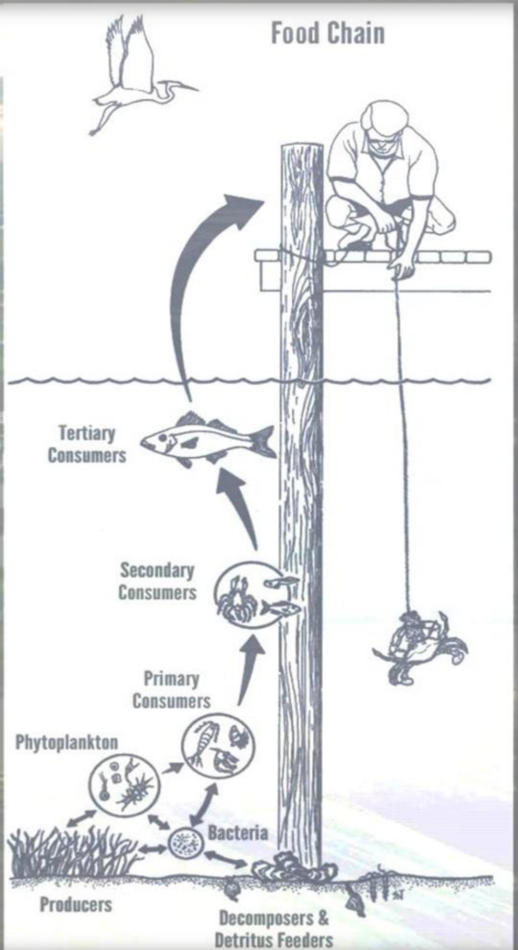
Lower Food Web Dynamics in California's Bay-Delta Ecosystem:

Current understanding and future interactions in a changing landscape

Zooplankton and estuary food web dynamics



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Université Lille1 Sciences et Technologies

SMW

LOG

cnrs dépasser les frontières

Background

Estuaries are very complex systems (*interface between land and oceans*)

Estuaries are heavily impacted by human activities (*Harbors, transportation, Industrial activity, agriculture, urbanization, pollution, etc.*)

In addition to their economic role, estuaries are still playing significant ecological role (*offering several ecological services, etc.*)

In Europe and USA the restoration of estuarine ecosystems already started and will be certainly reinforced in the future.

Seminar Objective

Broad decadal declines of lower pelagic fish populations in California's Bay-Delta ecosystem, with concomitant declines in primary and secondary productivity, have driven policy, management, and regulatory efforts to identify approaches that will restore the pelagic food web.

But how can we restore these ecological functions? What about the role of zooplankton?

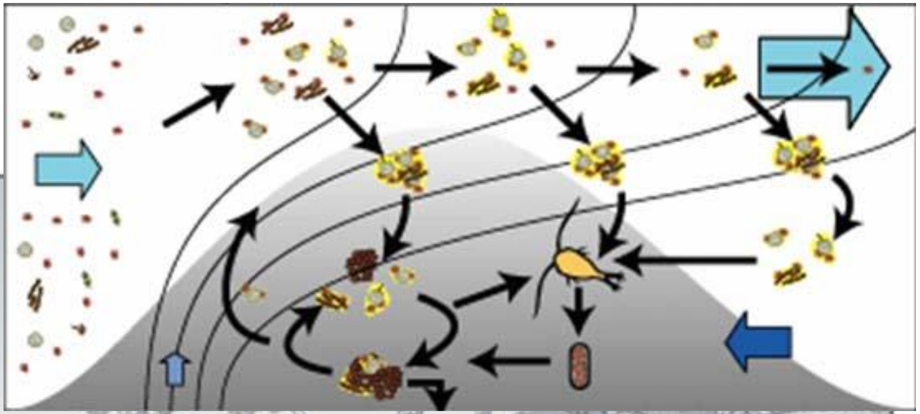
Need of a global approach and a real feedback between scientists, managers and all actors of the estuarine system.

Zooplankton in estuaries:

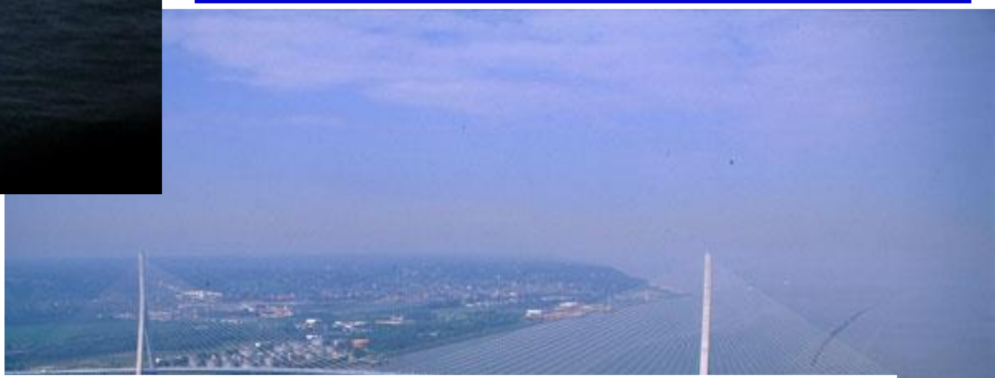
-Low diversity

-Cryptic species (high physiological capacities)

- Few endemic species



San Francisco estuary is one of the most studied 'system' with significant knowledge on the zooplankton compartment.

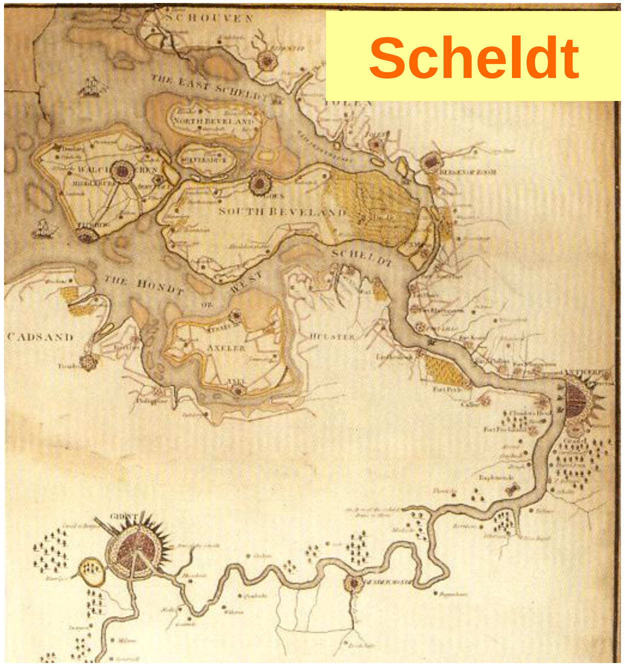


At local scale both systems are very different (we do not have a generic and universal framework) but from scientific and/or global management angles these systems are comparable

19th century

Seine

Natural system



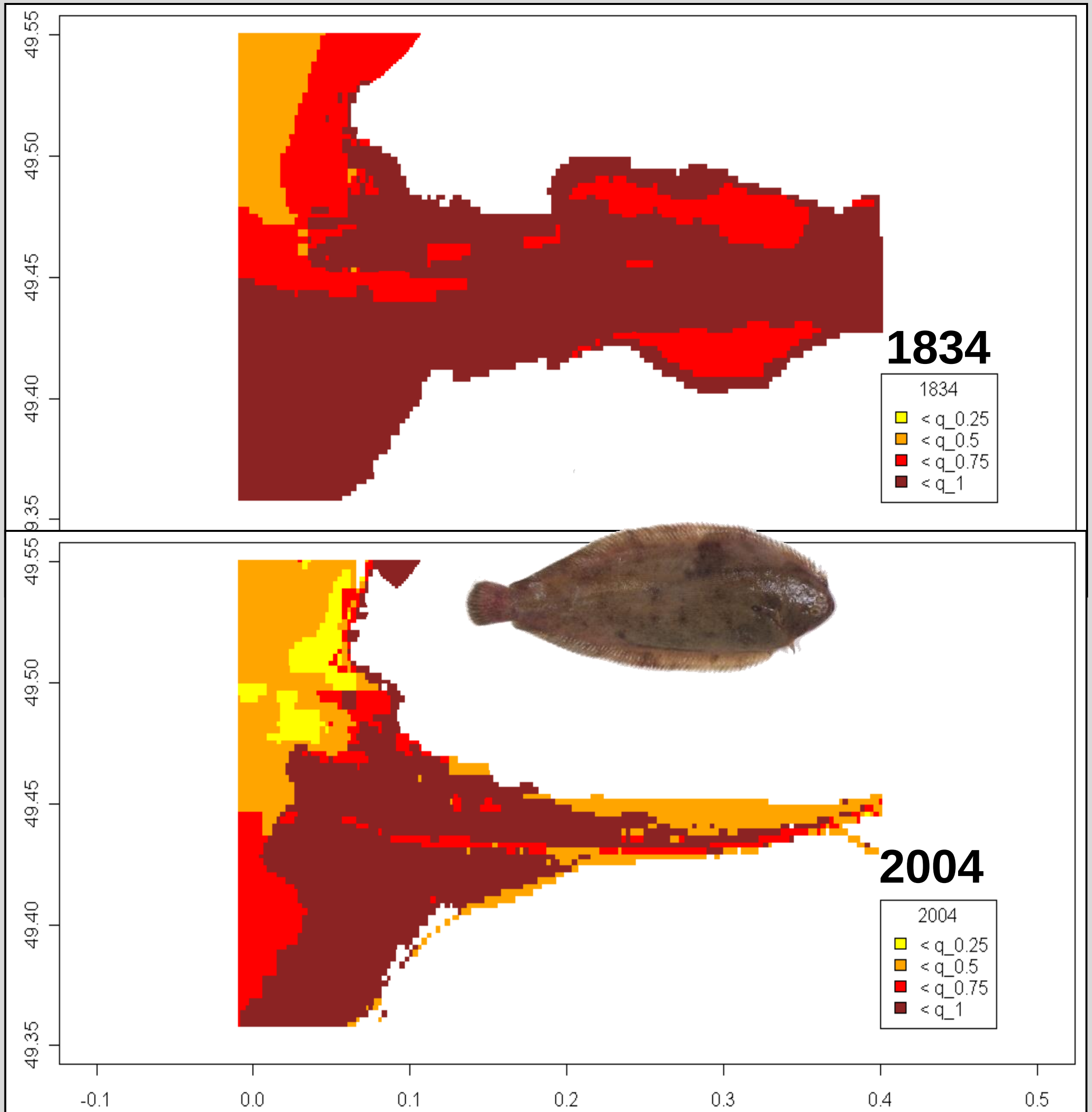
Scheldt

Today

Anthropogenic footprint

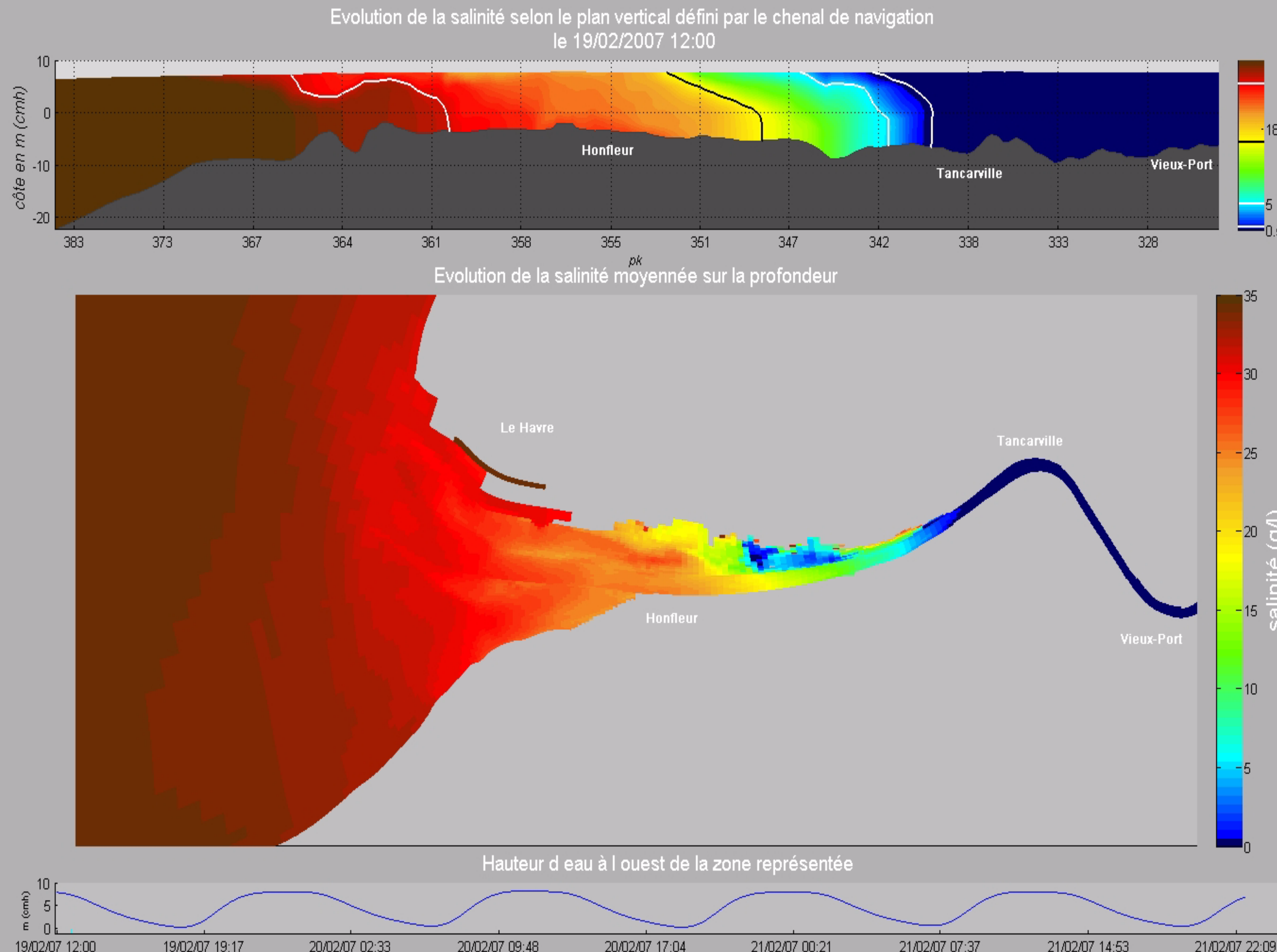
➔ Loss of natural habitats and a decrease of the resilience of the system (i.e. flooding, eutrophication, etc.)

Mapping of the habitat of the juveniles of the flatfish *Solea solea* in the Seine estuary



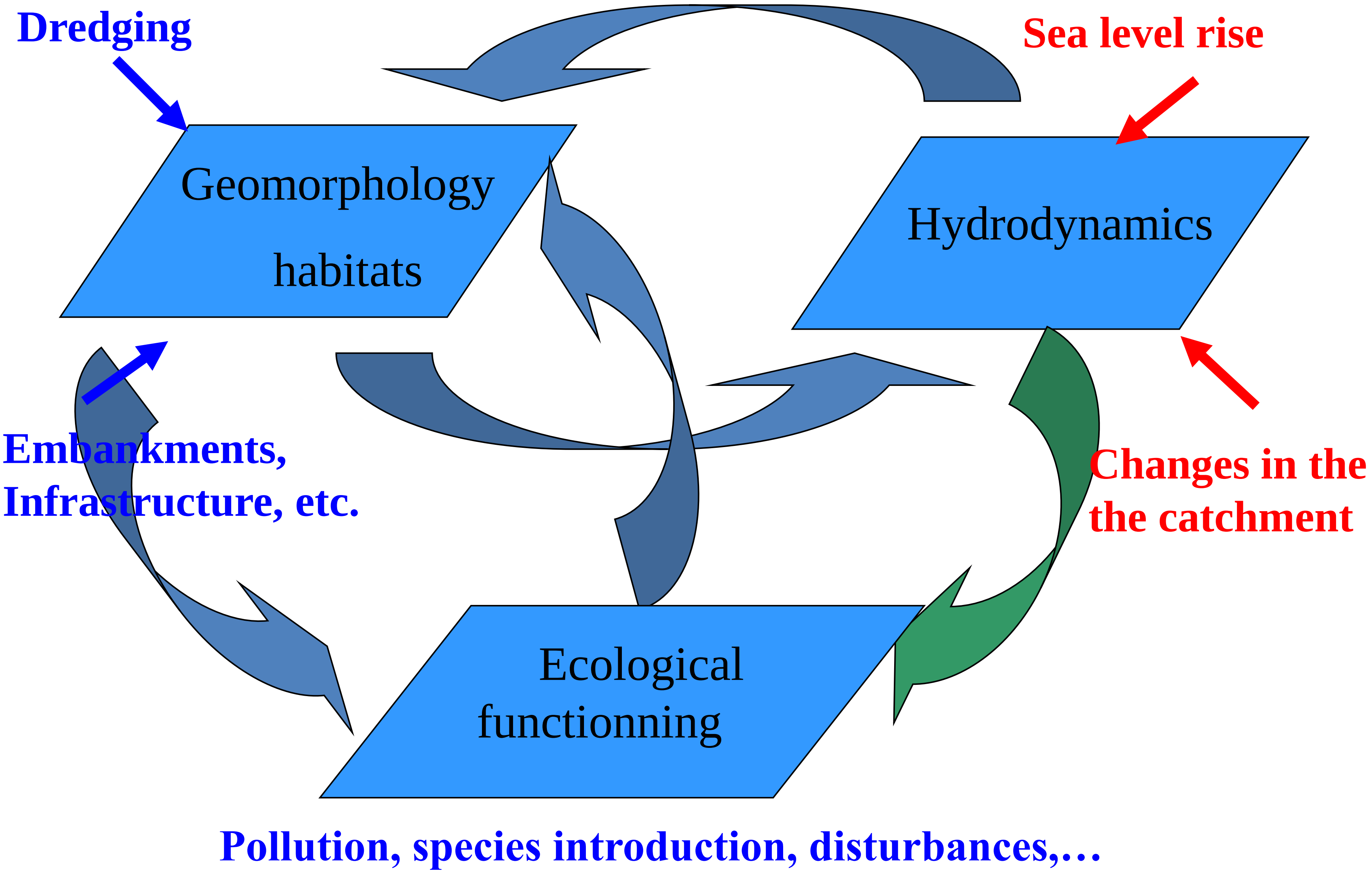
These changes of the Seine estuary induced an annual loss of 20% of the total production of juveniles of *Solea solea* in the Eastern English Channel.

From Rochette et al. (2008)



From JP Lemoine GIP Seine-Aval (2013)

Schematic representation of an estuarine system

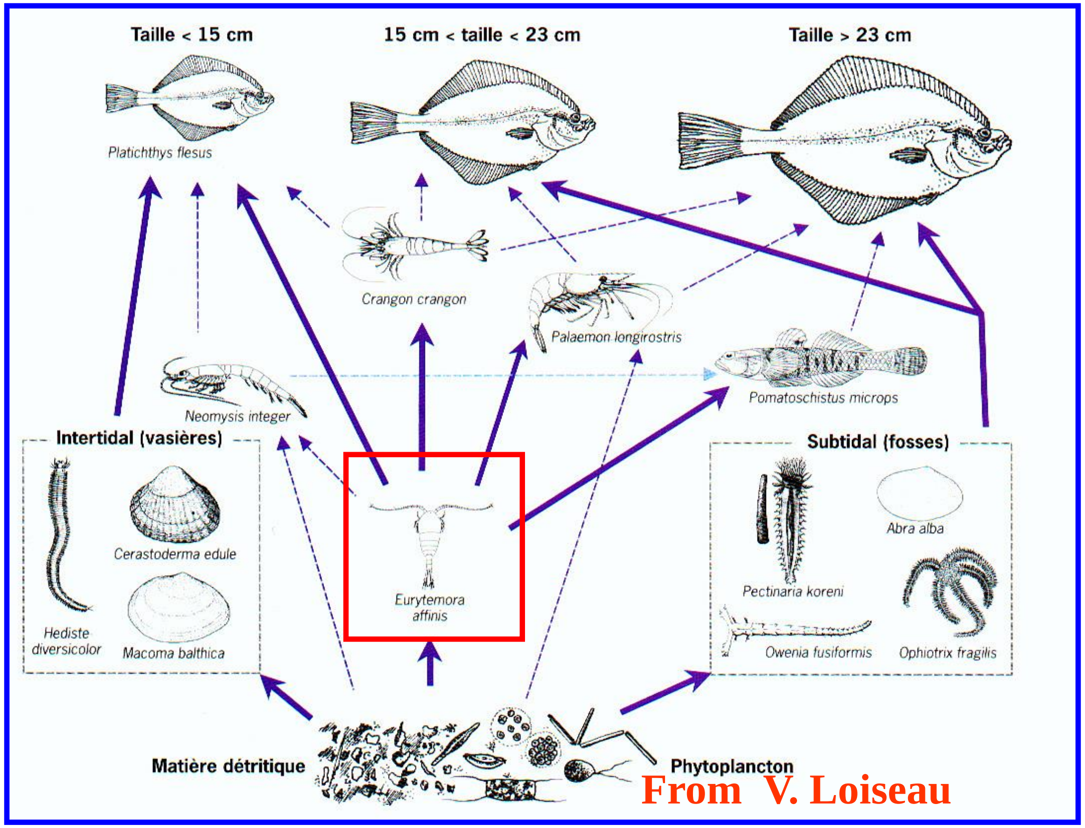


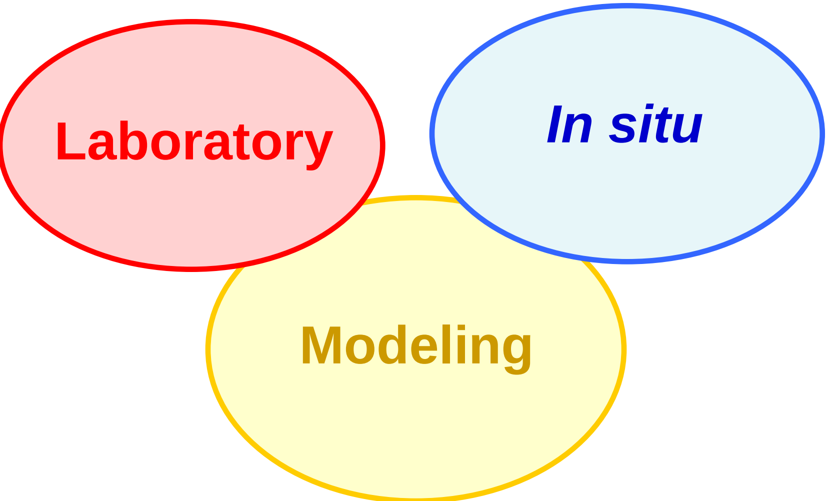
Different phases of the scientific program Seine-Aval

1995-2000	2001-2003	2004-2006	2007-2012
Biological structure	Fisheries, risk assessment,…	Habitat restoration, management, indicators	Climate change, biodiversity dynamics,..

Understanding the system – developing tools – stimulating interdisciplinary studies

Estuarine food web in the Low Salinity Zone (LSZ) based on the knowledge of the first phase of the Seine Aval program





First challenge: to develop <u>biological indicators</u> of the water quality (in the Seine estuary) based on the copepod <u>*Eurytemora affinis*</u>.

Gene expression

Proteomics

Enzymatic activity

Behaviour/Mating

Morphology

Development/Growth

Fecundity/Survival

Longevity

Bioaccumulation

Vulnerability (predators & epibionts)

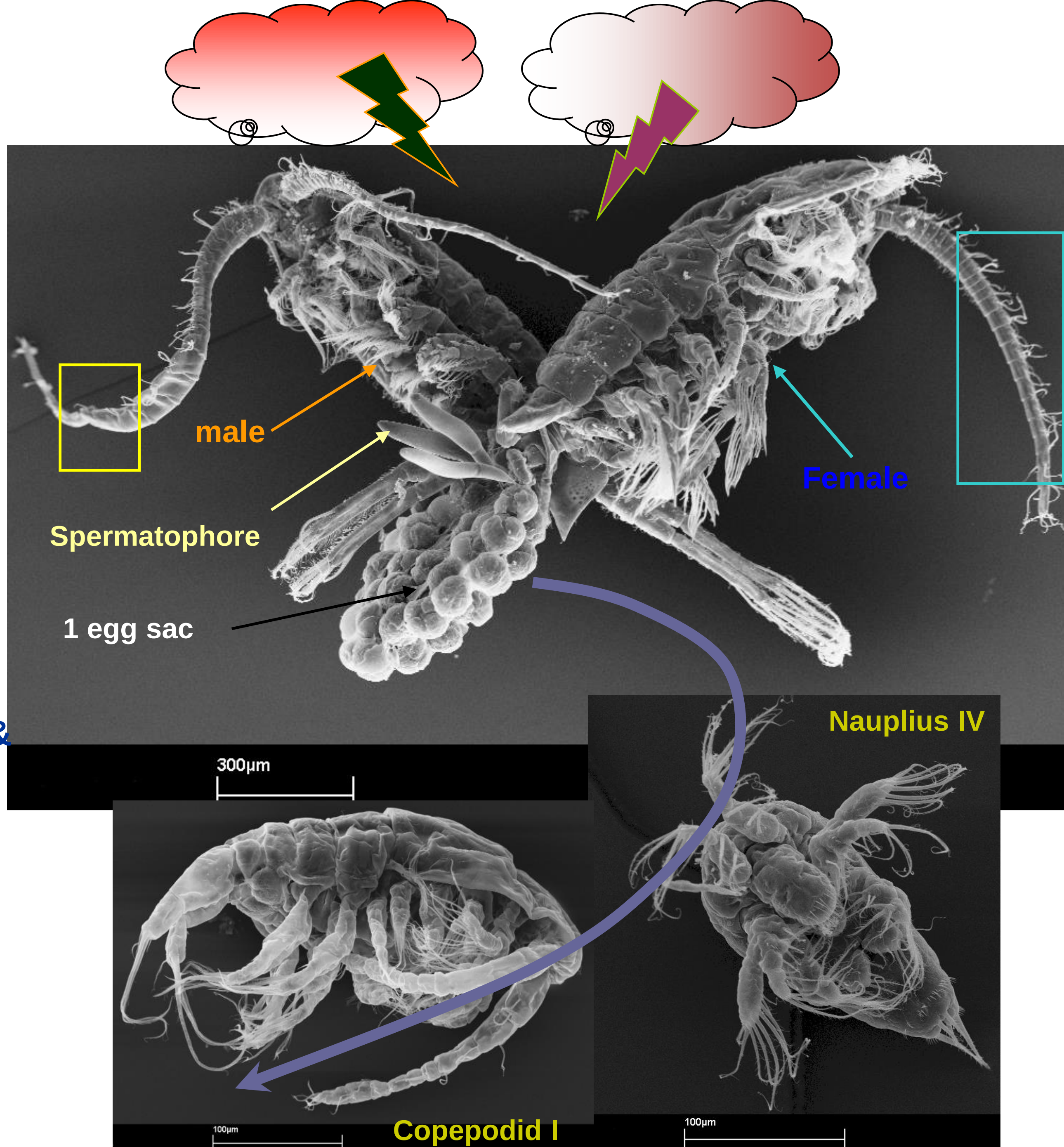
Effect of turbulence

Plasticity/Adaptation

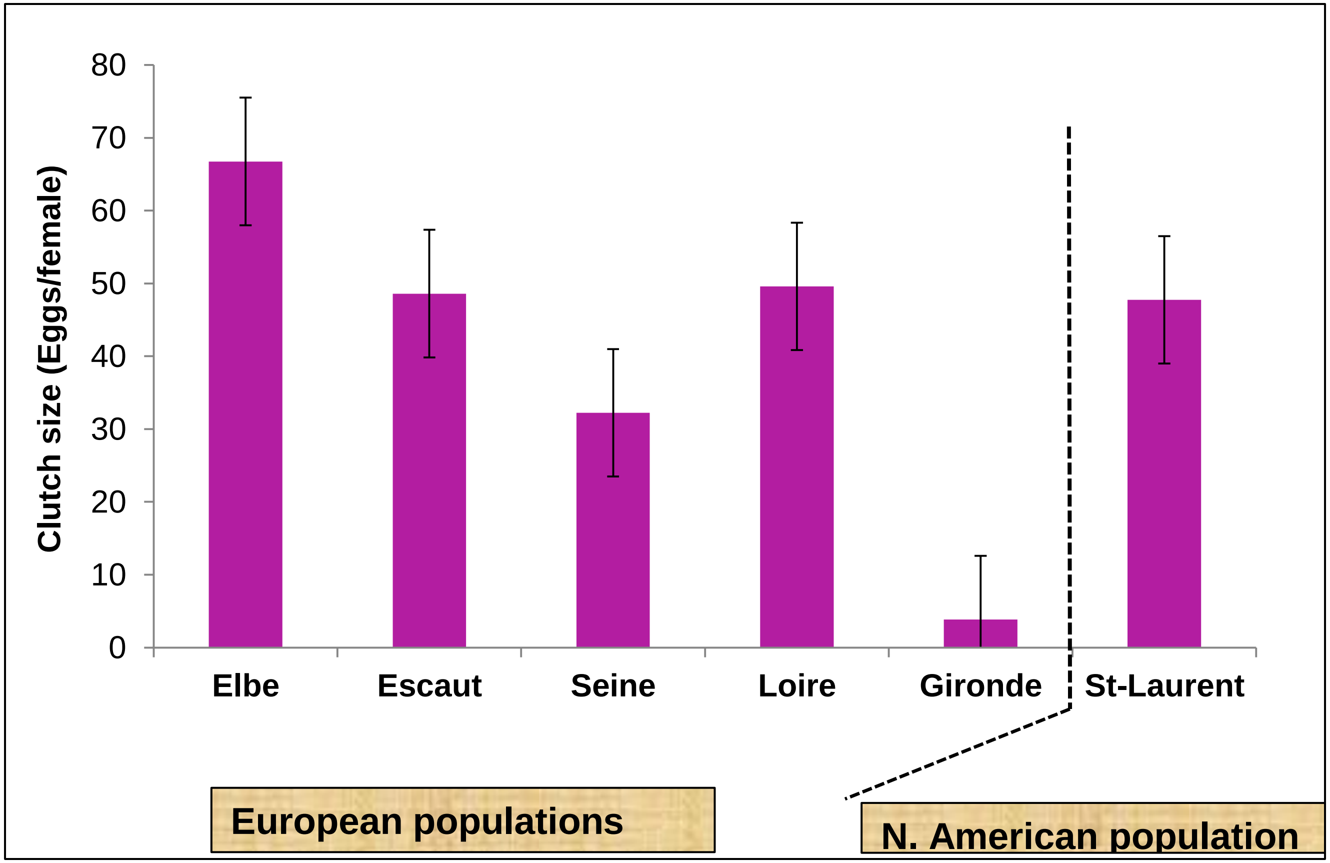
Resting eggs/Diapause

Competition with *Acartia*

Modeling (IBM)



Eurytemora affnis: large geographical distribution in the North Atlantic Sector



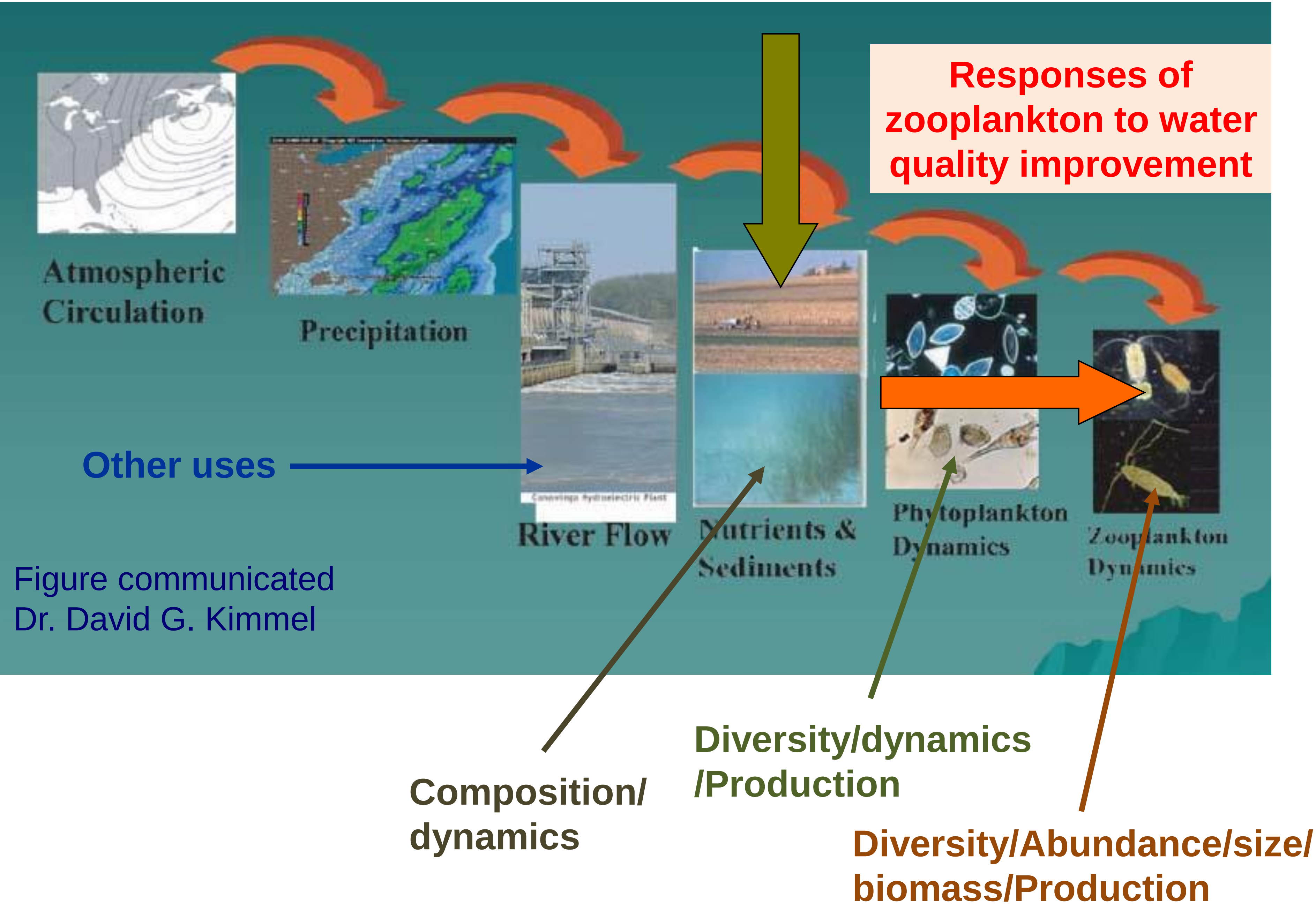
Communicated by Dr. Anissa Souissi

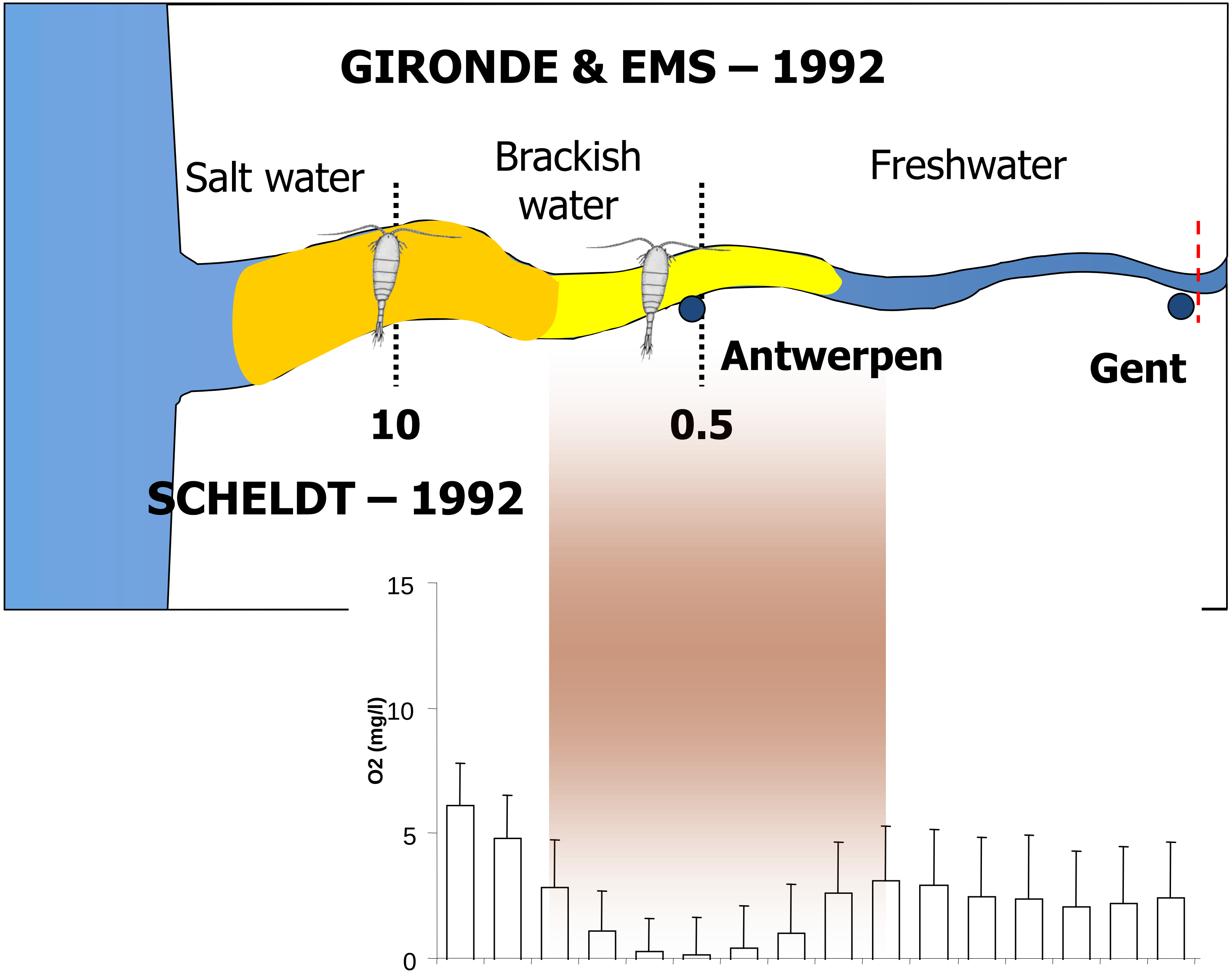
-We should promote the inter-site and inter-ecosystem comparisons (create research networks)

- Reveal impacts on a few key species as well as species assemblages / diversity

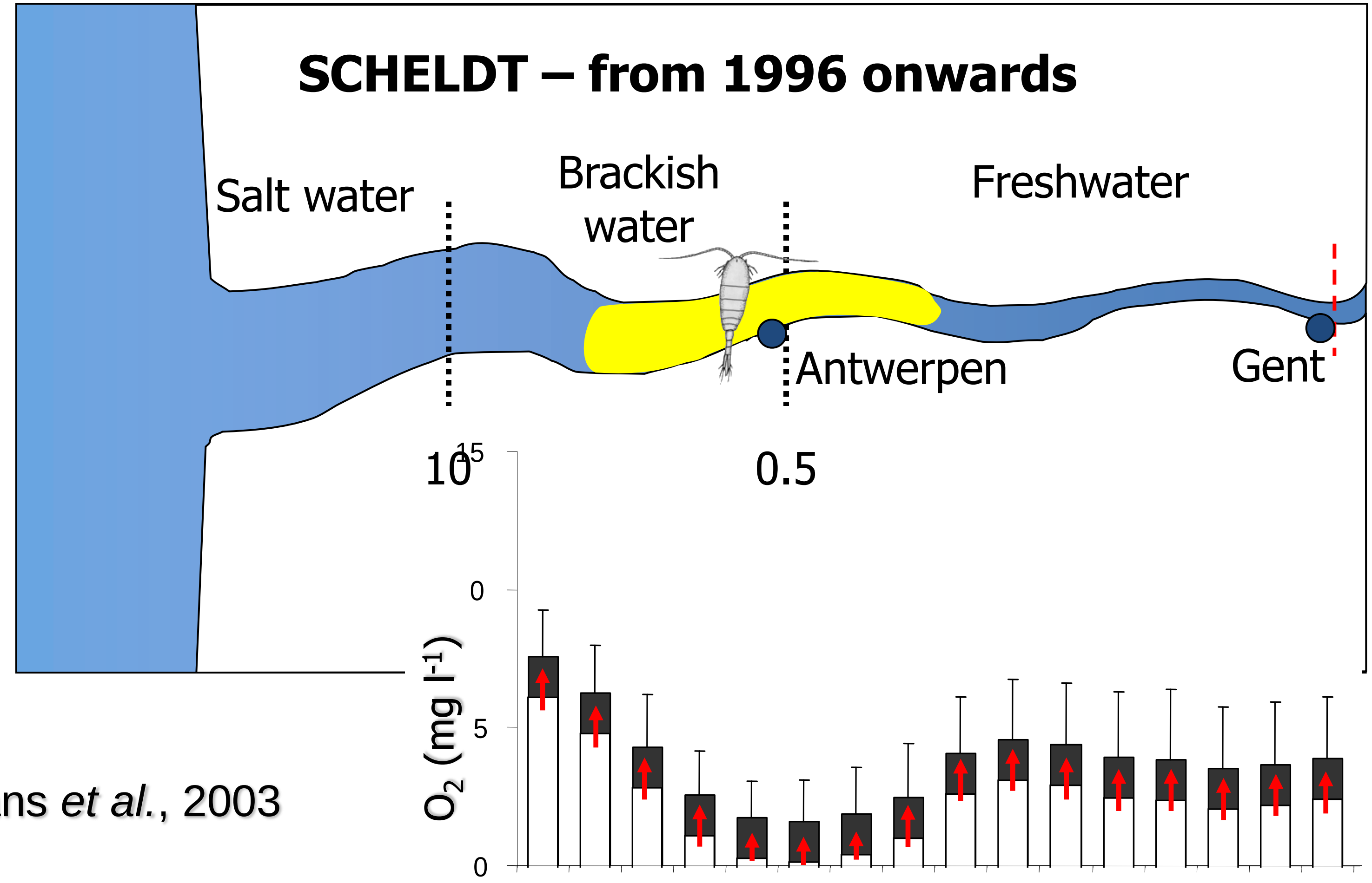
-Account for multiple drivers (stressors) interacting with climate variability.

Regional climate variability vs lower food web levels



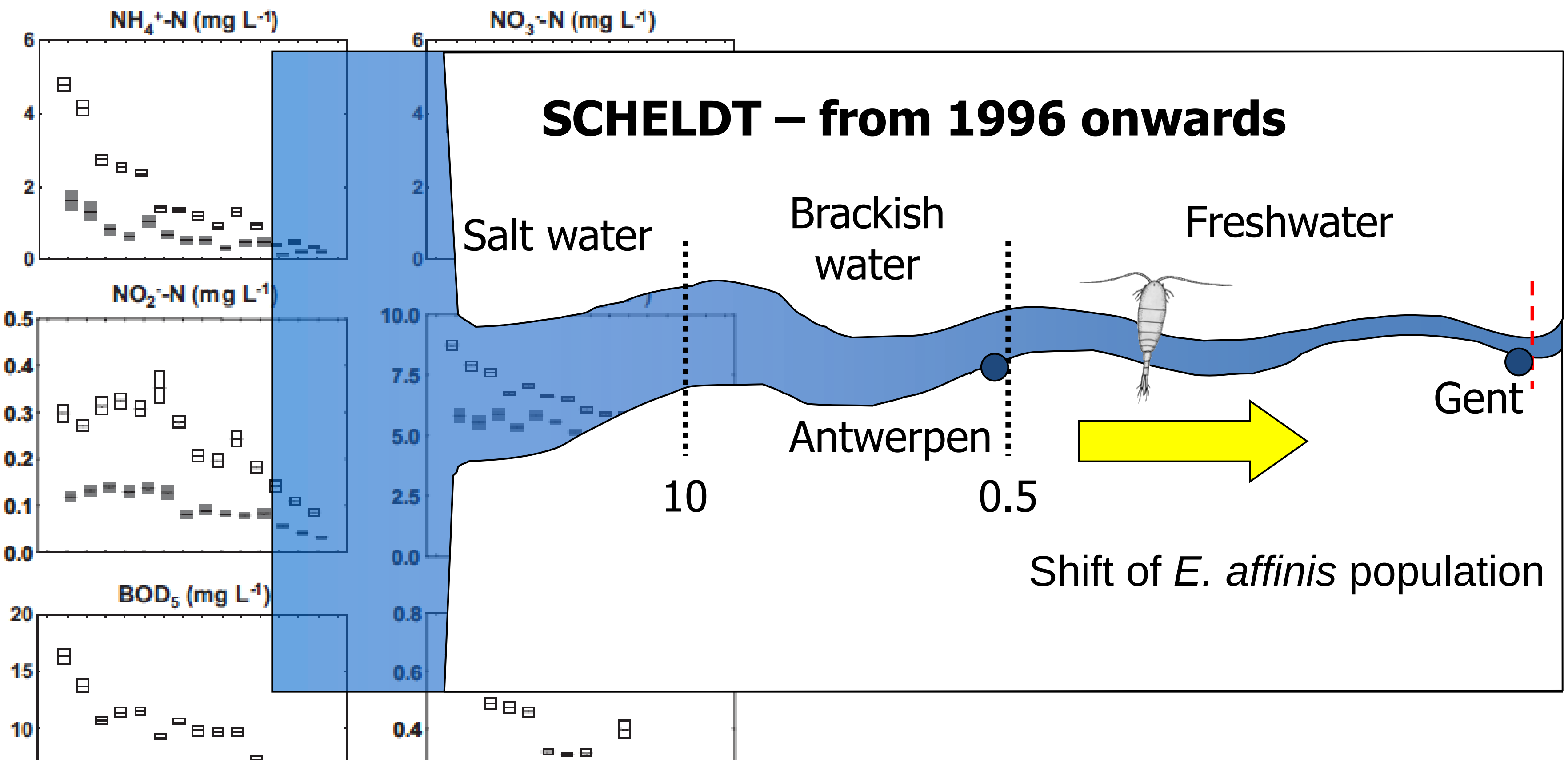


Communicated by Pr. Micky Tackx



Appeltans *et al.*, 2003

Communicated by Pr. Micky Tackx

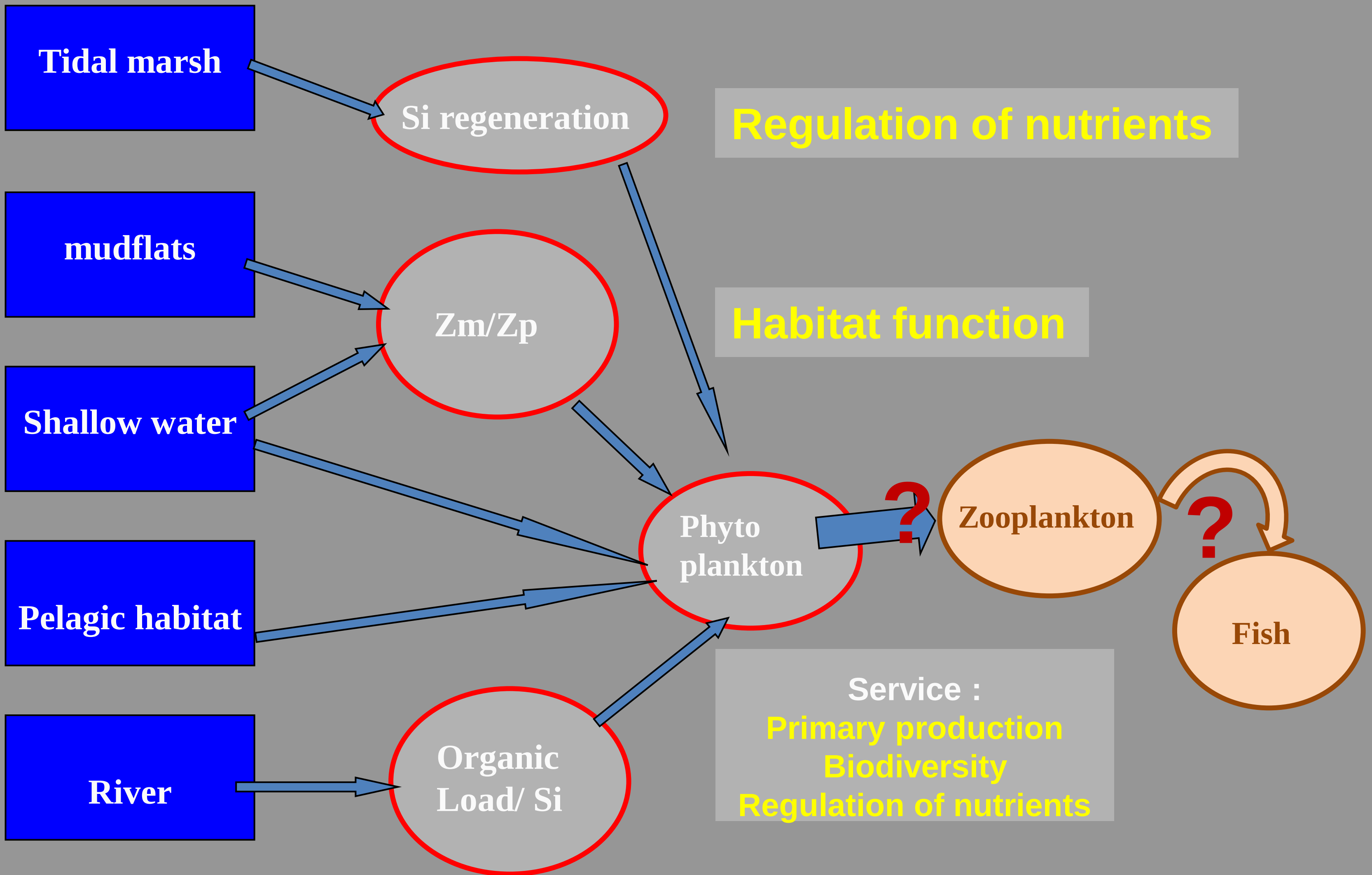


Spatial spring distribution of the copepod *Eurytemora affinis* (Copepoda, Calanoida) in a restoring estuary, the Scheldt (Belgium) Mialet et al. (2010)

Response of zooplankton to improving water quality in the Scheldt estuary (Belgium) Mialet et al. (2011)

Restoration program in the Scheldt estuary:

A 3500 ha restoration project is being realized combining safety and ecosystem functioning

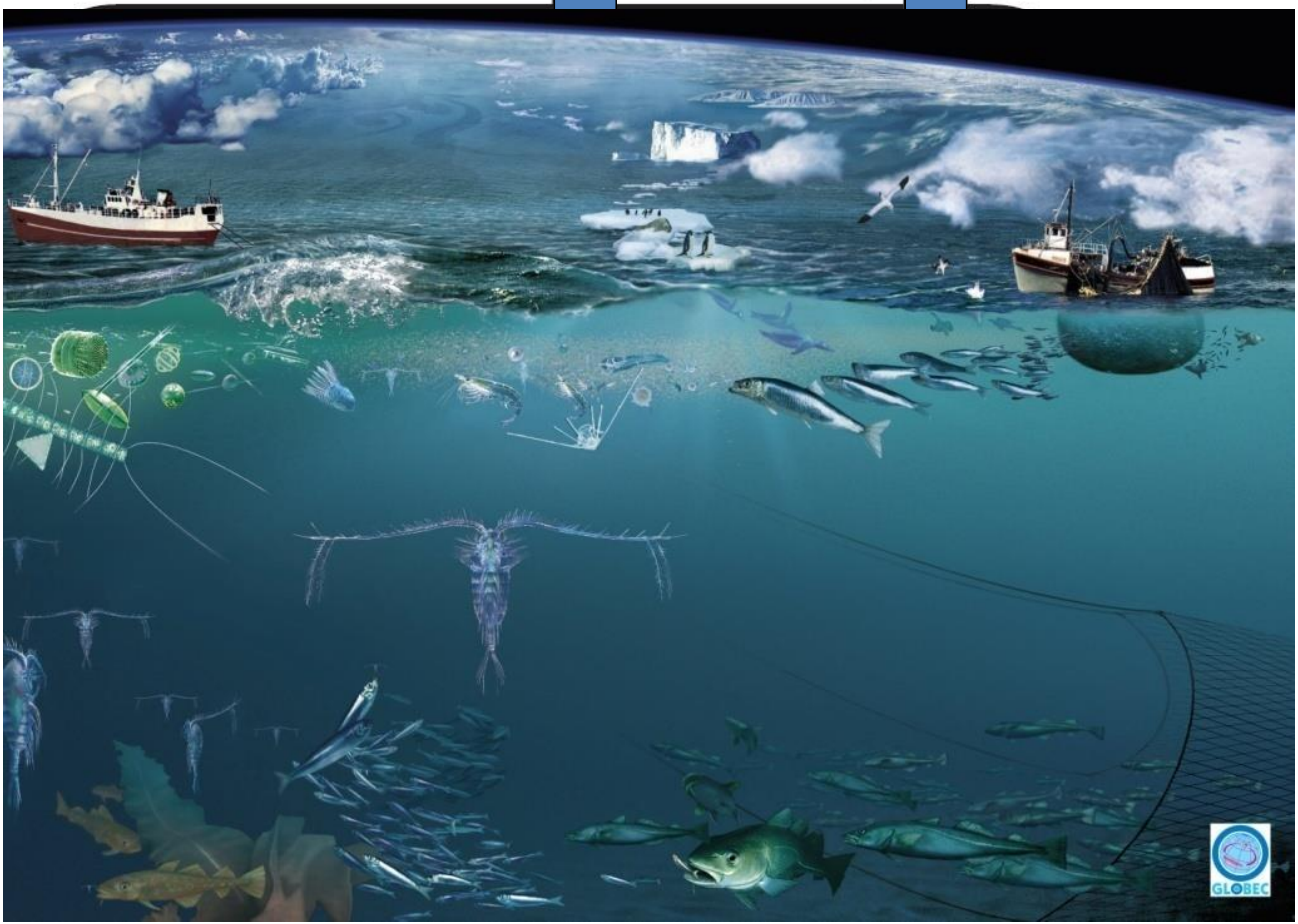


Modified from Pr. Patrick Meire and col.

Marine ecosystems

FISHERIES YIELD

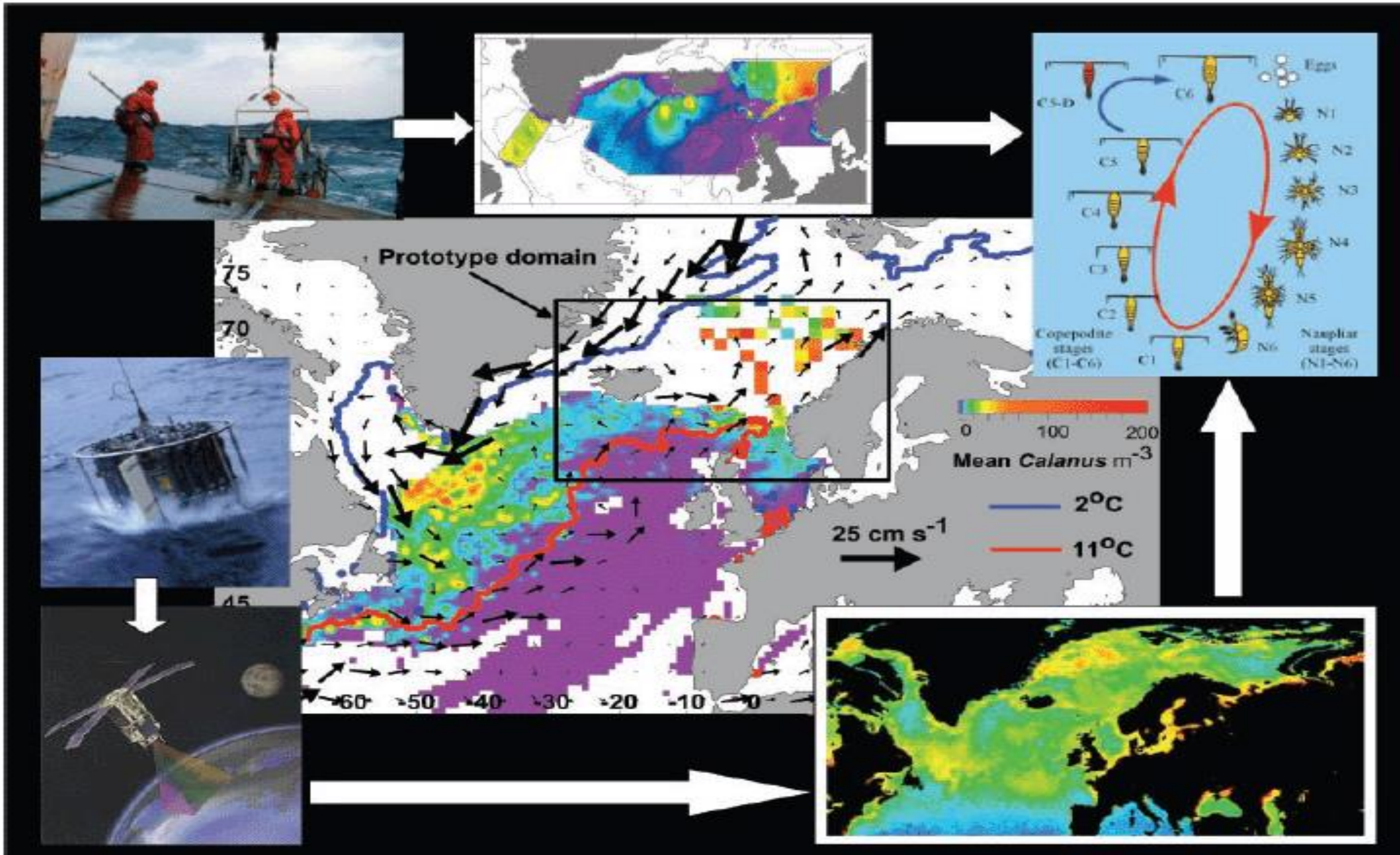
ATMOSPHERE COMPOSITION

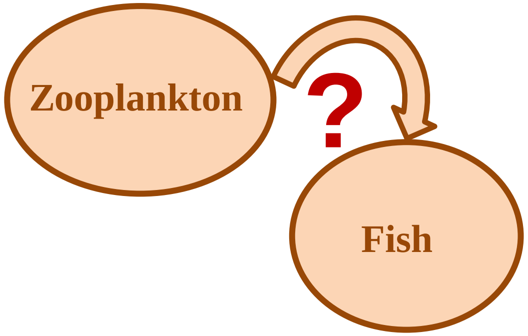


Challenges of Modeling Ocean Basin Ecosystems

Science 2004

Brad deYoung,[1*] Mike Heath,[2] Francisco Werner,[3] Fei Chai,[4] Bernard Megrey,[5] Patrick Monfray[6]





Link between zooplankton and fisheries

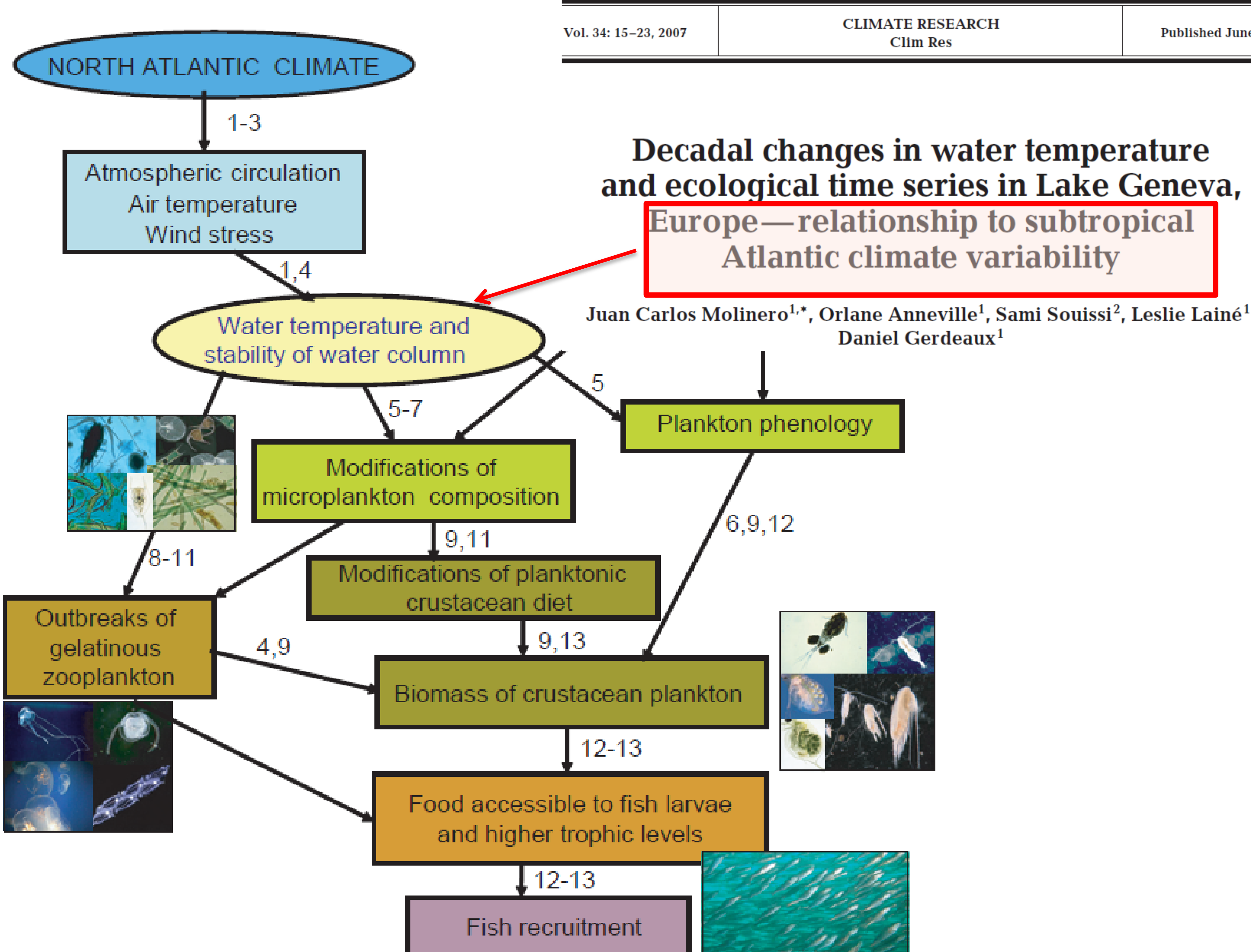
GLOBEC INTERNATIONAL NEWSLETTER APRIL 2007

Effects of global changes on aquatic ecosystems in Western Europe: role of planktonic communities

Sami Souissi[1] (Sami.Souissi@univ-lille1.fr), Juan Carlos Molinero[1,2], Grégory Beaugrand[1], Orlane Anneville[2], Priscilla Licandro[3], François Schmitt[1], Fernando Gomez[1], Dietmar Straile[4], Daniel Gerdeaux[2] and Frédéric Ibanez[5]

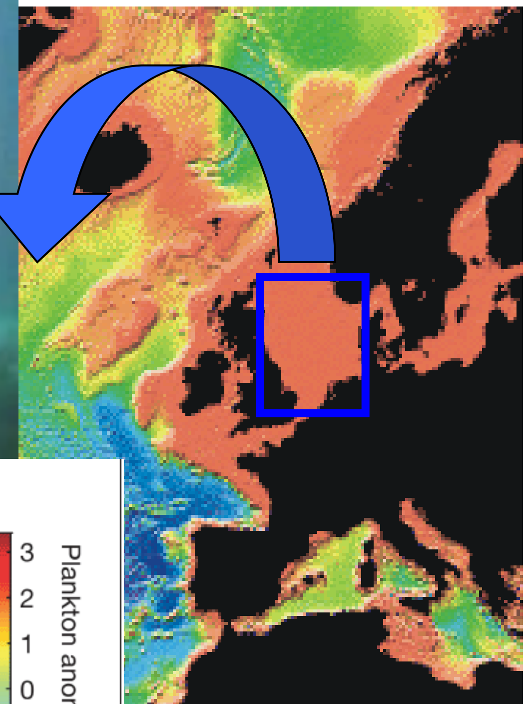
[1]Université de Lille 1 - CNRS FRE ELICO - Station Marine, Wimereux, France
[2]INRA - UMR CARTEL, Thonon les Bains, France
[3]SAHFOS, Plymouth, UK
[4]Limnologisches Institut, Universität Konstanz, Germany
[5]Laboratoire d'Océanographie de Villefranche, Villefranche-sur-mer, France

INSTITUT FRANCAIS DE LA BIODIVERSITÉ



Vol. 34: 15–23, 2007
CLIMATE RESEARCH
Clim Res
Published June
Decadal changes in water temperature and ecological time series in Lake Geneva, Europe—relationship to subtropical Atlantic climate variability
Juan Carlos Molinero[1,*], Orlane Anneville[1], Sami Souissi[2], Leslie Lainé[1]
Daniel Gerdeaux[1]
NORTH ATLANTIC CLIMATE
1-3
Atmospheric circulation
Air temperature
Wind stress
1,4
Water temperature and stability of water column
5
5-7
Plankton phenology
Modifications of microplankton composition
6,9,12
9,11
8-11
Modifications of planktonic crustacean diet
Outbreaks of gelatinous zooplankton
4,9
9,13
Biomass of crustacean plankton
12-13
Food accessible to fish larvae and higher trophic levels
12-13
Fish recruitment

Cod recruitment dynamics in the North Sea



Beaugrand et al. (2003) Nature

Plankton effect on cod recruitment in the North Sea

Grégory Beaugrand[1,2], Keith M. Brander[3], J. Alistair Lindley[2], Sami Souissi[1] & Philip C. Reid[2]

[1] *CNRS, UMR 8013 ELICO, Station Marine, Université des Sciences et Technologies de Lille BP 80, 62930 Wimereux, France*
[2] *Sir Alister Hardy Foundation for Ocean Science, The Laboratory Citadel Hill, Plymouth PL1 2PB, UK*
[3] *ICES, Palaegade 2–4, 1261 Copenhagen K, Denmark*

The Atlantic cod (*Gadus morhua* L.) has been overexploited in the North Sea since the late 1960s and great concern has been expressed about the decline in cod biomass and recruitment[1]. Here we show that, in addition to the effects of overfishing[1], fluctuations in plankton have resulted in long-term changes in cod recruitment in the North Sea (bottom-up control). Survival of larval cod is shown to depend on three key biological parameters of their prey: the mean size of prey, seasonal timing and abundance. We suggest a mechanism, involving the match/mismatch hypothesis[2], by which variability in temperature affects larval cod survival and conclude that rising temperature since the mid-1980s has modified the plankton ecosystem in a way that reduces the survival of young cod.

Fish stock biomass fluctuates in space and time, but the causes

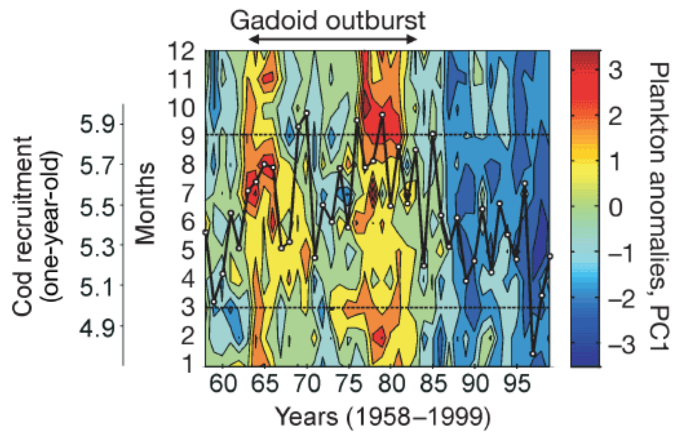
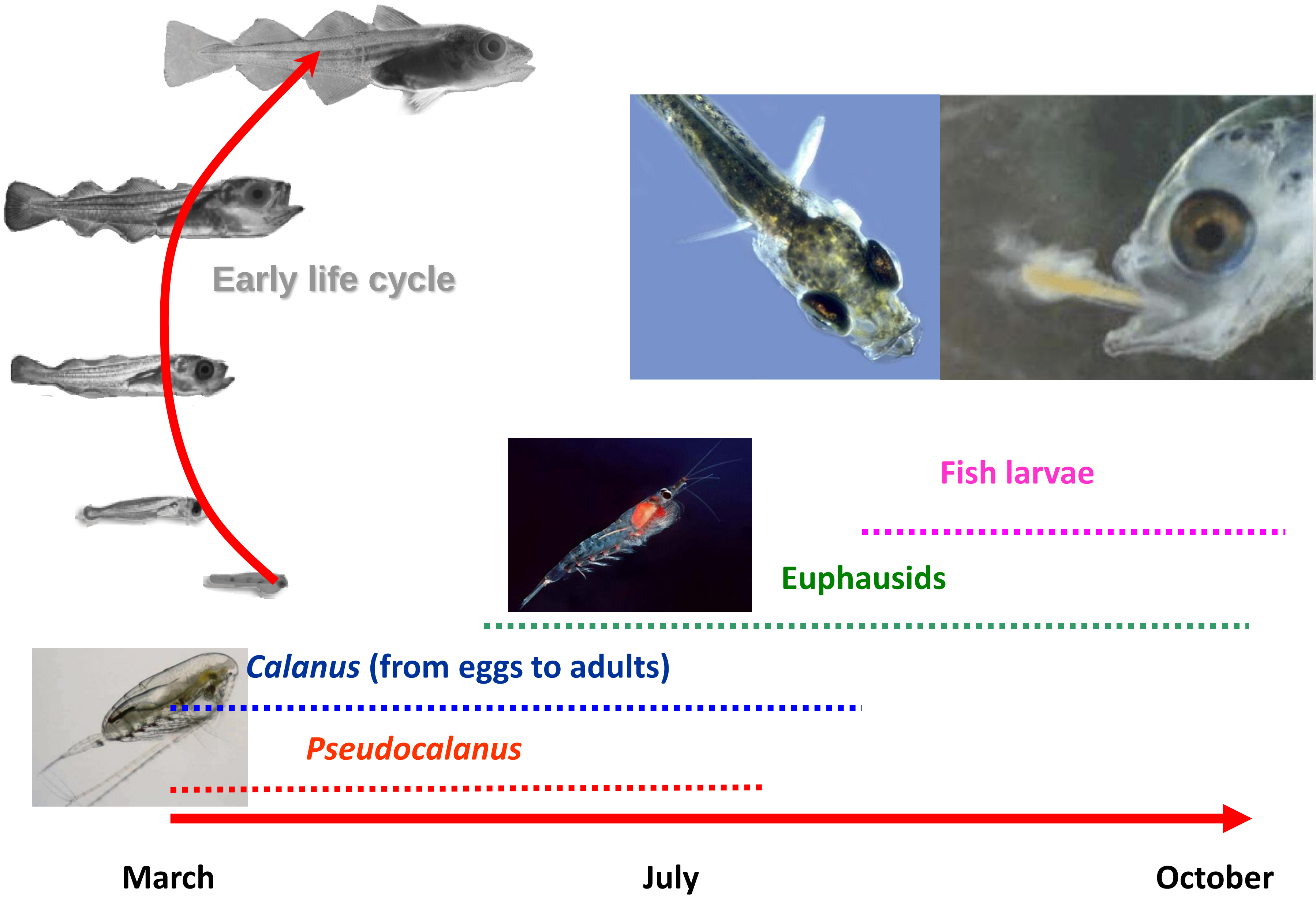
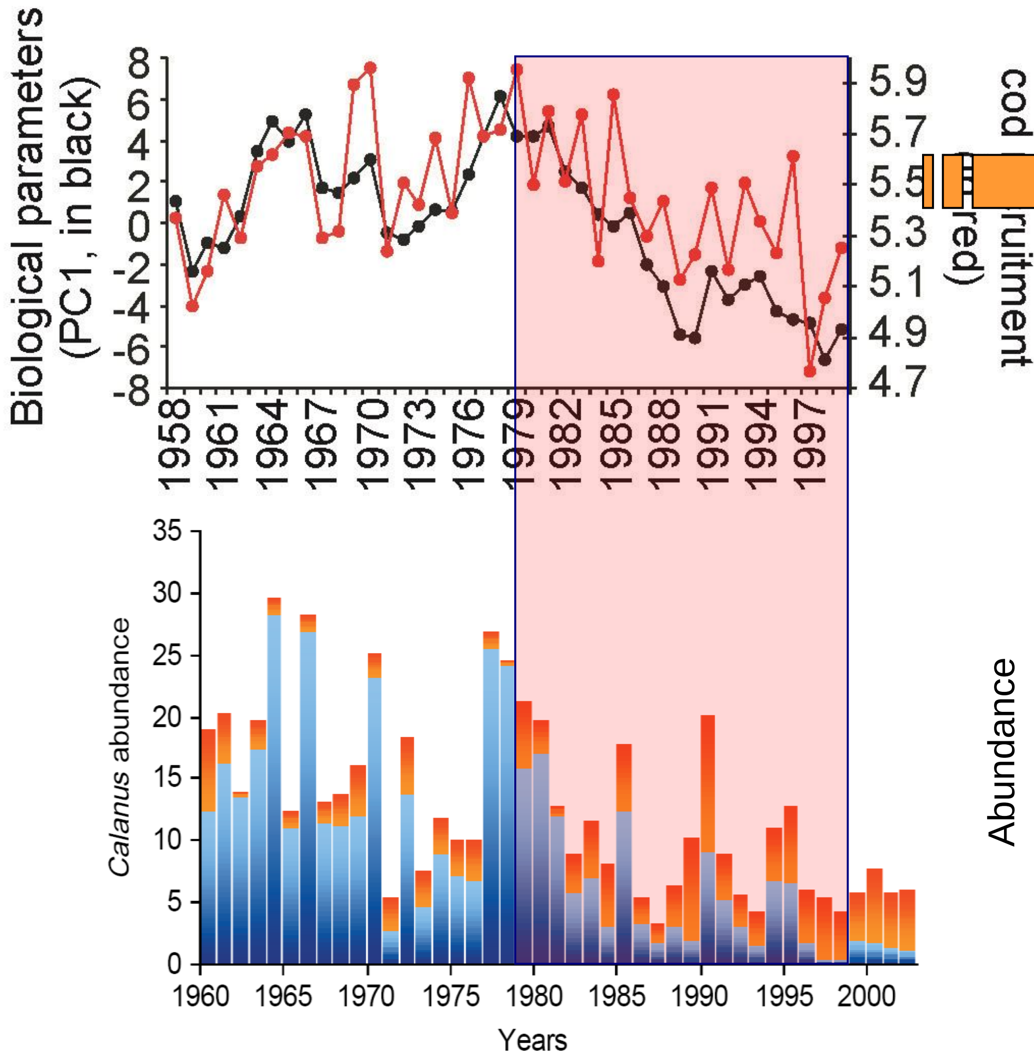


Figure 1 Long-term monthly changes (1958–1999) in the plankton index (as the first principal component, 33.78% of the total variability), resulting from analysis of the table years–months × biological indicators. The main variables related to this first principal component were, in order of importance, mean abundance (as mean number of individuals per CPR sample) of *C. finmarchicus* (normalized first eigenvector $C_m = 0.84$), euphausiids ($C_m = 0.72$), mean size of calanoid copepod ($C_m = 0.72$), *C. helgolandicus* ($C_m = -0.41$), calanoid copepod biomass ($C_m = 0.34$) and the genus *Pseudo-calanus* spp. ($C_m = 0.07$). A negative anomaly in the first principal component indicates a low value for all biological parameters with the exception of *C. helgolandicus* (opposite pattern) and *Pseudocalanus* spp. (no relationship). Cod recruitment (one-year-olds; in decimal logarithm) in the North Sea (curve in black) is superimposed with a lag of one year. The period of the 'gadoid outburst'[11] is indicated. Horizontal dashed lines indicate the period (March–September) of larval cod occurrence in the North Sea.

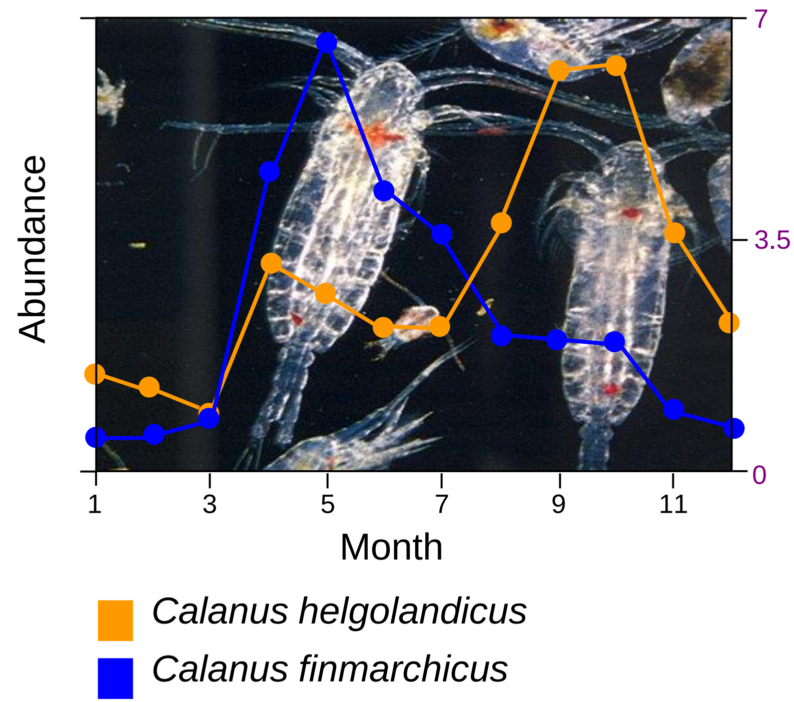
Empirical biological indicator for cod recruitment



a. Cod recruitment (one-year old) and biological parameters (original)



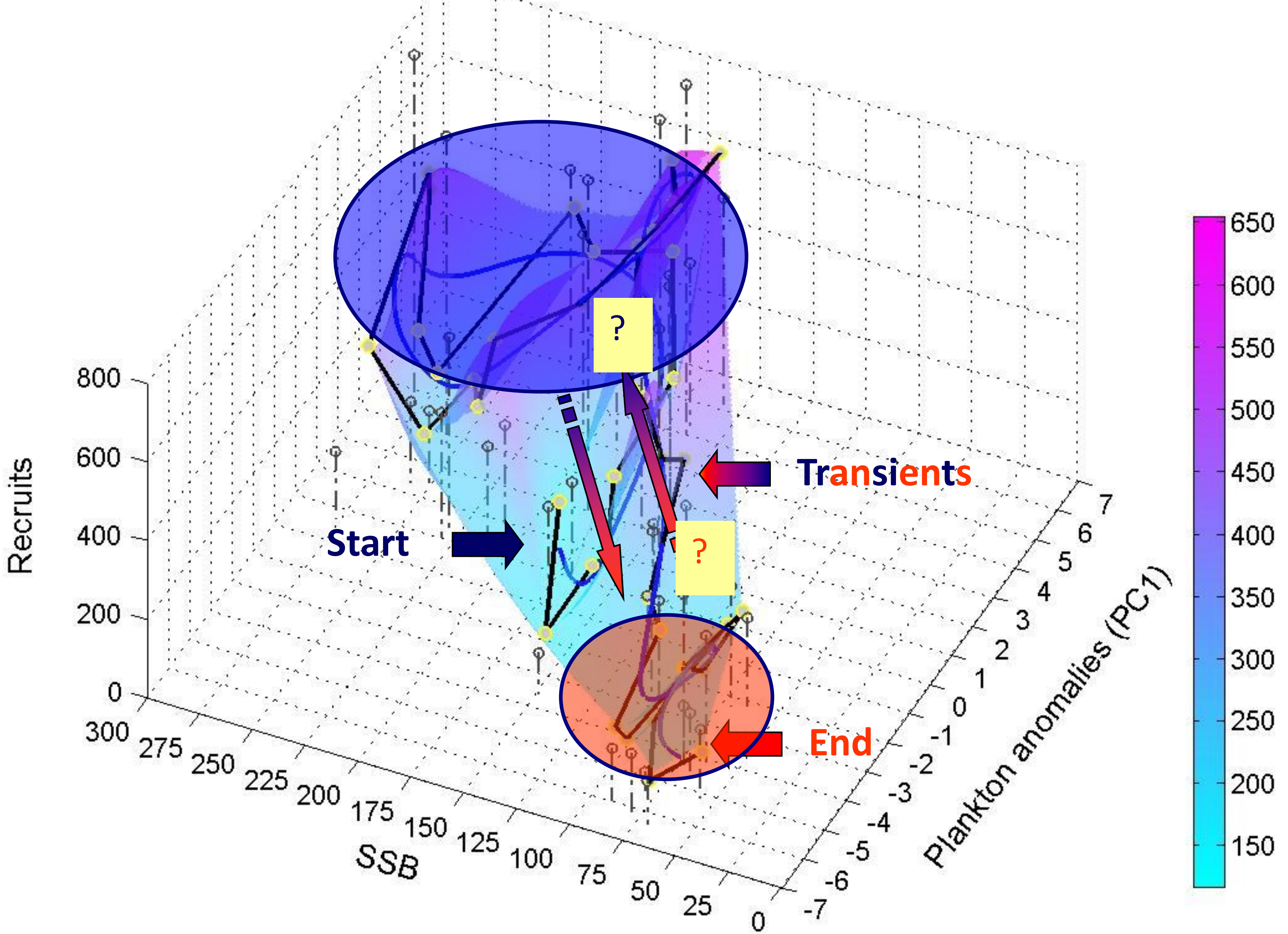
Is-it possible to forecast the impact of plankton changes on stock assessment of cod?



Beaugrand et al. (2003) Nature

Hays et al., (2005) TREE

Stock – recruitment – zoolankton: a dynamical system



Souissi et al. unpublished

Stock – recruitment : need of a new paradigm

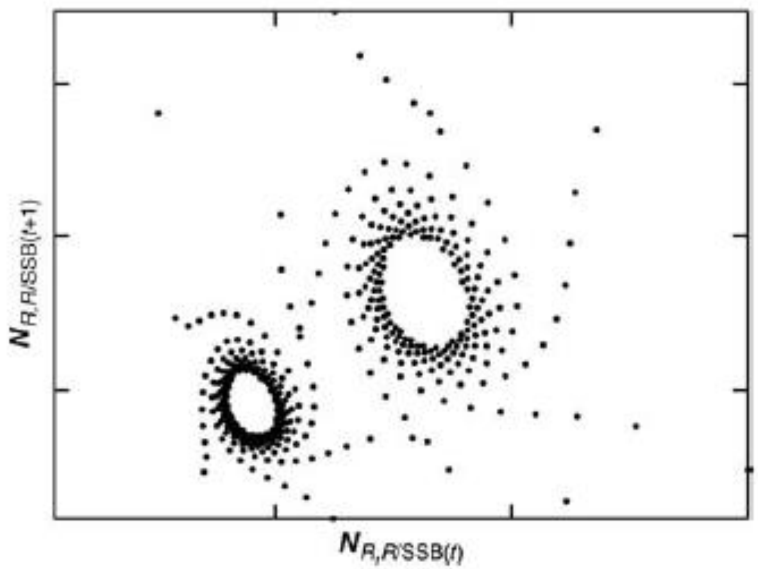
ICES Journal of Marine Science, 54: 427–443. 1997

Stock and recruitment in Baltic cod (*Gadus morhua*): a new, non-linear approach

A. P. Solari, J. M. Martín-González, and C. Bas

On the dynamics of *Sardina pilchardus*: orbits of stability and environmental forcing

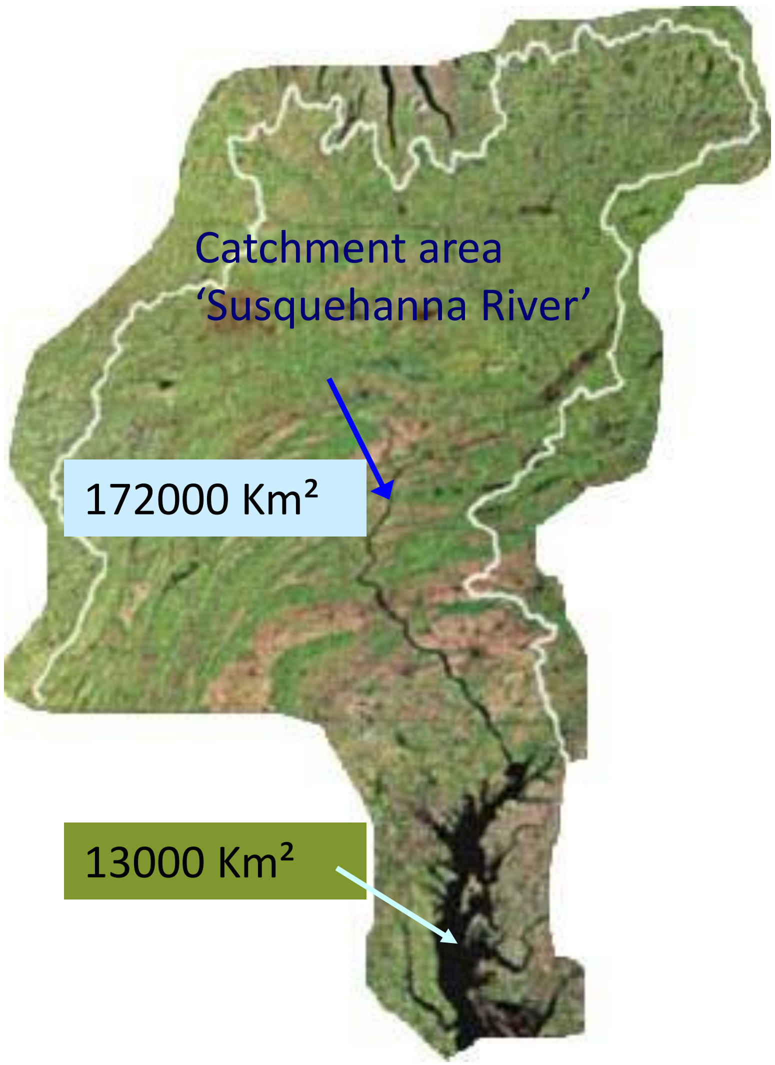
Solari et al. (2010) ICES JMS

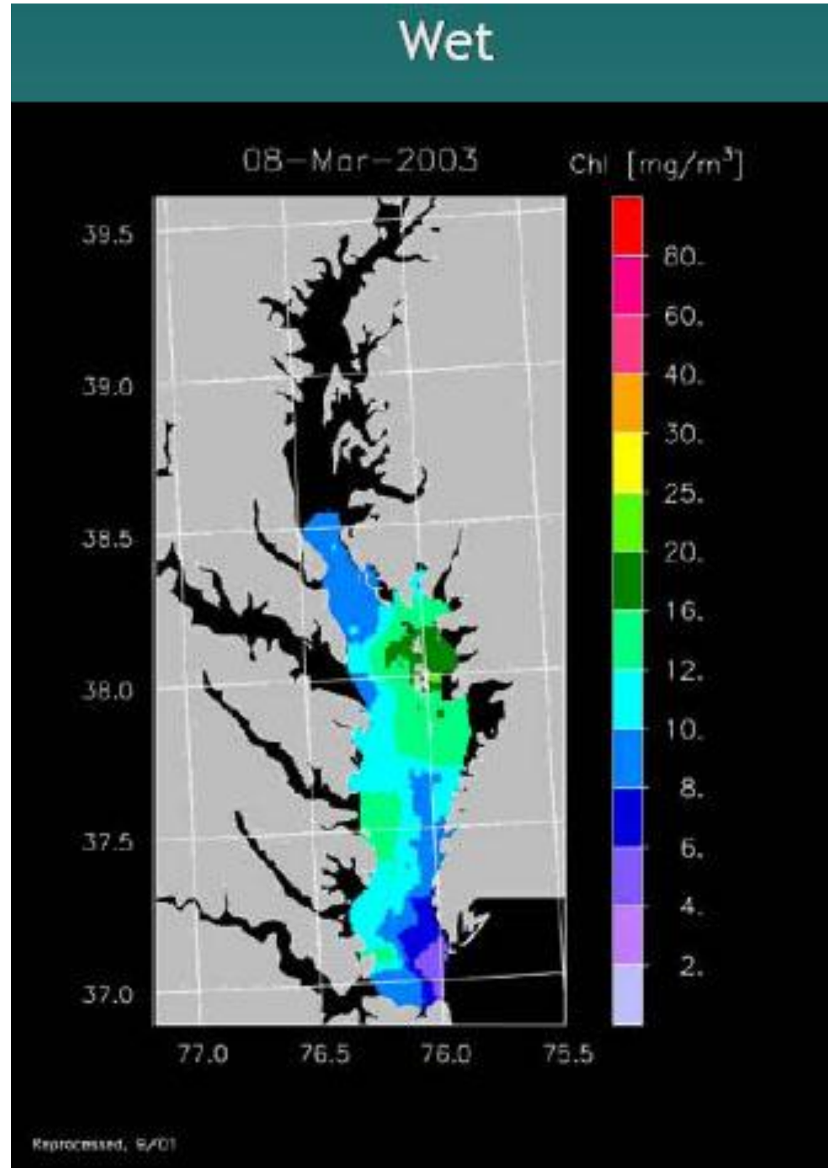


Carrying capacity of an ecosystem can oscillate between several states (attractors) that can be determined by density-dependent and density independent factors.

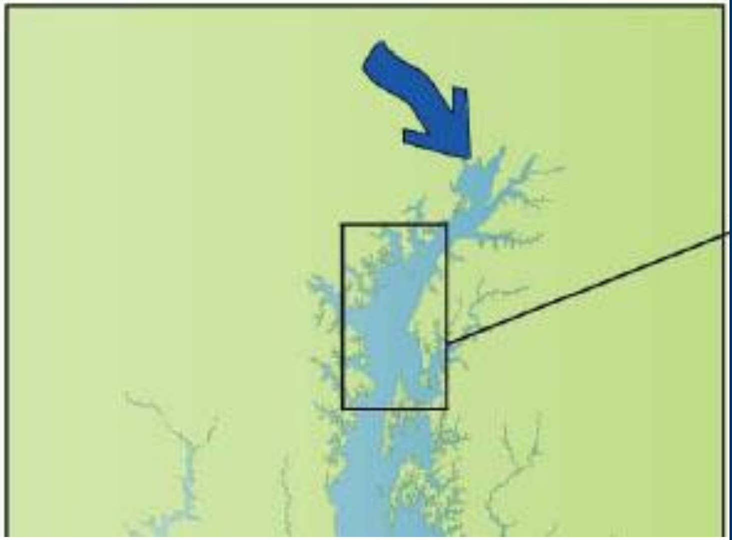
Is-it possible to restore/improve the carrying capacity of an aquatic ecosystem (i.e. California's Bay-Delta ecosystem)?

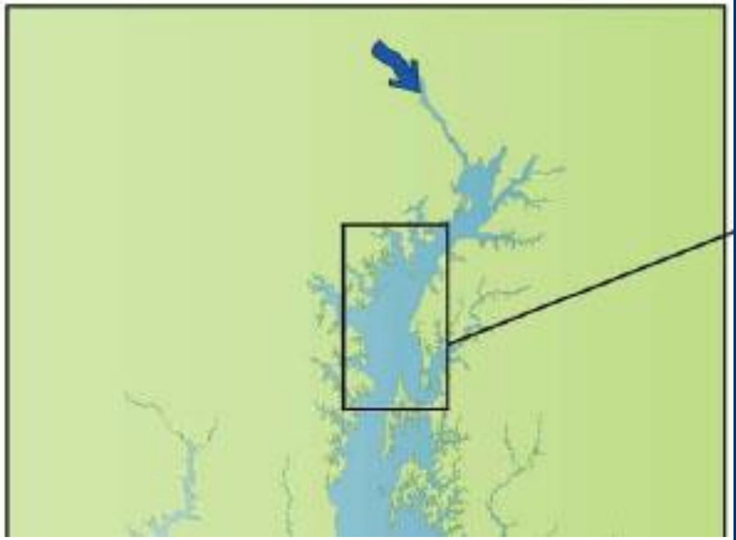
Modifications of the pelagic ecosystem in the Chesapeake bay



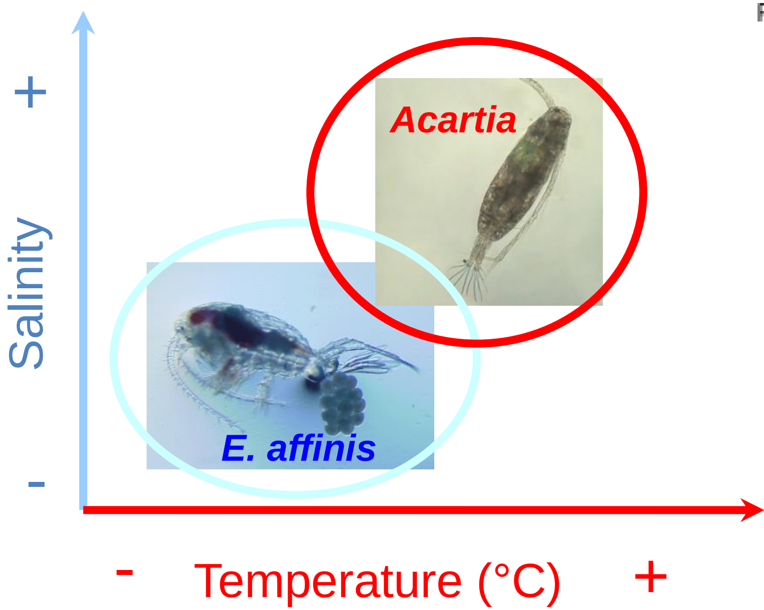


From Kimmel et al. (2006, 2008)

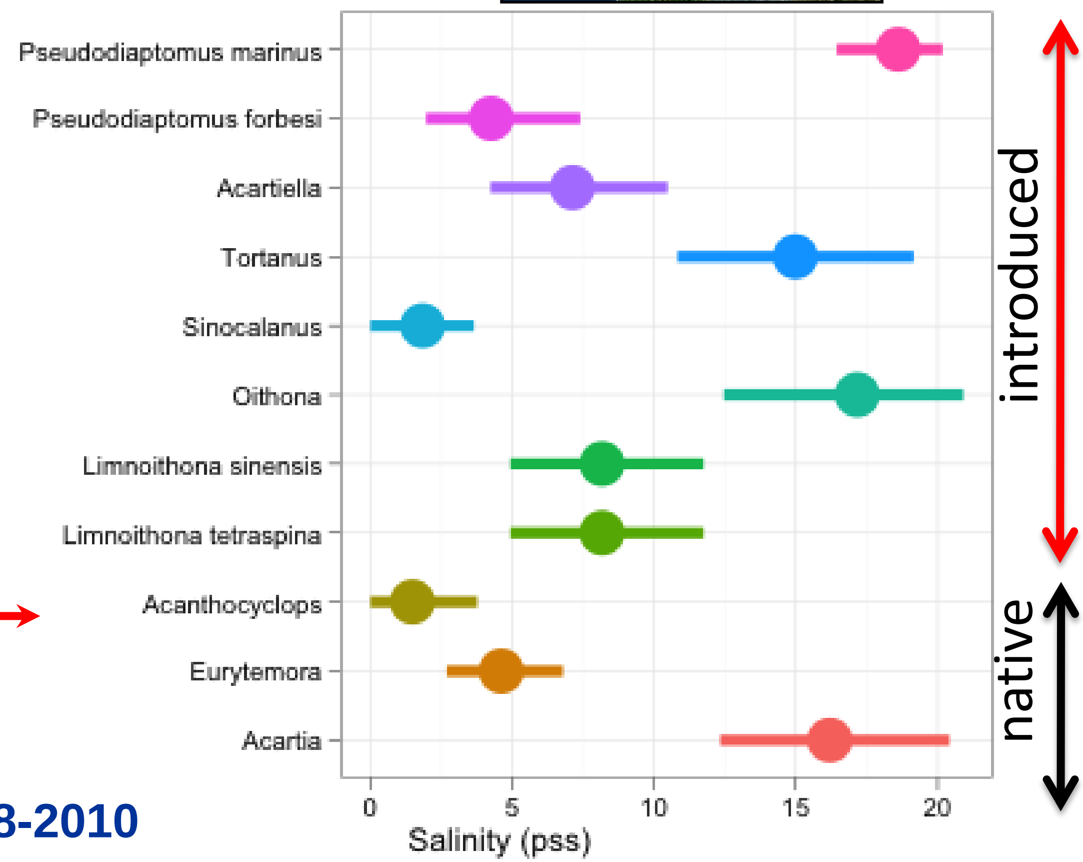




From Kimmel et al. (2006)



Souissi et al. ZOOSEINE 2008-2010



From Winder & Jassby (2010)

Freshwater ecosystems: large lakes as an example

Fisheries Management and Ecology

Fisheries Management and Ecology, 2009, **16**, 492–500

Influences of human activity and climate on the stock-recruitment dynamics of whitefish, *Coregonus lavaretus*, in Lake Geneva

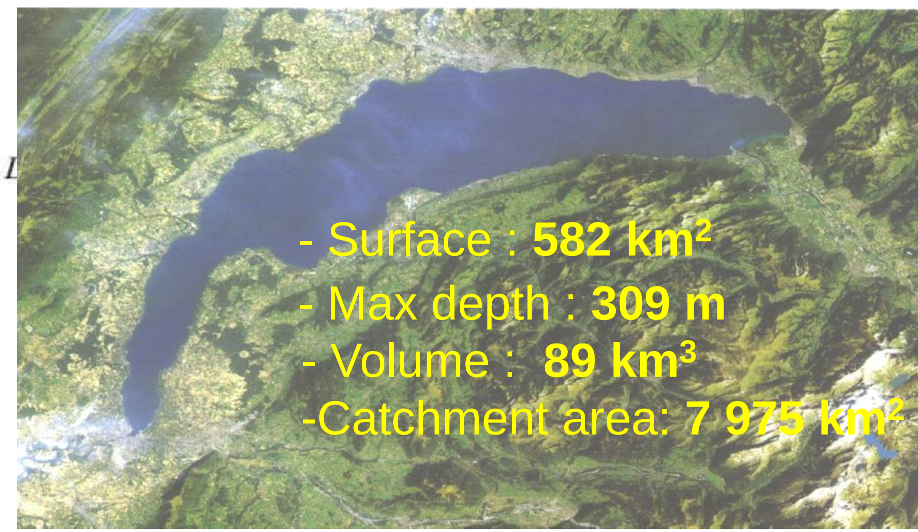
O. ANNEVILLE

INRA, Station d'hydrobiologie lacustre, Thonon les Bains Cedex, France

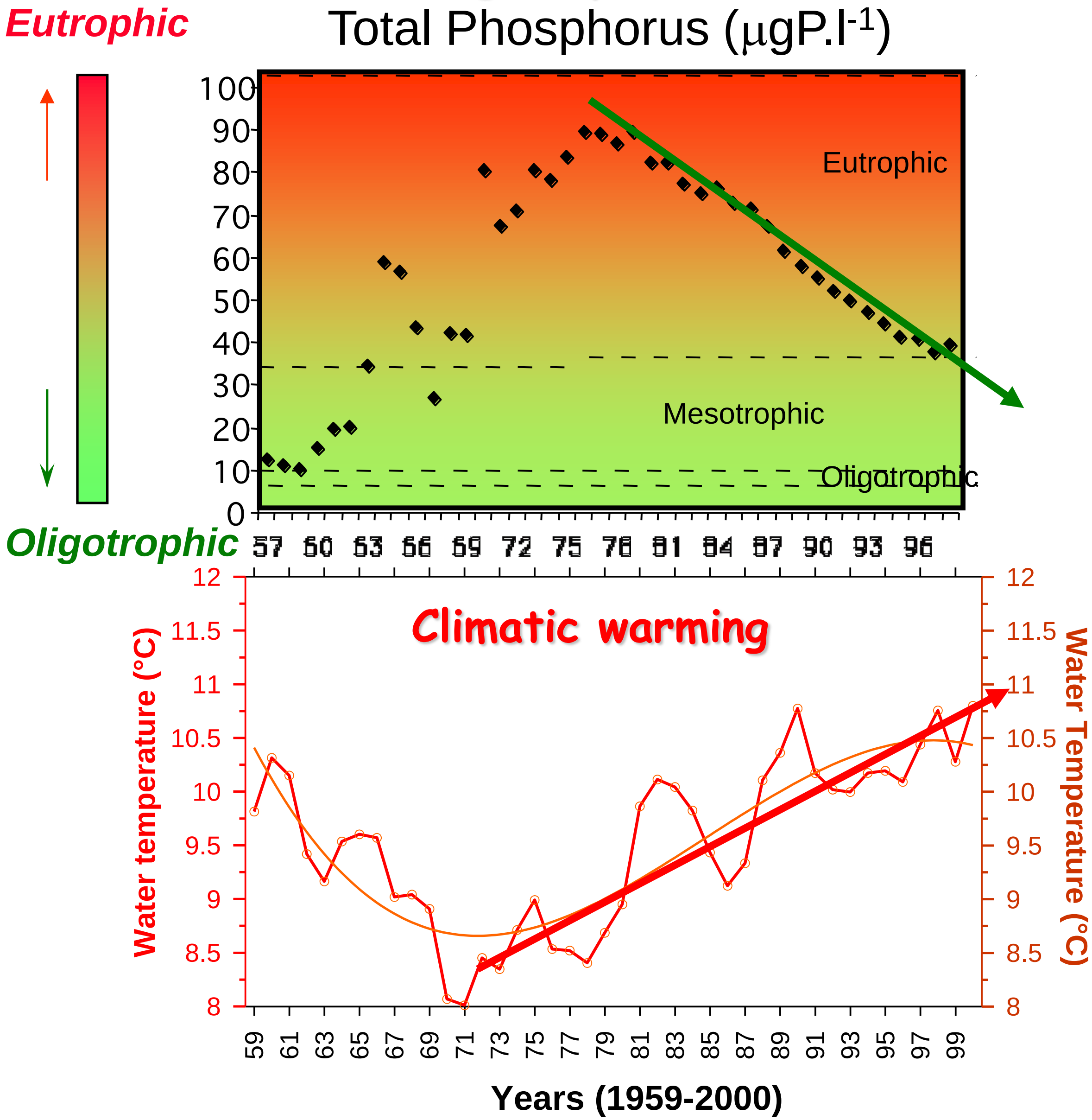
S. SOUISSI

Université des Sciences et Technologies de Lille-Lille 1, L

Wimereux, UMR CNRS 8187, Wimereux, France



Eutrophication- Oligotrophication



Consequences of two opposite driving forces on lake ecosystem and fish production

Souissi et al. (to be submitted)

No Density-Dependence

Linear stock-recruitment model

Anneville, Souissi et al. (2009)

Recruitment was improved

Phosphorus reduction

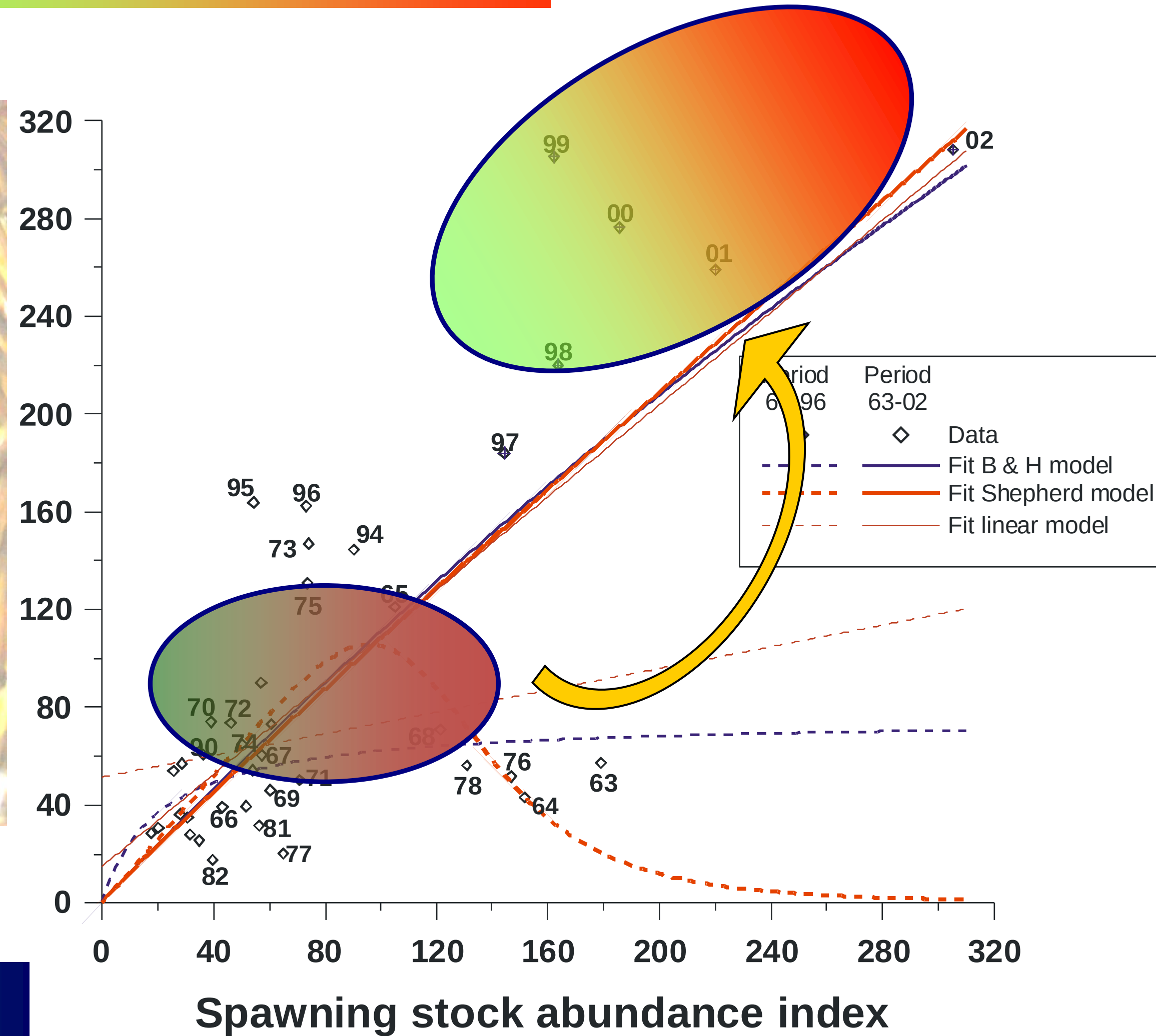
-Survival of eggs

Water warming

-Good match between zooplankton timing and larval development

Aquaculture

-Stocking of eggs and release of whitefish larvae in the lake

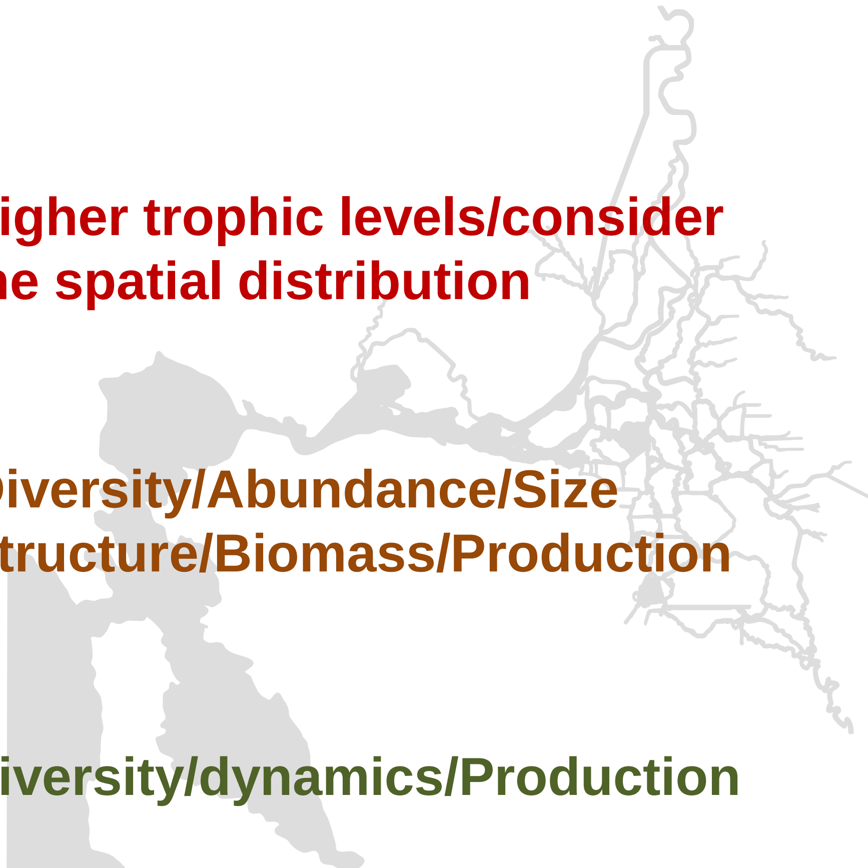


Density-Dependence

Shepherd stock-recruitment model

Caranhac and Gerdeaux (1998) Arch. Hydrobiol.

Partial conclusion

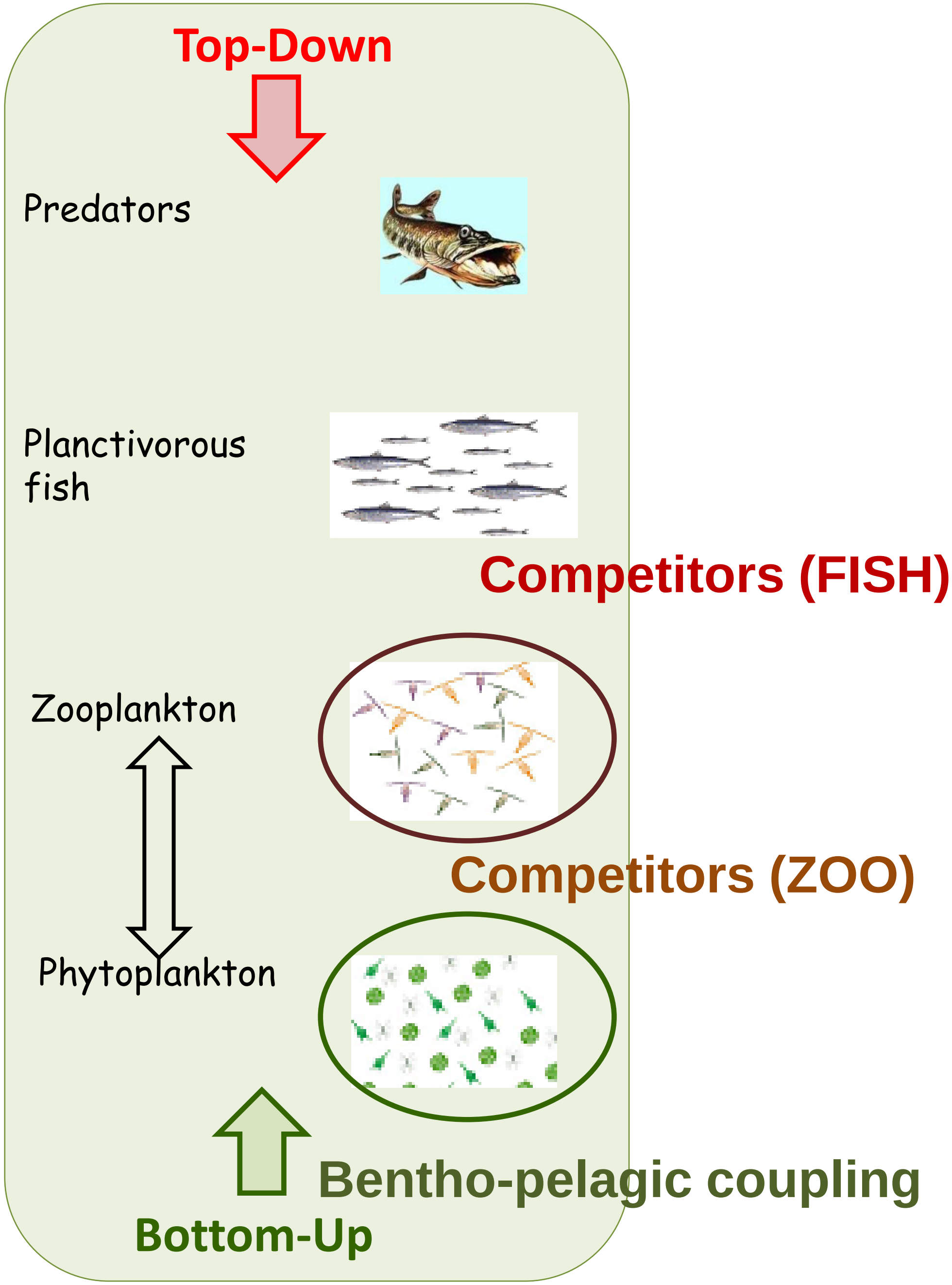


Higher trophic levels/consider the spatial distribution

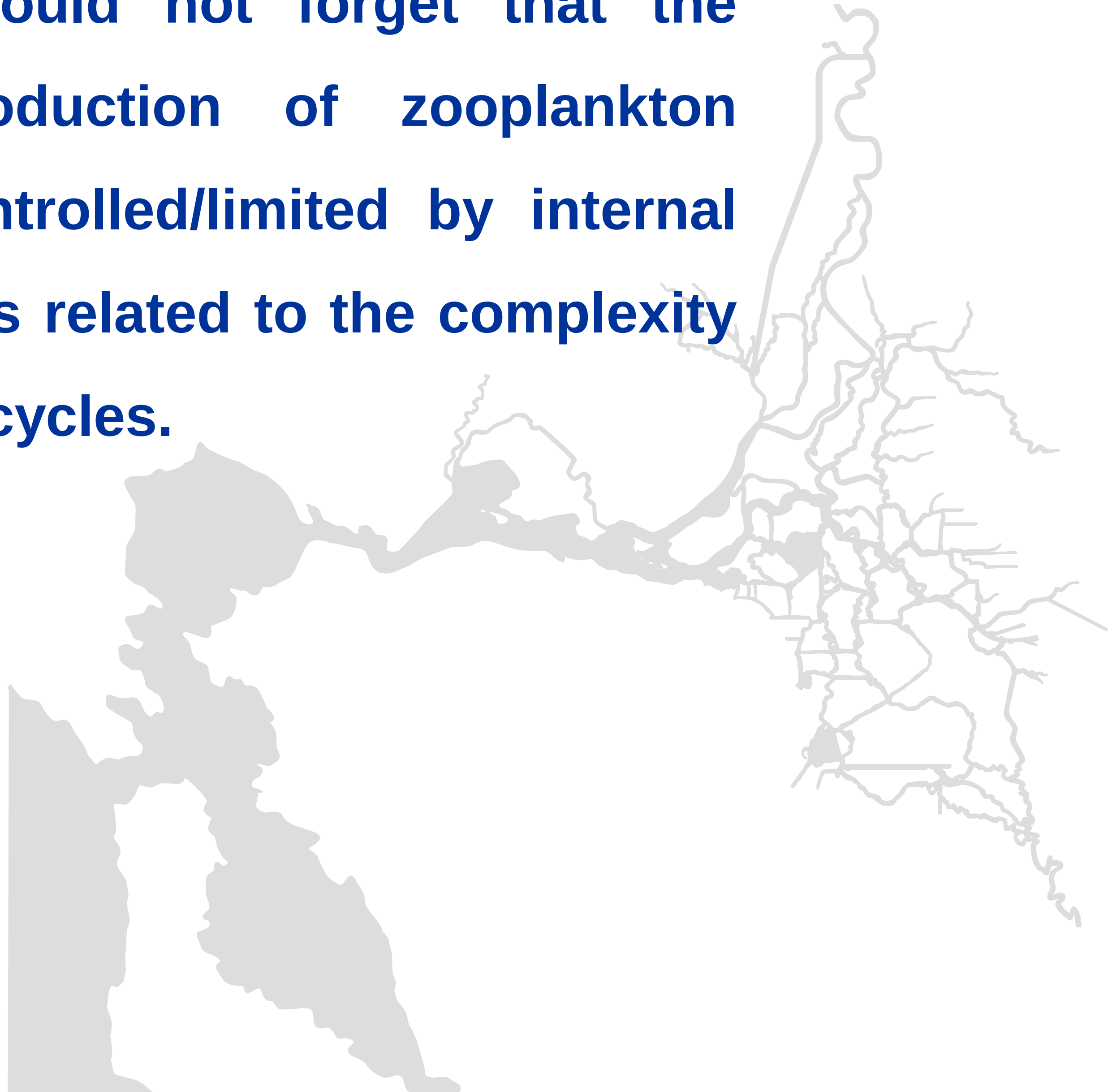
Diversity/Abundance/Size structure/Biomass/Production

Diversity/dynamics/Production

Water quality and pelagic habitats



But we should not forget that the biomass/production of zooplankton can be controlled/limited by internal mechanisms related to the complexity of their life cycles.



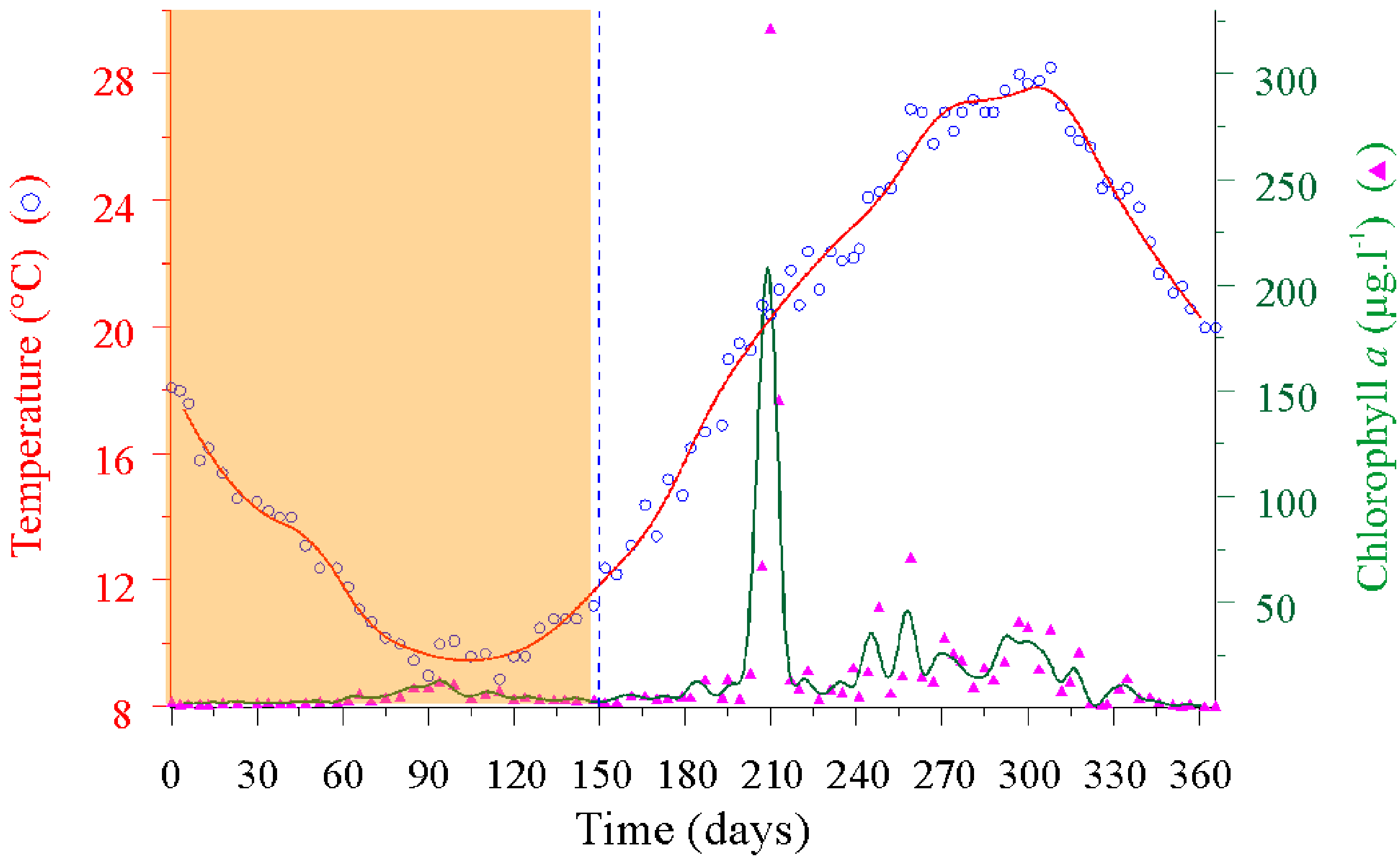
ELSEVIER

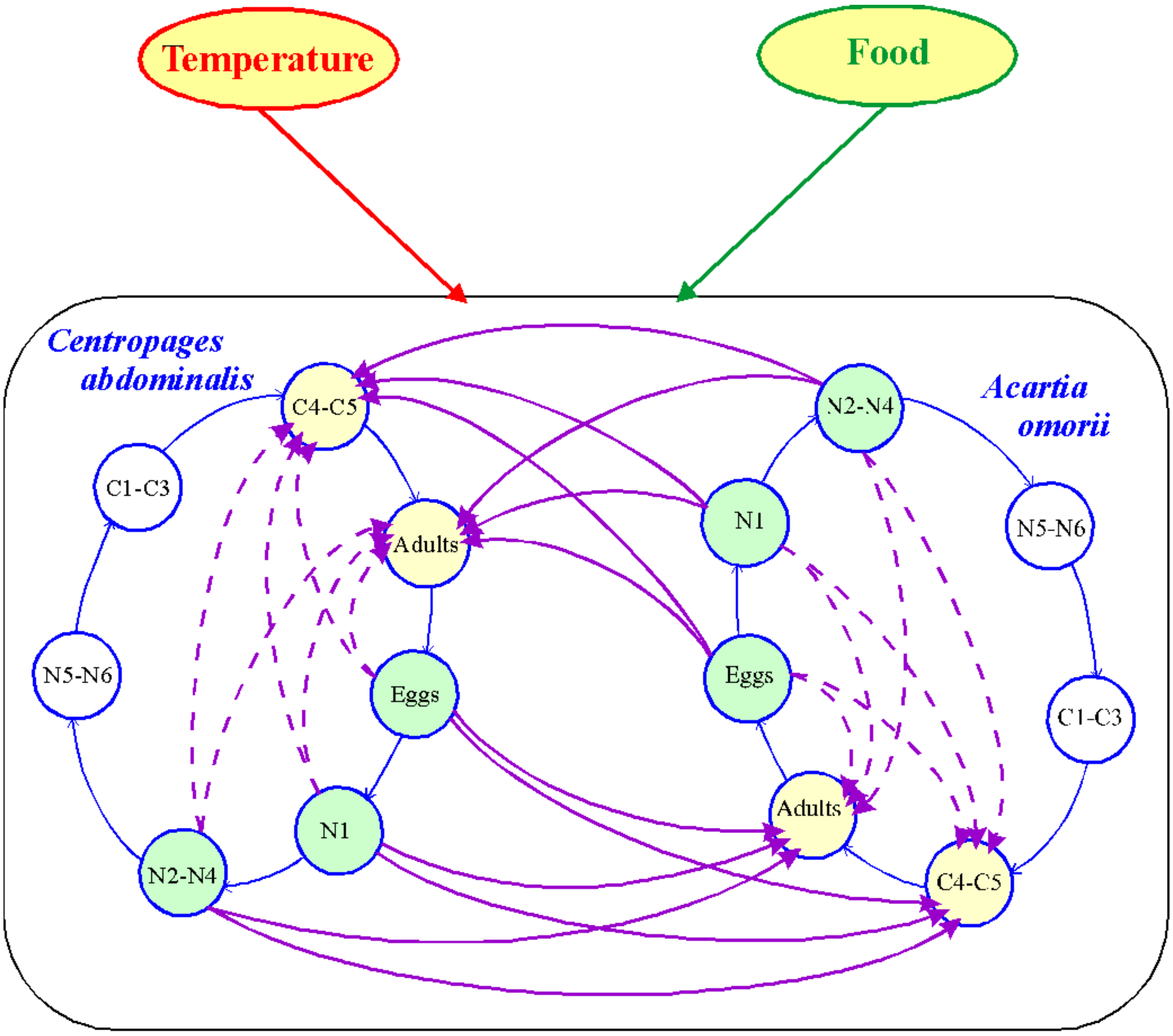
Journal of Marine Systems 15 (1998) 495–501

JOURNAL OF MARINE SYSTEMS

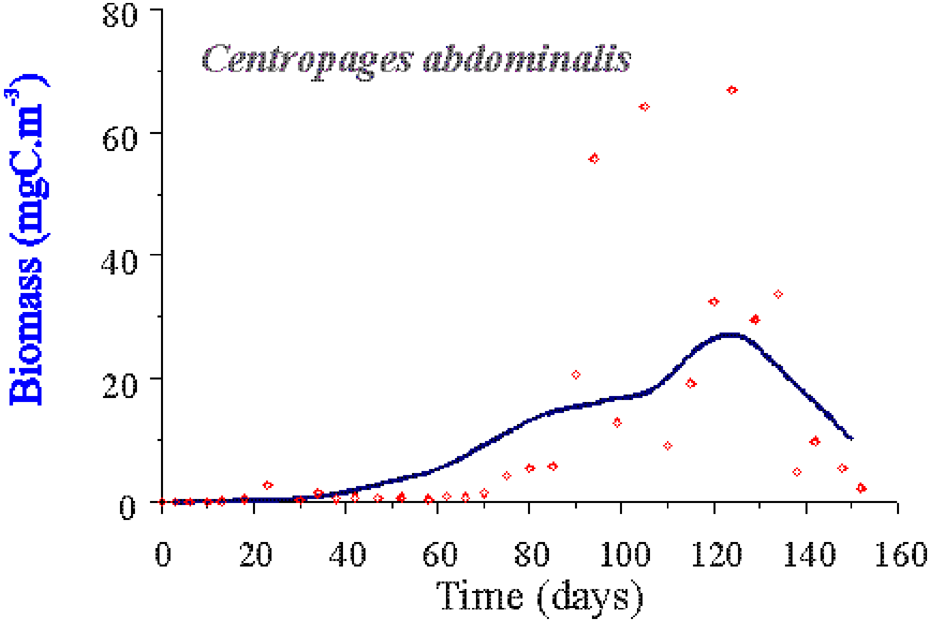
Copepods attain high abundance, biomass and production in the absence of large predators but suffer cannibalistic loss

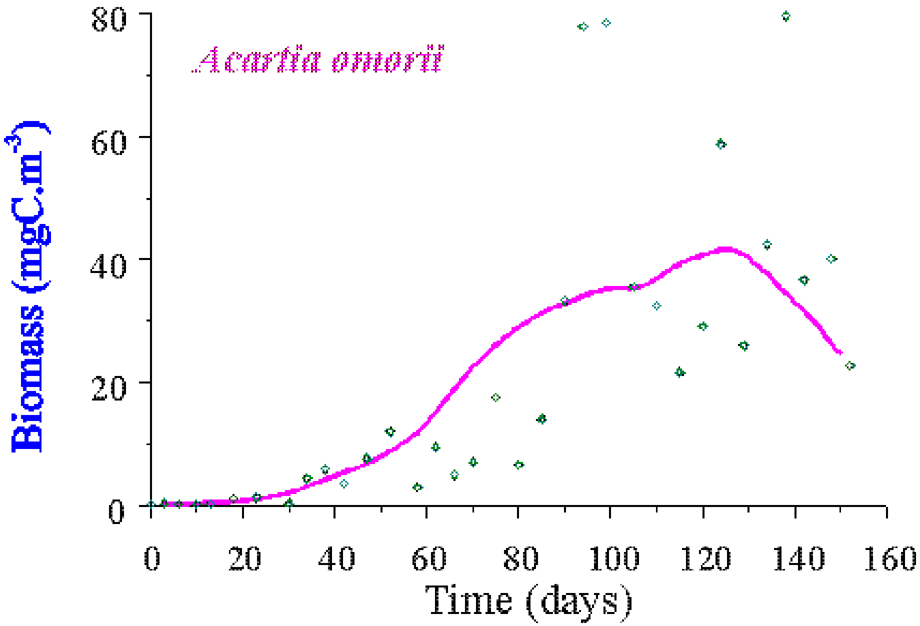
Shin-ichi Uye *, Dong Liang





Souissi et al. (1997); Souissi & Nival (1997); Souissi & Ban (2001); Souissi et al. (2004, 2005)





It is important to consider the life cycle of the key copepods and use <u>experimental</u> and <u>modeling approaches</u> to better understand the studied system(s)

In conclusion

Zooplankton is one of the key components of estuary food web and should be deeply studied (see Wim's talk for the review of the situation in the SF estuary)

Make a global cost-benefit analysis based on the objectives of the restoration program:
Why (mitigate natural and human impacts)?
How much (surface/type of habitat)?
Where (Upper or Lower estuary)?
How (Ecological Engineering)?
Define a list of indicators to be monitored in order to assess the effect of the restoration program?


Thank you for your attention
Special thanks to my research group members, international collaborators and many funding sources