Impact of Global Change on the marine planktonic ecosystem:

Phytoplankton and Zooplankton

Albert Calbet
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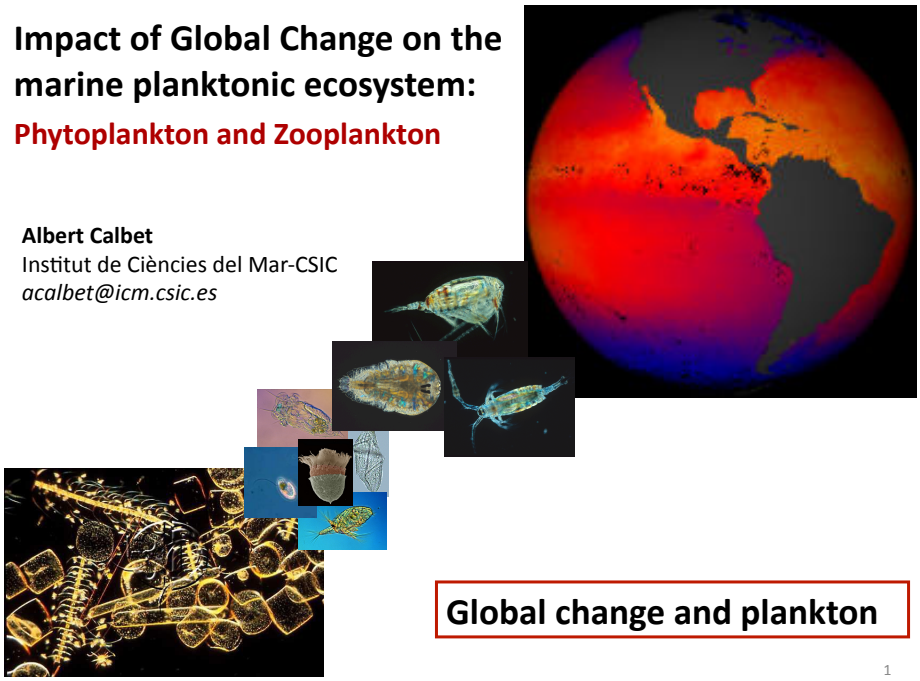
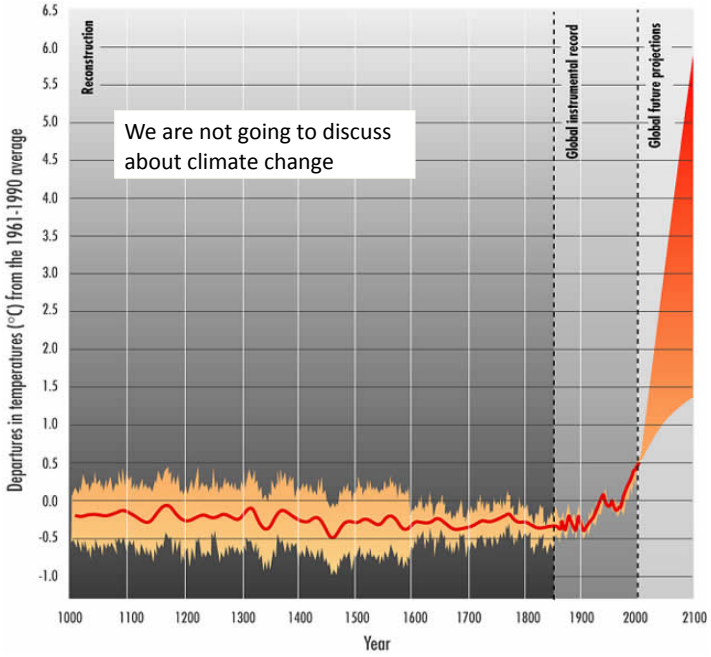
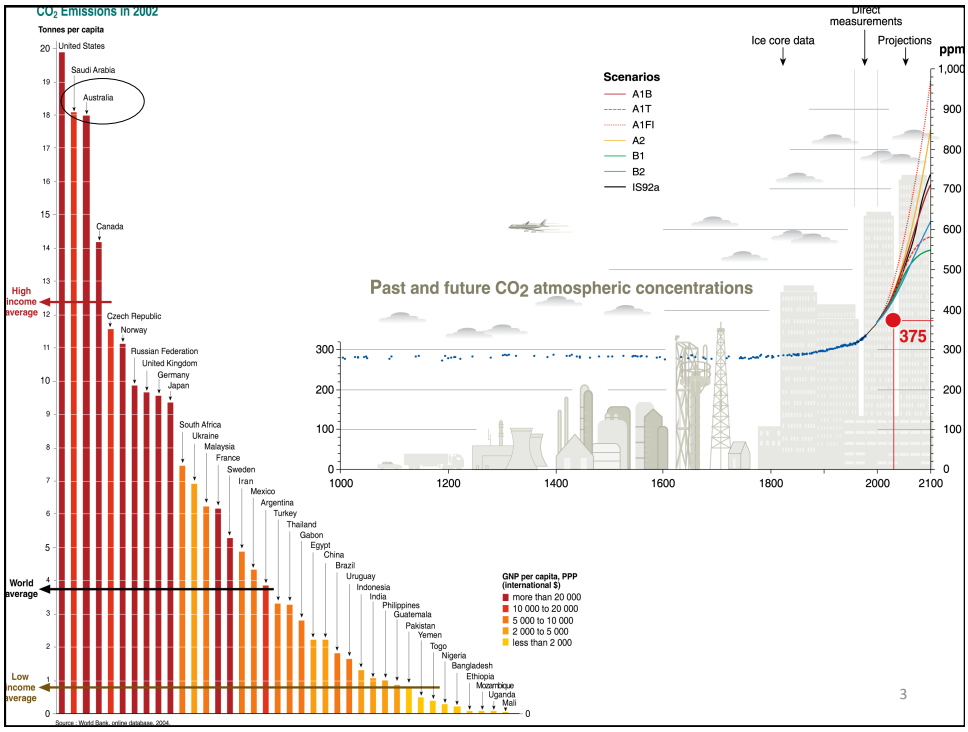


Global change and plankton

1



IPCC


CO2 Emissions in 2002
Tonnes per capita
United States
Saudi Arabia
Australia
Canada
High income average
Czech Republic
Norway
Russian Federation
United Kingdom
Germany
Japan
South Africa
Ukraine
Malaysia
France
Sweden
Iran
Mexico
Argentina
Turkey
Thailand
Gabon
Egypt
China
Brazil
Uruguay
Indonesia
India
Philippines
Guatemala
Pakistan
Yemen
Togo
Nigeria
Bangladesh
Ethiopia
Mozambique
Uganda
Mali
World average
Low income average
GNP per capita, PPP (international $)
more than 20 000
10 000 to 20 000
5 000 to 10 000
2 000 to 5 000
less than 2 000
Source : World Bank, online database, 2004
Direct measurements
Ice core data
Projections
ppm
Scenarios
A1B
A1T
A1FI
A2
B1
B2
IS92a
Past and future CO2 atmospheric concentrations
375
3


La preuve du réchauffement de la planète
vu sur Humour.com
18th Century
1900
1950
1970
1980
1990
2006
4

NOT A NEW IDEA!

MONTHLY WEATHER REVIEW

Editor, W. J. HUMPHREYS

VOL. 61, No. 9
W.B. No. 1112

SEPTEMBER 1933

CLOSED NOVEMBER 3, 1933
ISSUED DECEMBER 27, 1933

IS OUR CLIMATE CHANGING? A STUDY OF LONG-TIME TEMPERATURE TRENDS

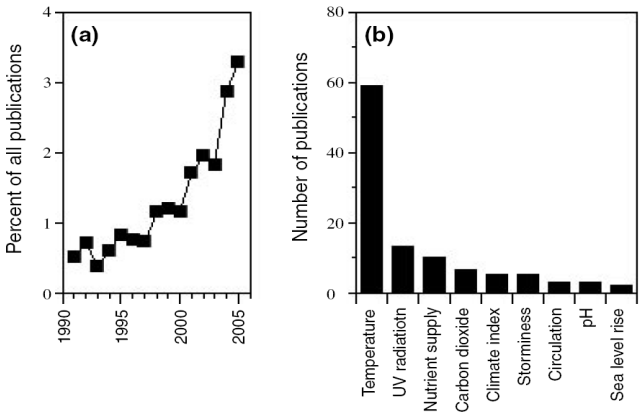
By J. B. KINCER

[Weather Bureau, Washington, D.C., Sept. 29, 1933]

The present wide-spread and persistent tendency toward warmer weather, and especially the recent long series of mild winters, has attracted considerable public interest; so much so that frequently the question is asked "Is our climate changing?" Historic climate has always been considered by meteorologists and climatologists to normal; that every one of the last 13 of these has been mild, and that the warmest winter of record, going back considerably more than a century, was that of 1931–32. This is in marked contrast with "granddad's day", for the 19 winters of 1854–55 to 1872–73, 14 of which were colder than normal, with 1855–56 the coldest in more than

5

Climate Change Research: Marine Biology



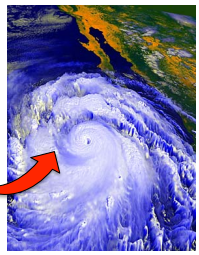
Harley et al (2006) Ecology Letters

6

LETS CLARIFY CONCEPTS:

Global change
(includes many aspects)

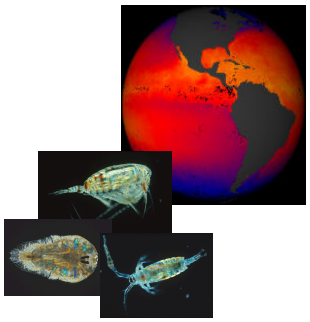
Global warming



Climate change

7

Global change and plankton



Climate change mechanisms
- temperature
- turbulence
- rainfall: eutrophication, annoxia
- acidification
- UV

Climate change effects
- distribution
- abundance
- phenology (life cycles)

Other Global Change effects on plankton
- Pollutants
- Overfishing
- Invasive species

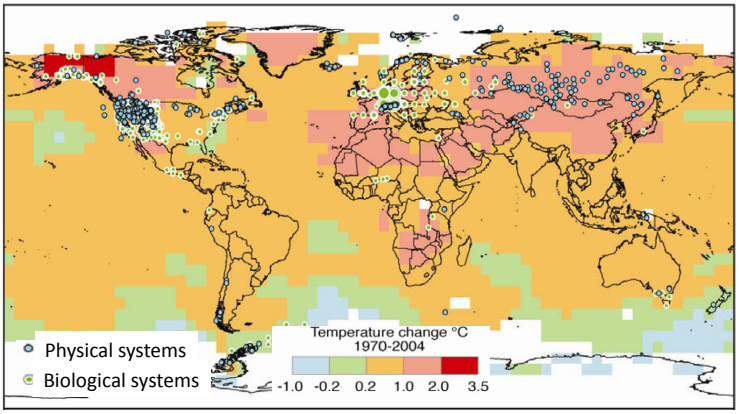
8

What I want you to take from this lecture

- Climate change has many impacts beyond simply warming
- Complexity of climate change on physics and chemistry has a myriad of biological impacts
- Global change further include additional impacts

9

Earth System Changes
Physics & Biology



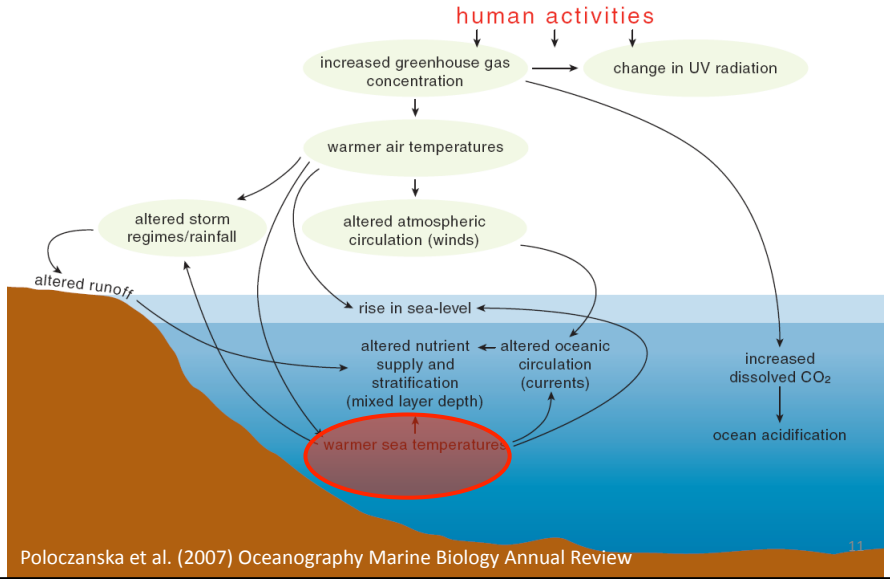
Studies
1-30
31-100
101-800
801-1200
1201 -7500

	Terrestrial		Marine	
	Physical	Biological	Physical	Biological
# significant changes	764	28,586	1	85
% consistent with warming	94%	90%	100%	99%

IPCC WG1 AR4

10

Complexity of Climate Change

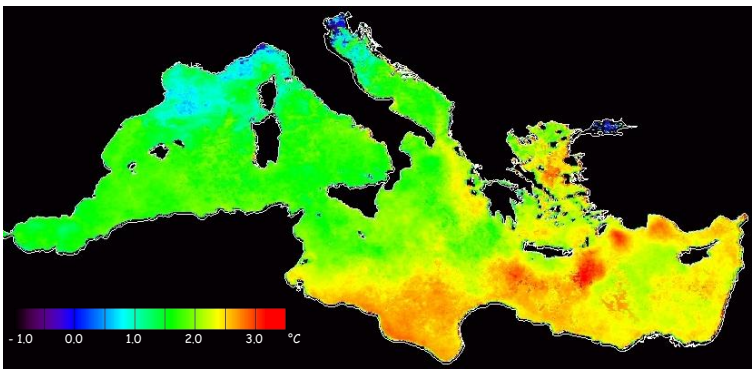


Poloczanska et al. (2007) Oceanography Marine Biology Annual Review

11

total SST change (°C)
from AVHRR data 1982 - 2003

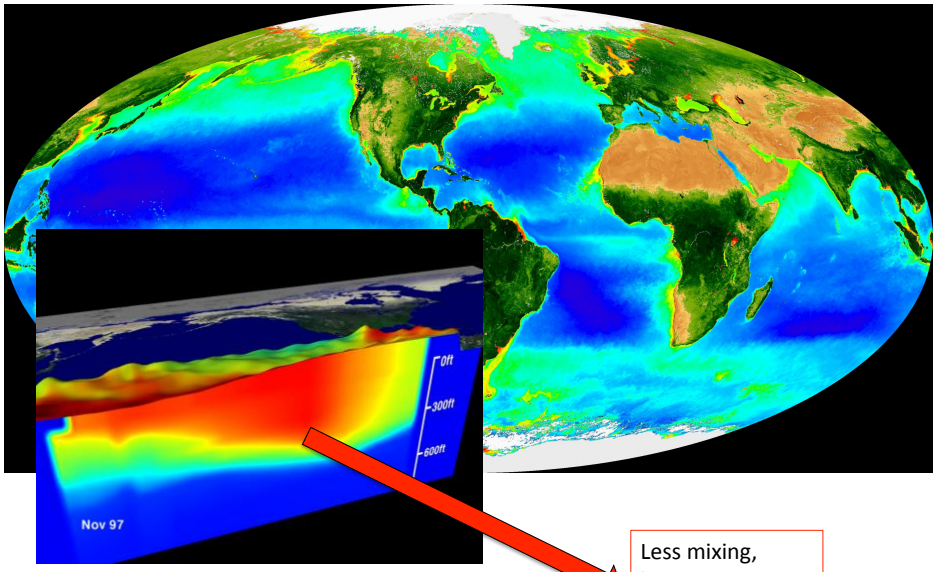
Satellite observations from more than 2 decades show that average annual SST in the Mediterranean Sea has increased at a rate of 0.1°C/year in the western basin and of 0.12°C/year in the eastern one. Over the entire time series the trends translate to 2.2°C and 2.6°C, respectively.



Leo Nykjaer, Joint Research Centre, EC, Ispra (Italy)
Geophysical Research Letters (subm.)

From S. Fraga

Warming effects on thermocline



Open ocean

Less mixing,
less nutrients,
less production

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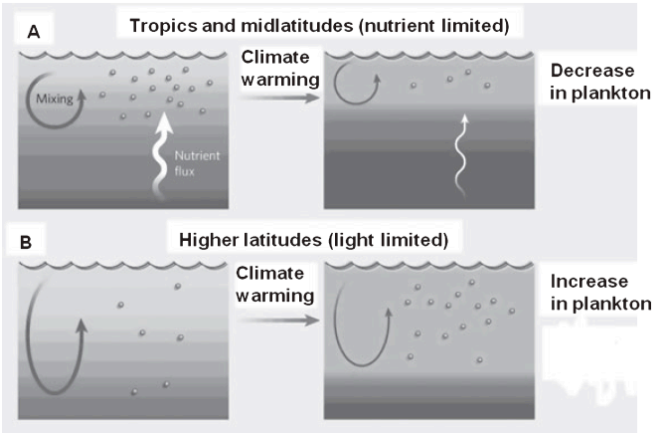
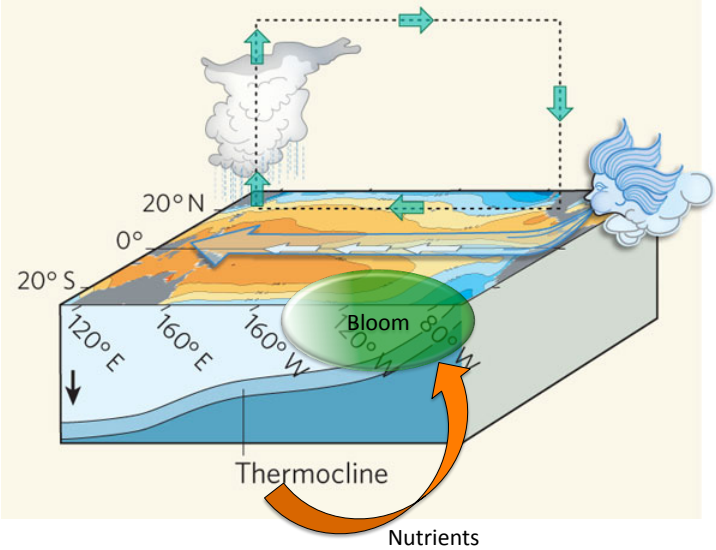
Different community response according to latitude



Predicted phytoplankton response to increased temperature in ocean surface waters:
(A) reduced productivity in the thermally stratified water of tropical and midlatitudes caused by reduced nutrient supply; (B) increased productivity at polar and subpolar salt-stratified oceans where reduced mixing keeps plankton closer to the well-lit nutrient-sufficient surface layers.
Adapted from Doney (2006).

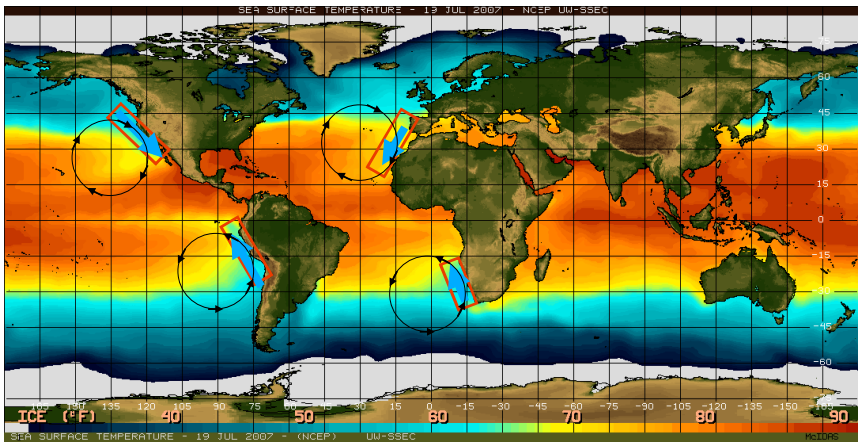
14

Warming effects on thermocline: Upwelling



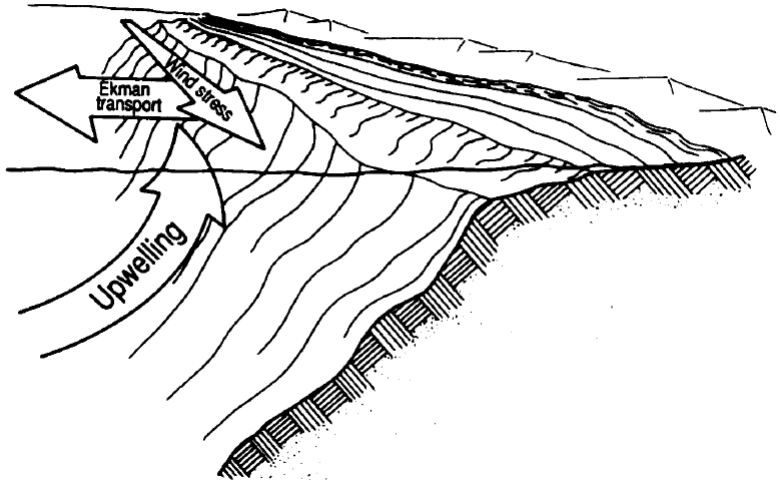
15

Upwelling systems

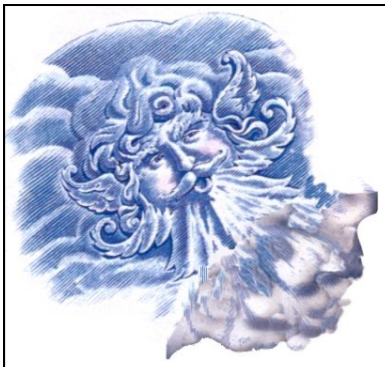


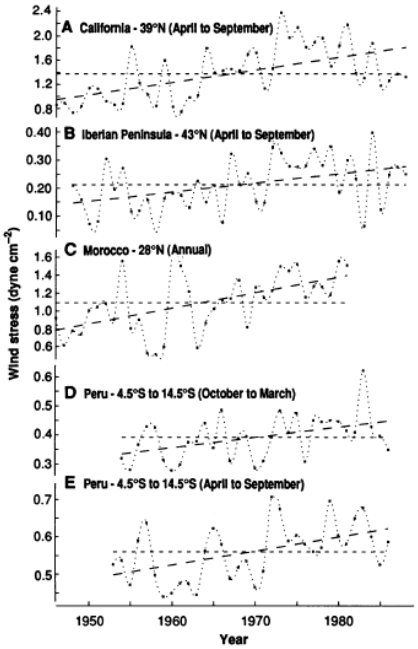
Slide from S. Fraga

Also when wind is along the coast



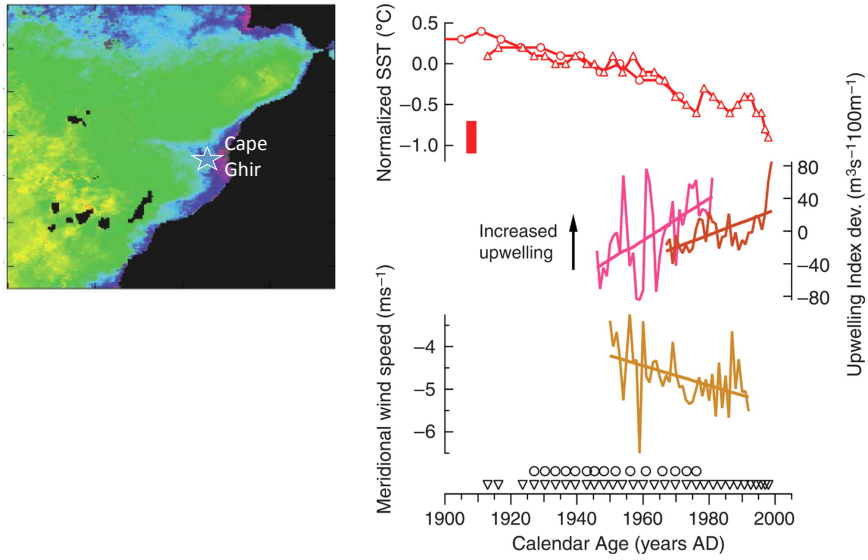
17





Bakun, A, *Science* 1990

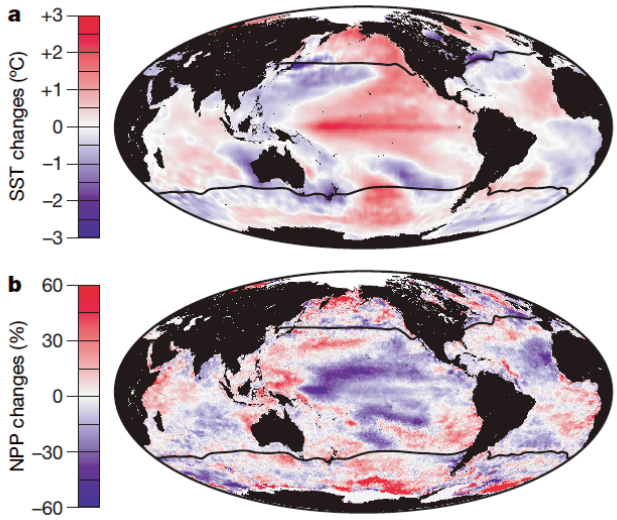
18



McGregor *et al.*, *Science* 2007

19

1999-2004: Inverse relationship sea surface temperature and Primary Production in open ocean, but not in productive systems

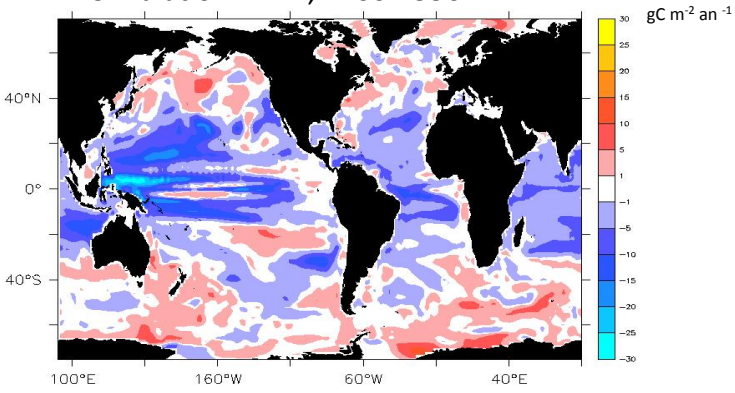


Behrenfeld et al. 2006

Altered Nutrient Supply - PP

- PP decreases globally (-5 to -10%) BUT increases at Poles (20 to 30%)

Simulation NPZD, 2100-1990



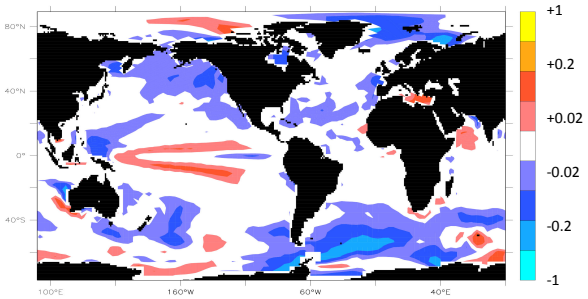
21

Bopp (2005)

Altered Nutrient Supply – Size Changes

- T increase stratification
- Diatoms replaced by small phytoplankton at mid/high Latitudes

Diatom/(Nanophyto + Diatoms)



Mechanisms

Stratification ↗

⇩

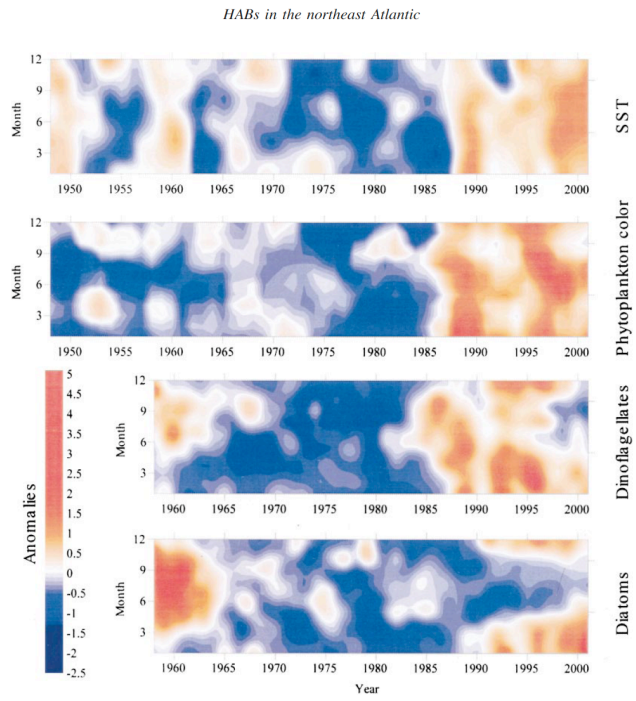
Nutrient Supply ↘

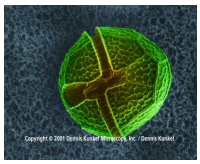
⇩

Diatoms/ NanoPhyto ↘

22

Bopp (2005)

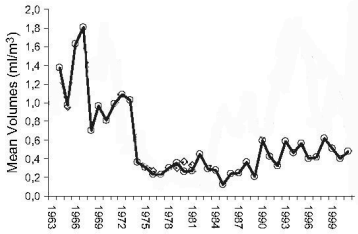




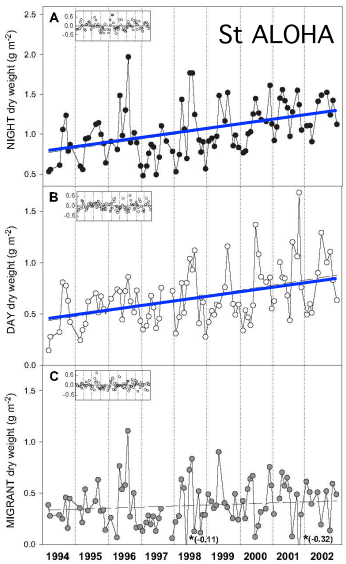
HABs can take advantage of the situation, because they grow well in stable waters

Edwards et al. 2006

Effects of global warming on zooplankton



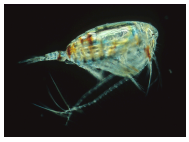
Perú upwelling *(Ayón et al. 2004)*



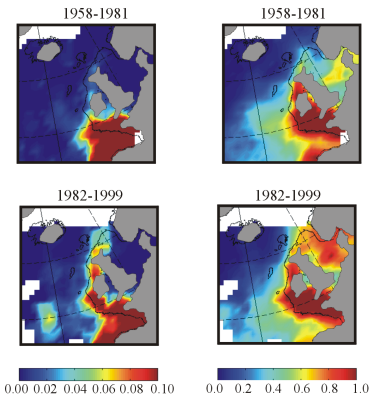
80% reduction in zooplankton biomass in the Pacific Ocean (South California). 1951-1993 temperature rised 1.5°C (Roemmich and McGowan 1995).
But, likely due to decrease in tunicates (salps)

Sheridan and Landry 2004

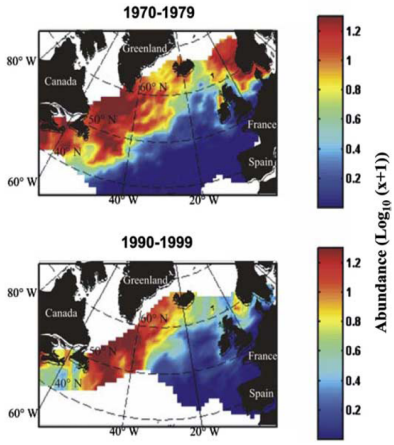
Species migration



Warm **temperate** **Temperate species**



Calanus finmarchicus

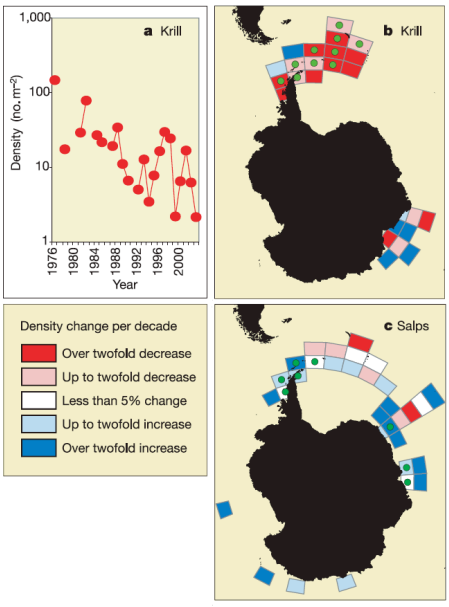


Beaugrand et al. (2002)

Bonnet et al. (2005)

25

Side-effects warming in Polar systems

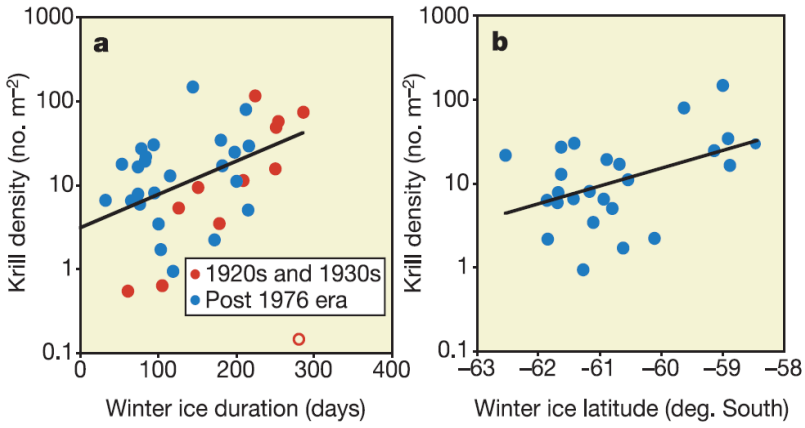


Decline in Krill
Increase in salps

Atkinson et al (2004) Nature

26

Good correlation between Krill abundance and ice extension and duration



27

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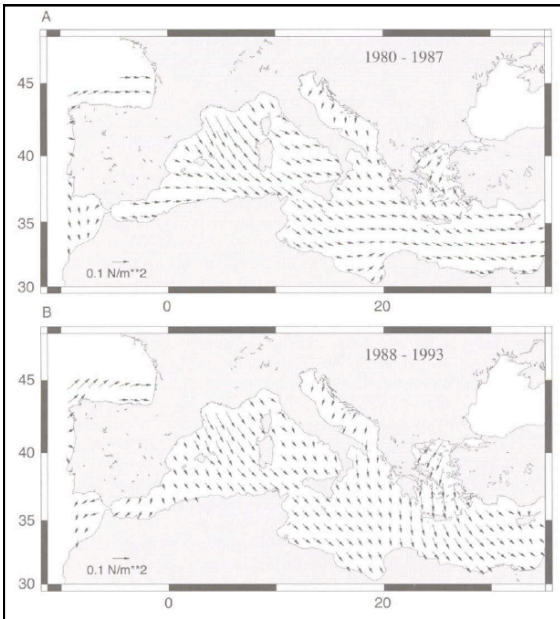

Figure 86: Wind stress from the climatology of the Southampton Oceanography Centre for the periods (A) 1980–1987, and (B) 1988–1993. From Samuel et al., 1999 reproduced with permission.

In the Mediterranean

Significant weight height

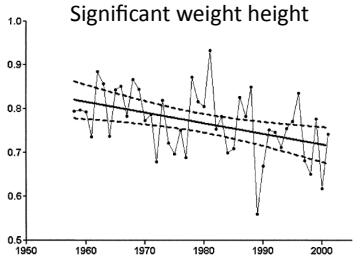

Figure 87: Time series of the average winter SWH (values in meters), linear regression (straight line) and 95% confidence interval (dashed line) (from Lionello and Sanna, 2005).

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Progressive warming of the Ligurian Sea

Vandromme et al. 2011 PICES meeting

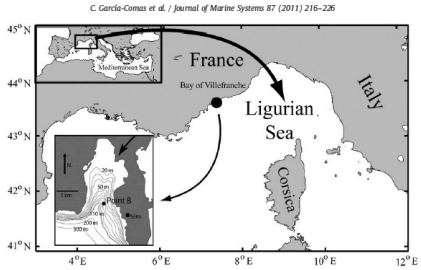
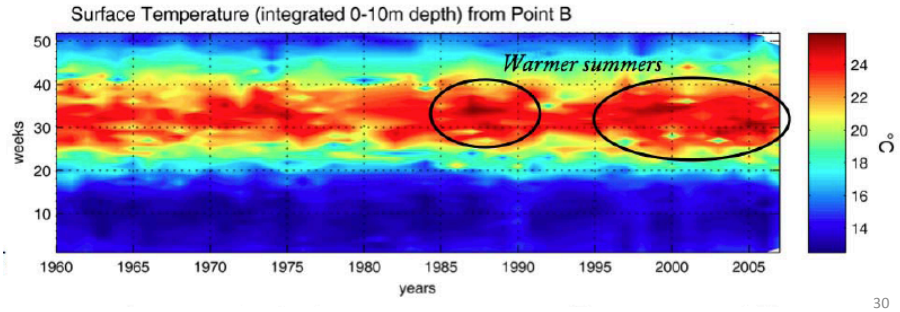
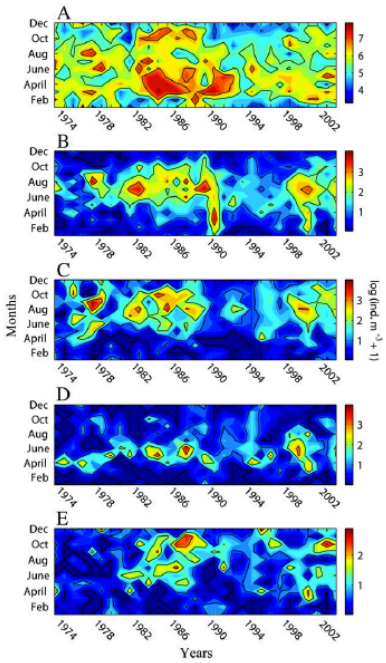


Fig. 1. Location of the Ligurian Sea in the Western basin of the Mediterranean Sea, and Point B sampling site at the entrance of Villefranche Bay.



30



Copepods

Decapod larvae

Chaetognaths

Siphonophores

Jellyfish

Ligurian Sea zooplankton

Changes rather associated to NAO than to global warming

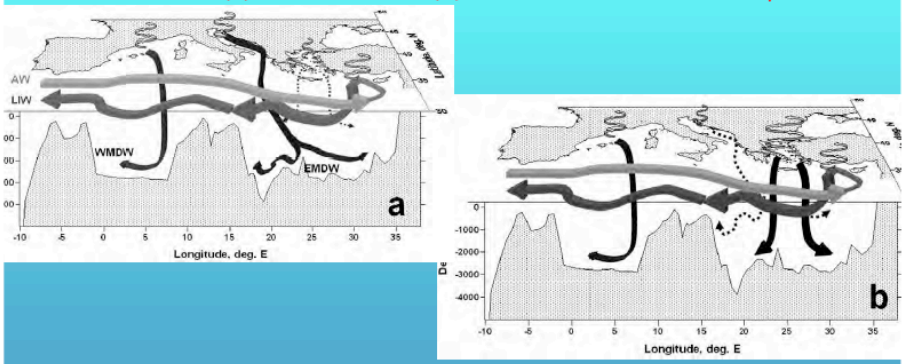
García-Comas et al. 2011

31

1991-1993 Eastern Mediterranean Transient

Shift of the source of E. Mediterranean Deep water from the Adriatic to the Aegean: increase of salinity (decrease of precipitation), intense deep water formation in S.Aegean, outflow in the EMedit

Pre-EMT (a) and Post-EMT (b) thermohaline circulation patterns

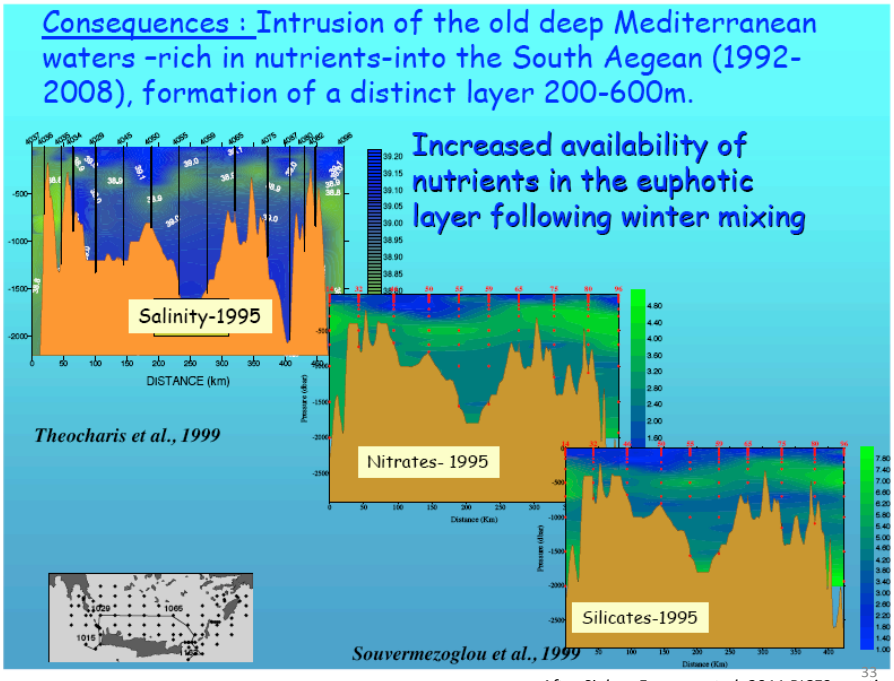


Tsimplis et al., 2006

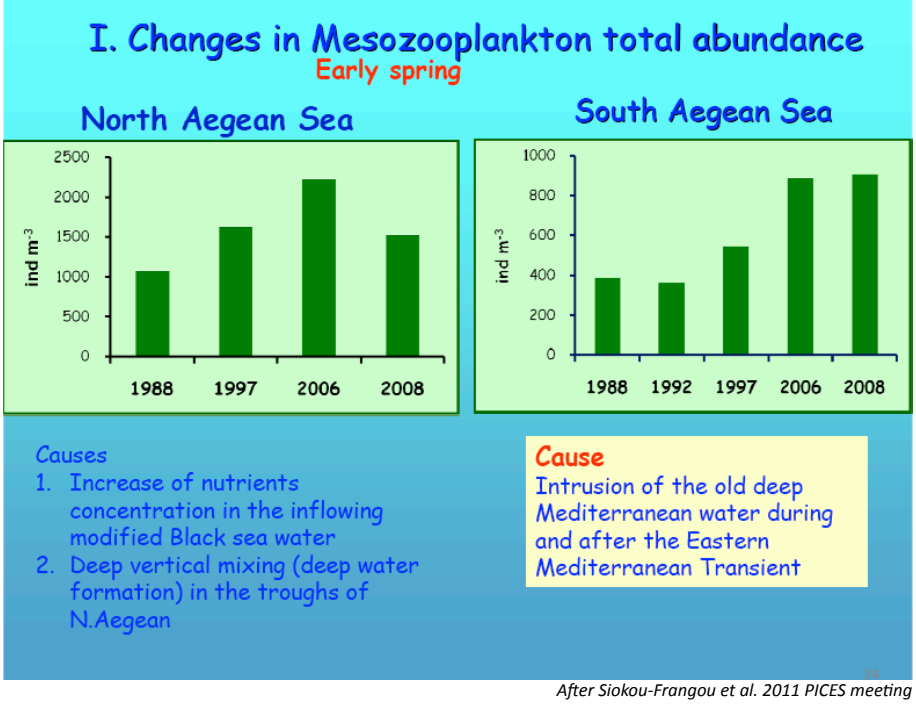
Uplifting of the old-EMDW (Adriatic) by several thousand meters.

32

After Siokou-Frangou et al. 2011 PICES meeting



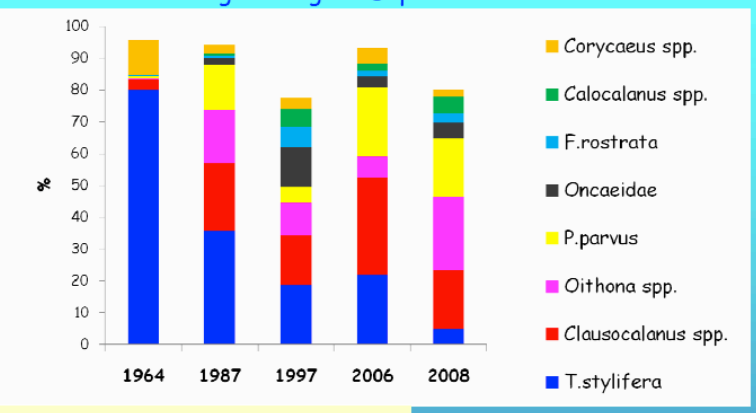
After Siokou-Frangou et al. 2011 PICES meeting



After Siokou-Frangou et al. 2011 PICES meeting

II. Changes in the species dominance and rank order

North Aegean August-September



Increase
Clausocalanus spp. (C.furcatus): from 6th to 1st or 2nd
Oithona spp. rare-3rd-1st
Paracalanus parvus
Calocalanus spp.

Decrease
T.stylifera
Corycaeus spp.

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After Siokou-Frangou et al. 2011 PICES meeting

Decrease
Temora stylifera,
Nannocalanus minor
C.helgolandicus
Corycaeus spp.,

→ **Warm temperate**

Increase
Clausocalanus furcatus,
Oithona spp. (O.plumifera, setigera, atlantica)
Oncaeidae (O.media, O.mediterranea)
Calocalanus spp,
Farranula rostrata
Ctenocalanus vanus

→ **Warm temperate to subtropical**

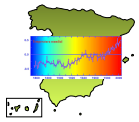
Probably related to temperature increase

Tropicalization of the Mediterranean Sea

36

After Siokou-Frangou et al. 2011 PICES meeting

And in Spain...

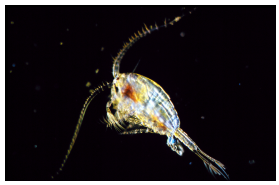


Place	Location	Years measured	Rising rate (ºC década)
Donostia	Puerto	56	-0.062
		11	0.001
Asturias	Océano	10	0.43
	Costa	10	0.16
La Coruña	Costa	13	0.53
Málaga	Costa y océano	10	0.2
Baleares	Costa	5	0.2
L'Estartit	Plataforma	28	0.4

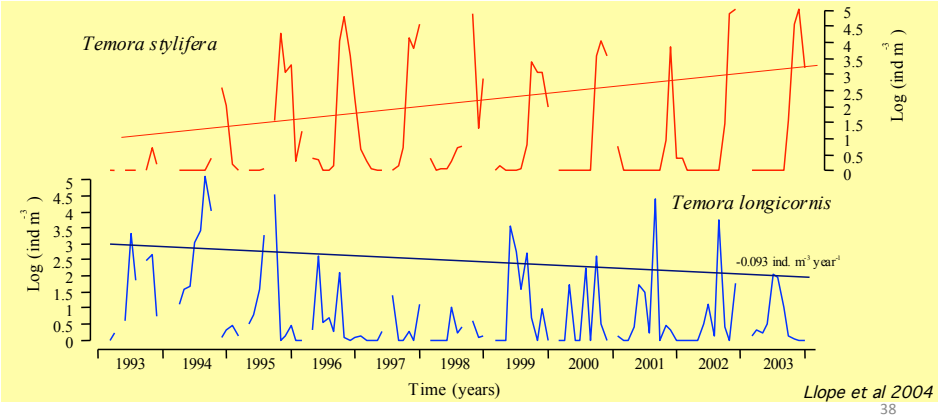
Anadón et al. 2005

37

Species replacement



North Spain



Llope et al 2004

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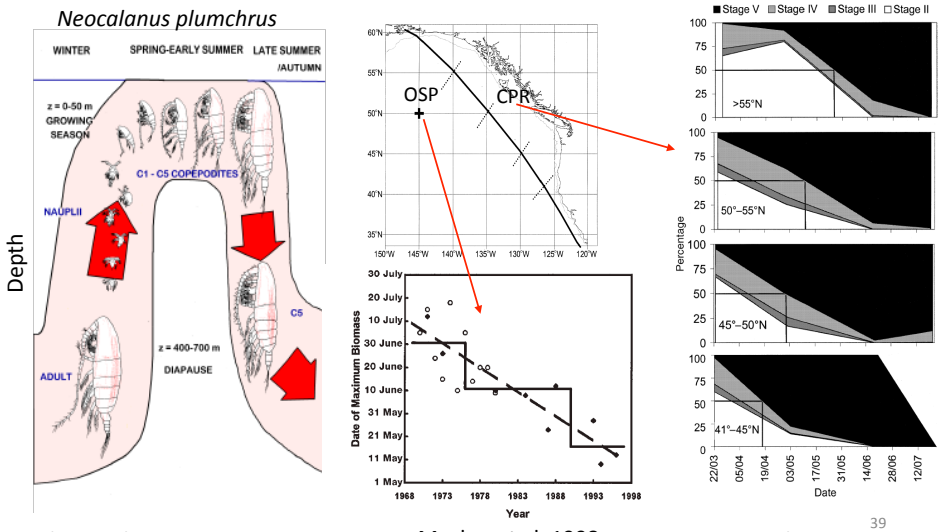
Warming-related Plankton Changes
Phenology – Northeast Pacific



Mackas et al. 1998 | Mackas et al. 1998 | Batten et al 2003

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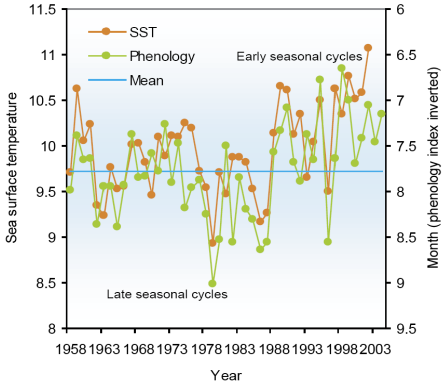
Warming-related Plankton Changes
Phenology – North Sea Meroplankton

Meroplankton may be more sensitive to temperature change than holoplankton



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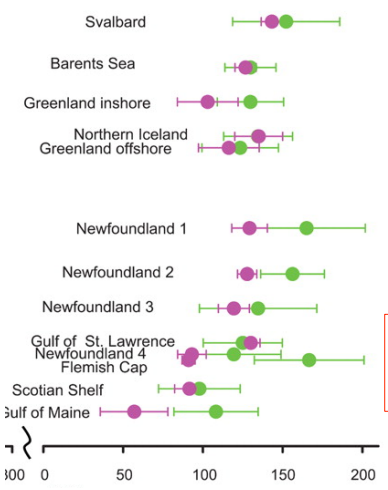
Warming-related Plankton Changes

Phenology – Shrimp hatching and Phytoplankton



- Decapod larvae are very sensitive to warming, with earlier phenology in warmer years

Phytoplankton
Shrimp larvae

Koeller et al. 2009

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Warming-related Plankton Changes

Phenology – North Sea Ecosystem Impacts

Season	Group	Days forward (1958-2002)
Summer	Diatoms	22 d
	Dinoflagellates	23 d
	Copepods	10 d
	Other zooplankton	10 d
	Meroplankton	27 d

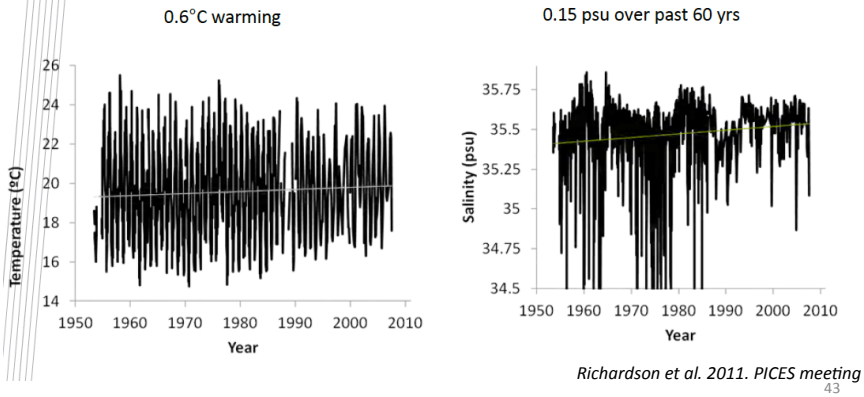
Potential mismatch between phyto and zoo

42

Edwards & Richardson (2004) Nature

Warming-related Plankton Changes
Phenology – eastern Australia

Long-term physical changes



Richardson et al. 2011. PICES meeting

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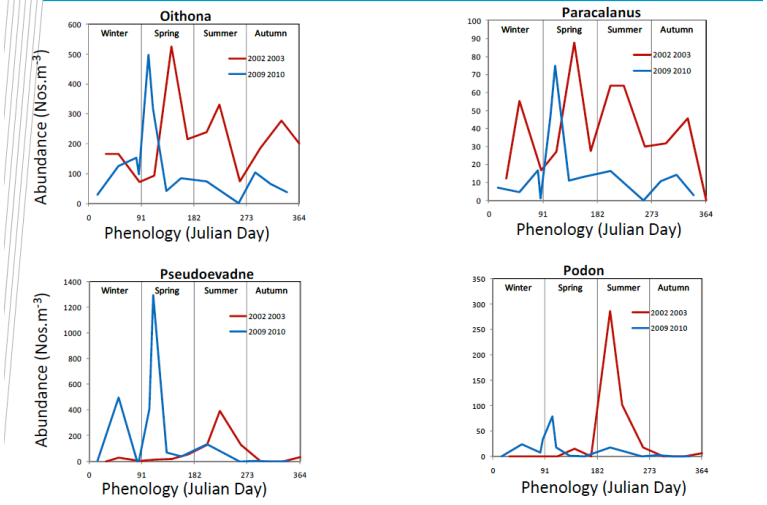
Warming-related Plankton Changes
Phenology – eastern Australia

Phenology changes (warm vs cold year)



Richardson et al. 2011. PICES meeting

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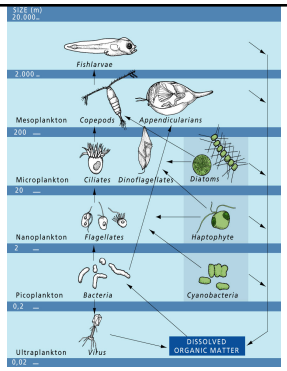
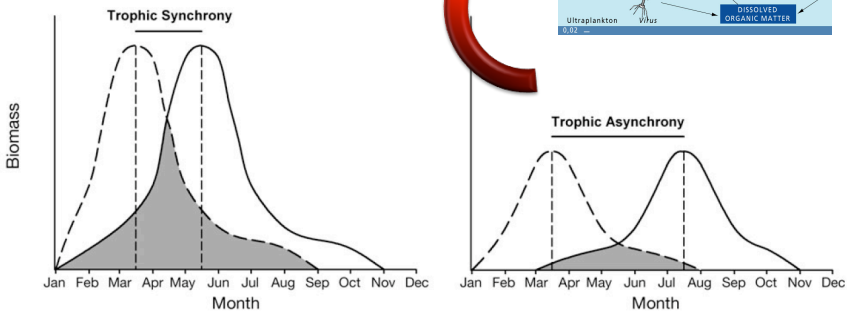
Global food web effects



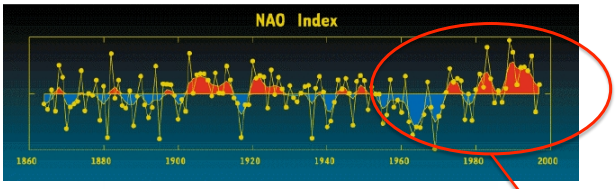


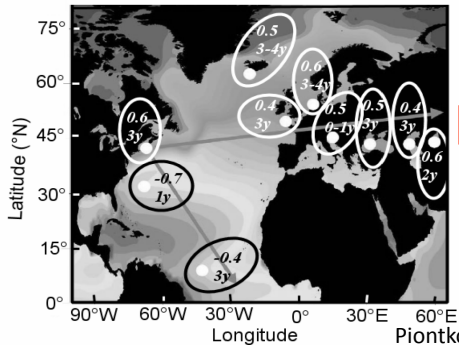
Sydeman and Bograd 2009

45

Not everything is result of warming:

NAO and Zooplankton





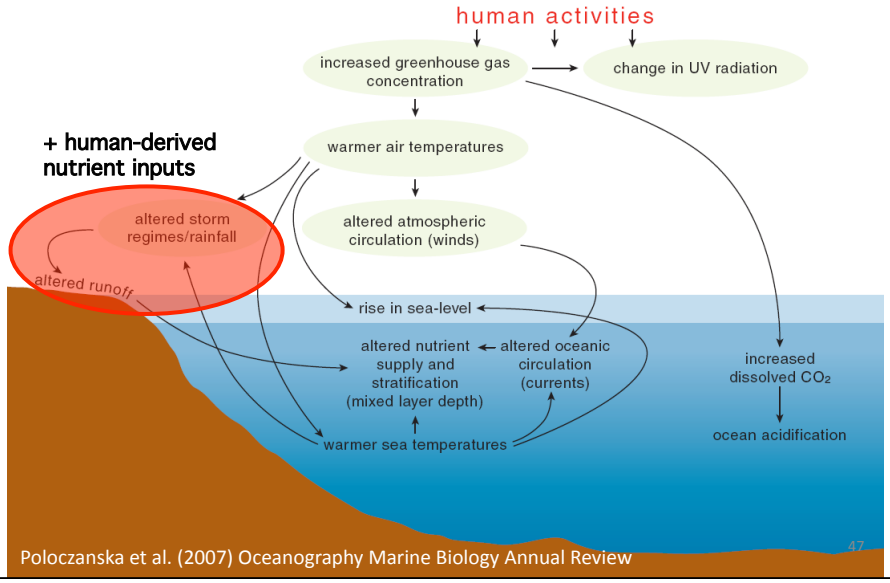
Most published studies

Piontkovski et al (2006) JPR

Mackas & Beaugrand (submitted)

46

Complexity of Climate Change



Poloczanska et al. (2007) Oceanography Marine Biology Annual Review

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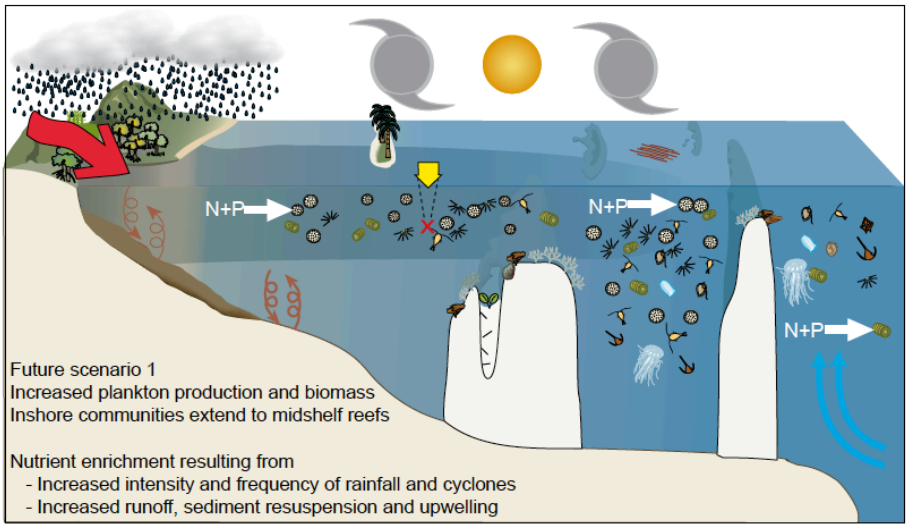
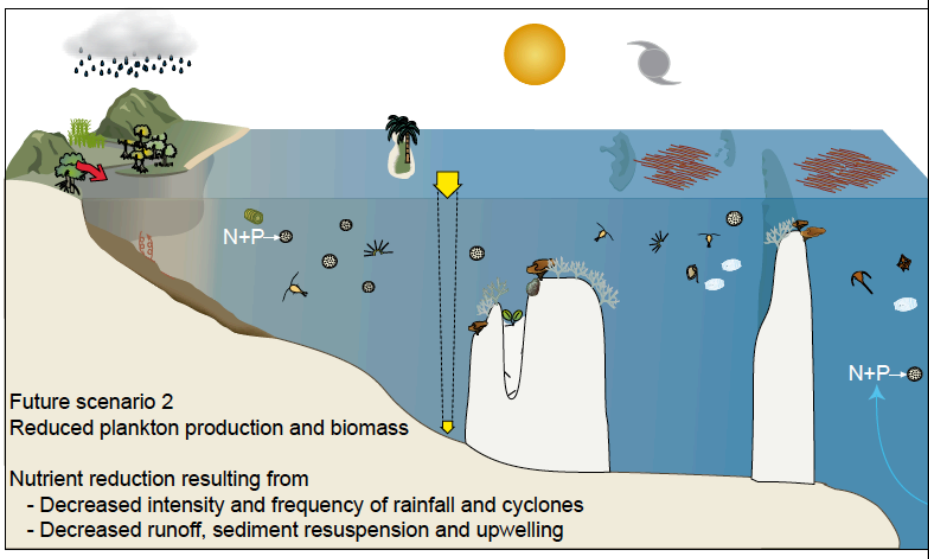
Figure 6.5 *Future scenarios under two different nutrient enrichment regimes*



Mckinnon et al. 2007



Mckinnon et al. 2007

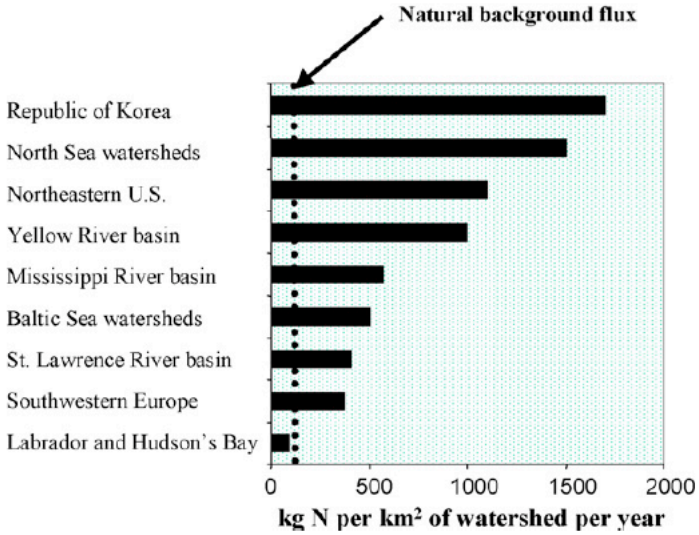


Fig. 2. Average annual flux from the landscape to coastal oceans in rivers for contrasting regions of the world in the temperate zone, expressed per area of watershed. Based on data in Howarth et al. (1996, 2002a, 2005) and Bashkin et al. (2002).

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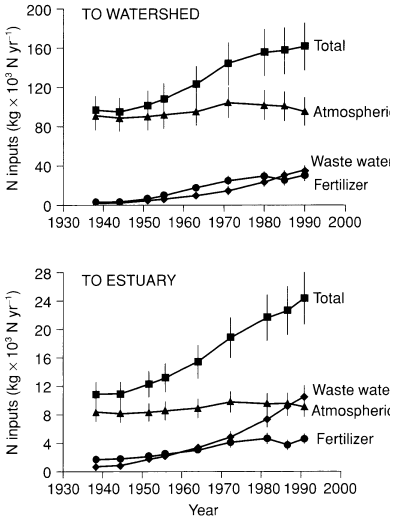

Waquoit Bay, Massachusetts, USA

Figure 12.3 Calculated changes in land-derived nitrogen (N) loads by waste water, atmospheric deposition, and fertilizers to the watershed of Waquoit Bay (top), and to the bay itself (bottom), 1938–1990. From Bowen and Valiela (2001).

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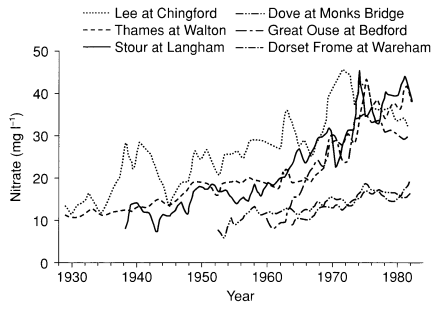
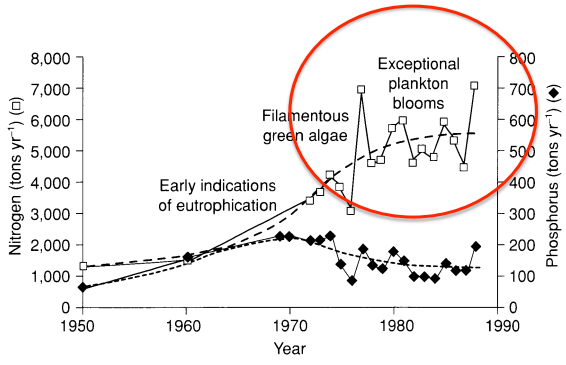


Gulf of Mexico

Figure 12.16 Top: annual flux of nitrogen (N) and discharge from the Mississippi region to the Gulf of Mexico, 1955–1996 (data from Goolsby et al. 2001). Bottom: nitrate concentrations in the water of several British rivers during the latter half of the 20th century (from Nedwell et al. 1999).



Laholm Bay, Baltic Sea

Figure 12.14 Time course of loads of nitrogen and phosphorus to Laholm Bay on the Baltic Sea, with notes on the producer responses along the way. From Rosenberg et al. (1990).

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Harmful Algal Blooms

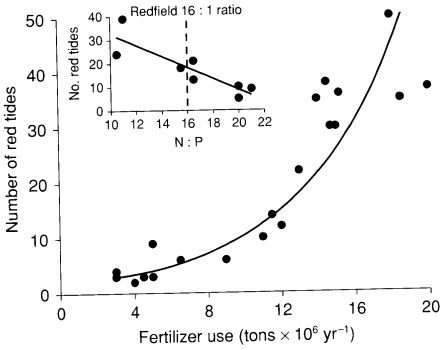

Figure 12.18 Relationship of the number of red tides per year in Chinese coastal waters (1970–1992) and annual use of fertilizer on adjoining land. Inset: number of red tides per year plotted against the average ratio of nitrogen to phosphorus (N : P) in water, in the same coastal sites. Data from sources cited in Anderson et al. (2002).

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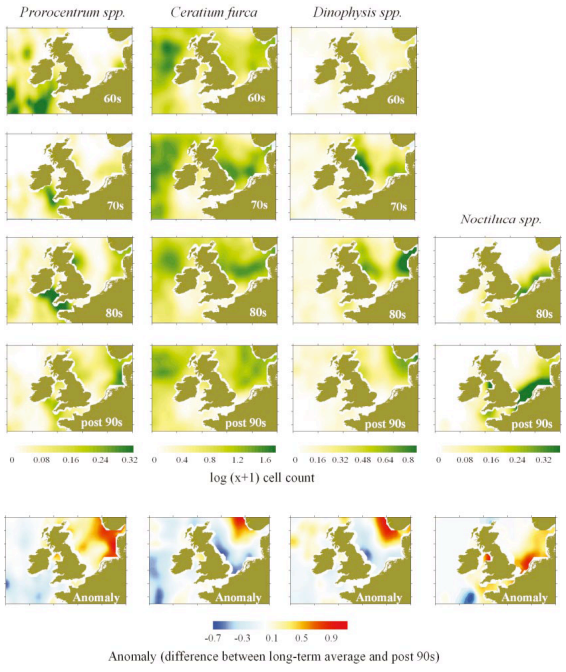
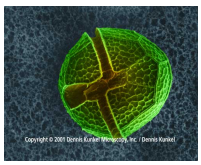
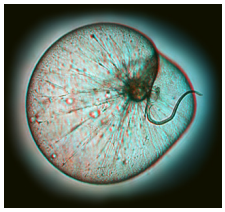


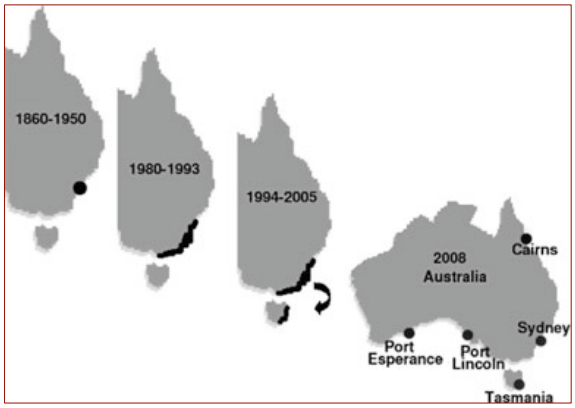


Combined effect of nutrients and temperature

Edwards et al. 2006

Noctiluca in Australian waters





Apparent range expansion of *Noctiluca scintillans* in the Australian region, comparing distribution records in 1860–1950, 1980–1993 (expansion of blooms in the Sydney region), 1994–2005 (range extension into Tasmania), and 2008 (first reports in Queensland, West Australia, and South Australia).
After Hallegraeff et al. (2008).

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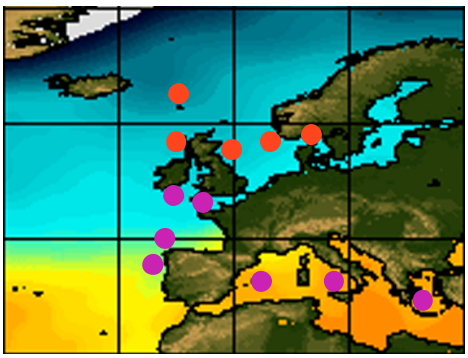
NOT EVERYTHING IS NEGATIVE: *Alexandrium catenella / tamarense*

In western Europe there are two clades of the *Alexandrium catenella / tamarense* species complex. The NA clade, which is toxic, is on the north and the non toxic or weakely toxic WE clade has a more souther. A slight shift towards the north of these populations would cause the substitution of a dangerous toxic species for a non toxic one.

NA clade
WE Clade



S. Fraga

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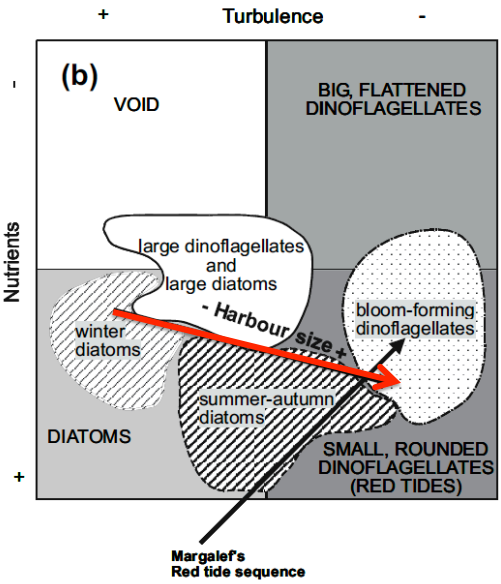

Also effects due to increased harbor number, etc.

Vila and Masó 2005

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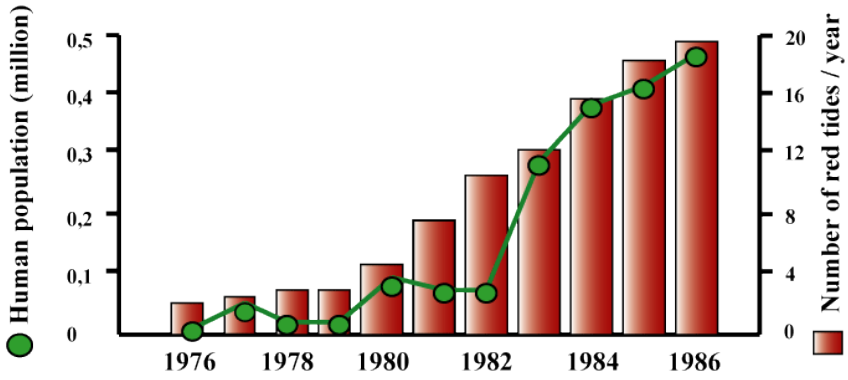
And within the harbors



Increase in human population and number of red tides in Tolo Harbour, Hong Kong. Redrawn from Lam et al. 1989

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Hypoxia

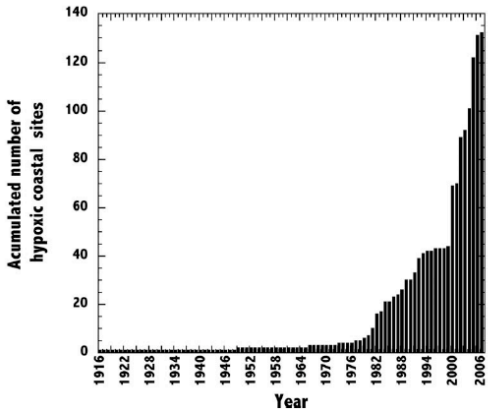

Fig. 1. Accumulated number through time of coastal sites where hypoxia has been reported. Exponential growth rate = 5.54% ± 0.23% year^{-1} (R^2 = 0.86, $P \leq 0.01$).

Vaquer-Sunyer and Duarte 2008

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