Royal Netherlands Institute for Sea Research

Creating a Better Understanding of Ecosystem Functioning

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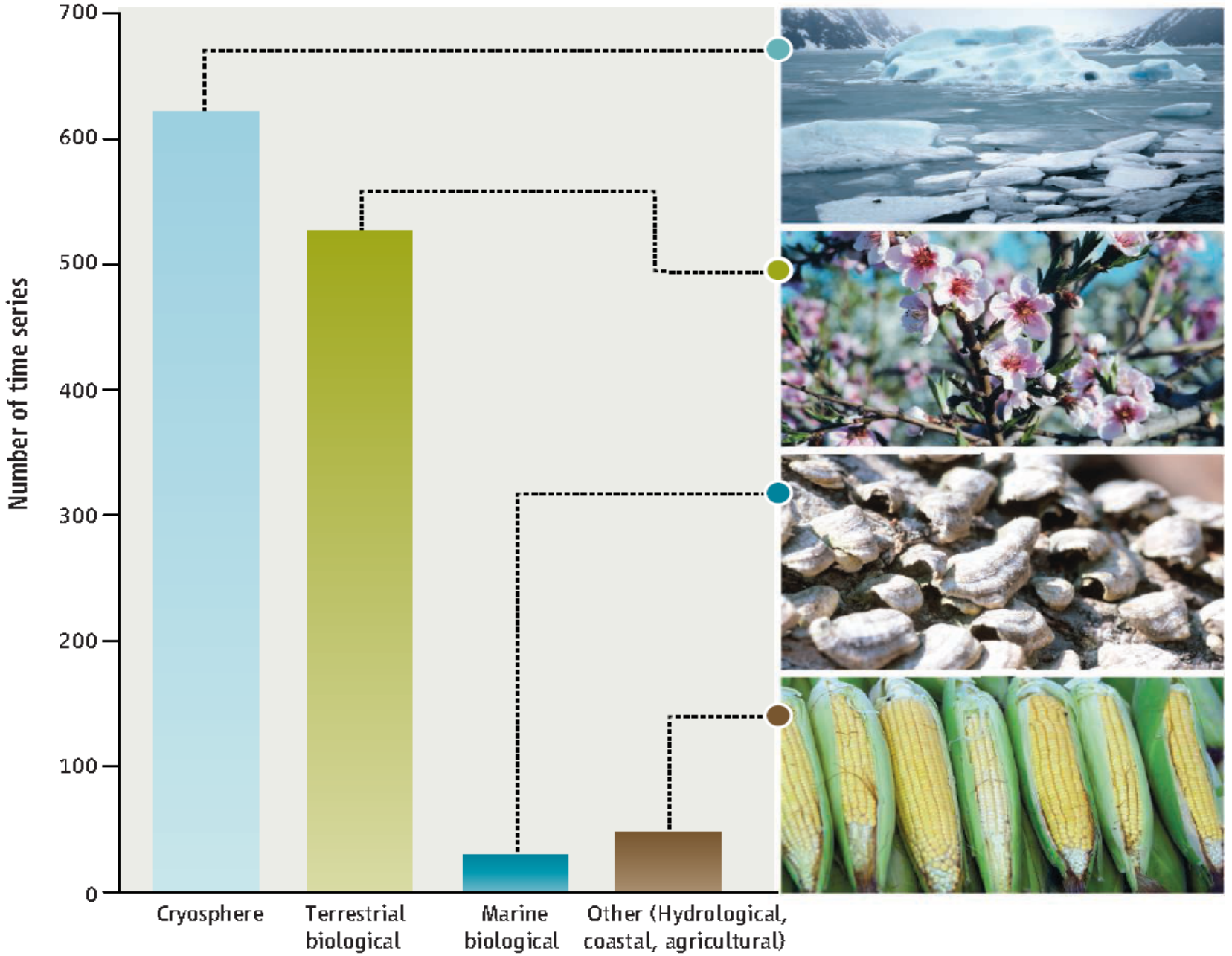
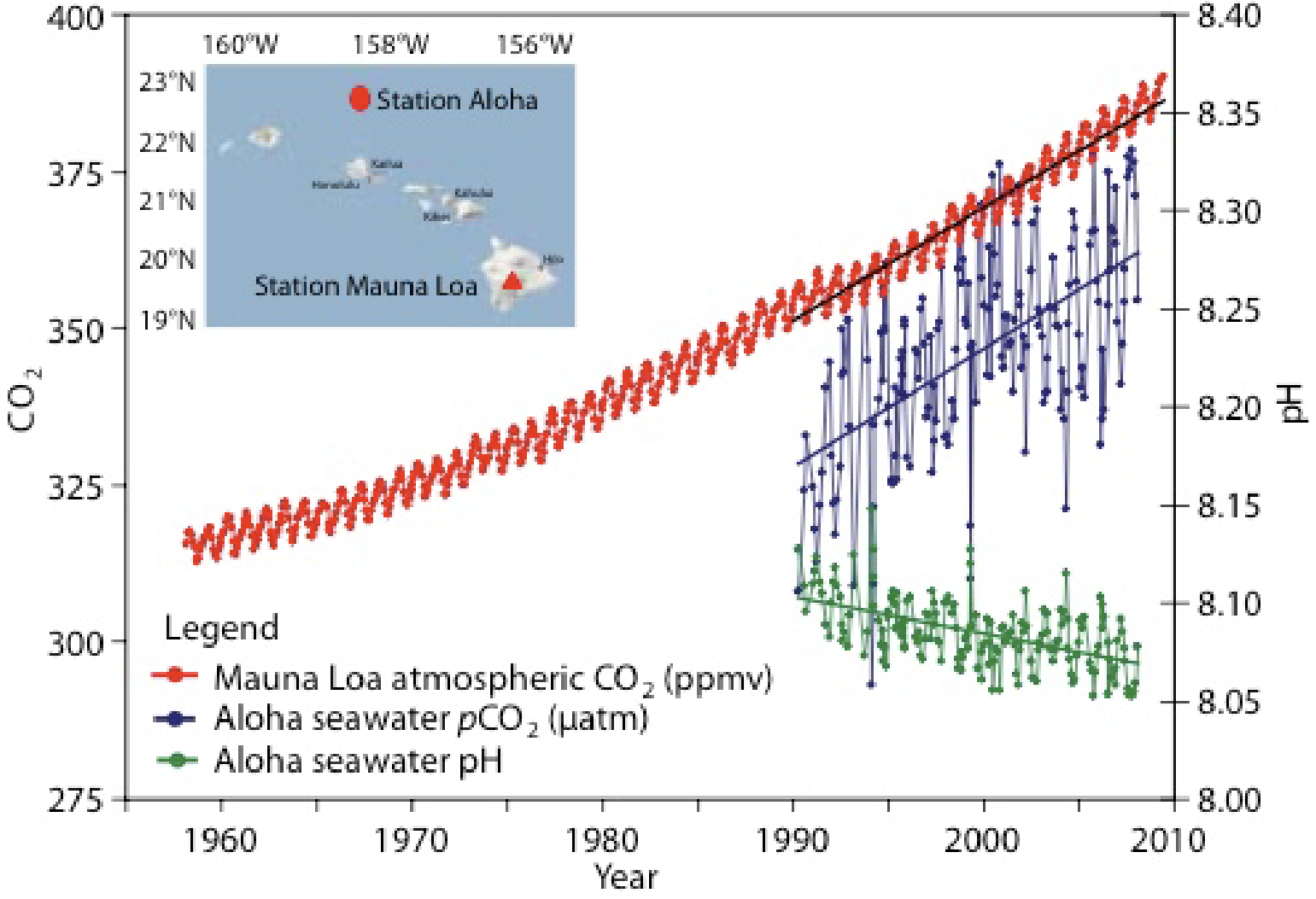
Why should we create a better understanding of marine ecosystems and can we?

- The recent IPCC (Intergovernmental Panel on Climate Change) Fourth Assessment Report (*1)* noted 28,586 significant biological changes in terrestrial systems but only 85 from marine and freshwater systems.



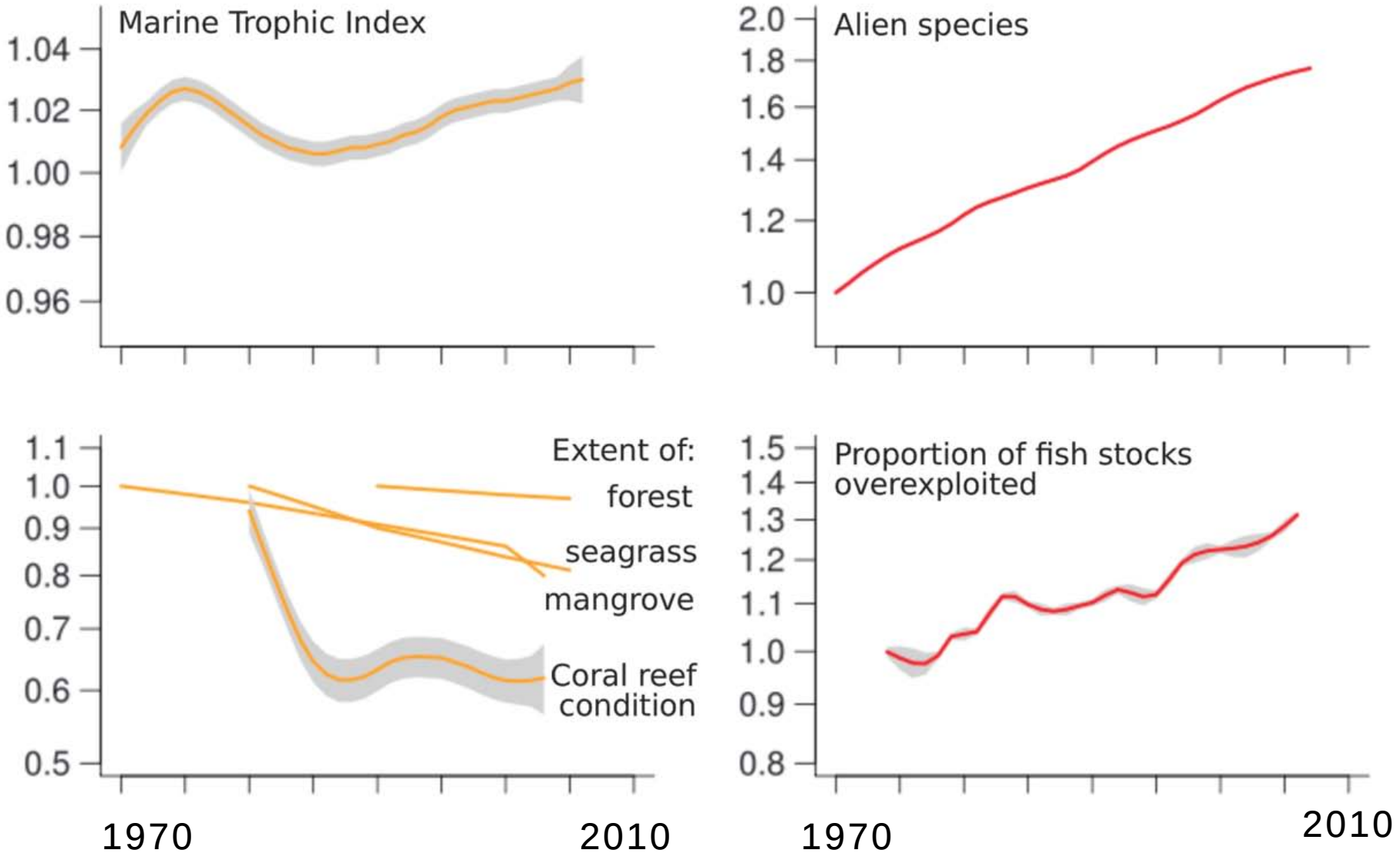
Marine undersampling. The number of time series from different environments included in the recent IPCC (Intergovernmental Panel on Climate Change) Fourth Assessment Report differ widely. Marine systems are vastly underrepresented compared with terrestrial systems (*1*).


160°W
158°W
156°W
23°N
22°N
21°N
20°N
19°N
Station Aloha
Station Mauna Loa
400
375
350
325
300
275
CO_2
8.40
8.35
8.30
8.25
8.20
8.15
8.10
8.05
8.00
pH
1960
1970
1980
1990
2000
2010
Year
Legend
Mauna Loa atmospheric CO_2 (ppmv)
Aloha seawater pCO_2 (µatm)
Aloha seawater pH

Global Biodiversity: Indicators of Recent Declines

Stuart H. M. Butchart,[1,2]* Matt Walpole,[1] Ben Collen,[3] Arco van Strien,[4] Jörn P. W. Scharlemann,[1] Rosamunde E. A. Almond,[1] Jonathan E. M. Baillie,[3] Bastian Bomhard,[1] Claire Brown,[1] John Bruno,[5] Kent E. Carpenter,[6] Geneviève M. Carr,[7]† Janice Chanson,[8] Anna M. Chenery,[1] Jorge Csirke,[9] Nick C. Davidson,[10] Frank Dentener,[11] Matt Foster,[12] Alessandro Galli,[13] James N. Galloway,[14] Piero Genovesi,[15] Richard D. Gregory,[16] Marc Hockings,[17] Valerie Kapos,[1,18] Jean-Francois Lamarque,[19] Fiona Leverington,[17] Jonathan Loh,[20] Melodie A. McGeoch,[21] Louise McRae,[3] Anahit Minasyan,[22] Monica Hernández Morcillo,[1] Thomasina E. E. Oldfield,[23] Daniel Pauly,[24] Suhel Quader,[25] Carmen Revenga,[26] John R. Sauer,[27] Benjamin Skolnik,[28] Dian Spear,[29] Damon Stanwell-Smith,[1] Simon N. Stuart,[1,12,30,31] Andy Symes,[2] Megan Tierney,[1] Tristan D. Tyrrell,[1] Jean-Christophe Vié,[32] Reg Watson[24]

SCIENCE VOL 328 28 MAY 2010


Marine Trophic Index
1.04
1.02
1.00
0.98
0.96
Alien species
2.0
1.8
1.6
1.4
1.2
1.0
1.1
1.0
0.9
0.8
0.7
0.6
0.5
Extent of:
forest
seagrass
mangrove
Coral reef condition
1970
2010
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
Proportion of fish stocks overexploited
1970
2010

Trends in spawning cod biomass* and in fishing mortality

*quantity of mature fish

Stock size

Fishing mortality

North Sea Cod

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North Sea cod at crisis point

By Alex Kirby
BBC News Online environment correspondent

Cod stocks around the British coast are now so low that fishing should stop until they recover, scientists say.

The number of young North Sea cod in early 2003 was the lowest for 20 years.

North Sea cod "face collapse like Newfoundland's"

In many areas, the fish are even less numerous than the scientists had predicted.

They believe it will take several years before there can be any hope of a real recovery

SEE ALSO:
- Cod crisis 'worse than thought' 11 Jun 03 | Europe
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- EU tightens cod fishing rules 06 May 03 | Europe
- 'If we can't fish, we can't live' 18 Feb 03 | England

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North Sea sees recovery of cod stocks

Cod stocks in the North Sea are showing encouraging signs of a "rapid" recovery after being on the brink of extinction.

By Jasper Copping
Published: 9:00PM GMT 31 Jan 2009

From The Times
September 10, 2009

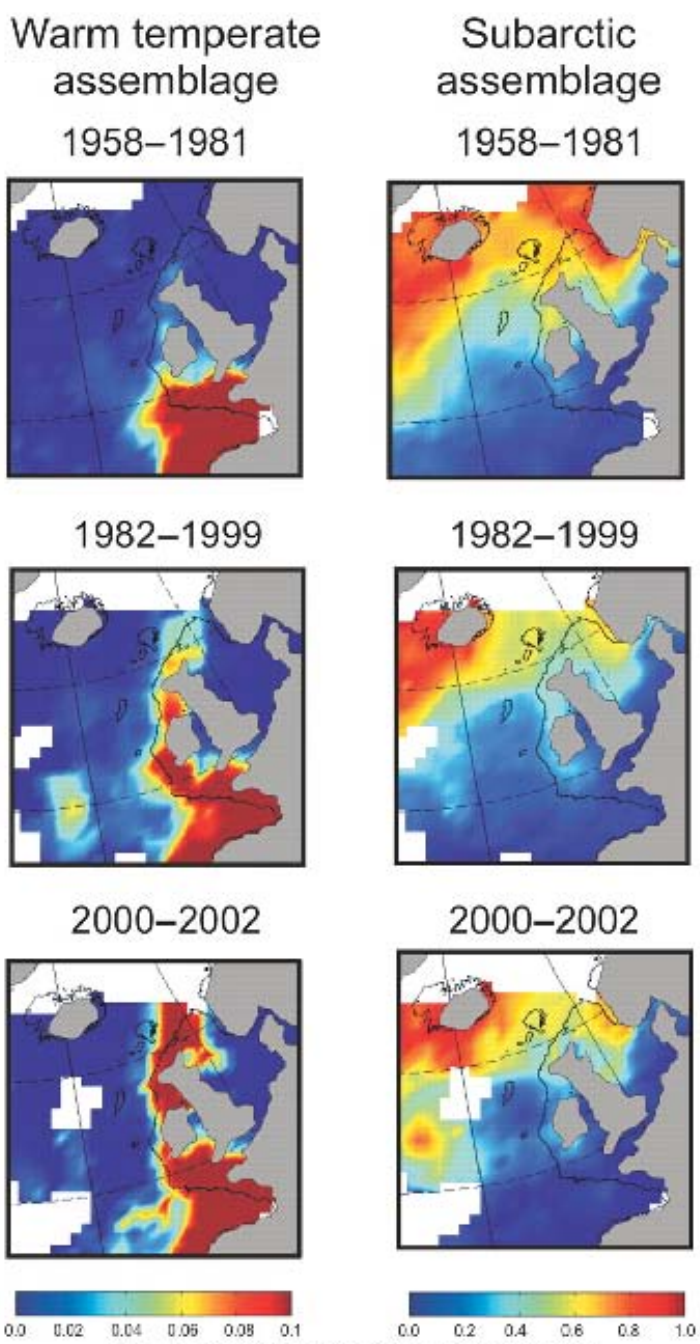
North Sea cod 'doomed by climate change'

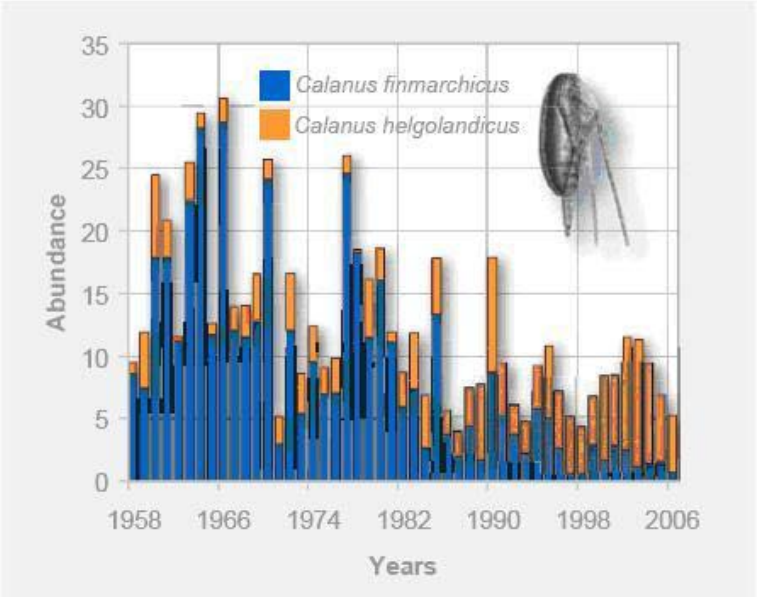
Simon de Bruxelles

Cod are doomed to disappear from the North Sea because of climate change and not just as a result of over-fishing, researchers have discovered.

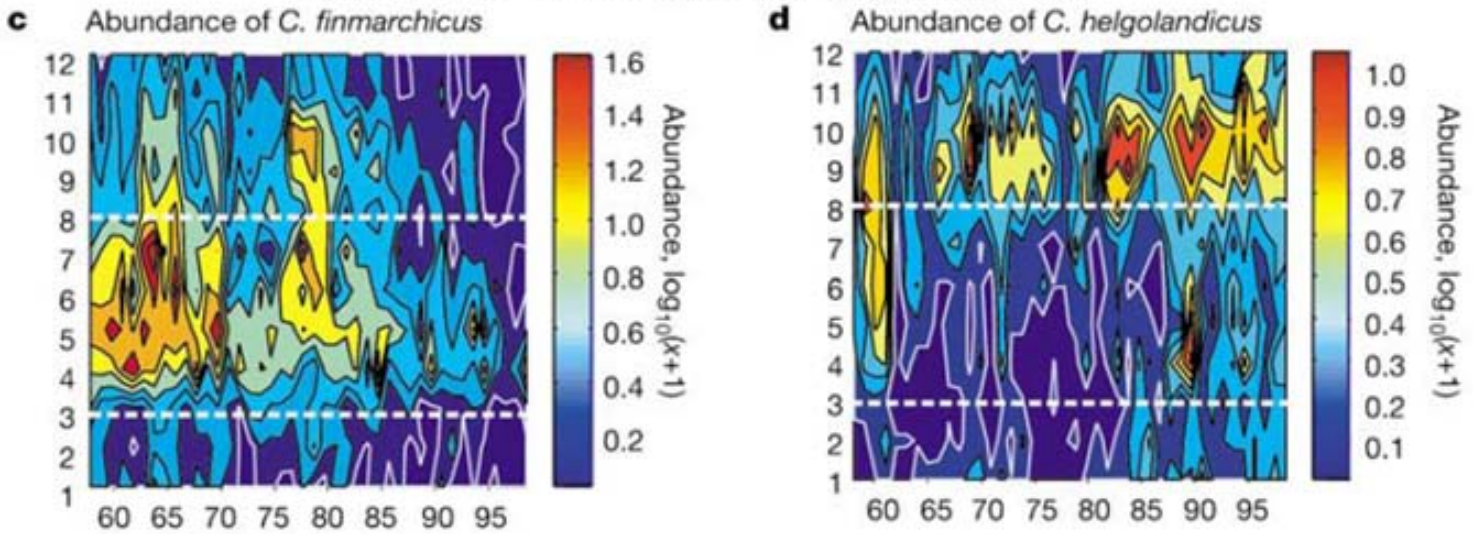
news

Climate findings let fishermen off the hook

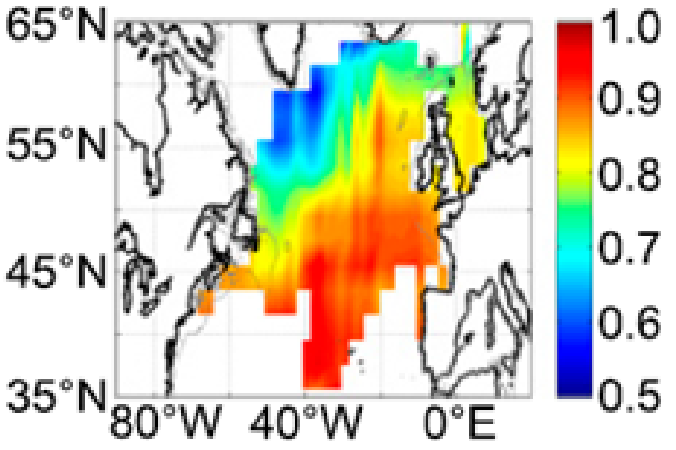

Warm temperate assemblage
Subarctic assemblage
1958–1981
1958–1981
1982–1999
1982–1999
2000–2002
2000–2002
0.0 0.02 0.04 0.06 0.08 0.1
0.0 0.2 0.4 0.6 0.8 1.0
Mean number of species per sample



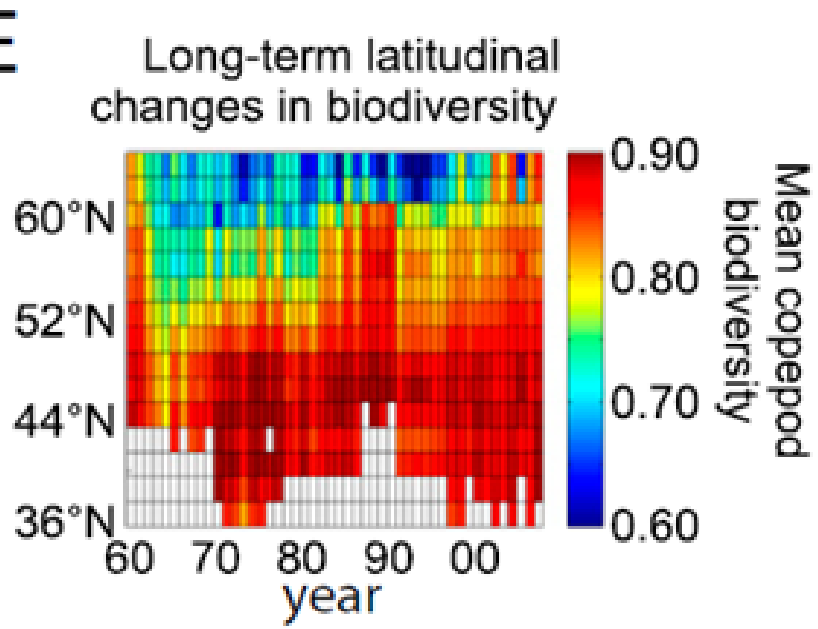
Mismatch between the timing of *Calanus* prey and larval cod

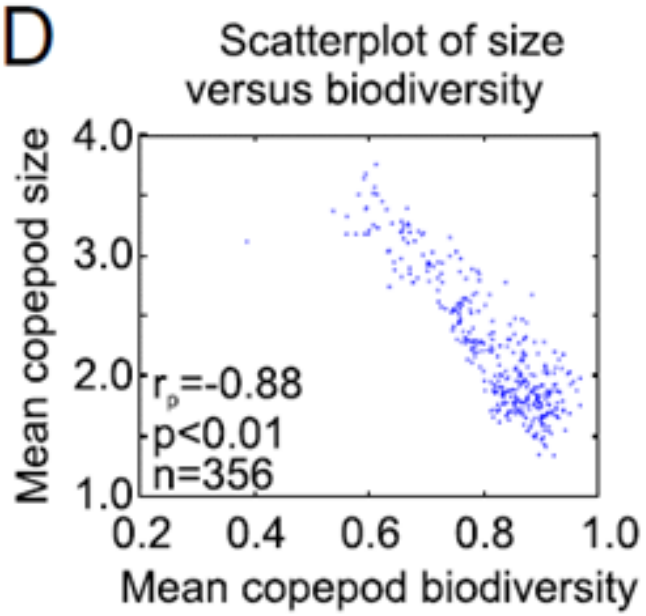


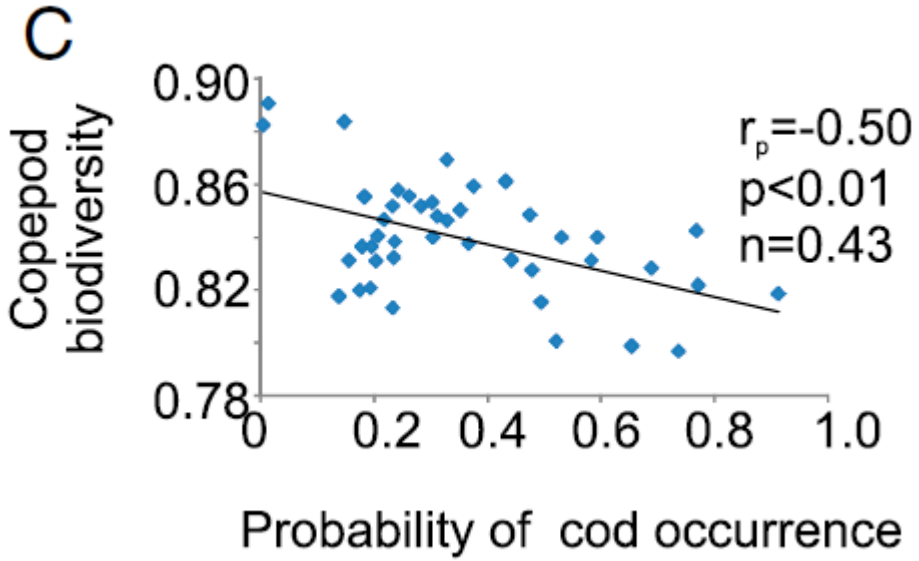
A


Mean copepod biodiversity
65°N
55°N
45°N
35°N
80°W
40°W
0°E
1.0
0.9
0.8
0.7
0.6
0.5

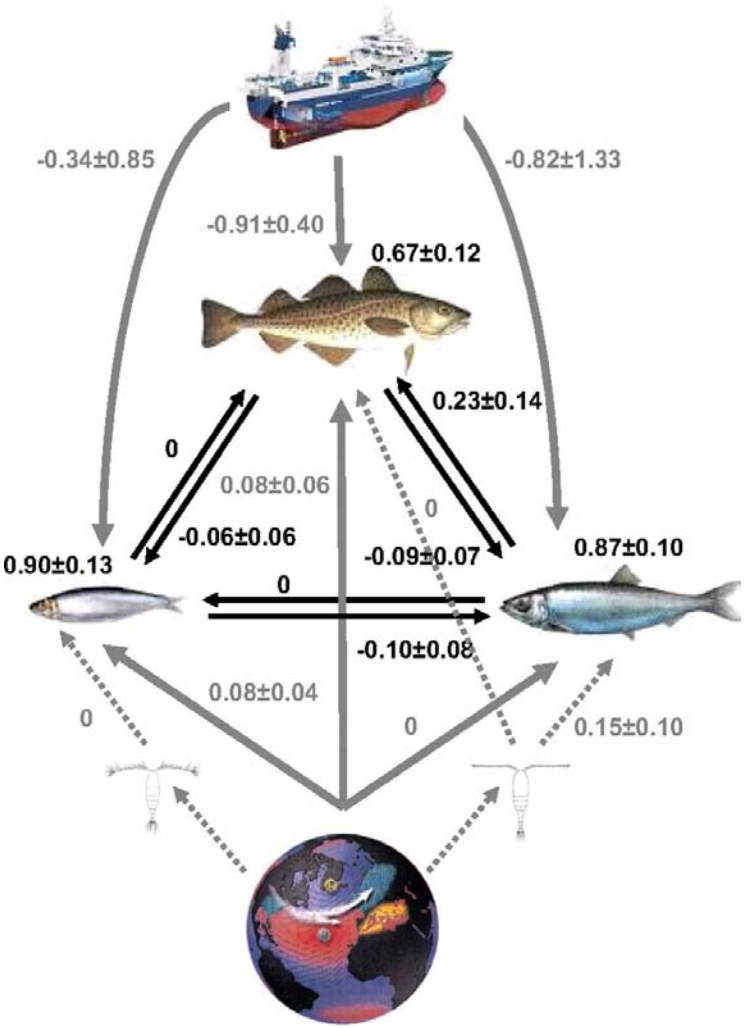
E


Long-term latitudinal changes in biodiversity
60°N
52°N
44°N
36°N
60
70
80
90
00
year
0.90
0.80
0.70
0.60
Mean copepod biodiversity

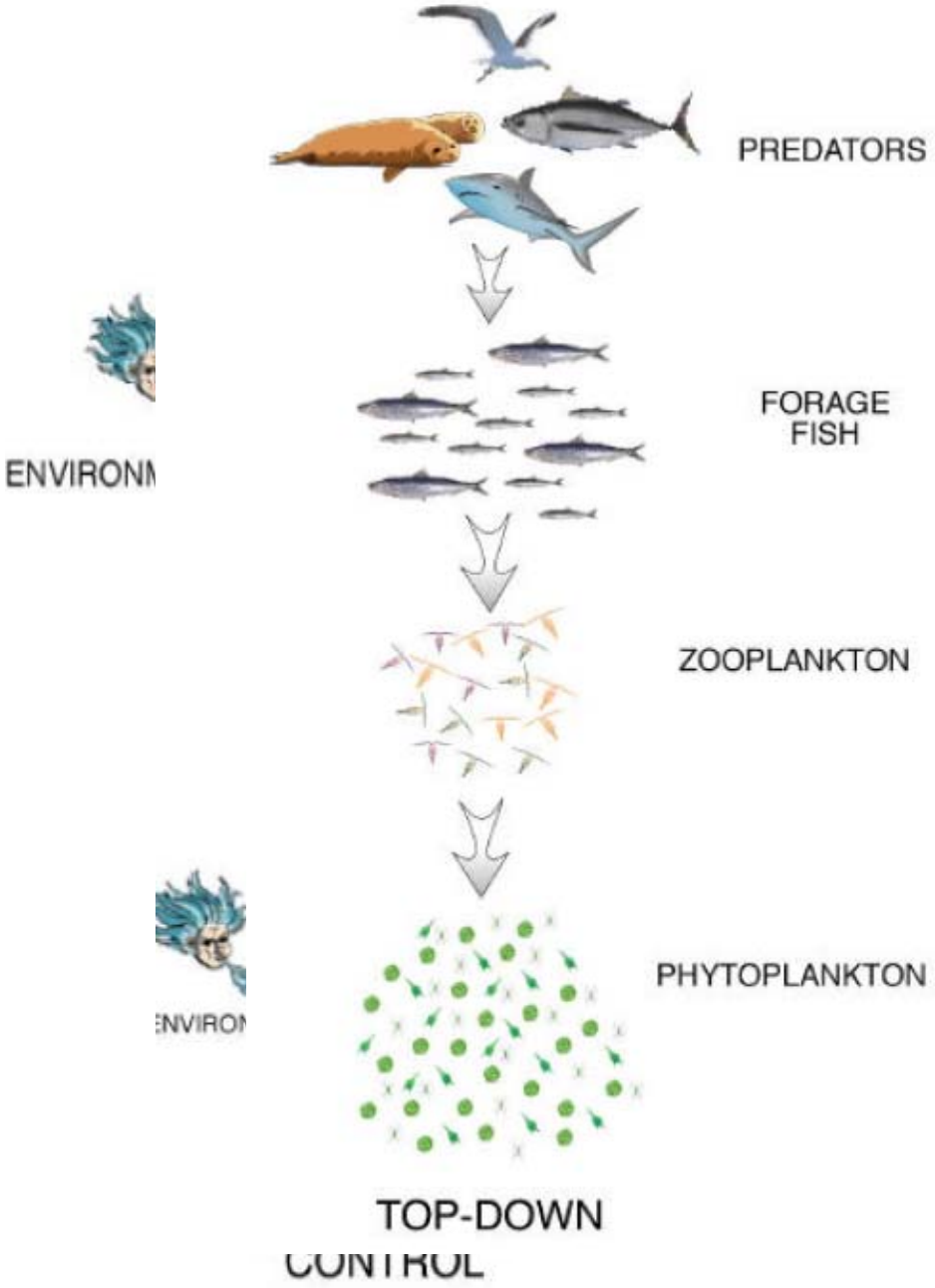

D
Scatterplot of size versus biodiversity
Mean copepod size
4.0
3.0
2.0
1.0
r_p=-0.88
p<0.01
n=356
0.2
0.4
0.6
0.8
1.0
Mean copepod biodiversity


C
Copepod biodiversity
0.90
0.86
0.82
0.78
r_p=-0.50
p<0.01
n=0.43
0
0.2
0.4
0.6
0.8
1.0
Probability of cod occurrence

A schematic view of the Baltic Sea upper-trophic food web.

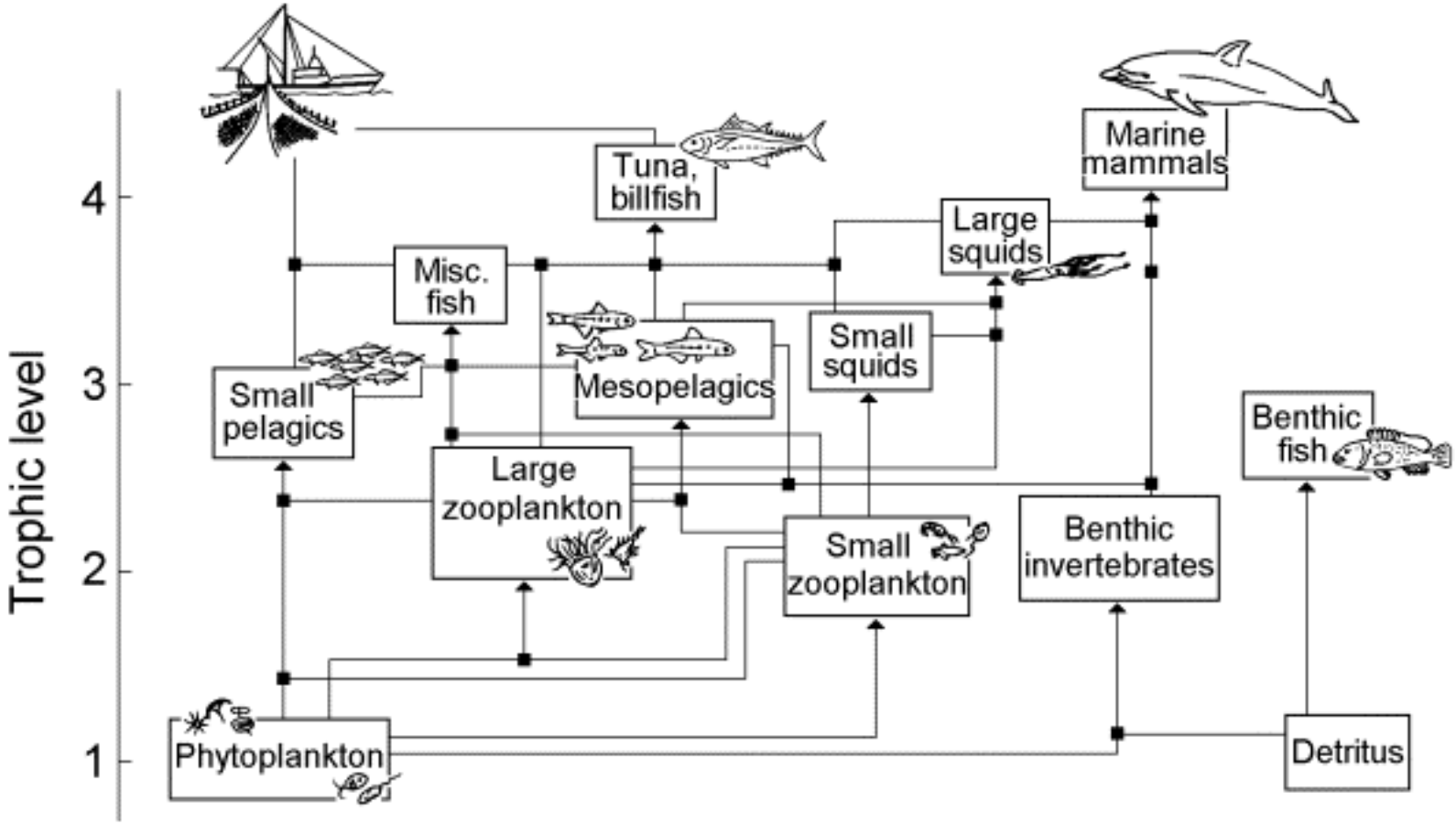


Lindegren M et al. PNAS 2009;106:14722-14727

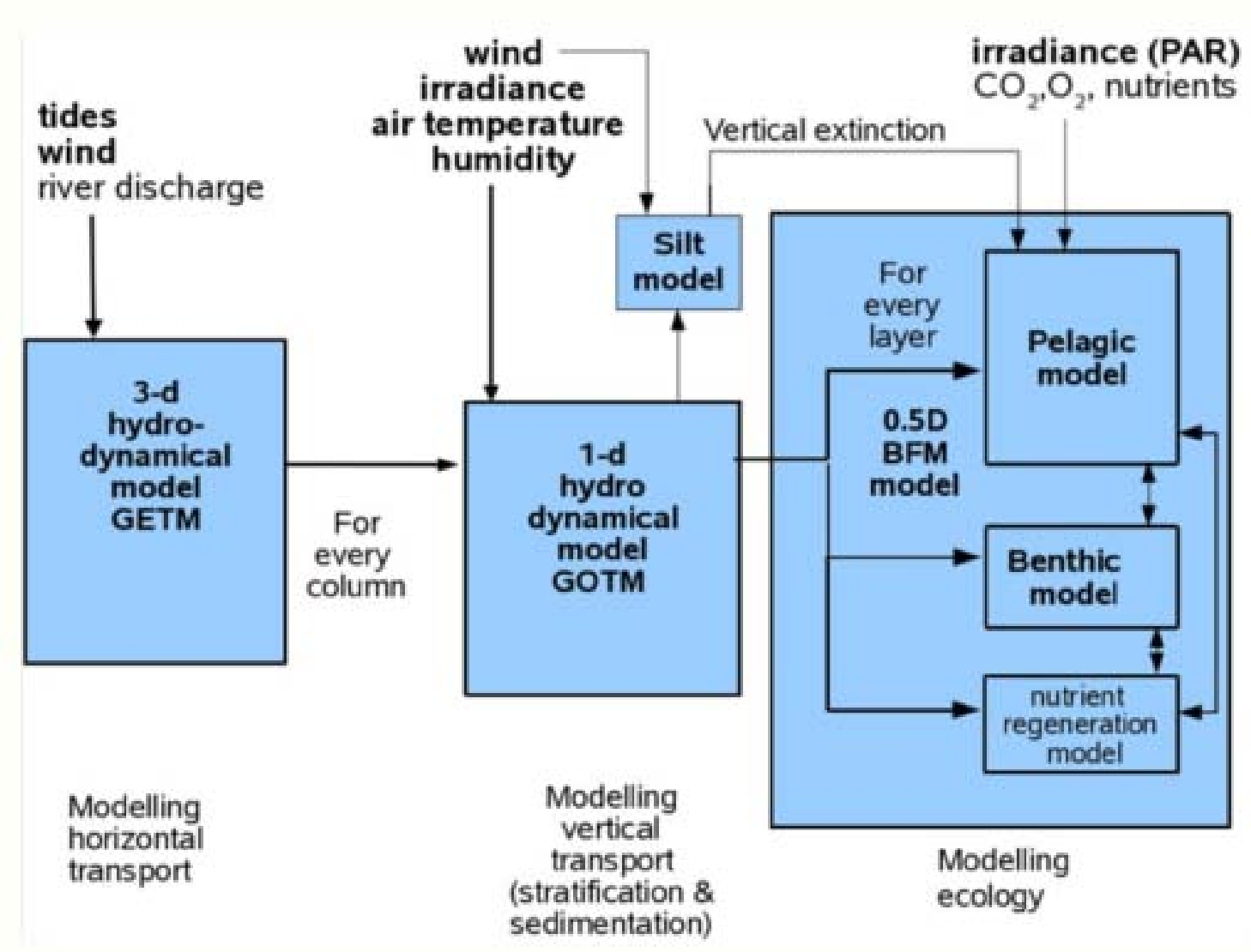

PREDATORS
FORAGE FISH
ZOOPLANKTON
PHYTOPLANKTON
TOP-DOWN
CONTROL

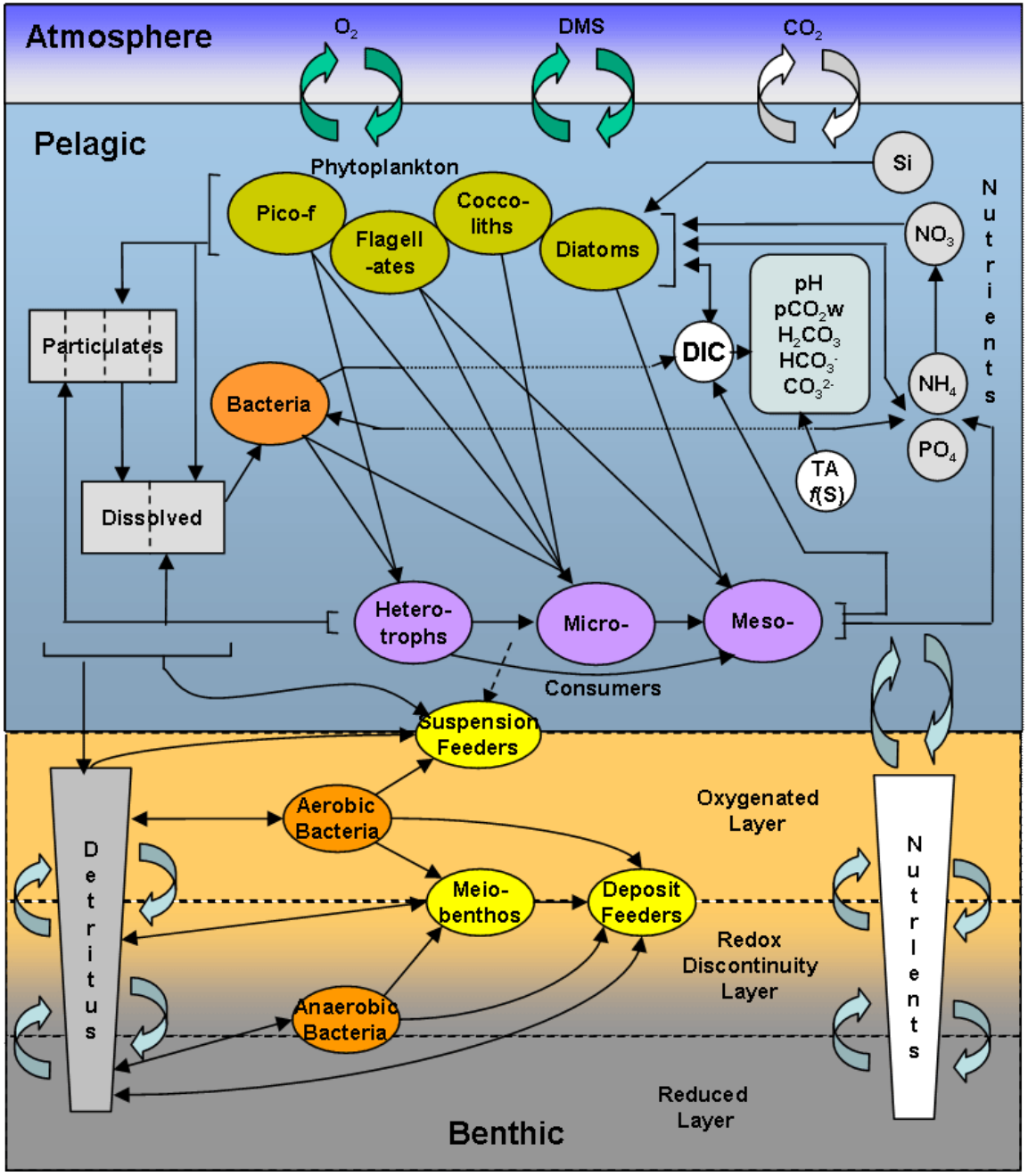
/ et al. 2001

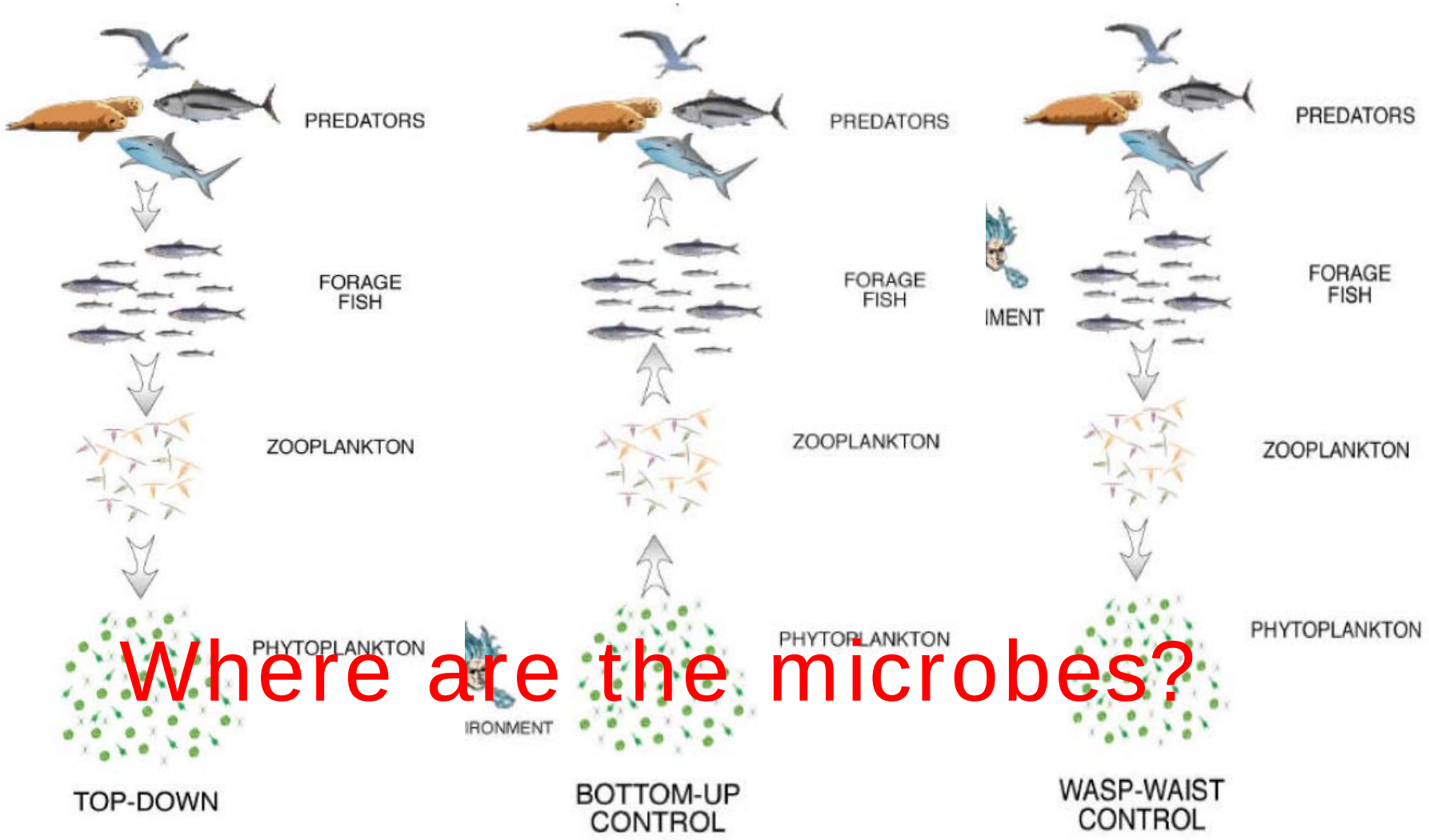
Models?


Trophic level
4
3
2
1
Tuna, billfish
Marine mammals
Misc. fish
Large squids
Small squids
Mesopelagics
Small pelagics
Large zooplankton
Small zooplankton
Benthic fish
Benthic invertebrates
Phytoplankton
Detritus

European Regional Seas Ecosystem Model

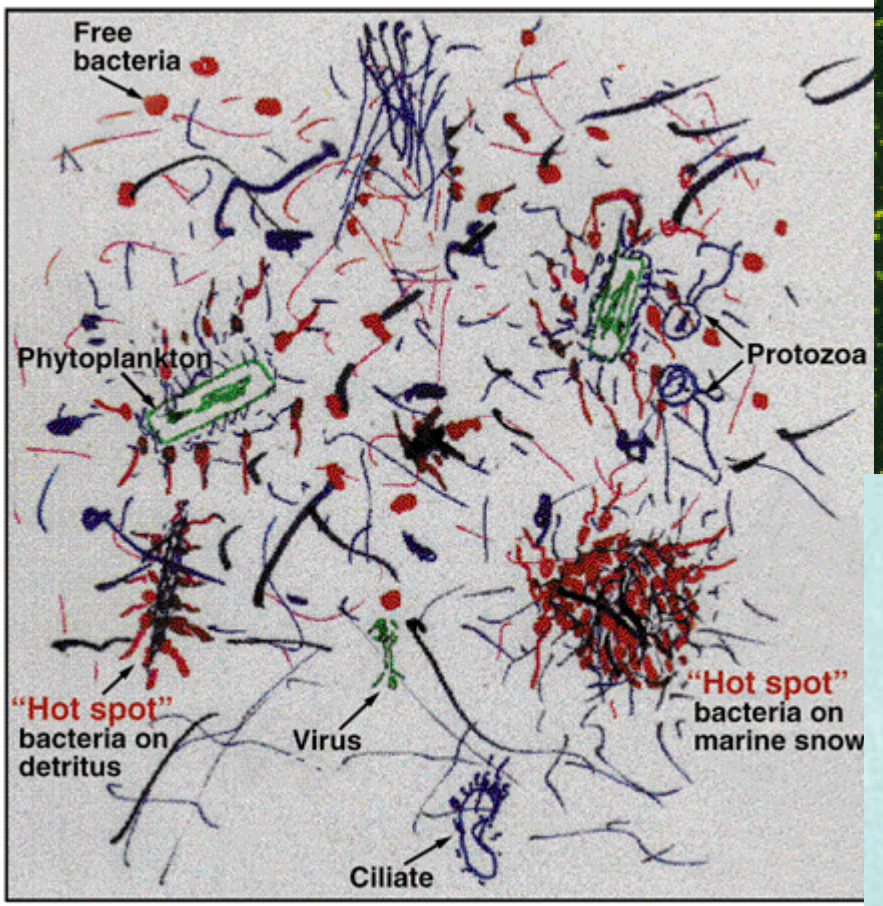


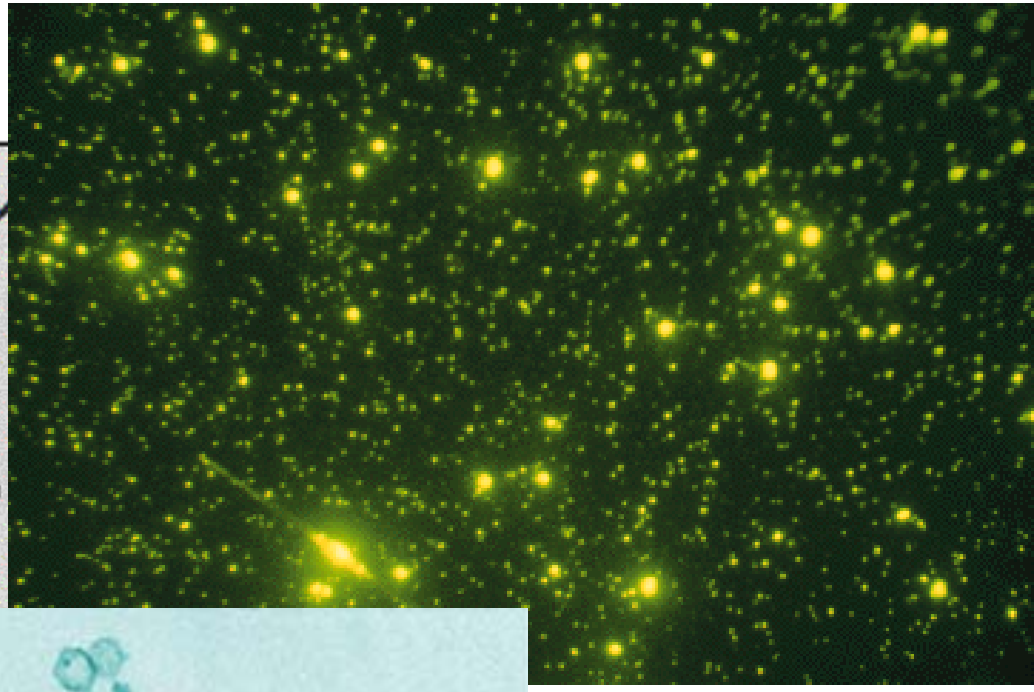

Atmosphere
O2
DMS
CO2
Pelagic
Phytoplankton
Pico-f
Flagell -ates
Cocco- liths
Diatoms
Si
NO3
Nutrients
pH
pCO2w
H2CO3
HCO3-
CO3 2-
DIC
NH4
PO4
TA f(S)
Particulates
Dissolved
Bacteria
Hetero- trophs
Micro-
Meso-
Consumers
Suspension Feeders
Aerobic Bacteria
Oxygenated Layer
Detritus
Meio- benthos
Deposit Feeders
Redox Discontinuity Layer
Anaerobic Bacteria
Nutrients
Reduced Layer
Benthic

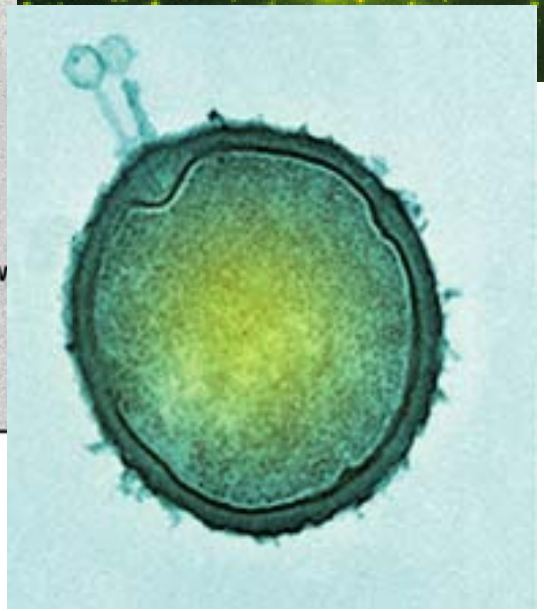


Where are the microbes?

Cury et al. 2001


Free bacteria
Phytoplankton
Protozoa
"Hot spot" bacteria on detritus
Virus
"Hot spot" bacteria on marine snow
Ciliate





New organisms = new metabolisms

Proteorhodopsin phototrophy in the ocean

Oded Béjà*†, Elena N. Spudich†‡, John L. Spudich‡, Marion Leclerc* & Edward F. DeLong*

Bacterial Rhodopsin: Evidence for a New Type of Phototrophy in the Sea

Oded Béjà,[1] L. Aravind,[2] Eugene V. Koonin,[2] Marcelino T. Suzuki,[1] Andrew Hadd,[3] Linh P. Nguyen,[3] Stevan B. Jovanovich,[3] Christian M. Gates,[3] Robert A. Feldman,[3] John L. Spudich,[4] Elena N. Spudich,[4] Edward F. DeLong[1]*

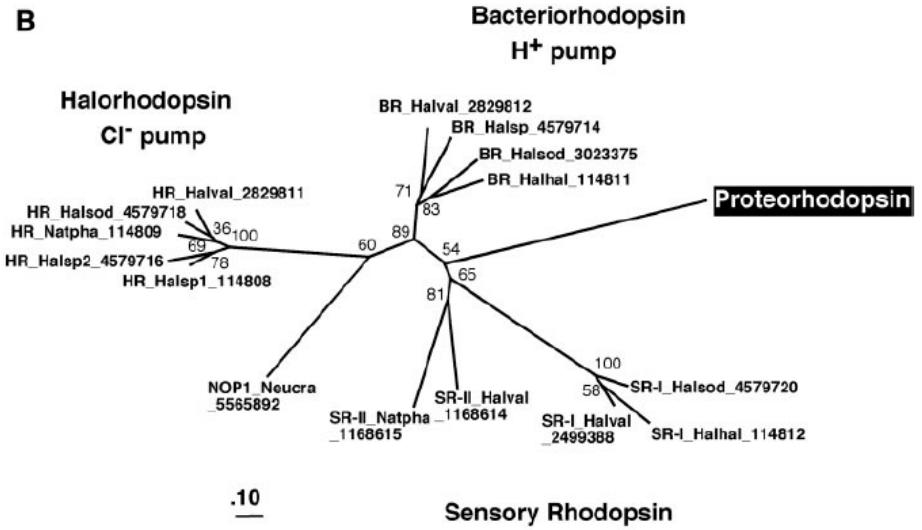
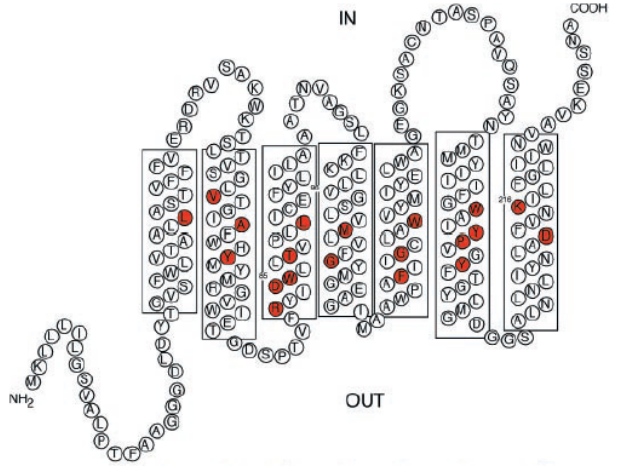


Fig. 2. Secondary structure of proteorhodopsin. Single-letter amino acid codes are used (33), and the numbering is as in bacteriorhodopsin. Predicted retinal binding pocket residues are marked in red.



Recent discoveries of new marine bacteria[2, 3, 4, 5, 6, 7, 8, 9] include all three modes of photosynthesis: oxygenic photosynthesis (OP), anaerobic anoxygenic photosynthesis (AnAnP) and aerobic anoxygenic photosynthesis (AAnP), as well as two other potentially important light-driven processes, rhodopsin-based (RH) and phytochrome-based (PC) interactions that involve both light and DOM. Together, these light-driven processes, as well as others not shown here, sustain and control the flow of external energy into the global ocean. Each metabolic pathway is also dependent on the availability of DOM, ranging from low dependence (true photosynthesis) to high dependence (light-stimulated DOM respiration). DOM has at least two key functions: metabolism (ATP formation) and biosynthesis. Pure OP may be the exception in low-nutrient oceans, whereas mixed light–DOM metabolic processes are more likely in the open sea. Ecologists have yet to establish a comprehensive metabolic budget for these complex marine systems.

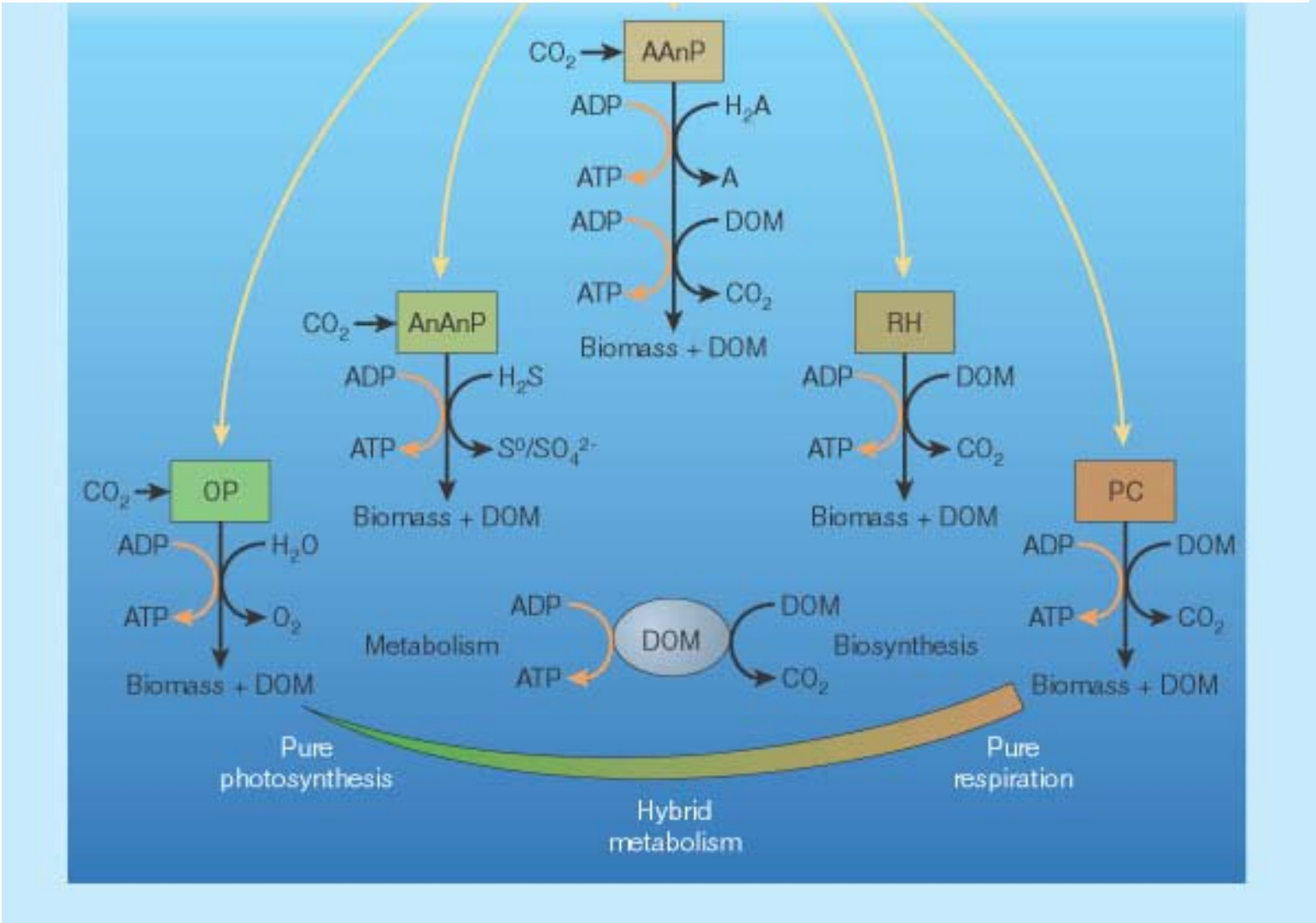
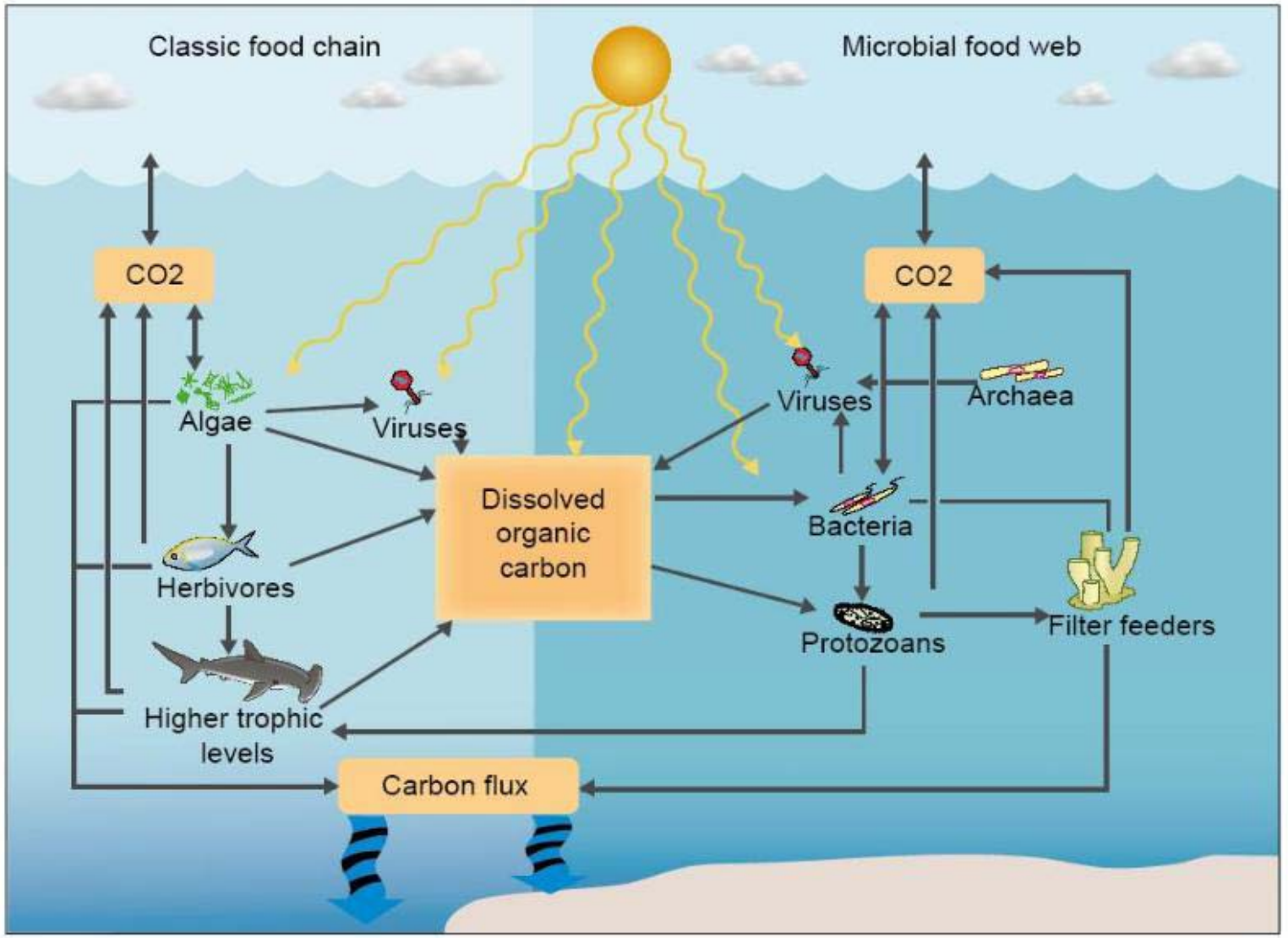
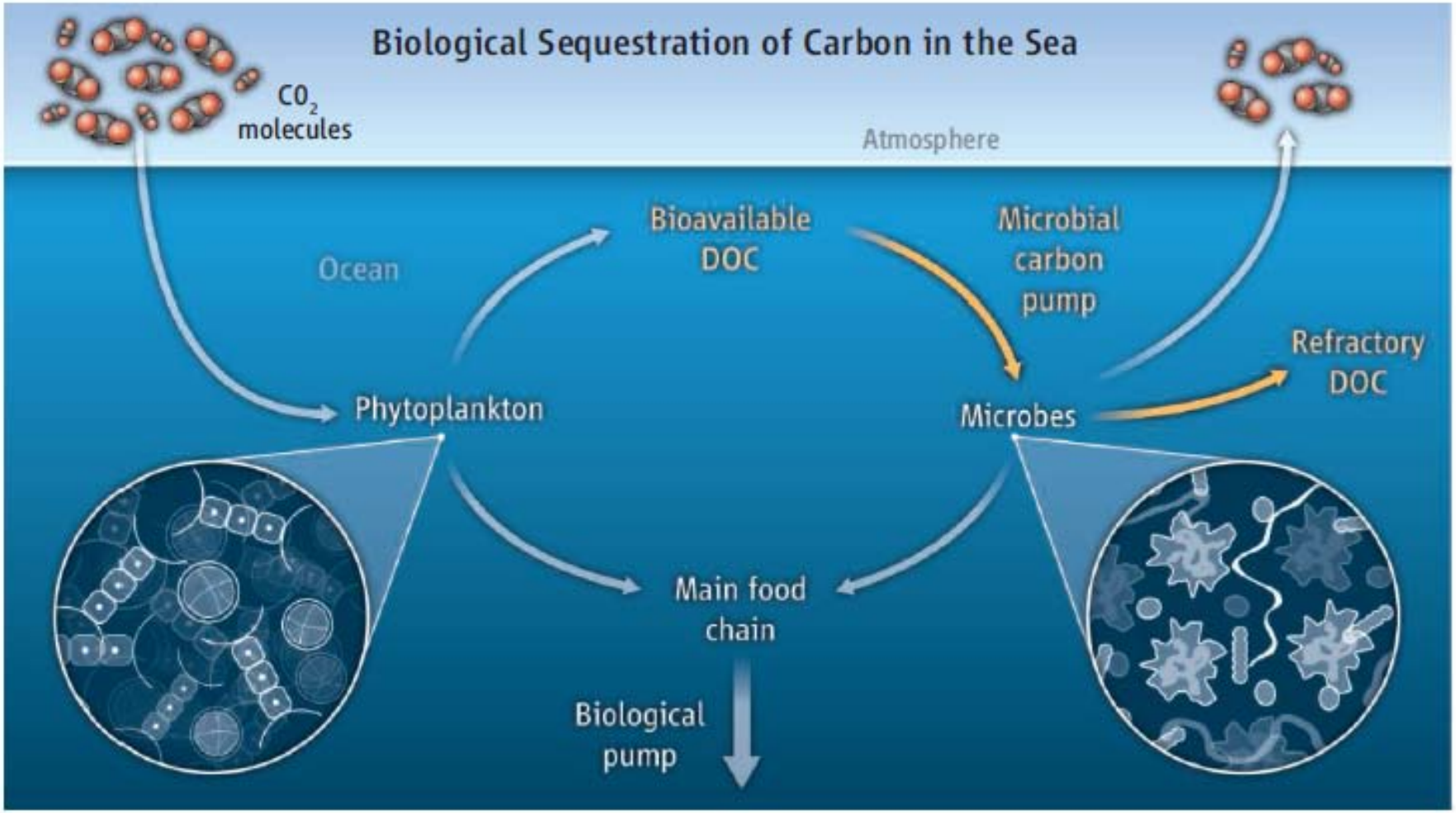
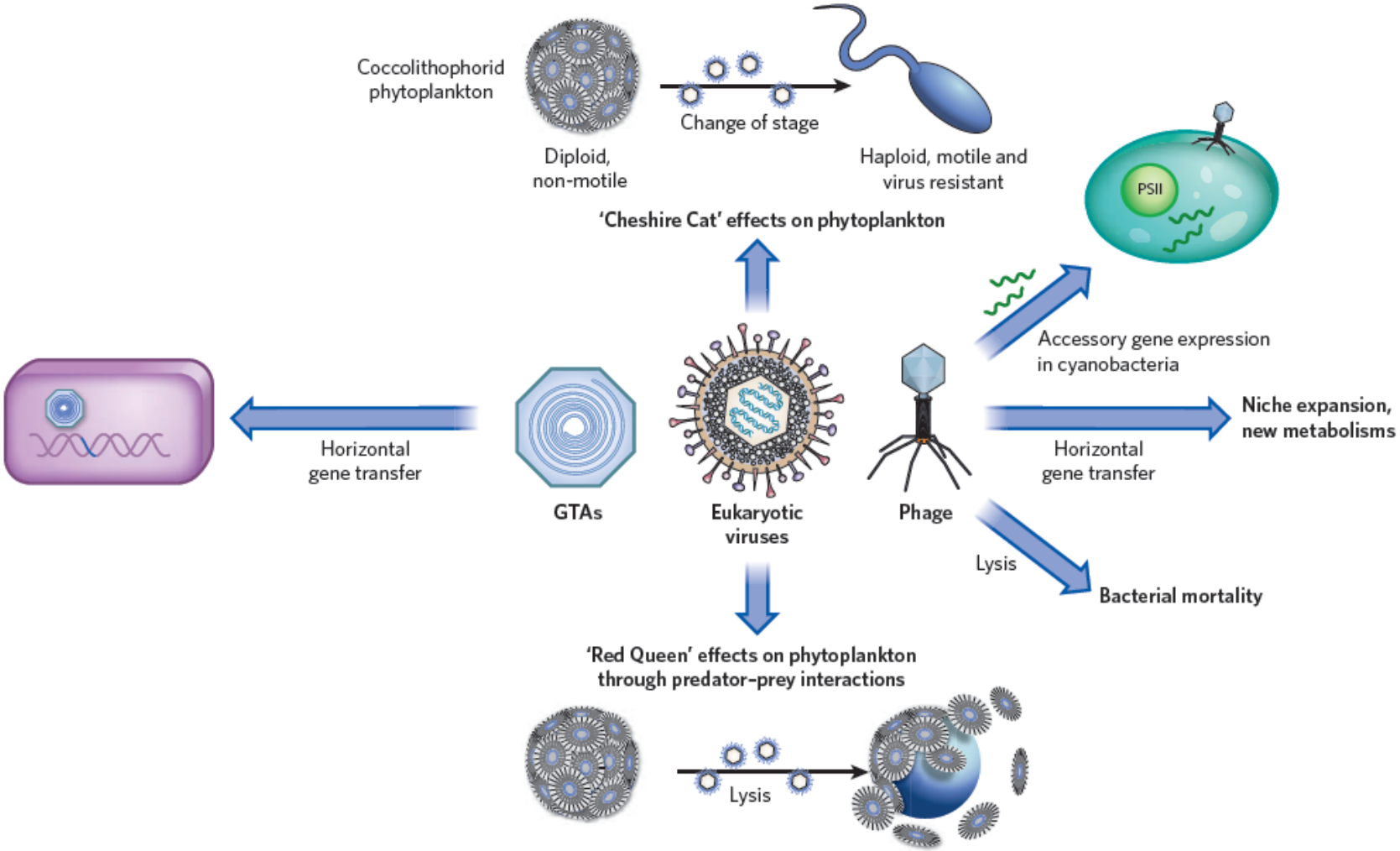


Figure 5.3 *An overview of the classical food chain and microbial loop (Adapted from DeLong and Karl[24])*





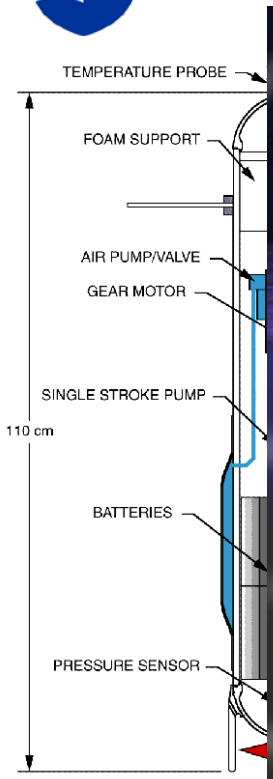
Double-barrel pump. Each year, the biological pump deposits some 300 million tons of carbon in the deep ocean sink. Even more massive amounts are suspended in the water column as dissolved organic carbon, much of which is converted into refractory forms by the microbial carbon pump.

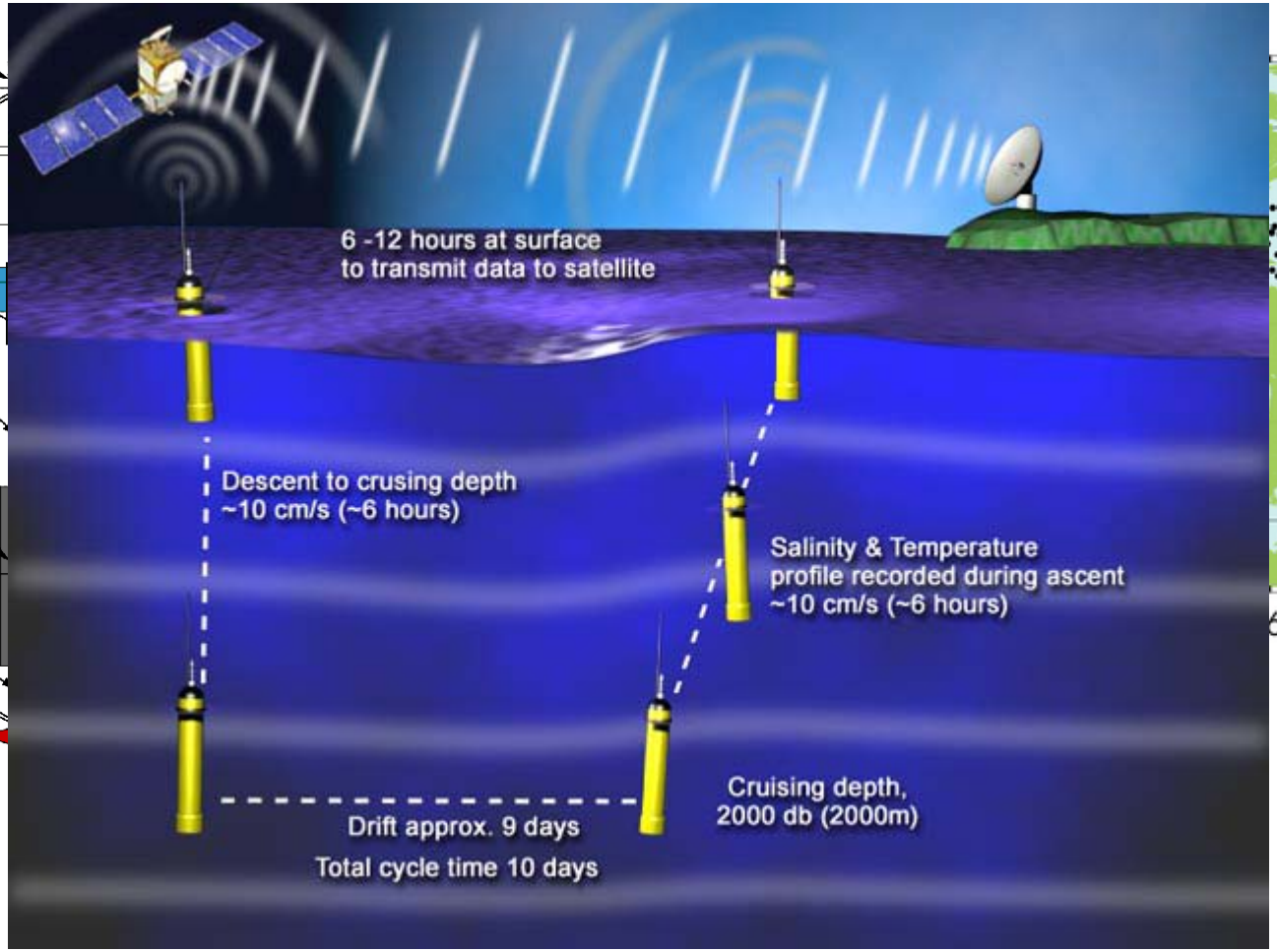

Coccolithophorid phytoplankton
Diploid, non-motile
Change of stage
Haploid, motile and virus resistant
'Cheshire Cat' effects on phytoplankton
PSII
Accessory gene expression in cyanobacteria
Niche expansion, new metabolisms
Horizontal gene transfer
Horizontal gene transfer
GTAs
Eukaryotic viruses
Phage
Lysis
Bacterial mortality
'Red Queen' effects on phytoplankton through predator-prey interactions
Lysis

Can we create a better understanding?

- Knowledge on marine ecosystems is acquired continuously and has often brought about paradigm shifts
- Predicting the future state of ecosystems with any accuracy is fraught with difficulties
  - Modelling entire food webs and biogeochemical cycles for the purpose of prediction is impossible (too many and still unknown state variables).
  - Modelling selected subsets of state variables for particular purposes may be adequate but is often insufficient
- Are scenarios an alternative? Can they be used for management and decision making?
- Scenarios, as models, require accurate observation of the state of the ecosystem.

Ocean observation


TEMPERATURE PROBE
FOAM SUPPORT
AIR PUMP/VALVE
GEAR MOTOR
SINGLE STROKE PUMP
110 cm
BATTERIES
PRESSURE SENSOR


6 -12 hours at surface
to transmit data to satellite
Descent to crusing depth
~10 cm/s (~6 hours)
Salinity & Temperature
profile recorded during ascent
~10 cm/s (~6 hours)
Cruising depth,
2000 db (2000m)
Drift approx. 9 days
Total cycle time 10 days


60°W
0°

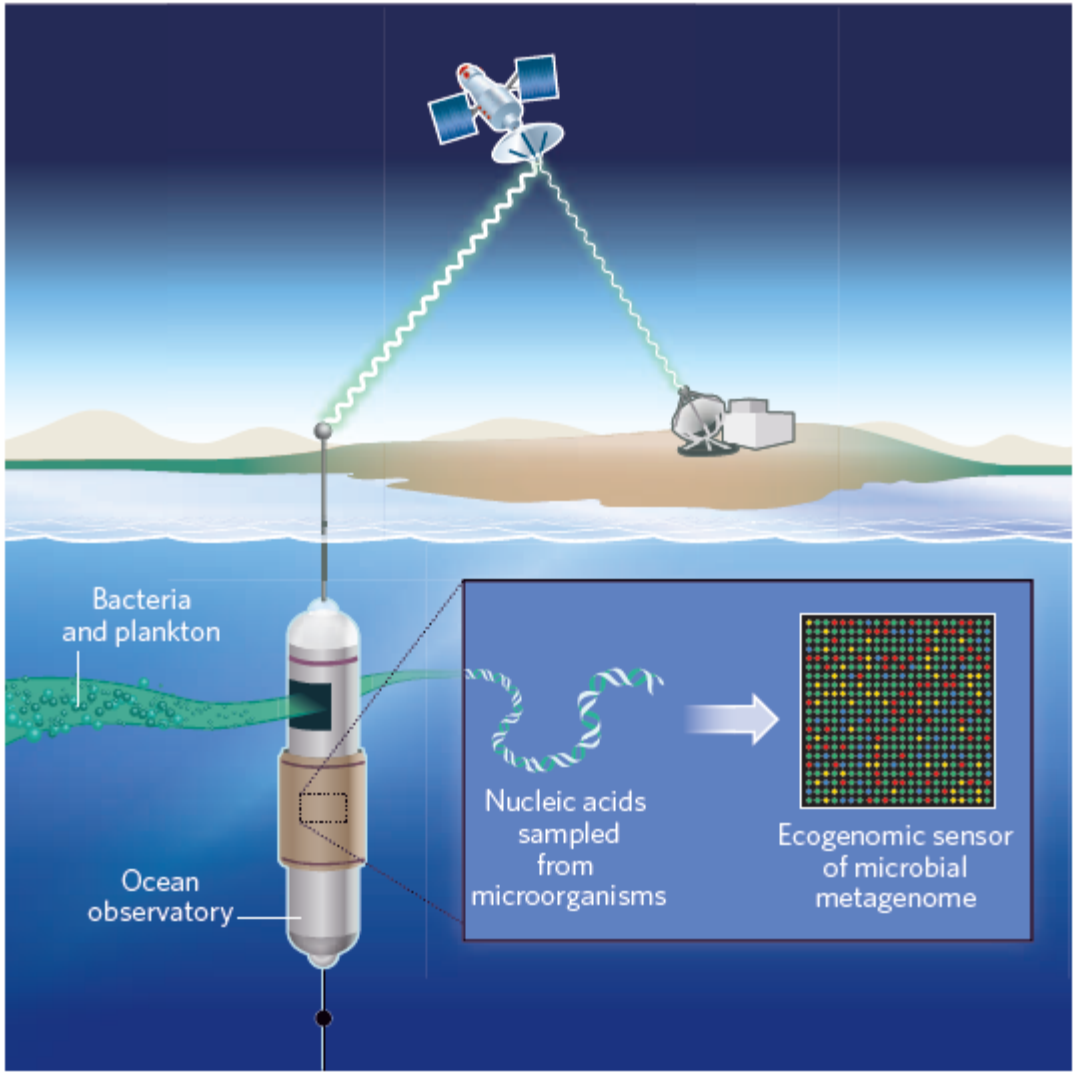
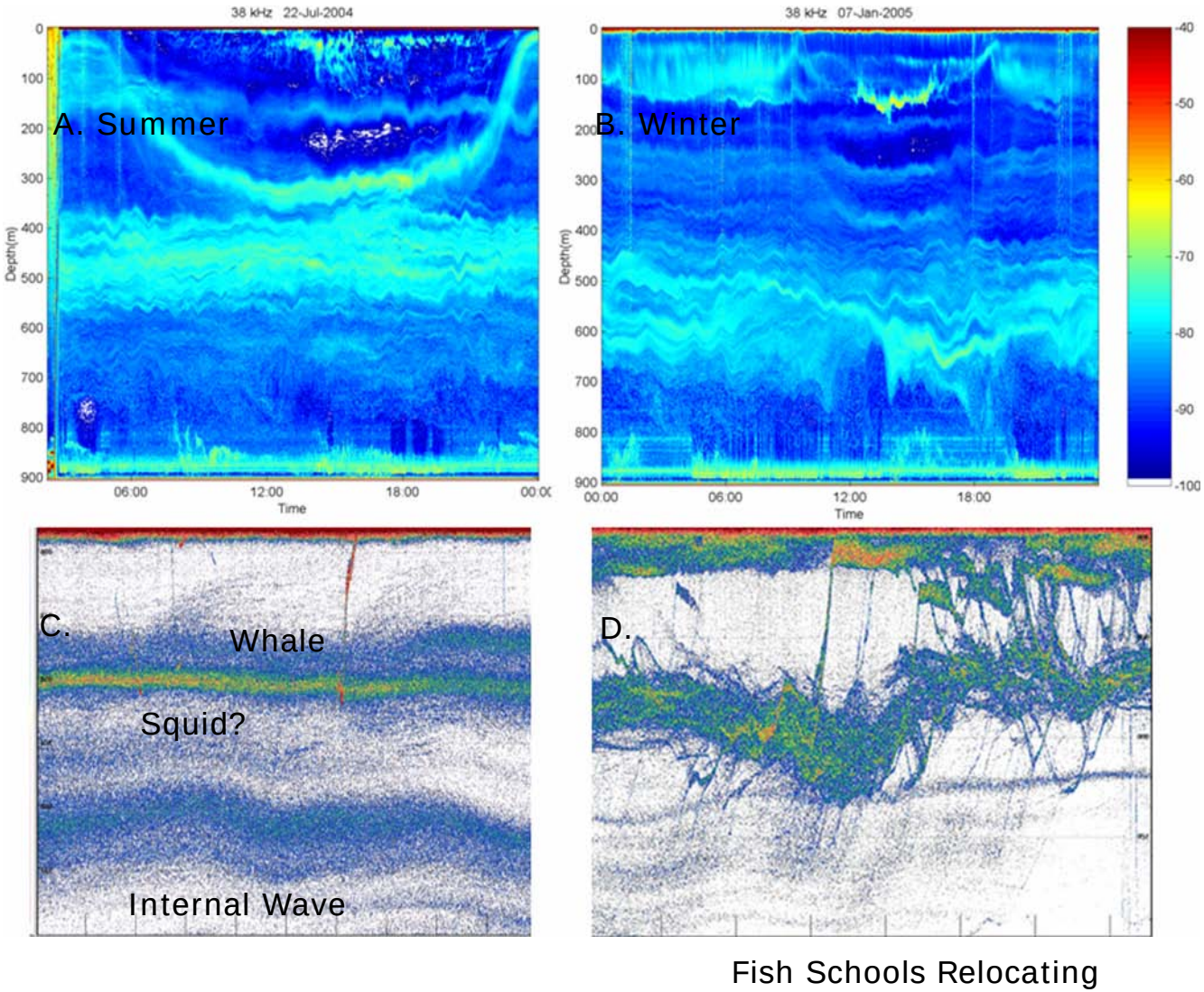


Figure 3 | Miniaturized ecogenomic sensors to measure microbial activity. The sensors could be installed into advanced ocean observatories to monitor DNA and RNA from diverse microbial communities. Subsystems for monitoring, data management and communication, and data modelling would be incorporated for data contextualization. The sensors would report to a worldwide network of laboratories in real time by satellite telemetry.

CoML & Ocean Observing

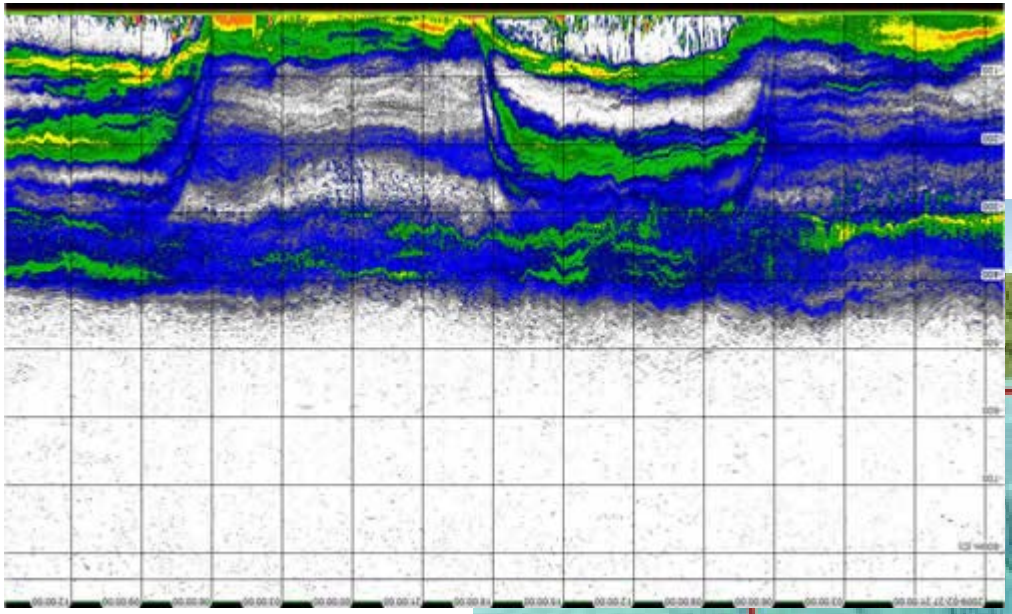


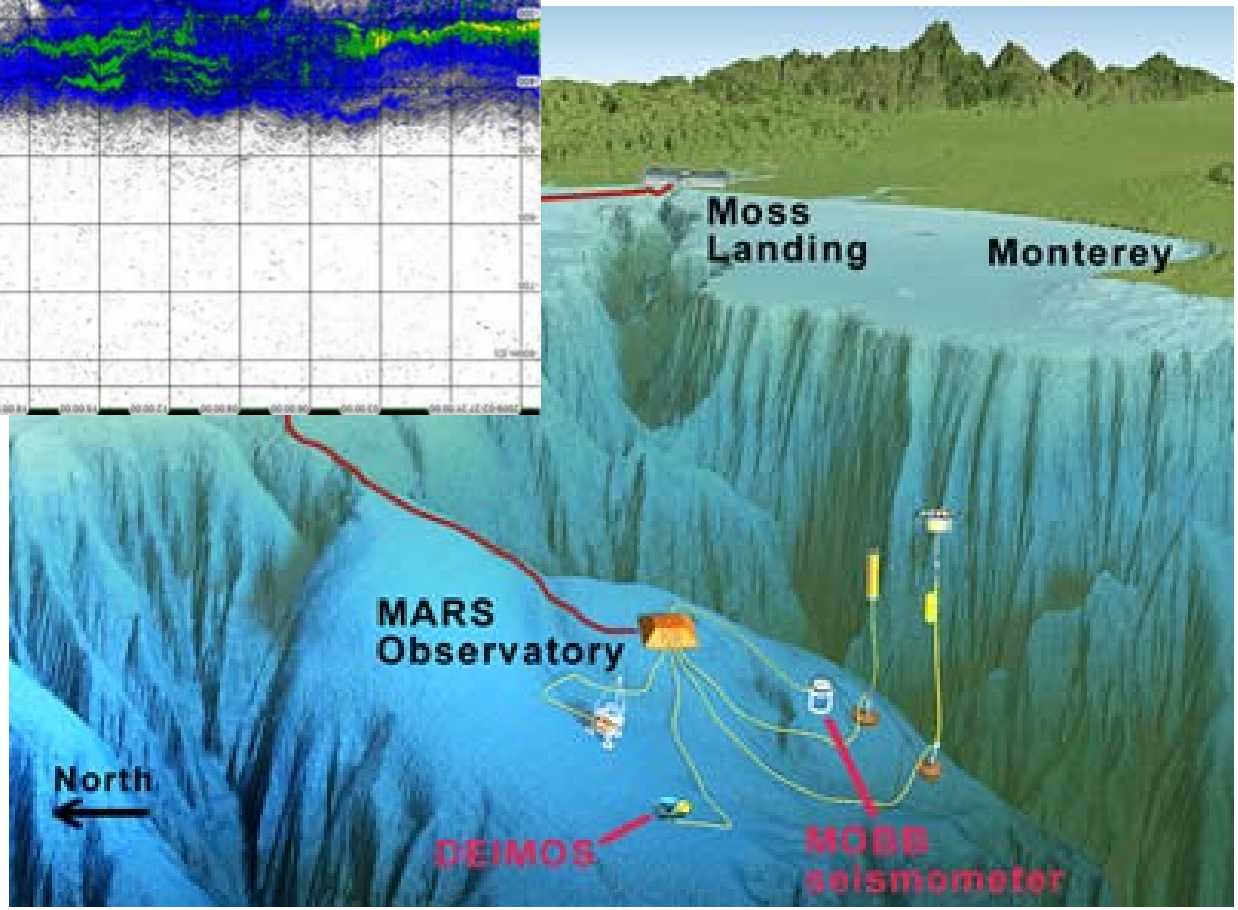
Fish Schools Relocating

Upward-looking Simrad sonar in the Charlie-Gibbs Fracture Zone on the Mid-Atlantic Ridge. (A) and (B): Dramatic reduction in diurnal plankton migration in winter versus summer.

(C): 100m whale dives to feed, likely on squid, above an internal wave moving the whole plankton community. (D): Fish school breaking up at 50m and reforming near surface.
Time bars 15 min.

Data from CoML MAR-ECO project.

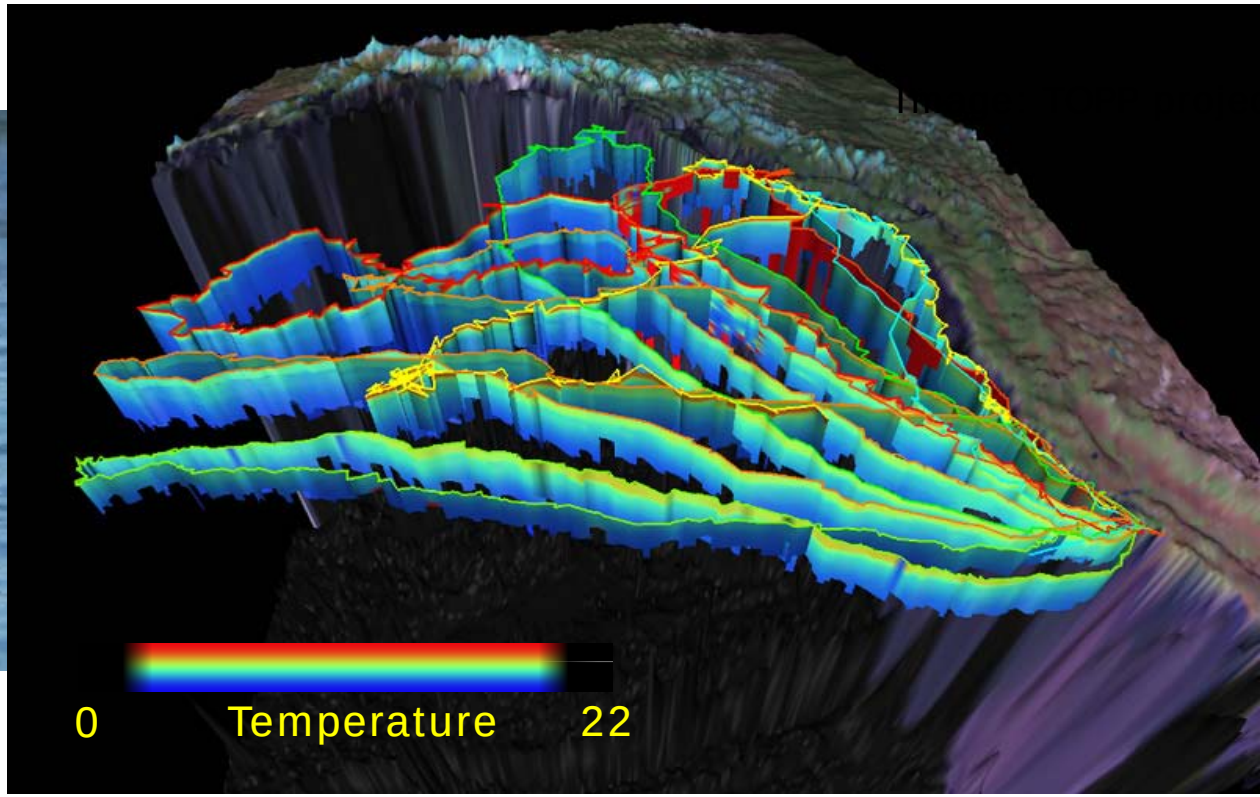



Moss
Landing
Monterey
MARS
Observatory
North
DEIMOS
MOBB
seismometer

CoML & Ocean Observing

Animal oceanographers – collecting vast amounts of oceanographic data

Some animals dive 1000m



7 seals tracked during 2-3 month summer feeding migrations

Conclusions

- New discoveries that profoundly change our view on how marine ecosystem function are still made regularly, even in shallow waters.
- Mechanistic understanding of whole ecosystem functioning is changing and improving continuously with continued exploration.
- The oceans are complex systems that as a whole cannot be captured in equations and algorithms
- Therefore quantitative prediction of the state of the oceans is an illusion (as for the weather).
- Adequate observation of the oceans remains therefore essential (as for the weather) to create a better understanding of marine ecosystem functioning.
- Innovation is based on new knowledge

Thank you for your attention