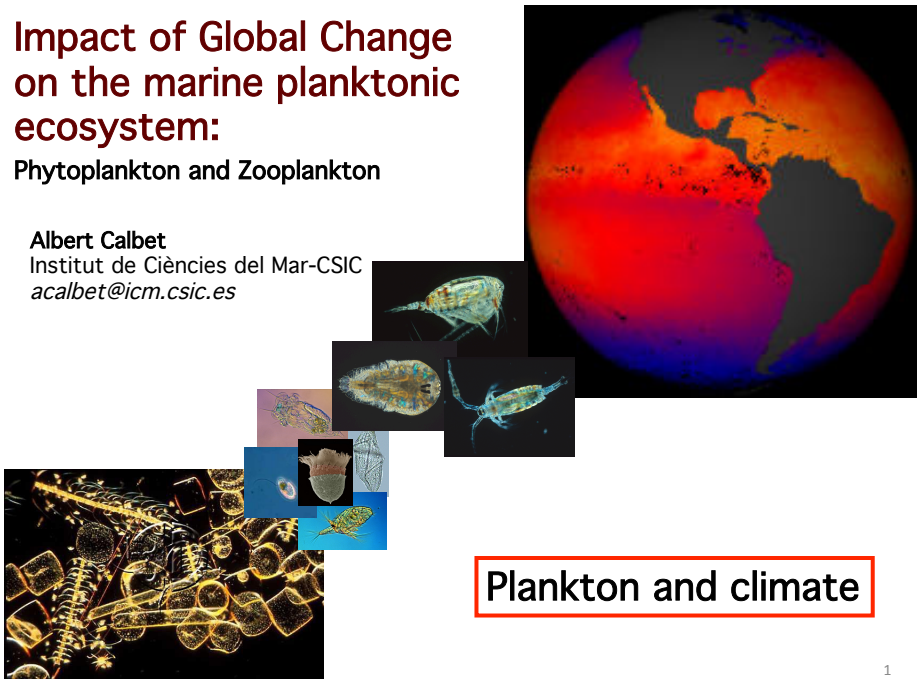
Impact of Global Change on the marine planktonic ecosystem:

Phytoplankton and Zooplankton

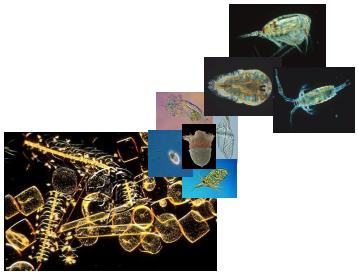
Albert Calbet
Institut de Ciències del Mar-CSIC
acalbet@icm.csic.es



Plankton and climate

1

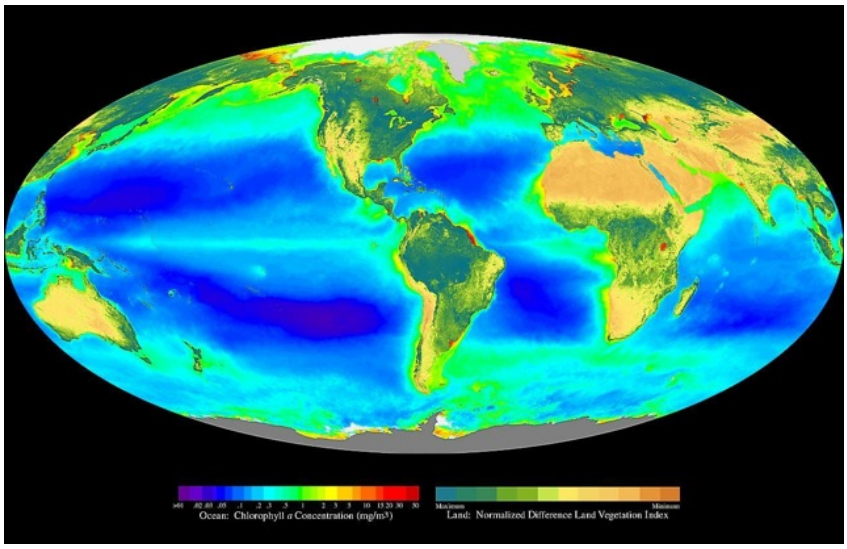
Plankton and climate



1. Global patterns of distribution (low and high latitudes)
2. Daily cycles
3. Seasonality
4. The importance of long term series
5. Multiannual phenomena: ENSO, NAO, etc.

2

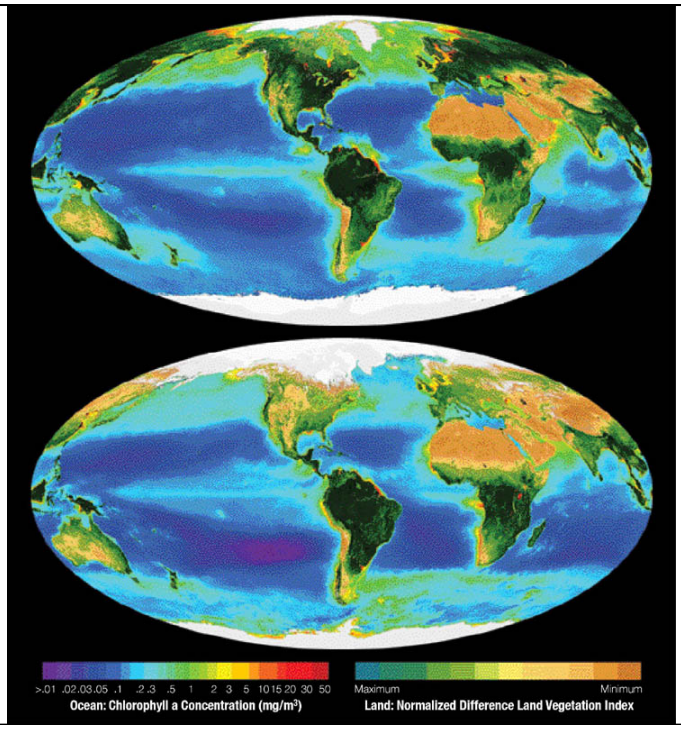
Phytoplankton distribution



3

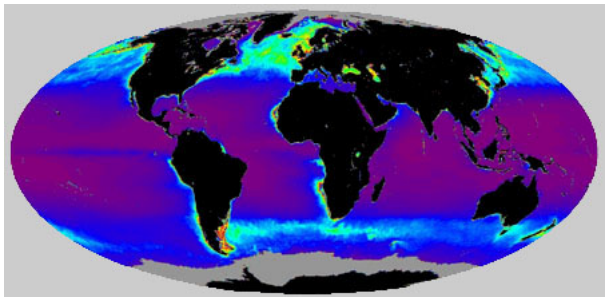
Summer

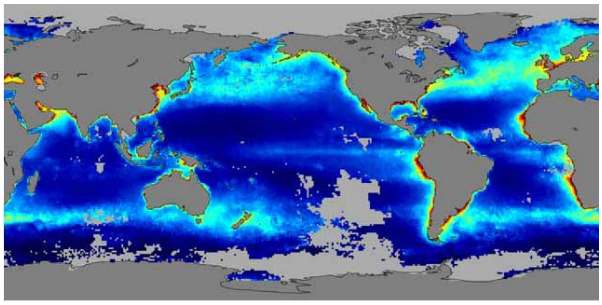
Winter



4

Primary production



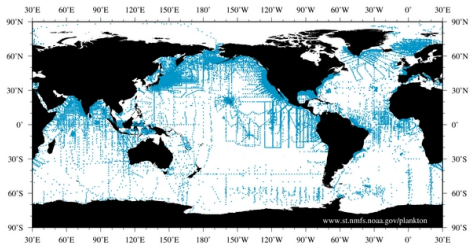


Net Primary Productivity (grams Carbon per m² per year)

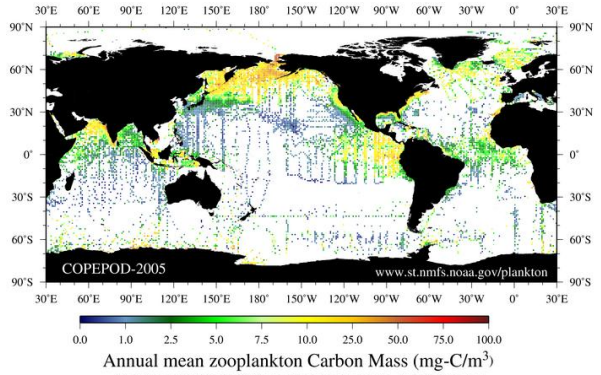
0 200 400 600 800

5

Copepod distribution

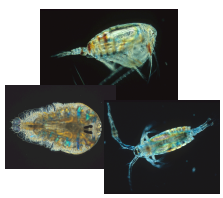


COPEPOD–2007: Distribution of ALL BIOMASS TYPES observations.



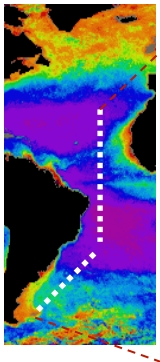
Annual mean zooplankton Carbon Mass (mg-C/m^3)

(Sampling depth interval: 0 - 200 meters; Sampling mesh: ~330 micrometers)

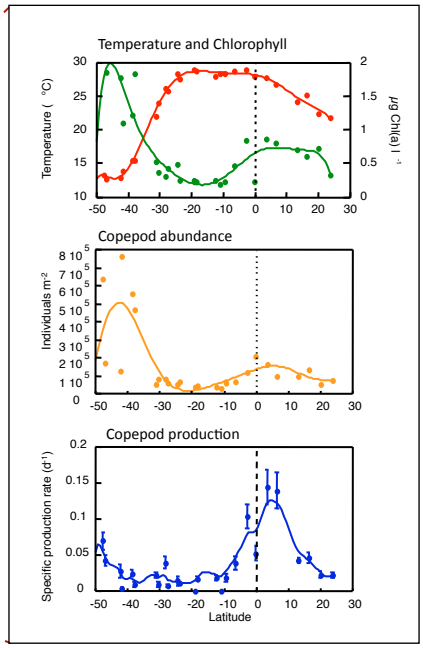


6

Usually, high phytoplankton areas support more zooplankton (but not necessarily more productivity)

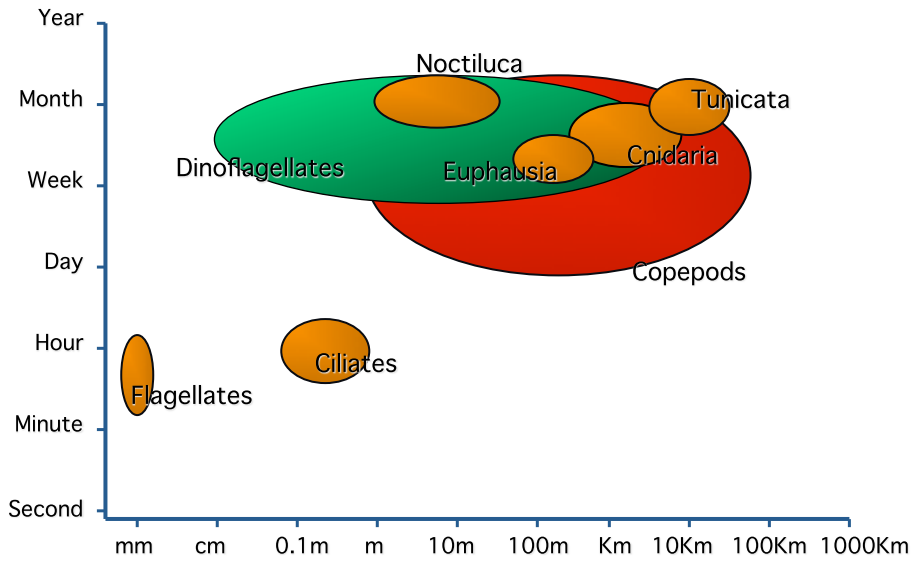


Calbet, A. and Agustí, S., 1999



7

The zooplankton distribution is heterogeneous both in time and space

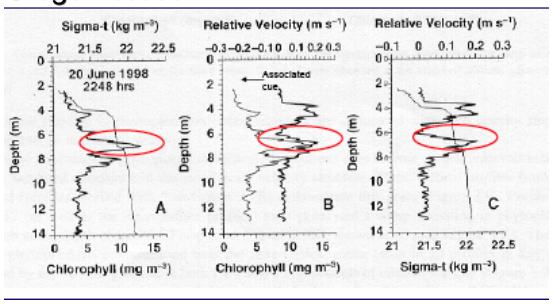


Marine zooplankton colloquium 2001

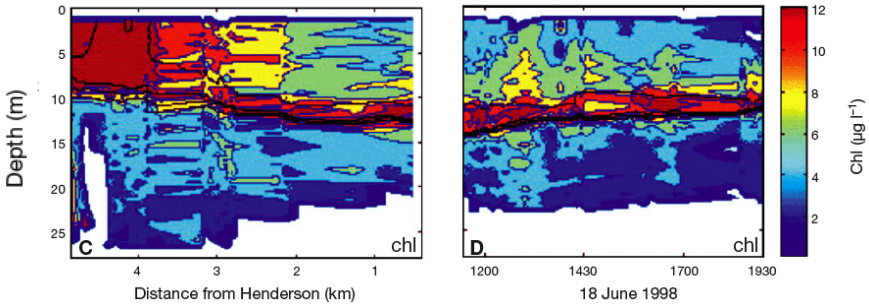
8

Fine-scale distribution of phytoplankton

Oregon coast



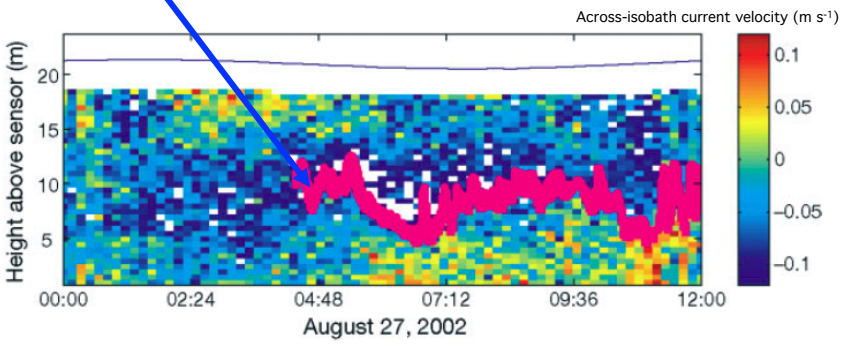
East Sound, Washington (McManus et al. 2003)



9

Fine-scale distribution of Zooplankton

Zooplankton 1 m wide layer



Monterrey Bay, *McManus et al. 2005*

10

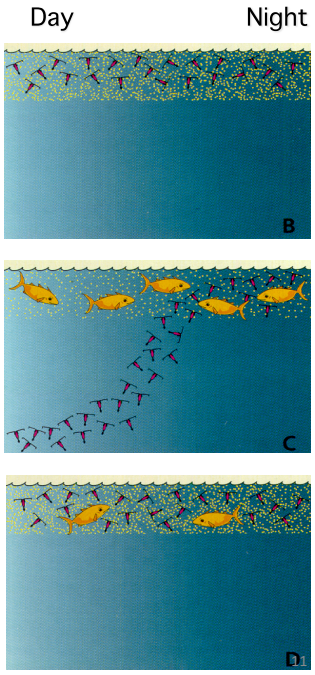
Vertical migrations and daily rhythms

Why zooplankton migrate?

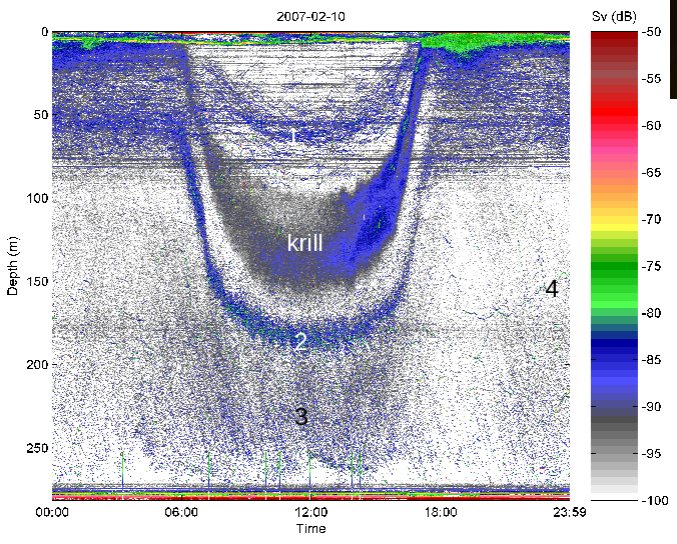
- To avoid predators
- Adults and egg dispersion
- Metabolic benefits

?

Vertical migrations are connected to feeding rhythms

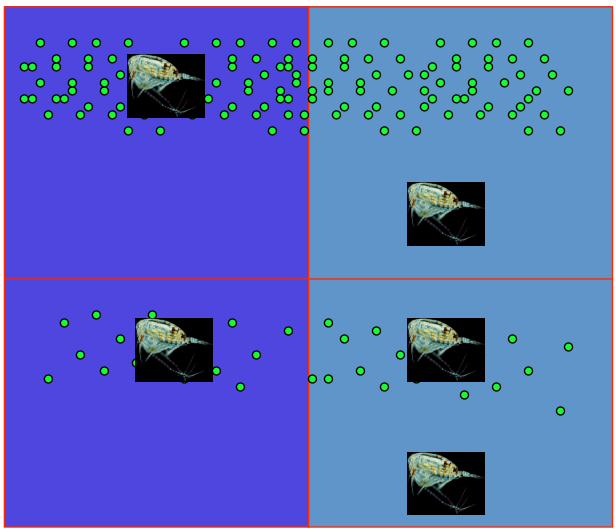


Daily cycles: vertical migration



Norwegian Ocean Observatory Network

Does predation risk affects daily feeding patterns?



High food

?

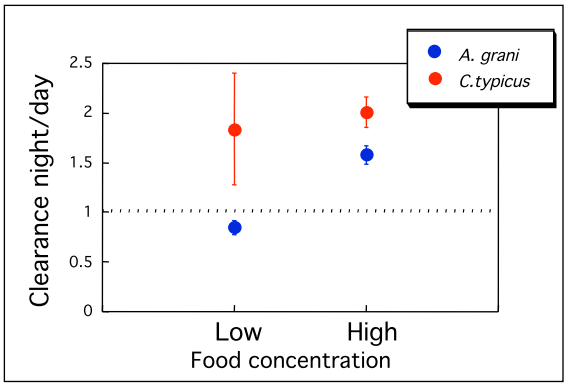
Low food
Higher predation risk

13

Light-day cycles

Centropages typicus
(coastal, open ocean)

Acartia grani
(harbors, estuaries)



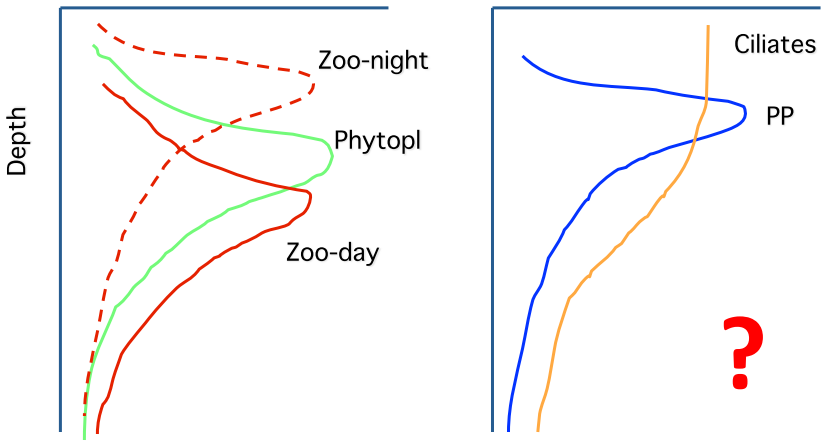
A. grani losses rhythm at low food concentrations

C. typicus keeps rhythm

Calbet et al. 1999

14

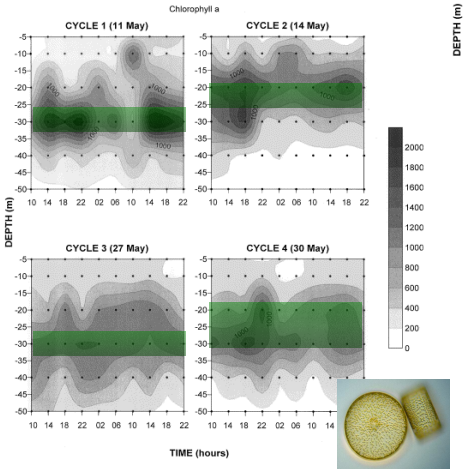
But, what is the use of vertical migration in oligotrophic seas?

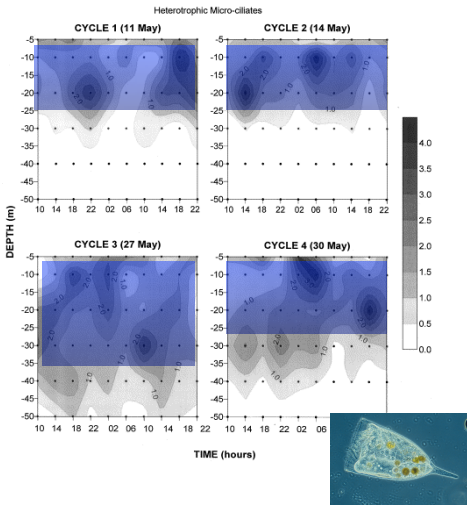


15

Phytoplankton and ciliate distribution

Ligurian sea (NW Mediterranean)





Also dispersion, metabolic benefits

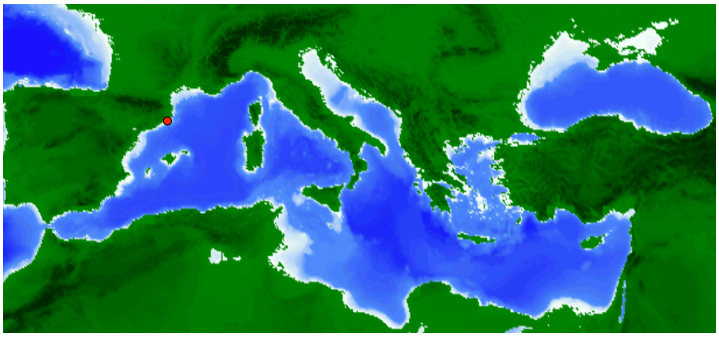
Pérez et al. 2000

16

Seasonal succession of zooplankton in Blanes Bay

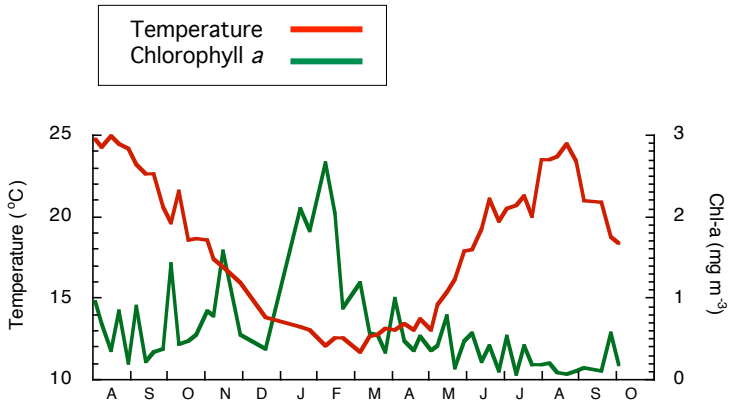
Blanes Bay, Catalonia, Coastal area. August 1995-October 1996

Calbet et al. 2001



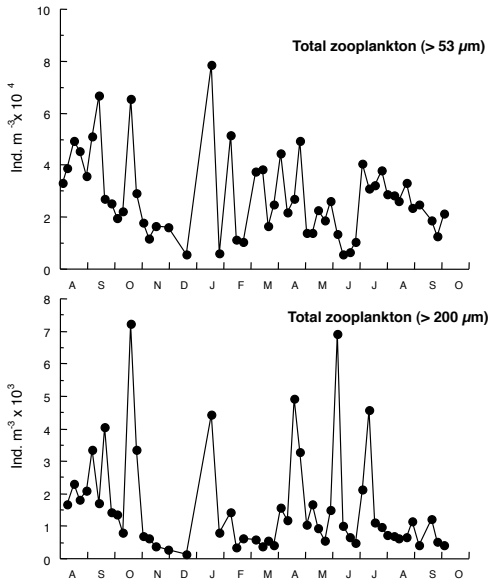
17

Phytoplankton and temperature



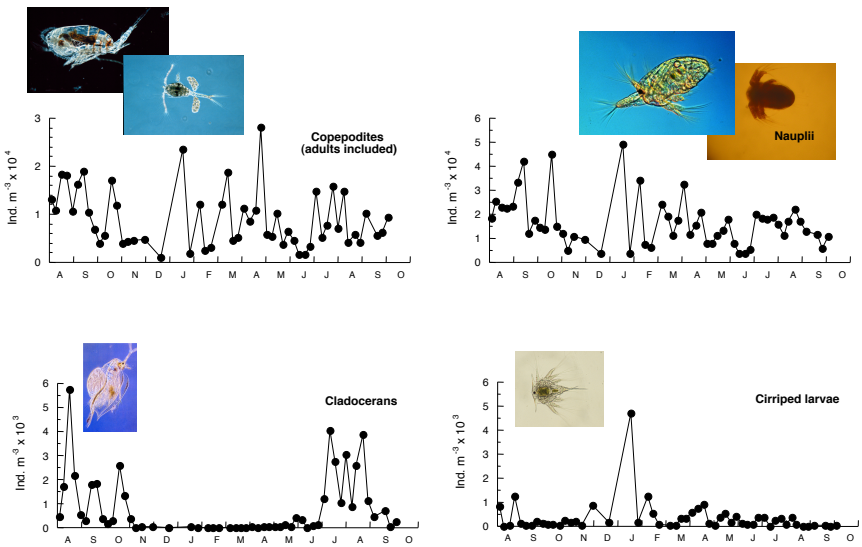
18

Total zooplankton abundance along the seasonal cycle



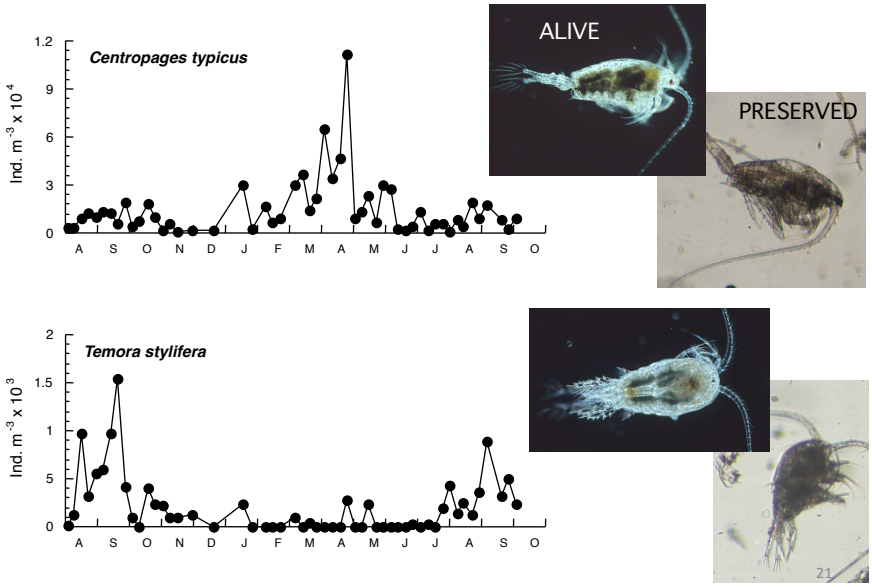
19

Main groups: crustaceans



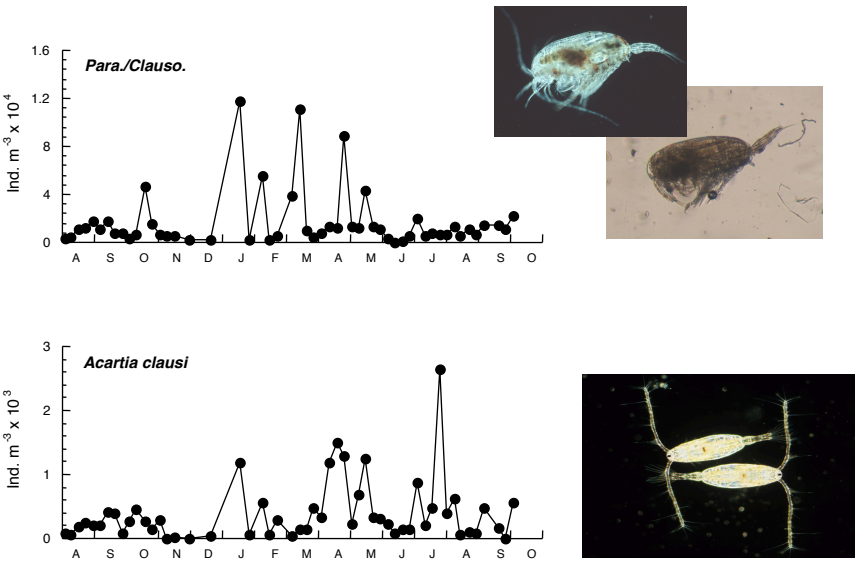
20

Copepods: calanoids



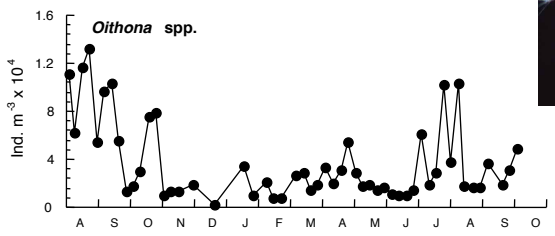
21

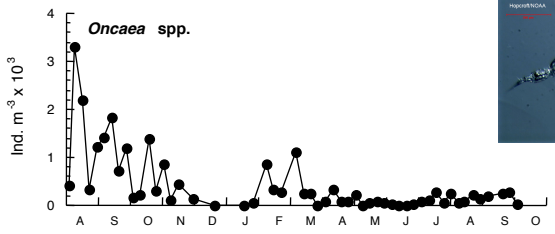
Copepods: calanoids

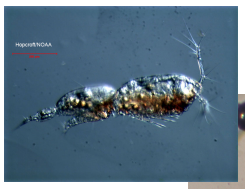


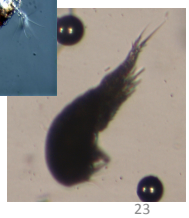
22

Copepods: cyclopoids



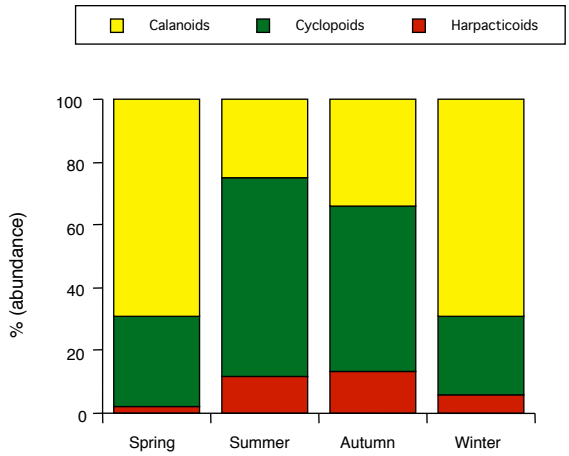






23

Summary: seasonal % abundance of main groups



24

Seasonality: species succession

Be aware of natural variability in space and time

Centropages typicus

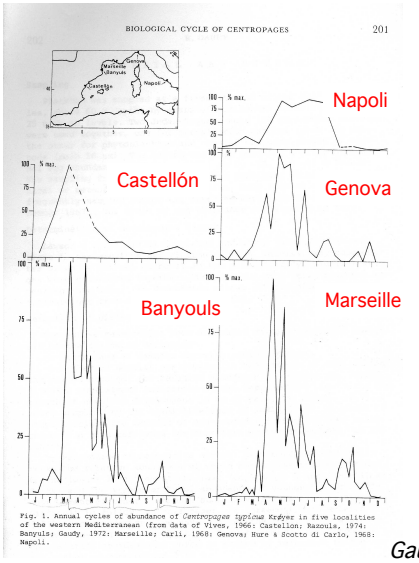
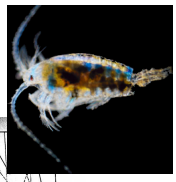


Fig. 1. Annual cycles of abundance of *Centropages typicus* Krøyer in five localities of the western Mediterranean (from data of Vives, 1966: Castellon; Razouls, 1974: Banyuls; Gaudy, 1972: Marseille; Carli, 1968: Genova; Rure & Scotto di Carlo, 1968: Napoli.

Gaudy 1984

25

Razouls 1974 (*C. typicus*, Banyuls)



Variability in time

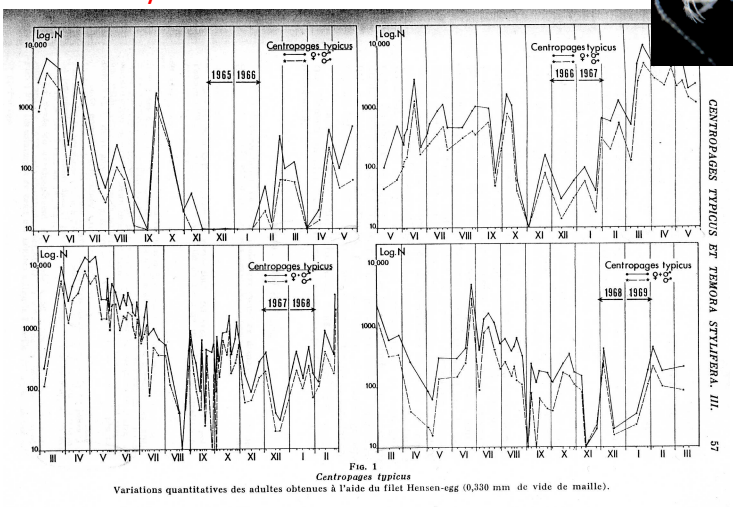


Fig. 1
Centropages typicus
Variations quantitatives des adultes obtenues à l'aide du filet Hensen-egg (0,330 mm de vide de maille).

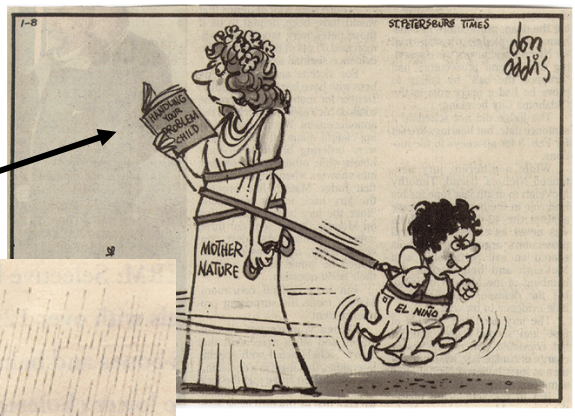
This variability may be result of large-scale climatic events

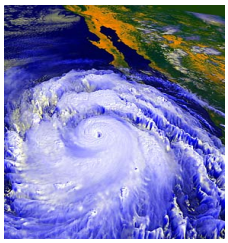
26

"EL NIÑO"

?

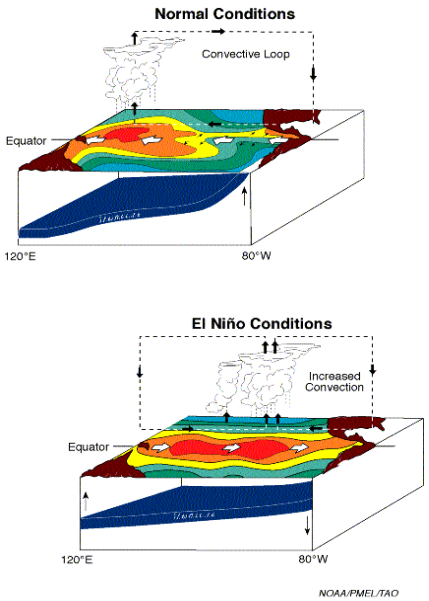
Handling your problem child

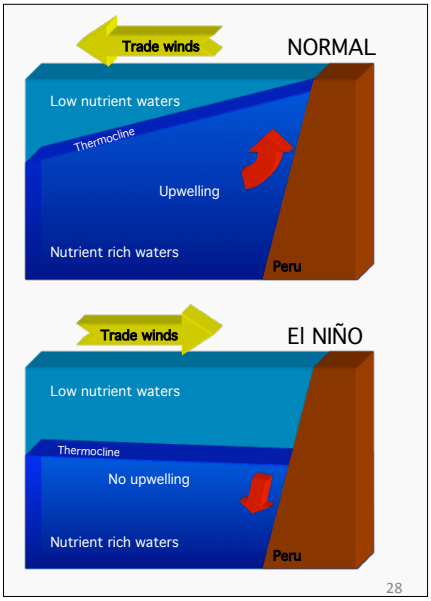




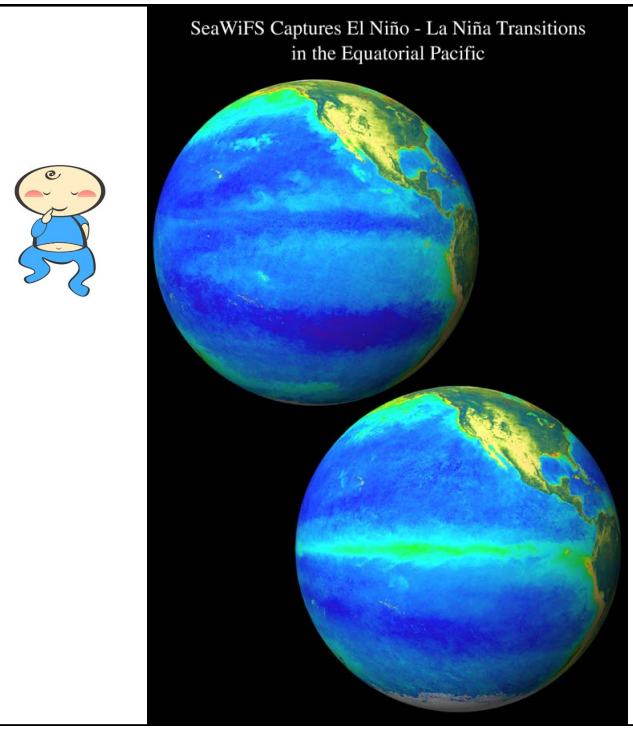
27

EL NIÑO (ENSO) ≈ 5 years





28



29

Baja California

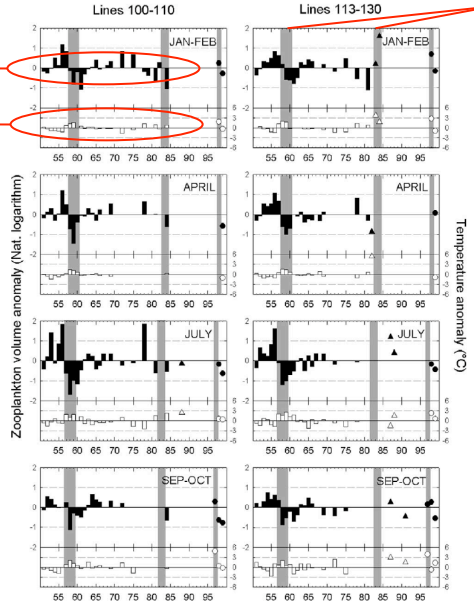
Zooplankton

Temperature

Lines 100-110

Lines 113-130

Strong ENSO



ENSO effects on zooplankton

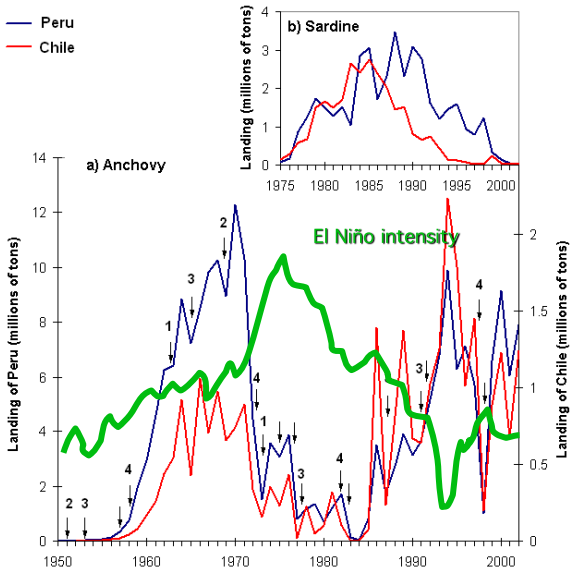
1) Positive relationship temperature and ENSO

2) Inverse relationship ENSO and Zooplankton

Fig. 6. Annual anomalies of zooplankton displacement volume (dark symbols) and temperature at 10-m depth (open symbols) by season in northern (left panels) and central (right panels) Baja California. Anomalies were estimated for CalCOFI (bars), CICIMAR (triangles) and IMECOCAL cruises (circles), after removing the long-term mean for the period 1951–1984. (Only CalCOFI cruises were used to calculate long-term mean.) Shaded areas indicate strong ENSOs.

30

El Niño effects

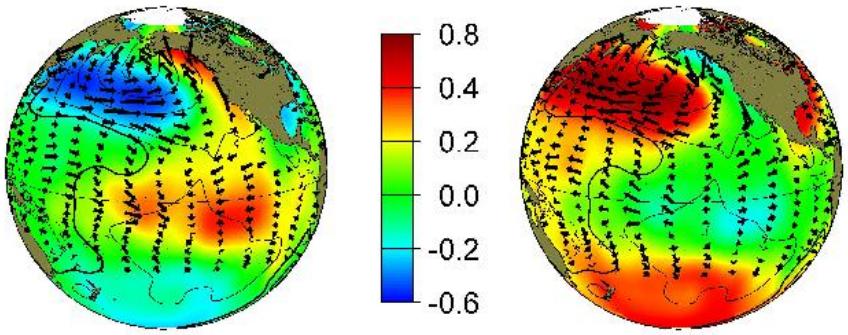


31

The Pacific Decadal Oscillation (PDO)

Cool phase

Warm phase



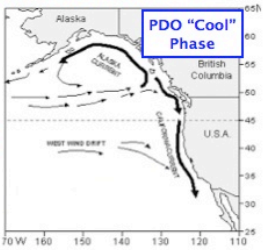
32

CHANGES IN COPEPOD COMMUNITIES

A working mechanistic hypothesis: source water …

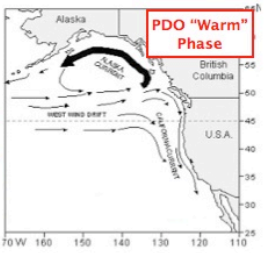
Cool Phase ♉

Transport of boreal coastal copepods into NCC from Gulf of Alaska



Warm Phase ♉

Transport of sub - tropical copepods into NCC from Transition Zone offshore



Discussion: Ordination (similarity) of zooplankton samples from Newport show that two copepod communities occur: Warm phase of PDO results in a "warm water community" Cold phase of PDO results in a "cold water community". This leads to the *hypothesis* that Warm/Cold Copepods communities on Oregon Shelf are associated with advection of warm/cold waters during different phases of PDO.

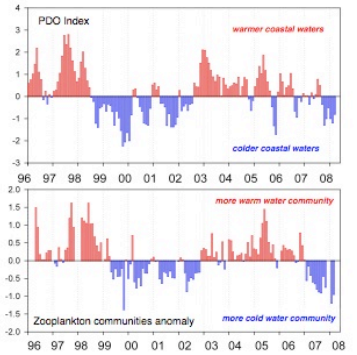
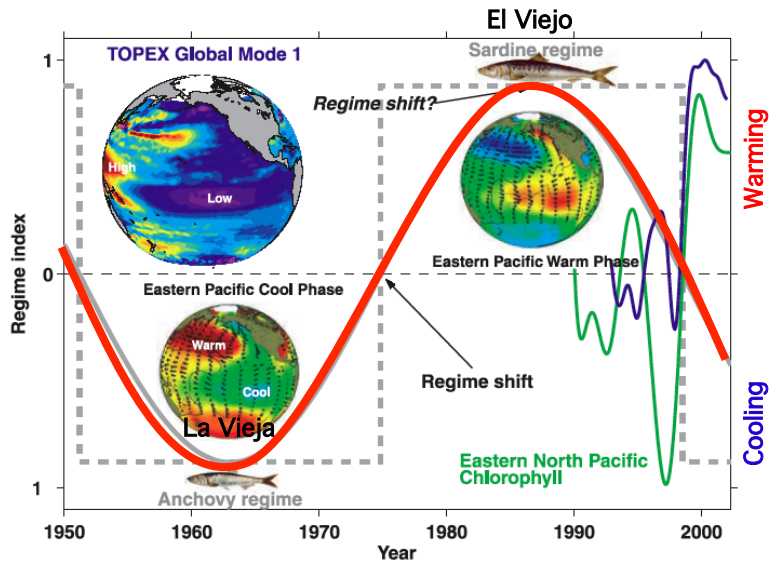


Figure 1: Correlation between zooplankton species distribution and PDO. (A) The PDO index. **(B)** Anomalies in Zooplankton Communities recorded in the Northern California Current, off the Oregon Shelf, Newport station.

Kesiter, Perterson et al., in prep.

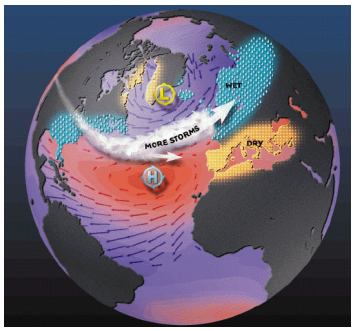
33

El Viejo y la Vieja: 25 year scales



Chavez et al. 2003

34



The NAO is the dominant mode of winter climate variability in the North Atlantic region ranging from central North America to Europe and much into Northern Asia. The NAO is a large scale seesaw in atmospheric mass between the subtropical high and the polar low.

Possitive NAO

Stronger than usual subtropical high pressure center and a deeper than normal Icelandic low.

More and stronger winter storms crossing the Atlantic Ocean on a more northerly track.

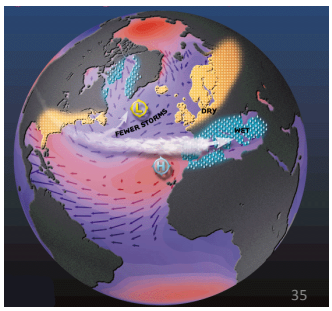
This results in warm and wet winters in Europe and in cold and dry winters in northern Canada and Greenland

Negative NAO

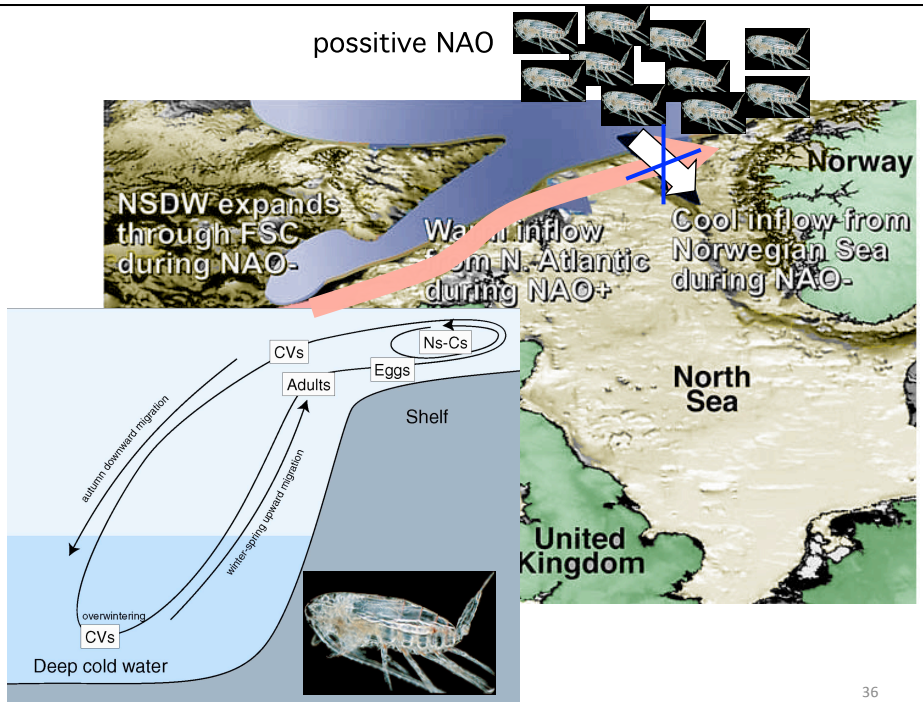
Weak subtropical high and a weak Icelandic low.

Fewer and weaker winter storms crossing on a more west-east pathway.

They bring moist air into the Mediterranean and cold air to northern Europe

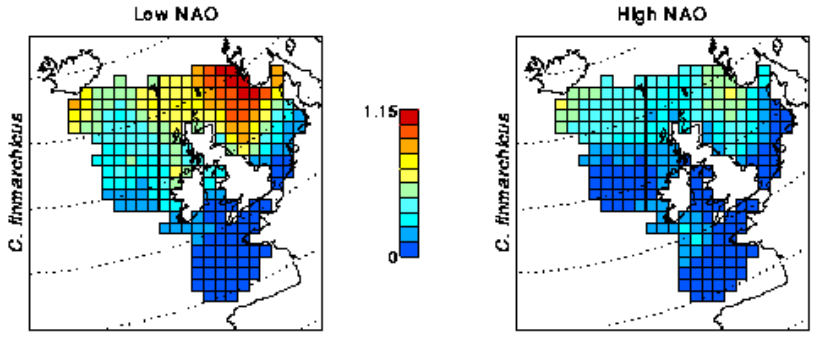


35

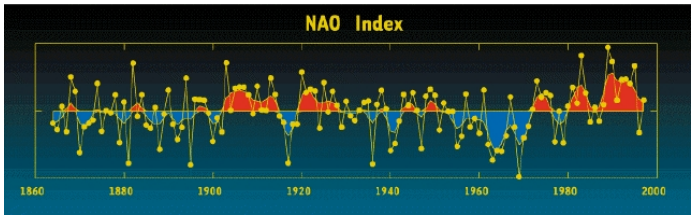


36

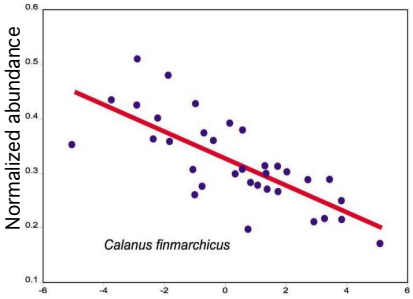
Calanus finmarchicus (70% Zooplankton biomass)



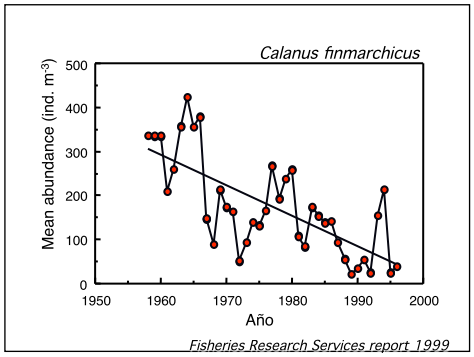
Fromentin and Planque 1996



37



North Sea



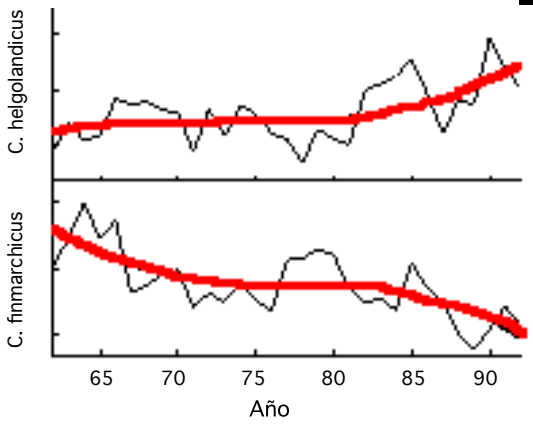
Lately, the relationship is broken because *C. finmarchicus* decrease

38

Fomentin and B. Planque, 1996

Species replacement

North Sea and NE Atlantic



Fromentin and Planque 1996

39

NAO in the Mediterranean

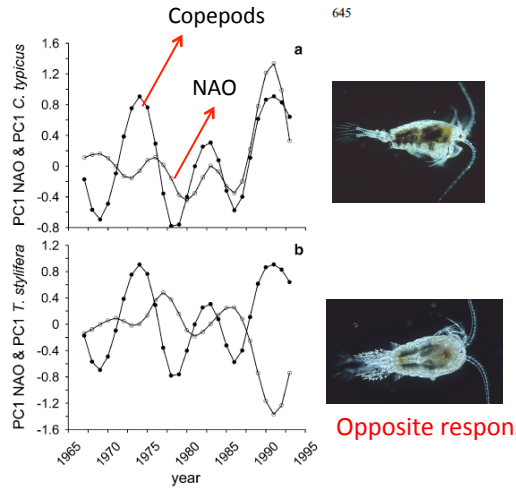


Fig. 4 Synchronous changes in the trend of the long-term variability in copepods (*open symbols*) and the NAO (*solid symbols*): **a** Low frequency changes (represented by the first principal component) of *C. typicus* and winter NAO ($r = 0.77$; $P < 0.01$) obtained by Eigen Vector Filtering (EVF); **b** Low frequency changes of *T. stylifera* and winter NAO ($r = -0.76$; $P < 0.01$), same representation as top figure

Opposite response to NAO

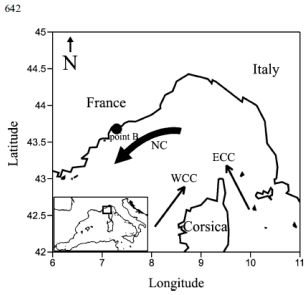


Fig. 1 Map of the western Mediterranean indicating the studied area and mean circulation pattern: NC, Northern Current; WCC, Western Corsica Current; ECC, Eastern Corsica Current. The sampling station (Point B) is indicated

Molinero et al. 2005 40

Summary

Major effects of climate on plankton:

- day?

- seasonal?

- Multiannual?

41