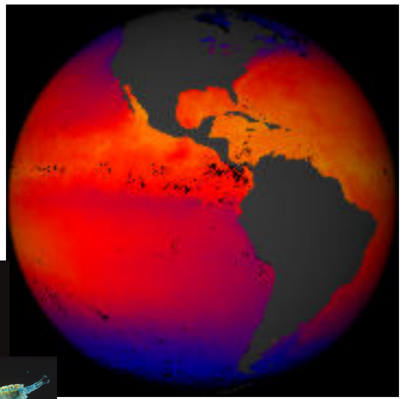
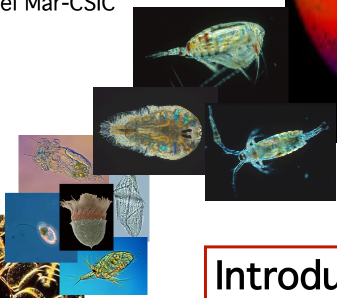
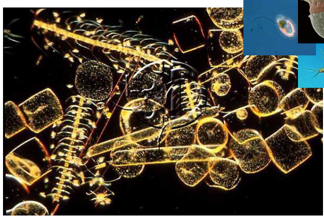
Impact of Global Change on the marine planktonic ecosystem:

Phytoplankton and Zooplankton

Albert Calbet
Institut de Ciències del Mar-CSIC
acalbet@icm.csic.es







Introduction to the plankton: main groups and dynamics

Topics

Class 1: Introduction
- What is plankton?
- Main groups
- Food webs
- Ecological relevance

Class 2: Plankton and climate
- Global patterns of distribution
- Daily cycles
- Seasonality
- Multiannual phenomena: ENSO, NAO, etc.

Class 3: Global change and plankton
- Introduction
- Climate change and plankton
  - *Factors*
    - temperature
    - turbulence
    - UV
  - *Effects*
    - distribution and abundance
    - phenology

Class 4: Other Global Change mechanisms
- Acidification
- Eutrophication: HABs, Annoxia,
- Pollutants
- Overfishing
- Invasive species

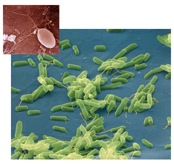
Class 5: The future
- Perspectives for the future?
- Remediation of global change (involving the ocean)

What is plankton?

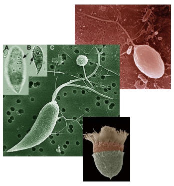
Plankton is the aggregate of all microscopic organisms that drift on the oceans' currents.
The name plankton is derived from the Greek word "planktos", meaning "wanderer" or "drifter.

Classification according to size

Picoplankton



Nanoplankton



Microplankton

Mesoplankton

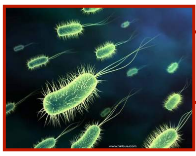
?

> 20 mm = Macro, Mega...

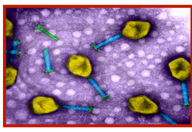
Classification according trophic role

Phytoplankton are the **primary producers** of the planktonic world. They are photosynthetic plankton and include organisms such as diatoms, dinoflagellates, and cyanobacteria.

Zooplankton are the **consumers** of the planktonic world. As such, they feed on other plankton to obtain the energy and nutrients they need to survive. Zooplankton include protozoans, copepods and other crustaceans, larvae of benthic organisms, the larvae of fish, etc (even medusae).



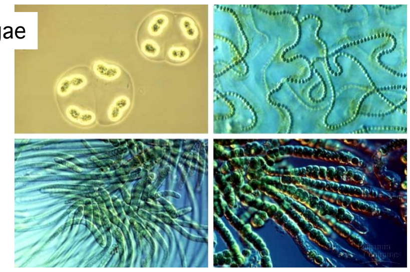
Bacterioplankton are the **recyclers** of the planktonic world. They are free-floating bacteria and archaea that serve to break-down and recycle waste material in the seas.



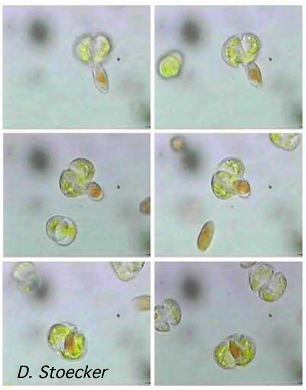
Virioplankton - Viruses

Caution!!!

Not all phytoplankton are algae



Cyanobacteria

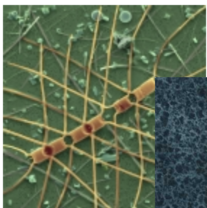


Not all zooplankton are animals

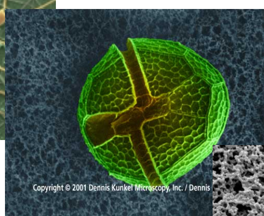
Mixotrophy

Here we will talk about phytoplankton and zooplankton

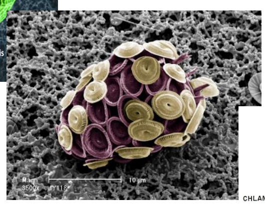
Phytoplankton major groups used in this course



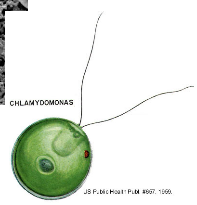
Diatoms



Dinoflagellates



Coccolithophorids

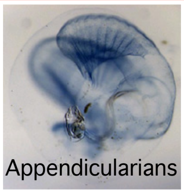


Other flagellates

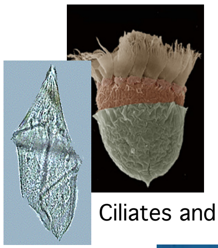
?

Zooplankton major groups used in this course

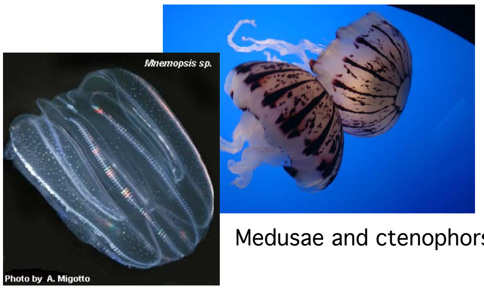

Copepods


Appendicularians

Fish larvae



Ciliates and dinoflagellates

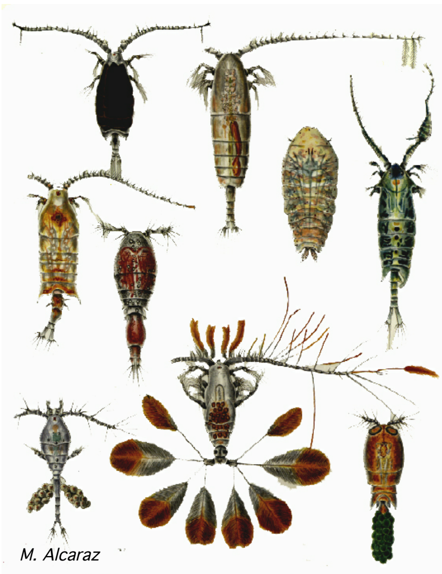

Flagellates



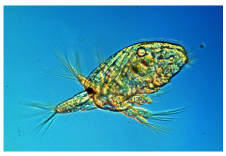
Medusae and ctenophors

?

About copepods

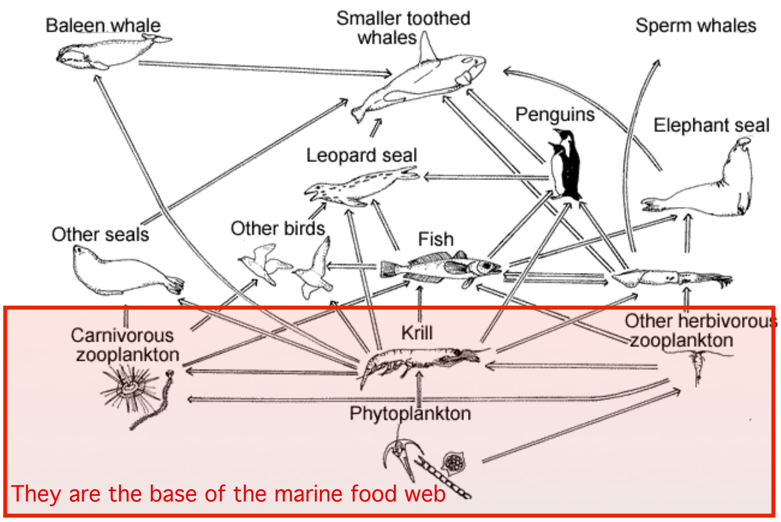


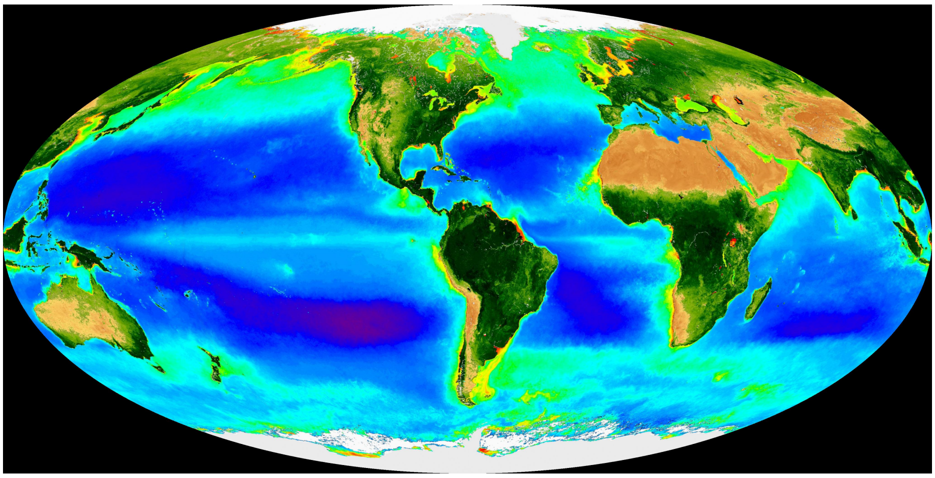

Calanus sp. Adult


Nauplius

The most abundant metazoans on Earth

Why the study of plankton is important?

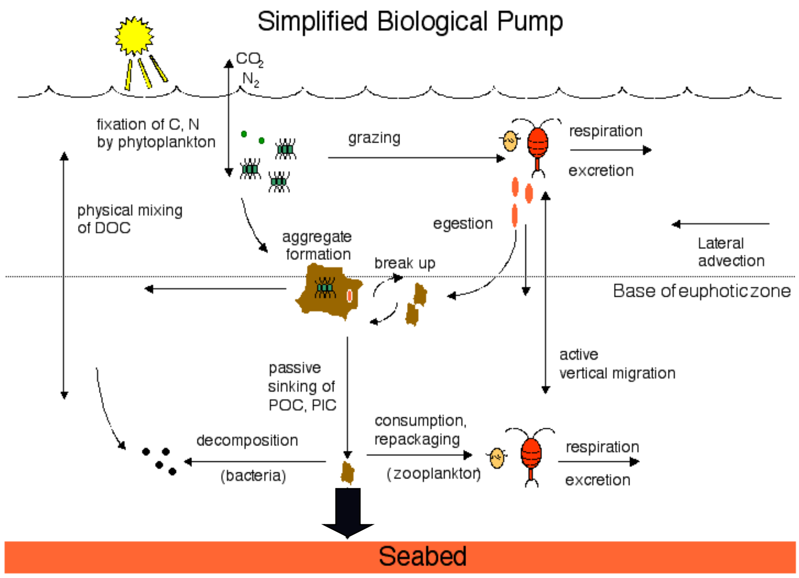




50% of World's primary production occurs in the oceans
90% of ocean's primary production is due to phytoplankton

Field et al. 1998

Plankton feeds the benthos with their activity and regulates the CO_2 cycle:



C4 YT THE NEW YORK TIMES, TUESDAY, MAY 1, 2007

Putting Plankton to Work Against Global Warming

Continued From First Business Page

top oceanographers — wants to commercialize ocean fertilization.

Their efforts underscore a growing effort to pull carbon from the atmosphere. Solutions include planting or restoring forests and — once many economic and technical obstacles are overcome — capturing tons of carbon from coal burning for electricity and oil refineries, piping it back underground or burying it under the ocean.

The technological solutions are starting to come from Silicon Valley, where investors and innovators are turning to environmental businesses. They are investing, too, in fossil fuel alternatives like wind, solar and ethanol power.

The financial returns for reducing carbon could be considerable, said Daniel M. Kammen, a professor at the University of California, Berkeley.

In Europe, where there is a market for carbon credits, it is now worth only $2 to offset a ton of carbon emissions. But not long ago, that figure was $35, and it is expected to rise again as the limits imposed under the Kyoto Protocol on global warming start to bite. Planktos believes that it can make a healthy profit if it receives $5 a ton for capturing carbon dioxide.

"The cost of offsetting carbon through these technologies is less than the cost of building solar panels or windmills," Mr. Kammen said. "There's no question that this is going to grow," he said of various carbon offset strategies.

But the question in the case of iron fertilization is whether the exuberance and marketing spirit of Silicon Valley and its can-do attitude are getting ahead of scientific reality. And some oceanographic experts say that there is a risk of doing more harm than good from artificially stimulating plankton growth in the ocean.

It is widely accepted by scientists that dumping iron in certain areas of the ocean can cause plankton to bloom. But there is considerable skepticism over whether doing so will lead to long-term absorption of carbon dioxide from the atmosphere, said Ken Buesseler, senior scientist at the Woods Hole Oceanographic Institution.

Mr. Buesseler said that while carbon might be absorbed initially, there was ample evidence that when the plankton was eaten or decomposed, at least some of the carbon wound up going back into the atmosphere. The level of absorption depends on how much of the resulting mass of plankton sinks to the sea bed.

And some scholars in the field are concerned that creating plankton blooms could release methane and nitrous oxide, which might increase greenhouse gases. "There are some potentially dangerous side effects," said Paul G. Falkowski, professor of geology and marine science at Rutgers University.

Mr. Buesseler has organized a conference for the fall to bring together the experts in ocean fertilization to assess the years of research in the field and see what might be done to further it. He also wants to explore the policy issues; one unresolved question is whether regulatory bodies will even endorse iron fertilization as a valid means of carbon sequestration that would be allowed under any so-called cap-and-trade system to limit global warming gases.

Many scientists, even those who see long-term promise in the approach, worry that the commercial and political pressures are accelerating the programs too quickly. But others say that such pressure might not be an entirely bad thing.

"The marketing is pushing us forward faster, saying, 'Damn the science,' " Mr. Buesseler. But the vastly heightened concerns about global warming that are driving the market, he said, make it worth the effort. "I'm willing to consider it," he said, "when I consider the consequences of doing nothing."

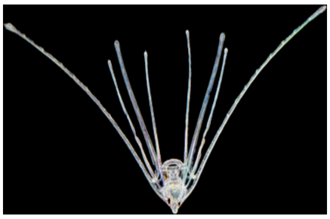
Photographs by Jay Paul for The New York Times

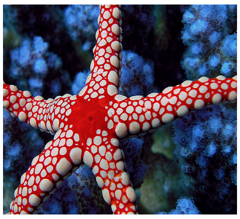
Michael Bailey, left, Melodie Grubbs and Peter Wilcox on the Weather-Bird II, a 115-foot research vessel, that will promote plankton growth.

The Energy Challenge

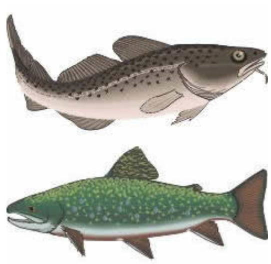
Articles in this series are examining the ways in which the world is, and is not, moving toward a more energy-efficient, environmentally benign future. Previous articles are at nytimes.com/energychallenge.

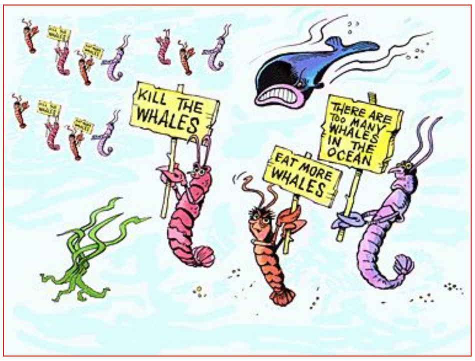
Many benthic organisms have planktonic larvae

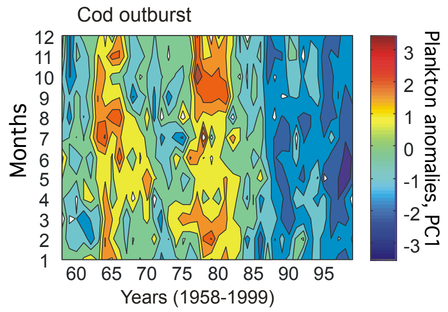




And more zooplankton means more fish, “and whales”





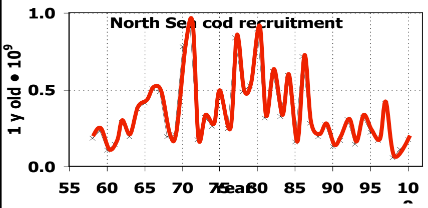
Sometimes this relationship is highly specific; North Sea *C. finmarchicus* and cod



Monthly values of the first PC (33.78% of the total variability).

Main variables by order of importance:

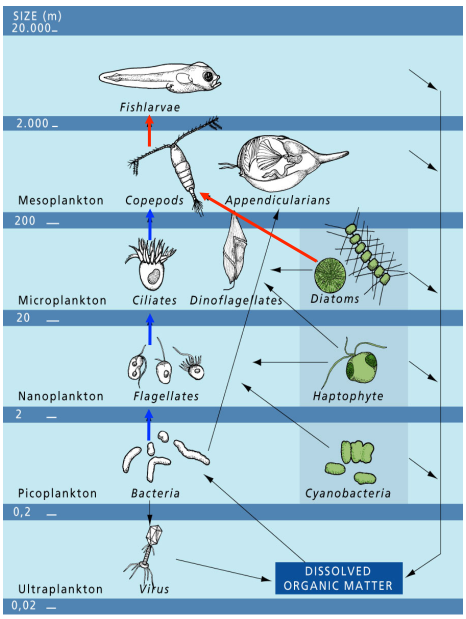
1. mean abundance of *C. finmarchicus*
2. mean abundance of euphausiids
3. mean size of calanoid copepod
4. mean abundance of *C. helgolandicus*
5. calanoid copepod biomass
6. mean abundance of *Pseudocalanus* spp.



This does **not** mean that changes in plankton are the only cause of decline in cod

Beaugrand et al. 2003

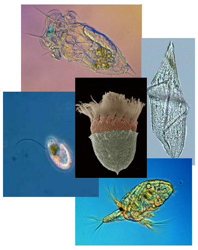
How do the planktonic organisms structure in the ocean?



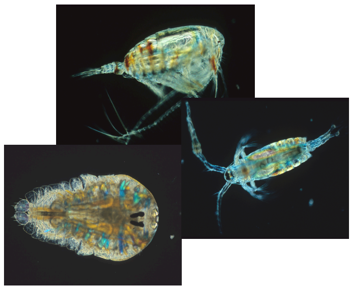
The 'classical food chain based on microplankton (large diatoms)

Microbial food web based on nano- and picoplankton (cyanobacteria etc)

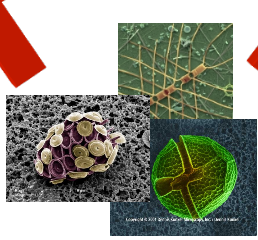
Lets consider 3 main groups of the food web



Microzooplankton



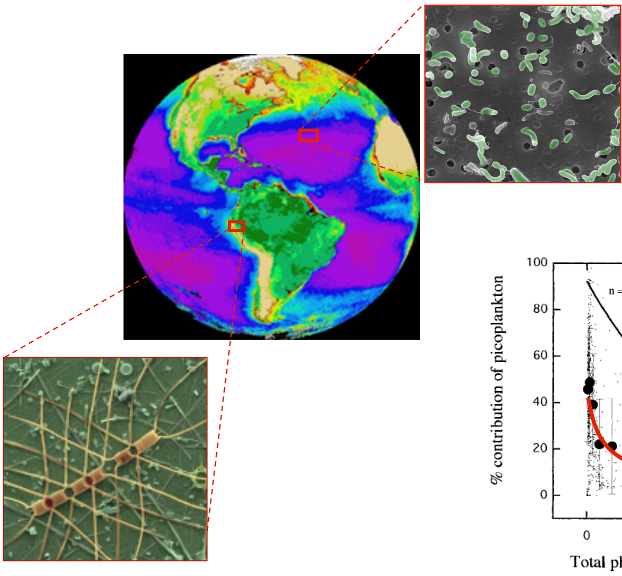
Mesozooplankton (copepods, etc.)



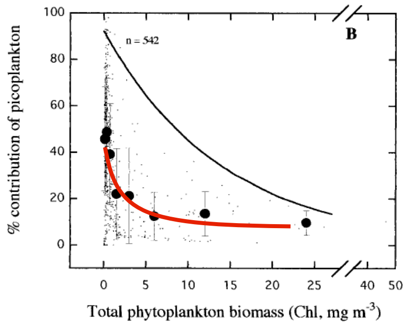
Phytoplankton

How are they going to relate in different ecosystems?

How things work in different ecosystems?



Picoplankton < 2 μm

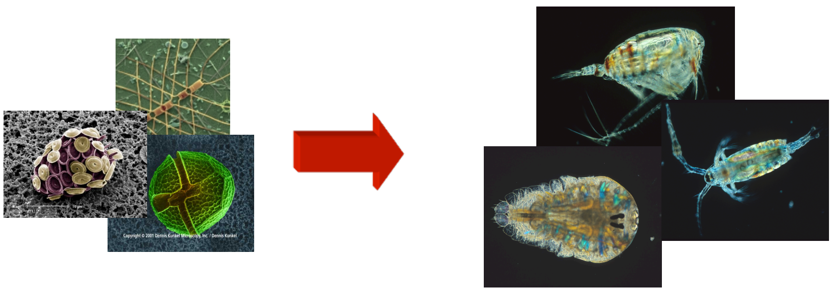


Agawin et al. 2000

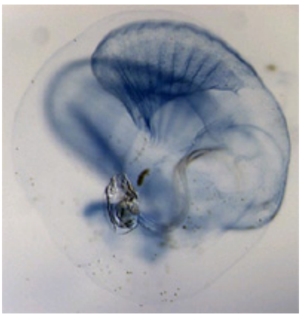
General biomass distribution patterns

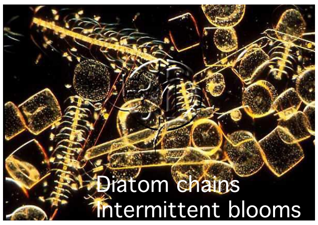
Upwelling Coastal	Oligotrophic Open ocean
↑ Classic food chain	↓ Classic food chain
↓ Microbial food web	↑ Microbial food web

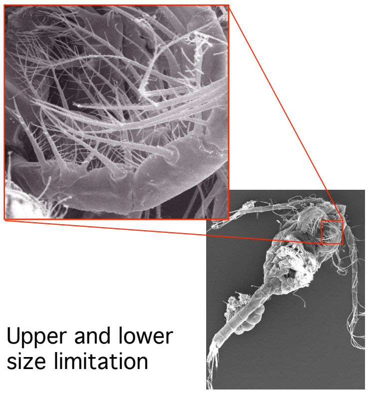
Modificado a partir de Gasol et al., 1997



Role of mesozooplankton shaping the food web

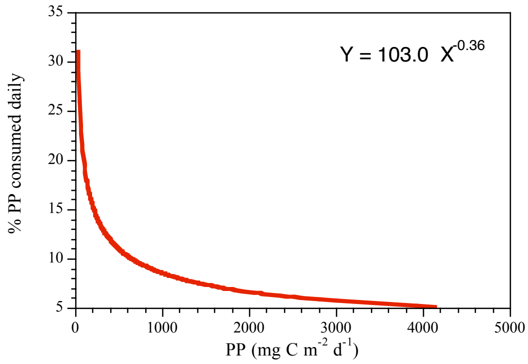






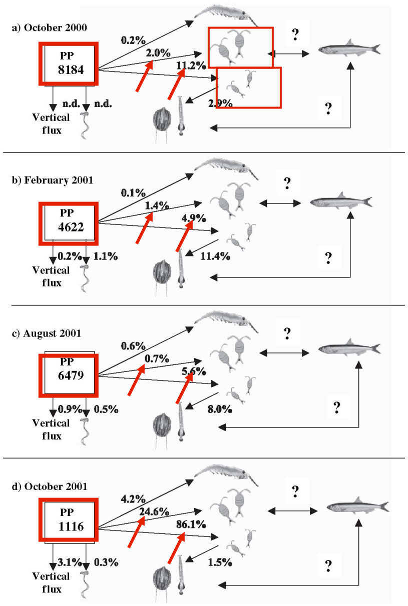
Upper and lower
size limitation

Mesozooplankton control of PP



Calbet 2001

Chile upwelling (*González et al. 2004*)



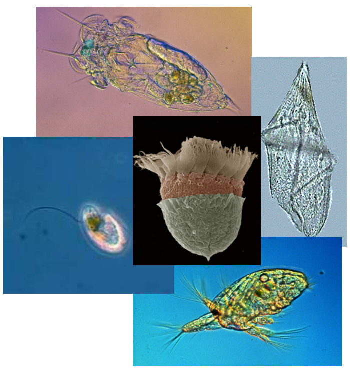
PP = 8184 mg C m^{-2} d^{-1}
Large copepods: 2.9%
Small copepods and appendic: 11.2%

PP = 4622 mg C m^{-2} d^{-1}
Large copepods: 1.4%
Small copepods and appendic: 4.9%

PP = 6479 mg C m^{-2} d^{-1}
Large copepods: 0.7%
Small copepods and appendic: 5.6%

PP = 1116 mg C m^{-2} d^{-1}
Large copepods: 24.6%
Small copepods and appendic: 86.1%

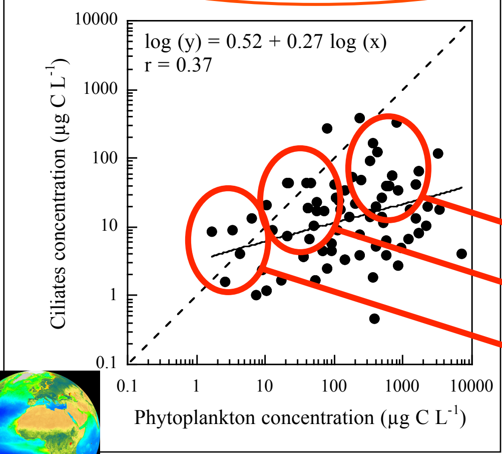
What about other prey?

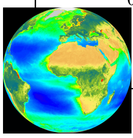


Immediate approach: CILIATES

Ciliates biomass = 7 μg C/l
Phytoplankton biomass = 92.2 μg C/l

1 order of magnitude





The proportion of ciliates decreases as the biomass of phytoplankton increases

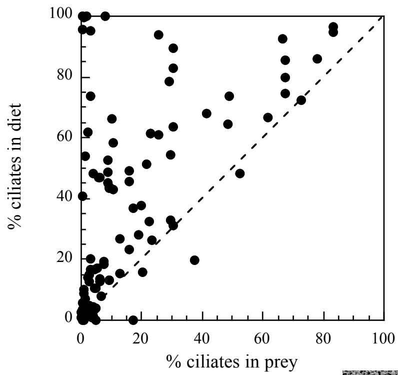
8%

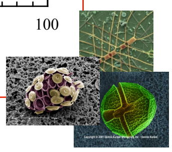
24%

45%

Calbet and Saiz 2005

Proportion of ciliates eaten by copepods





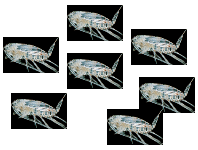
There is a clear selection for ciliates in most ecosystems:

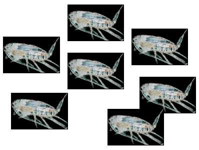
- 1/2 of diet in oligotrophic systems
- 1/3 of diet, on average
- 2.7 Gt C year^{-1} from ciliates

Calbet and Saiz 2005

Impacts upon ciliates

Mesozooplnakton impact upon the standing stock of ciliates: 0-200%
(Dolan 1991, Lonsdale et al. 2000, Koski et al. 2002, Calbet et al. 2003, Broglio et al. 2004)

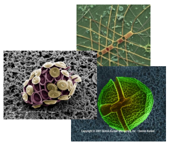




7 copepods l^{-1}

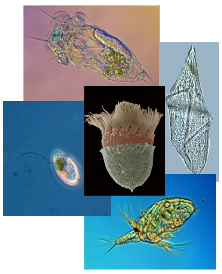
96 copepods l^{-1}

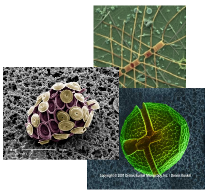
50% *standing stock*



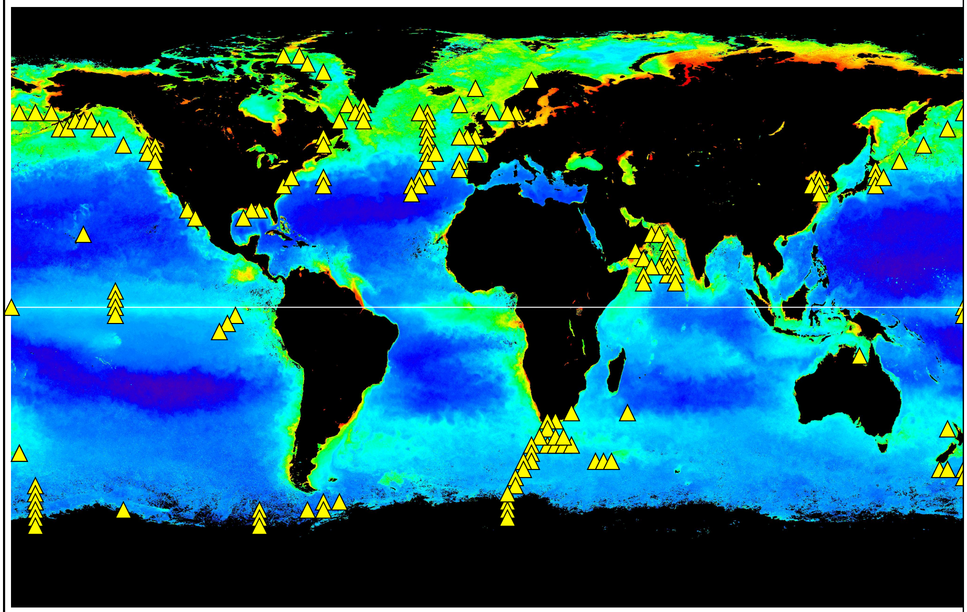
50% *standing stock*

What about microzooplankton grazing on phytoplankton?



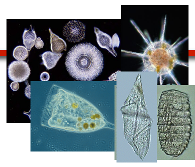


Global microzooplankton grazing assessment (*Calbet and Landry 2004*)



~ 1000 data points based on dilutions

Summary

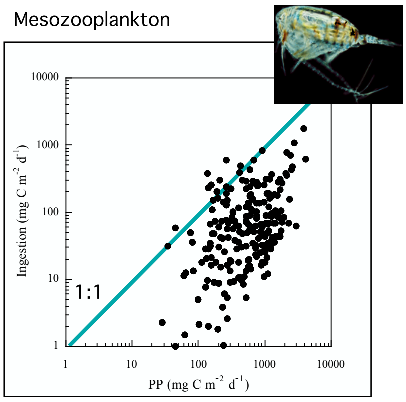


	Chl*a* (μg/L)	μ (d-1)	%PP grazed
Open ocean	0.6 ± 0.03	0.59 ± 0.02	70 ± 1.5
Costal	3.1 ± 0.5	0.67 ± 0.05	60 ± 3.3
Estuaries	13.0 ± 1.8	0.97 ± 0.07	60 ± 2.7
Tropical	1.0 ± 0.2	0.72 ± 0.02	75 ± 2.0
Temperate	5.2 ± 0.7	0.69 ± 0.03	61 ± 1.8
Polar	0.6 ± 0.1	0.44 ± 0.05	59 ± 3.3

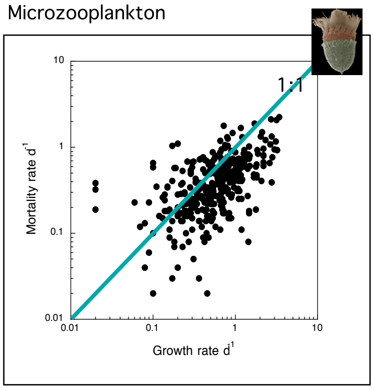
Calbet and Landry 2004

Summary

Mesozooplankton



Microzooplankton



Mean: 12% PP

Mean : 67% PP

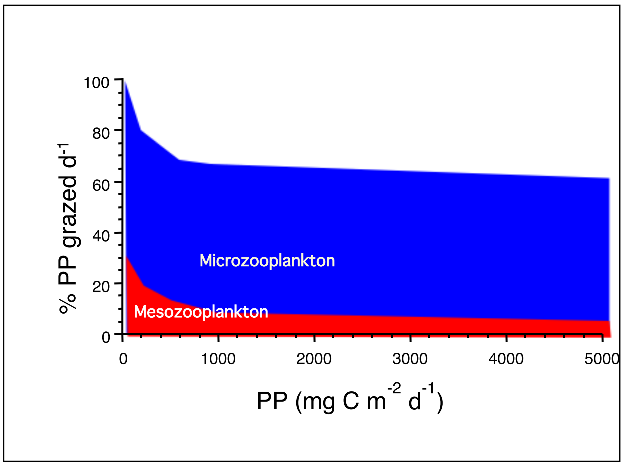
Calbet A. Limnol. Oceanogr. 2001

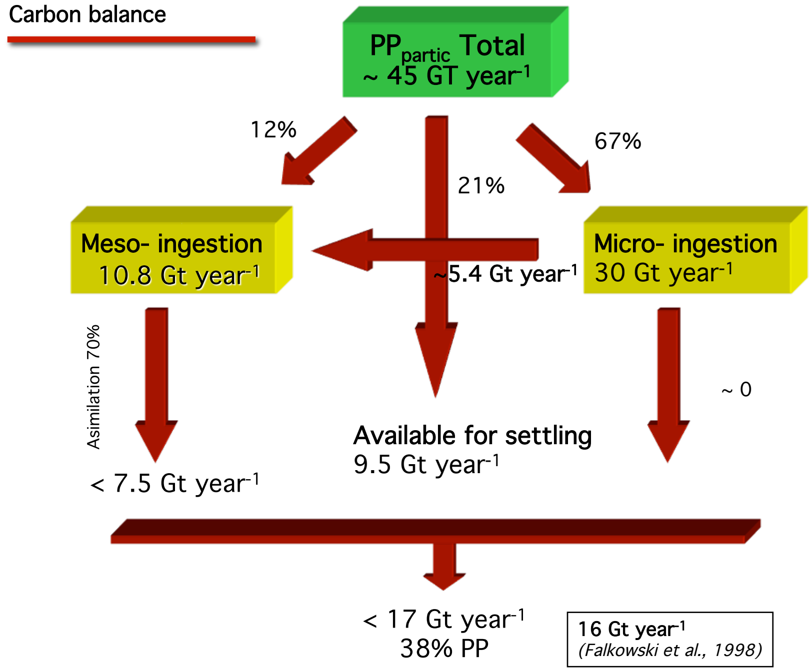
Calbet & Landry. Limnol. Oceanogr. 2004

Summary of zooplankton control on PP

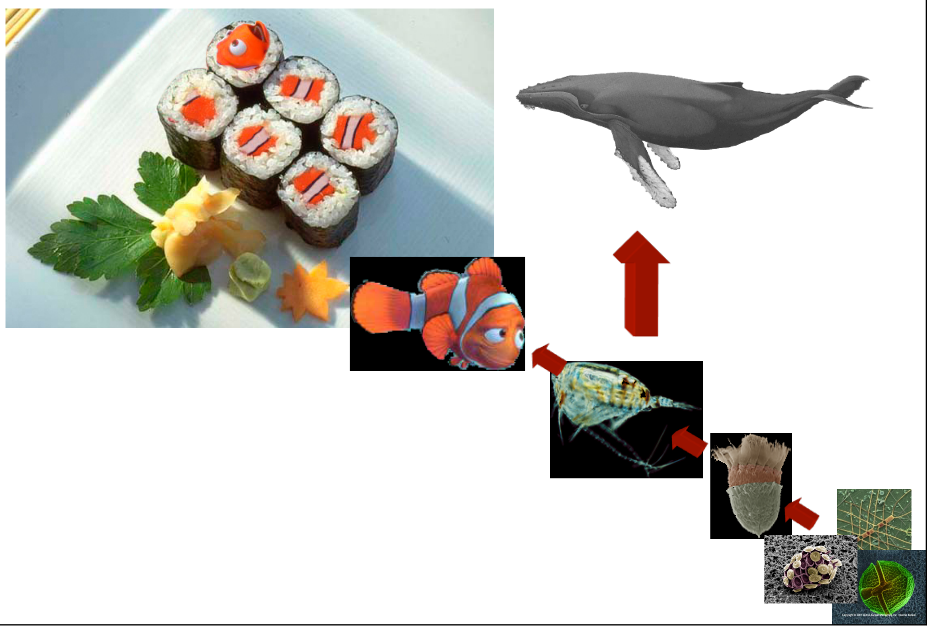
Mesozooplankton ingestion = 5.5 Gt C $year^{-1}$

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



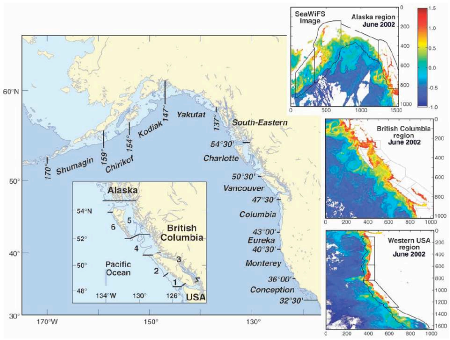


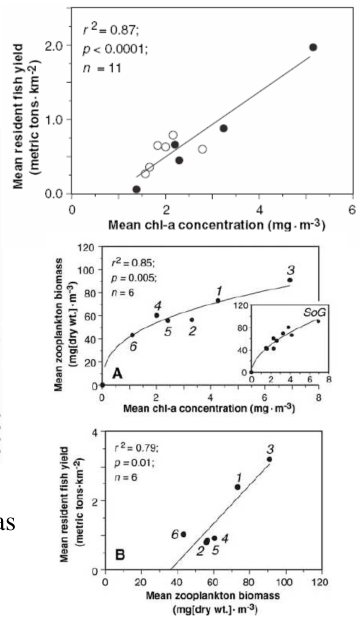
Mesozooplankton keeps having a key role as fish food



Good relationships phyto-zoo-fish

Ware and Thompson 2005. *Science 308:* 1280-1284





Relationship between SeaWiFS – chlorophyll a and fish yield from 11 areas

?

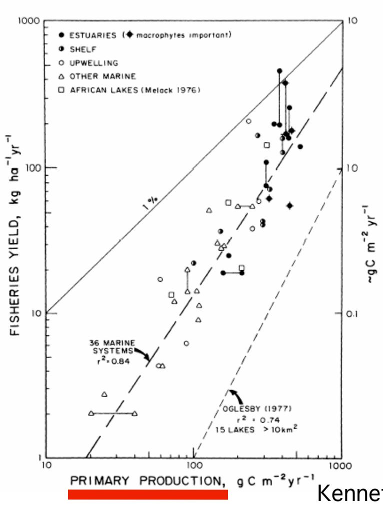
Kenneth Frank

Good predictive value of phytoplankton production as related to fish yield

Nixon 1988 – Physical energy inputs and the comparative ecology of lake and marine ecosystems

- One of the earliest quantitative relationships developed through cross-system comparisons
- Based on mean states

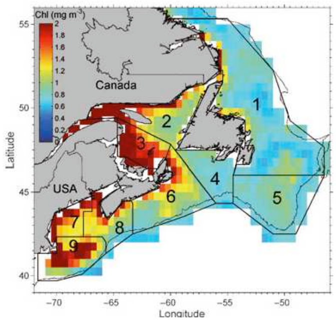
In FY = 1.55 In PP - 4.49

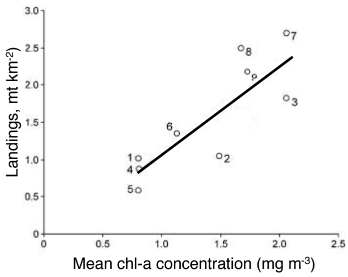


?

Kenneth Frank

Similar analysis conducted in the NW Atlantic



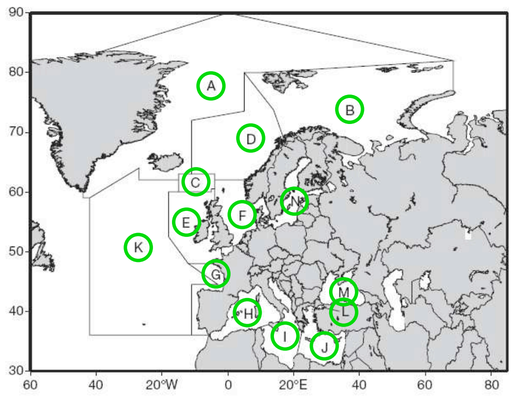


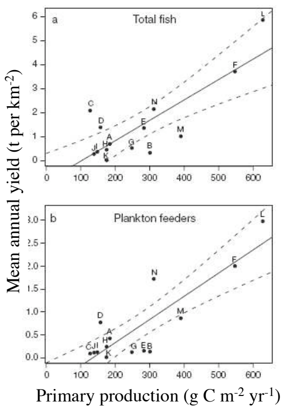
9 areas in NW Atlantic, outlined in black polygons, showing the annual mean SeaWiFS chl a (mg m^3)

Frank et al. 2006. *Ecol. Lett.* 9: 1096-1105

Kenneth Frank

European Seas





Conclusion: primary production regulates fisheries production

Chassot et al. 2007 *MEPS* 343: 45

Kenneth Frank

SOMETIMES THE RELATIONSHIP DOES NOT HOLD AND FISHERIES COLLAPSE

In the FAO fishing areas of --

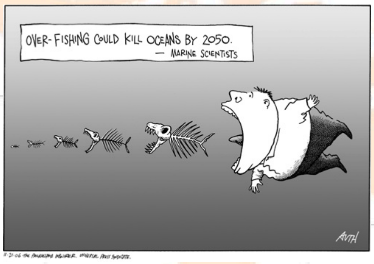
Western Central Atlantic

Eastern Central Atlantic

Northwest Atlantic

Northwest Pacific

Western Indian Ocean



69 – 77 % of stocks exploited at or beyond maximum sustainable levels

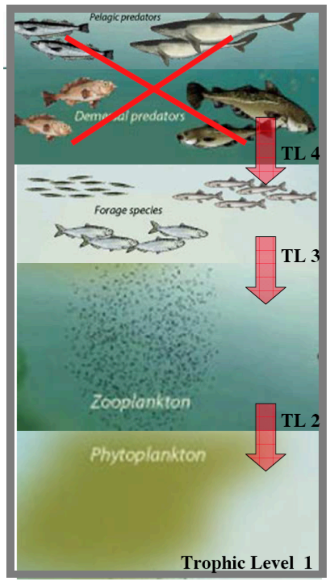
Situation more worrisome in Canadian Atlantic

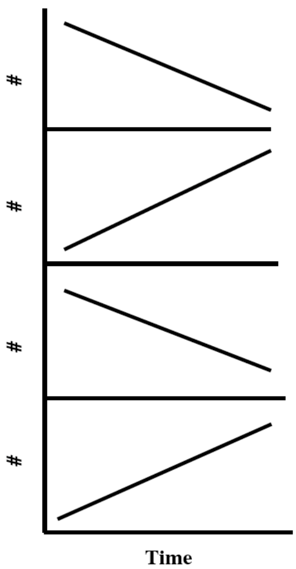
Figure 5. FAO major marine fishing areas for statistical purposes

The State of the World Fisheries and Aquaculture FAO 2006

Kenneth Frank

If top predators depleted then marine food chains may operate differently



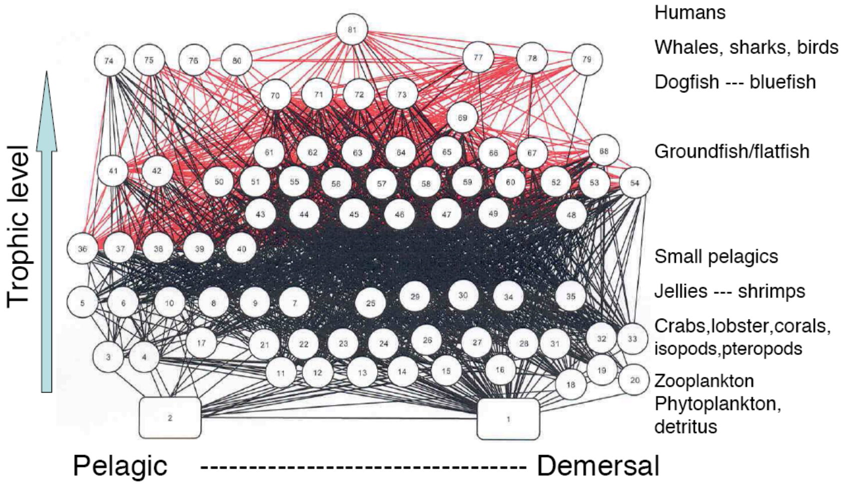


Negative correlation between adjacent trophic levels in food chain

K.T. Frank

Not always easy to model

Georges Bank food web



Summary

Major groups of plankton?

Relationship between groups?

Some times relationships do not hold: reasons?