SCOR Workshop on Ocean Biology Observatories

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Panel activities to date

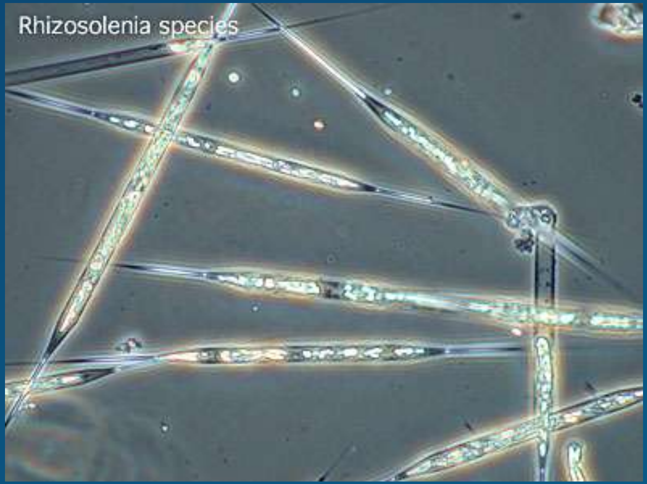
- Liason with CoML research projects related to technology issues
- Review of all CoML project renewal proposals
- Review of the CoML methodologies document
- Annual panel meetings with representatives from projects
- Special session at Techno-Ocean 2006
- Special workshop on geo-location of animal tags (resulted in Report and summary papers)

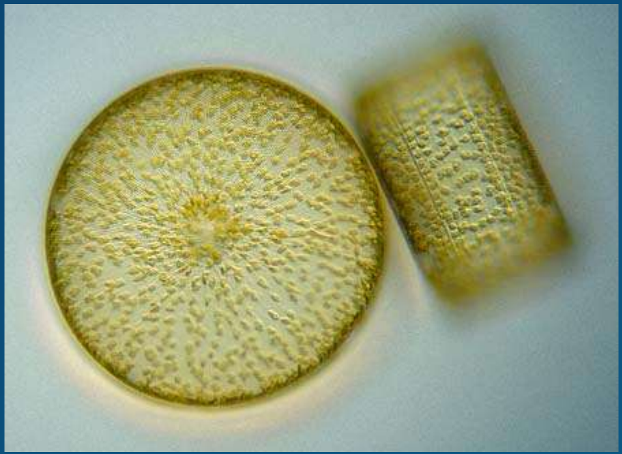
The Ocean - An Integral Part of Earth's Life Support System

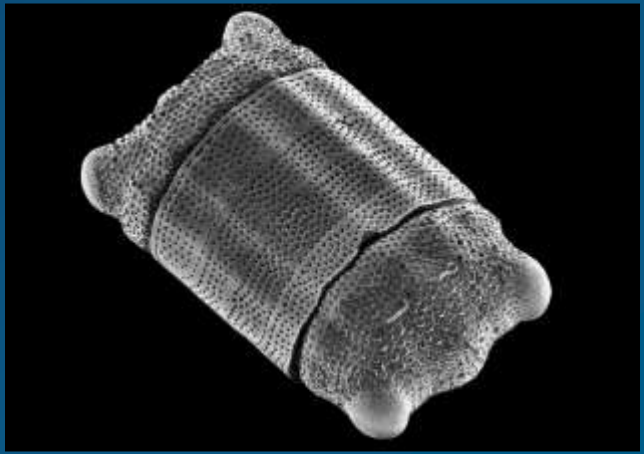
Phytoplankton and oxygen

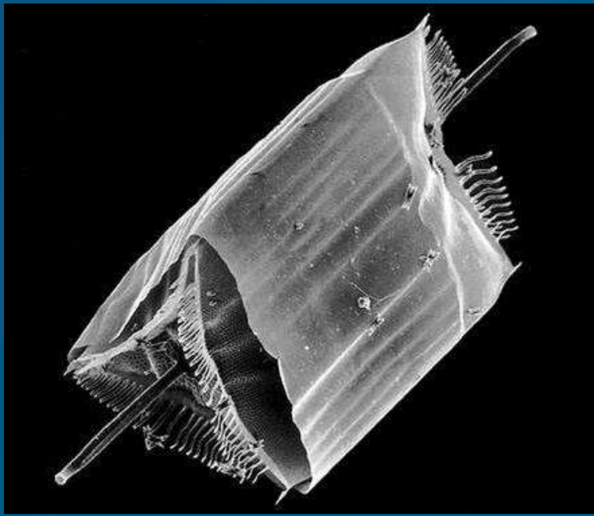
- Overall oceans produce nearly half of the atmosphere's oxygen

- Diatoms provide ~ 20-25% fixed carbon and atmospheric oxygen ("lungs of the ocean")

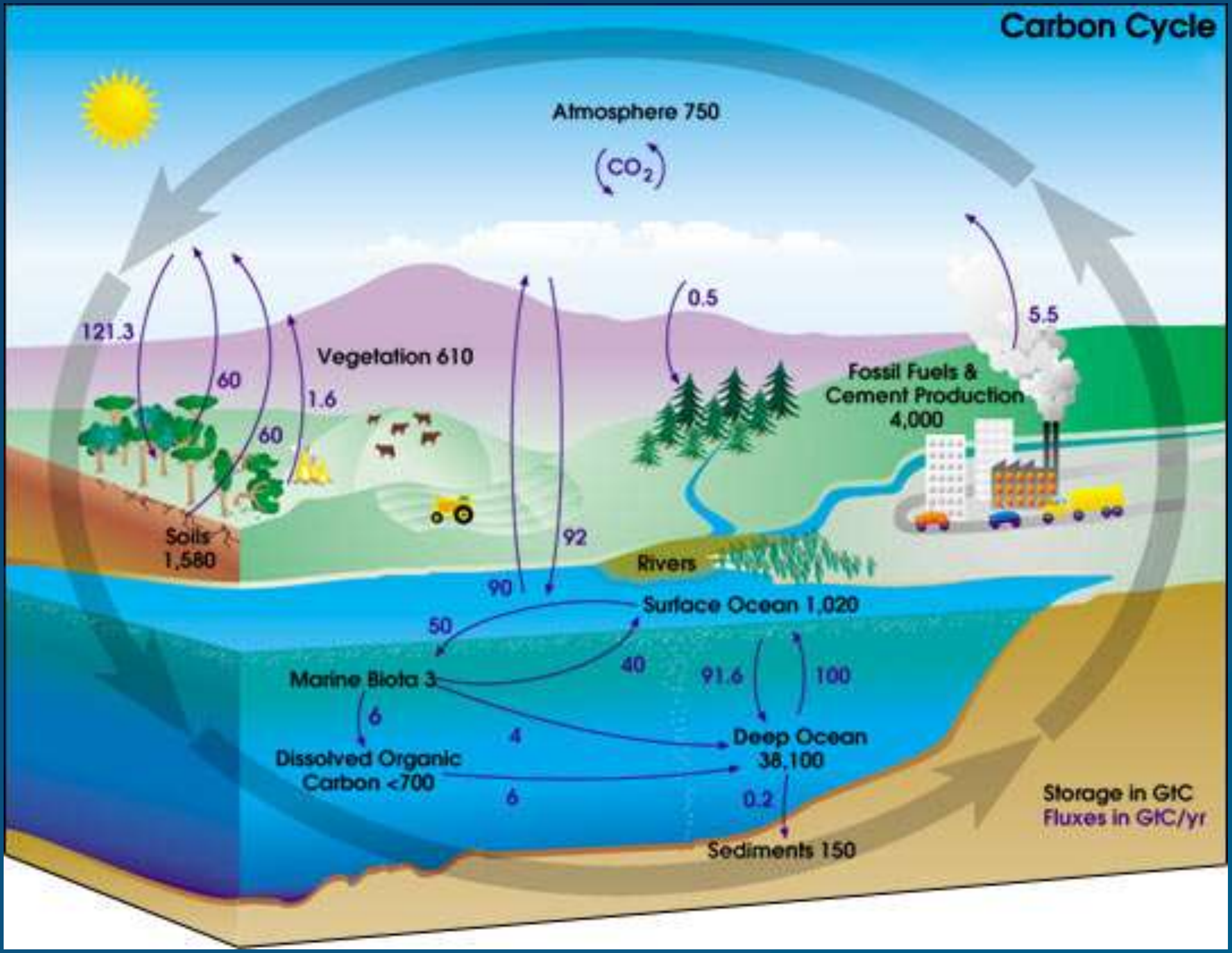






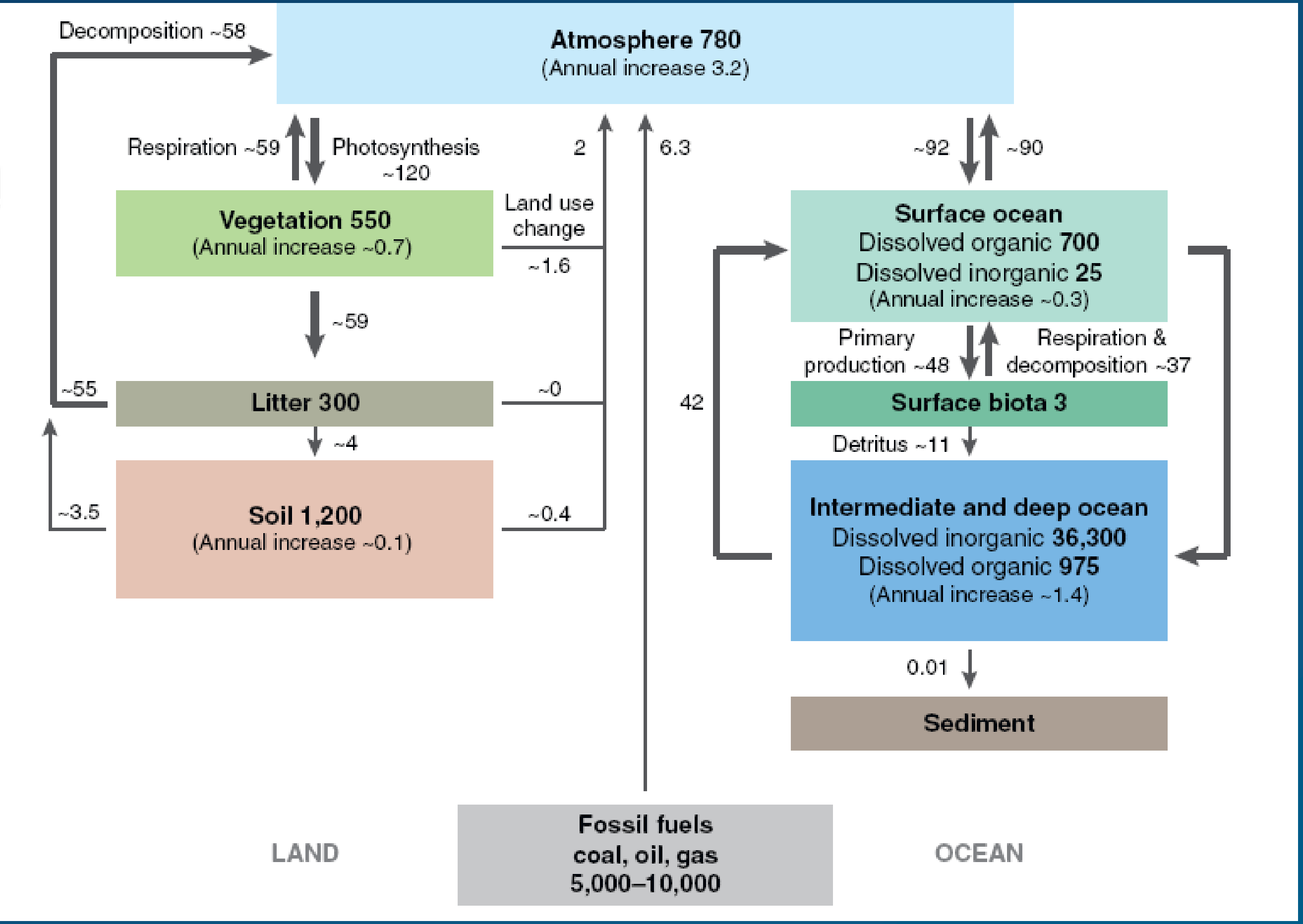


CO_2 fixation and the global carbon cycle



Global carbon cycle (1990s)

Pg C
Pg C yr^{-1}



Houghton 2007 Ann Rev Earth Planetry Sci 35:313-347

Role of the oceans in carbon uptake

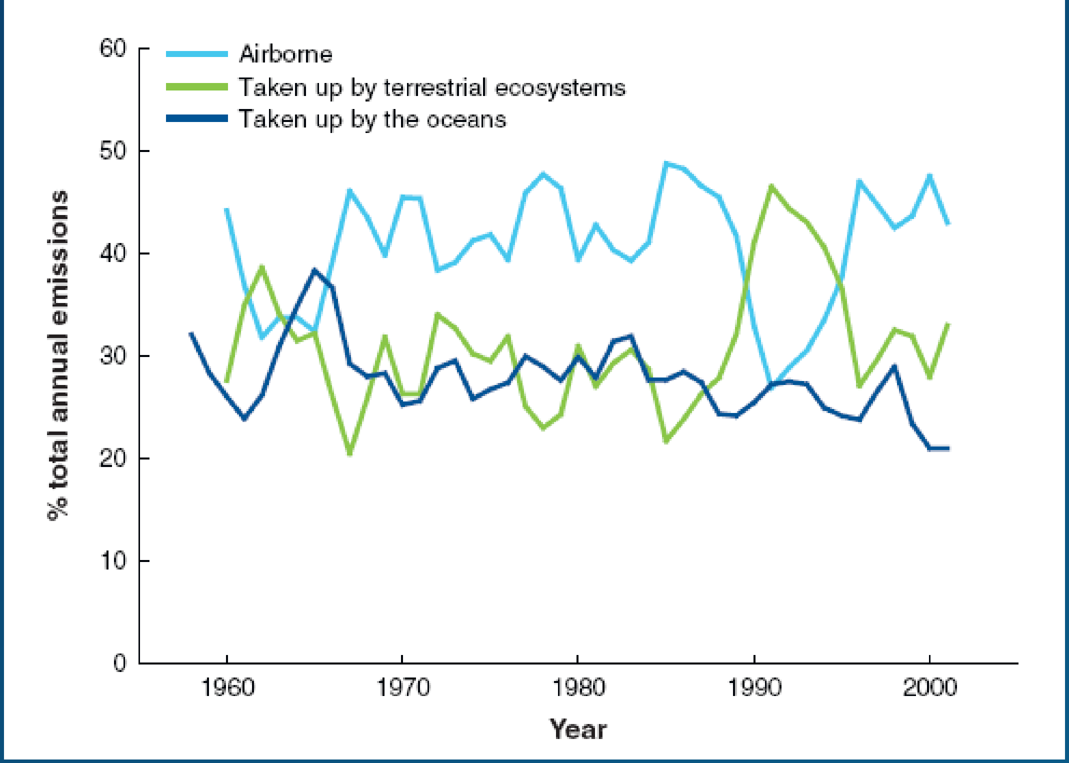


Table 1 The global carbon budget for two intervals (units are PgC)

	1800 to 1994	1850–2000
Emissions from fossil fuels and cement production	244 ± 20[1]	275[3]
Atmospheric increase	−165 ± 4[1]	−175[4]
Oceanic uptake	−118 ± 19[1]	−140[5]
Net terrestrial source	39 ± 28[1]	40
Land-use change (source)	174[2]	156[2]
Residual terrestrial sink	−135	−116

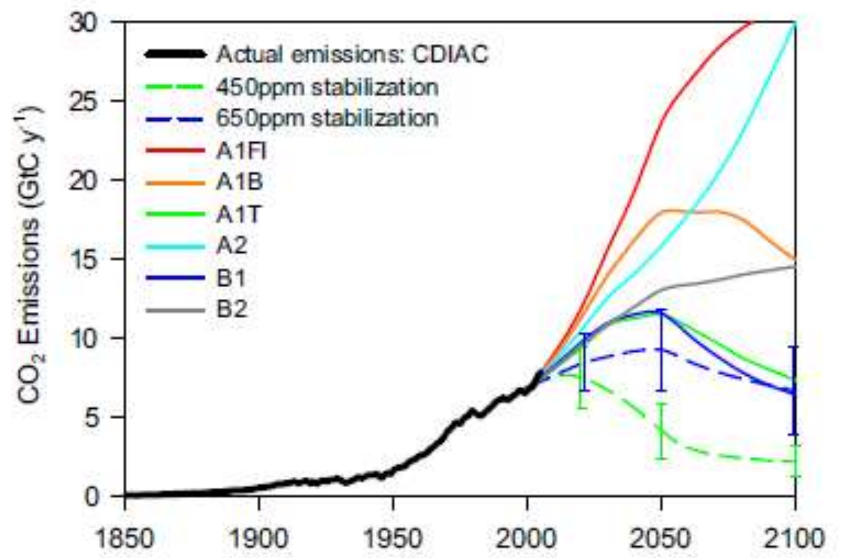
Global CO_2 emissions

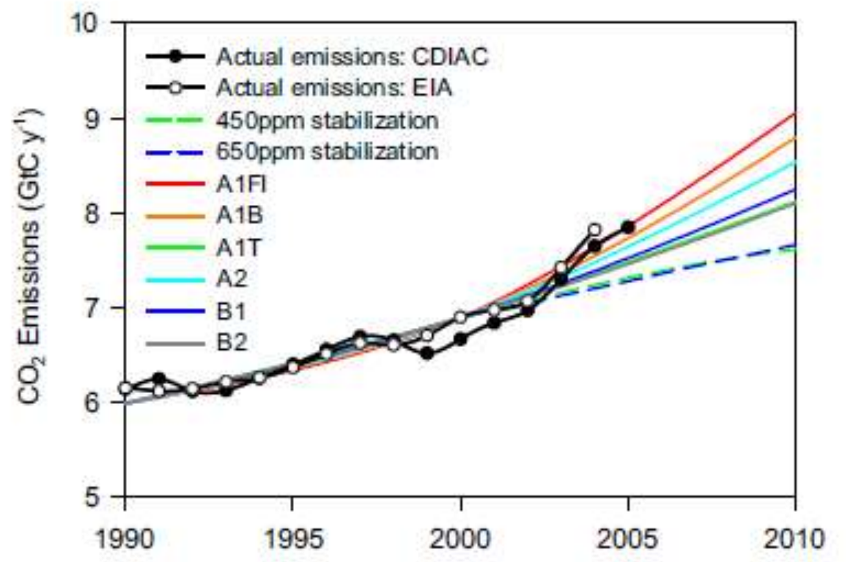
Global CO_2 emissions are now above the worst IPCC emission scenarios

CO_2 at ~ 450ppm in 25 years

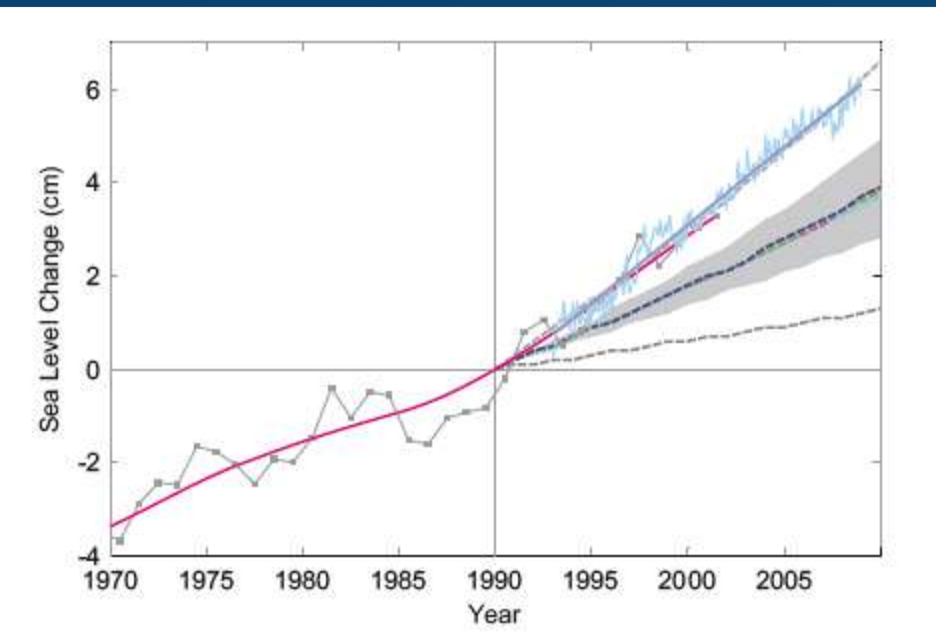
CO_2 > 600 within 50 years

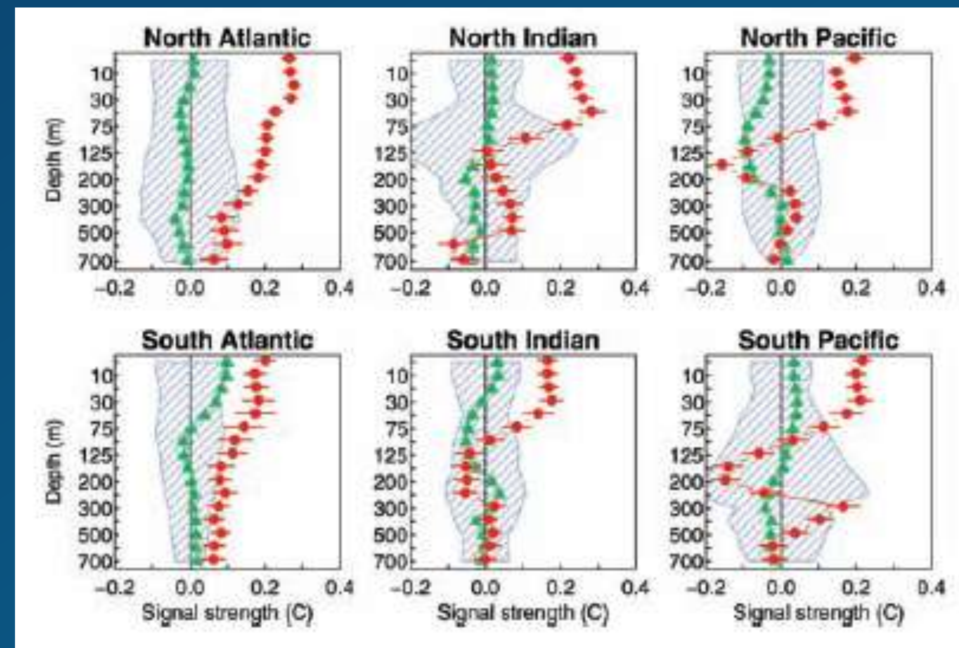
1000ppm by 2100 is now considered possible





Changes in sea level and ocean heat content



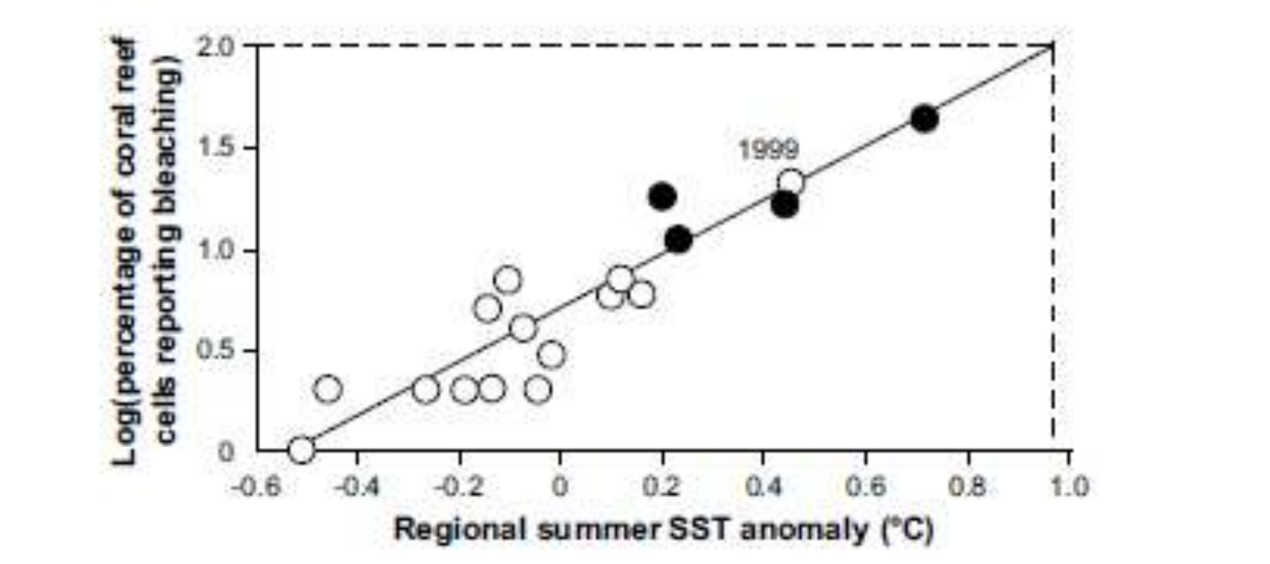


Richardson et al 2009 Climate Change, Global Risks, Challenges and Decisions

Barnett et al (2005) Science 309: 284-287 Actual temperature variability vs modelled internal natural variability in temperature (90% CL)

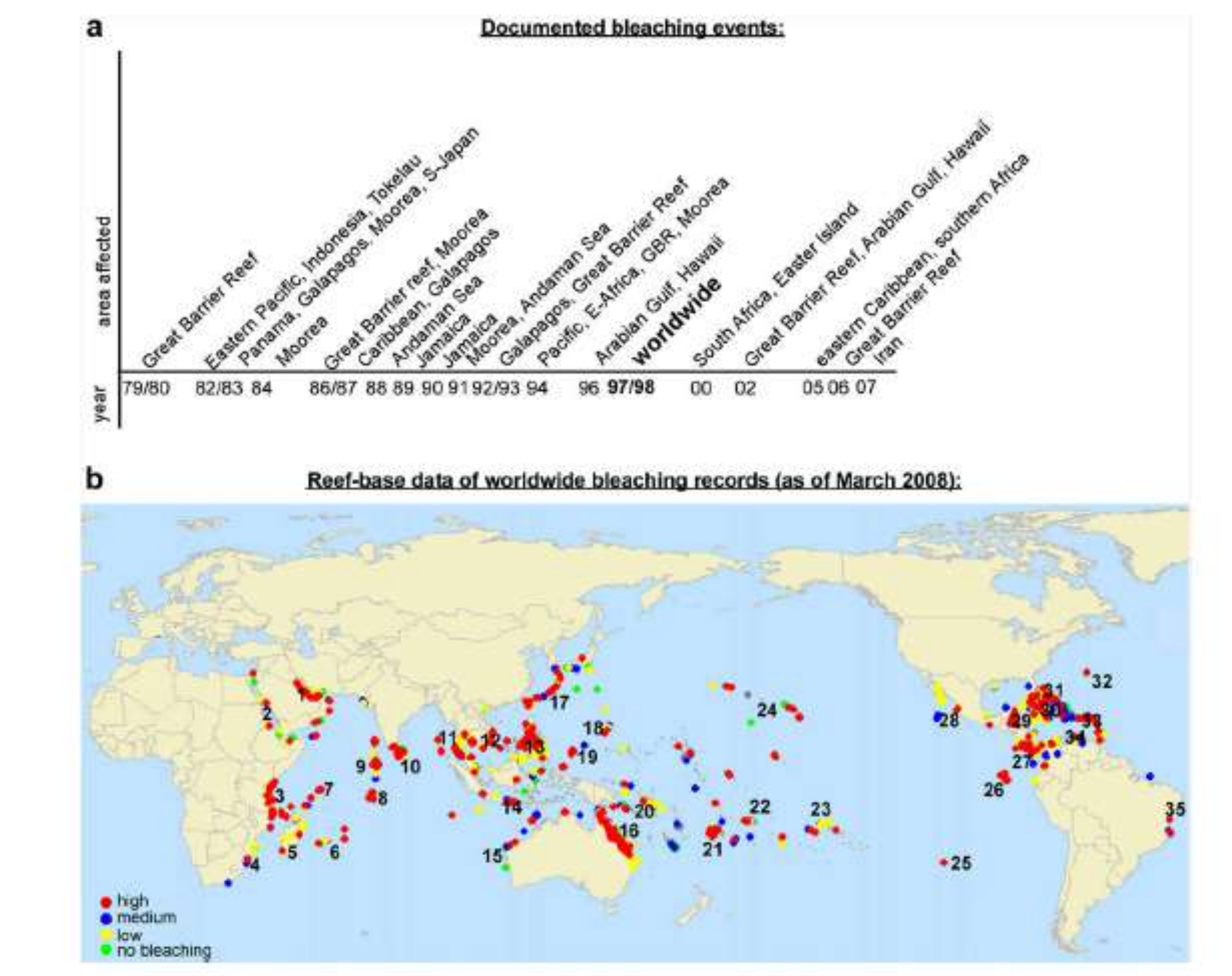
Coral bleaching

Relationship between SST and bleaching



Relationship between SST and the % of 1º Lat / long cells in which bleaching was detected in the Caribbean **(Baker et al. 2008 Est Coast Shelf Sci 80: 435-471)**

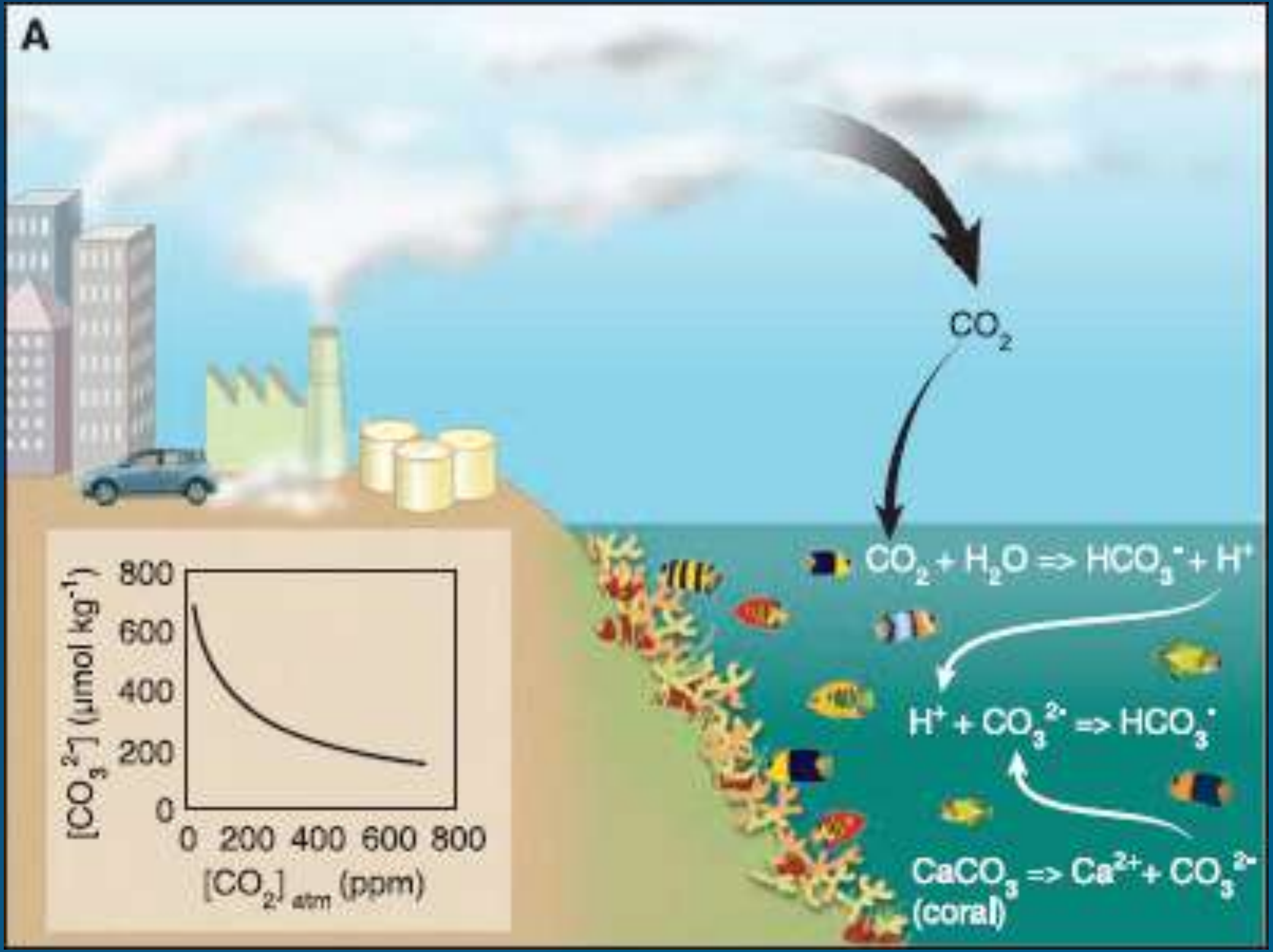
Bleaching events to date



Carbon chemistry

Increased CO_2 shifts the equilibrium of carbonate in seawater

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



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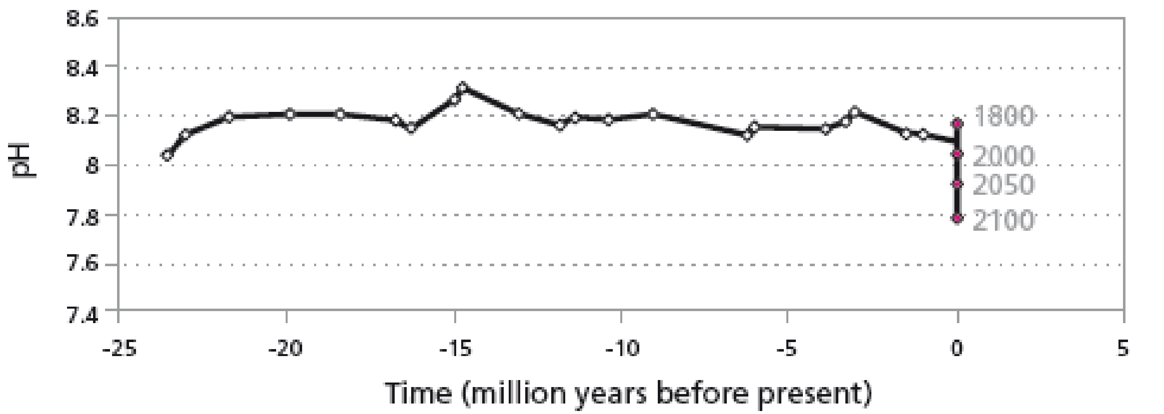
Change in pH has not been experienced in >20 million years



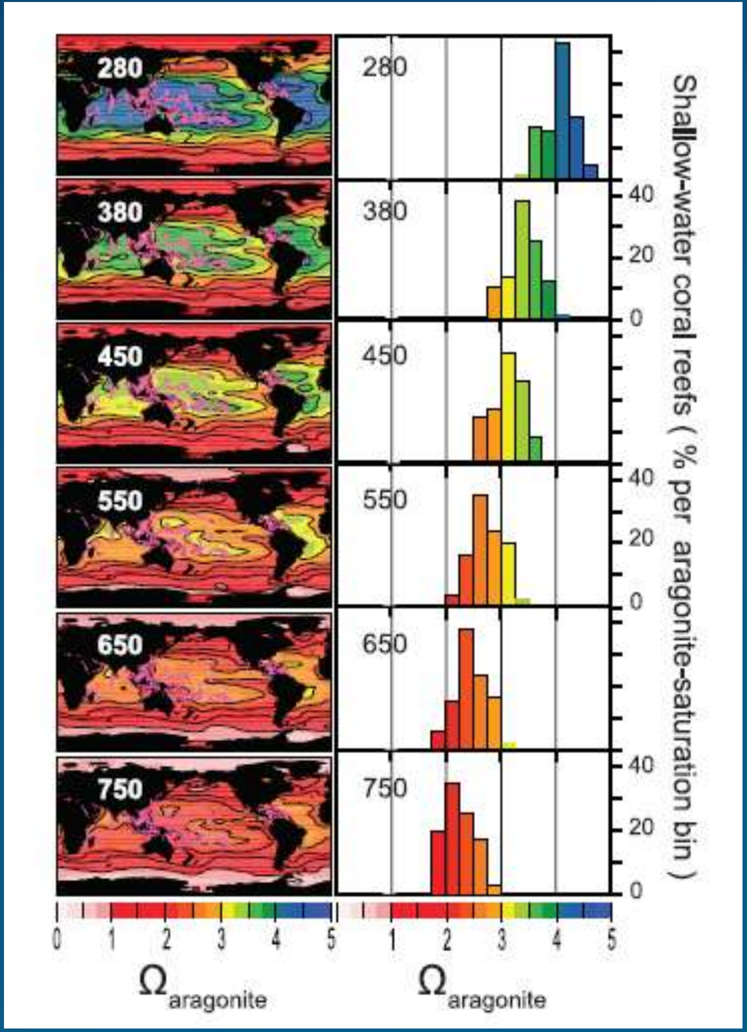
Ocean acidity (pH) over the past 25 millions years and projected to 2100[25]. The lower the pH, the more acidic the ocean becomes.

Ocean acidification

We will reach ~450ppm by 2030

Evidence showing
Decrease in growth rate
In Barrier Reef corals
By 14% since 1990
(similar studies Thailand, Caribbean)

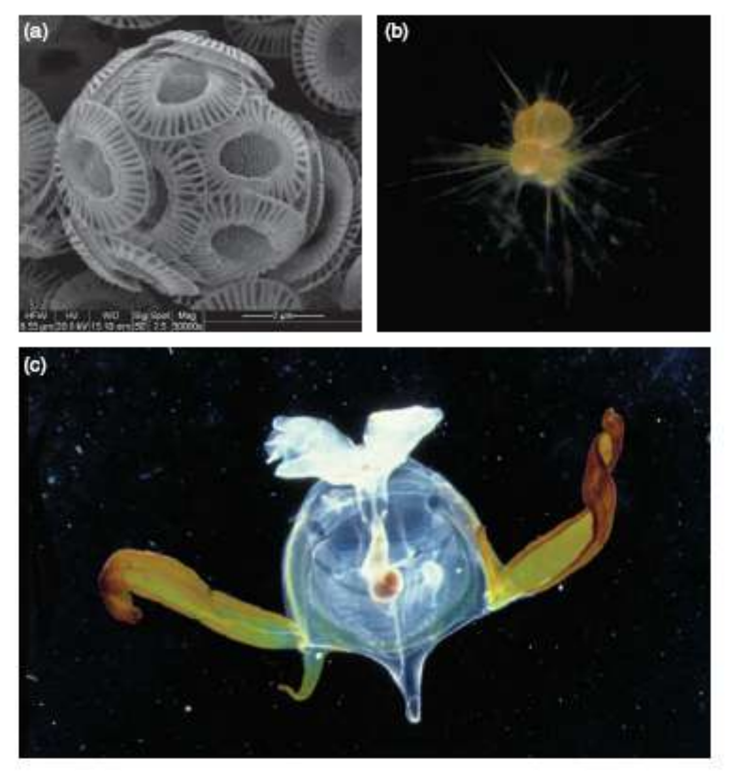
Cao & Caldeira (2008) Geophys Res Letts 35 L19609



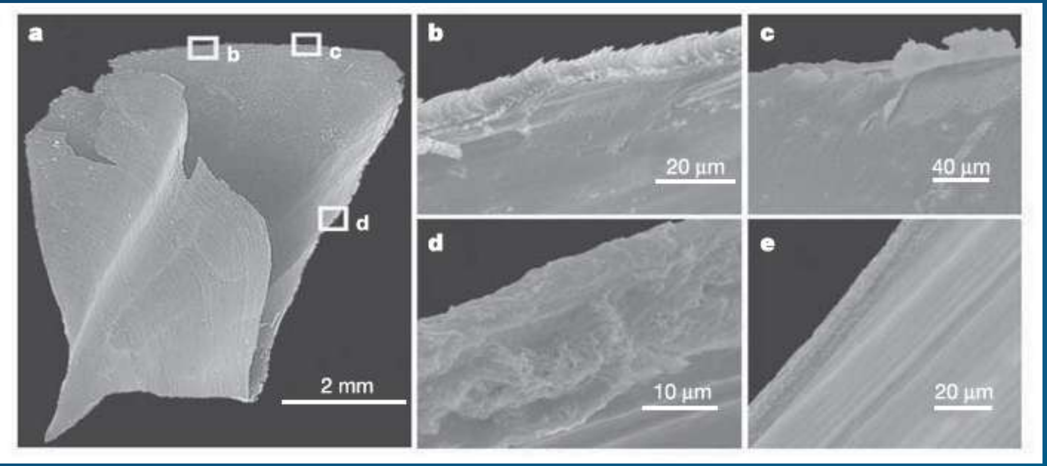
Coral reefs: the canary in the cage?

Examples of reefs from the Great Barrier reef that are analagous to the state of coral reefs in the future under different climate scenarios CRS-A, CRS-B and CRS-C. CRS-A = conditions stabilised at todays CO_2 levels. IPCC scenario B1 is predicting 550ppm CO_2 by 2100 and A2 800ppm.

Low pH will potentially affect all species with calcareous shells and exoskeletons



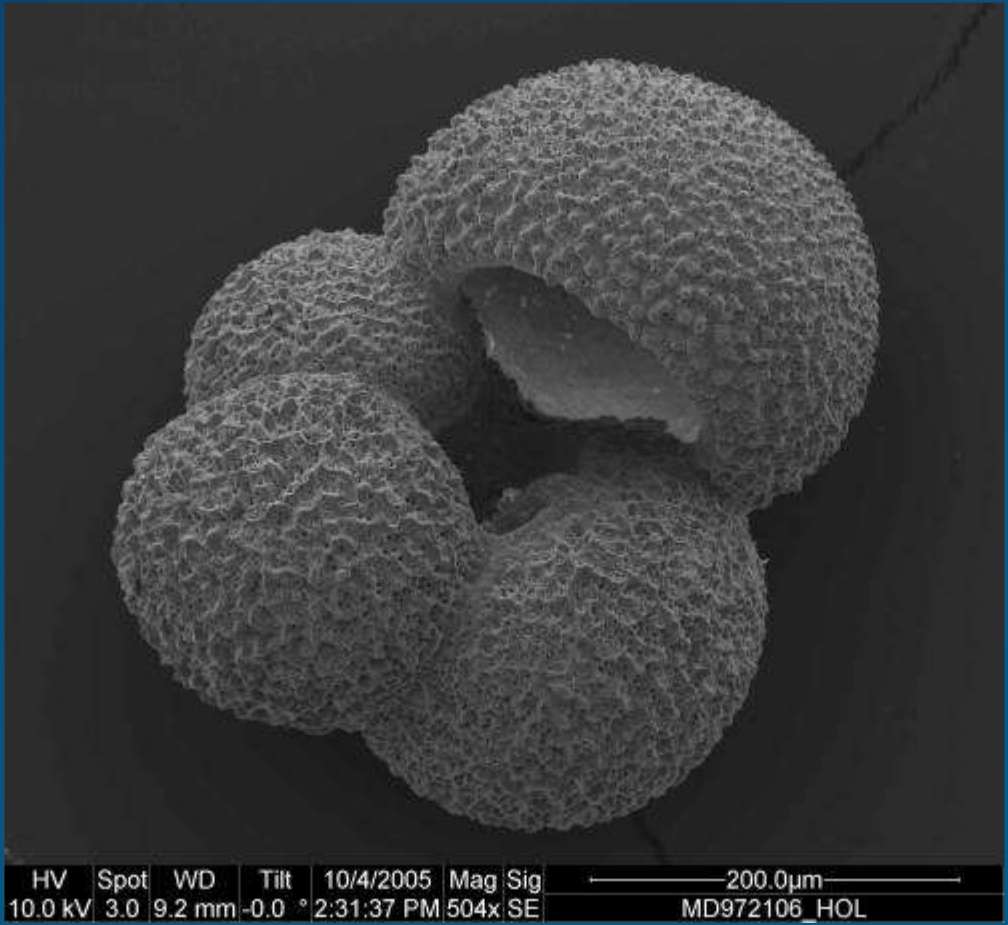
Pelagic organisms important in primary production and as important components of pelagic foodwebs have shells made of calcium carbonate.



Shell of *Clio* kept in water under-saturated with Aragonite for 48 hrs. Shell shows evidence of Erosion. Orr et al.Nature 437: 681-686

Globerigina bulloides – Southern Ocean

These Foraminifera are a third smaller than in recent past



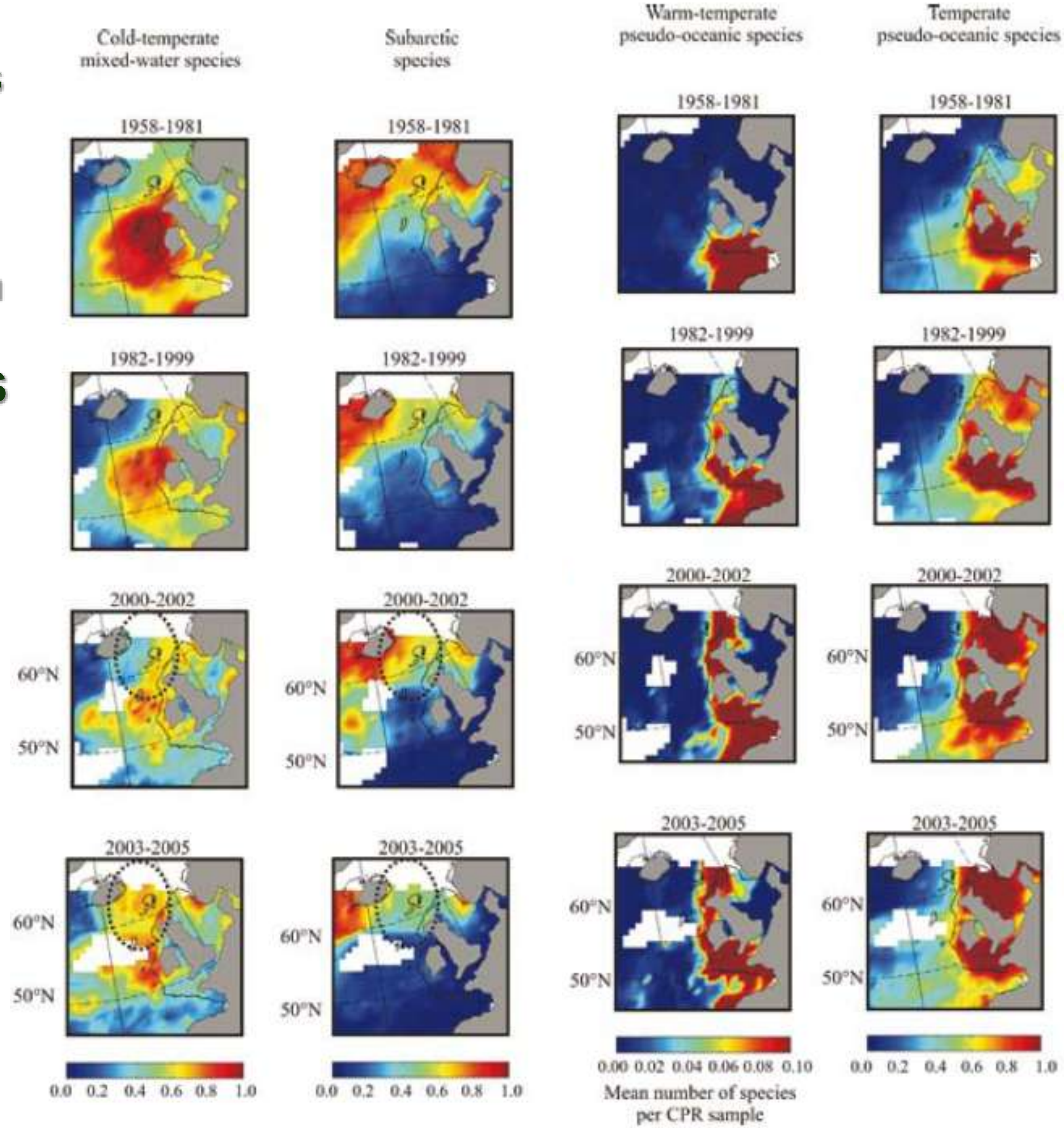
Moy et al 2009 Nature Geoscience 2: 276-280 (photo ACE-CRC)

Biogeography of plankton assemblages over 5 decades – North East Atlantic

Data synthesised from Hardy Plankton Recorders by SAFHOS

Warm water species invading temperate Waters.

Cold temperate and sub-arctic species Moving northwards



Changes in phenology

Edwards et al. (2008) Ecological Status Report: results from the CPR survey 2006/2007. *SAHFOS Technical Report, 5: 1-8.* Plymouth, U.K. ISSN 1744-0750

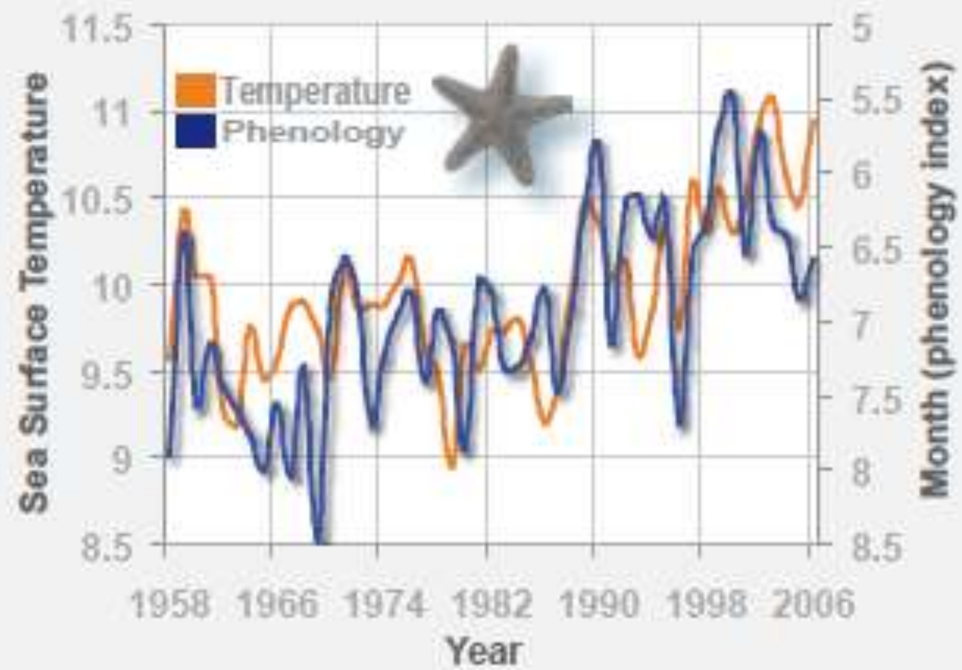


Fig. 3. Inter-annual variability in the peak seasonal development of echinoderm larvae (an indicator of plankton phenology) in the North Sea and it's relationship with sea surface temperature. Warmer temperatures = earlier seasonal appearance, colder temperatures = late seasonal appearance.

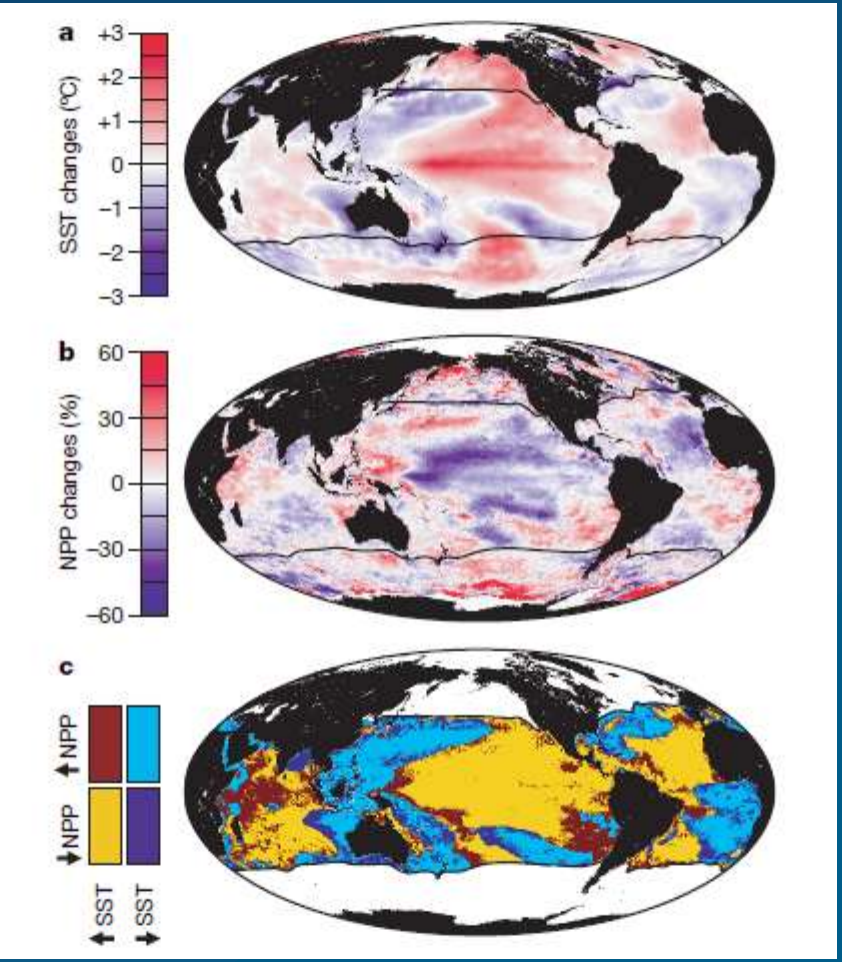
Changes in primary productivity with temperature

Climate controls on ocean productivity cause NPP to vary inversely with changes in SST.

Global changes in annual average SST (a) and NPP (b) for the 1999 to 2004 warming period. c, For 74% of the permanently stratified oceans NPP and SST changes were inversely related.
Yellow, increase in SST, decrease in NPP.
Light blue, decrease in SST, increase in NPP.
Dark blue, decreases in SST and NPP.
Dark red, increases in SST and NPP.

A similar inverse relationship is observed between SST and chlorophyll changes.

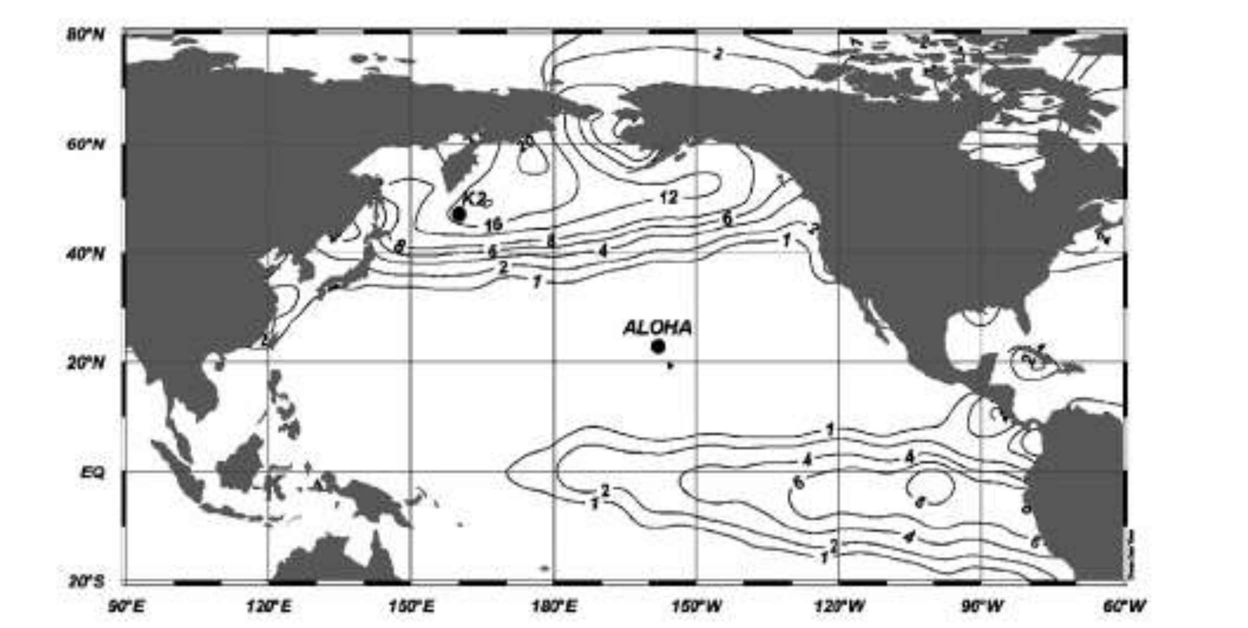
Behrenfeld et al. (2006) Nature 444: 752-755



Mid-water ecosystems

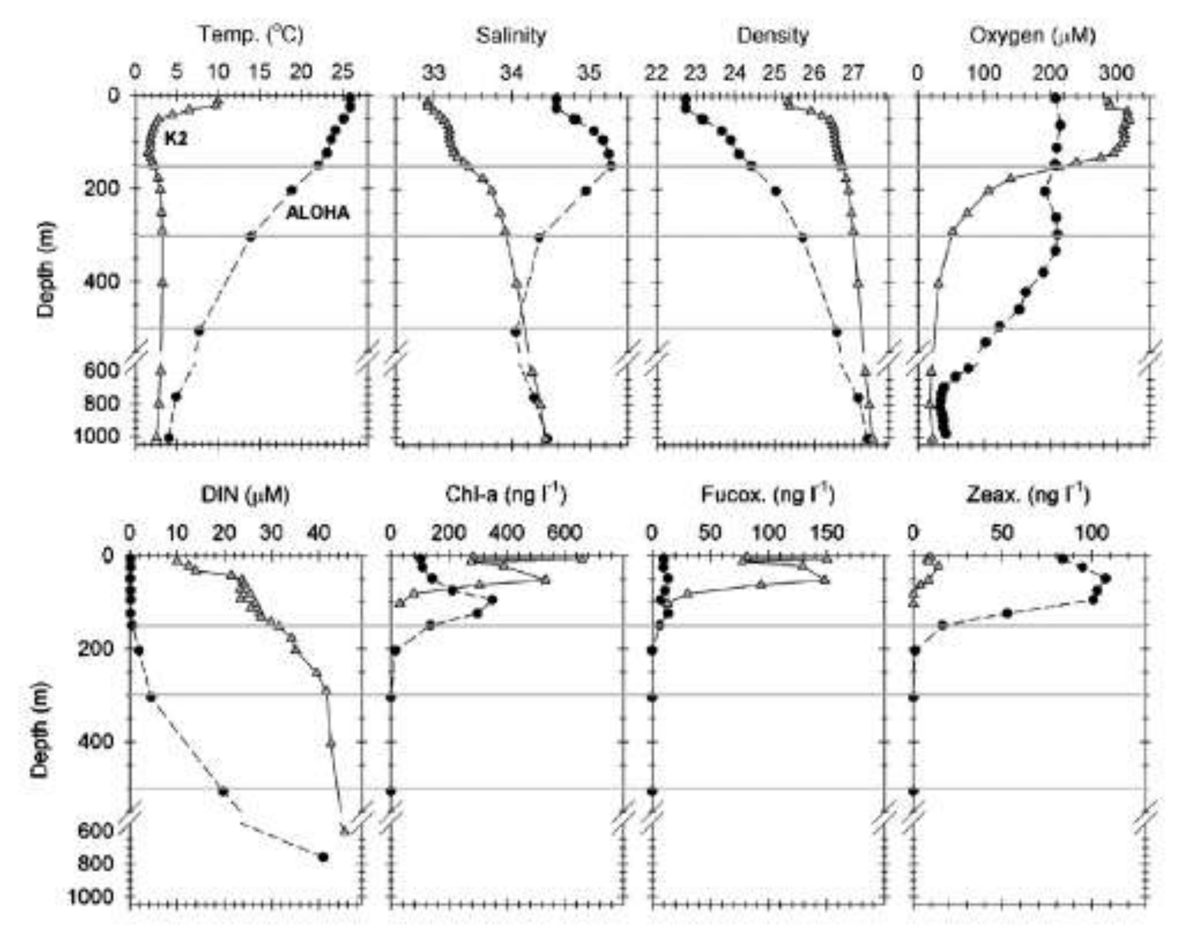
The role of animals in transport of POC

VERTIGO experiment



Vertigo compared nutrient fluxes at two sites in the Pacific, K2, a mesotrophic site and Aloha, an oligotrophic site
(Buesseler et al. 2008 Deep-Sea Res. II 55: 1522-1539)

Contrasts in physical and biogeochemical characteristics



Aloha = Circles; K2 = Triangles

Large difference in transfer efficiency in the twilight zone between Aloha and K2

	ALOHA			K2		
Dates on site	22 June to 9 July 2004			22 July to 18 August 2005		
Deployment start dates	23 June and 2 July 2004			30 July and 10 August 2005		
Mixed layer depth	49 m			26 m		
Depth of 0.1% light	~125 m			~50 m		
Physical properties						
	Temp. (°C)	*S*	O_2 (μM)	Temp. (°C)	*S*	O_2 (μM)
Mixed layer	26.10	34.63	210	9.61	32.91	285
150 m	21.93	35.26	204	2.17	33.46	198
300 m	13.55	34.33	210	3.37	33.97	29
500 m	7.62	34.04	115	3.17	34.18	21
1000 m	3.94	34.45	45	2.57	34.43	21
Particle properties (average by weight)						
	% POM	% $CaCO_3$	% Opal	% POM	% $CaCO_3$	% Opal
150 m	63.9	13.3	7.7	17.2	3.6	76.8
300 m	51.6	27.1	11.4	13.2	3.2	81.8
500 m	54.9	31.9	16.3	14.1	3.4	80.4
4000 m	13.3	59.9	26.9	7.6	8.5	77.0
POC fluxes (mg m^{-2} day^{-1})						
	First dep.	Second dep.		First dep.	Second dep.	
Integrated PP	180	220		530	365	
150-m POC flux	18	18		62	23	
300-m POC flux	7.2	6.0		47	17	
500-m POC flux	3.6	3.6		29	13	
Production, export, and flux ratios						
	First dep.	Second dep.		First dep.	Second dep.	
% PP >20 μm	12%	11%		30%	19%	
e ratio = flux at 0.1% light/PP	13%	11%		21%	11%	
T_{eff} = 500-m/150-m flux	20%	21%		46%	55%	

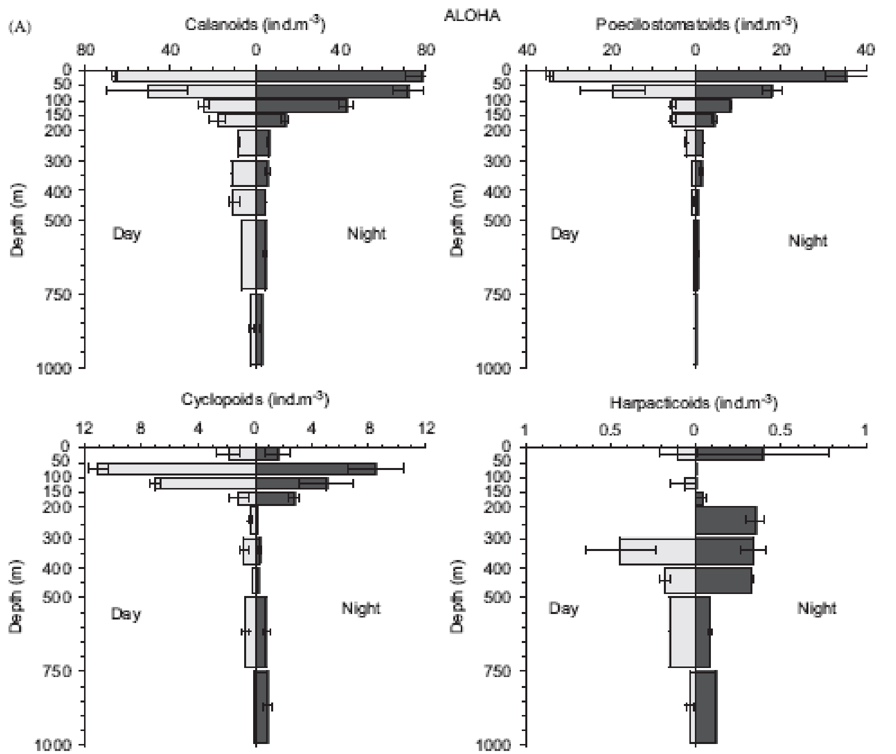
Buesseler et al 2007 Science 316: 567 - 570

Why the difference between the two sites?

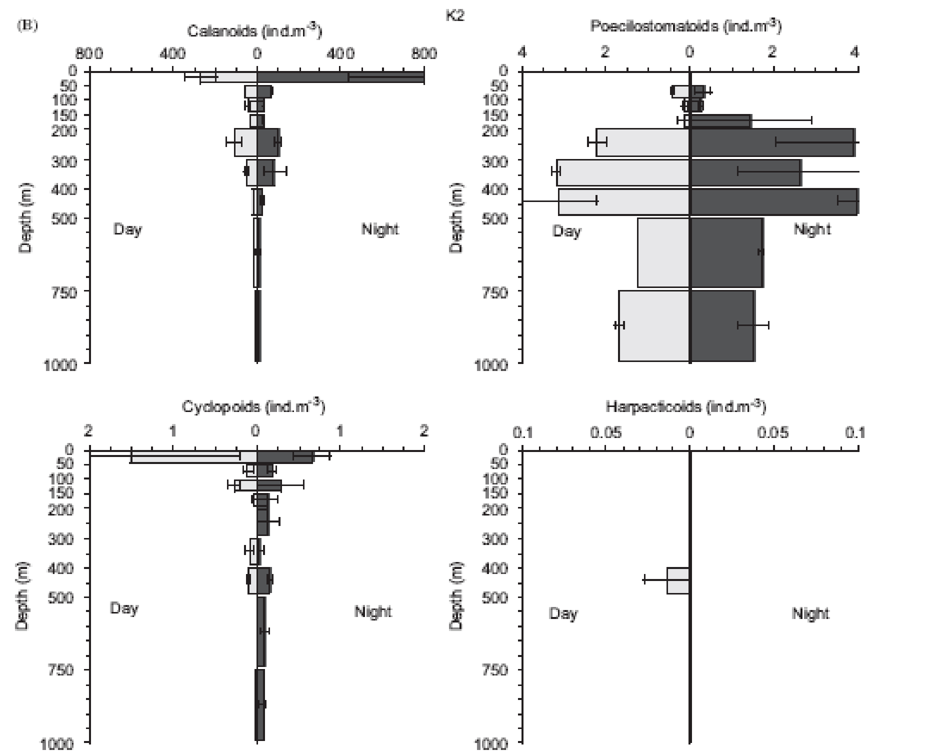
- At K2 predominance of large diatoms leading to enhanced delivery of production to deep sea (but sinking rates of particles not that different between sites)
- At K2 there was a much higher biomass of diurnally migrating zooplankton particularly *Neocalanus* spp
- Sinking of Faecal pellets important at both sites (repackaging of POC and associated nutrients)

Comparison of Copepods Aloha vs K2

Aloha



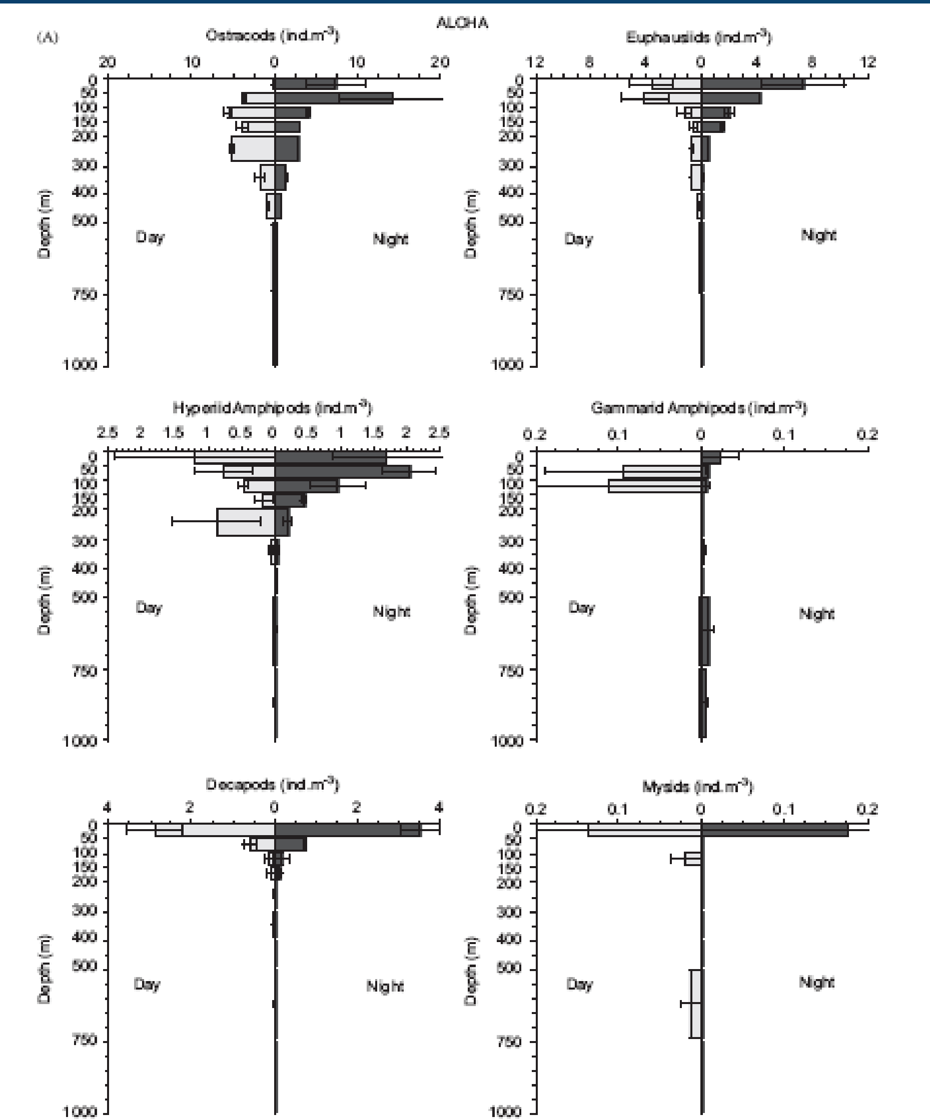
K2

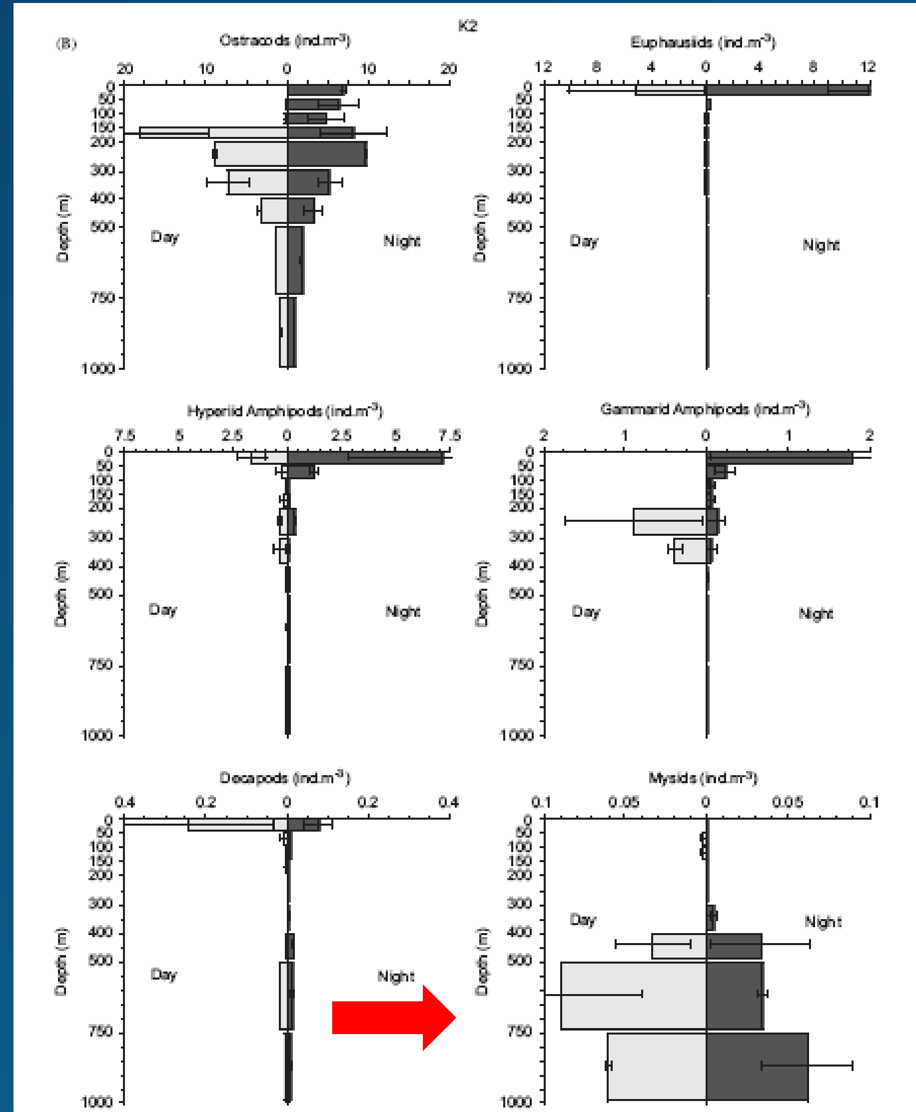


Note – Order of magnitude more biomass at K2 and larger biomass in twilight zone

Steinberg et al. (2008) Deep-Sea Res. II 55: 1615-1635

Comparison of other arthropod groups



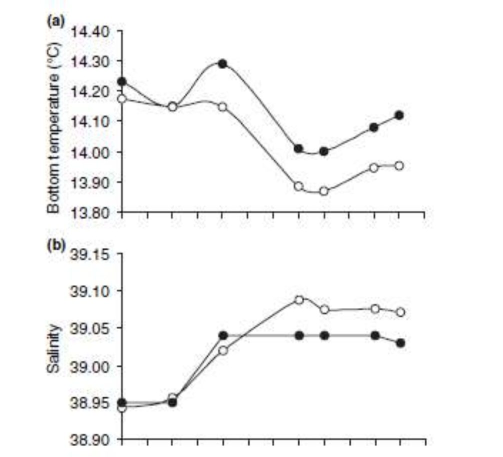


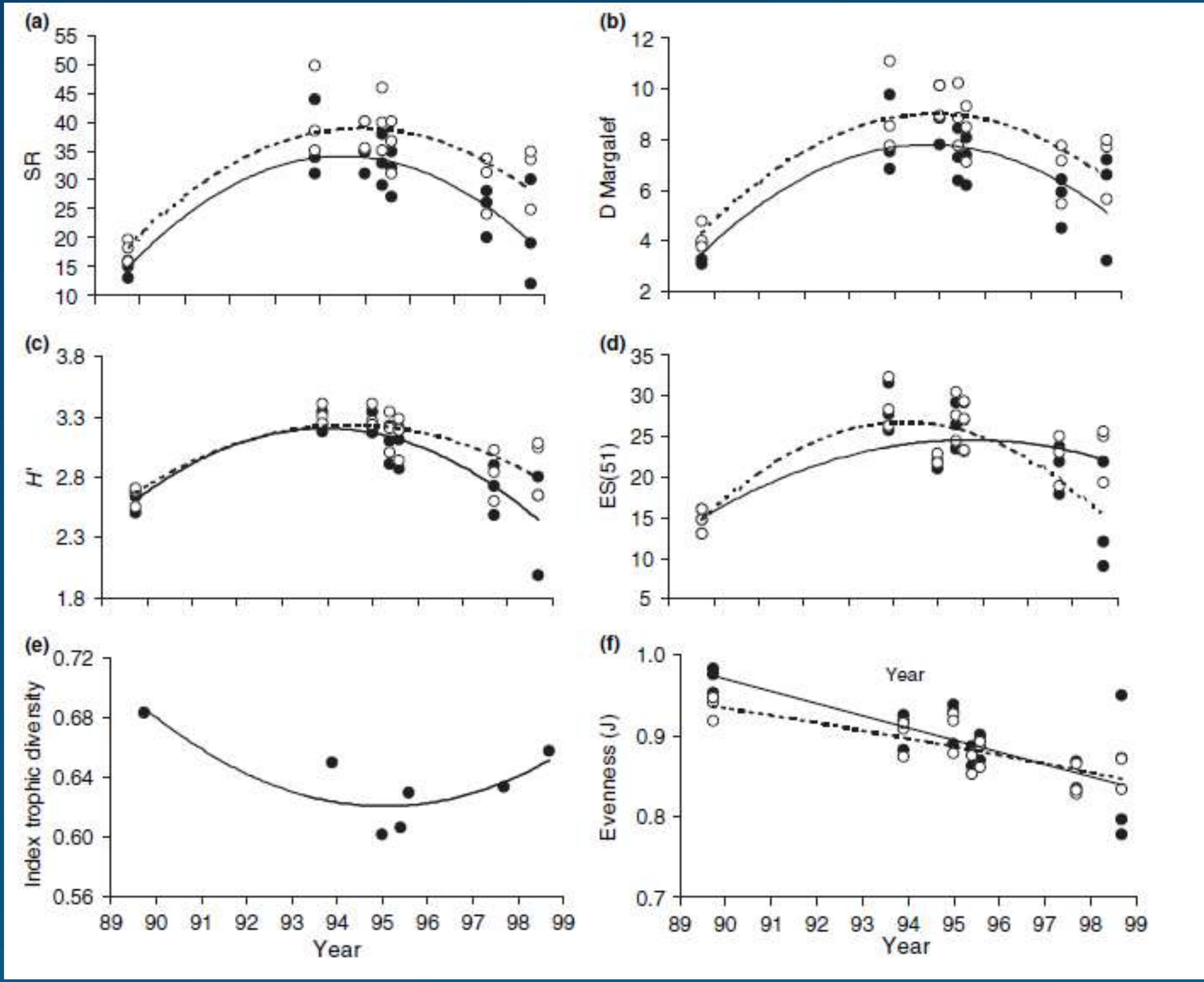
Active transport of carbon

- Large populations of diurnal migrators (especially copepods such as *Neocalanus*) support large populations of predators in mesopelagic zone
- Active transport of CO_2 and DOC by migrators through respiration and excretion was 11-44% of the sinking POC flux at Aloha but 26-200% at K2 (over 150m)
- The mesopelagic carbon demand of bacteria and zooplankton greatly exceeds that of the sinking POC
- Mesopelagic foodweb dependent on surface production via diurnal migrators
- Larger zooplankton at K2 also mean larger faecal pellets with higher sinking velocities
- Proportion of predators increase to ~ 3000m in the present and other studies

Benthic ecosystems

Changes in temperature affect deep-sea nematode diversity (Danavaro et al 2004)





Mediterranean deep sea

Warm – cool – warm 1989-1999

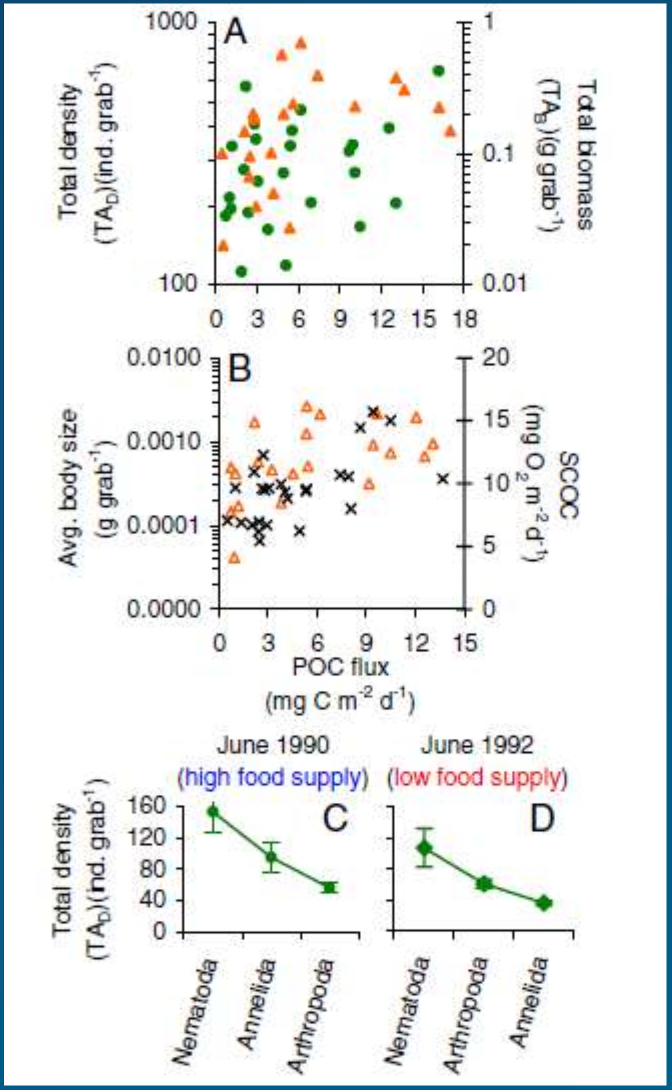
Changes in Pacific abyssal fauna

NE Pacific abyssal site

10 years

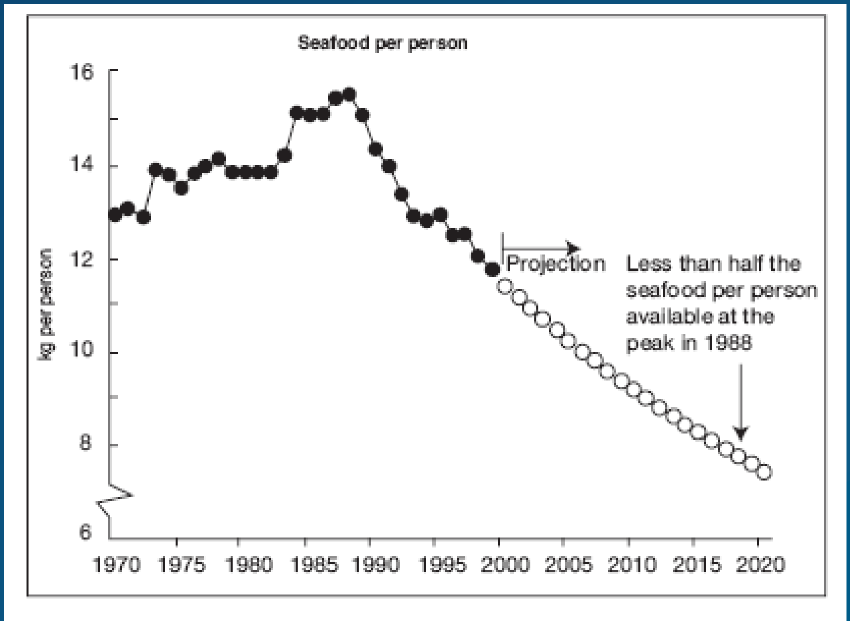
Climate driven variation in food availability drives metazoan abundance, phyla composition, rank abundance distributions and reminaralization

Ruhl et al. (2008) PNAS 105: 17006-17011



Global catches for capture fisheries and global decline of fish stocks

Source: FAO Fish Stat



Global catches stagnating as a result of overexploitation. Catches maintained by exploiting new stocks (FAO) but the supply of fish per person has been decreasing since 1990s.

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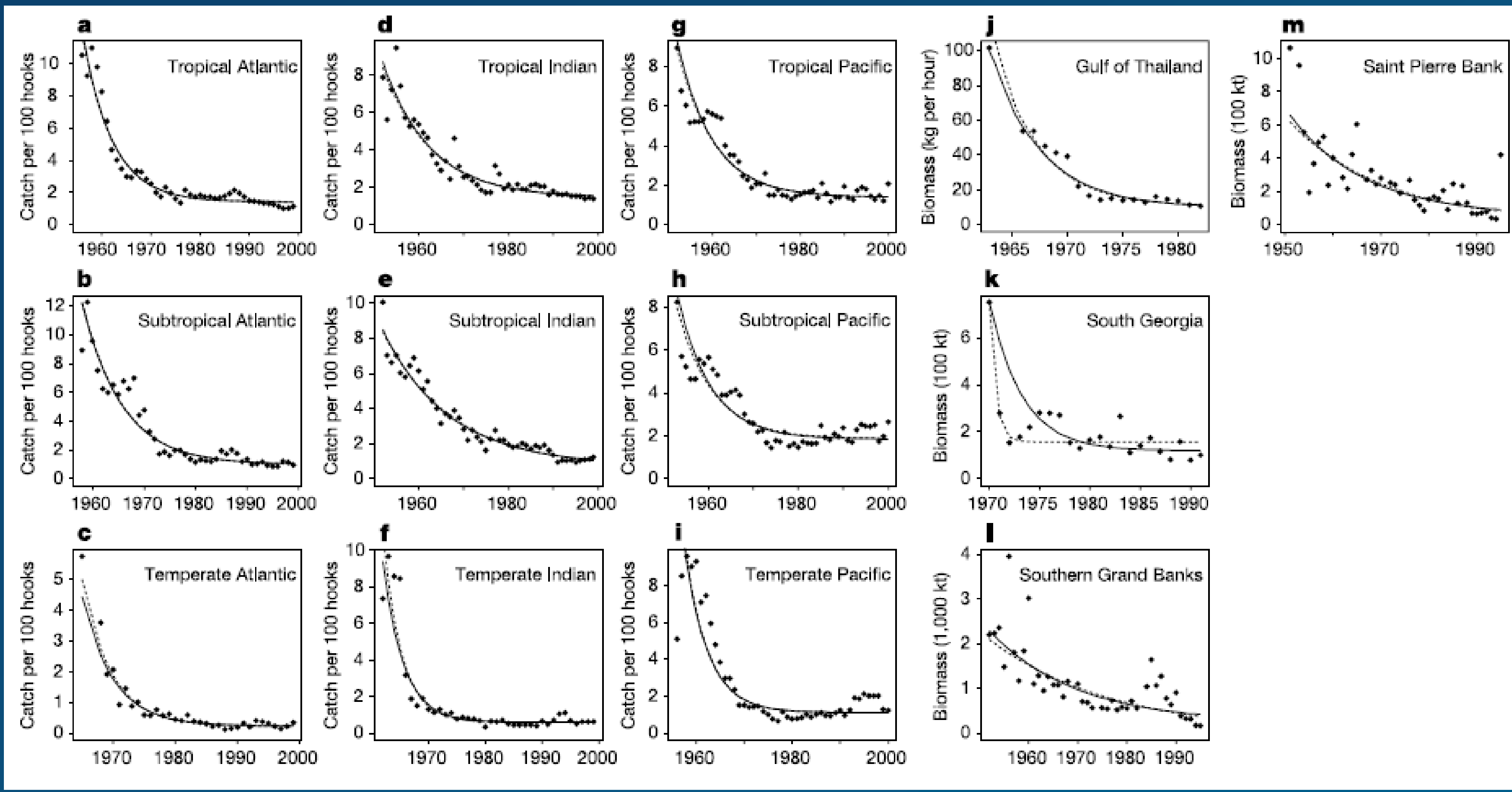
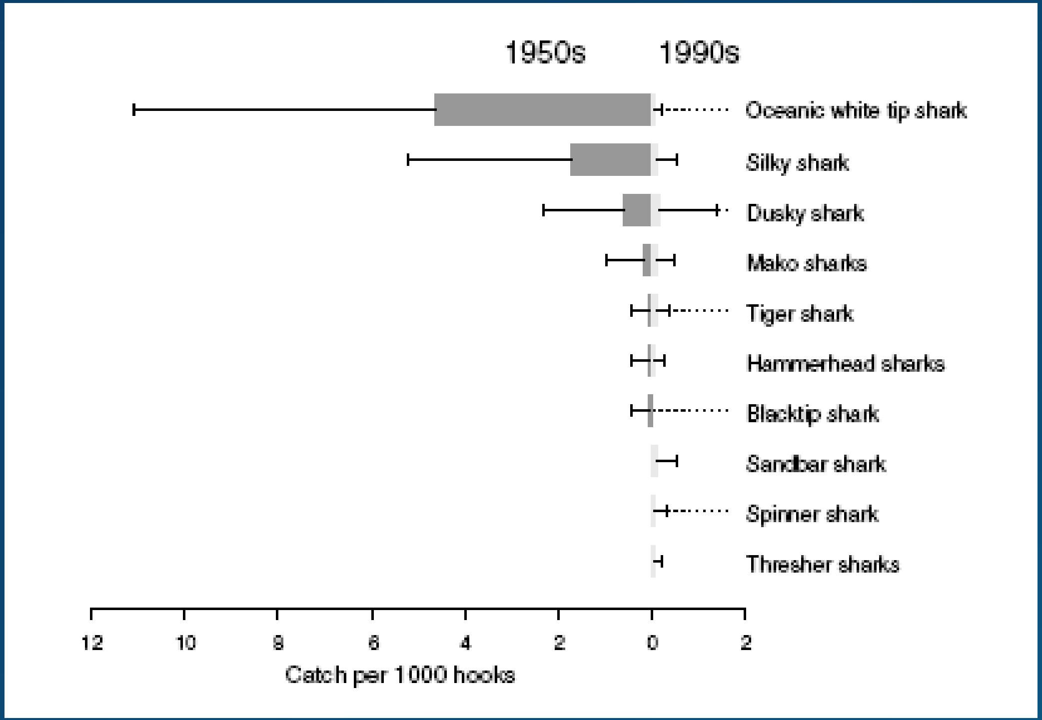
Trends in biomass for longline fisheries

Declines are rapid and consistent, generally within 10 years and sometimes as little as 2 years (South Georgia)



Myers & Worm Nature 423: 280-283

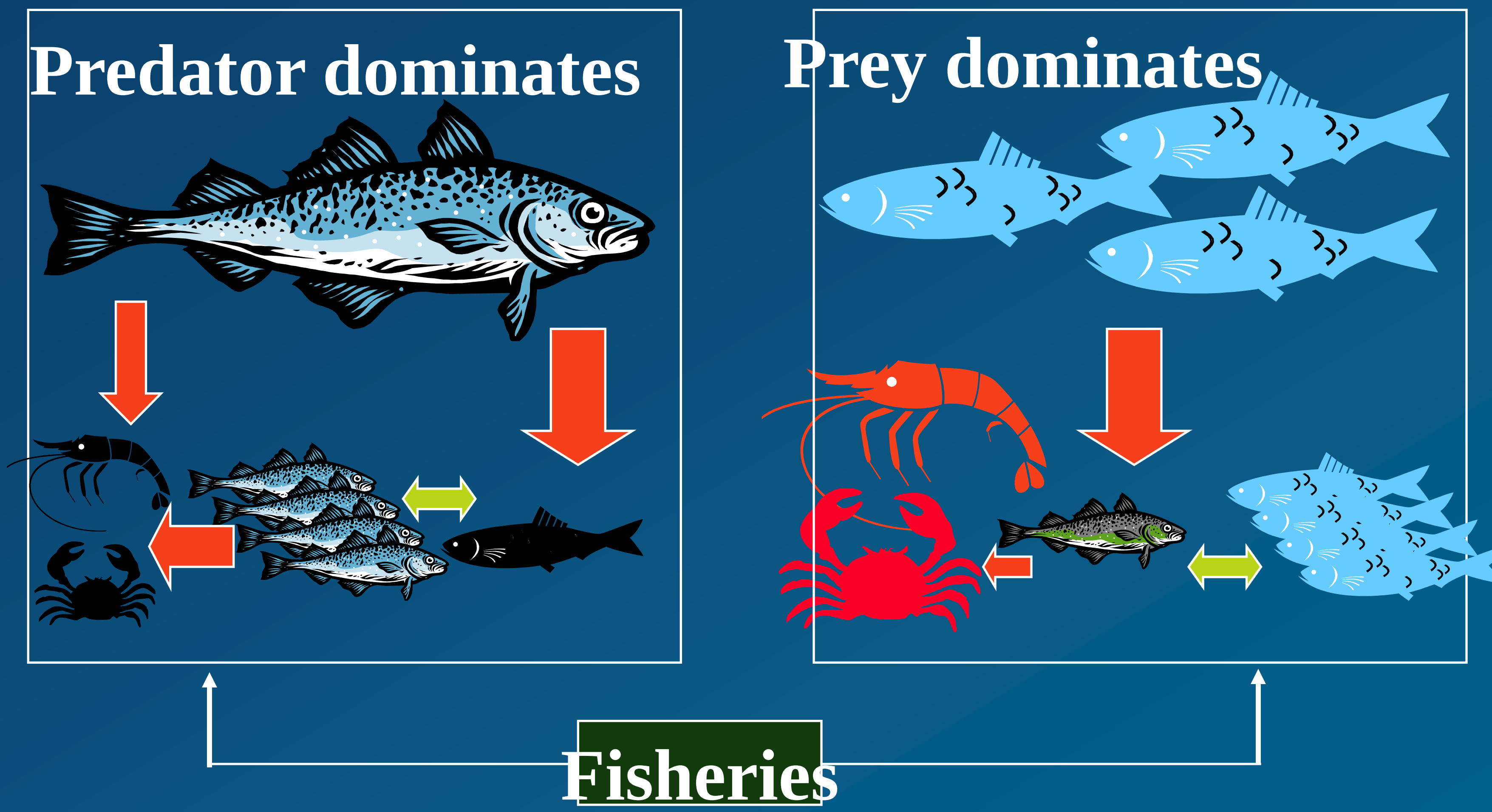
NW Atlantic US pelagic longline fishery



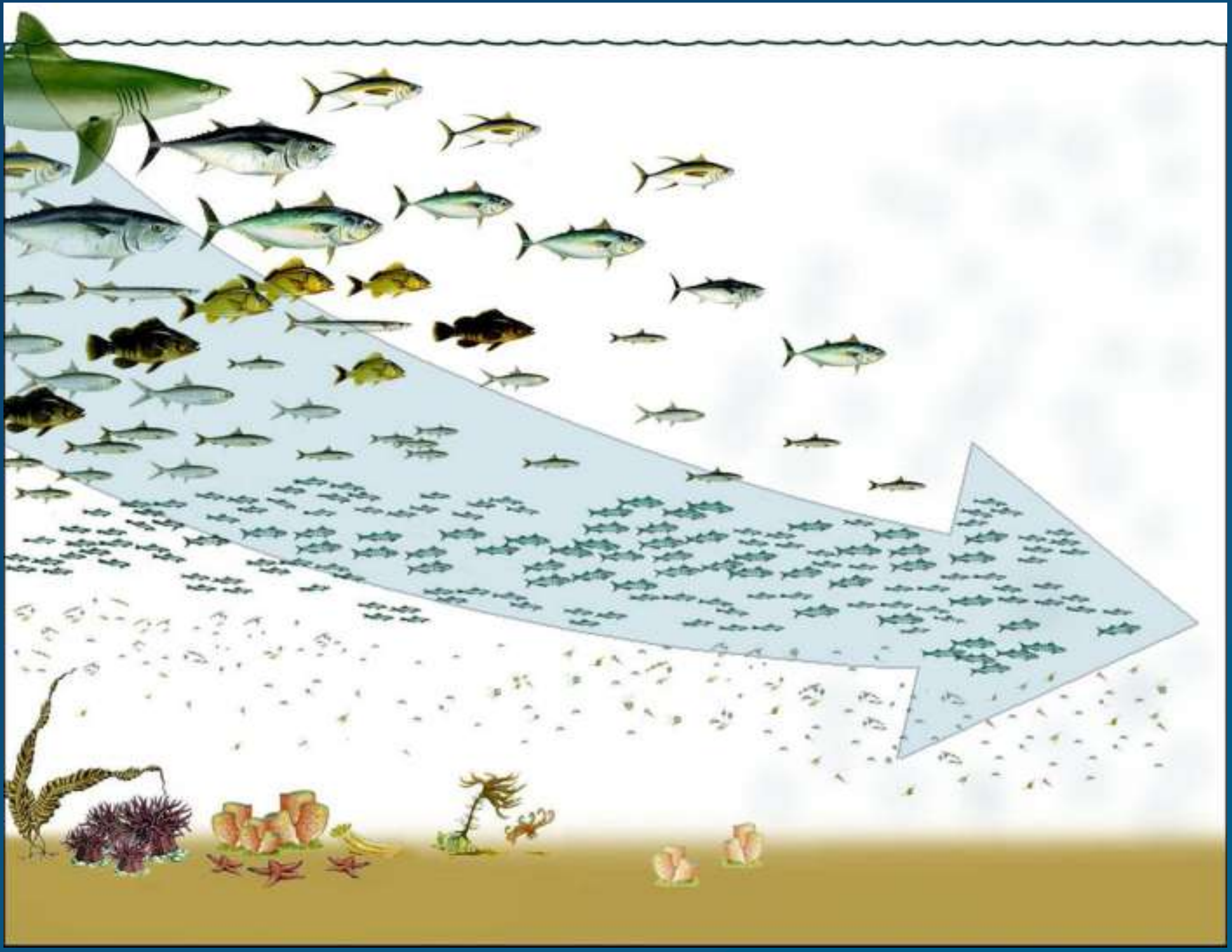
Mean catches per 10,000 hooks on yellowfin-targeted day time sets.

1950s and 1990s
Contours = 200m, 1000m

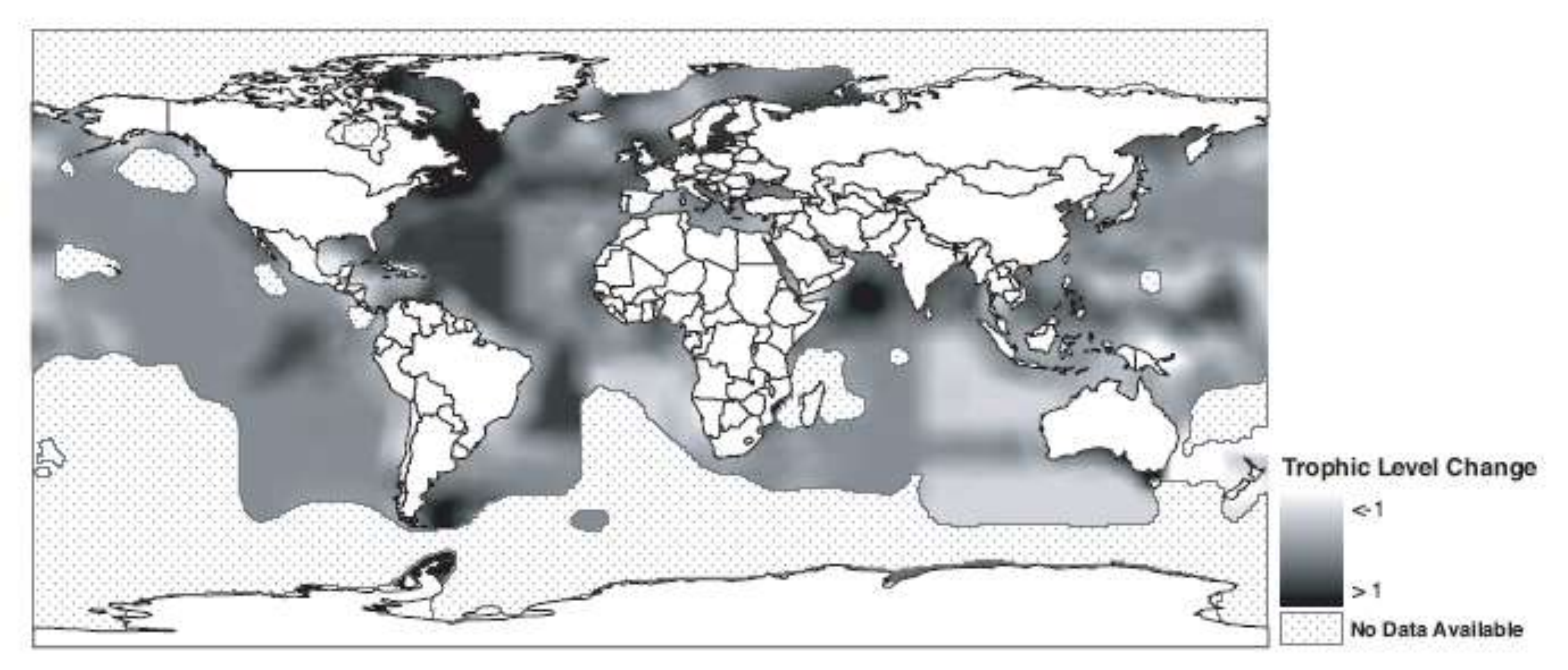
Shift in ecosystem between multiple stable states



Fishing down the foodweb

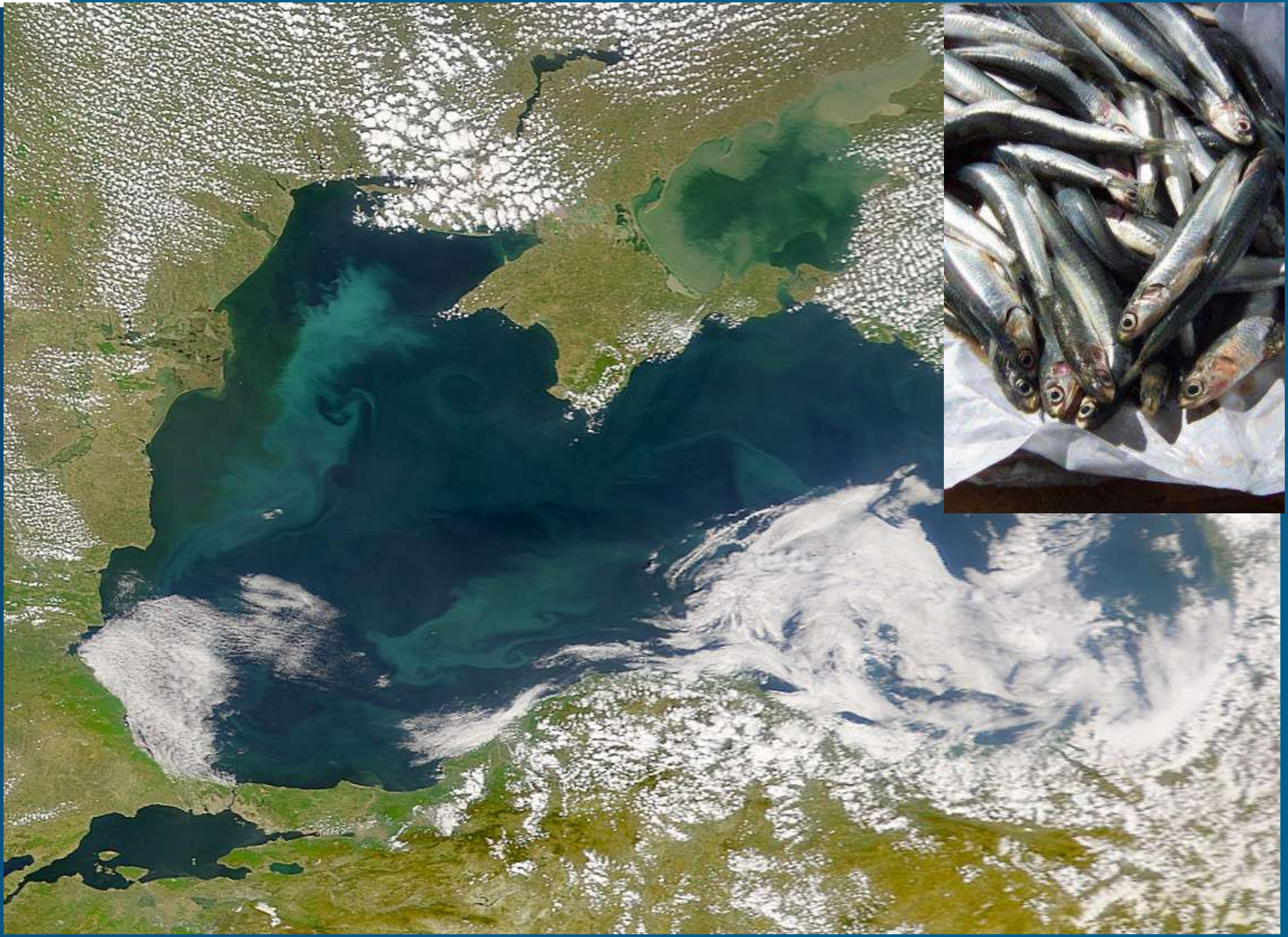


Trophic level change 1950-2000



Millenium Ecosystem Assessment

Ecological cascades: Black Sea anchovy



Cascading shifts in the Black Sea ecosystem

A) Pelagic predatory fish

B) Small planktivorous fish
-diamonds = fishing mortality

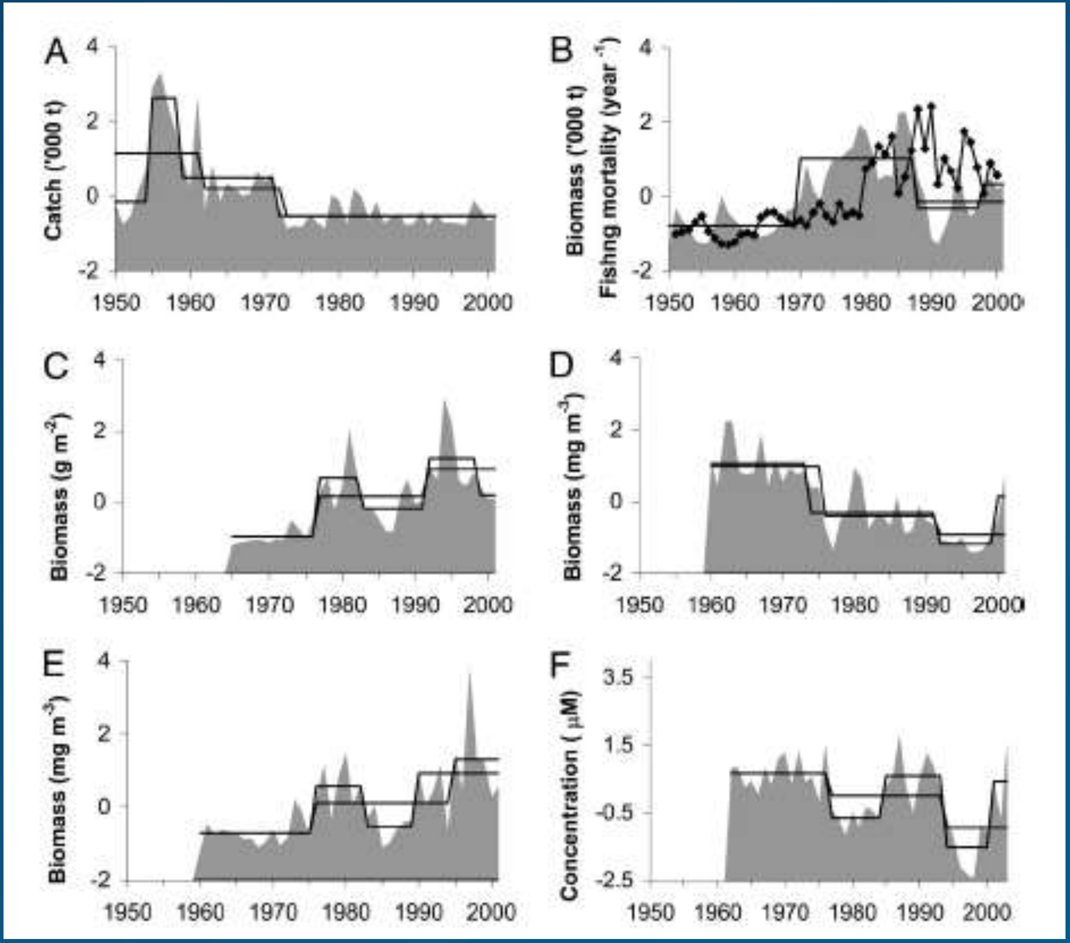
C) Gelatinous plankton

D) Zooplankton

E) Phytoplankton

F) Oxygen

Data standardised to zero mean, unit variance



Daskalov et al. (2007) PNAS 104: 10518-10523

Mnemiopsis leidyi

Anchovy fishery 400,000t per year

Profits $17 million per year

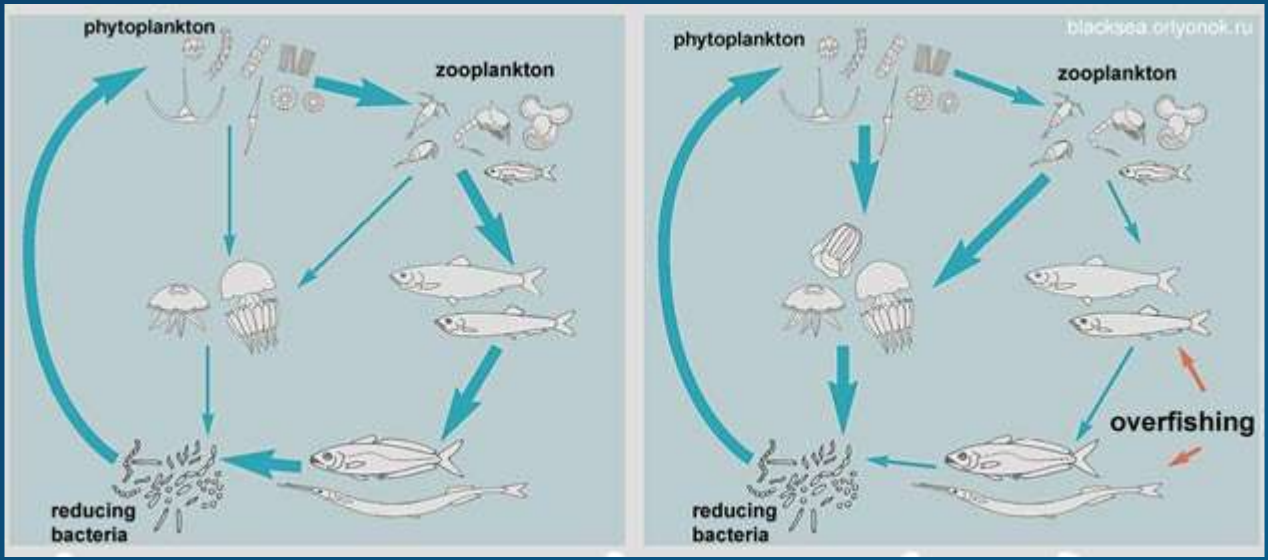
Post-*Mnemiopsis* 40,000t per year

Profits of $0.3 million

There has been some recovery in this ecosystem

Knowler (2005) Ecological Economics 52: 187-199

Trophic cascade Black Sea ecosystem



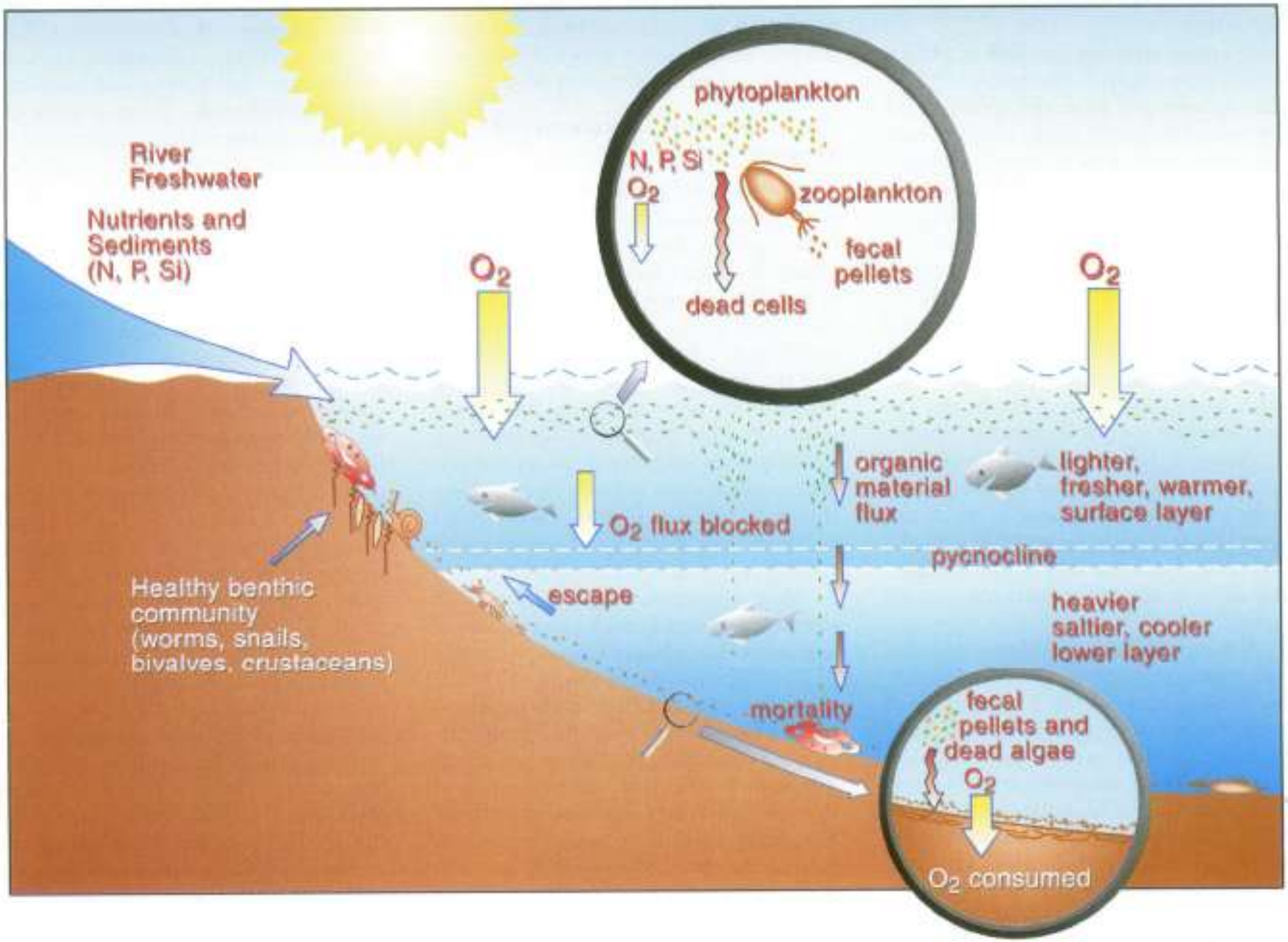
Regime shifts have promoted jellyfish blooms elsewhere

Removal of predators along with climatic changes has led to invasions by “jellyfish”.

Phyllorhiza punctata

'Jellyballs' off Georgia: Champ Warren lands a load of cannonball jellyfish onto the deck of a converted shrimp trawler. Georgia white shrimp have been overfished, but 'jellies' are thick due to a lack of predators and an abundance of algae. They are exported to China and Japan (Rick Loomis/*Los Angeles Times*)

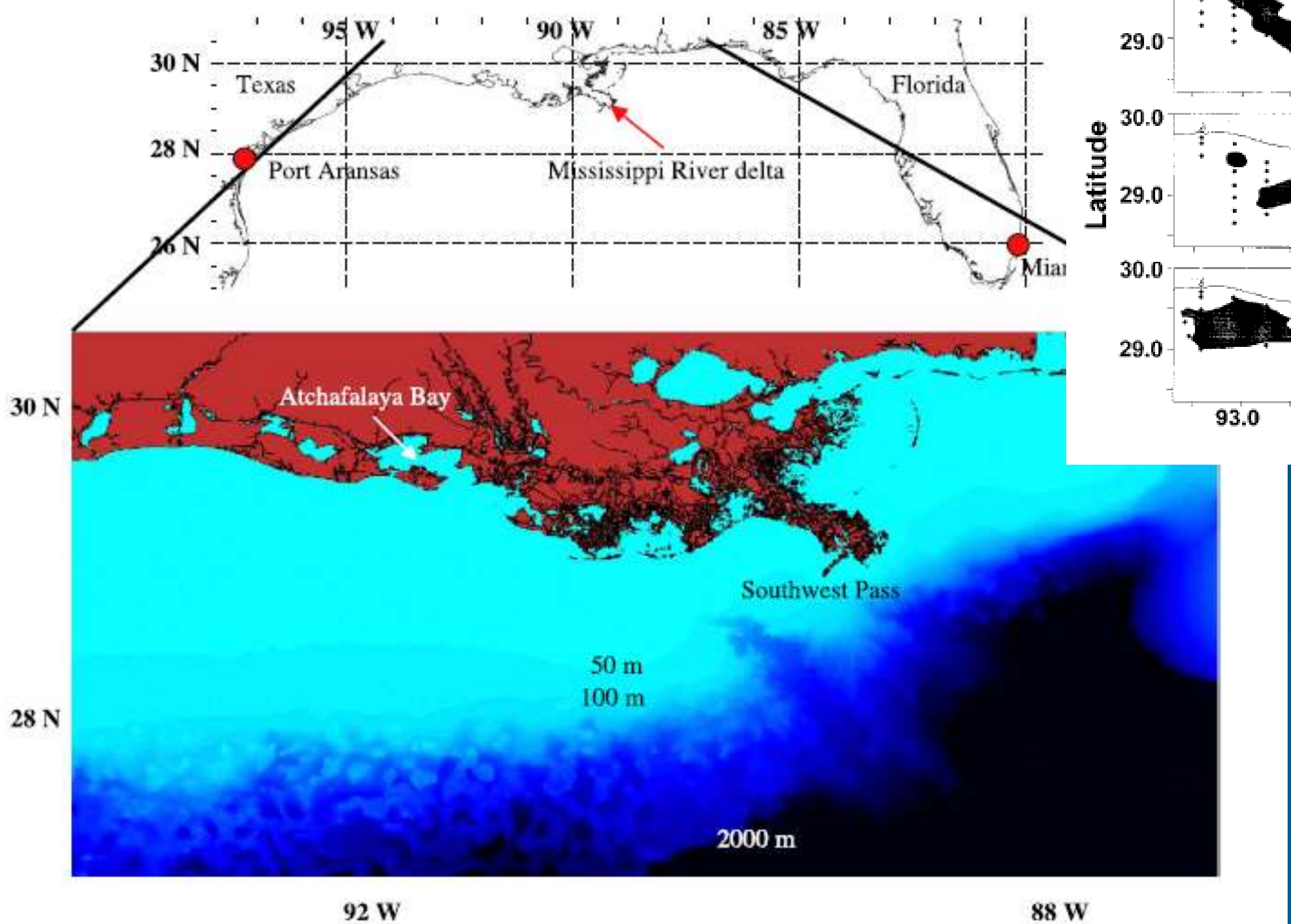
Eutrophication & the rise of "Dead Zones"

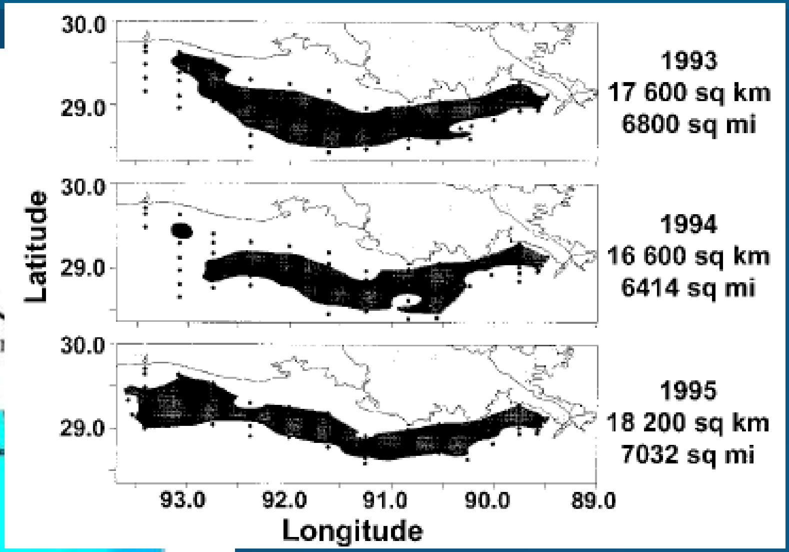


Dead zones

- Dead zones are areas of hypoxia (low oxygen) or anoxia (no oxygen).
- Marine animals start to suffocate at ~2mg O_2 l^{-1} (18% air saturation)
- Results from eutrophication (nutrient enrichment especially of nitrogen) generally originating from development of watersheds or expanded agriculture
- Nutrient enrichment leads to increases in surface production which sinks to the seabed. As this decomposes oxygen is used up.
- Can also lead to blooms of harmful algae
- Gulf of Mexico and the Baltic are the largest

Gulf of Mexico dead zone





Hypoxia first reported 1972

Occurs throughout summer months of most years

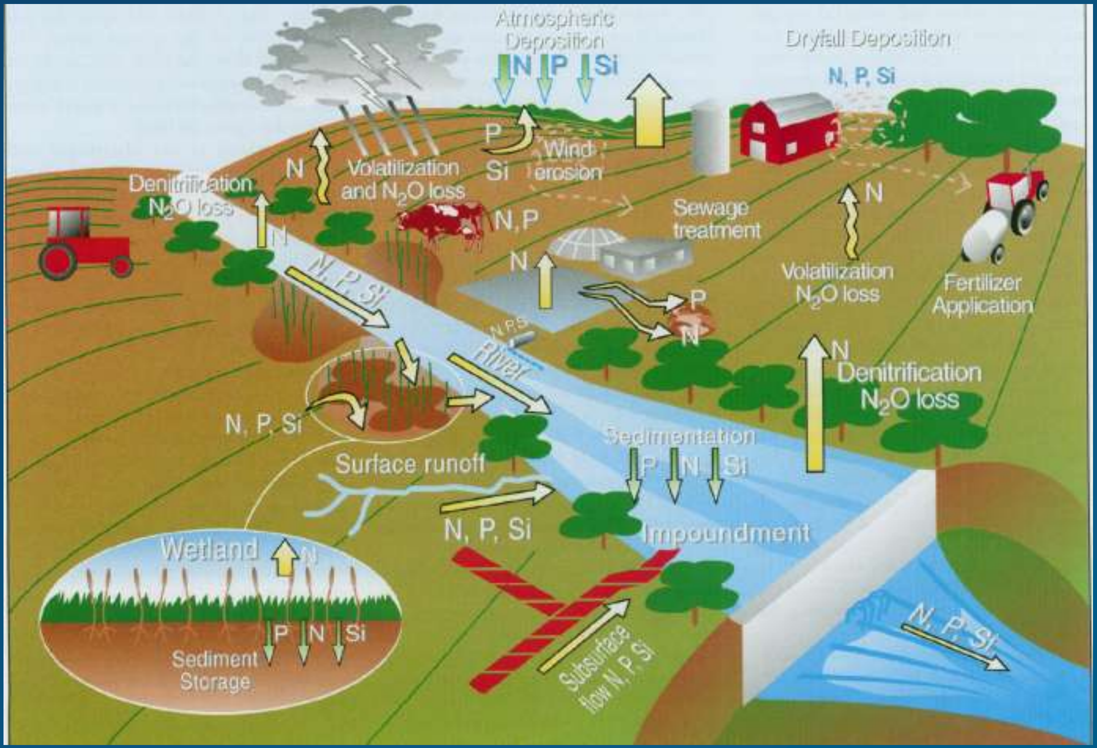
Dagg & Breed (2003) J. Mar Syst 43: 133-152

Climate change means an increase in the frequency and severity of hypoxia

The Mississippi delivers
About 31% of the riverine input of nitrogen to the Atlantic

About 565 kg N km^2 yr^{-1} drains in to the river from the catchment area, mainly as a result of agricultural fertilisers and nitrogen fixation by crops.

Warmer temperatures = greater stratification and lower dissolved O_2
Higher rainfall = greater river discharge

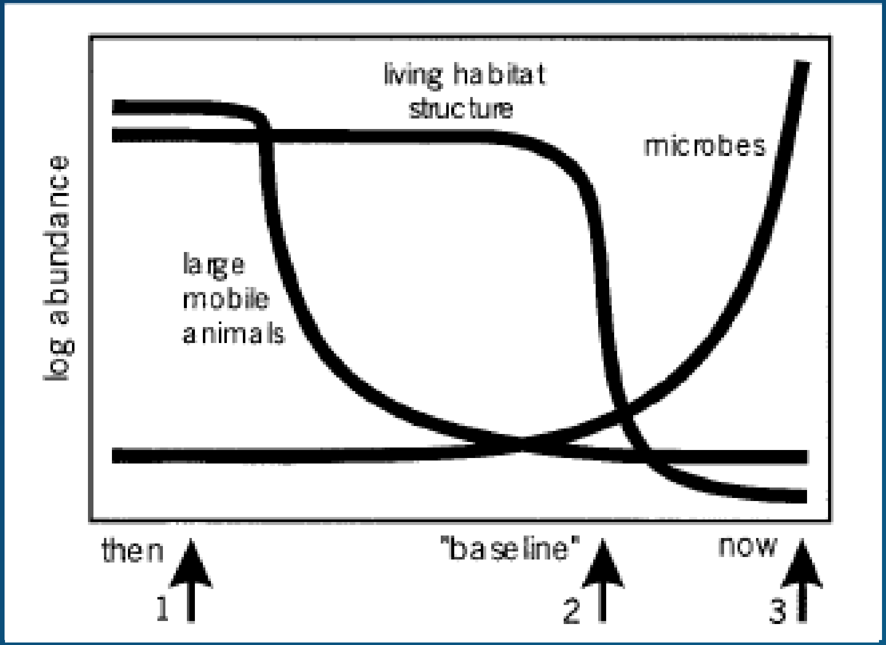


Results of eutrophication / hypoxia

Lauren Klabunde

Rick Loomis/LA Times

The Rise of Slime



JB Jackson (2001) PNAS 98: 5411-5418

Step change in knowledge of marine ecosystems

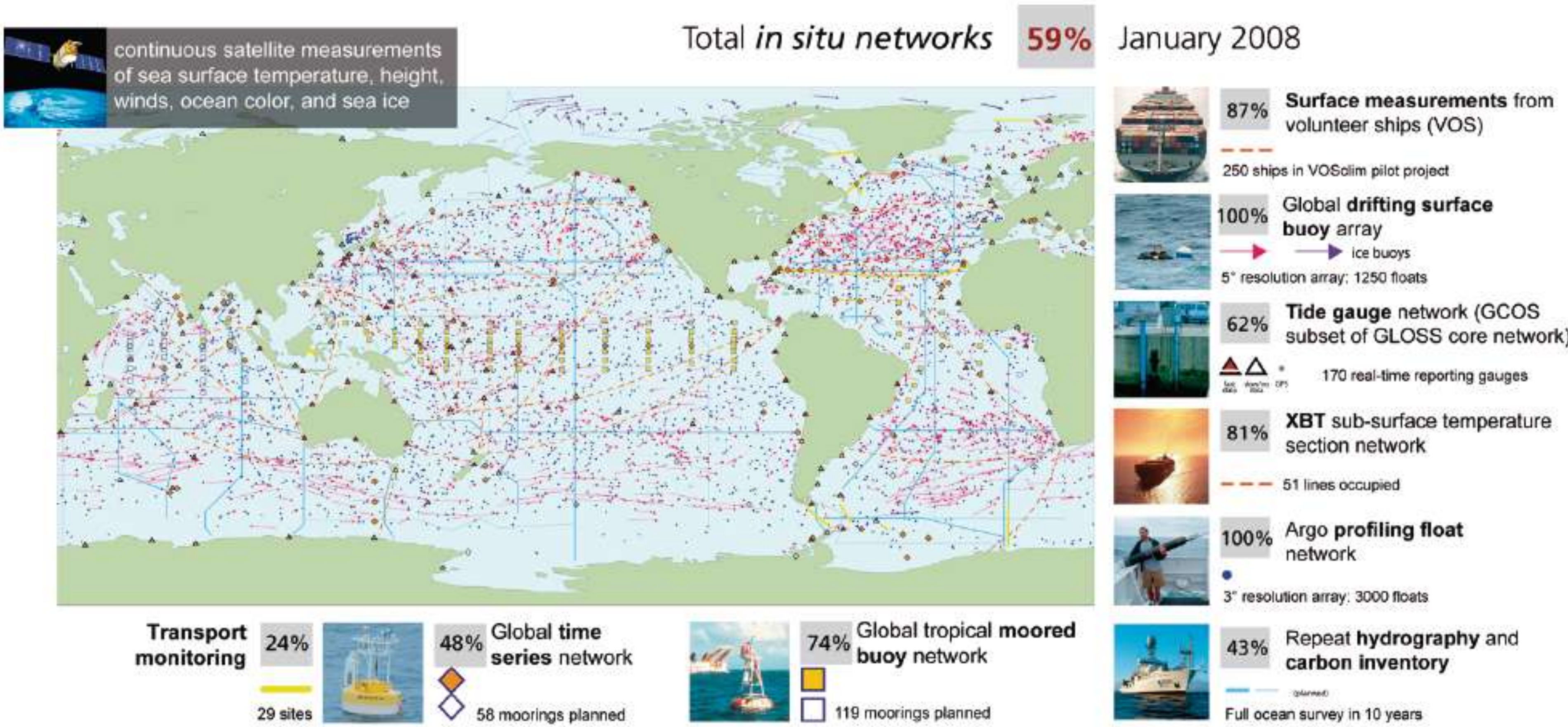
- Marine biologists have traditionally concentrated on small-scale experimentally tractable systems
- Climate change and other large-scale human disturbances of marine ecosystems mean that we need an understanding of biological processes at the ocean basin scale on short to long timescales
- Requires a massive change in approaches and technology (CoML is achieving this)

GOOS – The challenge

- To which of the 6 societal goals/benefits of GOOS are CoML programs most applicable?
  - Improve the safety and efficiency of marine operations
  - More effectively control and mitigate the effects of natural hazards
  - Improve the capacity to detect and predict the effects of global climate change on coastal ecosystems
  - Reduce public health risks
  - More effectively protect and restore healthy ecosystems
  - Restore and sustain living marine resources

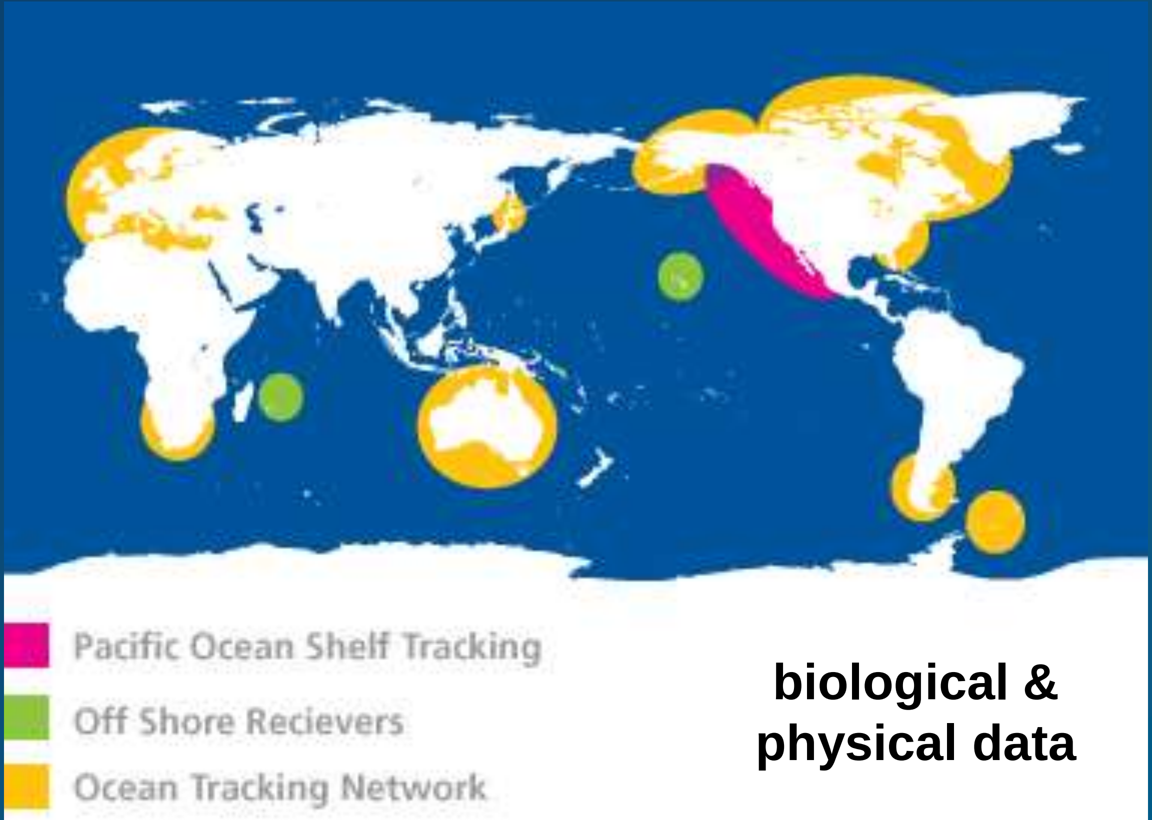
All of the above!

Current network of GOOS monitoring activities



Ocean Tracking Network

Ocean Tracking Network (OTN) links acoustic and archival technologies of shelf (POST) and open ocean (TOPP)



biological & physical data

In 5 years could be global, seamless

Globally shared software & database, integrated with GOOS

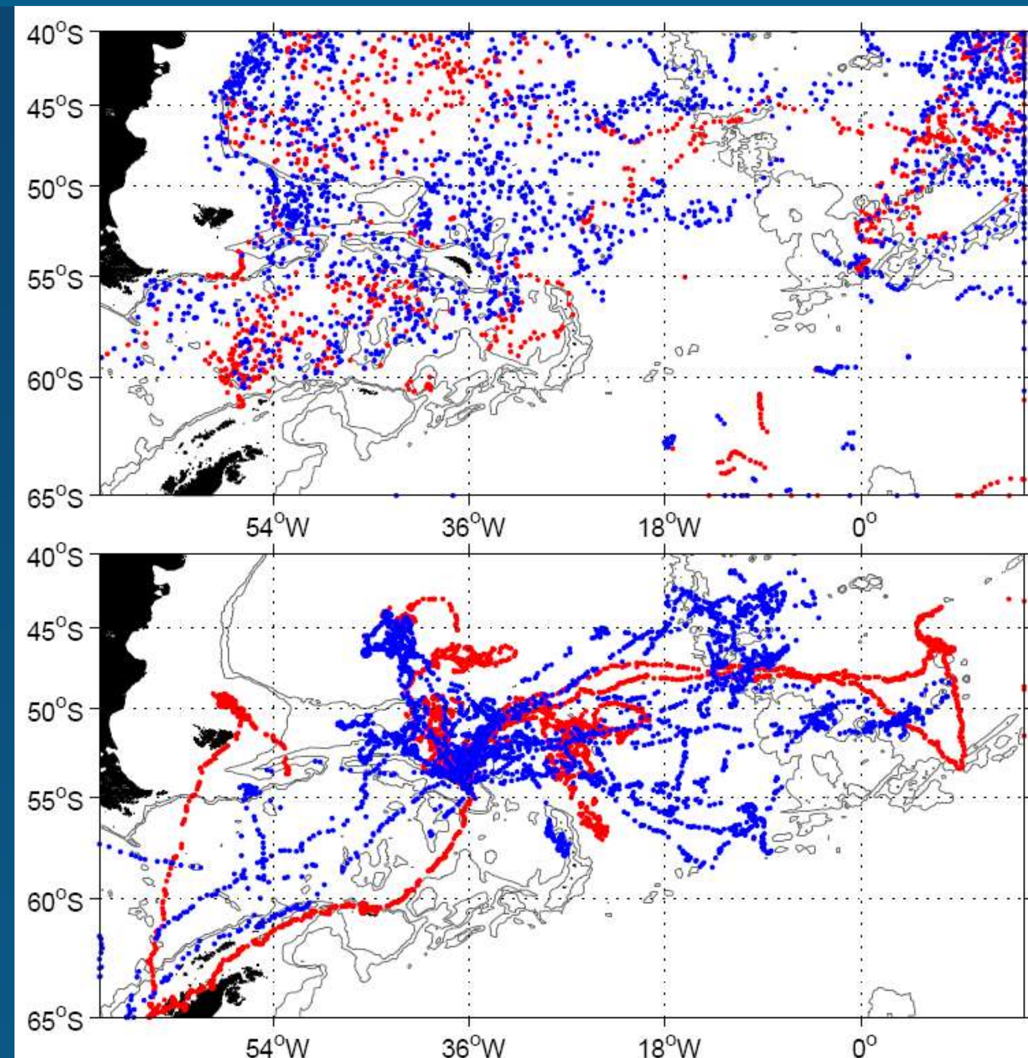
Benefit of merging datasets

Argo

- higher accuracy
- higher vertical resolution
- every 10 days
- freely drifting
- 2000 dbar

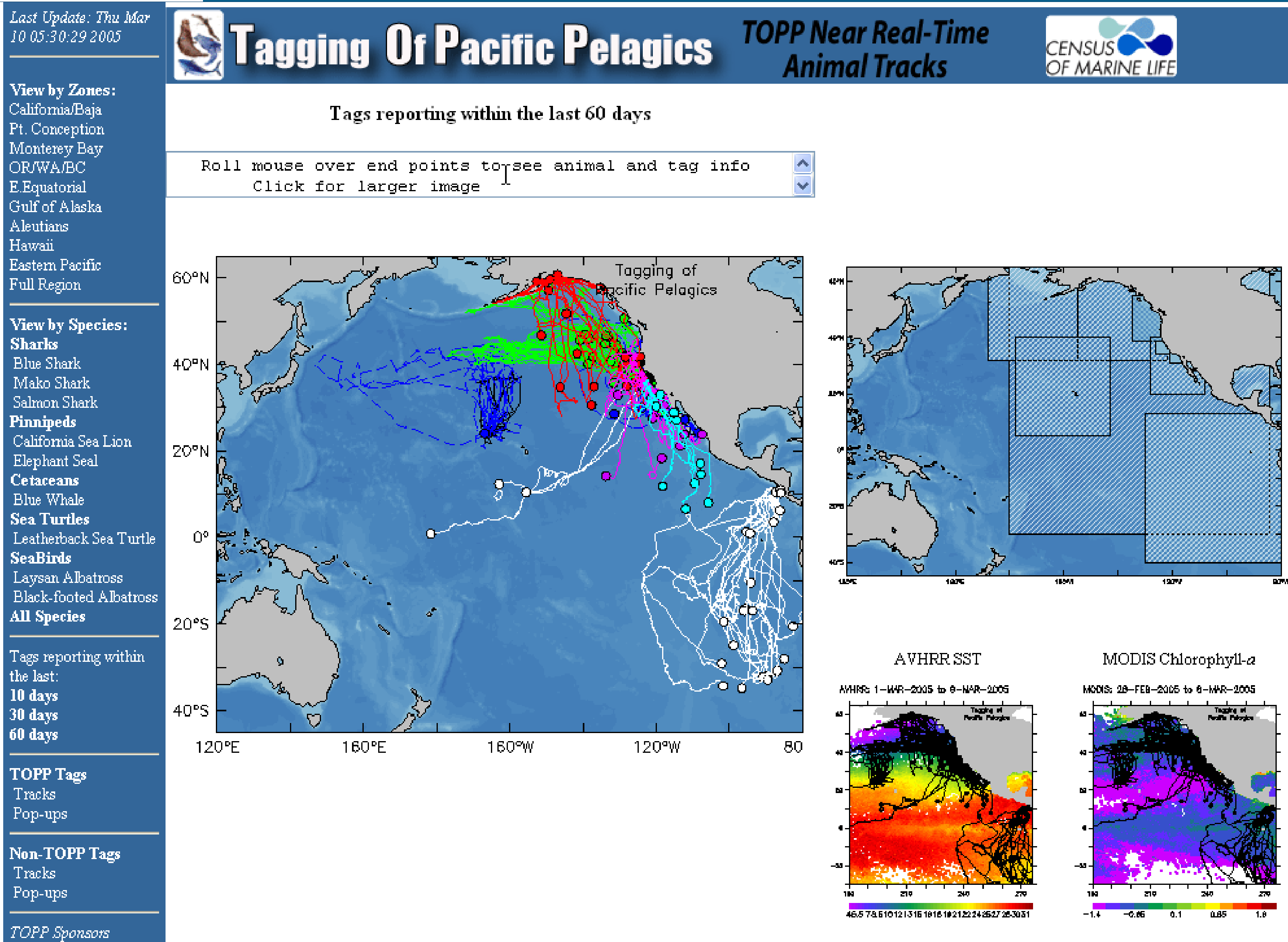
Animals

- higher temporal resolution (daily)
- higher spatial resolution (<50km)
- along animal migrations
- up to 2000 dbar



* 2004 * 2005

Near real time data collection (Now-casting)



TOPP website serves positions on 150 top predators daily

What other biological parameters should GOOS be monitoring?

- Molecular technologies
  - Harmful marine algae
  - Microbial, meiofaunal, macrofaunal communities
- Benthic ecosystems
  - Changes in abundance / biomass
  - Changes in biodiversity, ecosystem function
- Indicators within marine communities
  - Plankton communities (SAHFOS)
- Acoustic monitoring
  - Diurnal plankton migration
  - Cetaceans
- Physical measurements
  - Oxygen
  - pH

AND MANY MORE…..,.

Aims of the observatory workshop

Bring together biologists, observing community, and technological community to develop ocean biology observatories that could address the grand challenges of observing ocean life and its response to global change.

Here the definition of observatory is broad…..

Structure

Keynote presentations

1. Ocean acidification (Chair: John Volkman, Rapporteur: Scott Bainbridge)
2. Community structure (Chair: Bengt Karlson, Rapporteur: Rubens Lopes
3. Distribution vs physical structure (Chair: Dan Costa, Rapporteur: Ron O'Dor)
4. Changes in trophic structure (Chair: Han Pearl, Rapporteur: Bob Gisiner)
5. Benthic dynamics (Chair: Me Rapporteur: Kate Larkin

Each group to develop a report

•Background and context for observing approaches related to the group's topic
•Need for systematic long-term measurements over large scales
•What are the priority observations to address this issue?
•Where should the observations be made and at what frequency and duration?
•Observational technologies now available and on the horizon, and gaps in available sensors to address the need

Report

- Introduction
- Summary of discussions from each group
- Workshop summary and recommendations

a) How can different observational approaches be integrated and what advantages are gained?

b) What kinds of intercalibrations and validations are needed among sensors of the same type as well as different approaches.

c) How can such activities be funded, especially sustained observations.

d) How can data be integrated, delivered and visualised?

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- CoML