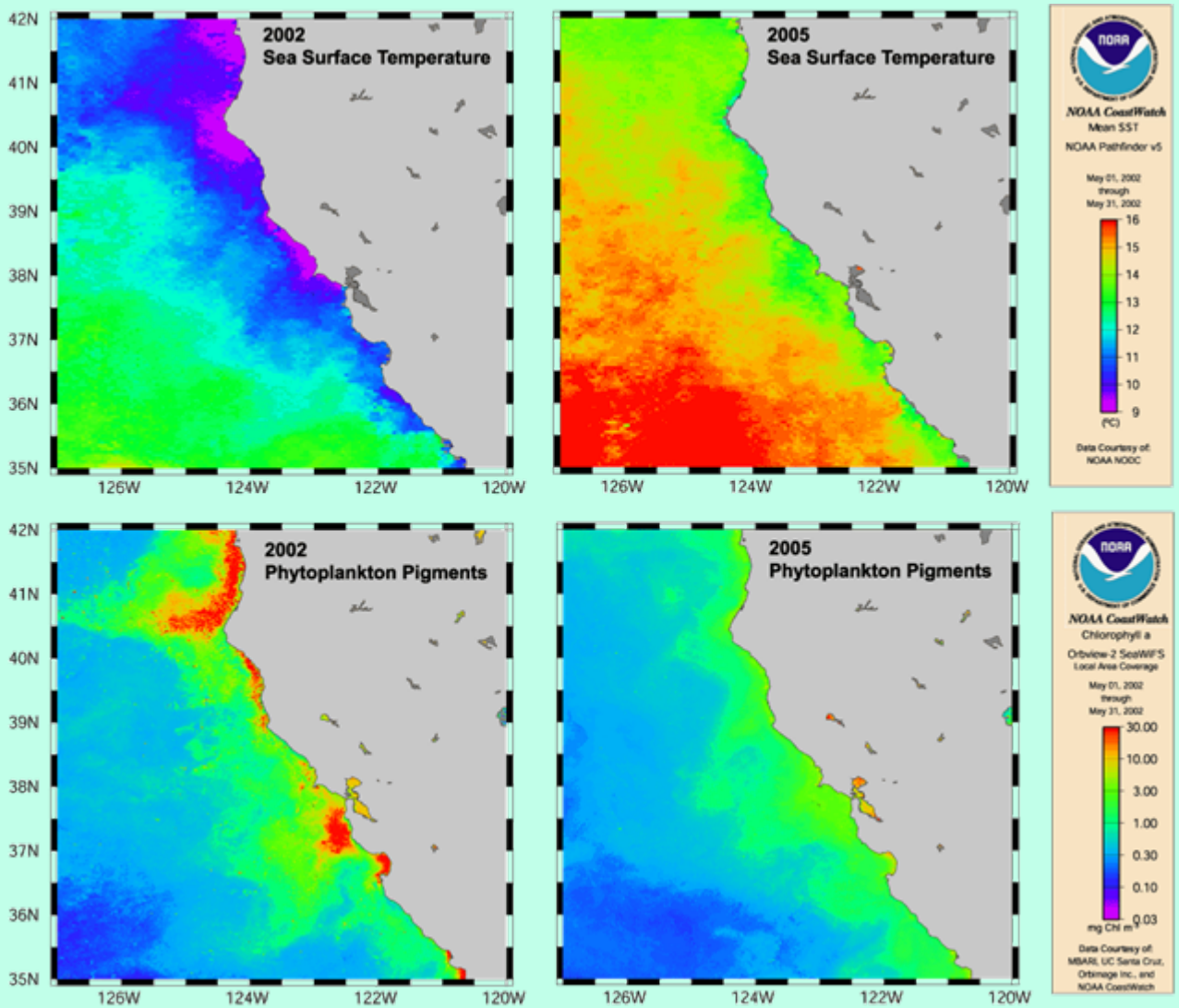
IPCC Projections 2100 AD

Mann et al (1999) and IPCC 2000

Climate Change Projected to Impact California Current Ecosystem

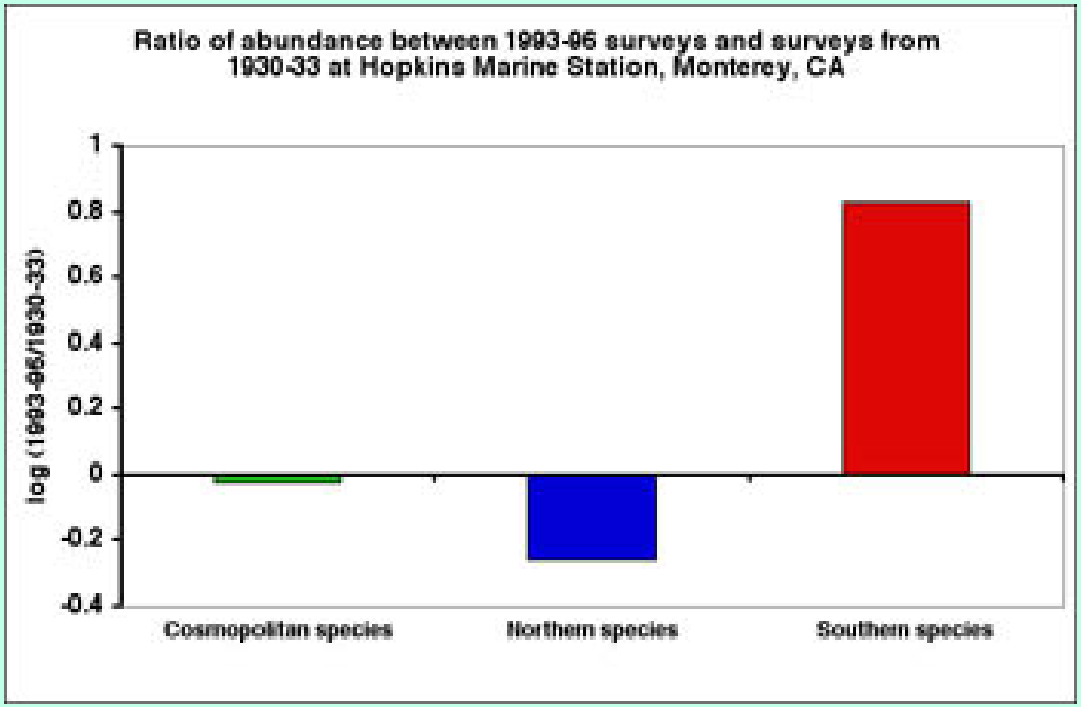
Projected changes - 21st century	Examples of ecological impacts
• Warmer summer temperatures; greater ocean stratification, weaker upwelling *(very likely)*	• Northward species shifts • Lower productivity & food • Exotic species introduced
• Warmer & wetter winters; greater freshwater inflow, coastal flooding *(very likely)*	• Reduced coastal water quality • Toxic blooms • Human health hazards
• Higher coastal sea level (*very likely*)	• Intertidal species displaced
• More extreme events; stronger storms, El Nino, hurricanes *(likely)*	• Greater coastal erosion • Fisheries reduced & displaced • Warm-water fisheries available
• Delayed seasonal cycle; delayed upwelling *(likely)*	• Delayed spring bloom • Reproduction, migration impacted

Less Production in 2005 due to Less Springtime Upwelling



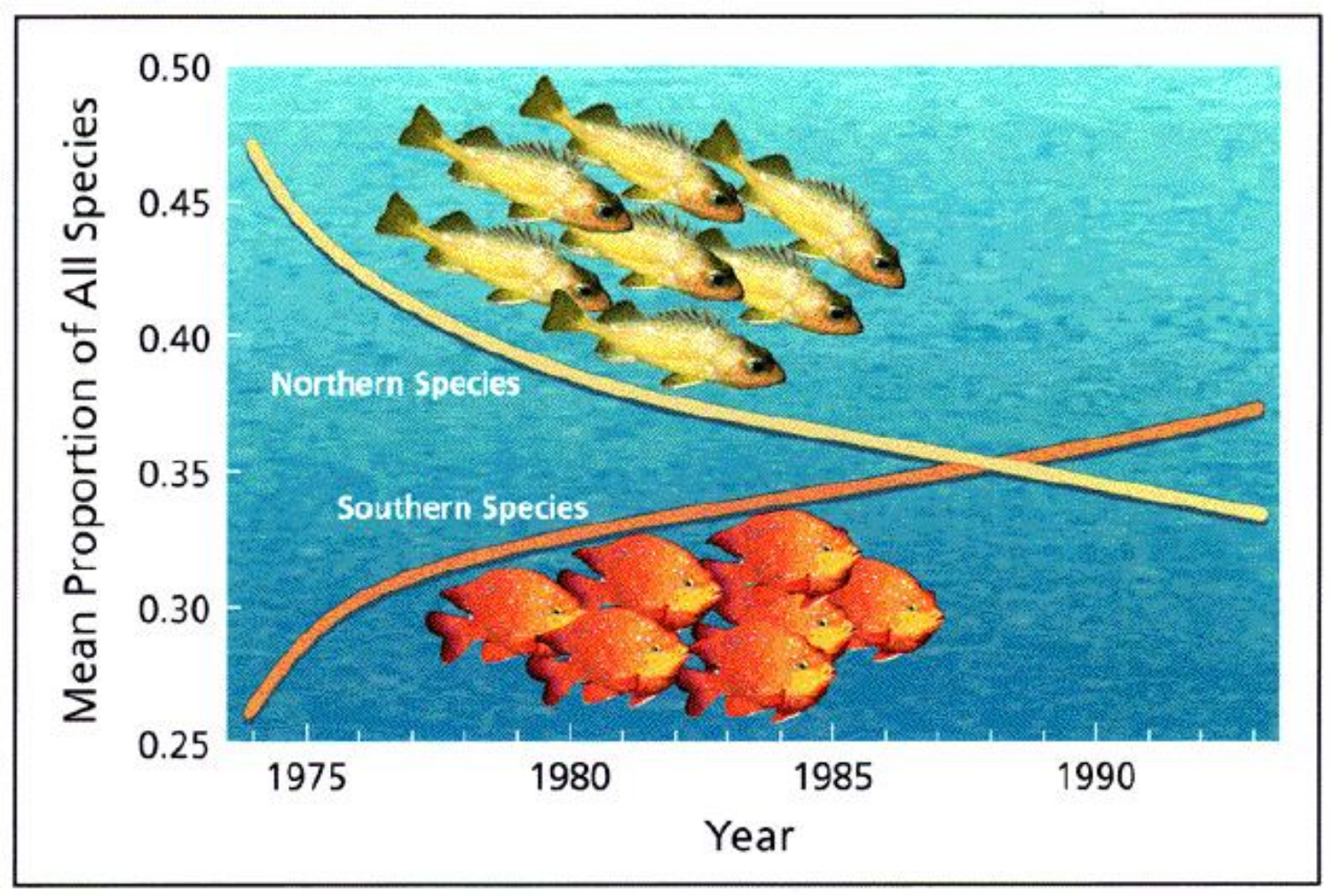
(from David Foley, NOAA NESDIS)

Warmer Climate Favors Southern Intertidal Species



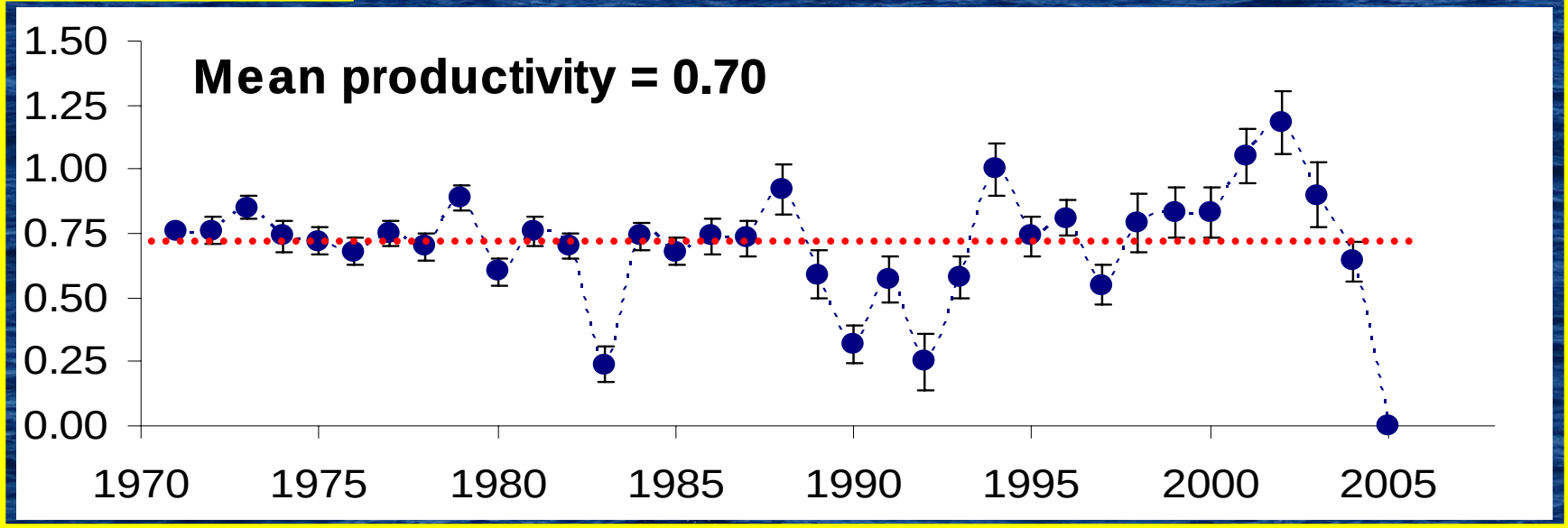
(from Berry et al., 1995)

California Marine Populations Shifting Northward



(from Union of Concerned Scientists)

2005-2006 - worst years on record for Farallon Island auklets (42 km west of San Francisco)



Nests abandoned due to delayed upwelling

From Sydeman and Bradley, PRBO

Summary and Conclusions

The California Current Marine Ecosystem is shaped by physical processes with time scales of days to decades

Climate variability leads to ecological variability

- Global atmosphere is ultimate source of variability

Modulation by global climate change may include

- delayed spring transition and stronger late-season upwelling
- northward shift, favorable for warm-water species
- increased variability expected with global warming
- fishery winners and losers
- more coastal stress

Timing is critical, e.g. rockfish recruitment, seabird breeding, salmon ocean entry

Mitigate global climate change by avoiding other ecological stressors, e.g. overfishing, coastal pollution

Management decisions must incorporate climate variability in marine ecosystems