Global climate change and regional impacts on marine ecosystems

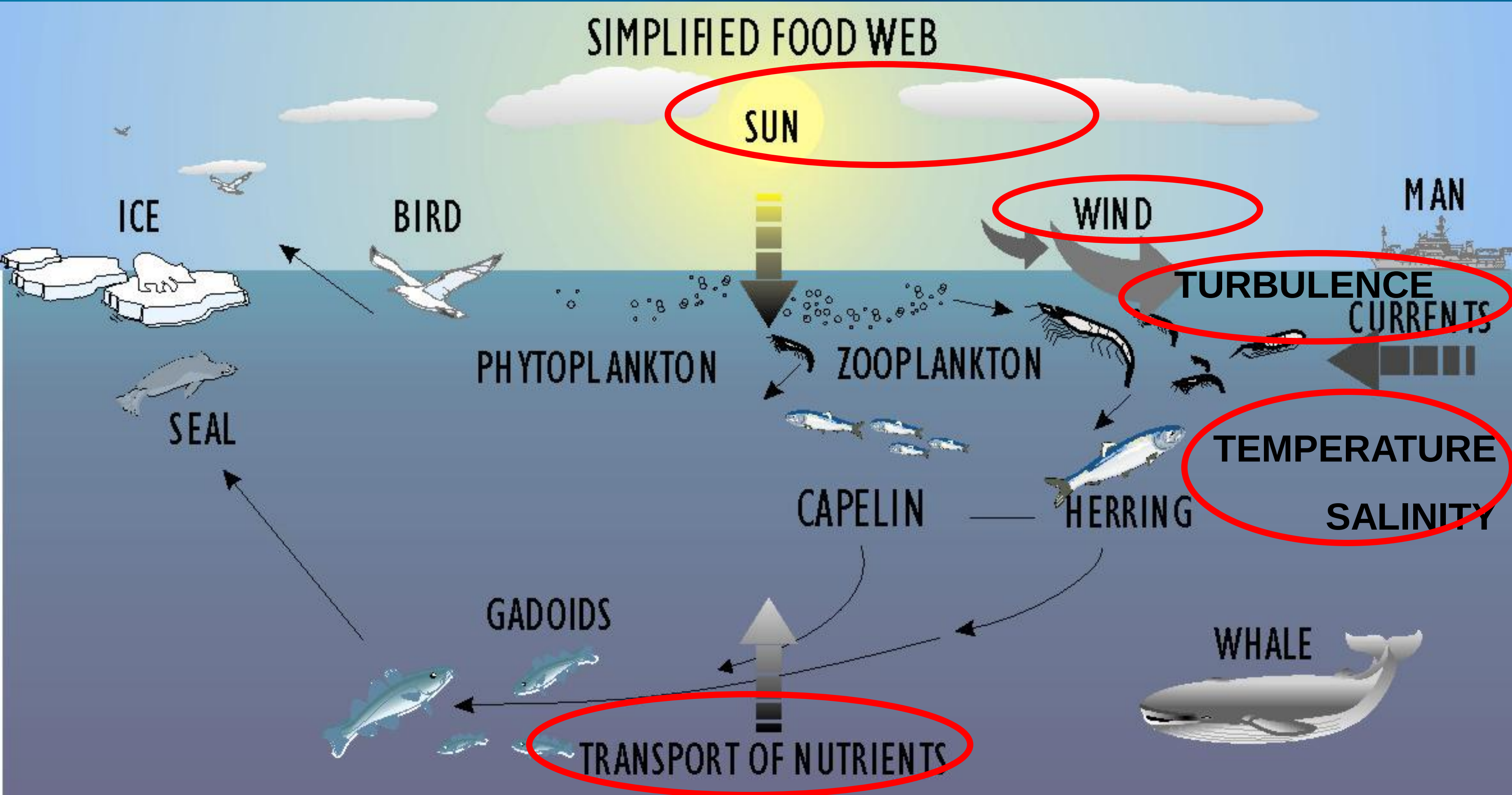
Svein Sundby

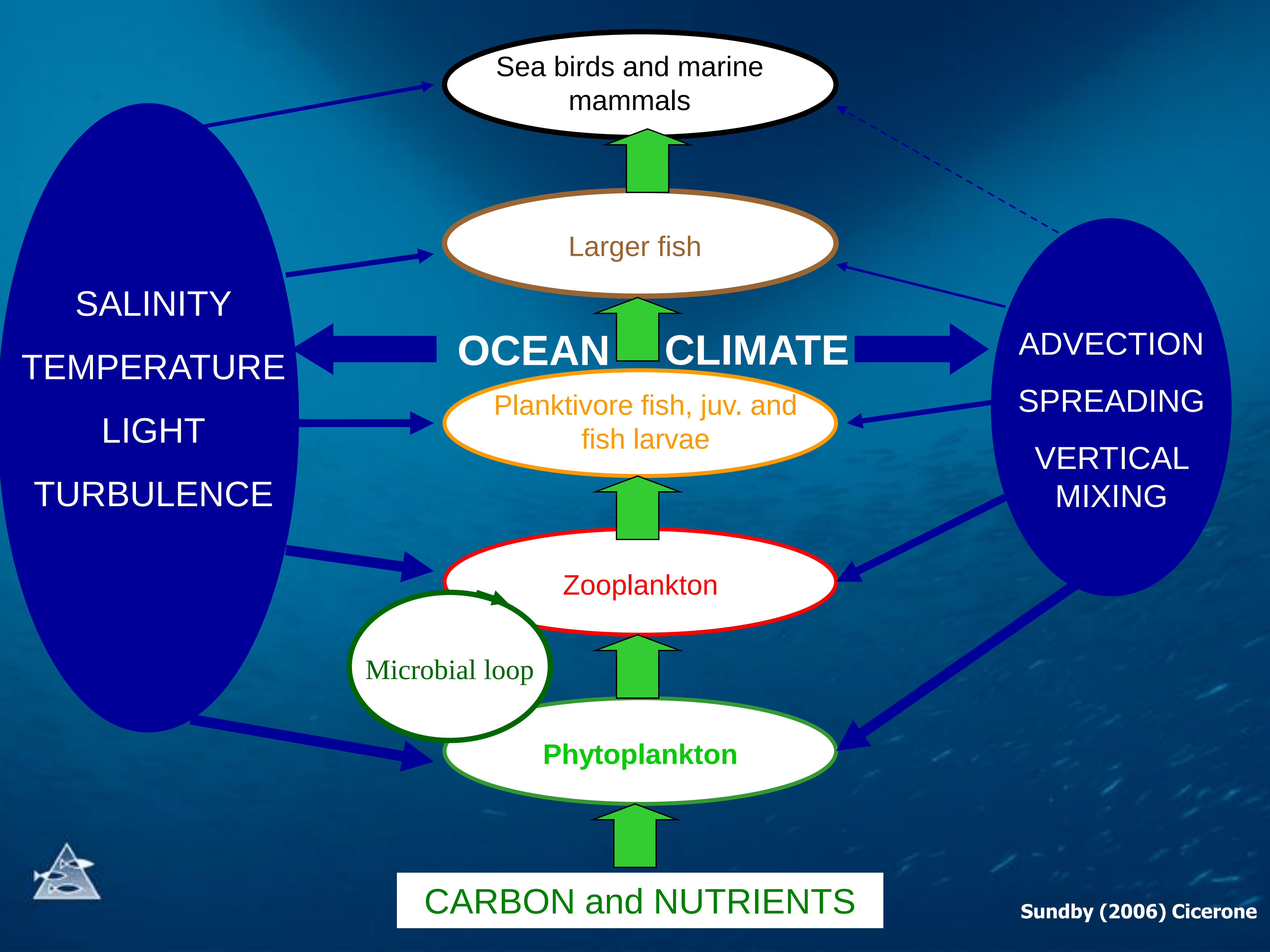
The legacy of Nansen in marine research
Relevance to development cooperation in fisheries

EAF-Nansen Project mini-seminar, Oslo, 13 October 2011

HAVFORSKNINGSINSTITUTTET
INSTITUTE OF MARINE RESEARCH

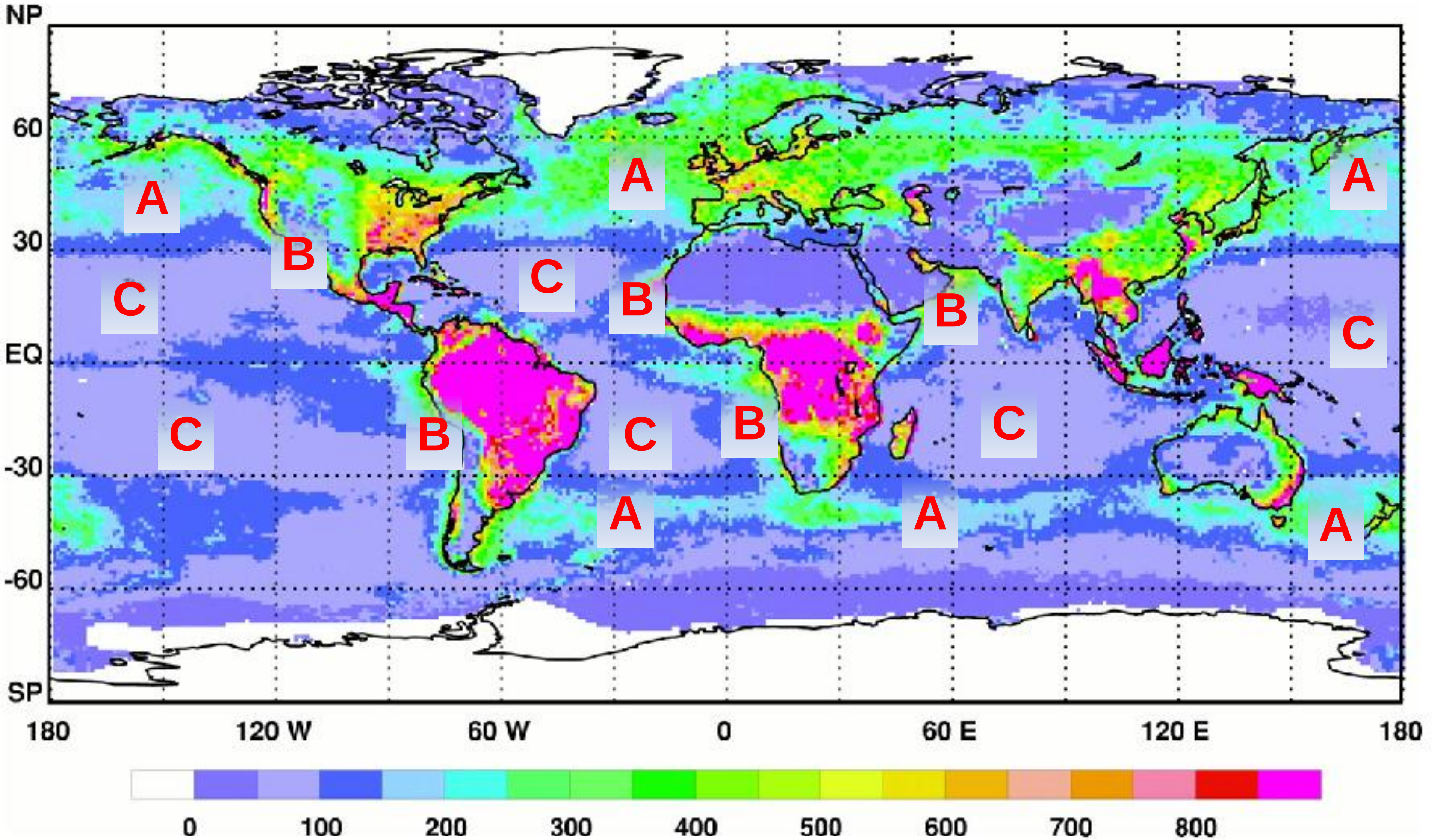
Food web and climate variables in the Barents Sea





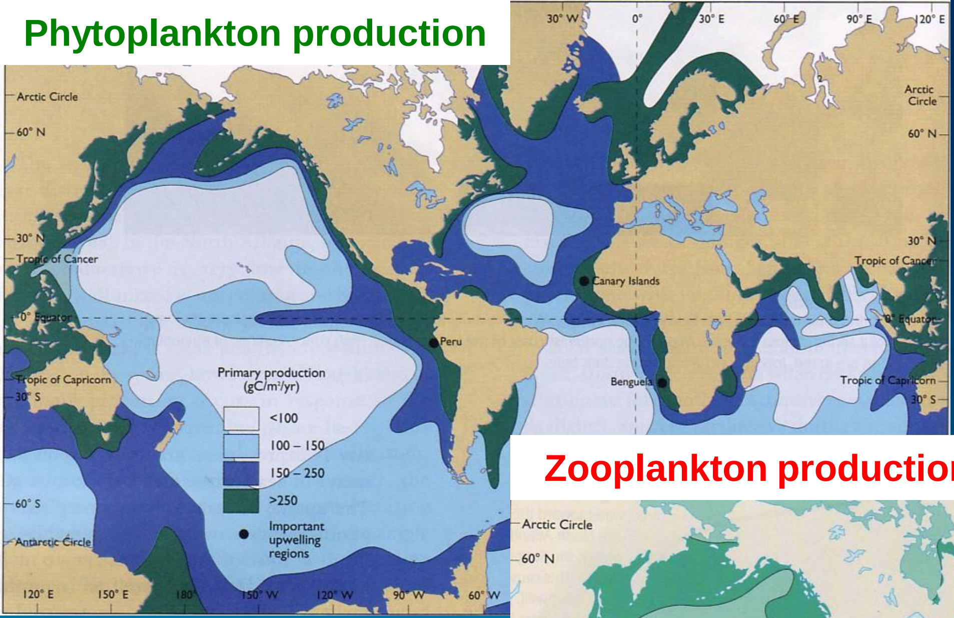
Sea birds and marine mammals
Larger fish
SALINITY
TEMPERATURE
LIGHT
TURBULENCE
OCEAN CLIMATE
ADVECTION
SPREADING
VERTICAL MIXING
Planktivore fish, juv. and fish larvae
Zooplankton
Microbial loop
Phytoplankton
CARBON and NUTRIENTS
Sundby (2006) Cicerone

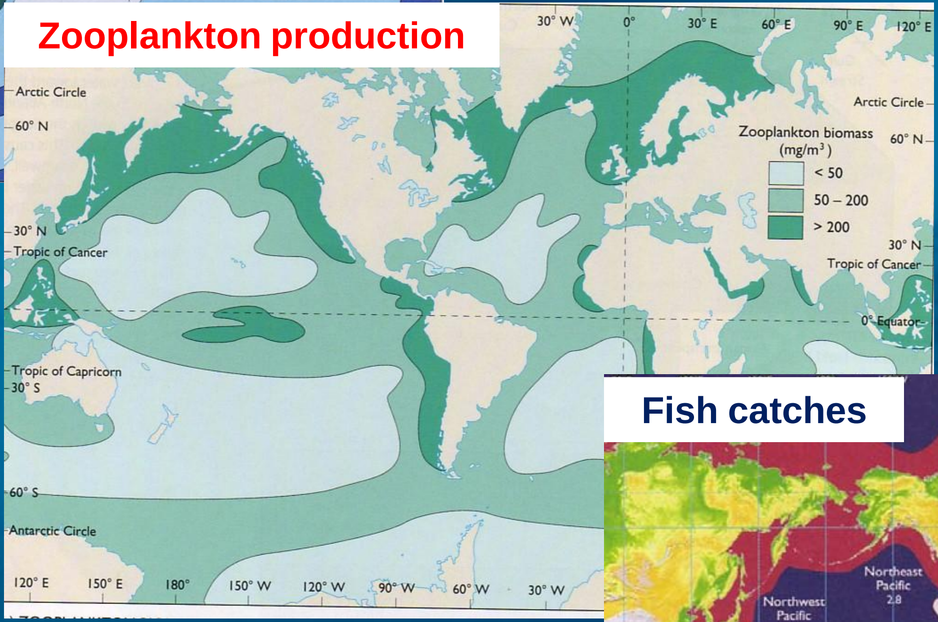
Global primary production 104.9 x 10^{15} g C $year^{-1}$ (46.2 % Ocean / 53.8 Land)

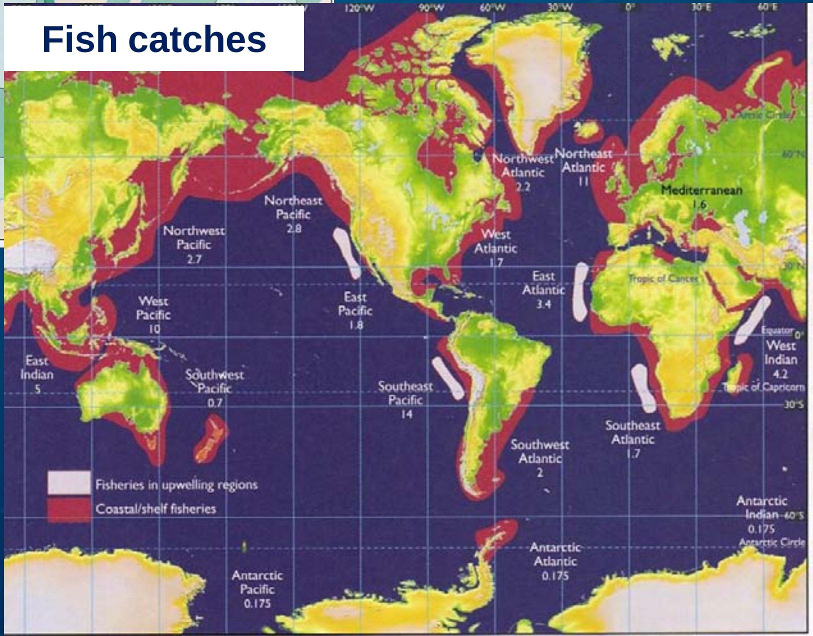


- A High-latitude spring-bloom systems
- B The large upwelling systems
- C Mid-ocean gyre systems

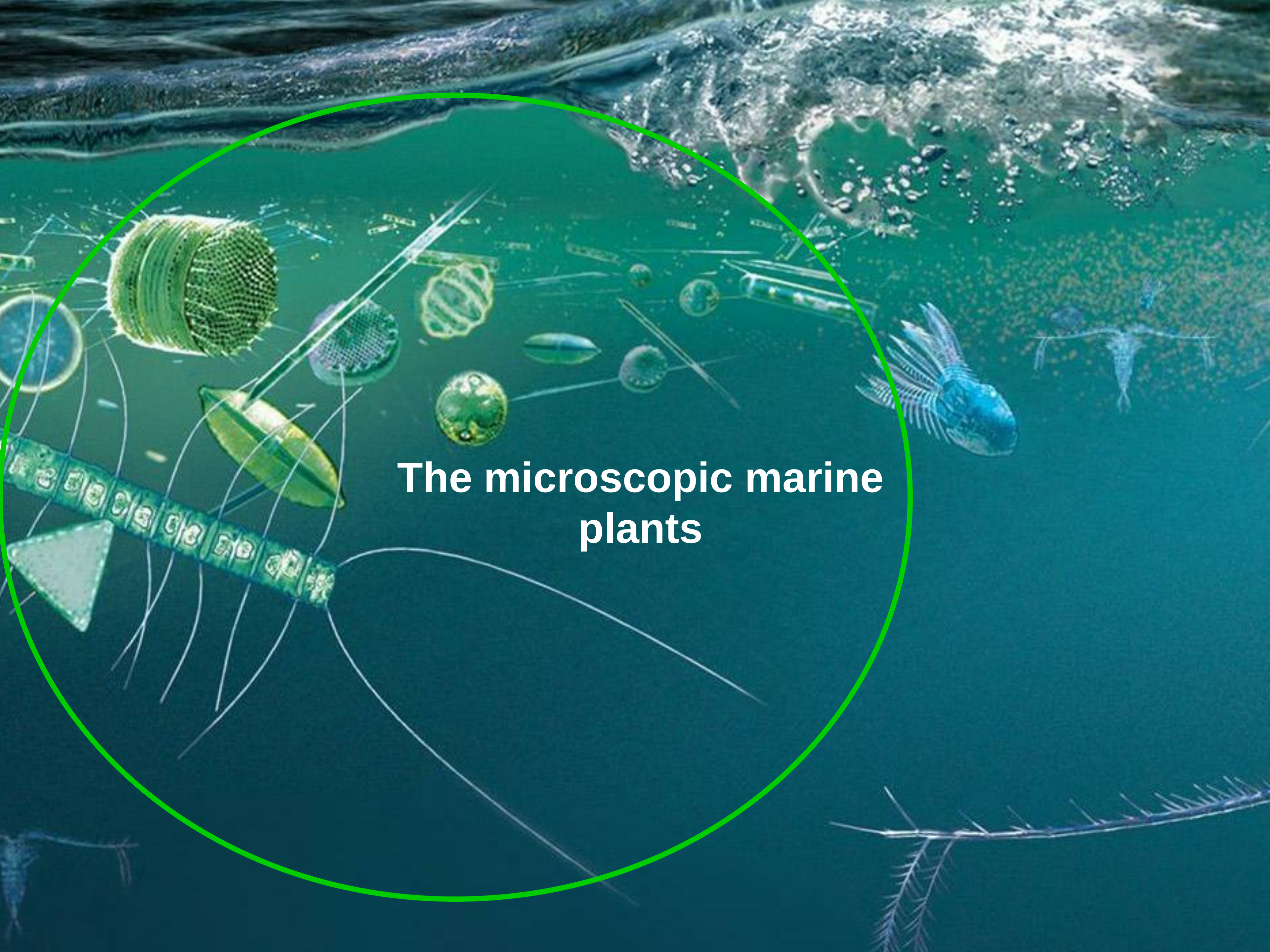
At large scales spatial distribution and abundance at different trophic levels are correlated







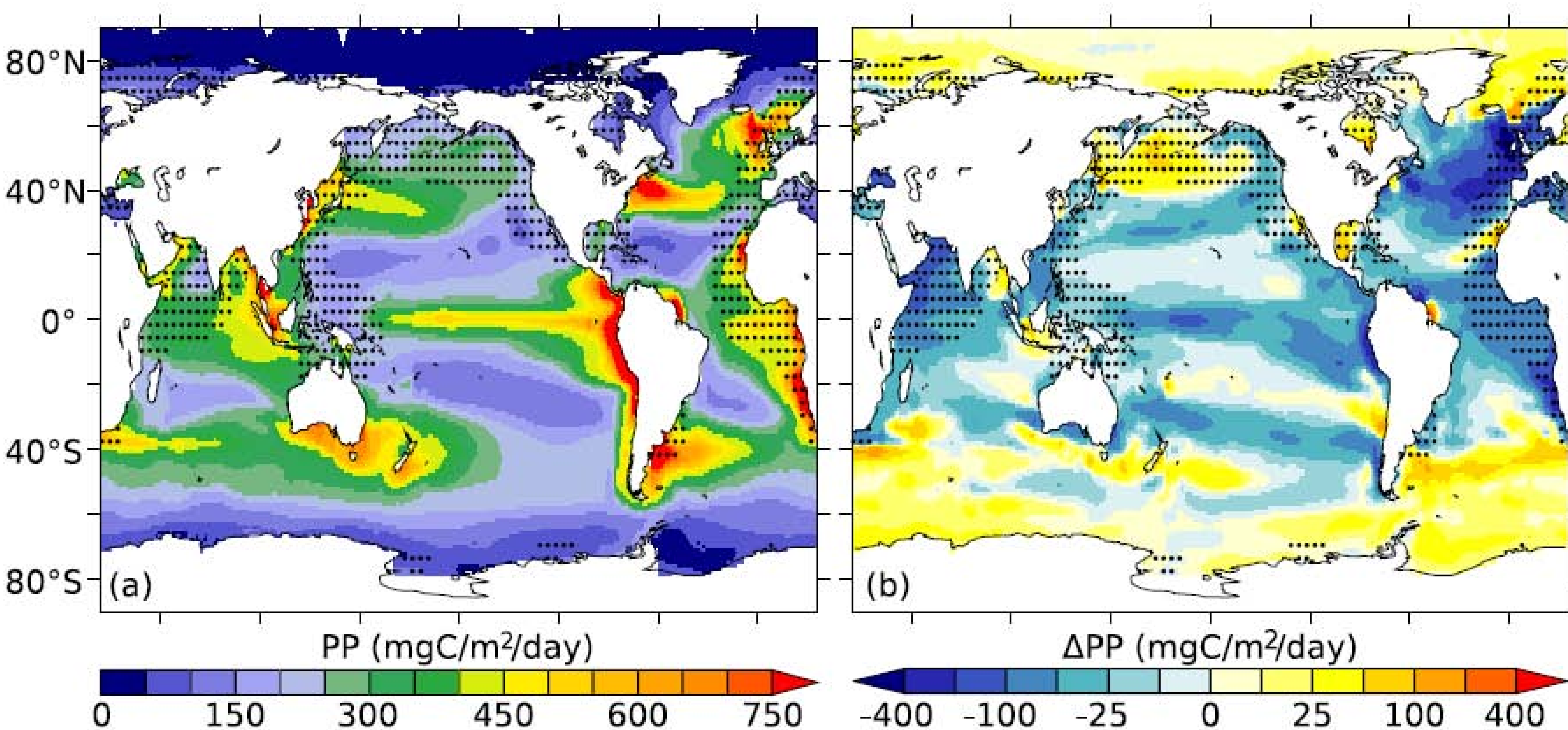
Pinet (2006)


The microscopic marine plants

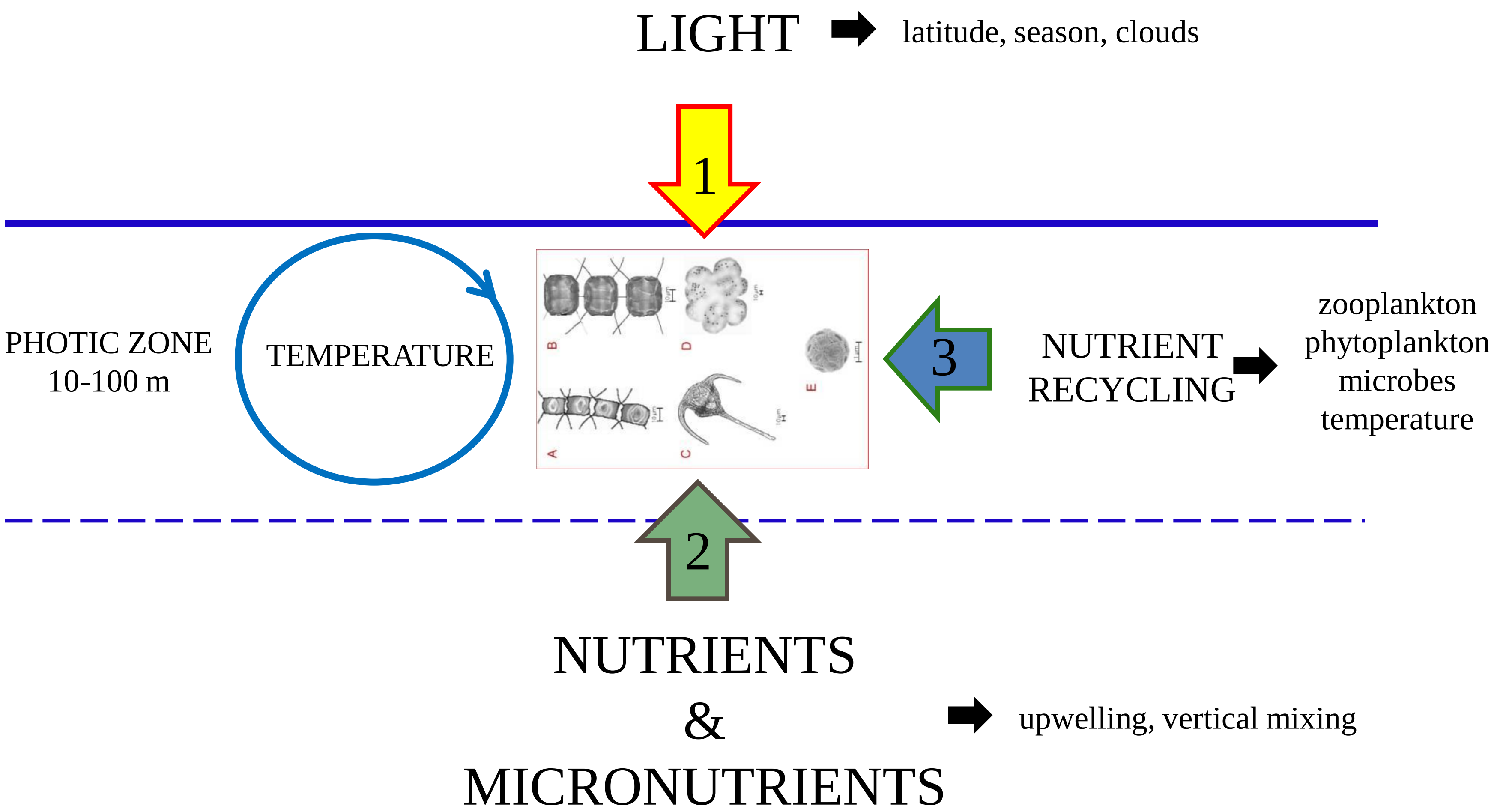
Globally modeled phytoplankton production (average of a group of different models)

Pre-industrial production (1860s)

Change in production at the end of this century (2090s)

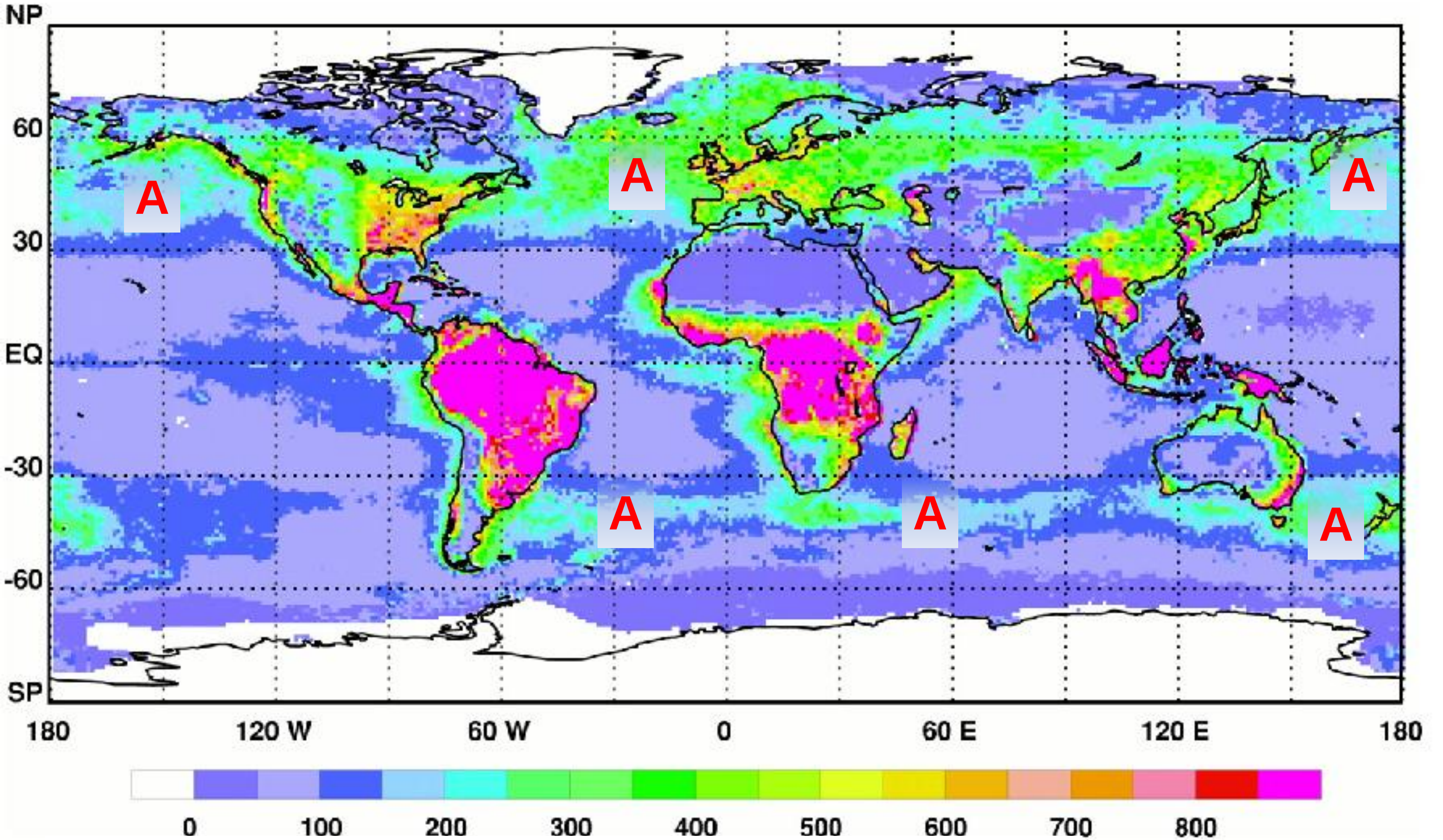


Steinacher *et al.* (2010) Biogeosciences



FACTORS DETERMINING PHYTOPLANKTON PRODUCTION & DYNAMICS

Global primary production 104.9 x 10^{15} g C $year^{-1}$ (46.2 % Ocean / 53.8 Land)



- A High-latitude spring-bloom systems
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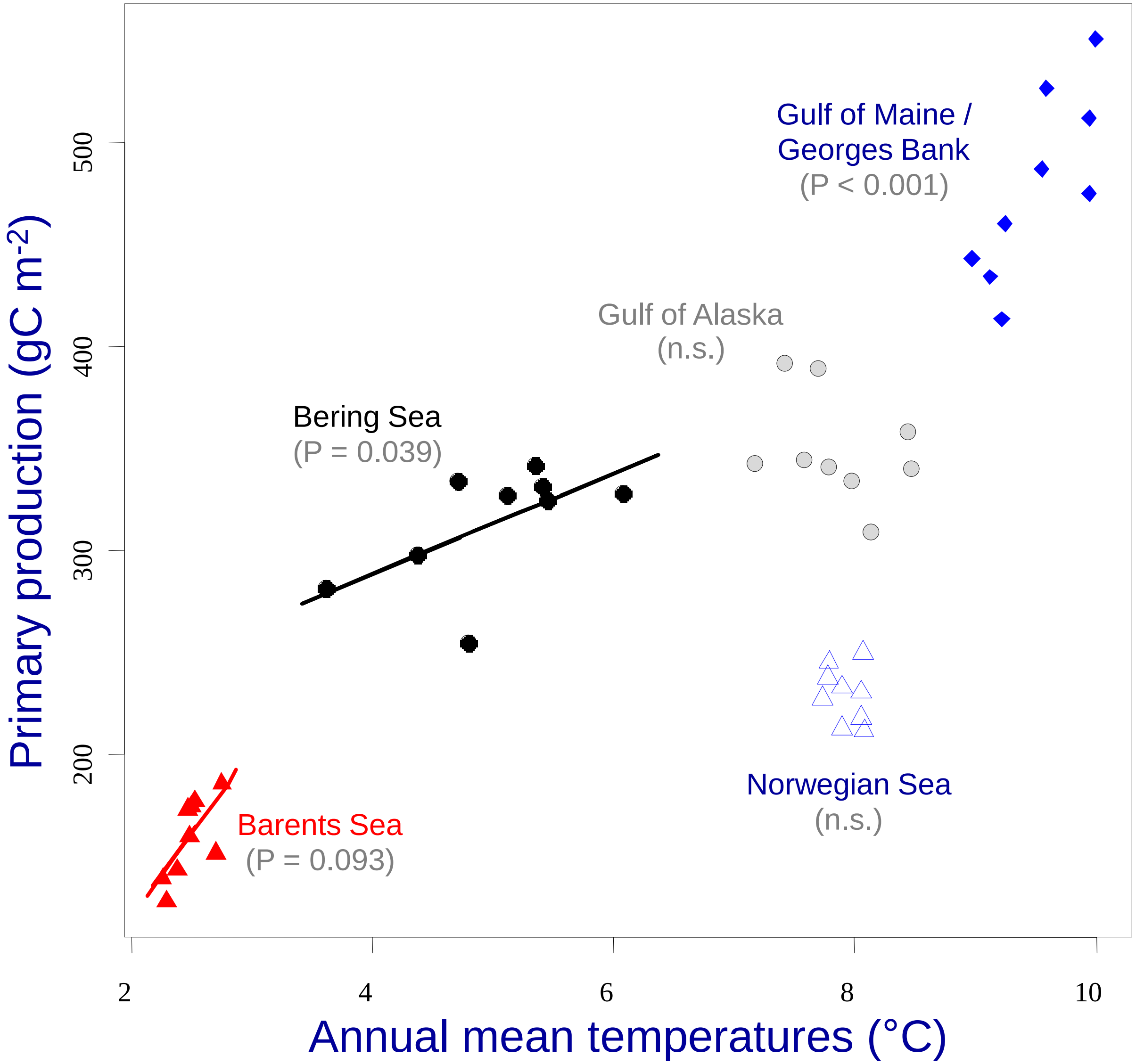
A Phytoplankton in **high-latitude (arctic and boreal)** marine ecosystems

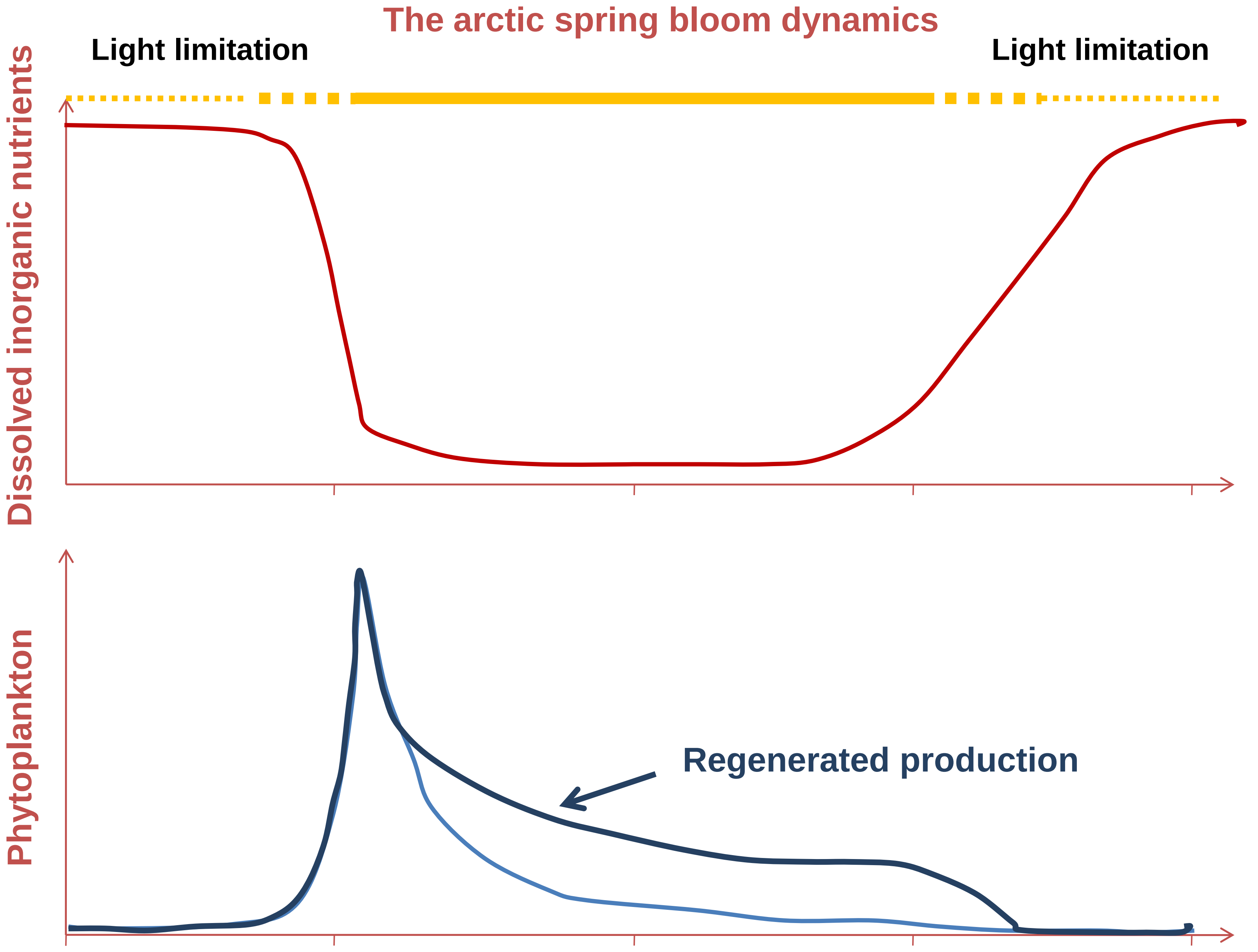
Temperature controls primary production at high-latitude marine ecosystems

➡

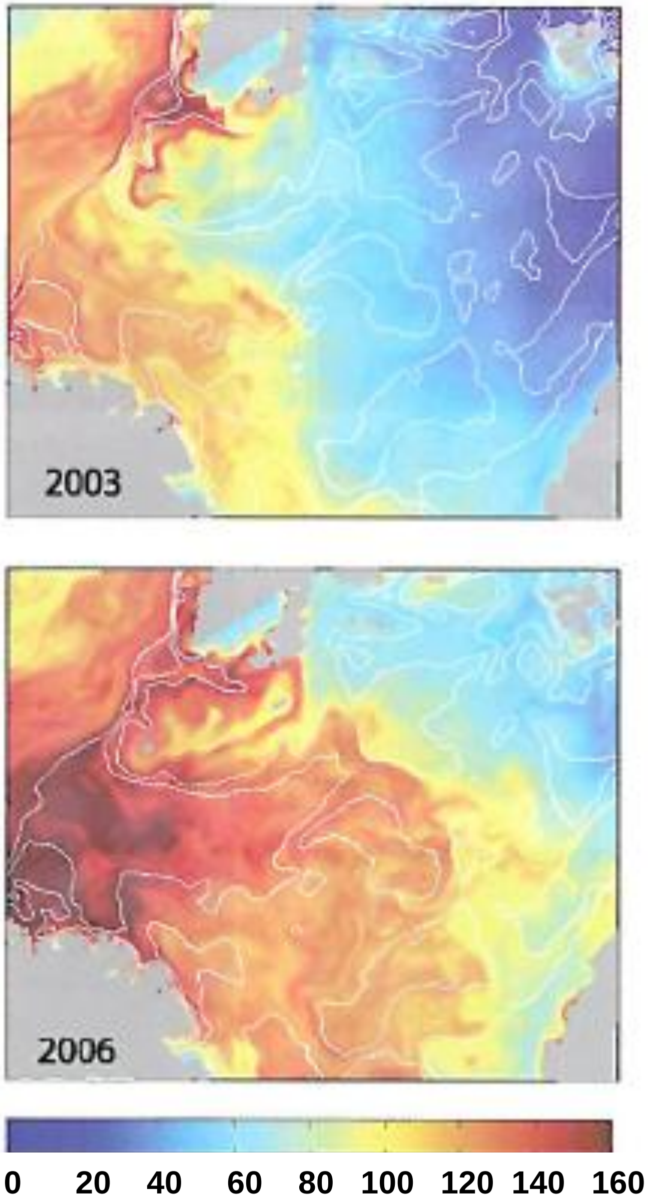
Global warming increases productivity



Mueter *et al.* (2009)
Norway-US Comparisons (MENU)



The arctic spring bloom dynamics
Light limitation
Light limitation
Dissolved inorganic nutrients
Phytoplankton
Regenerated production

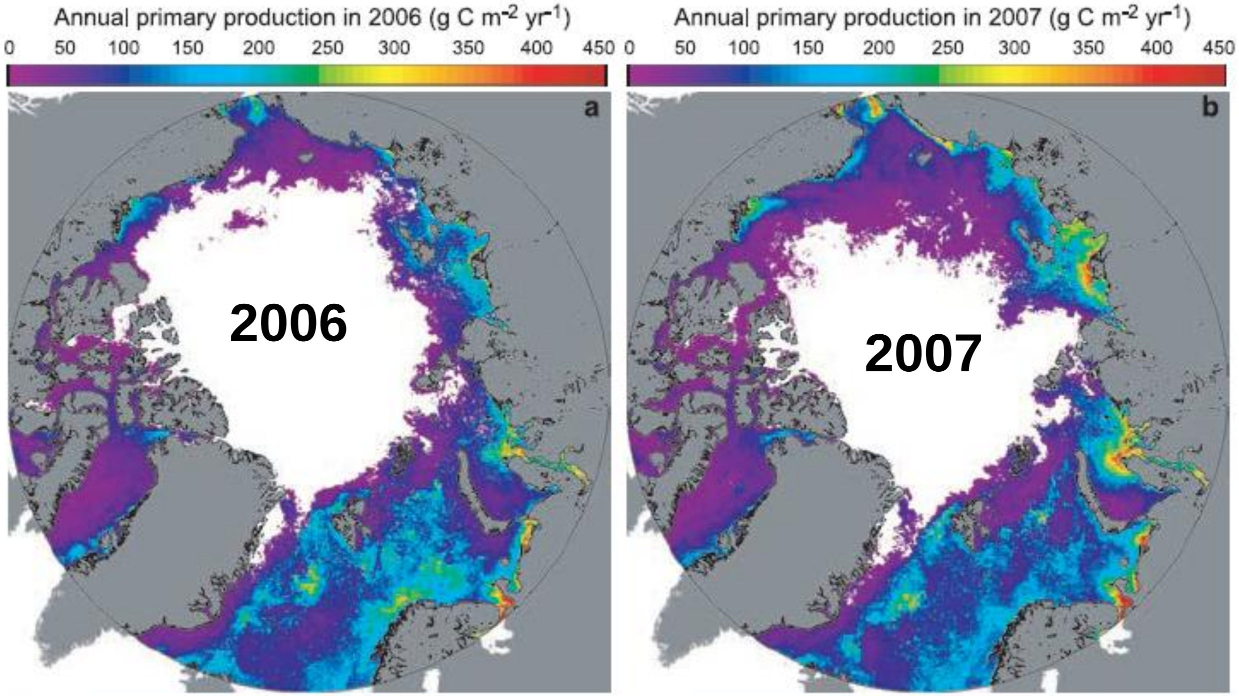


Cold year

Warm year

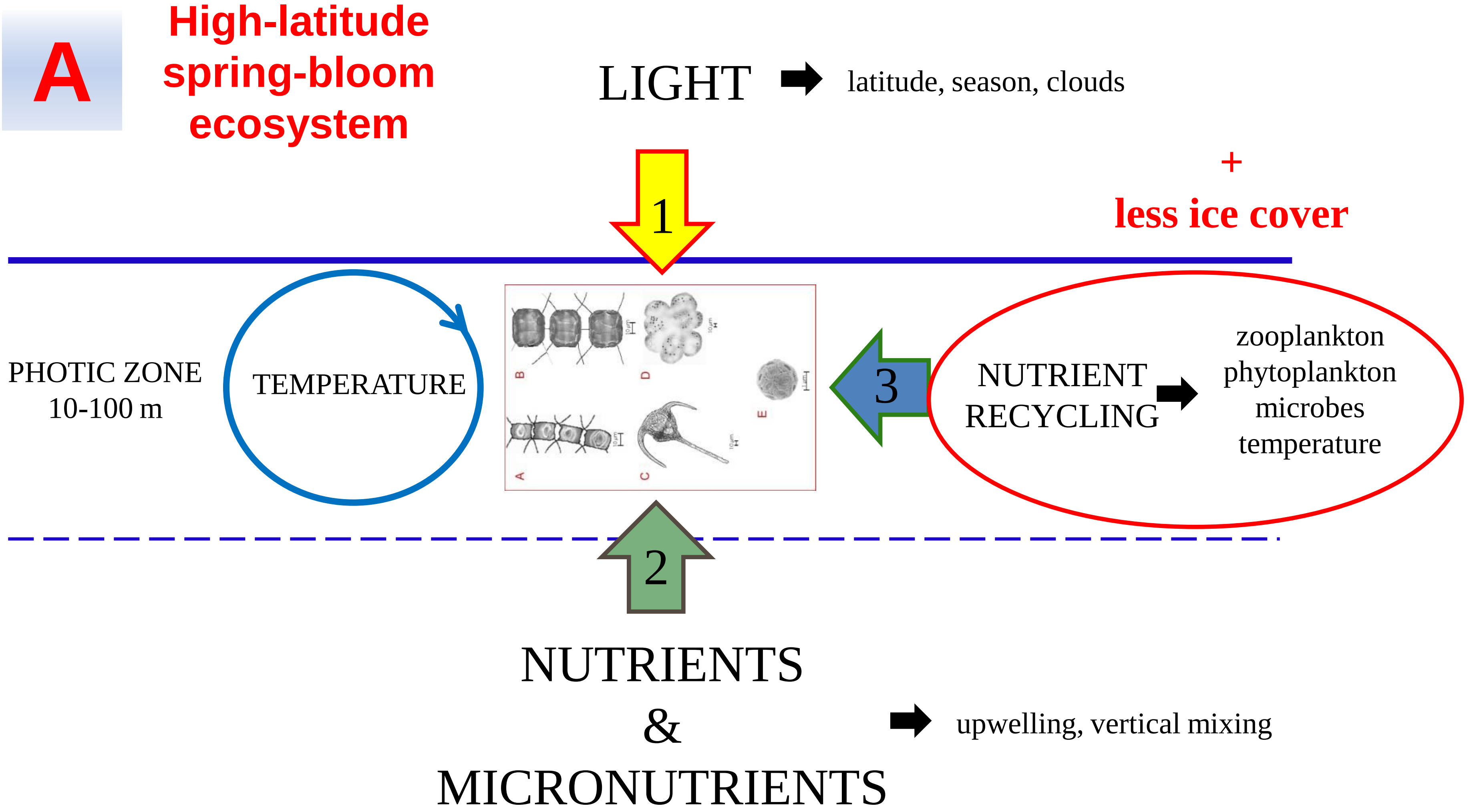
Annual primary production upper 50 m (g C /m²/year)

Ellingsen et al. (2009)



Annual primary production

Increasing primary production where the ice dissappears



FACTORS DETERMINING PHYTOPLANKTON PRODUCTION & DYNAMICS

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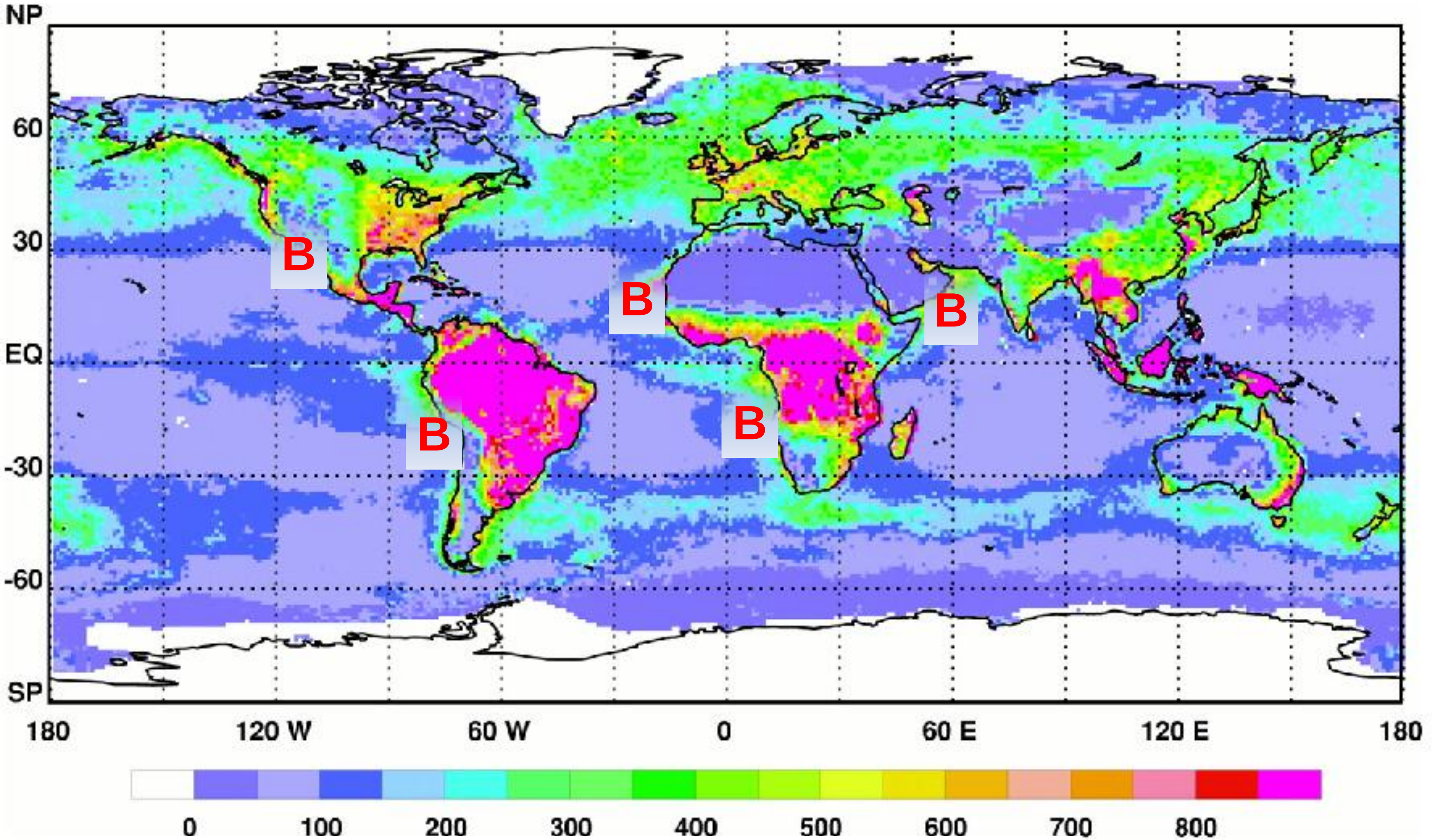

- A High-latitude spring-bloom systems
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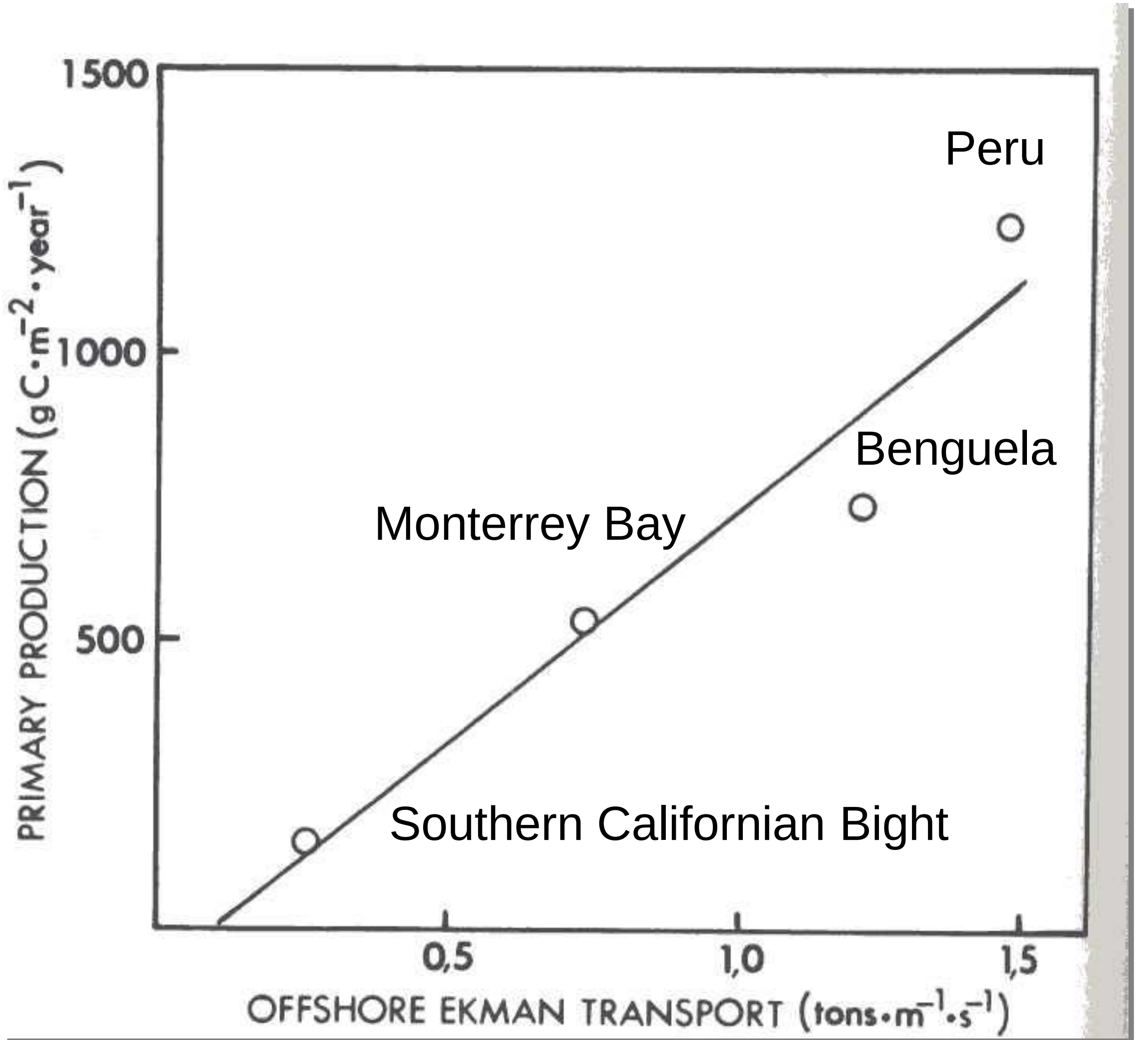
B

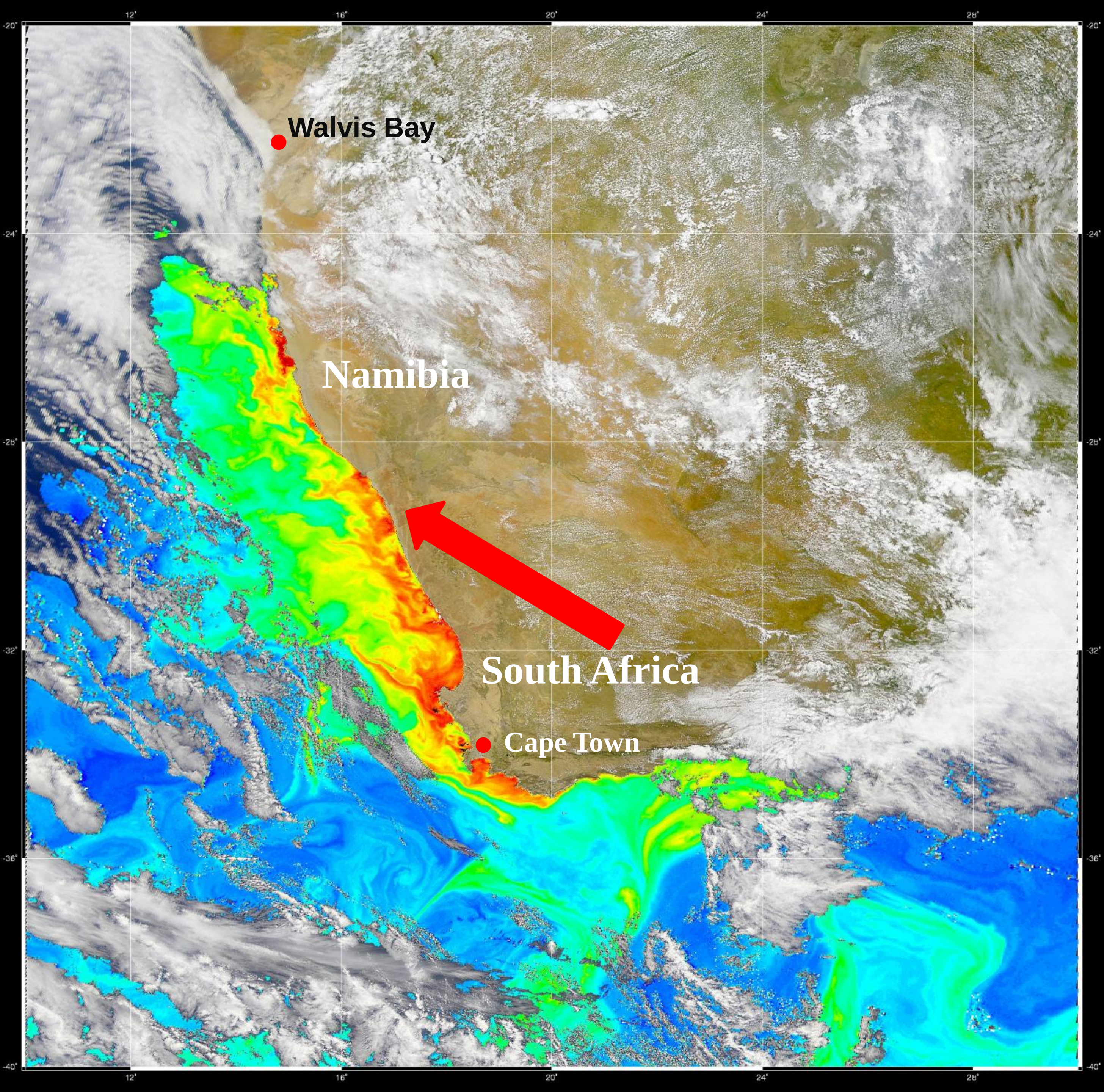
Primary production in **upwelling ecosystems**

Wind control phytoplankton production in upwelling regions

➡

Global warming probably increases productivity

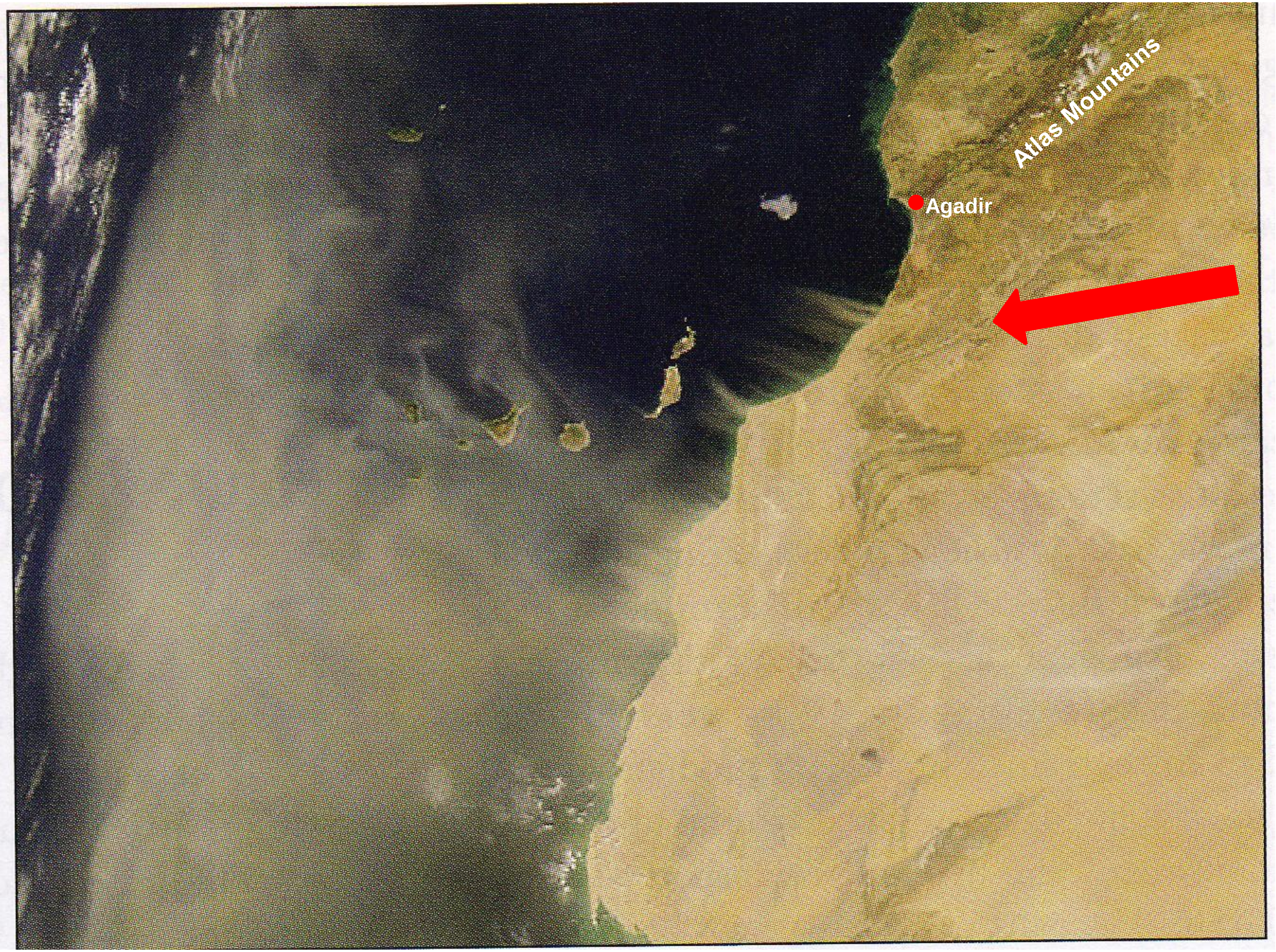




Benguela upwelling system –

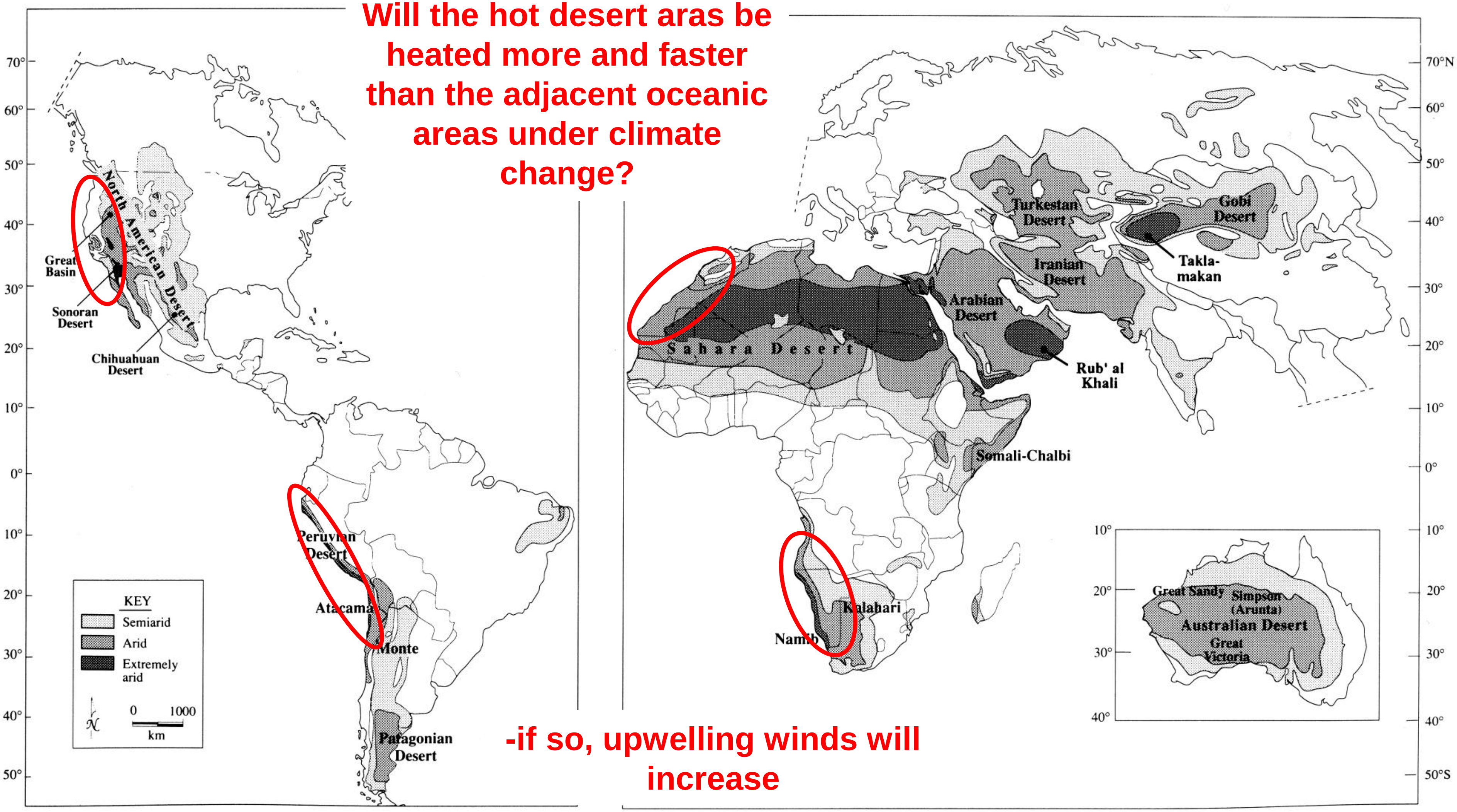
Forced by the southeasterly winds

Dust transport from Shahara across the Canary Current



Arid lands around the world

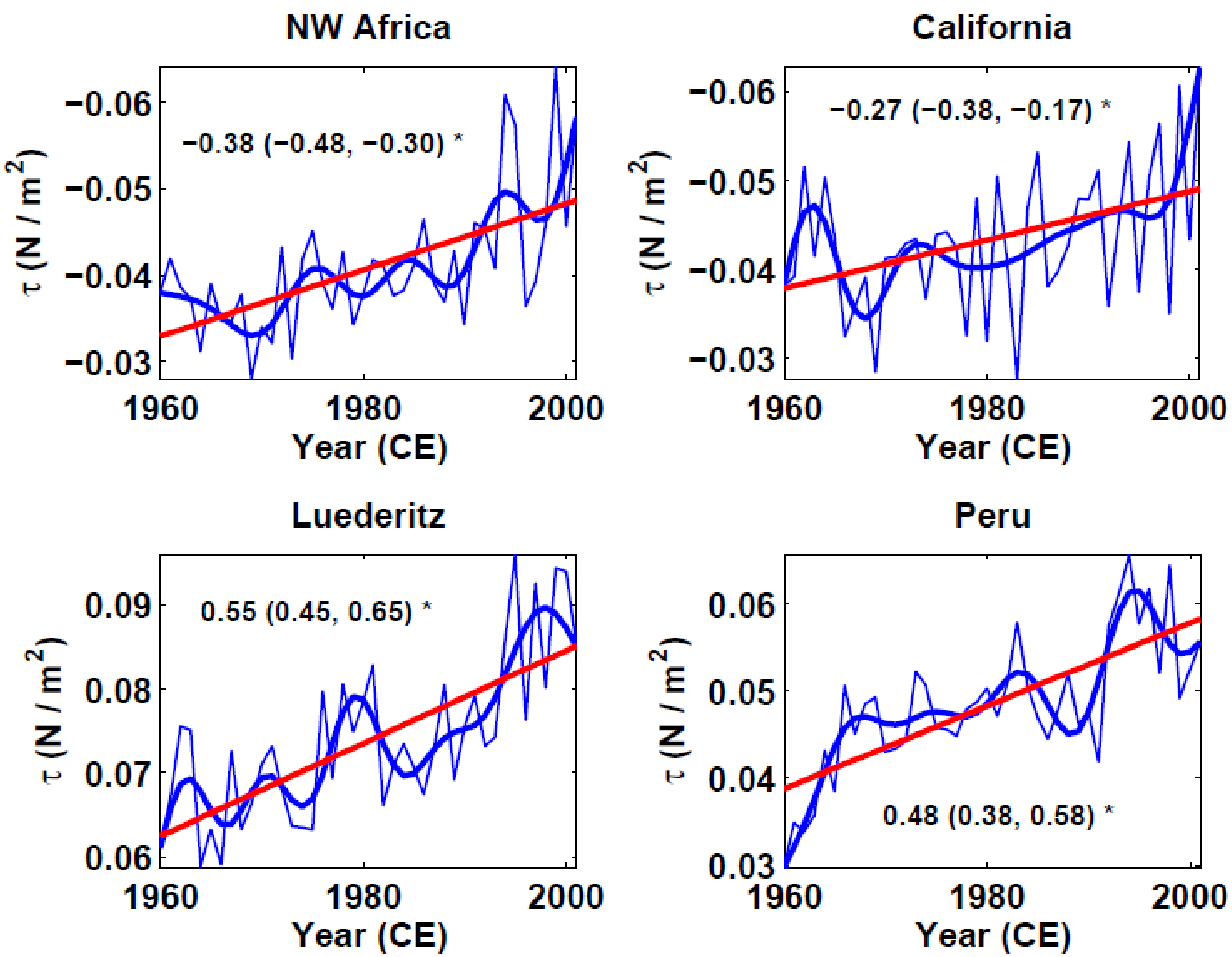
Will the hot desert aras be heated more and faster than the adjacent oceanic areas under climate change?



-if so, upwelling winds will increase

Wettstein (2009)

- and wind forcing has increased in all the four large upwelling ecosystems since 1960



Narayan *et al*. (2010)

B

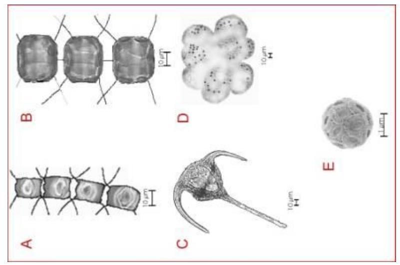
Upwelling ecosystem

LIGHT ➡ latitude, season, clouds

1

PHOTIC ZONE
10-100 m

TEMPERATURE



3

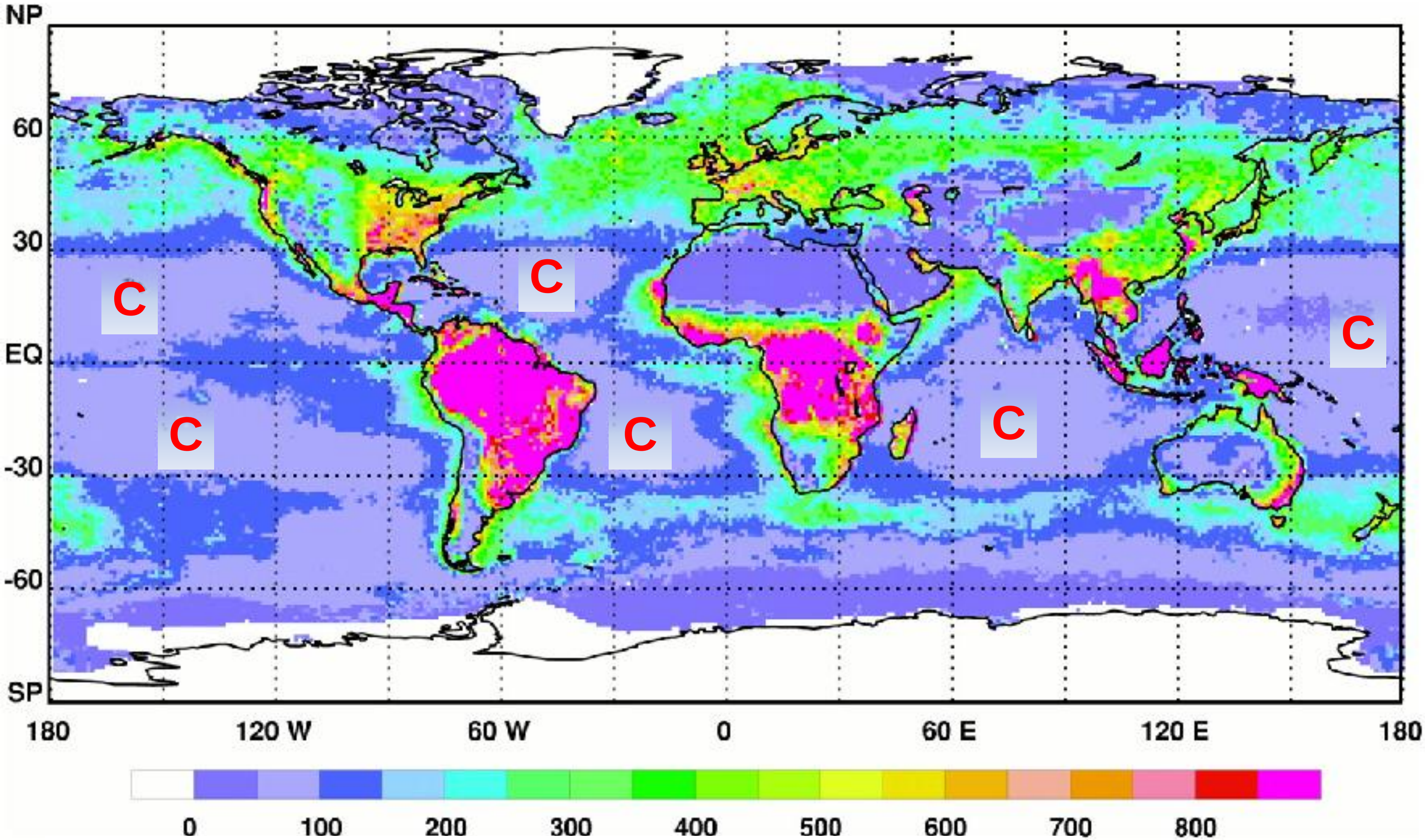
NUTRIENT RECYCLING ➡ zooplankton
phytoplankton
microbes
temperature

2

NUTRIENTS
&
MICRONUTRIENTS ➡ upwelling, vertical mixing

FACTORS DETERMINING PHYTOPLANKTON PRODUCTION & DYNAMICS

Global primary production 104.9 x 10^{15} g C $year^{-1}$ (46.2 % Ocean / 53.8 Land)



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Steady-state conditions for the tropical ocean

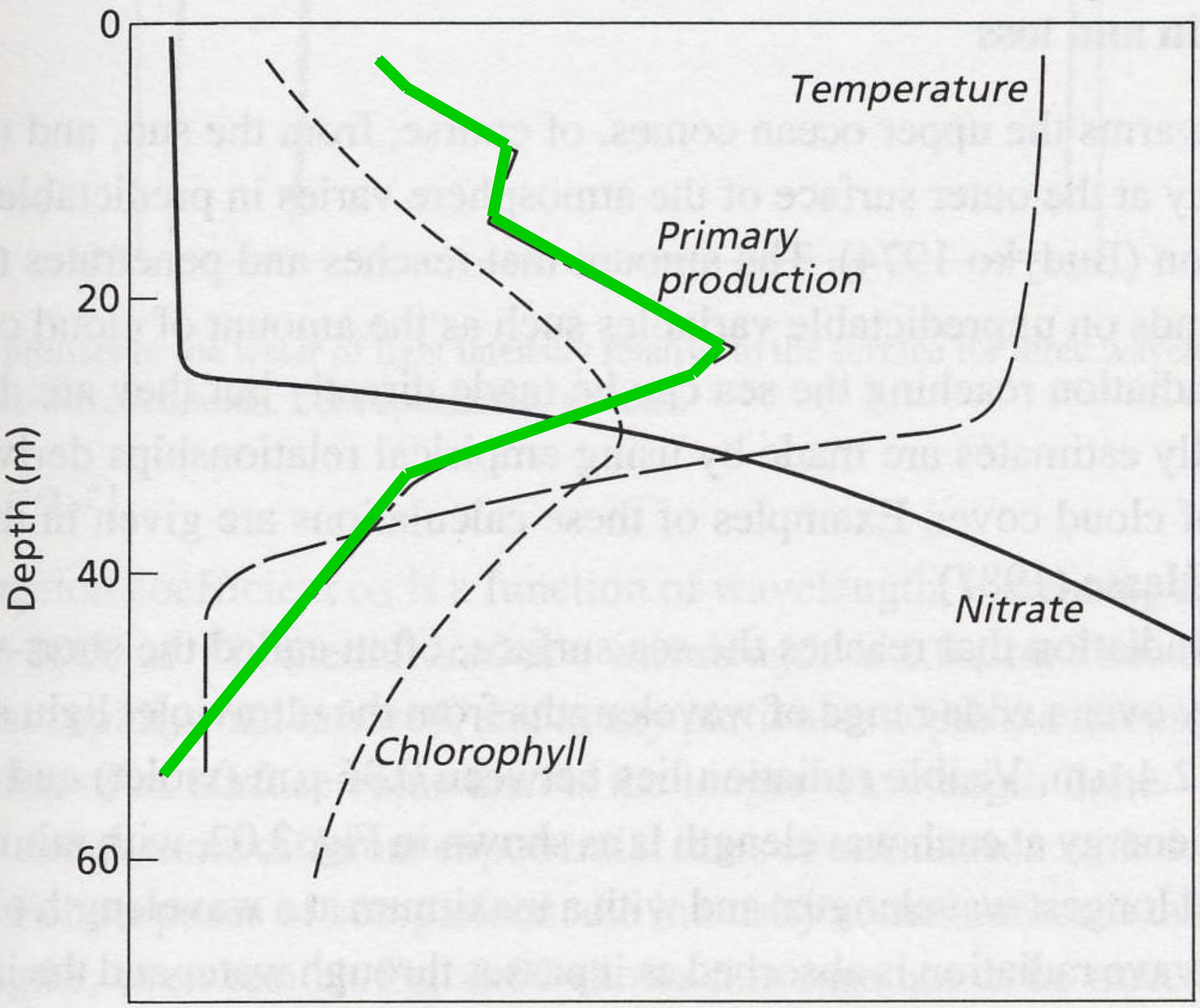
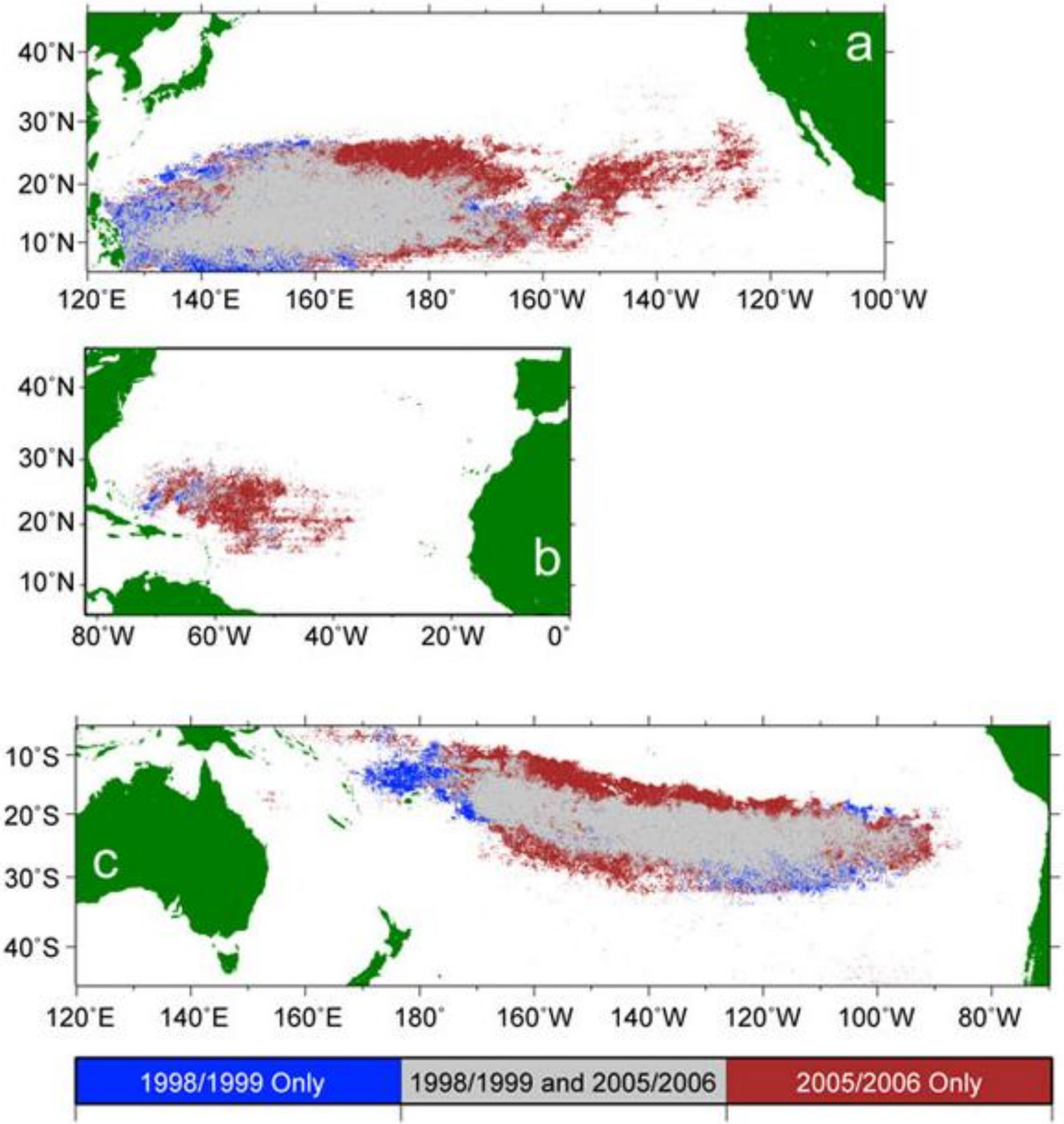


Fig. 3.01 Schematic diagram showing typical vertical structure of the water column in tropical latitudes ('typical tropical structure'—TTS). Note that the thermocline and the nutricline are at the same depth. The peak of primary production is more shallow than the peak of chlorophyll (= phytoplankton biomass).

C Primary production in **mid-ocean gyres – oligotrophic systems**

Thermal stratification controls primary production oligotrophic marine ecosystems.

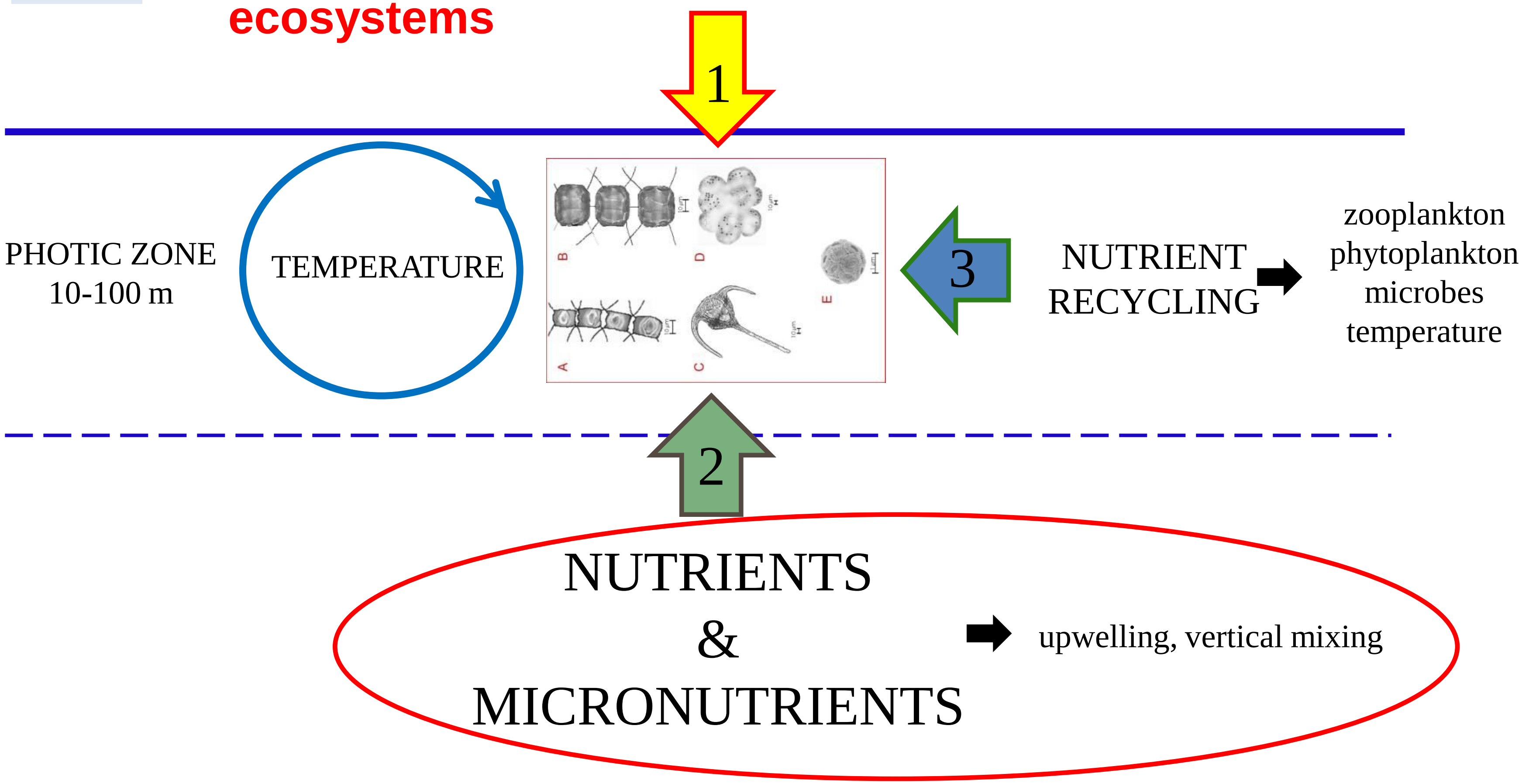


Global warming reduces productivity

Polovina *et al.* (2007)

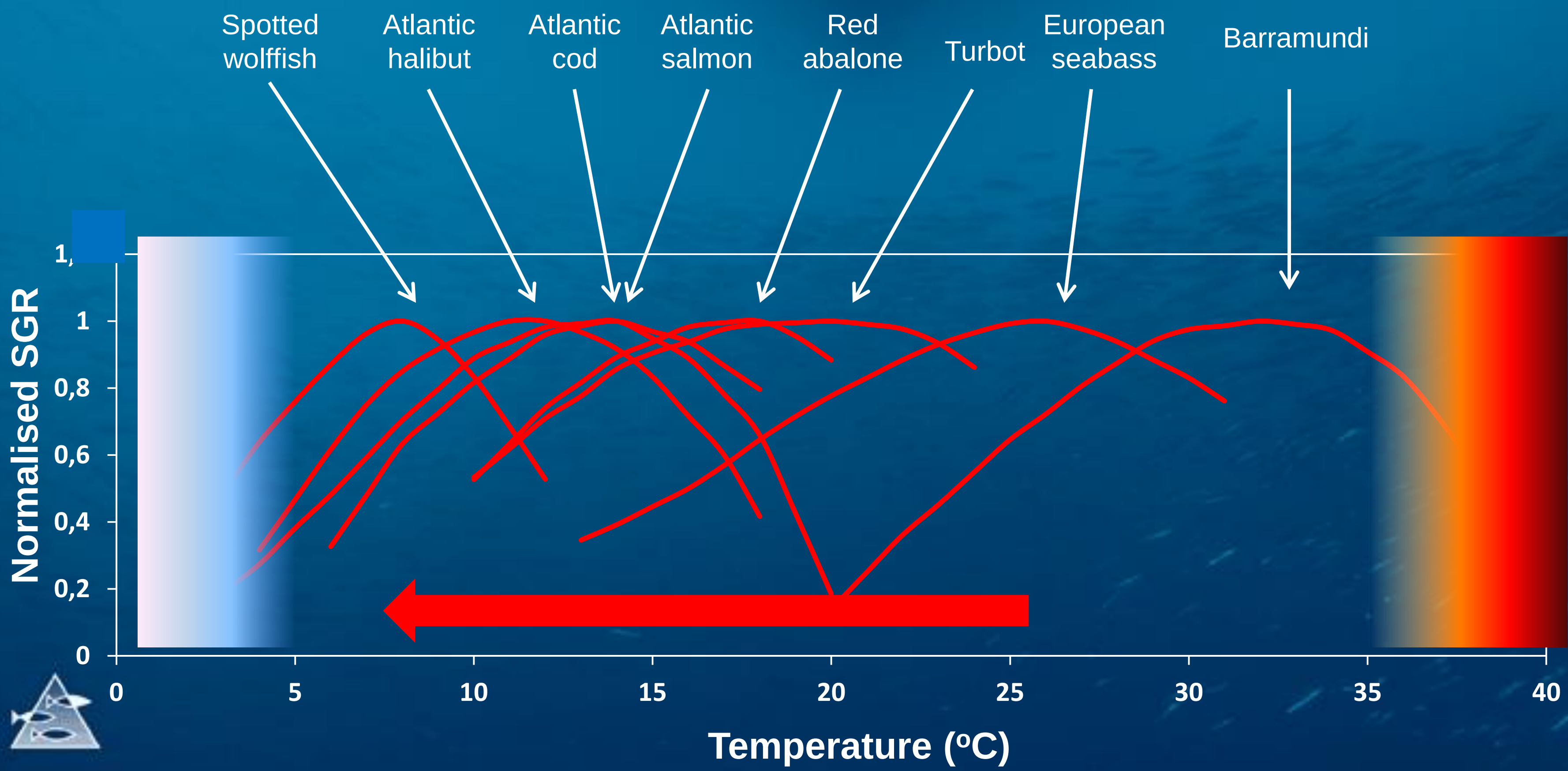
C Low-productive ocean-gyre ecosystems

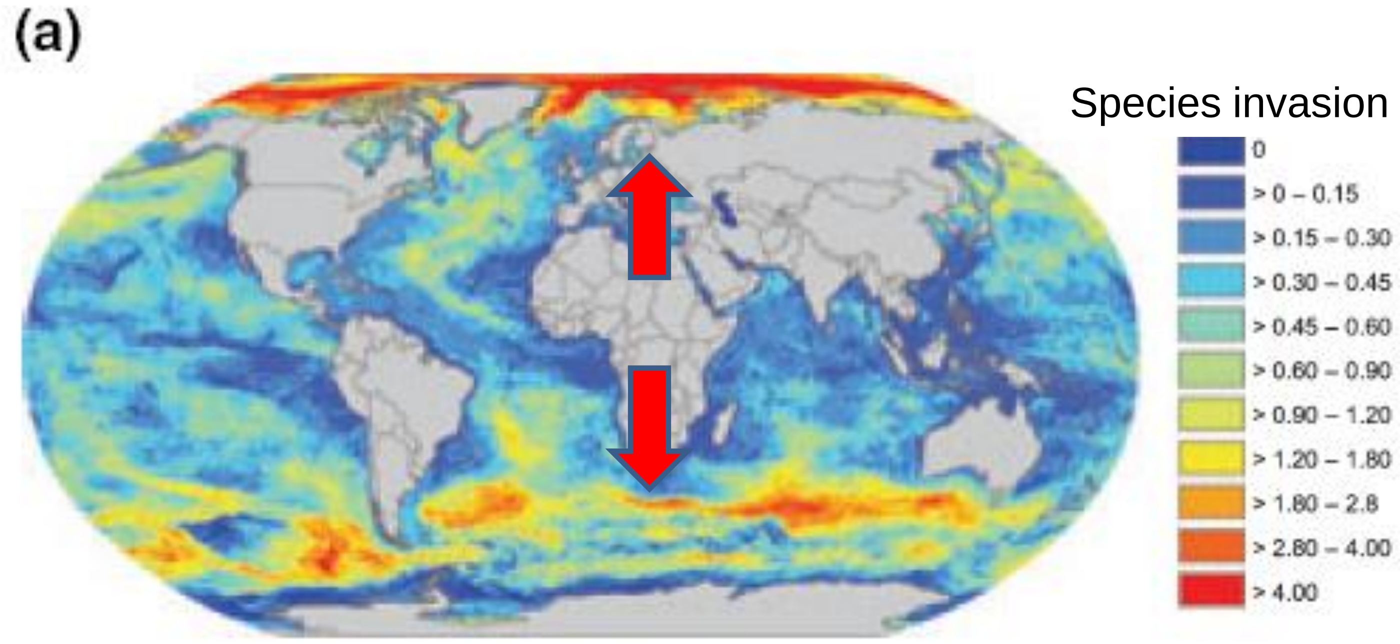
LIGHT ➡ latitude, season, clouds



FACTORS DETERMINING PHYTOPLANKTON PRODUCTION & DYNAMICS

Spotted wolffish: Imsland *et al.* (2006) Aquaculture
Atlantic halibut: Jonassen *et al*. (1999) Journal of Fish Biology ; Bjõrnsson and Trygvadóttir (1996) Aquaculture
Arctic charr: Larsson and Berglund (1998) Journal of Fish Biology
Atlantic cod: Otterlei *et al.* (2000) Can J. Aquat. Fish.; Bjõrnsson *et al.* (2007) Aquaculture
Atlantic salmon: Handeland *et al.* (2008) Aquaculture
Pollock: Person-Le Ruyet *et al.* (2006) Aquaculture
Red abalone: Steinarsson and Imsland (2003) Aquaculture
Turbot: Imsland *et al.* (2001) Aquaculture ; Van Ham *et al.* (2003) Aquaculture
European seabass: Person-Le Ruyet *et al.* (2004) Aquaculture
Barramundi: Katersky and Carter (2007) Aquaculture





Cheung *et al*. (2009) Fish and Fisheries


Unni Justsen with 22 kg swordfish in Vinjefjorden, Mid Norway, November 2006

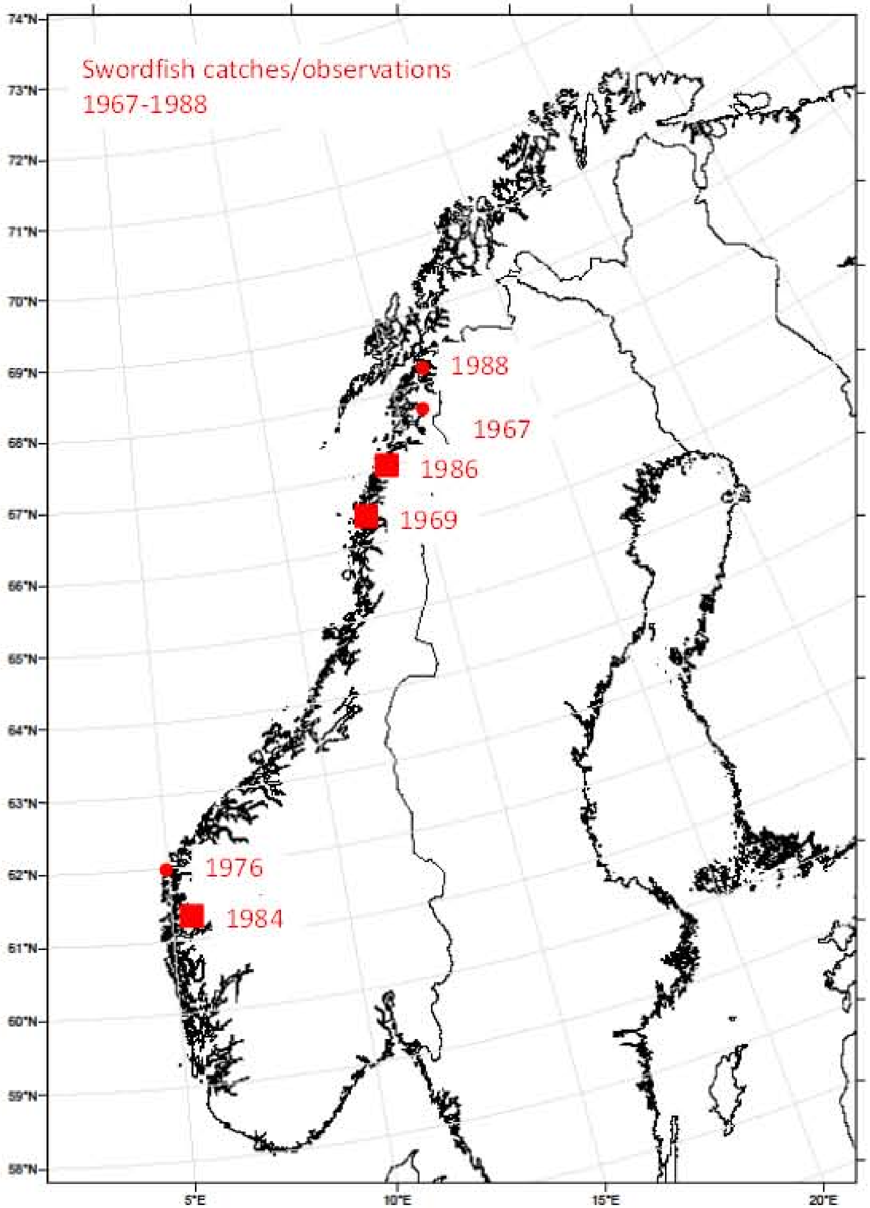
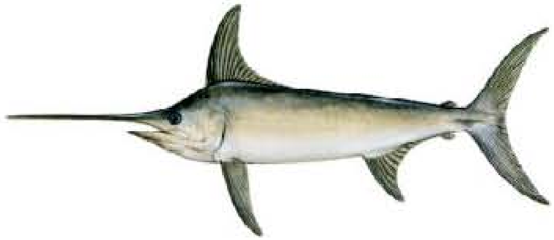


Figure 1. Catches and observations of swordfishes along the Norwegian coast and in the fjords period 1967-1988. Circles show exact location of the observation. Where exact locations are not indicate approximate location.

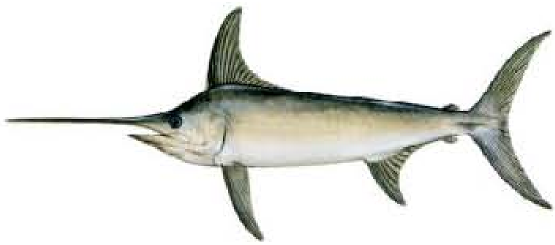
Swordfish



Family Xiphiidae, SWORDFISHES
Xiphias gladius

Observations 1967-1990

Swordfish



Family Xiphiidae, SWORDFISHES
Xiphias gladius

Observations 1990-2011

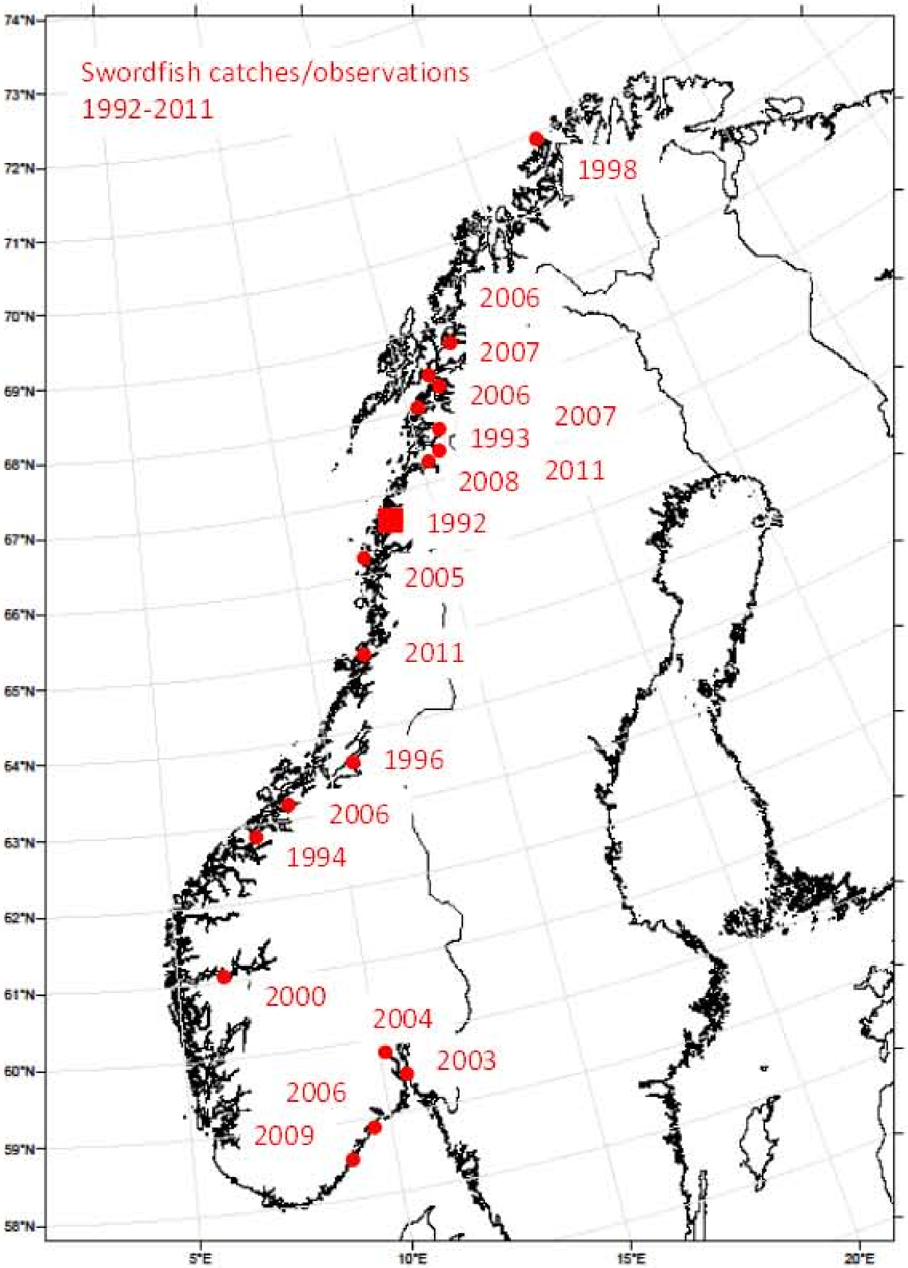
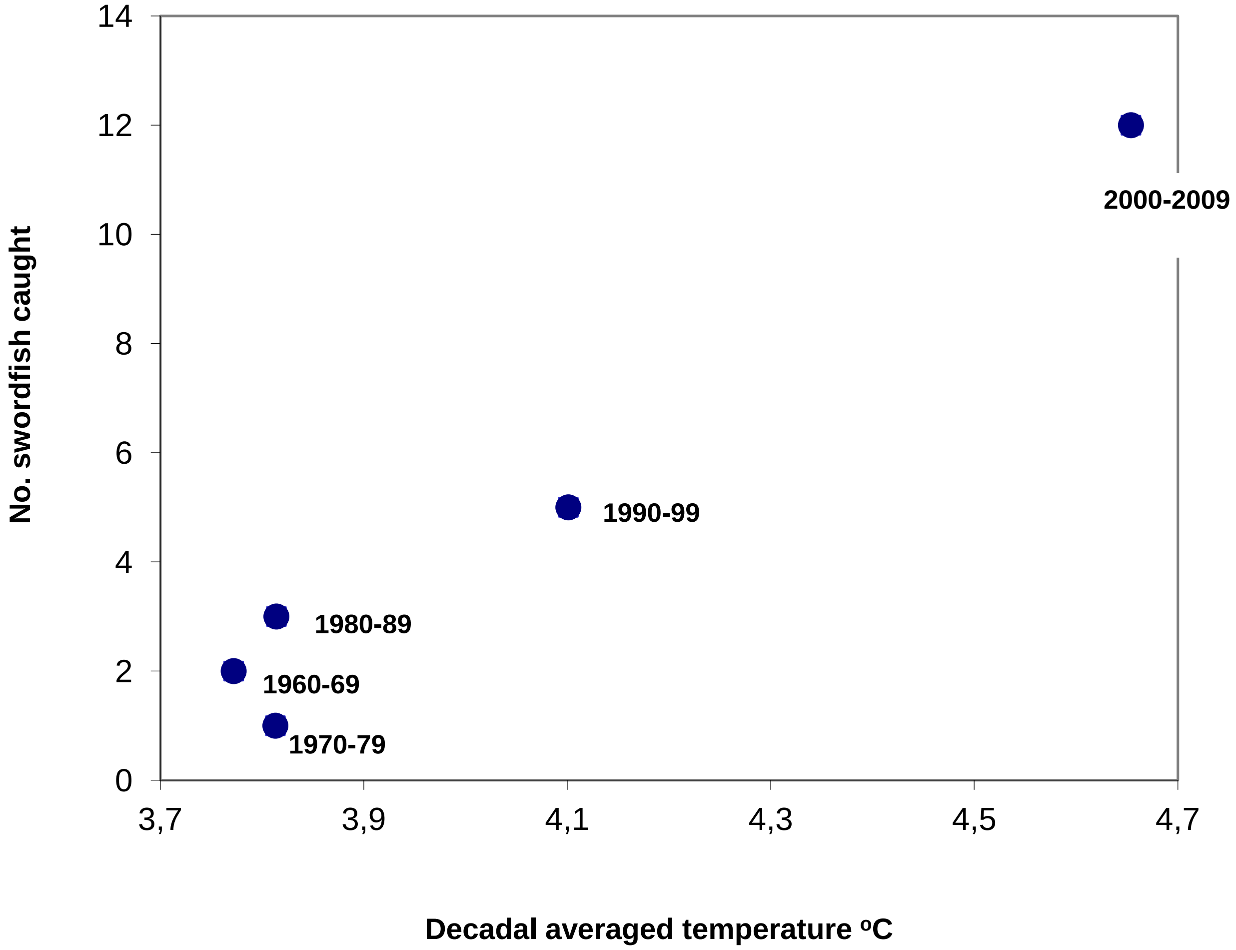
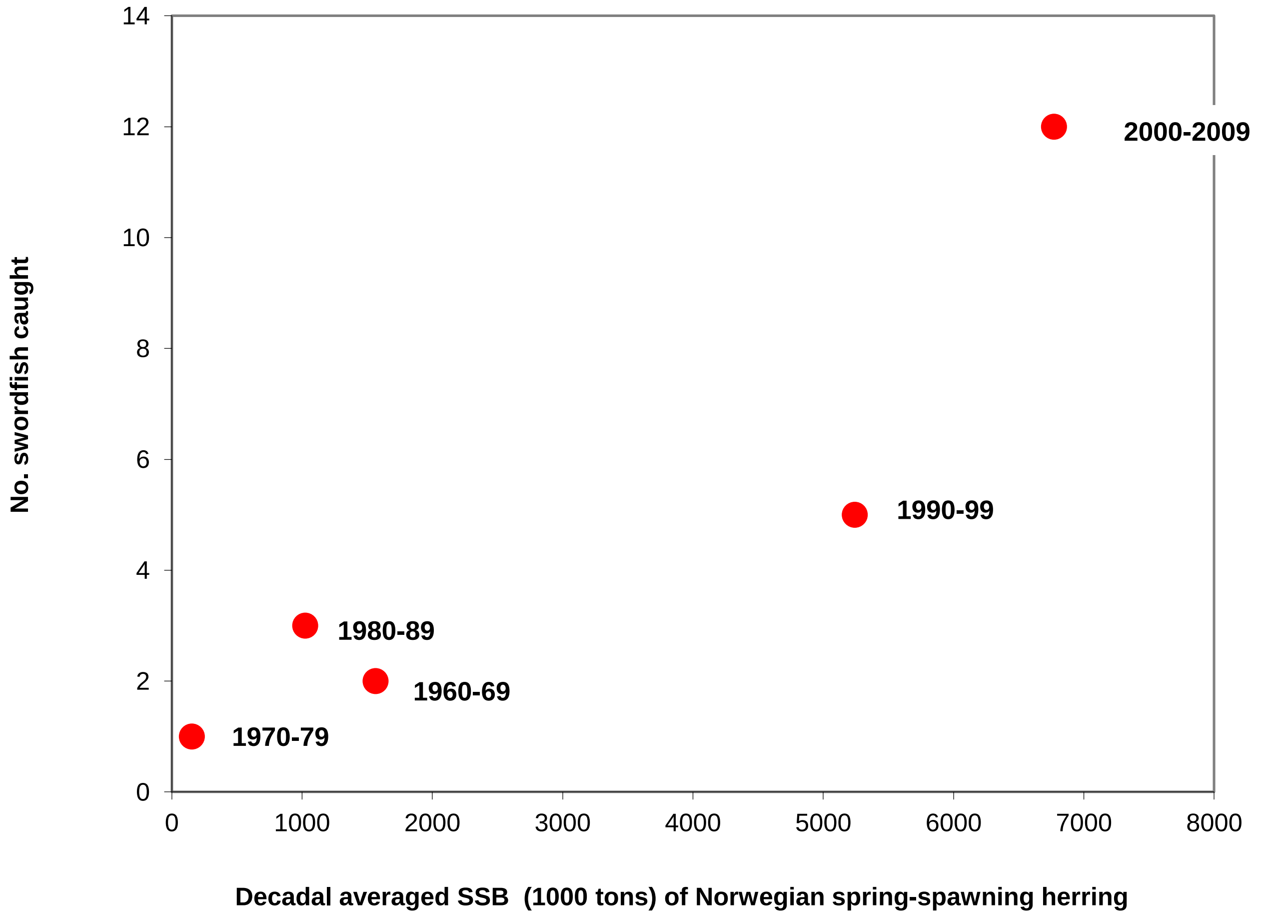


Figure 2. Catches and observations of swordfishes along the Norwegian coast and in the fjords during the period the period 1992-2011. Circles show exact location of the observation. Larger square indicates approximate location where exact location is not known.

No of swordfish caught in each decade versus the decadal averaged temperature of the northeastern North Atlantic (Temperature based on the Kola Section time series in the Barents Sea).



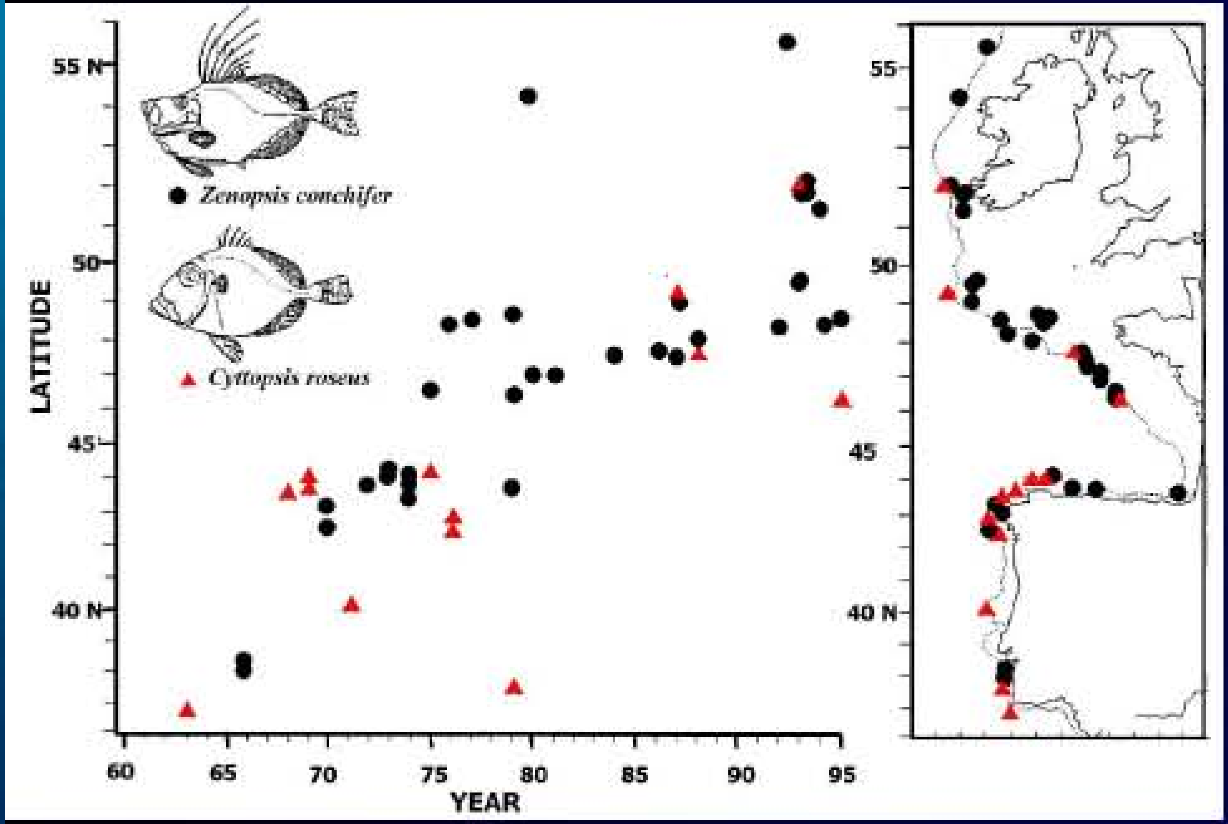
Number of swordfish caught in each decade versus the decadal averaged spawning-stock biomass (in 1000 tonns) of Norwegian spring-spawning herring.



Farther South

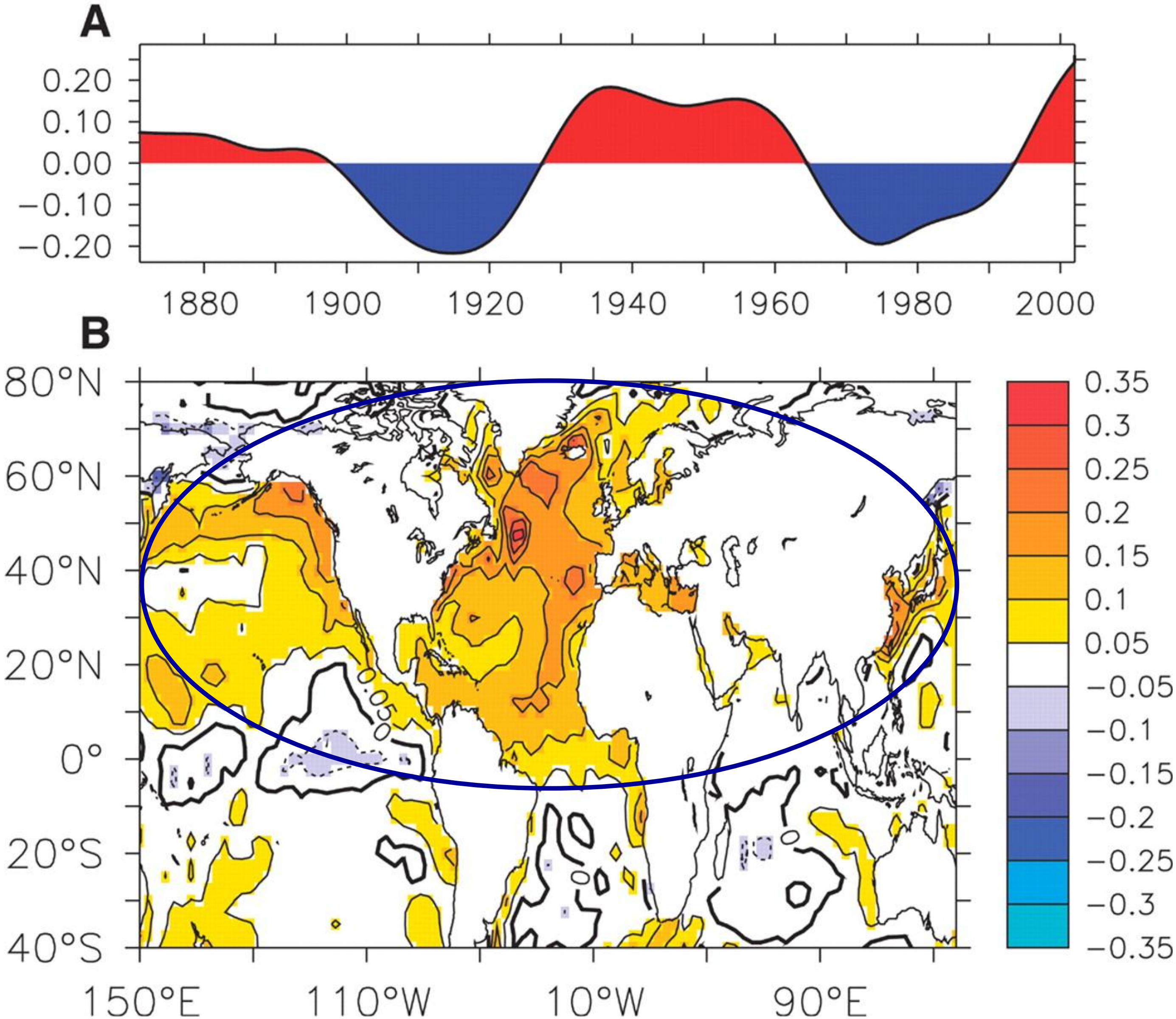
General northward displacement of commercial and non-commercial species of fish.

•In North Sea northward displacement of fish at rate of 7 km per year over 1990s, 7 times faster than on land (Perry, 2004)



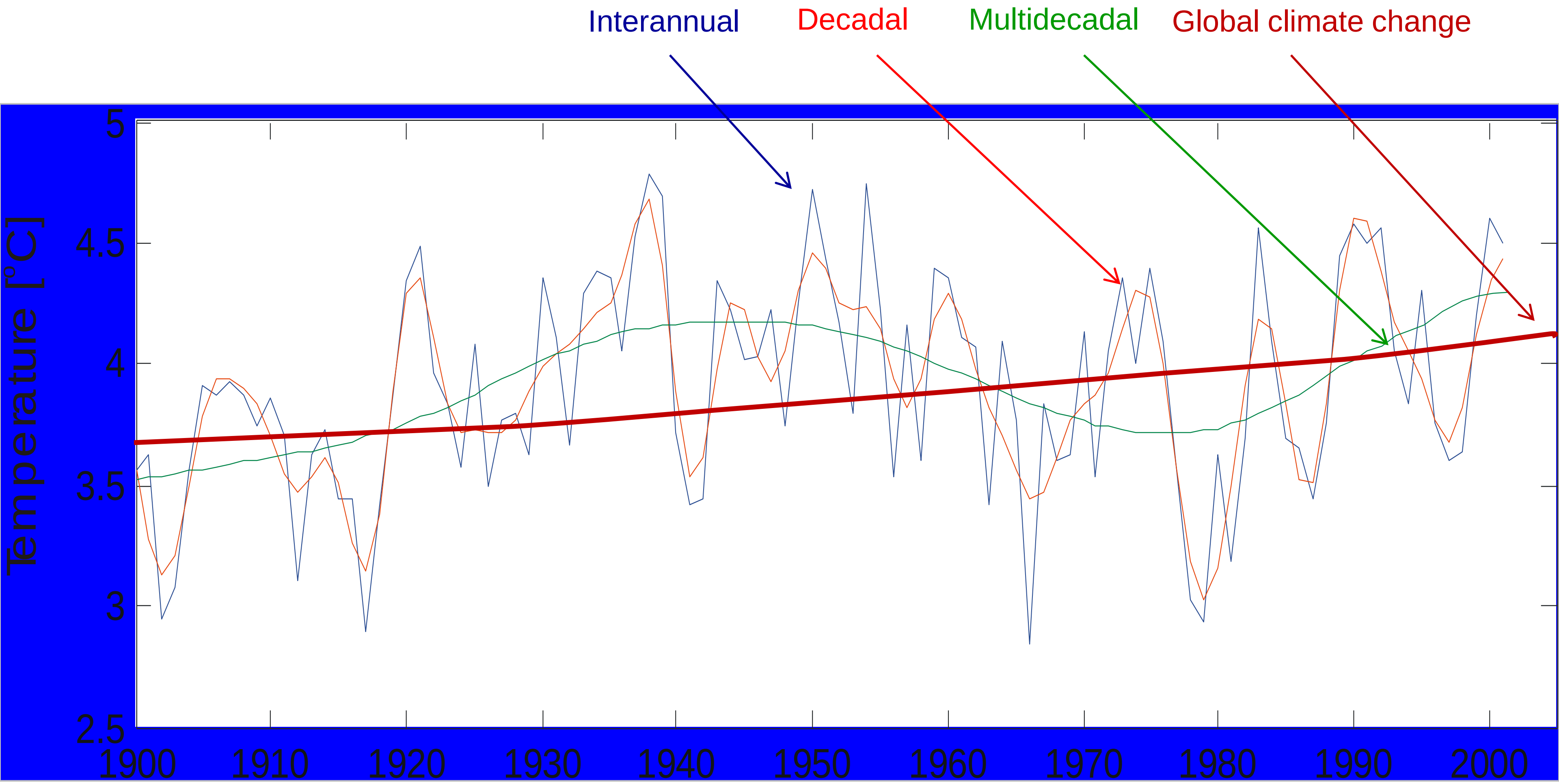
•Acceleration of southern species moving north from Iberian Peninsula to West of Scotland (Quero et al., 1998)

The Atlantic Multidecadal Oscillation (AMO) 1873-2000



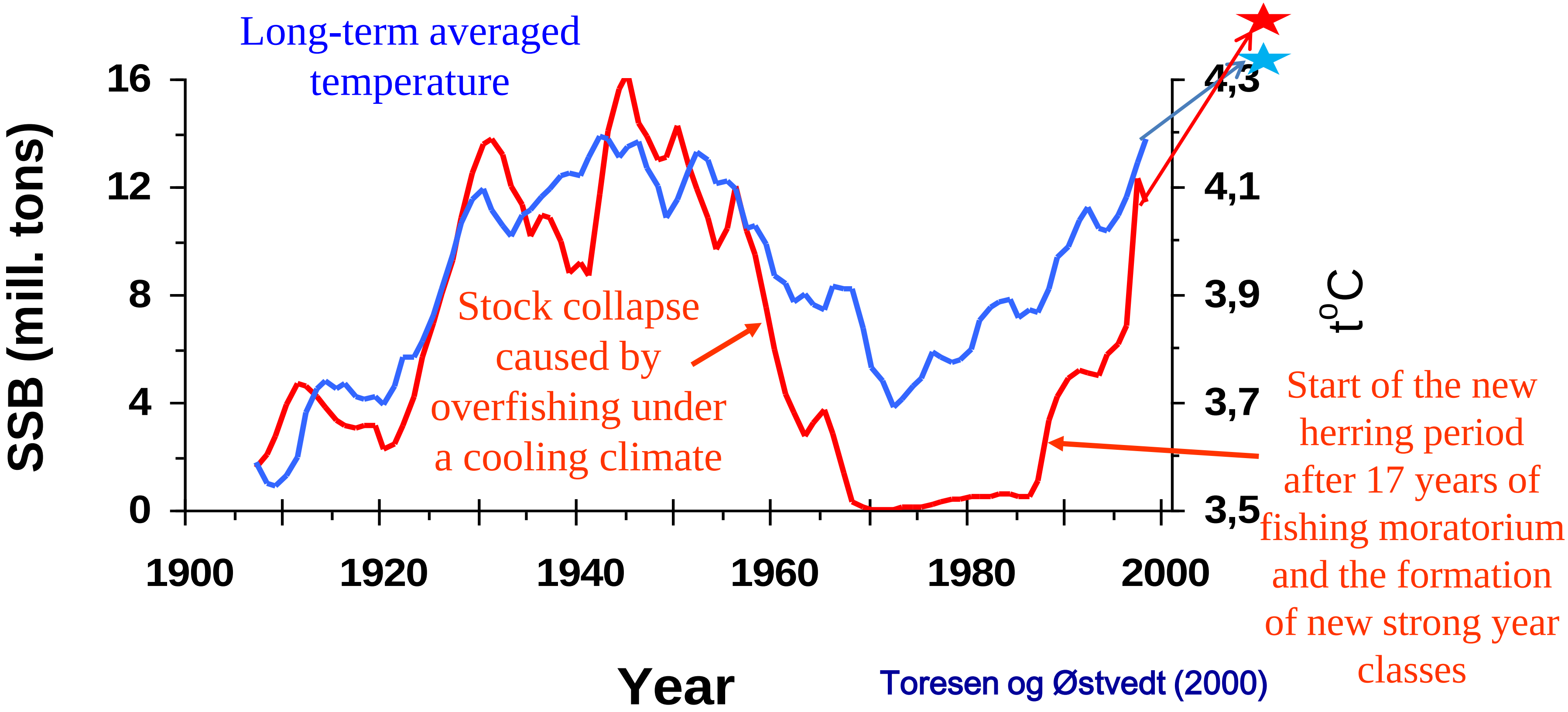
Sutton and Hodson (2005)

Ocean climate oscillations in the North Atlantic



Data source: The Kola Section, PINRO, Murmansk

Spawning stock biomass (SSB) of Atlantic herring and the longterm-averaged temperature

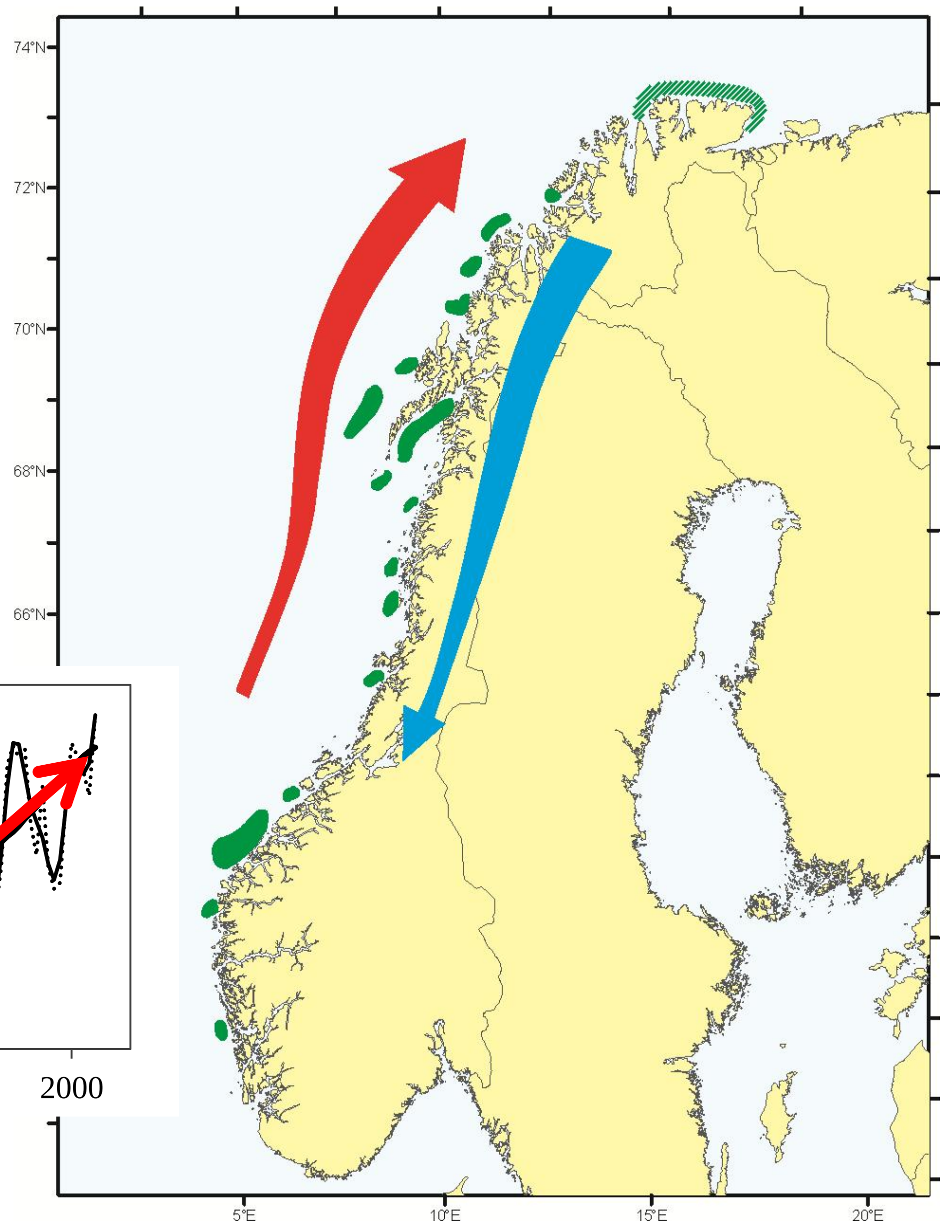


Climate response from Northeast-Arctic cod

In warming phases:

- Spawning sites displaced northward

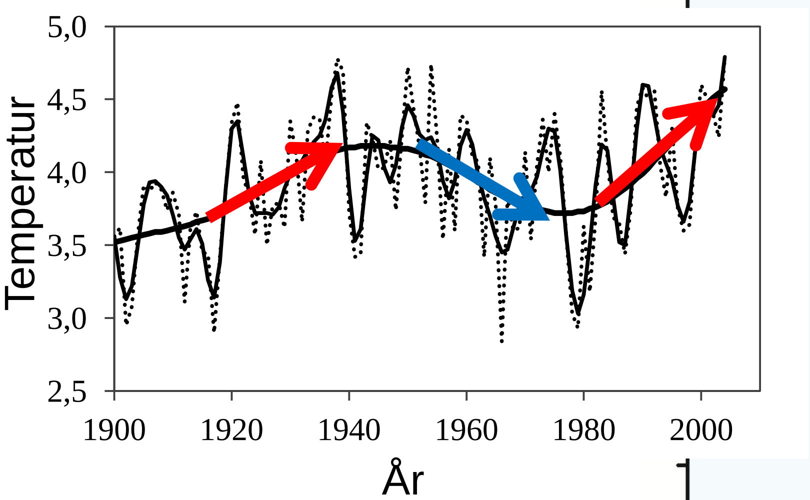
- Increasing spawning stock



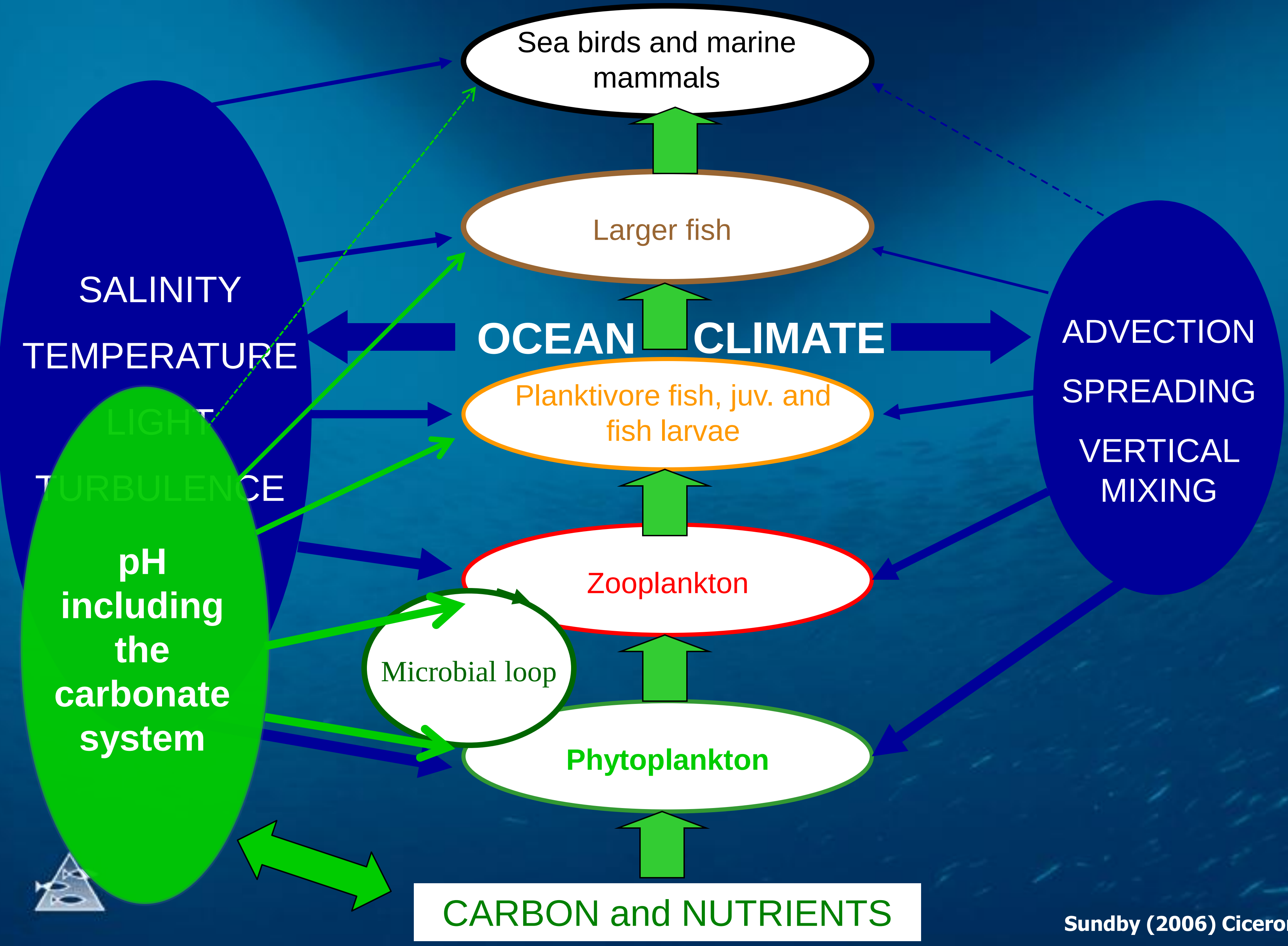
In cooling phases:

- Spawning sites displaced southward

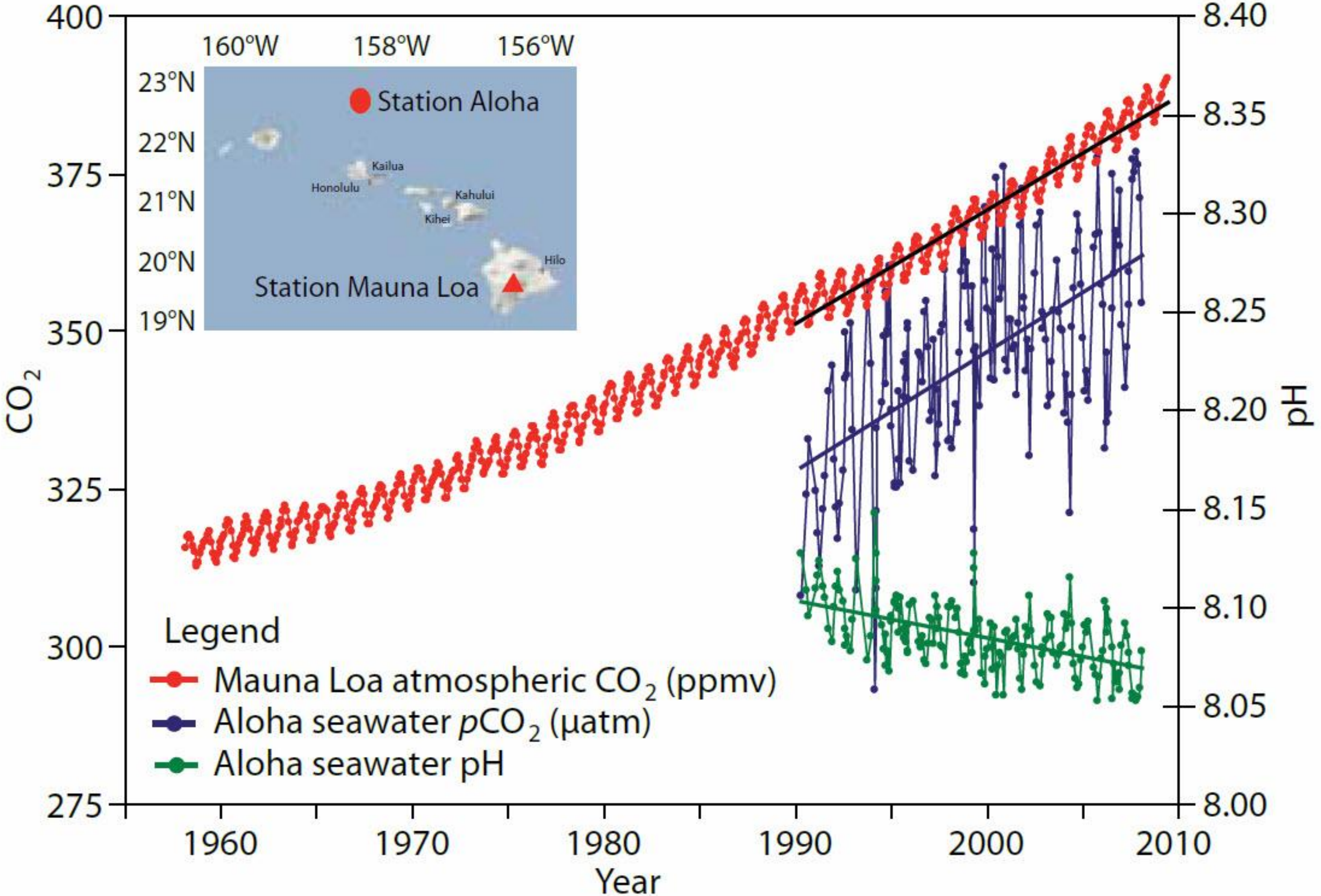
- decreasing spawning stock



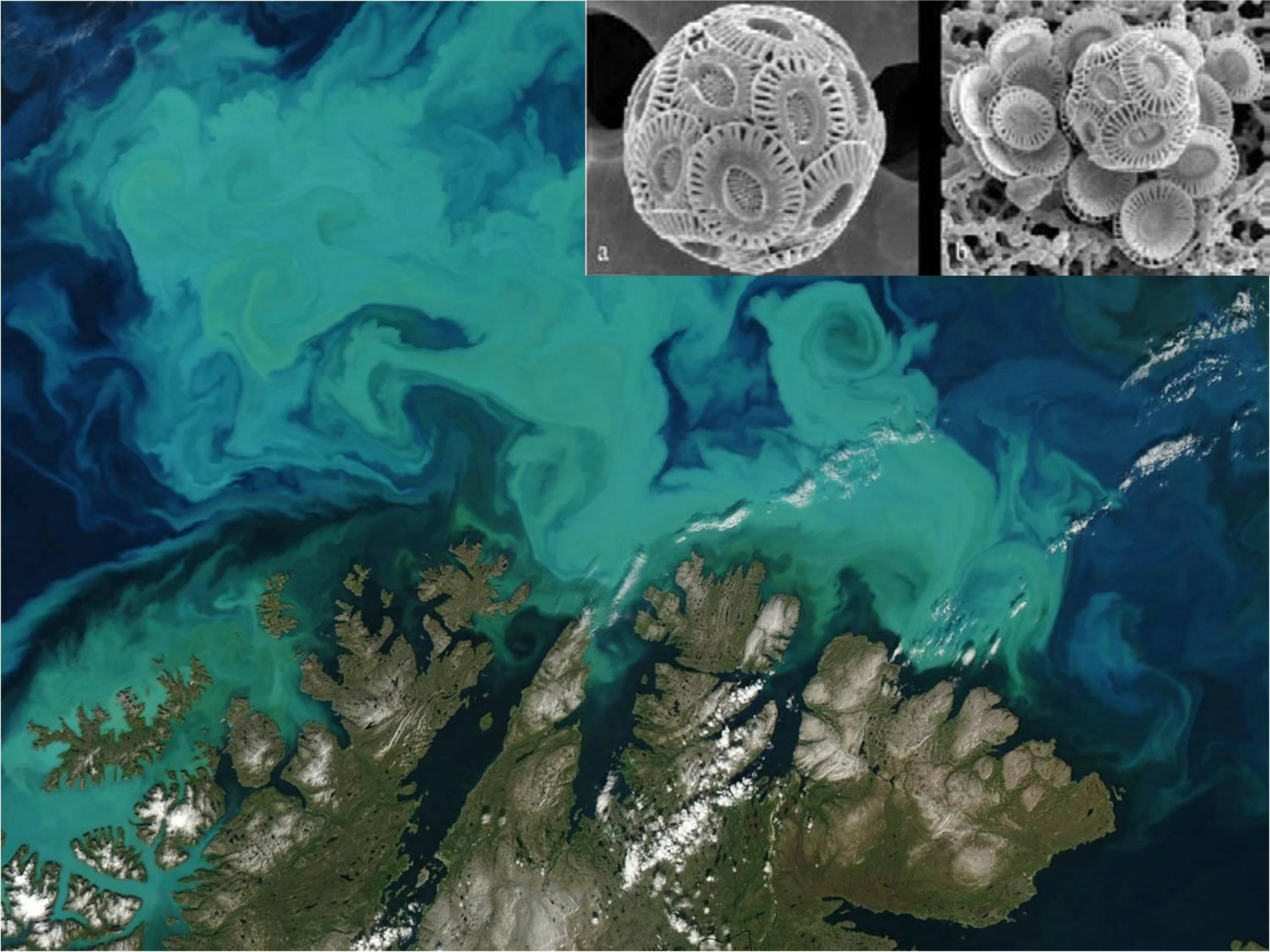
Sundby and Nakken (2008) IJMS



Sundby (2006) Cicerone



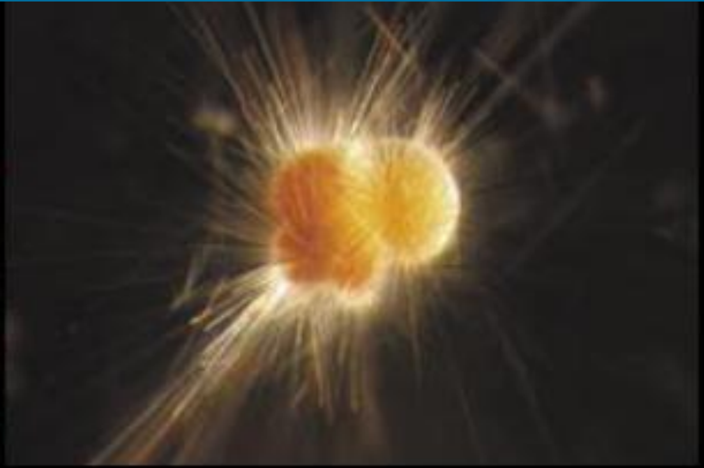
Doney et al. 2009. Oceanography 22(4): 16-25.


a
b

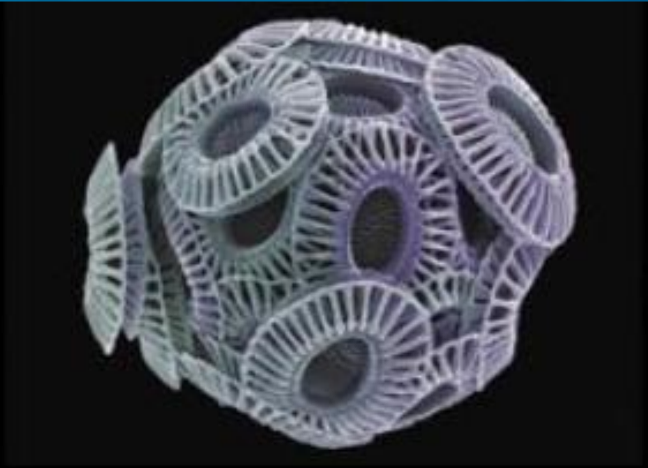
Beachy Head, the result of many thousands of years of coccolithophore formation (photograph from Encyclopædia Britannica Online).

Coral (*Millepora tenella*)

Coralline algae (*Amphiroa anceps*)

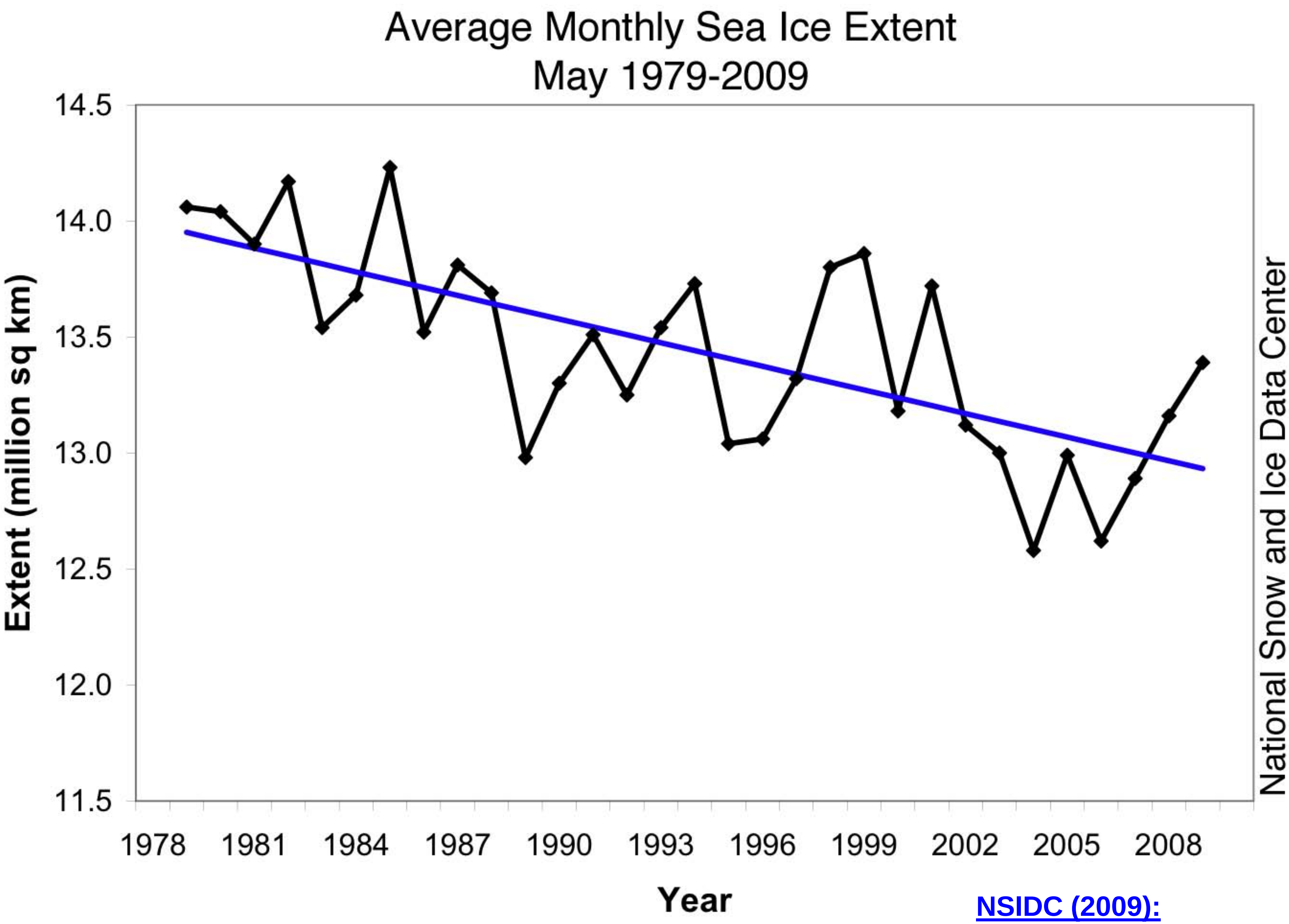


Foraminifer (*Globigerina bulloides*)



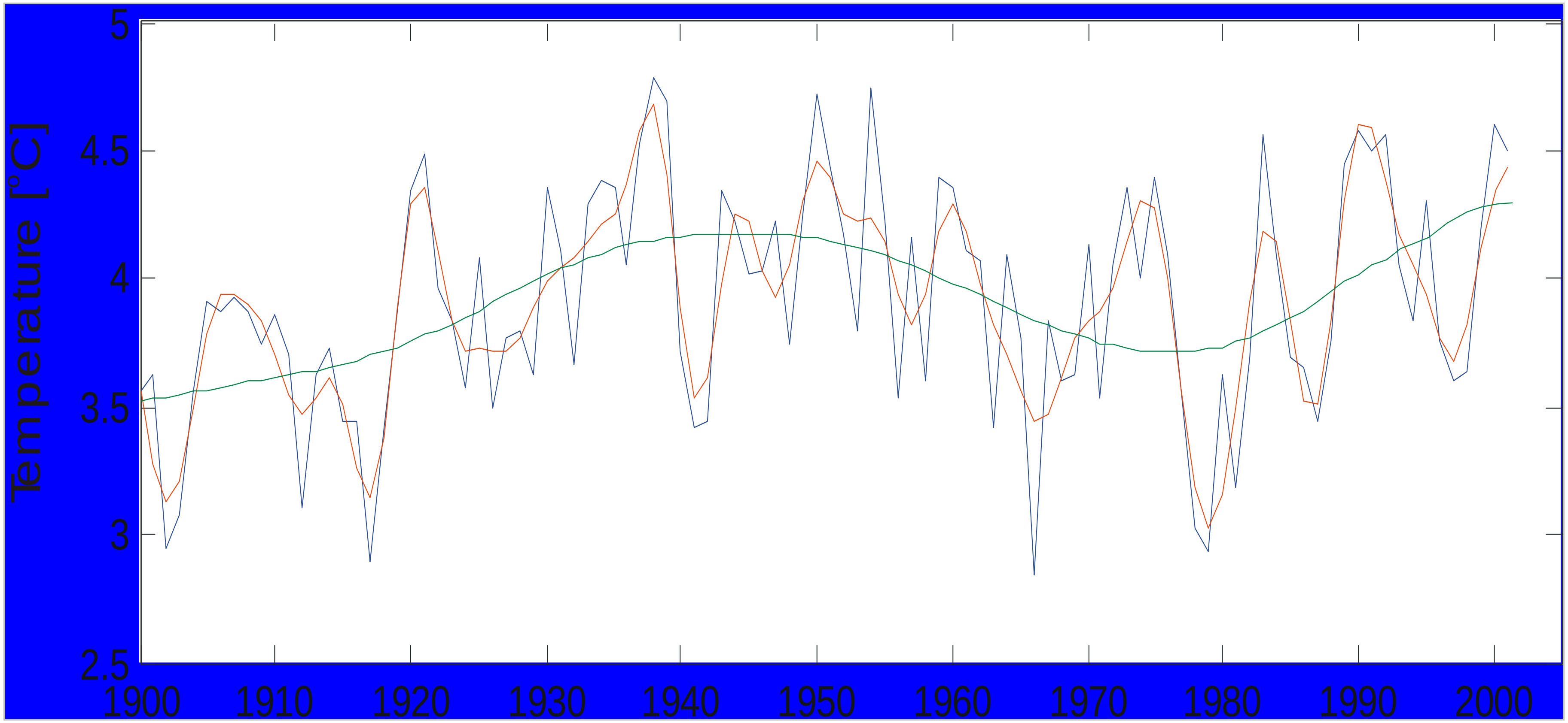
Coccolithophorid (*Emiliania huxleyi*)

Pteropod (*Limacina helicina*)

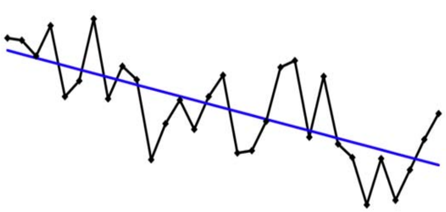


[NSIDC (2009): http://nsidc.org/arcticseaicenews/](http://nsidc.org/arcticseaicenews/)

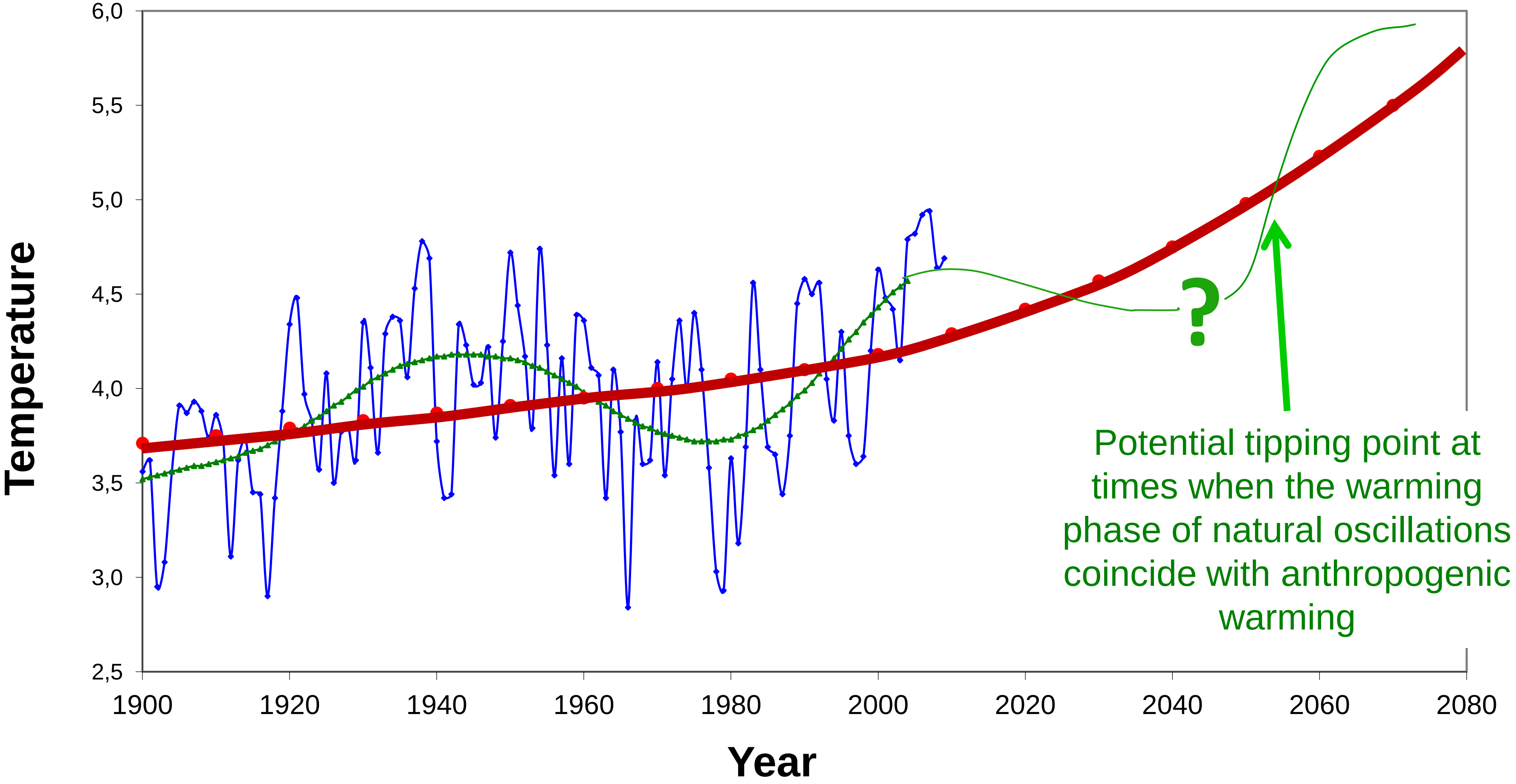
Ocean climate oscillations in the northern North Atlantic



How would we have interpreted development of Arctic sea ice extent if we had satellite data from the 1930s?



Barents Sea modelled climate change and observations



Conclusions

• Impacts of climate change on marine ecosystems is not uniform but varies depending on the critical physical and biological mechanisms

• High-latitude and upwelling ecosystems have the potential of higher production under climate change

• Low-latitude and mid-ocean gyre ecosystems will most probably decrease the productivity under climate change

• Long-term natural climate variability masks the effects of - and the predictability of - anthropogenic climate change

• Ocean acidification is the ”dark horse” and impacts will be uniformly negative across all marine ecosystems