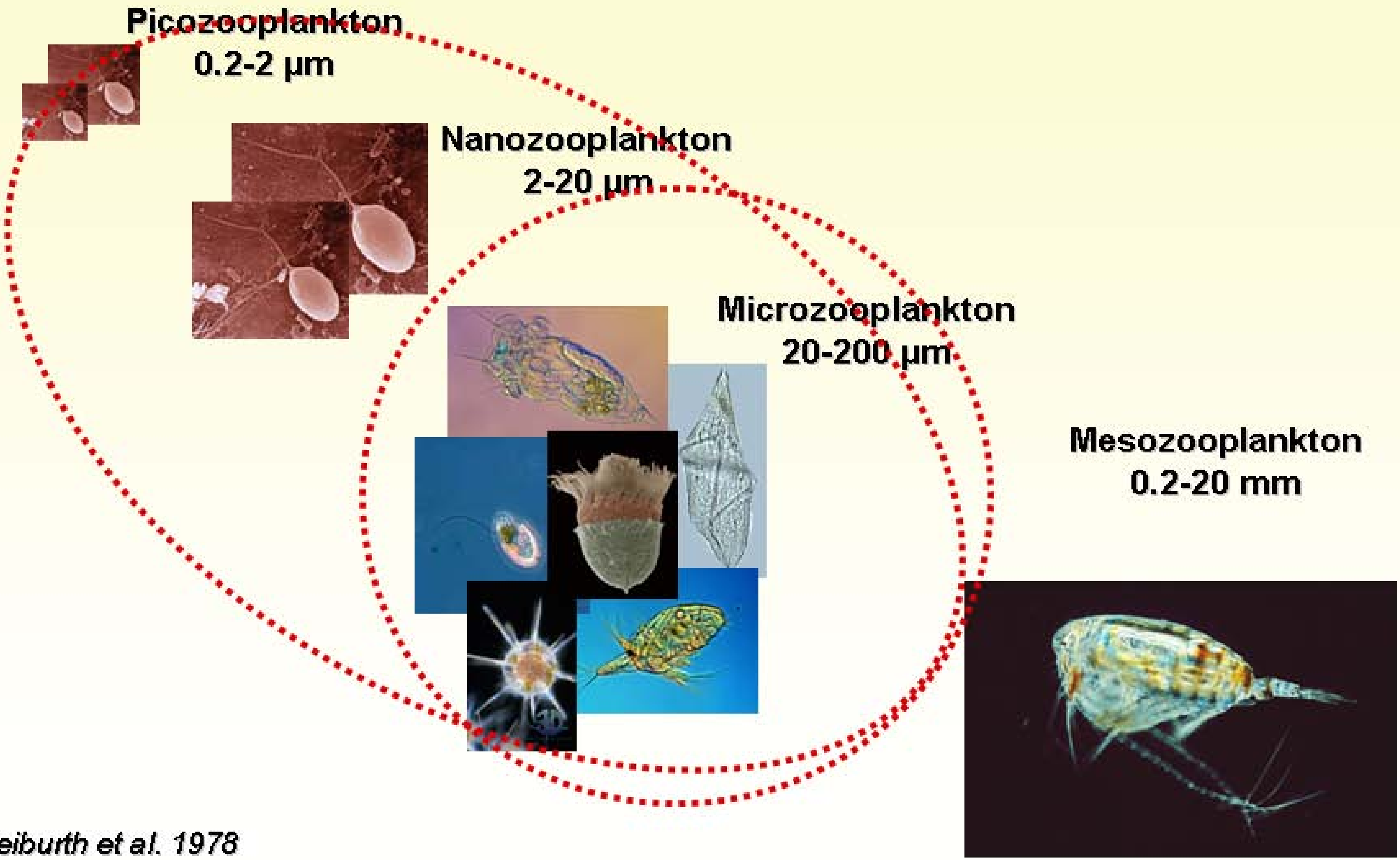
THE ROLE OF MICROZOOPLANKTON IN A CHANGING OCEAN

Albert Calbet

Marine Zooplankton Ecology Group

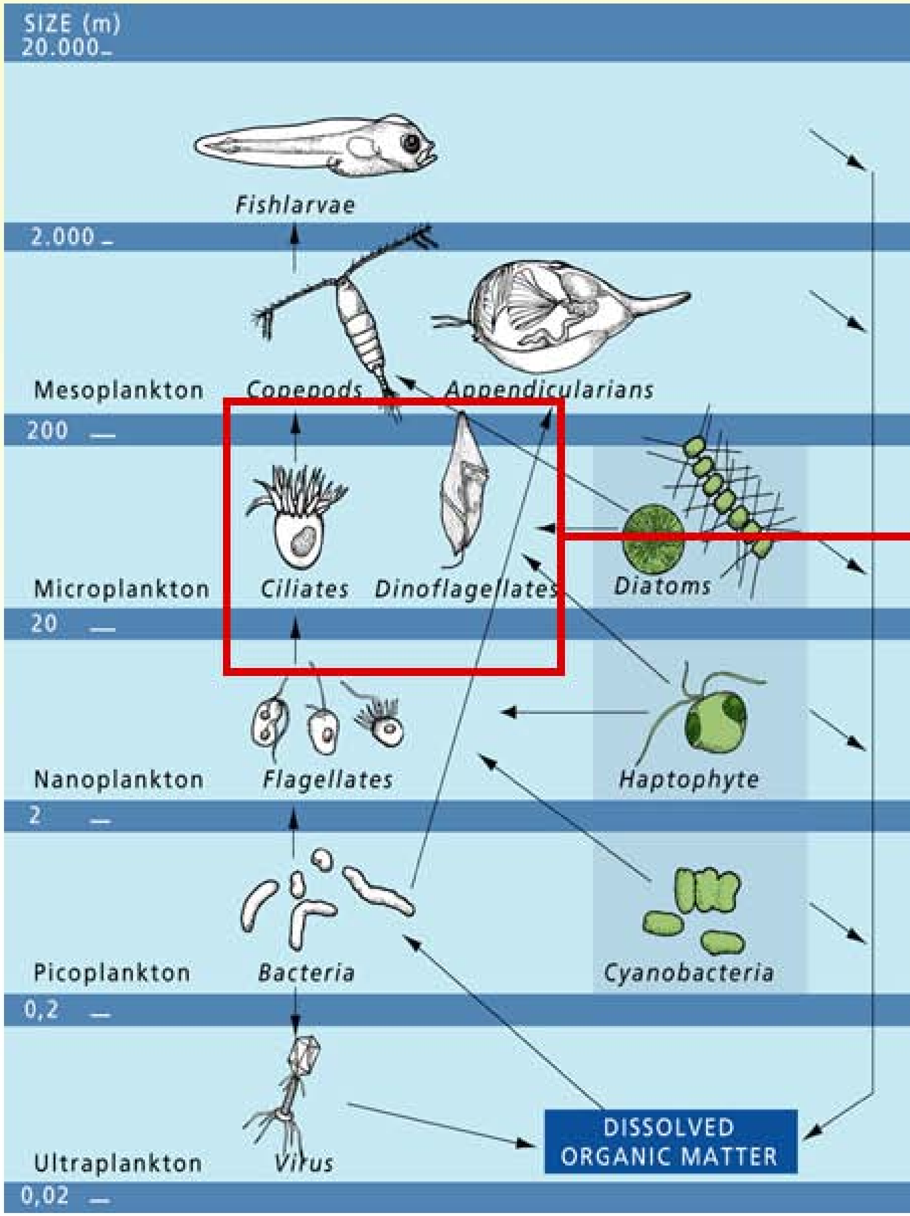
Institut de Ciències del Mar (CSIC) Barcelona

Microzooplankton: definition and main groups



Seiburth et al. 1978

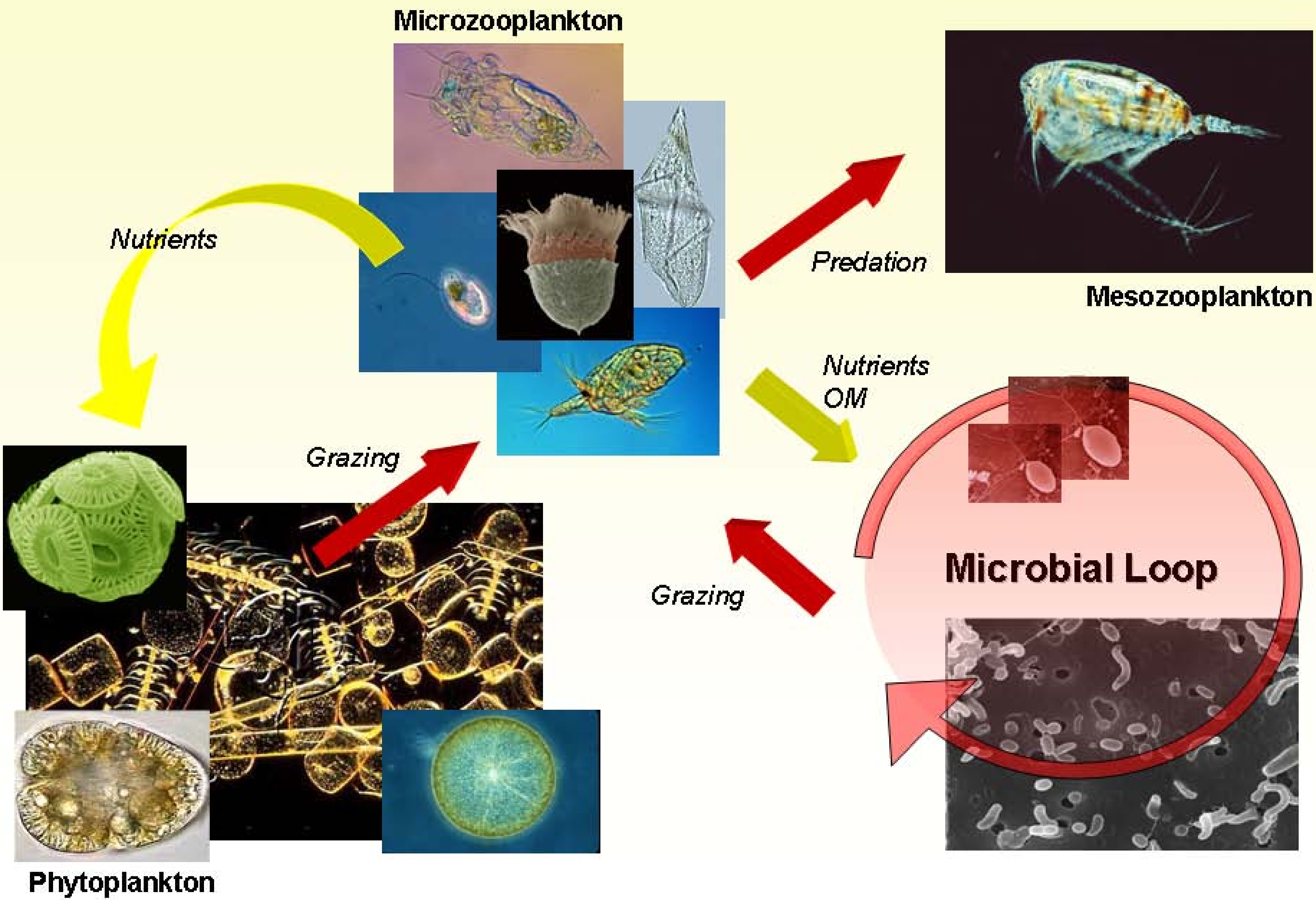
Why microzooplankton?



Kiørboe et al.

Key position in the food web

Microzooplankton: key roles in food webs



THE QUESTION:

Will global change affect the microzooplankton role in the oceans?

There are many possible effects of global change in the oceans

- **Physically driven changes**
  - Increase of temperature
  - Sea level rising
  - Change in currents and global ocean circulation patterns
  - Effects upon upwellings and, in general, on the trophic characteristics of the ecosystem
  - Influence on storm and climatic periodic episodes (ENSO, NAO, etc.)
  - Changes in precipitation patterns (more or less fresh water entering into the ocean)
  - Enhanced UV radiation

- **Chemically driven changes**
  - Acidification
  - Pollutants of different nature

- **Complex interactions and feed-backs**
  - DMS release
  - Cloud cover
  - Other feed-back mechanisms

Harley et al. 2006

Lets focus on:

- **Physically driven changes**
  - Increase of temperature
  - Sea level rising
  - Change in currents and global ocean circulation patterns
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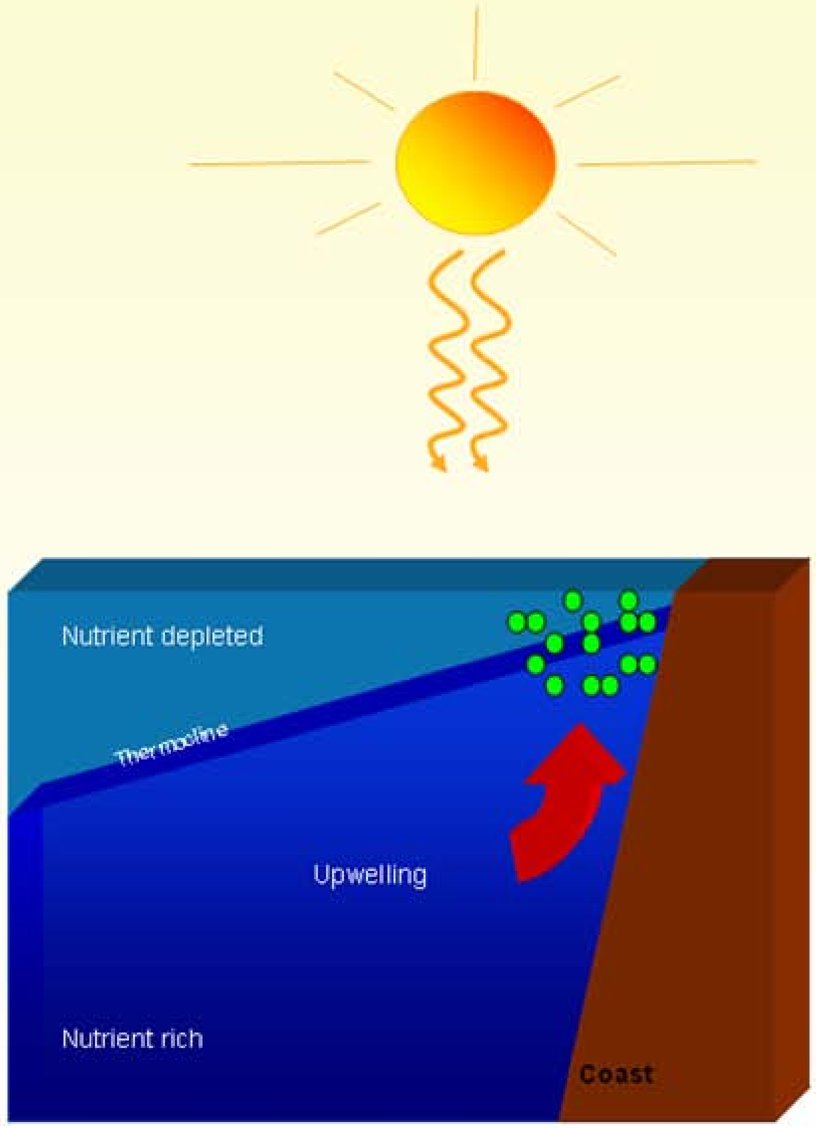
Thickening of the mixed layer



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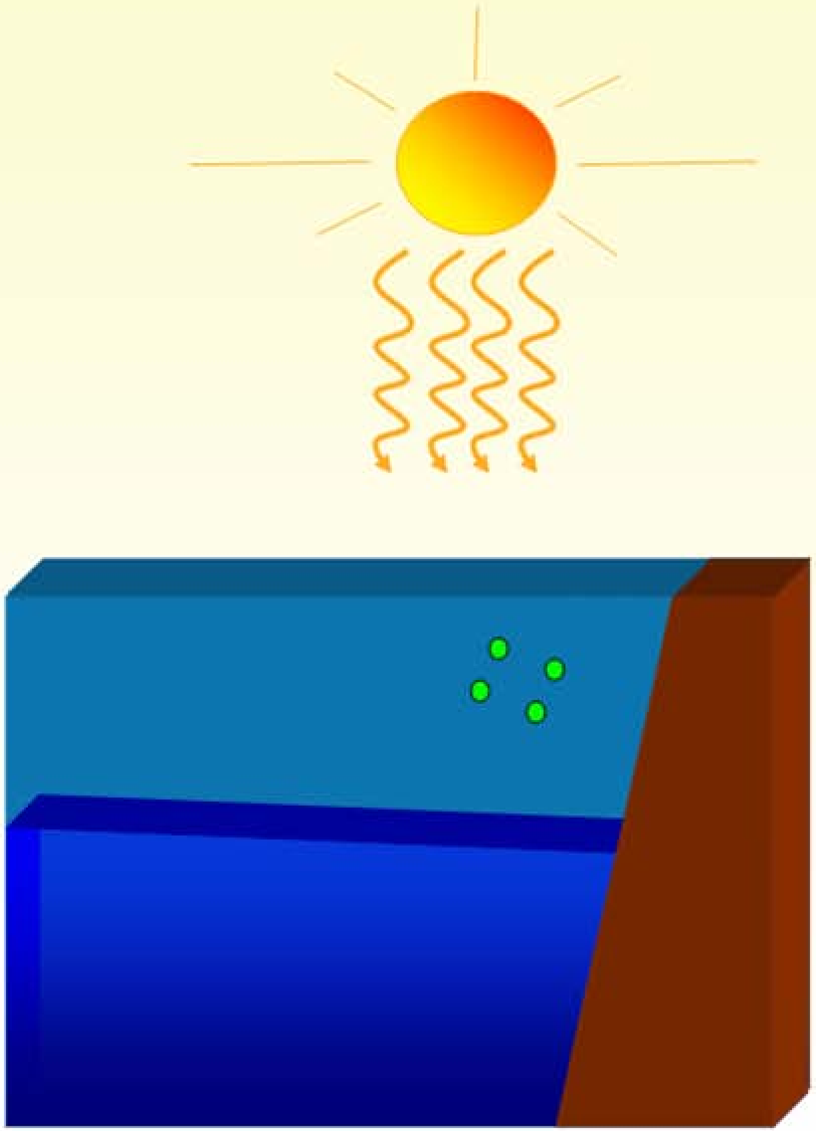
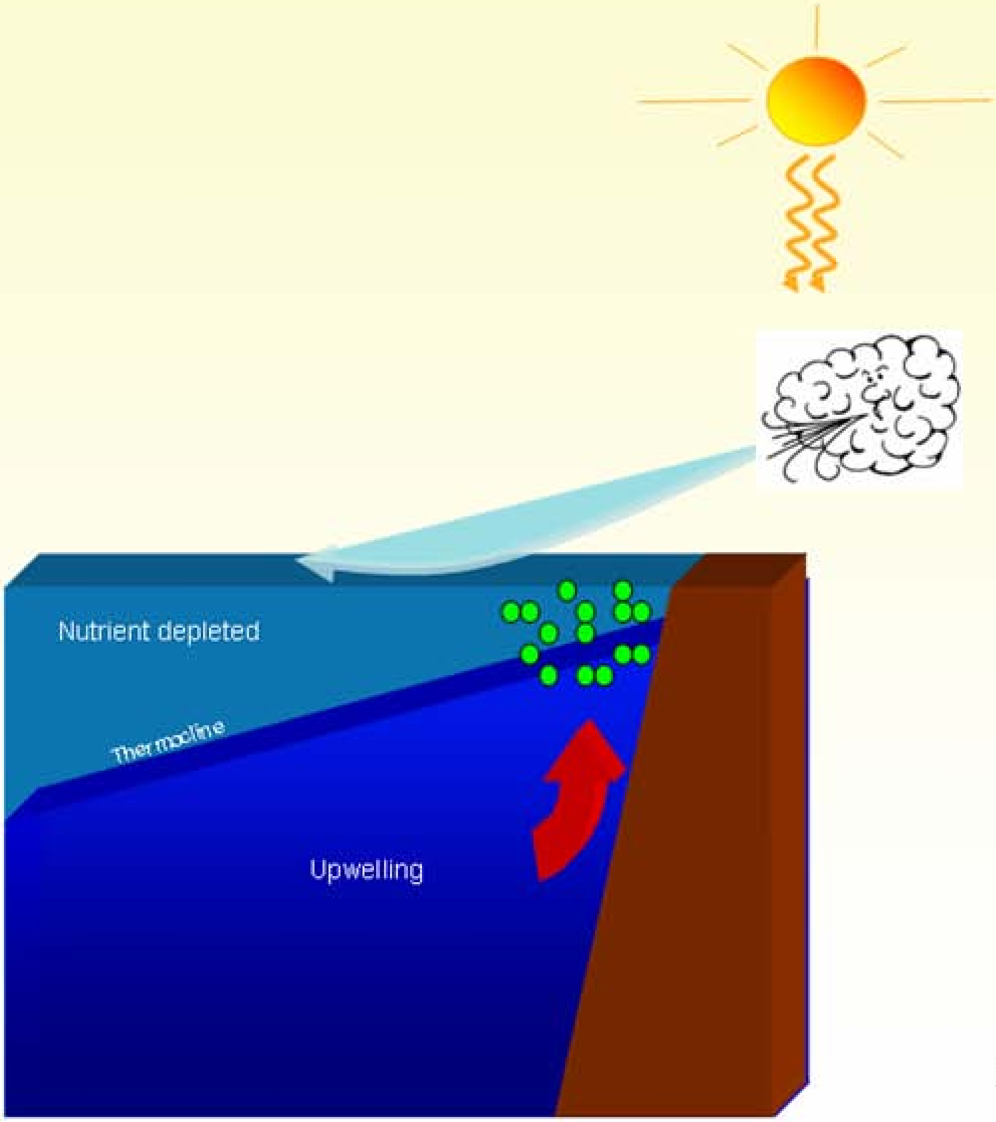
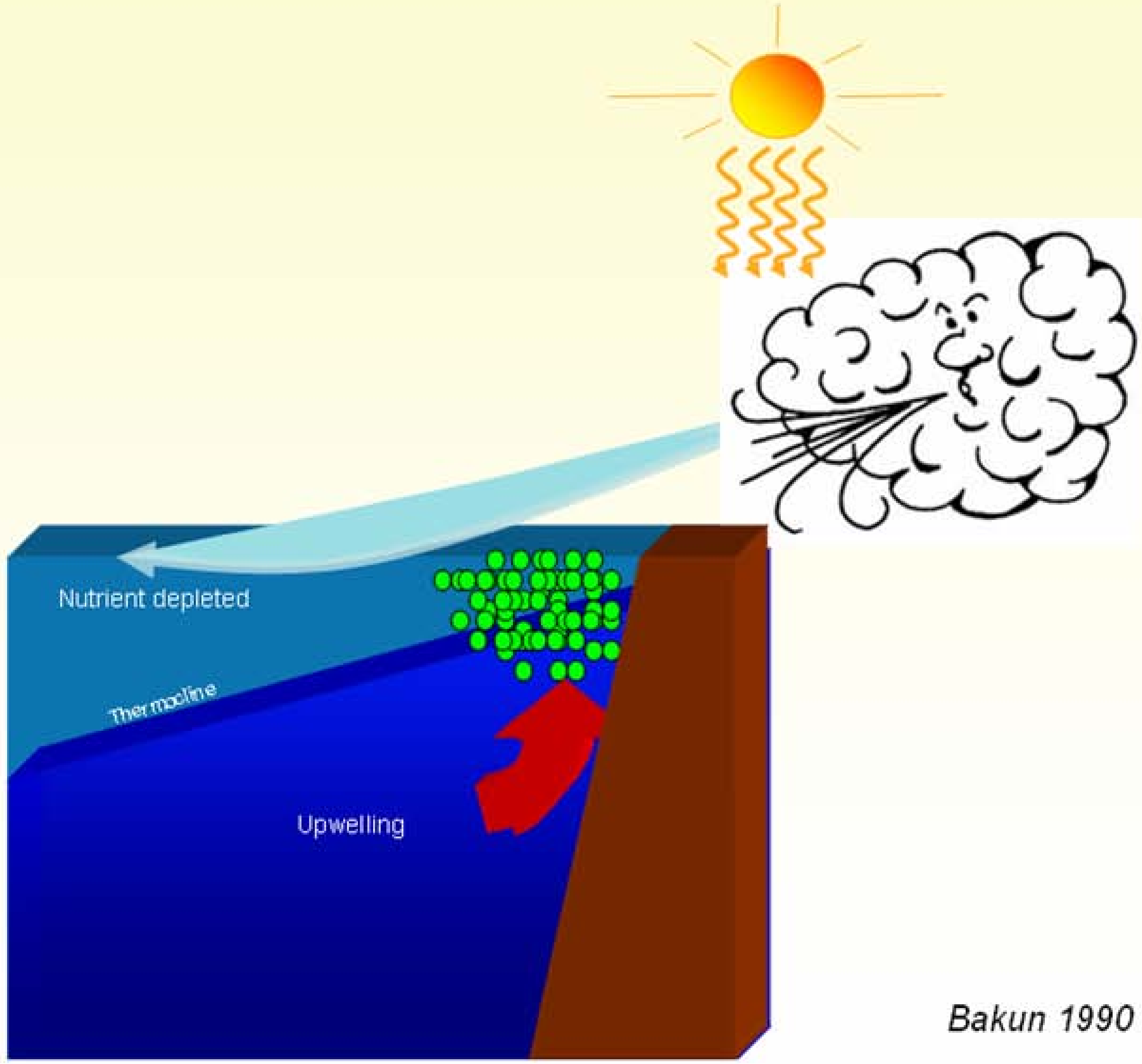


Enhanced upwelling



Bakun 1990

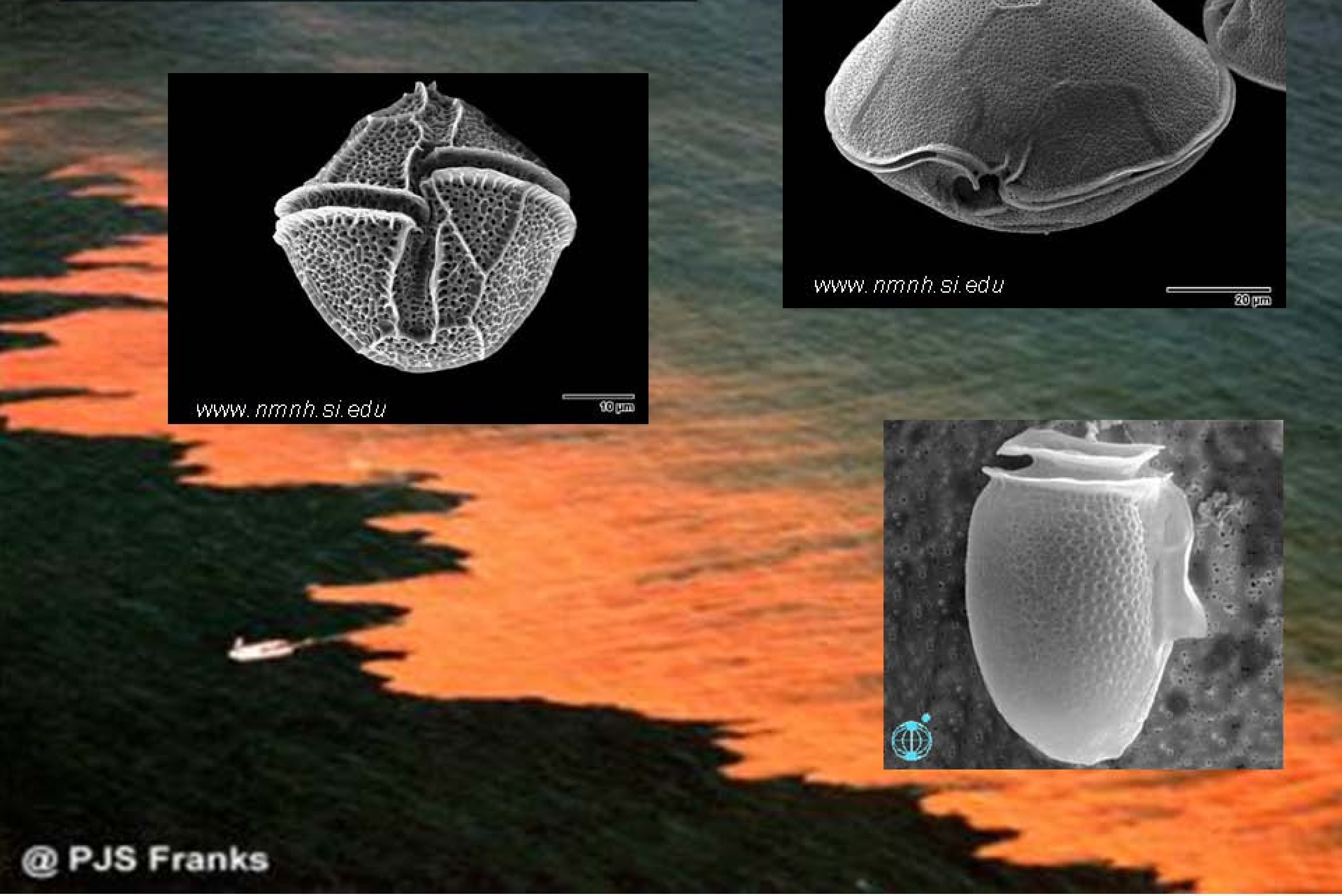
Enhanced upwelling



Bakun 1990

Eutrophication and HABs

HABs



Why HABs are important?

We are going to consider only 2 main global change scenarios:

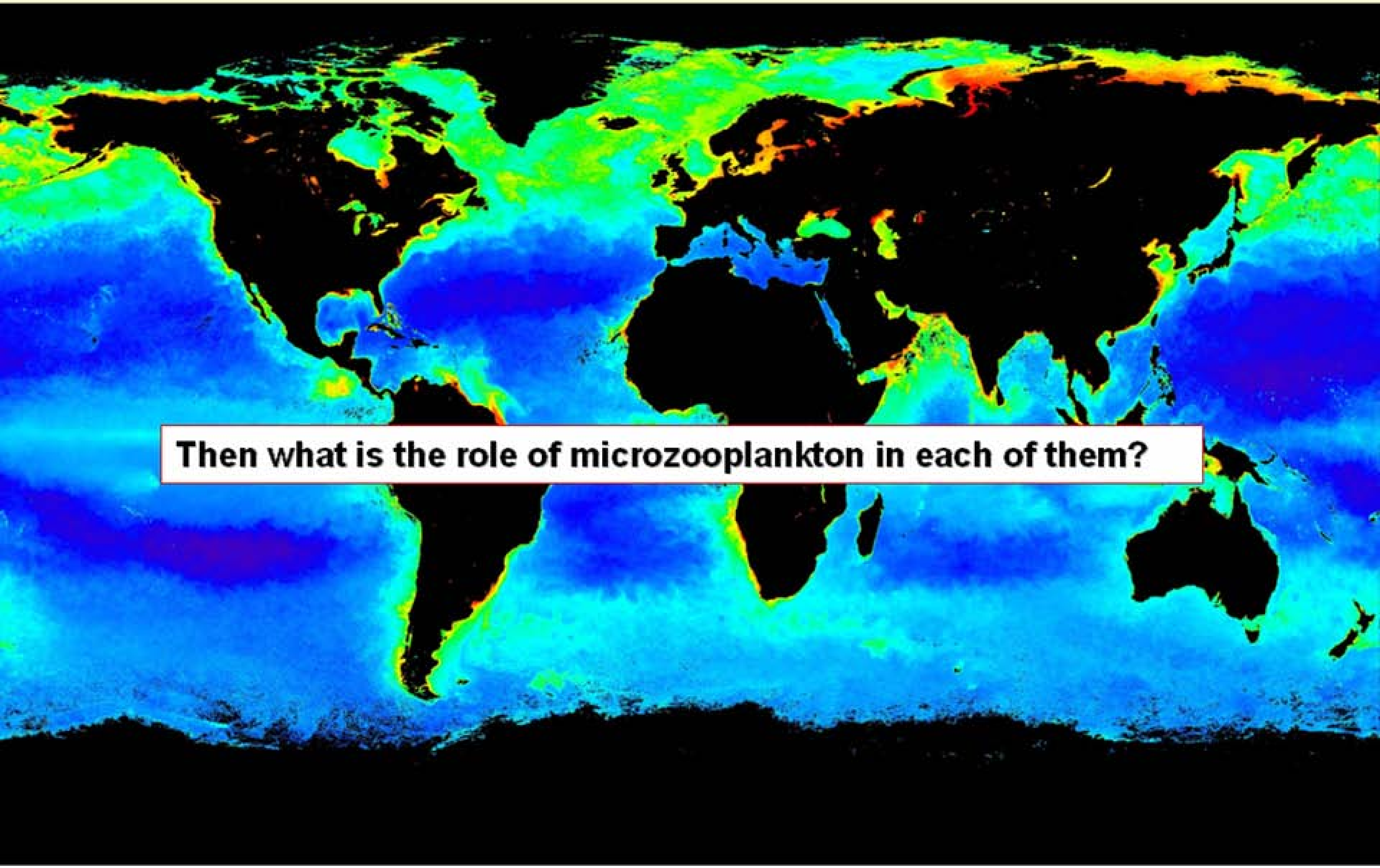
Increase in oligotrophy

www.divetrip.com/maldives

Increase in eutrophy (Blooms + HABs)

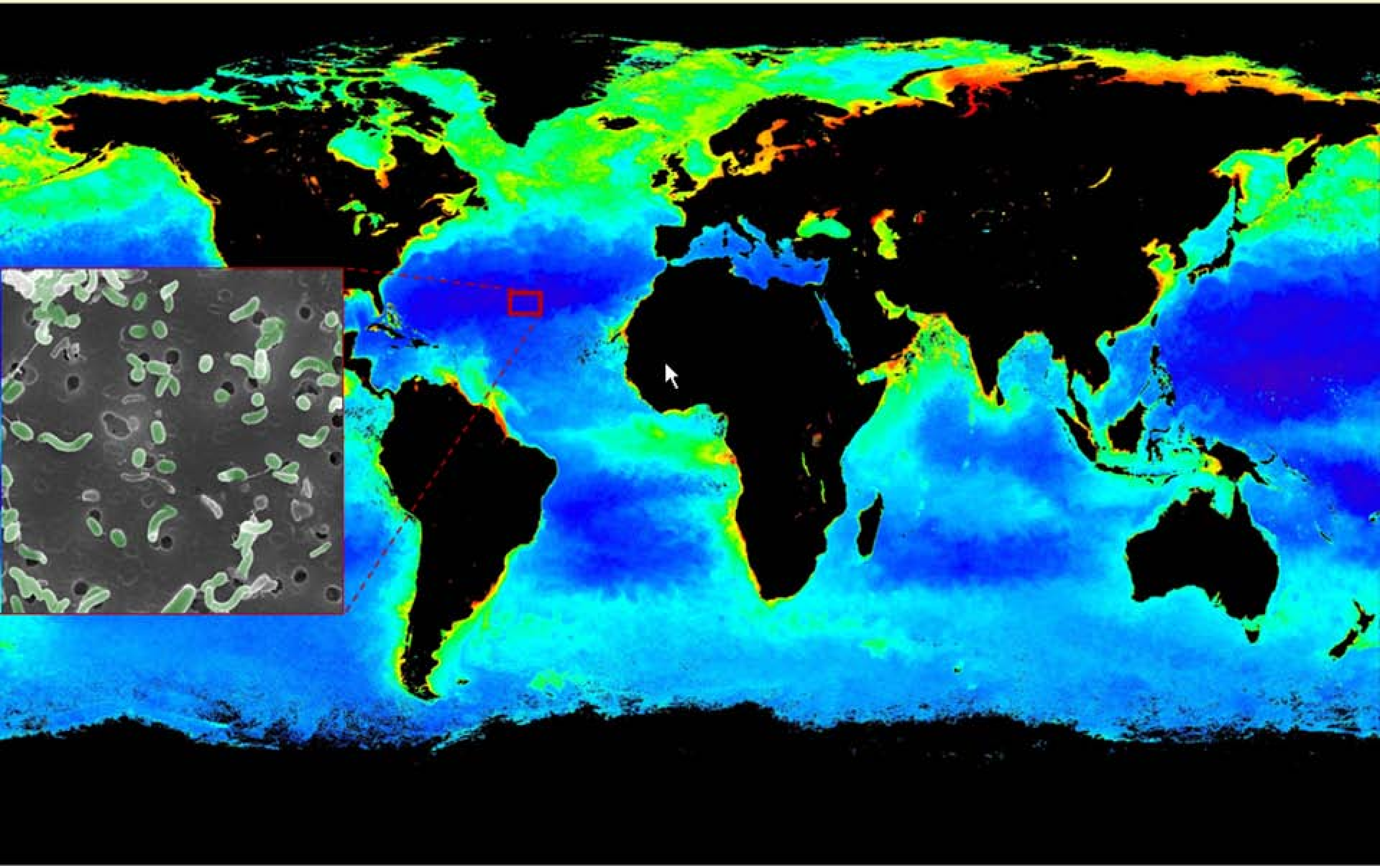
Leigh, near Cape Rodney. (Photo: M. Godfrey)

This scenarios obviously exist



Then what is the role of microzooplankton in each of them?

This scenarios obviously exist



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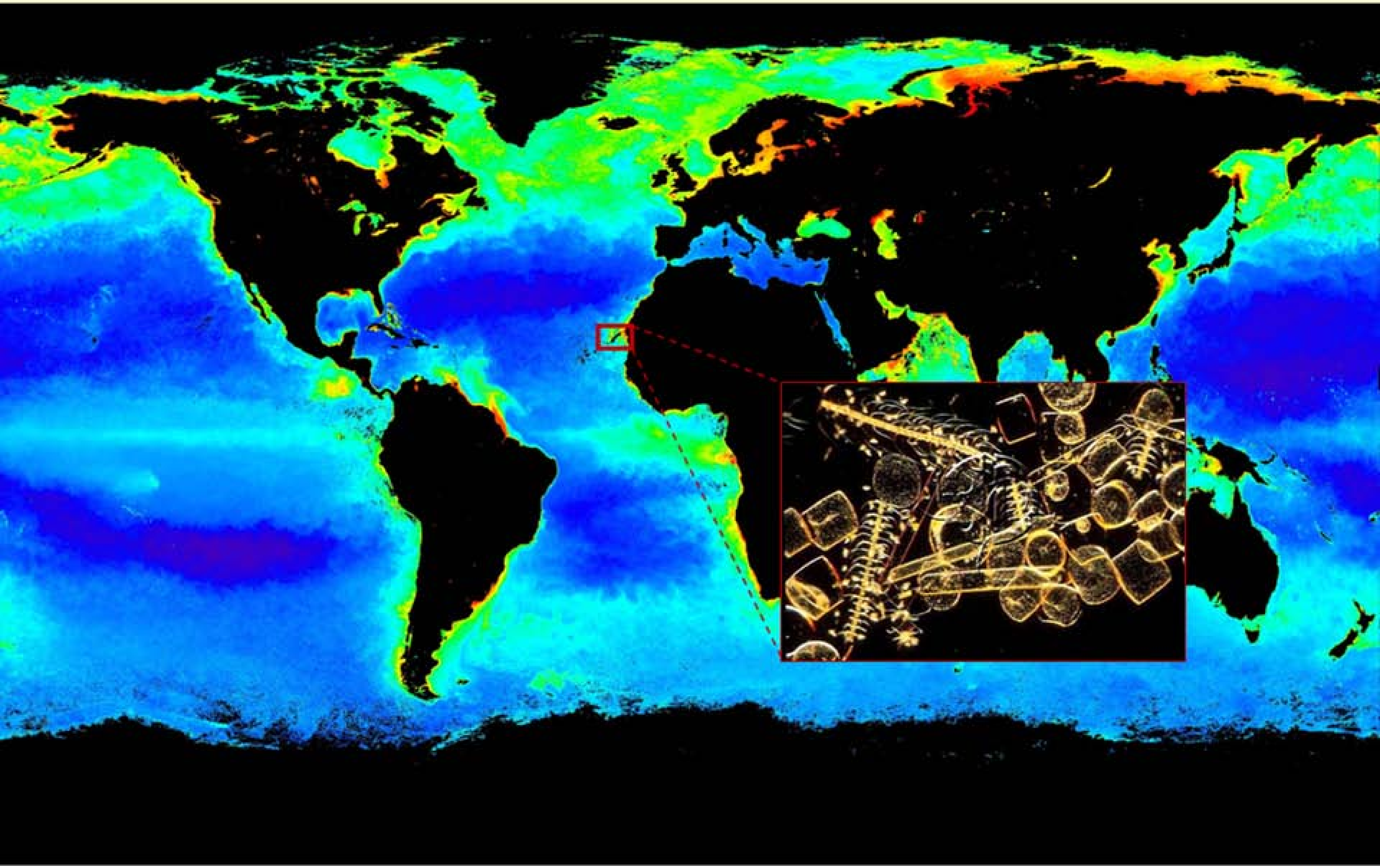
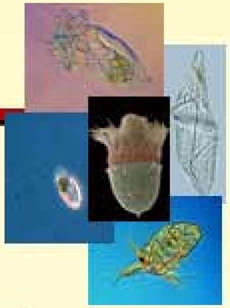


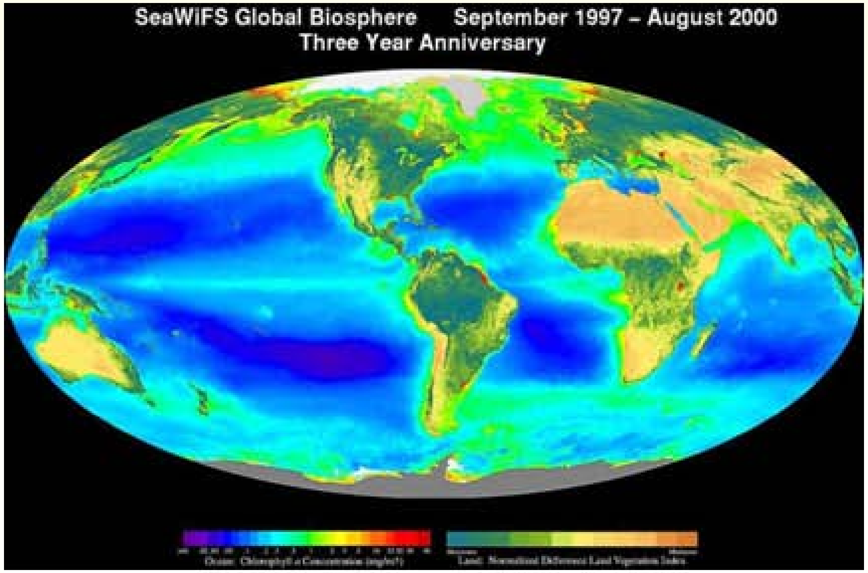
Main hypothesis



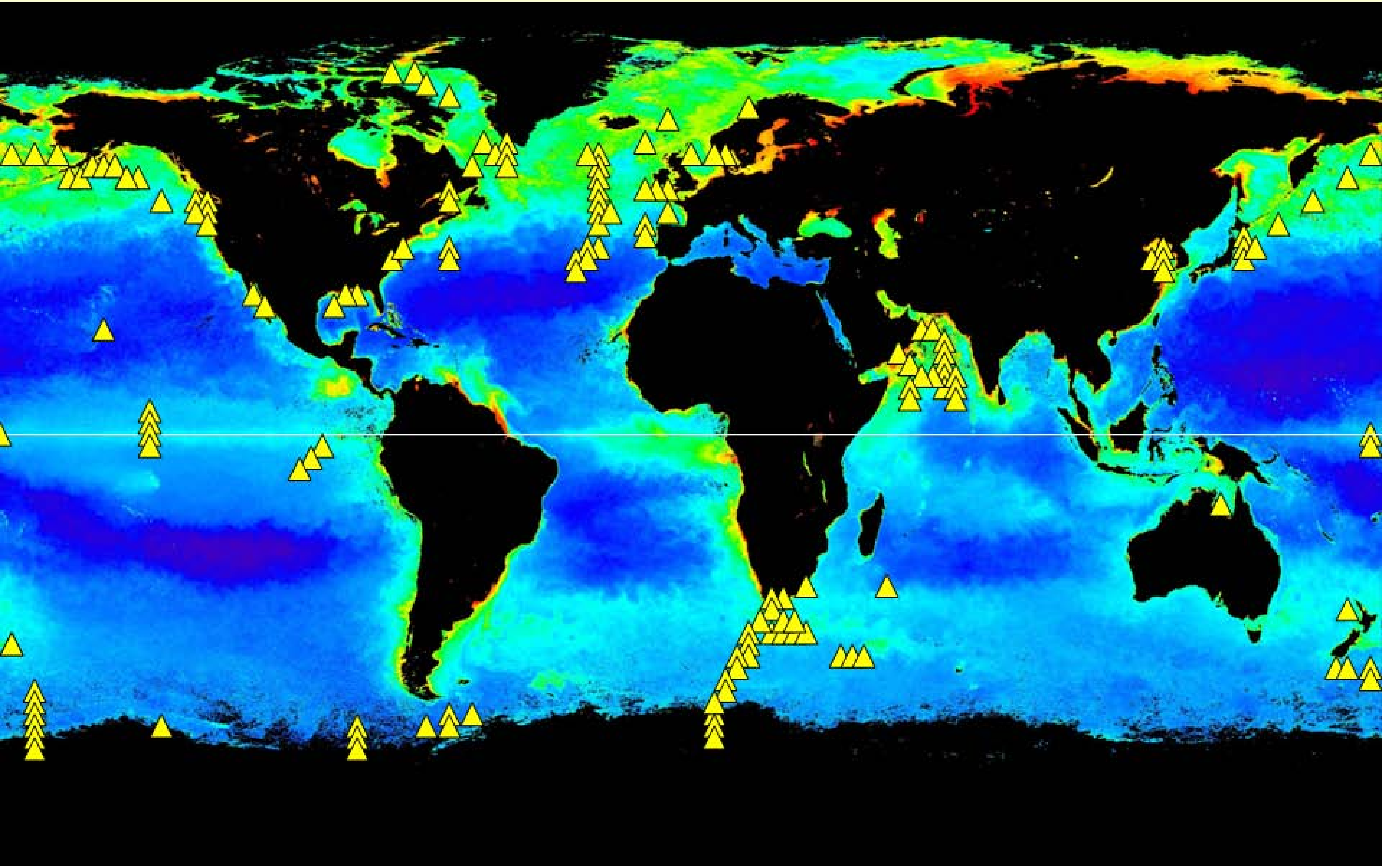
Hypothesis: the grazing impacts of microzooplankton on PP would depend on the trophic characteristics of the system.

- Low grazing impact in Upwellings

- High grazing impact on oligotrophic systems



Global microzooplankton grazing assessment (*Calbet and Landry 2004*)



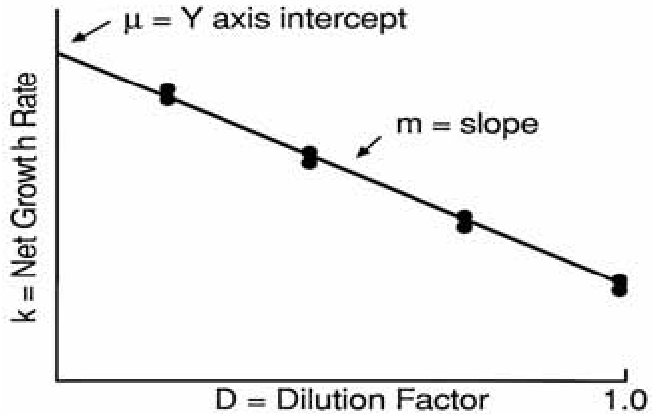
~ 1000 data points based on dilutions

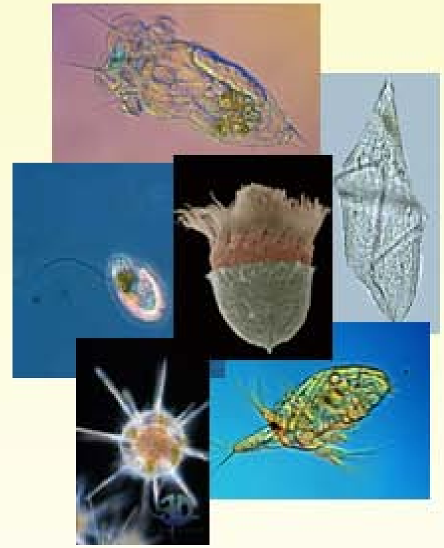
The dilution technique (*Landry and Hassett 1982*)

Standard Analysis of Dilution Experiments

$$k_i = \mu - m \cdot D_i$$

where: μ = phytoplankton growth rate (d^{-1})
m = mortality rate (d^{-1}), microzoopl. grazing





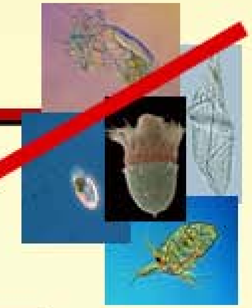
It estimates phytoplankton growth and mortality rates (grazing of the whole microzooplankton community)

Summary

	Chl*a* (µg/L)	μ (d^{-1})	%PP grazed
Open ocean	0.6 ± 0.03	0.59 ± 0.02	**70** ± 1.5
Costal	3.1 ± 0.5	0.67 ± 0.05	**60** ± 3.3
Estuaries	13.0 ± 1.8	0.97 ± 0.07	**60** ± 2.7
Tropical	1.0 ± 0.2	0.72 ± 0.02	**75 ± 2.0**
Temperate	5.2 ± 0.7	0.69 ± 0.03	**61 ± 1.8**
Polar	0.6 ± 0.1	0.44 ± 0.05	**59 ± 3.3**

Calbet and Landry 2004

Main hypothesis



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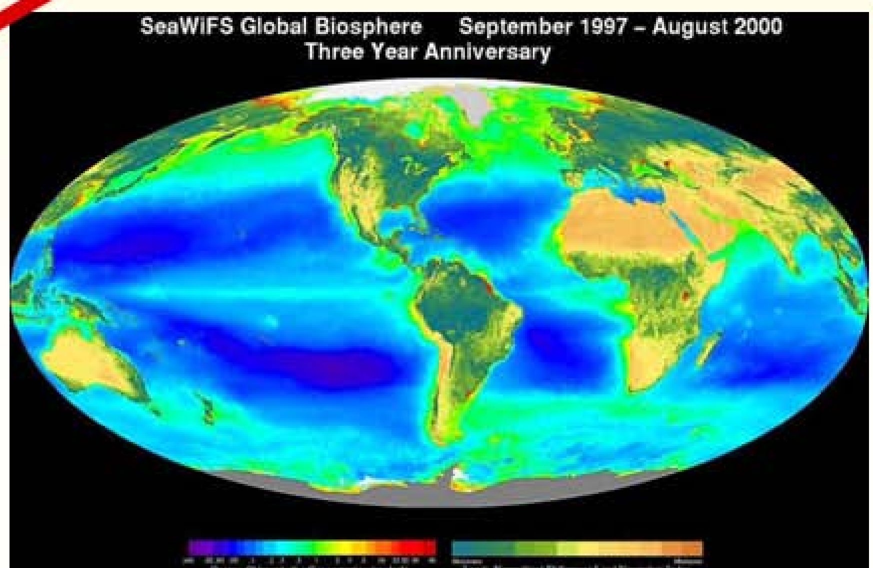
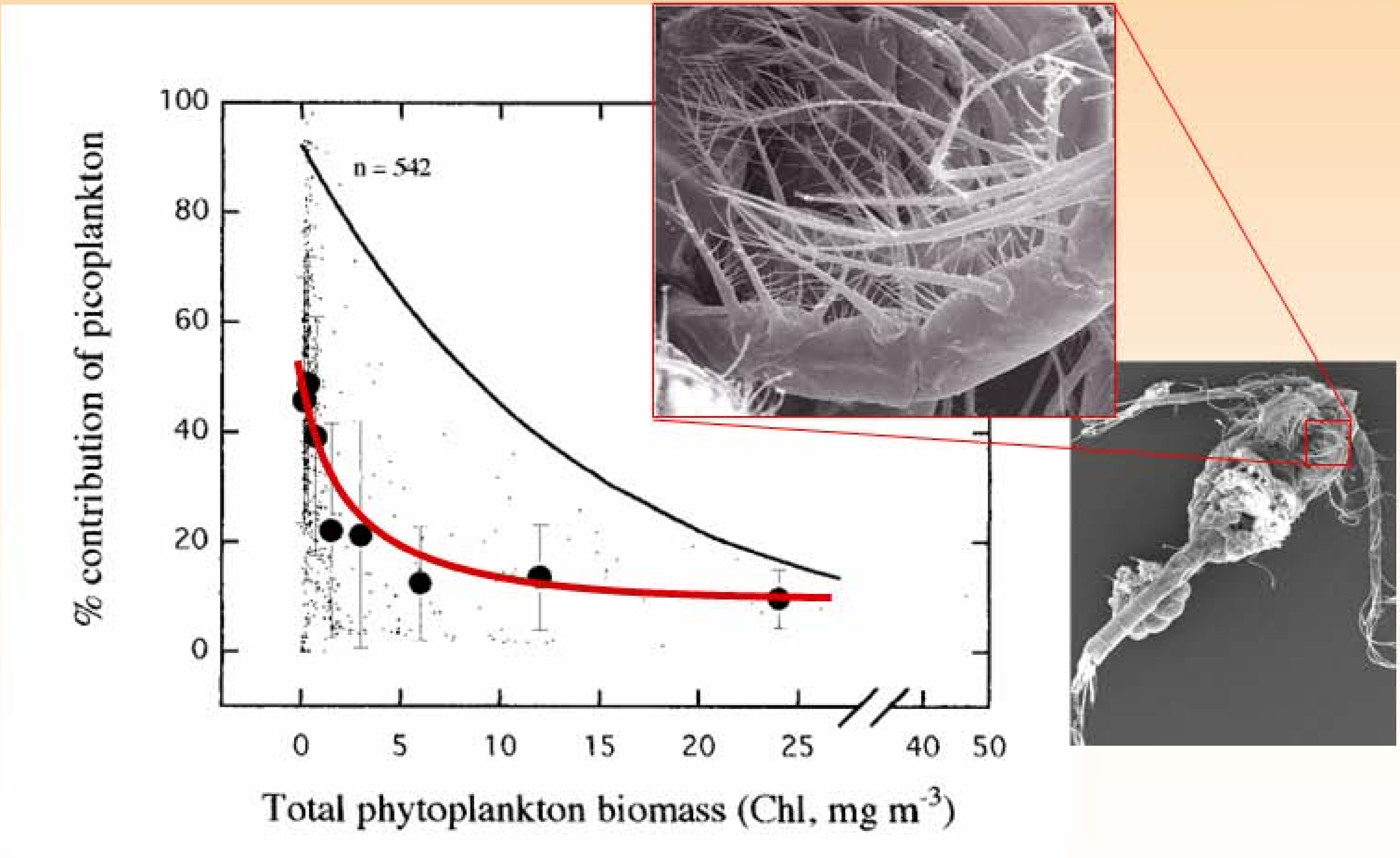


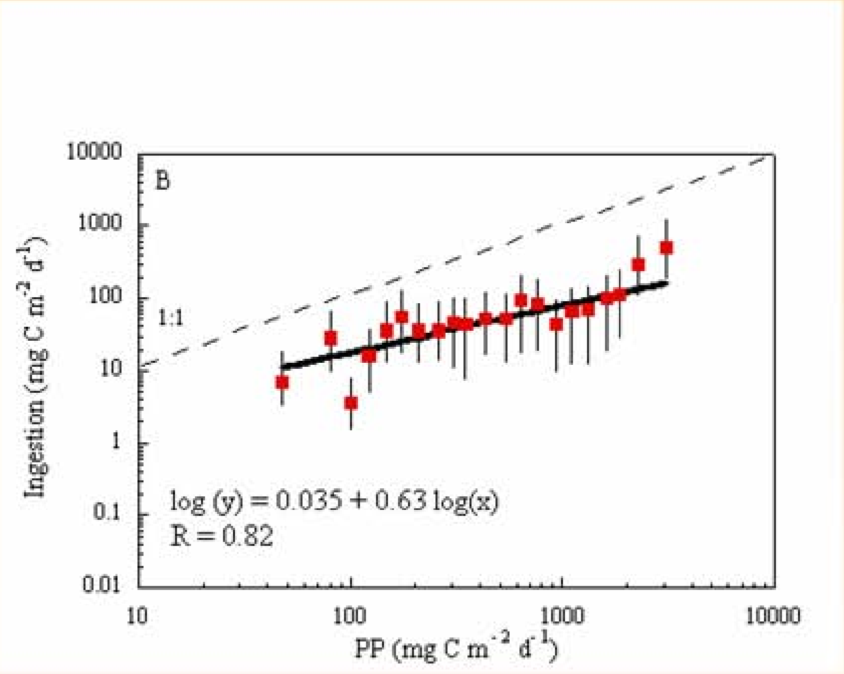
What about mesozooplankton?



Picoplankton < 2 µm

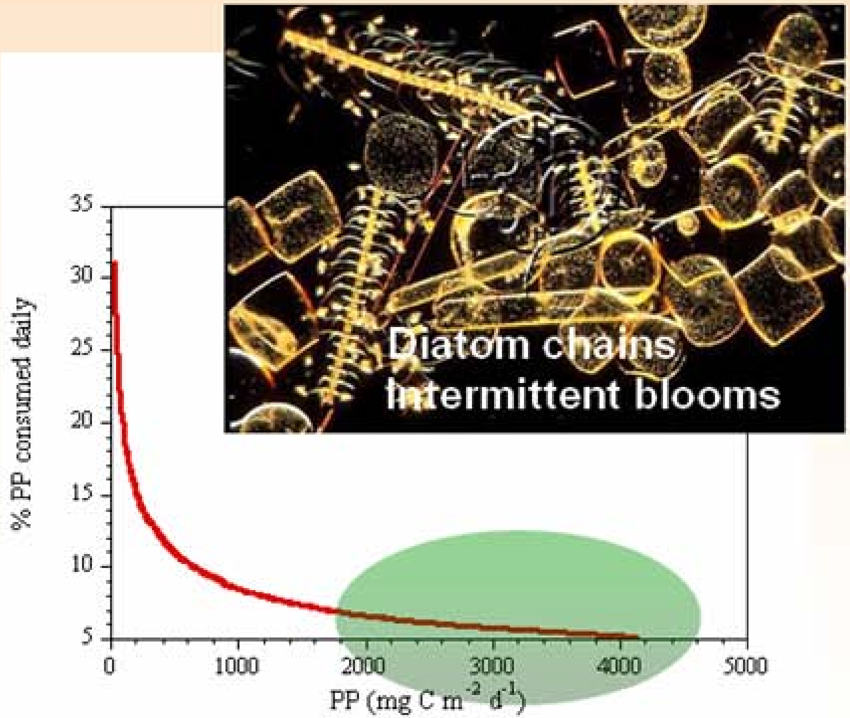
Agawin et al. 2000

Mesozooplankton control of PP



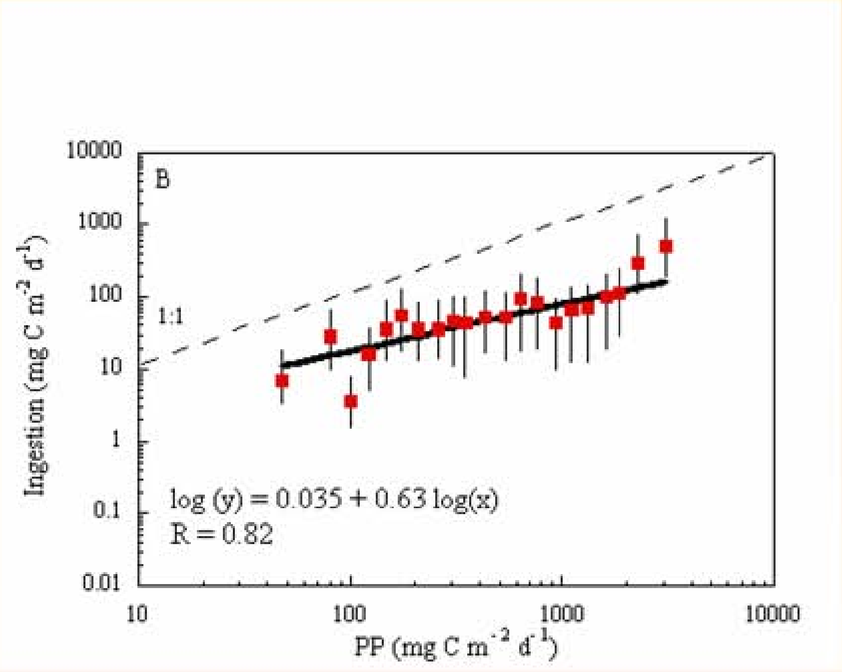
Hypothesis

The mesozooplankton impact on PP should be proportionally higher in productive ecosystems



Calbet 2001

Mesozooplankton control of PP



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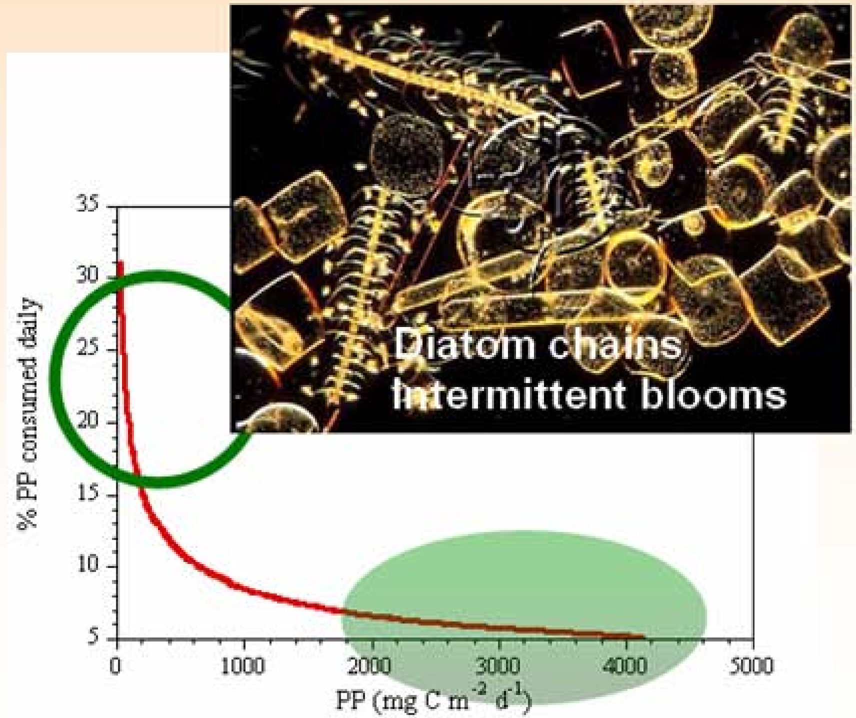
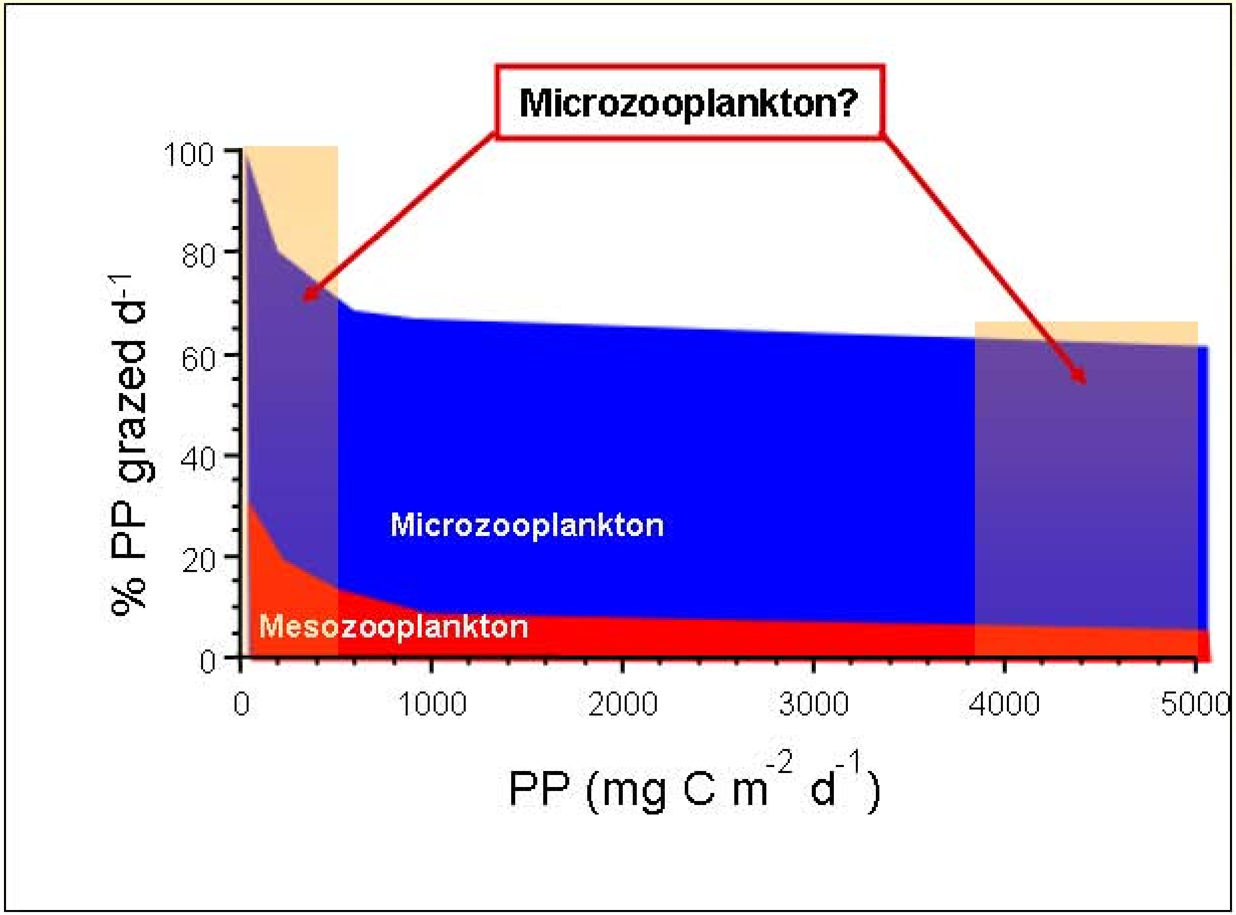


Calbet 2001

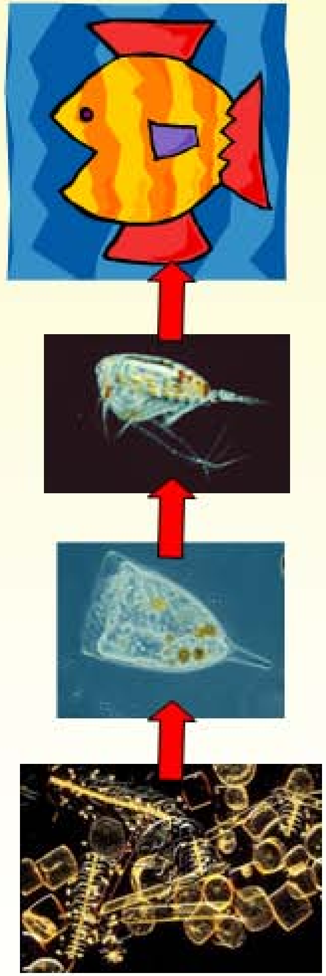
Summary of zooplankton control on PP

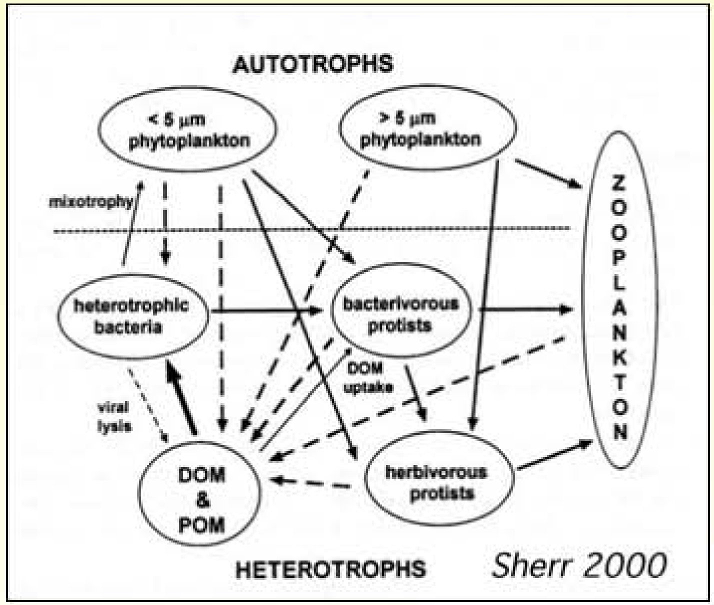
Mesozooplankton ingestion = 5.5 Gt C $year^{-1}$

Microzooplankton ingestion = 30 Gt C $year^{-1}$

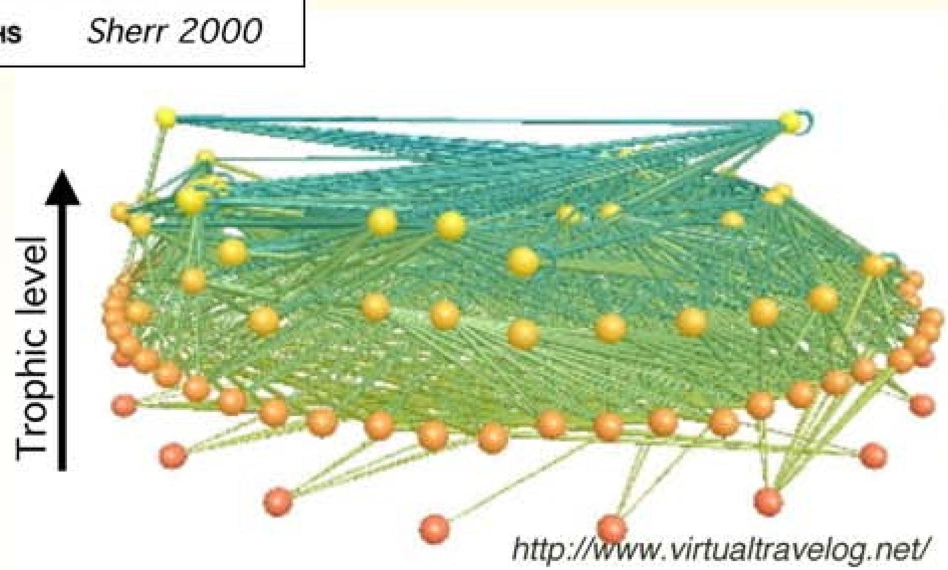


We need to go one step further: to identify the main grazers at each ecosystem

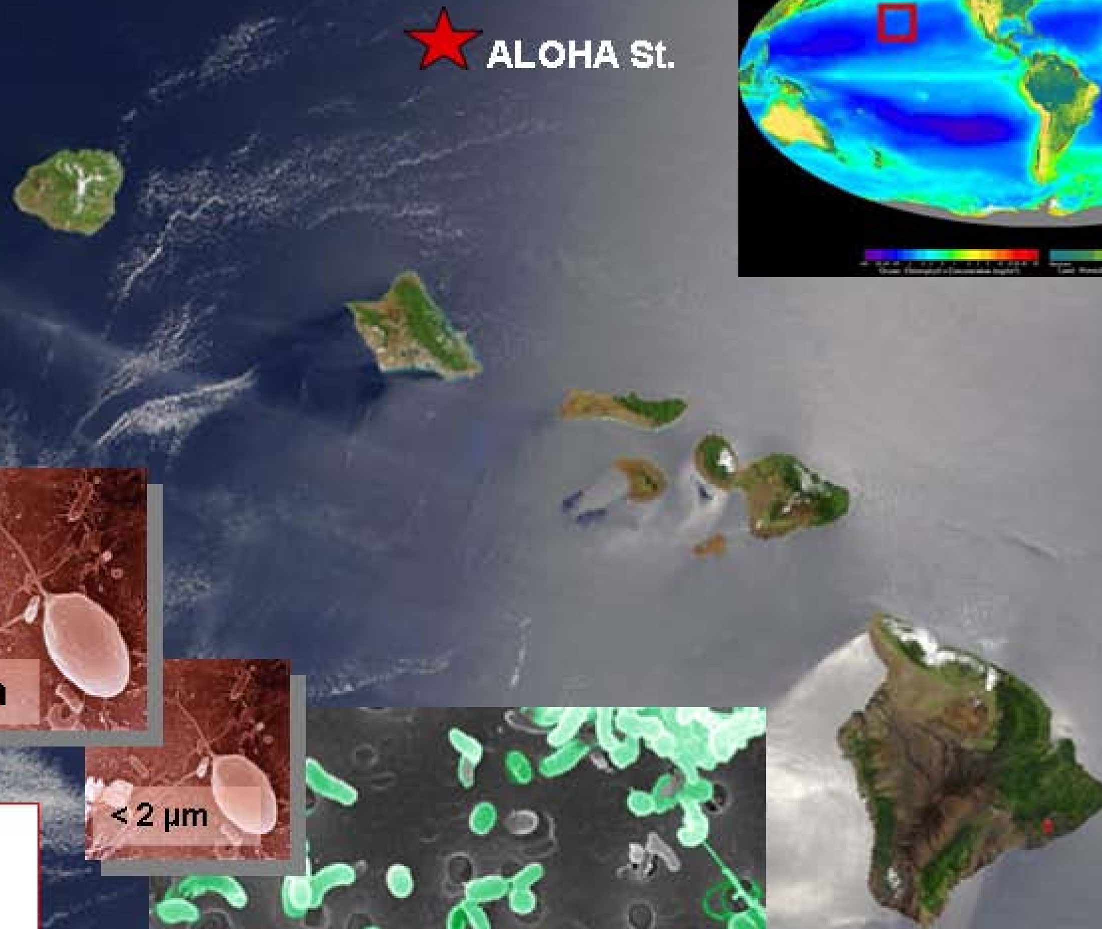


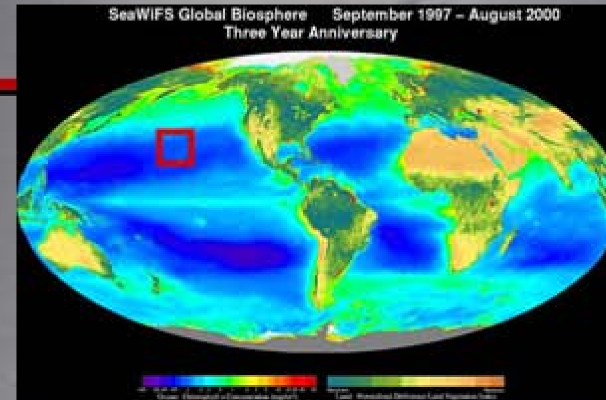


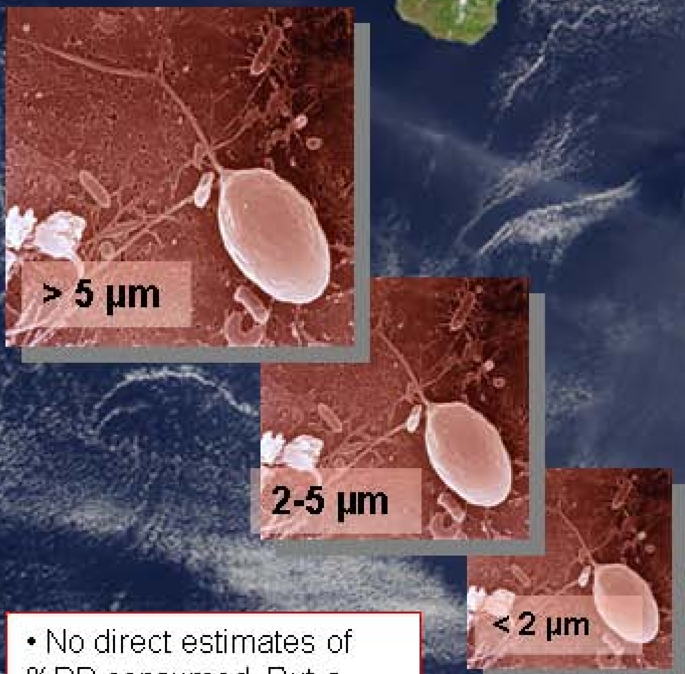
From the point of view of the economy of the system and nutrient recycling is not the same having a 2-3 step food web, than a long and imbricate one

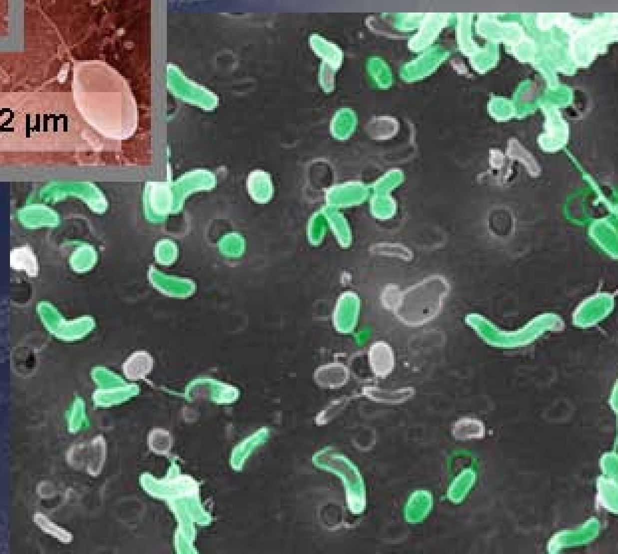


Subtropical Pacific (Hawaiian waters; *Calbet et al. 2001*)









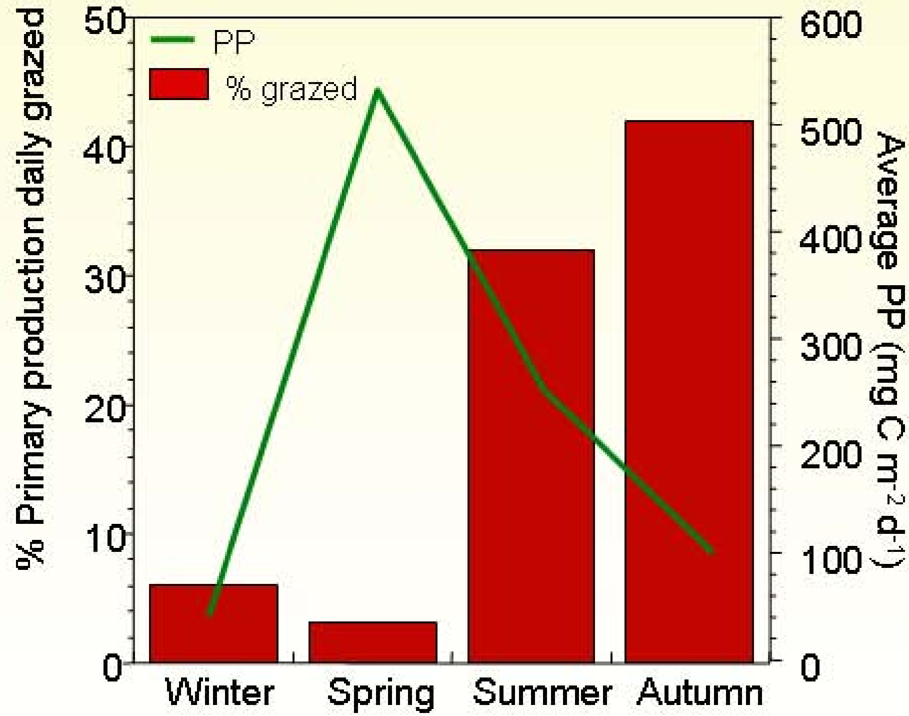
- No direct estimates of %PP consumed. But a high impact of small flagellates on PP is suggested.

- Many trophic steps within the flagellates group

Based on size-fractionated communities

Flagellate grazing in the northern Baltic Sea

Also based on size-fractionated communities



Even in more productive areas the impact can be relevant

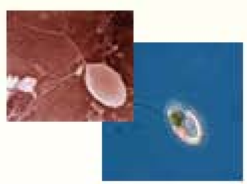
Kuosa 1991

Another approach: size-fractionated dilutions

STANDARD WHOLE WATER

Impact of the whole microbial community of grazers on total phytoplankton

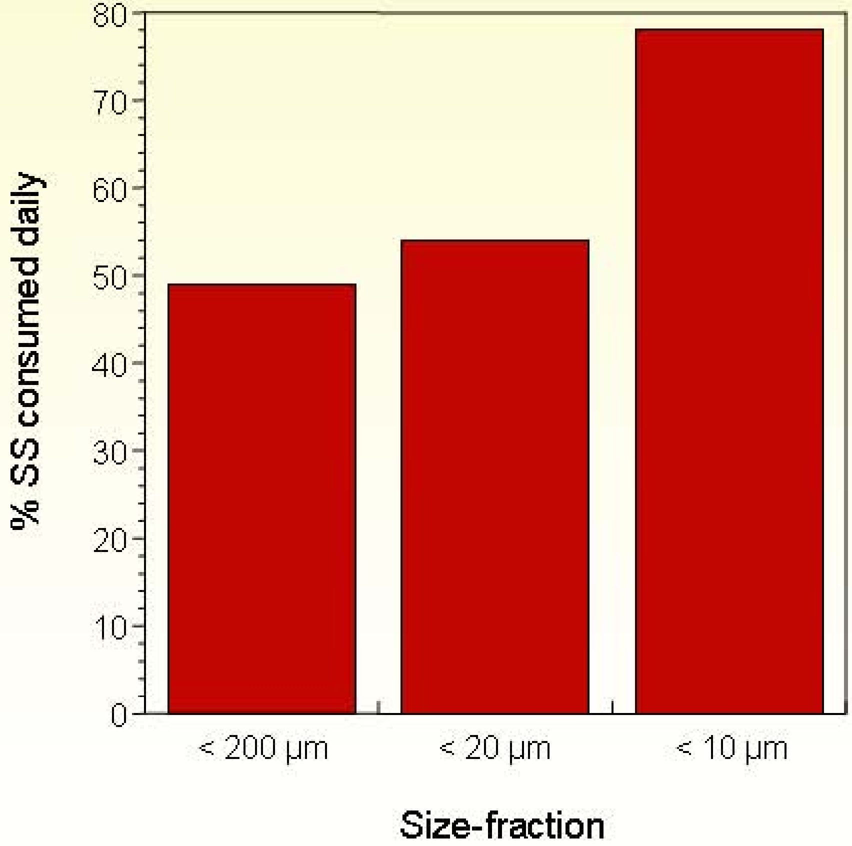
DIFERENT FRACTIONS
< 20 µm
< 10 µm
Etc.

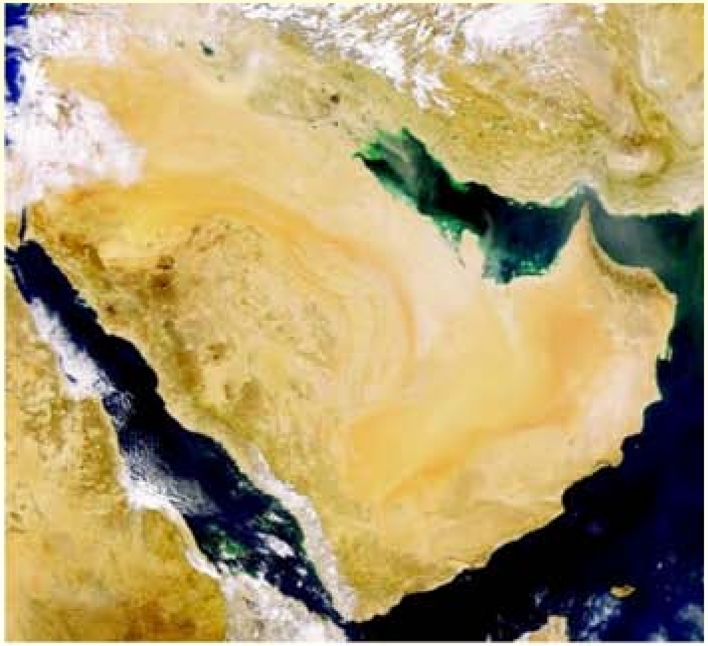


Potential impact of different groups of nanograzers on the phytoplankton (of each size-fraction)

Arabian Sea during the NE monsoon 1993

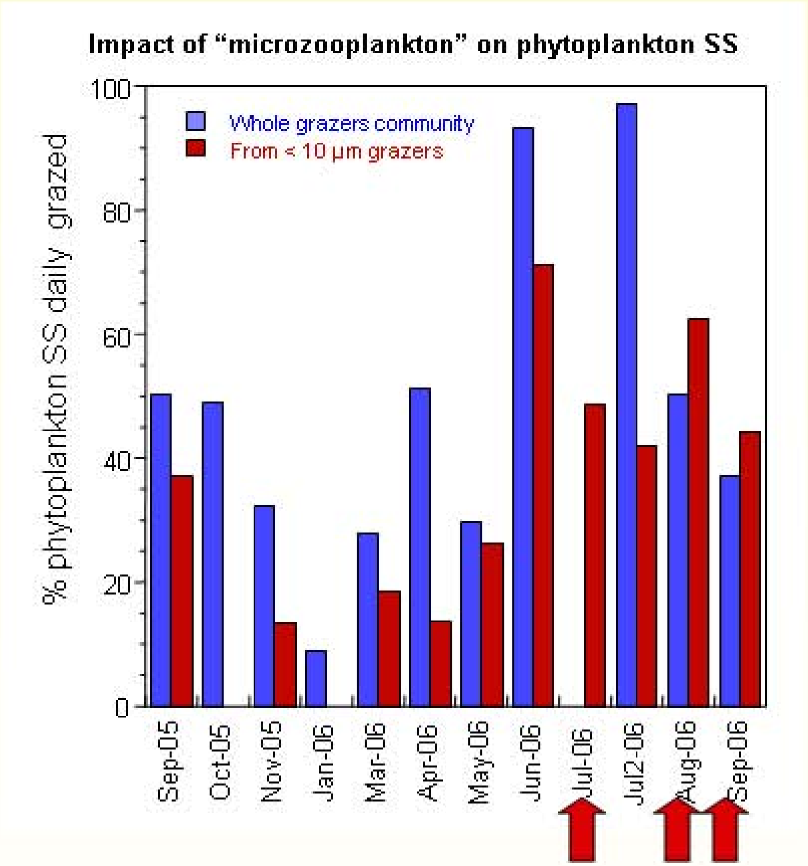
Picophytoplankton standing stock consumption



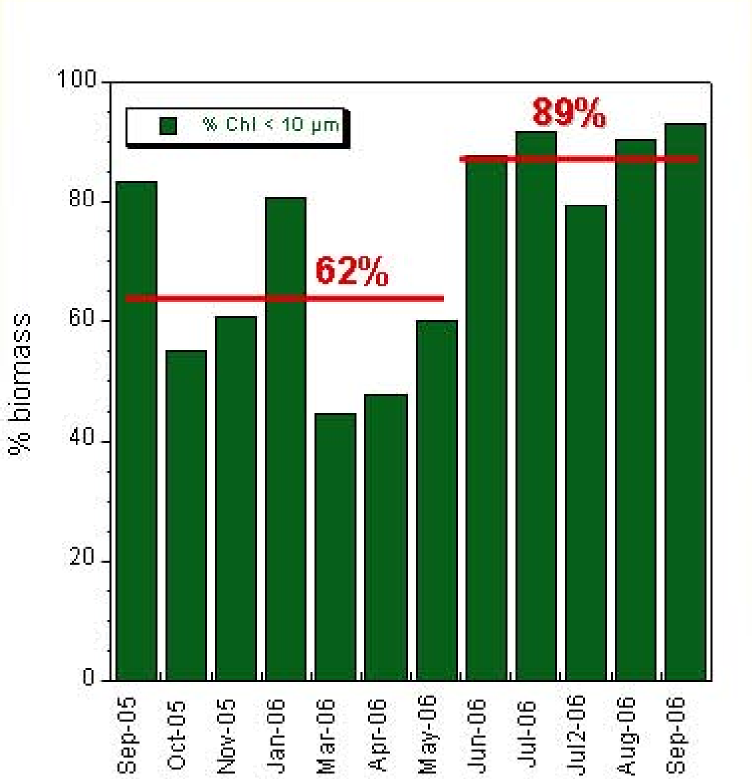


Reckermann and Veldhuis 1997

STUDY AREA: Coastal NW Mediterranean waters along a seasonal cycle



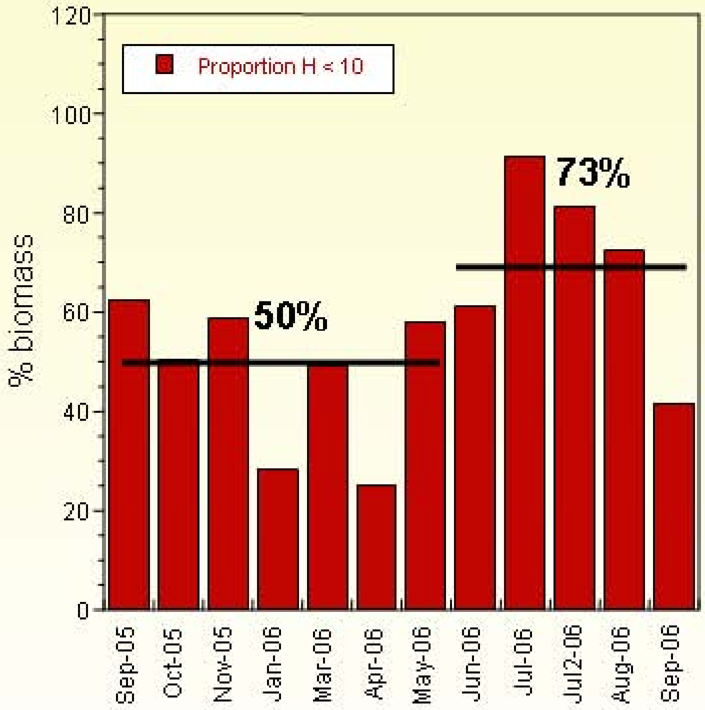
From end Spring to end Summer nano-sized grazers (< 10 µm) became very relevant



Phytoplankton < 10 µm also more relevant during this period

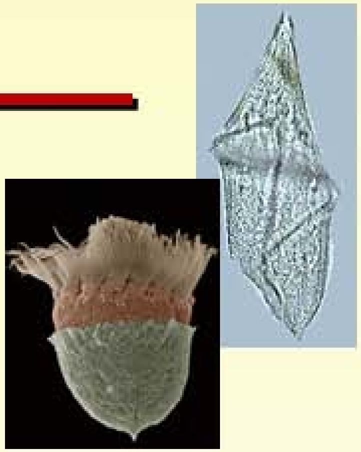
Calbet et al. submitted

Size-structure of grazers under oligotrophic conditions: summer

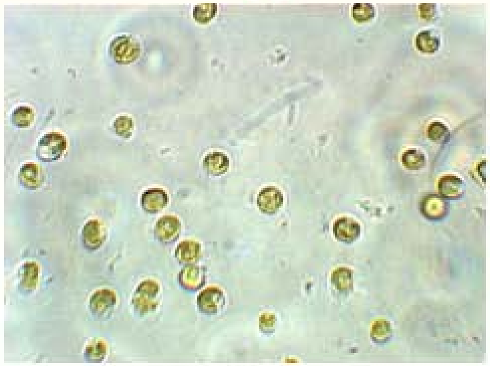


The grazers community is consequent with the variability in prey size spectrum

Micrograzers

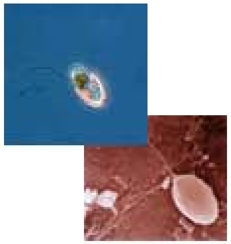


Nanograzers (different trophic levels)



Small phytoplankton

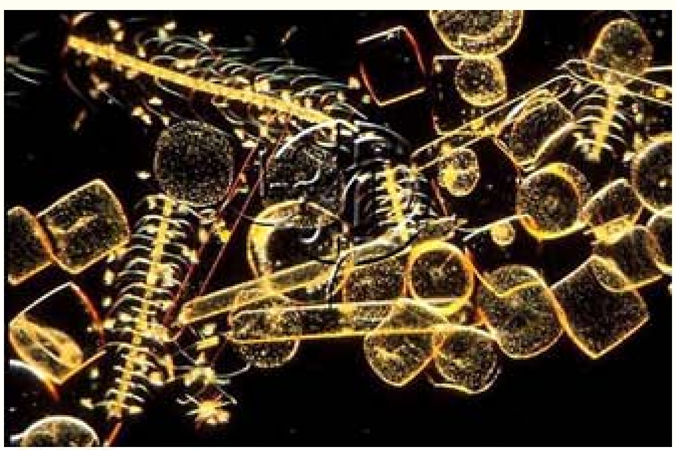
SUMMARY

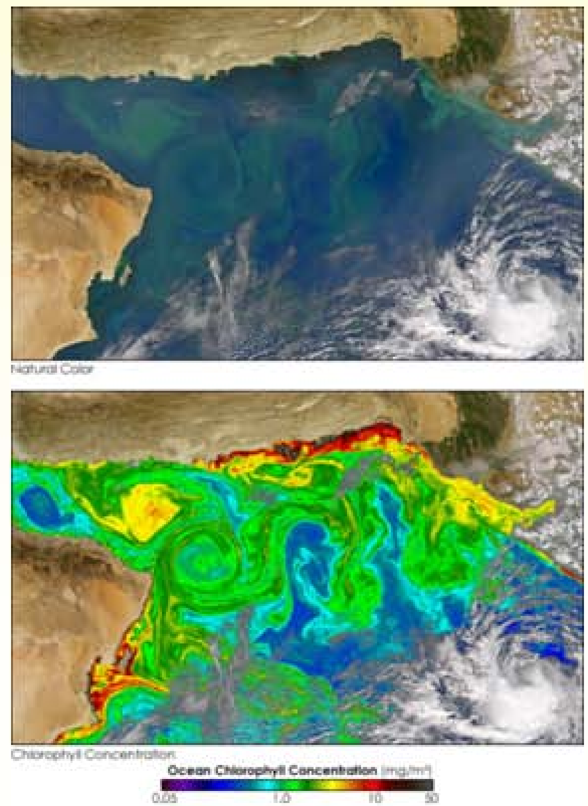


In oligotrophic ecosystems small flagellated phagotrophs highlight as very relevant grazers of the PP.

Then, why do we call them MICROZOOPLANKTON?

What about dense phytoplankton blooms?





Could ciliates be responsible for the grazing observed in dilution experiments?

Some ciliates can feed on large prey, but most are microphagous

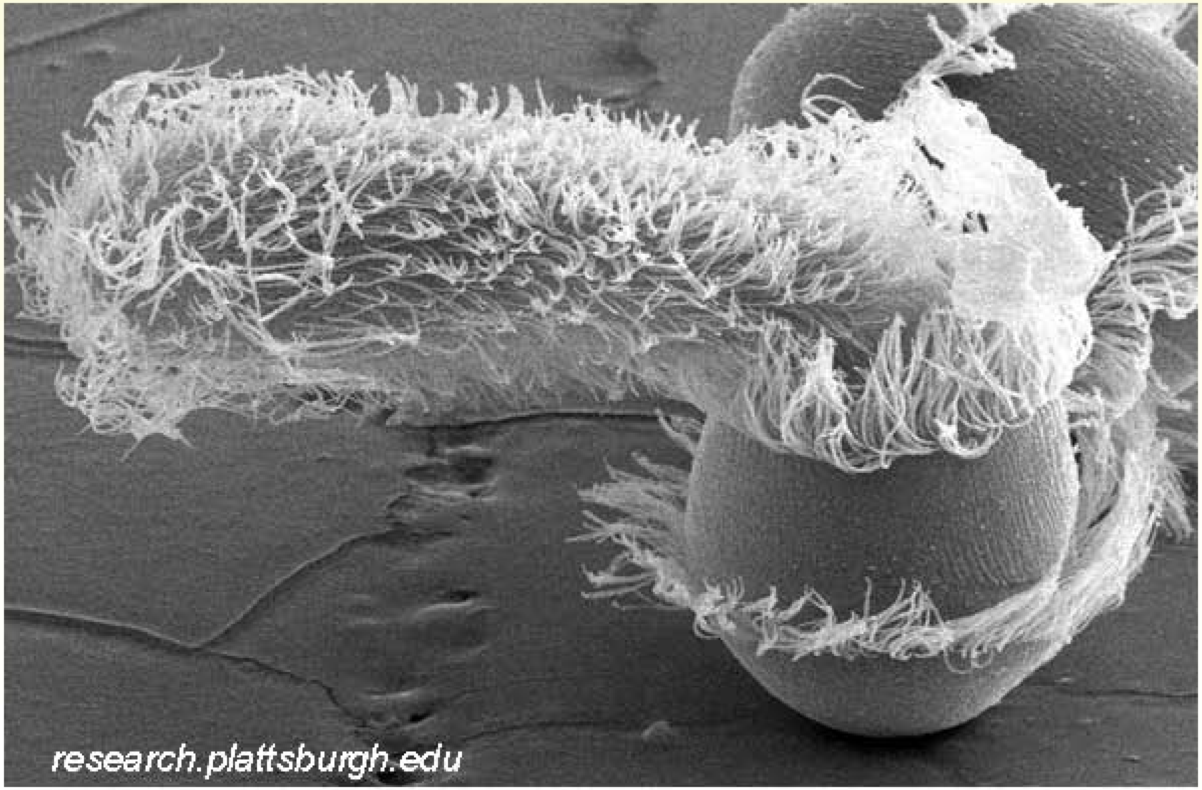
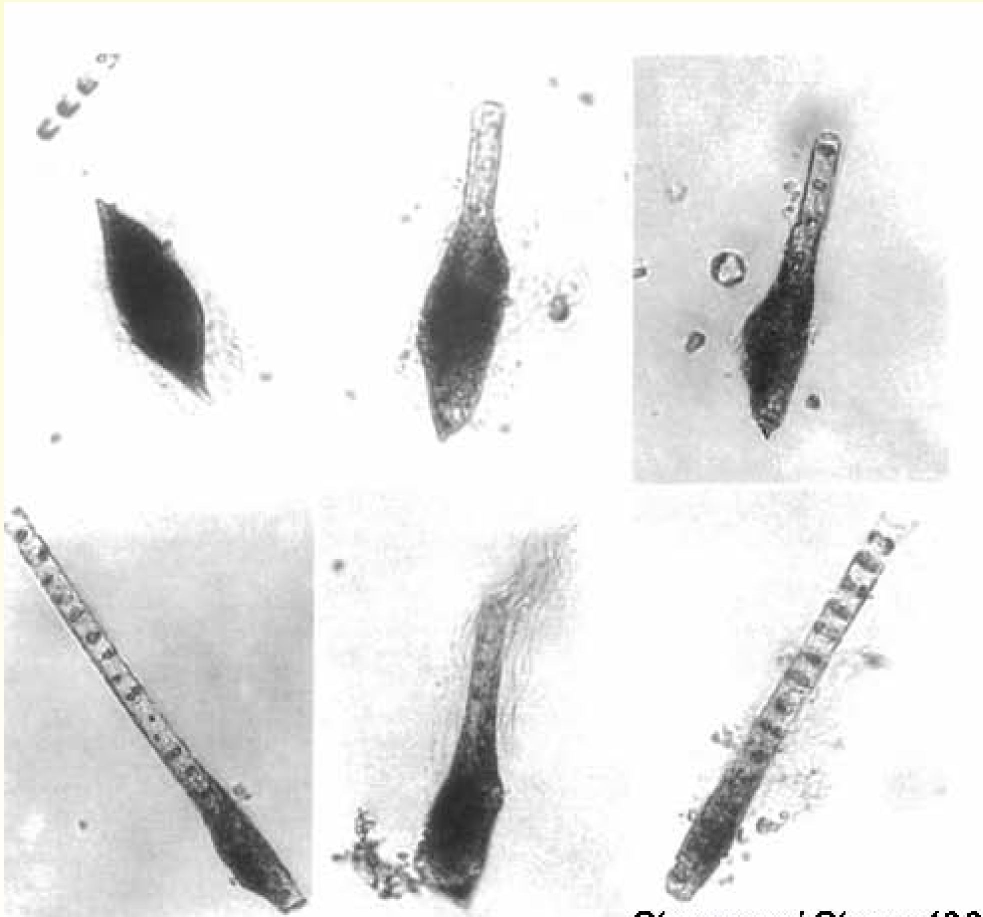
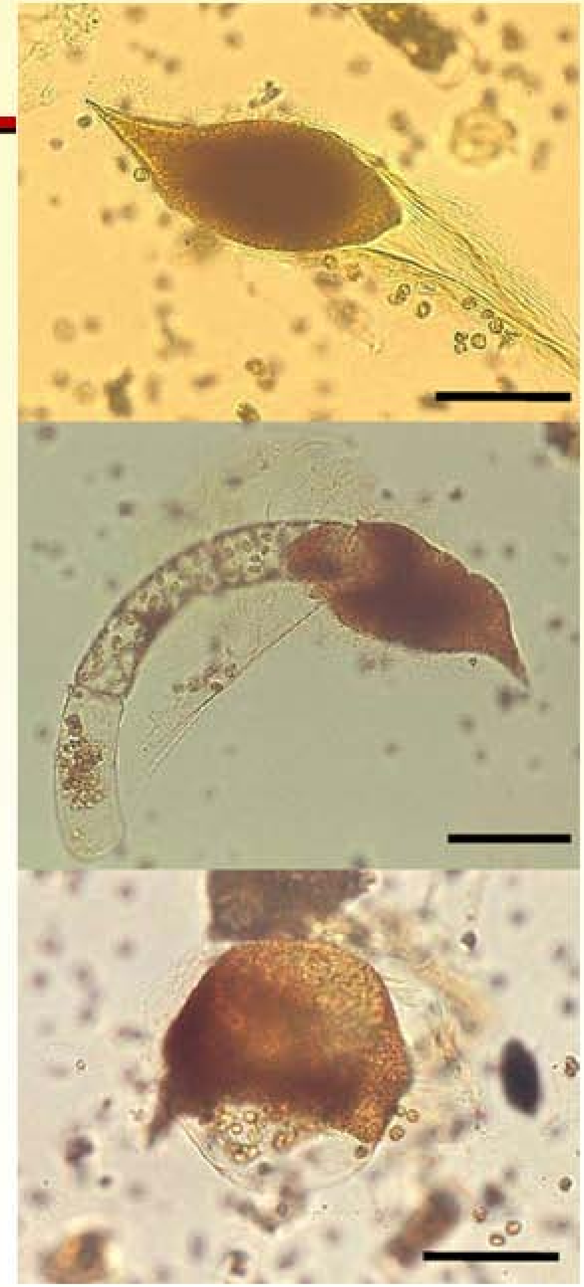


Photo: John Dolan

Heterotrophic dinoflagellates prey-size



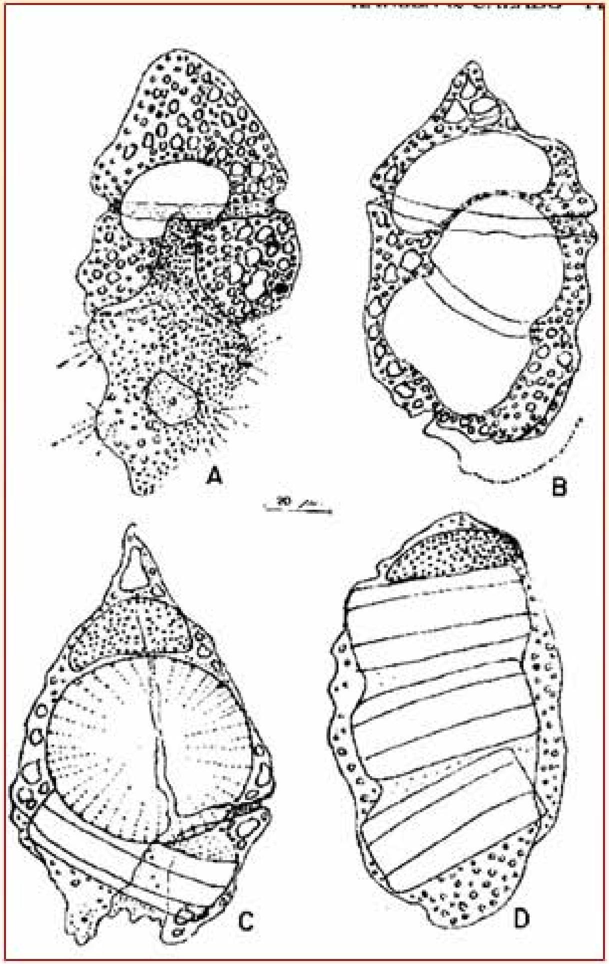
Strom and Strom 1996



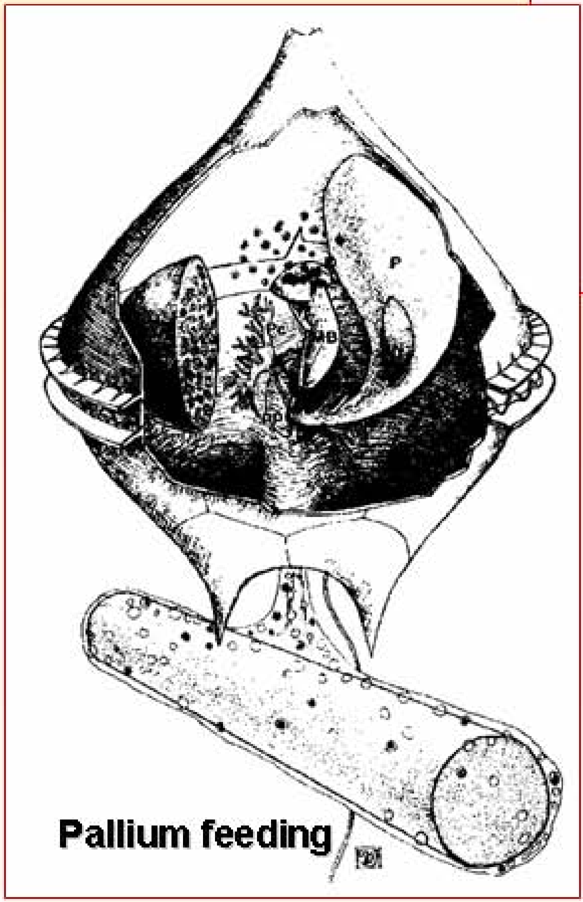
Stelfox-Widdicombe et al. 2004

Heterotrophic dinoflagellates have the potential of feeding on larger prey than ciliates

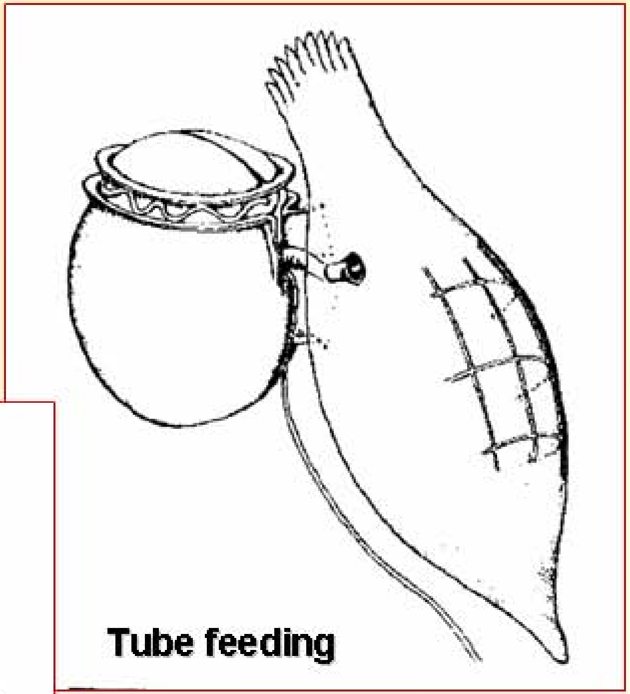
Feeding mechanisms



Direct engulfment



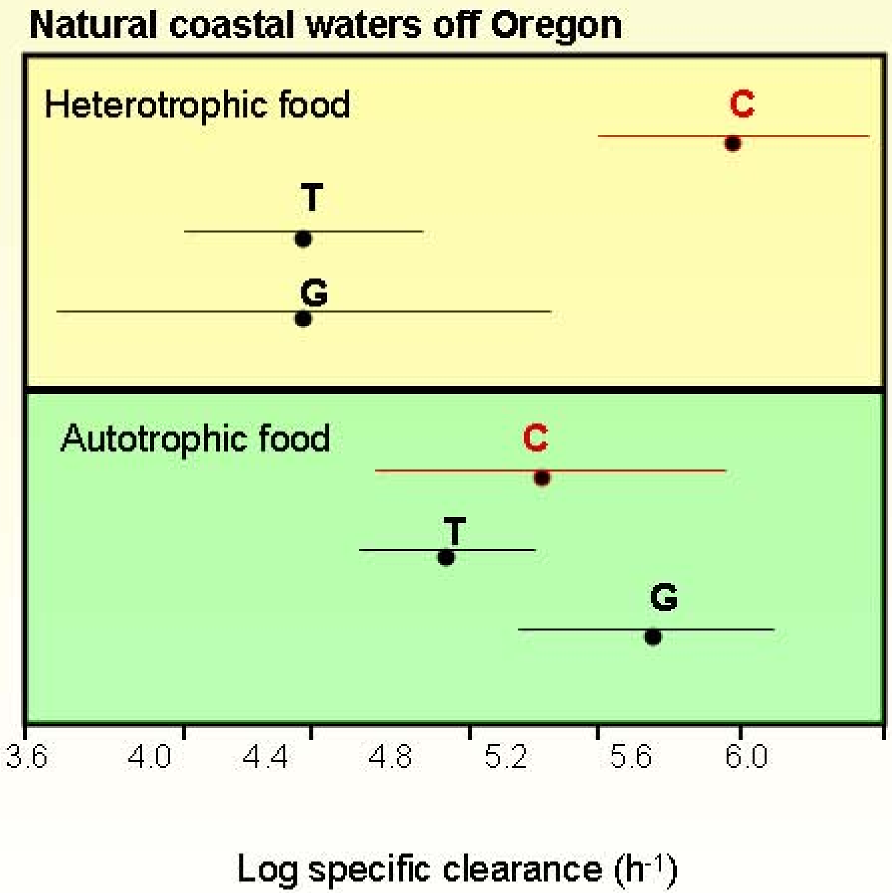
Pallium feeding



Tube feeding

Hansen and Calado 1999

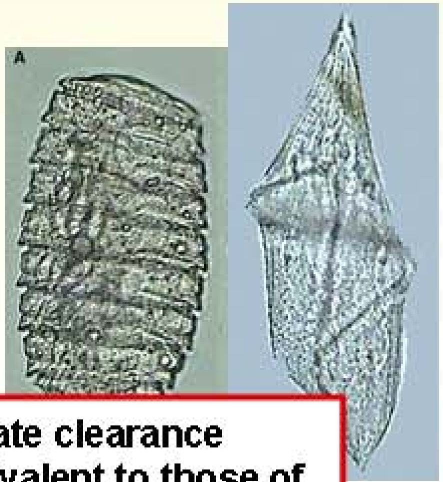
Clearance rates



C = Ciliates

T = Thecate dinoflagellates

G = Gymnodinoid dinoflagellates

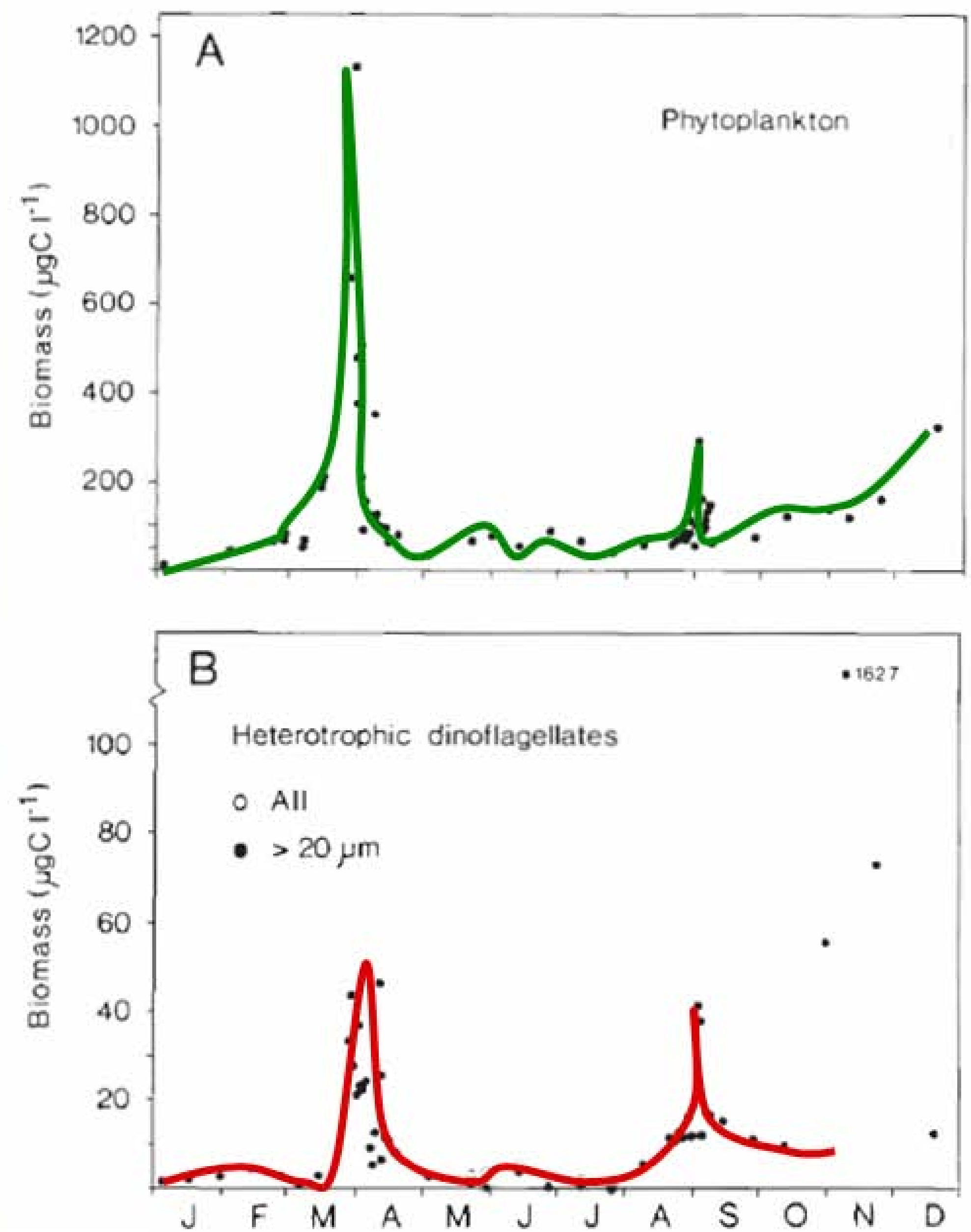


H. dinoflagellate clearance rates are equivalent to those of ciliates when feeding on phytoplankton

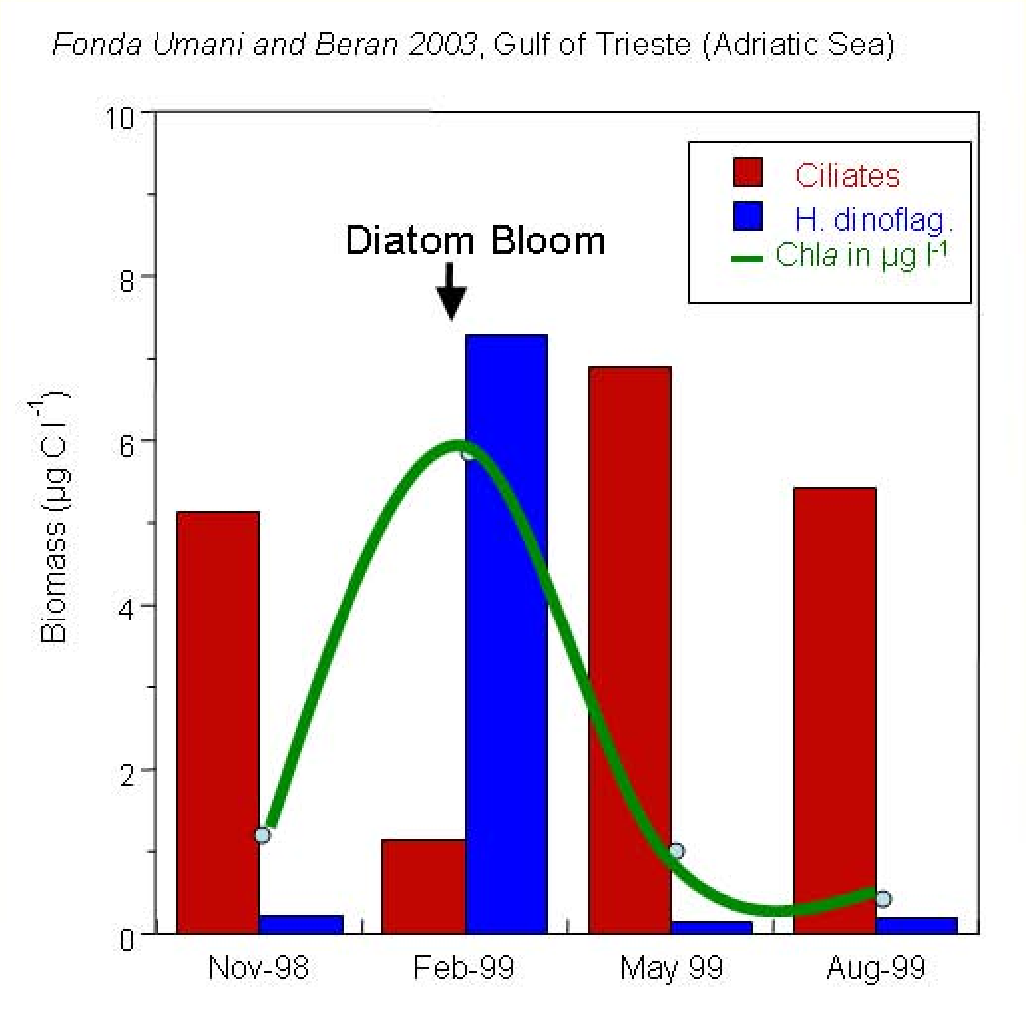
Neuer and Cowles 1995

Heterotrophic dinoflagellates biomass temporal distribution patterns coincide with those of phytoplankton

P.J. Hansen 1991, Southern Kattegat



Biomass distribution patterns



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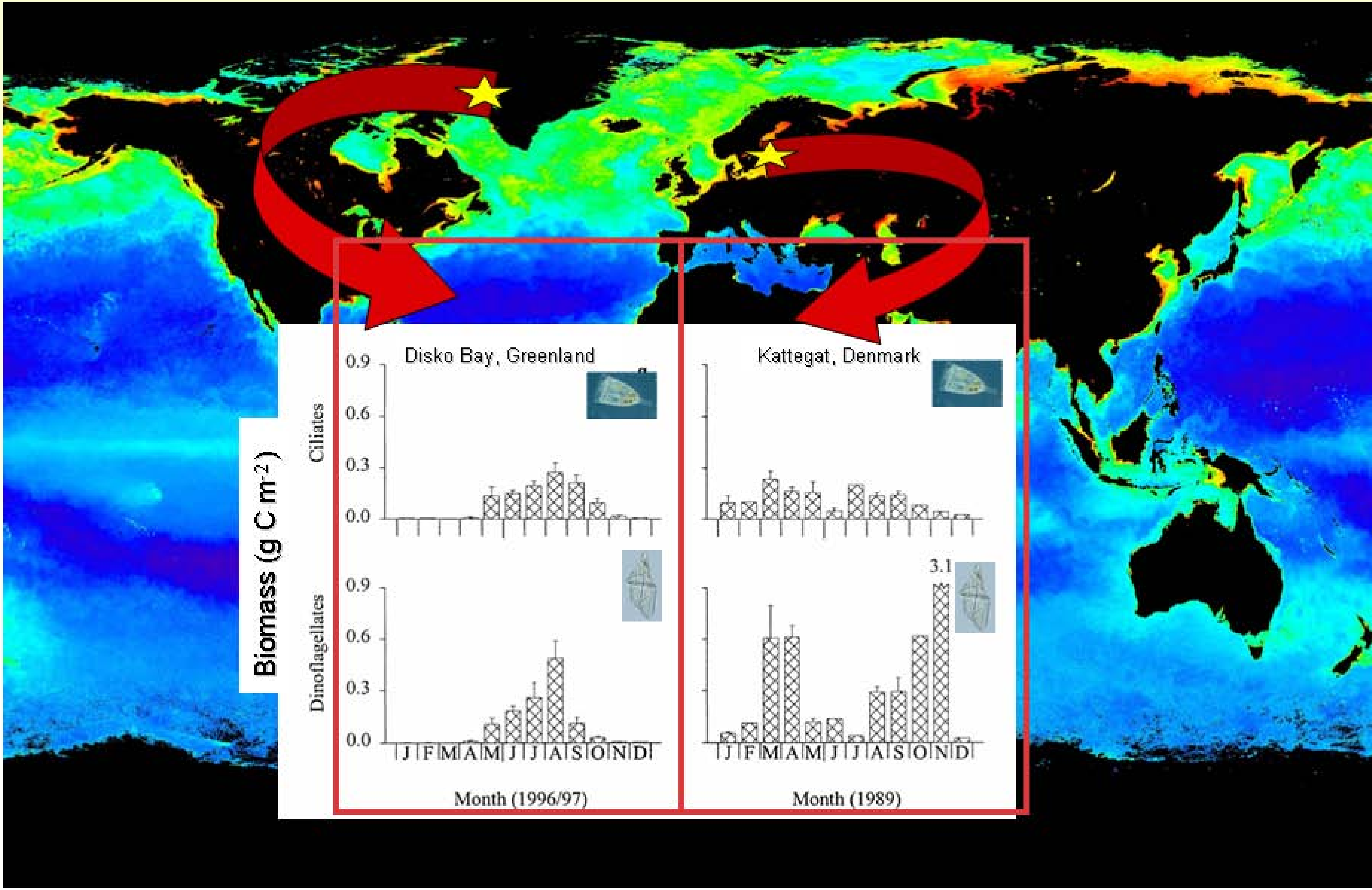


Levinsen and Nielsen 2002

Biomass distribution patterns

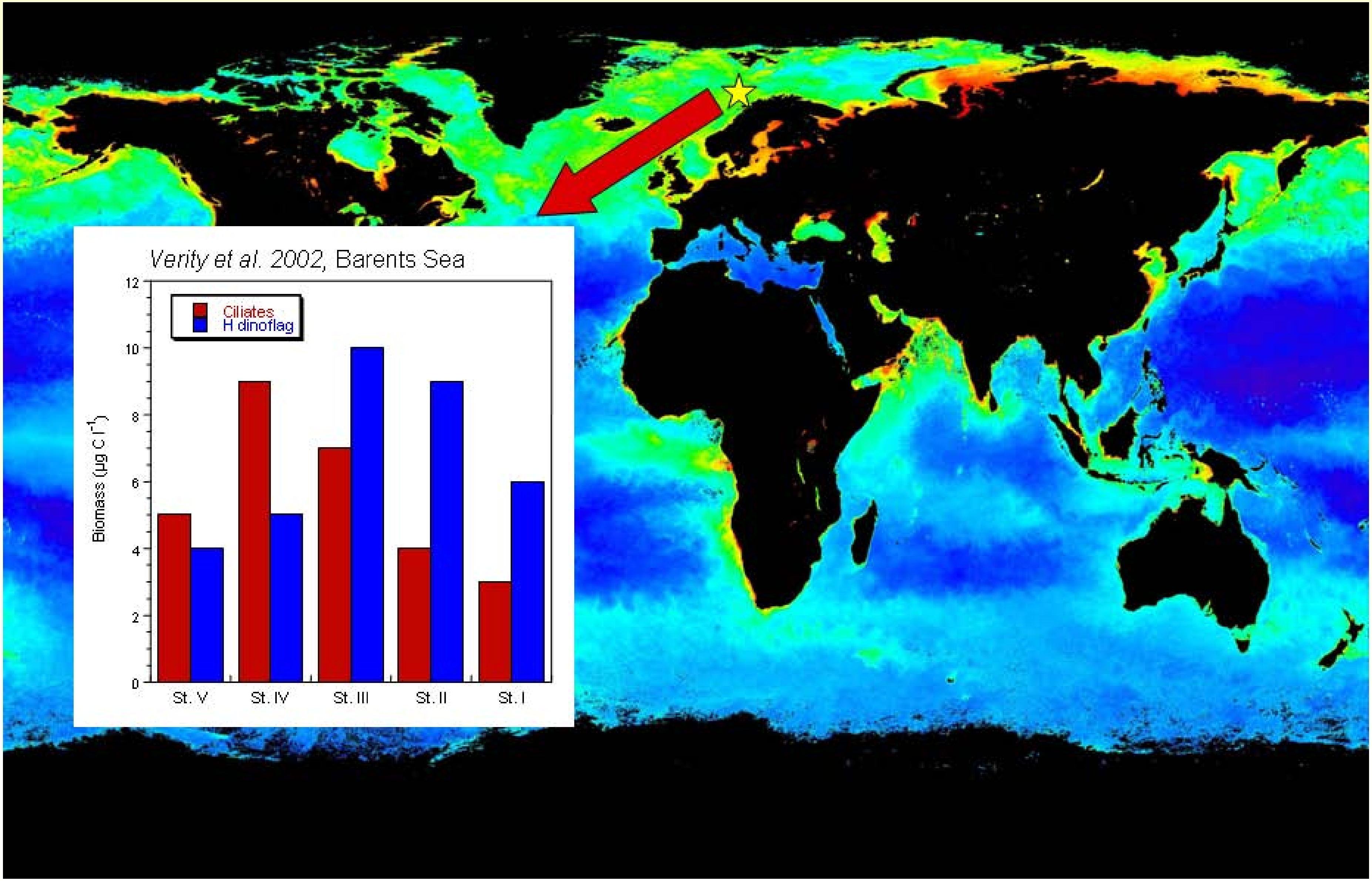


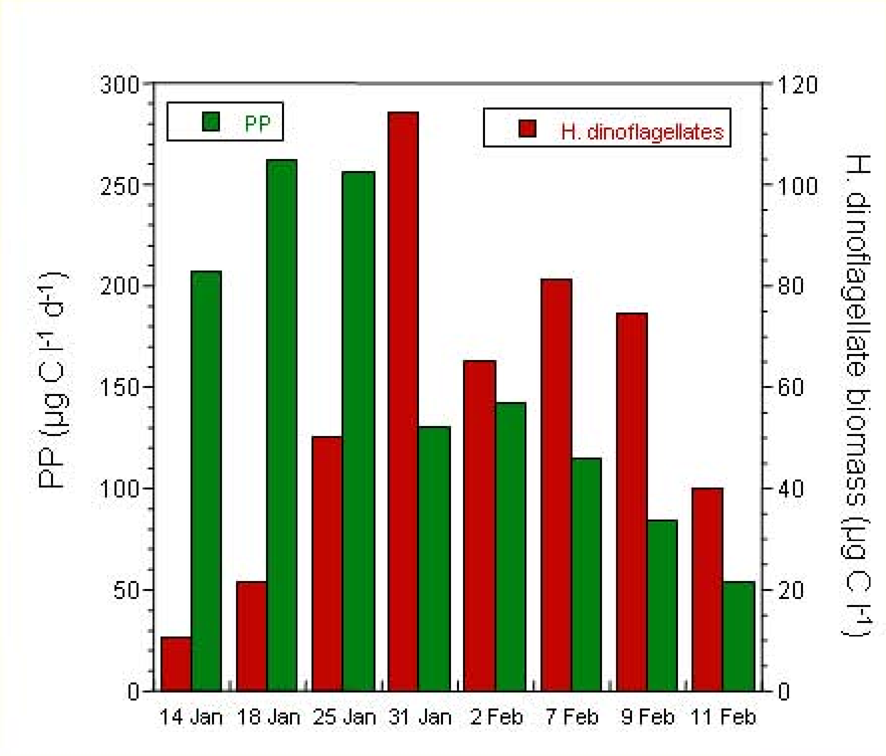
Table 1. The abundance and biomass of heterotrophic dinoflagellates (HTDs) and HTD biomass as a percentage of combined HTD and ciliate biomass (% Biomass) in various marine environments.

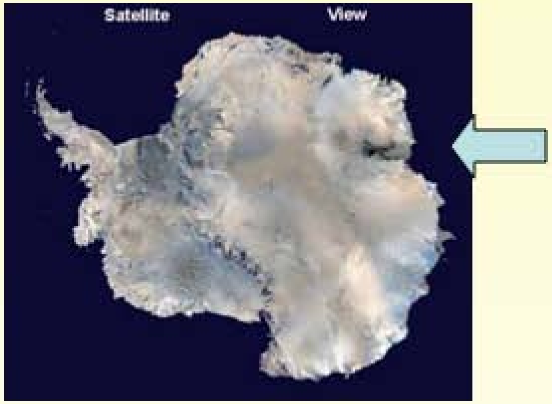
Location	Abundance (cells per liter)	Biomass (μg C per liter)	% Biomass	Reference
Kiel Bight, Germany		<1–25	5–62	Smetacek (1981)
Perch Pond, USA		0.2–480	2–85	Jacobson (1987)
Kattegat, Denmark	200,000[a]	162.7[a]	7–99	Hansen (1991b)
Northern Strait of Georgia, Canada		30[a]	23–49	Haigh and Taylor (1991)
Seto Inland Sea, Japan	4,000–90,000			Nakamura, Suzuki, and Hiromi (1995)
Gulf of Gdansk, Southern Baltic		100	80	Bralewska and Witek (1995)
Dogger Bank, North Sea	400–27,000	>1[a]	2	Nielsen et al. (1993)
Northern Gulf of Mexico			20–75	Strom and Strom (1996)
North Atlantic				
(slope)	6,000–9,000	0.9–2	54–68	Lessard (1991)
(front)	4,000–22,000	3.3–6.1	47–53	
(Gulf Stream)	500–1,600	0.1–0.5	45–60	
(Sargasso Sea)	100–1,000	0.1–0.5	22–63	
Sargasso Sea near Bermuda	900–28,600	0.1–2.1	21–96	Lessard and Murrell (1996)
Northeast Atlantic Ocean	2,000–67,000	0.9–18.3		Verity et al. (1993b)
Northeast Atlantic Ocean	65,000[a]		10–50	Verity et al. (1993a)
Northeastern Atlantic Ocean		0.3–10.3	13–94	Sleigh et al. (1996)
Equatorial Pacific	16–19	0.06–0.09	30–41	Stoecker, Gustafson, and Verity (1996)
Igloolik (polar)	660			Bursa (1961)
McMurdo Sound (polar)	40–140	0.3–2	75–97	Lessard and Rivkin (1986)
Subarctic North Pacific		0.5–2.1	20–56	Gifford and Dagg (1991)
Northeastern Atlantic Ocean			49–75	Burkill et al. (1993)
Bellingshausen Sea			24–61	Burkill, Edwards, and Sleigh (1995)
McMurdo Sound, Antarctica	28,000[a]	4[a]		Stoecker, Buck, and Putt (1993)
Coastal East Antarctica	4,500–33,600	10.6–114.5	56–91	Archer et al. (1996)
Antarctic Circumpolar Current	2,000–5,700	0.6–1.5	31–50	Klass (1997)
Polar Front Region	3,100–11,000	1.5–4	61–88	Klas (1997)
Ellis Fjord, Eastern Antarctica	100[a]			Grey et al. (1997)

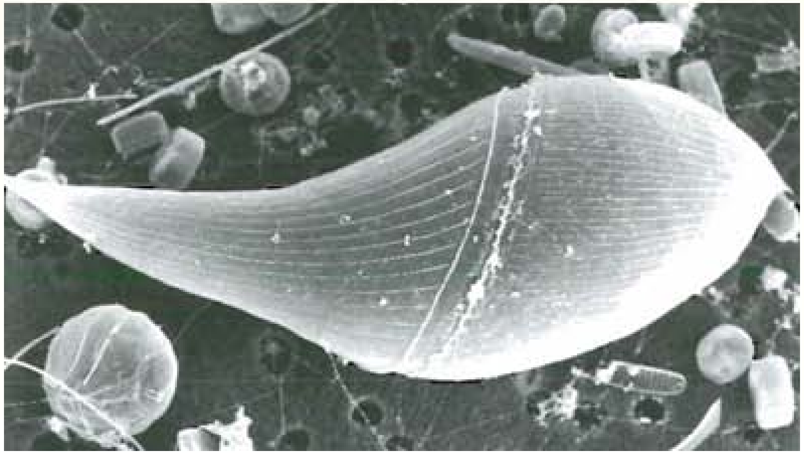
[a] Maximum abundance.

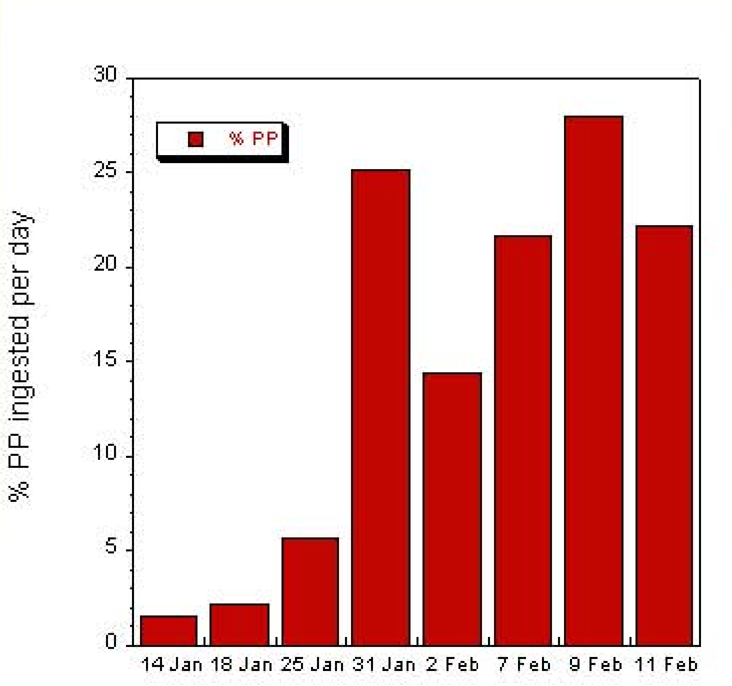
Jeong 1999

Some data: Coastal East Antarctica during a diatom bloom *(Archer et al. 1996)*

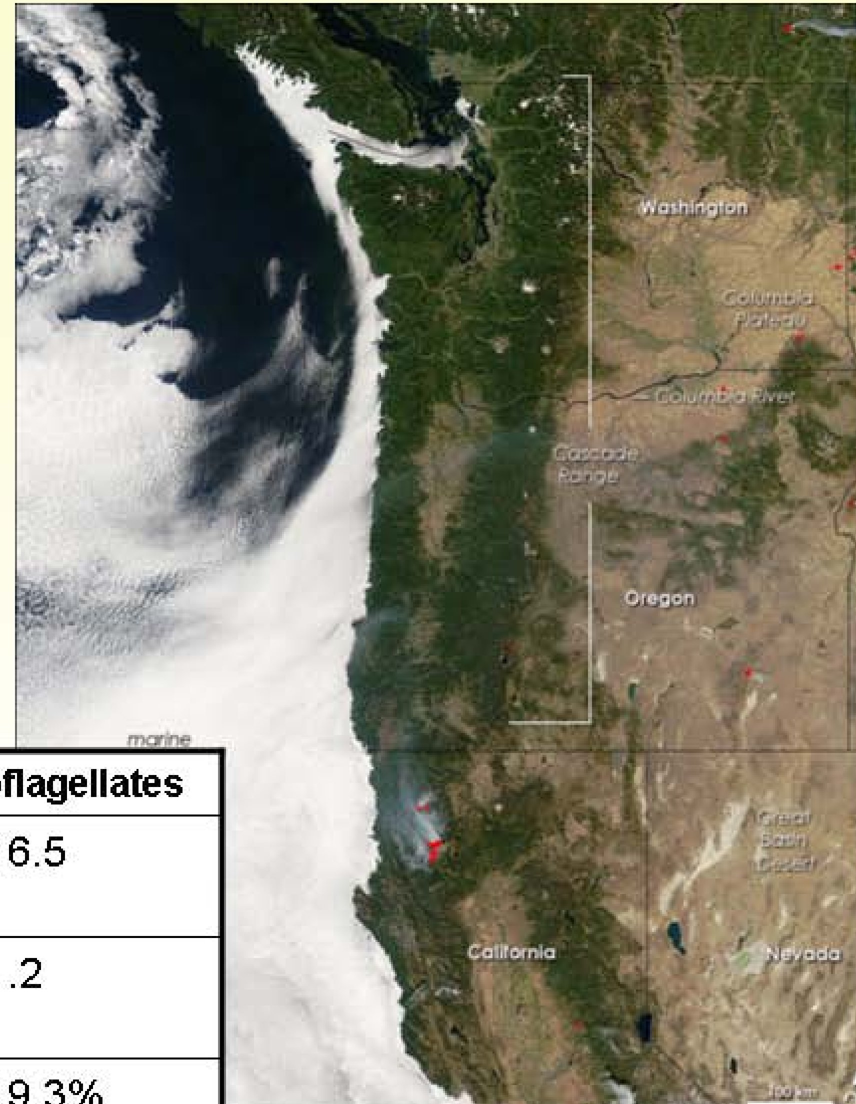








California current system (Sherr and Sherr: http://bioloc.coas.oregonstate.edu/SherrLab/)



	Ciliates	H. dinoflagellates
Abundance (Cells ml^{-1})	3.5 ± 2.0	17.5 ± 6.5
Biomass (µg C l^{-1})	2.0 ± 1.7	2.0 ± 1.2
% water column cleared	36.7 ± 22.5%	25.2 ± 9.3%

Protoperidinium bipes feeding on *Skeletonema costatum*

Calculated grazing impact of *P. bipes* on *S. costatum* = **2-80%** population removed per day.

For the co-occurring copepods **< 5%**

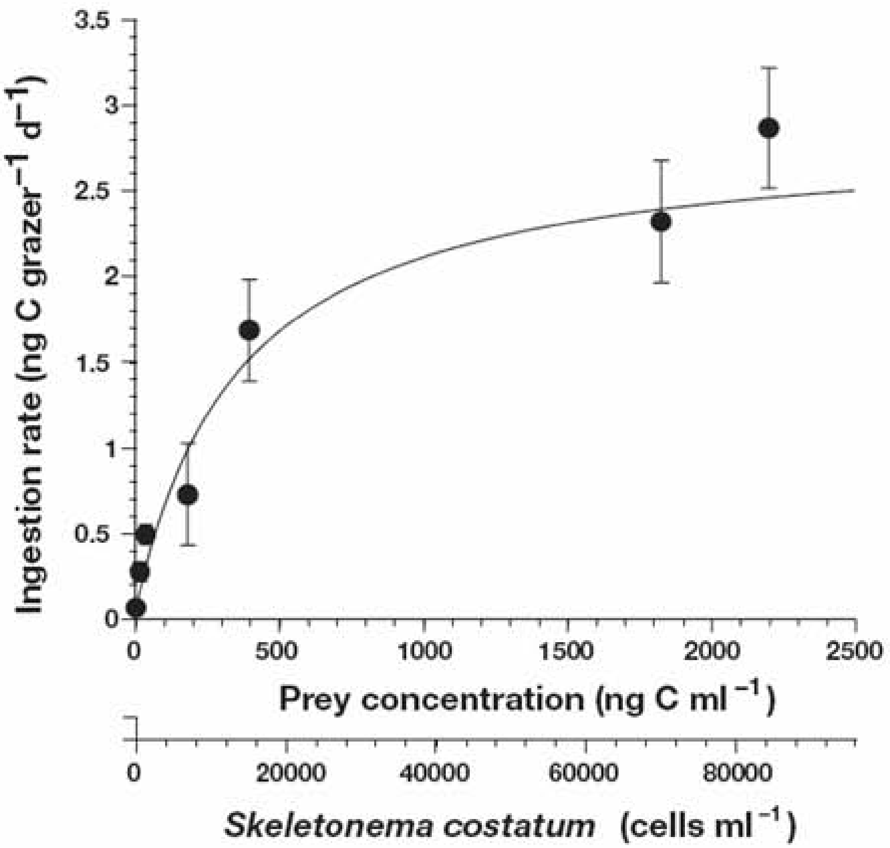
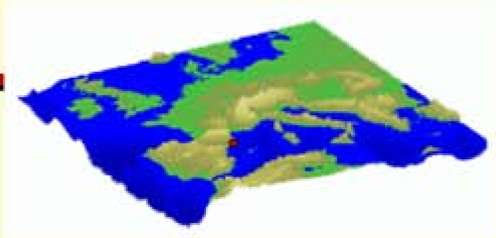


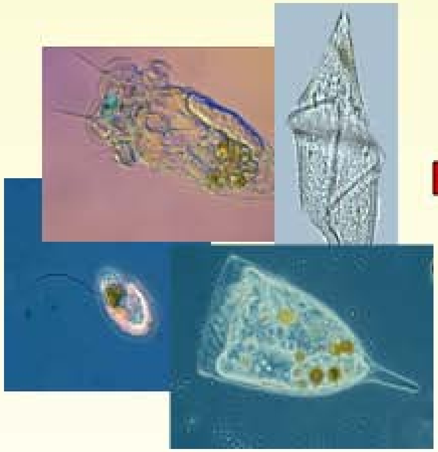
Fig. 2. Ingestion rates of *Protoperidinium bipes* feeding on *Skeletonema costatum* as a function of mean prey concentration (x, ng C ml^{-1}). Ingestion rates were calculated by averaging the instantaneous ingestion rates for 0 to 24 h and for 24 to 48 h. Symbols represent treatment means ± 1 SE. Curves are fitted by a Michaelis-Menten equation (Eq. 3) using all treatments in the experiment. Ingestion rate (IR, ng C grazer^{-1} d^{-1}) $= 2.9\,[x/(355 + x)]$, $r^2 = 0.794$

Jeong et al. 2004

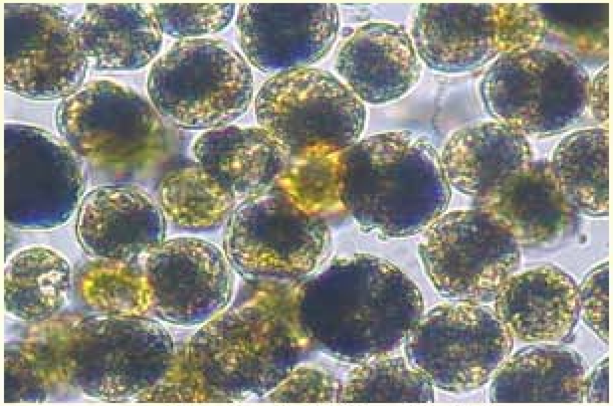
There are other important groups besides ciliates and dinoflagellates



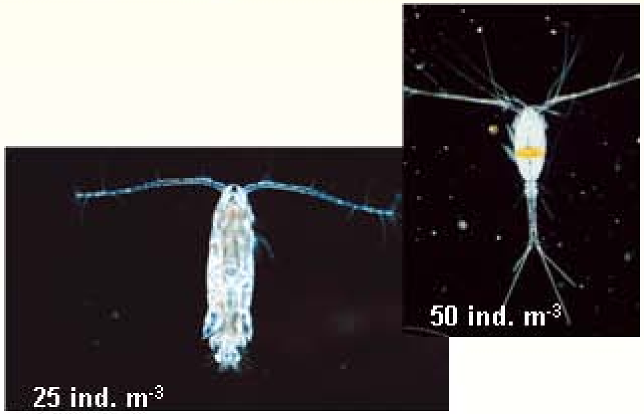
Alexandrium minutum bloom, NW Mediterranean harbor



> 100 % production and SS of *A. minutum*



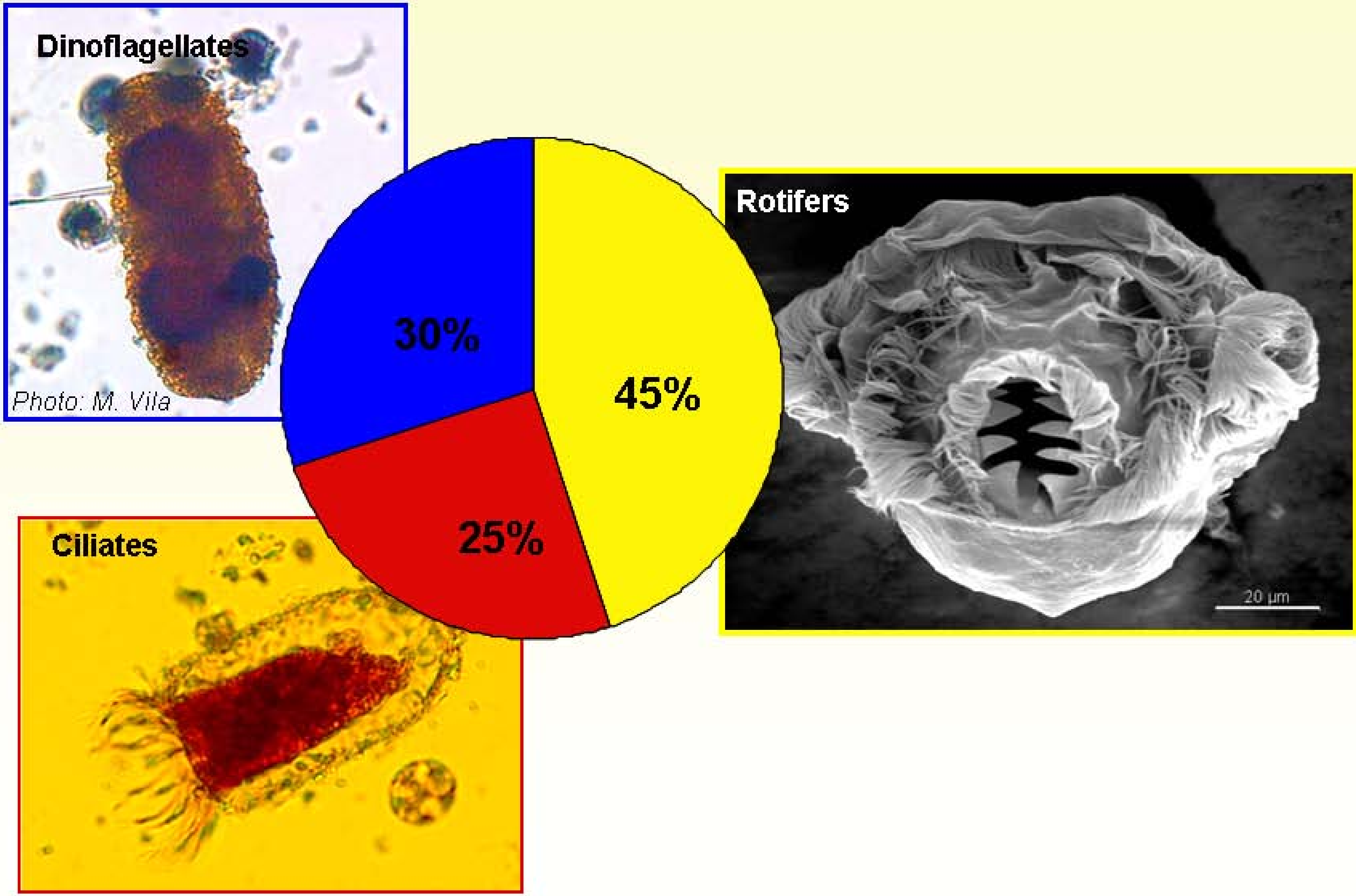
Up to 6 10^6 cells l^{-1}



0.01 % SS of *A. minutum*

(*Calbet et al. 2003*)

What microzooplankton groups are responsible for the grazing?



Calbet et al. 2003

In summary

Microzooplankton are (and, for sure, they will be in any global change scenario) key components of marine food webs.

They are diverse (not only ciliates are relevant), and likely each species has a distinct role in the ecosystem. This includes pico- and nanoflagellates, ciliates, dinoflagellates, other protists (mixotrophic also) and metazoans as well.

We should invest more effort in new methodologies that provide more resolution on the role of each group (species).

When facing dilution data maybe we should think in other names rather than microzooplankton: *protozoan grazers*, *microbial grazers*, etc.

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