Workshop IV

From regime shifts to novel systems - evaluating the social-ecological implications of lasting ecosystem changes for resource management

Plankton ecosystem response to the decadal variation of winter intensity in the Mediterranean Sea : a long-term study (1979-2014)

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Context and objectives

Context

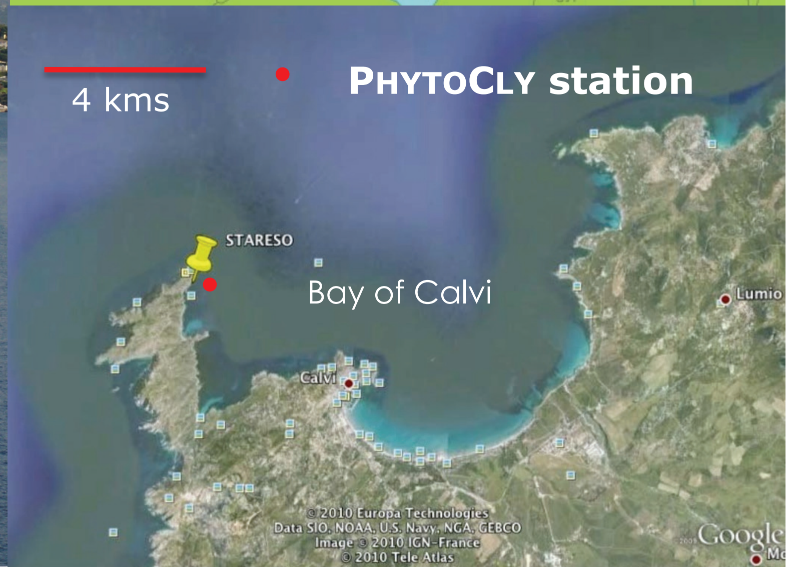
- Regime shifts are sudden, substantial, and temporally persistent changes in the state of ecosystems (de Young et al., 2008).
- In the Mediterranean Sea, several studies with distinct data sets indicate that the pelagic ecosystem underwent periods of change in the late 1980s and in the early 2000s (e.g. Molinero et al., 2008; Conversi et al., 2010; Vandromme et al., 2011).

Objectives

- To explore the synchrony between changes in environmental conditions from the end of the 1970s and phyto- and zooplankton dynamics in the well-preserved Bay of Calvi (Corsica island, Ligurian Sea, NW Mediterranean);
- To answer the question whether regime shifts occurred and to explore some of the potential impact on the pelagic food-web dynamics.

The studied area : the Bay of Calvi, Corsica, Western Mediterranean

- Open bay and narrow shelf
- Presence of a deep canyon in front of the city of Calvi
- Few anthropogenic pressures
- Low-runoff system
- Reference for the WFD



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Long-term time series (surface data, 1979-2014)

From 1979 :

- water temperature and wind (34 years)
- phytoplankton (chl *a*, 18 years; pigments, 15 years, continuous data from 2006)
- zooplankton (16 years, continuous data from 2003)

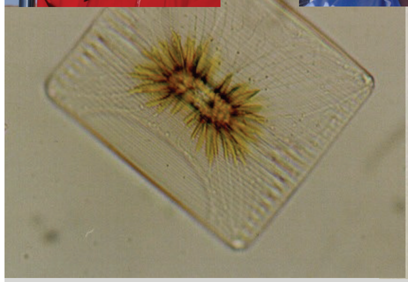
From 1988 :

- nutrients (16 years, continuous data from 2006).

High sampling frequency during the winter-spring period :

- Phytoplankton and nutrients : daily to biweekly
- Zooplankton : weekly.

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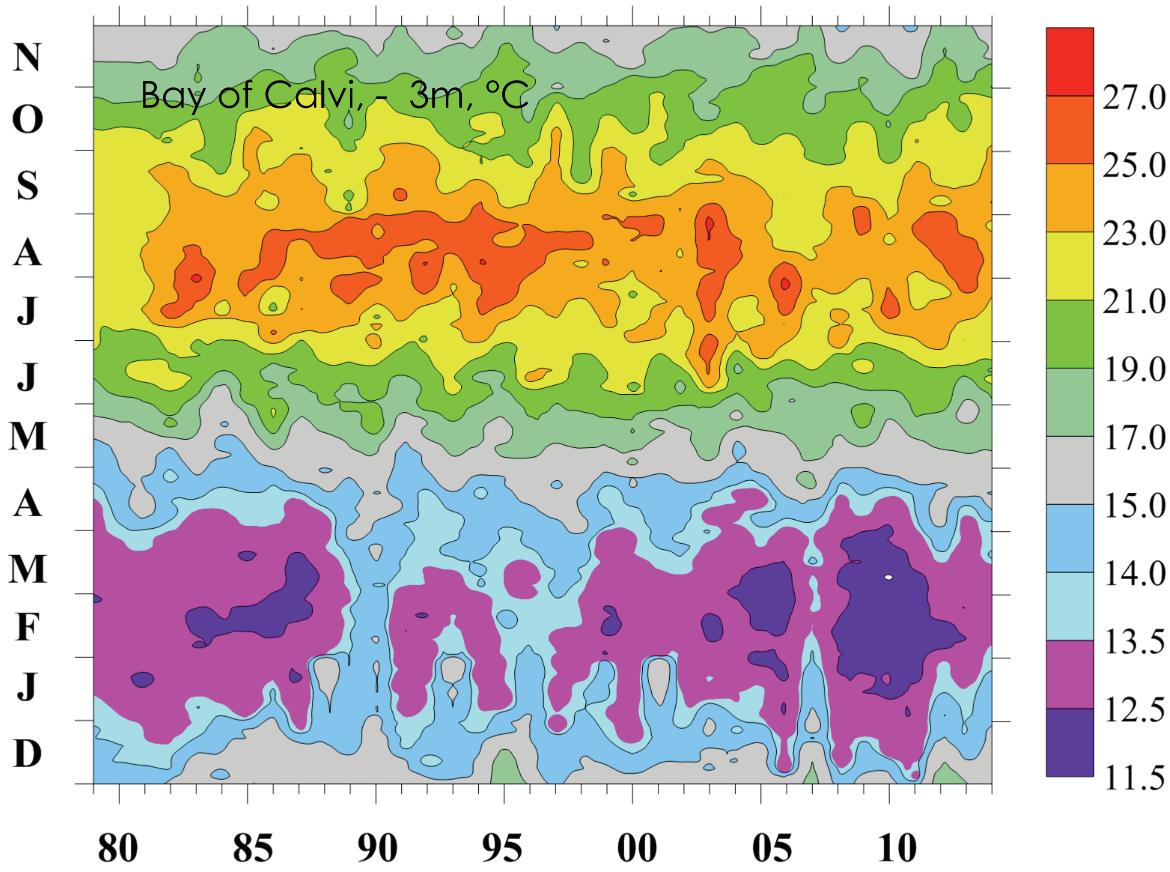
High interannual variability in subsurface water temperature

Temperature seems to play a critical role in triggering ecological regime shifts (Beaugrand et al., 2008).



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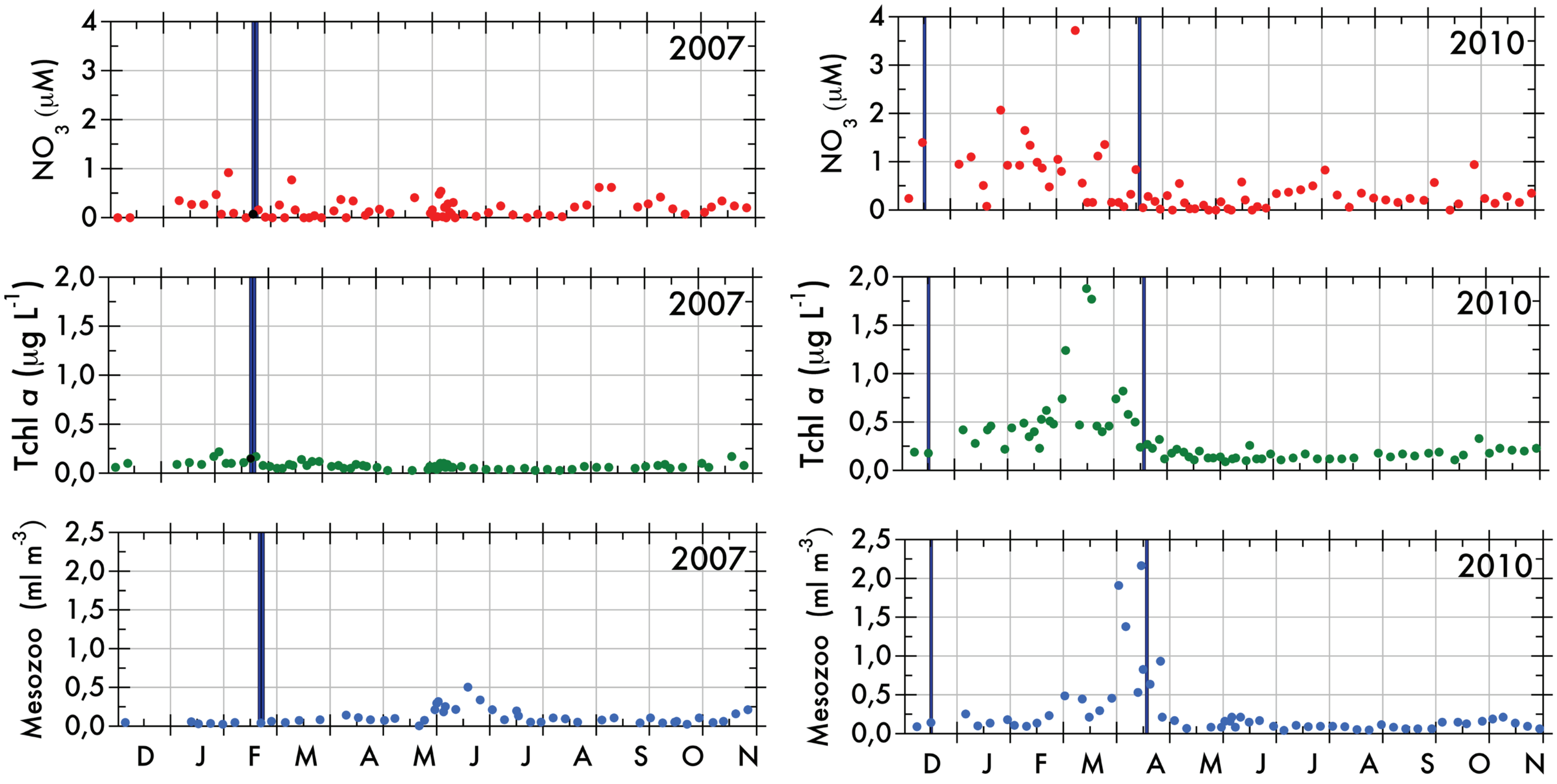
High interannual variability in nutrient, phyto- and zooplankton



The vertical dark bars identify the limits of the cold-water periods (≤13.5°C)

High interannual variability in nutrient, phyto- and zooplankton

Nutrients

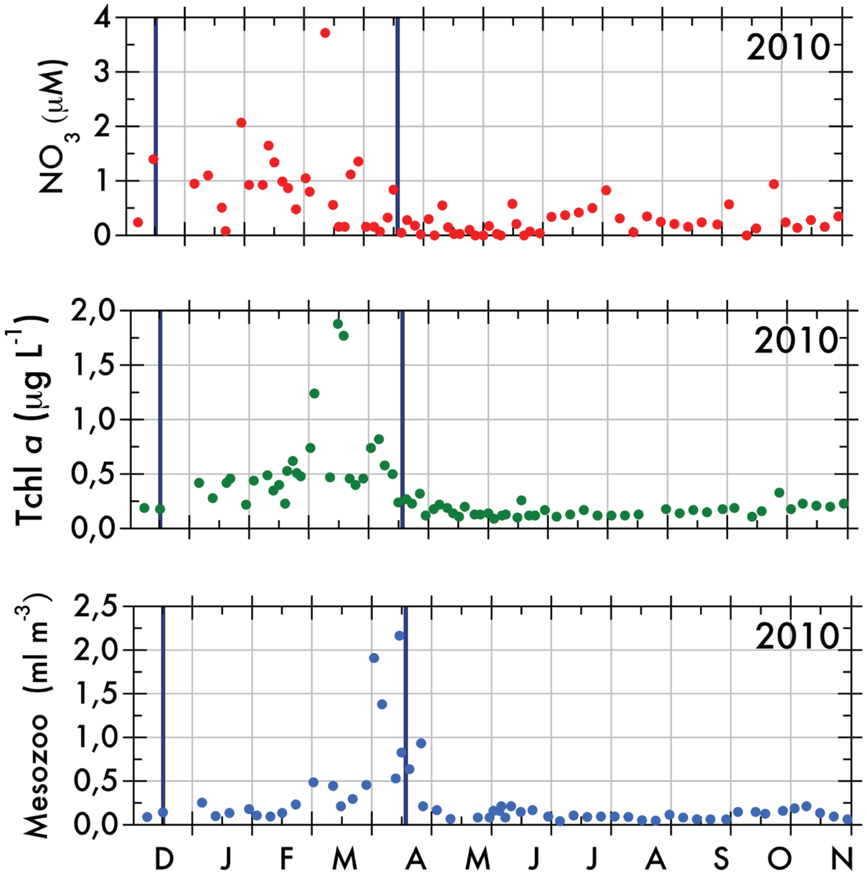
Nutrient enrichment of surface waters, although variable interannually in intensity, is driven every year by wind forcing during the cold-water period, when subsurface water is ≤13.5°C.

Phytoplankton biomass

All blooming years share one key characteristic, *i.e.* Tchl *a* always increases and peaks during the cold-water period

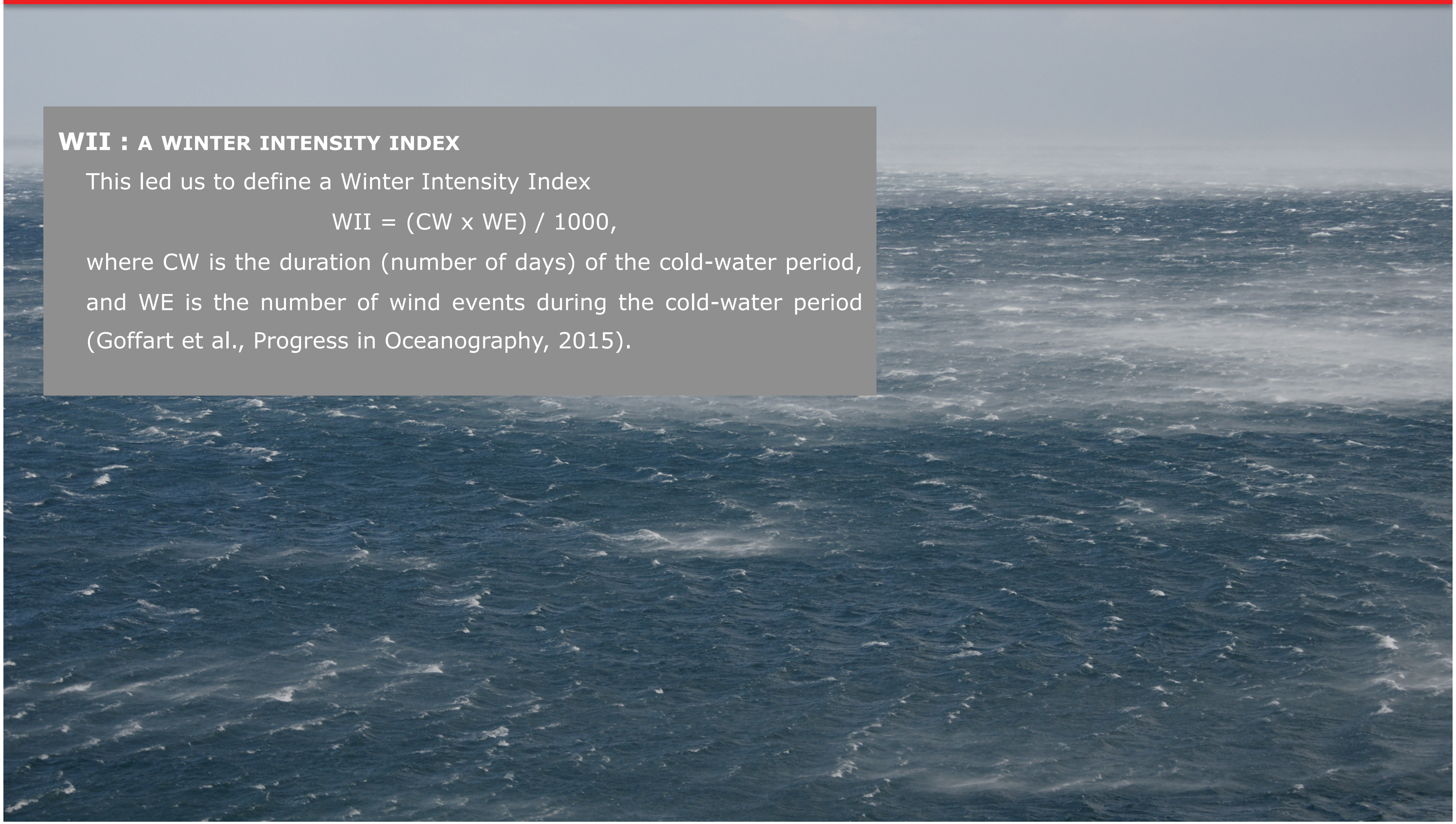
Driver of plankton dynamics

The main driver of nutrient replenishment and phytoplankton (chl *a*) development is the number of wind events (mean daily wind speed > 5 m s^{-1}) during the cold-water period (subsurface water ≤13.5°C; Goffart et al., 2015, Progress in Oceanography).



The vertical dark bars identify the limits of the cold-water periods (≤13.5°C)

Winter intensity index (WII)



WII : A WINTER INTENSITY INDEX

This led us to define a Winter Intensity Index

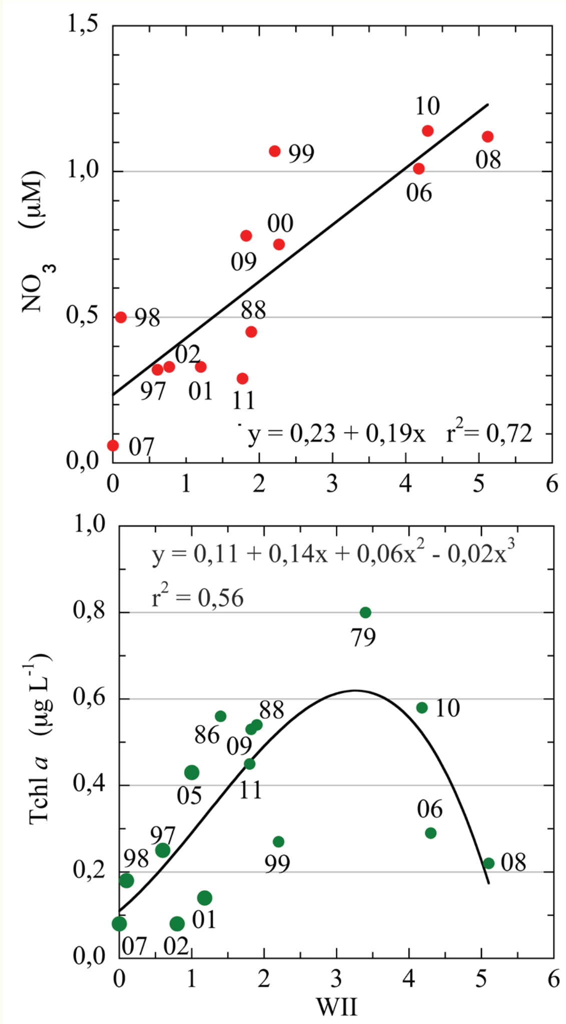
$$WII = (CW \times WE) / 1000,$$

where CW is the duration (number of days) of the cold-water period, and WE is the number of wind events during the cold-water period (Goffart et al., Progress in Oceanography, 2015).

Links between WII, nutrients and phytoplankton

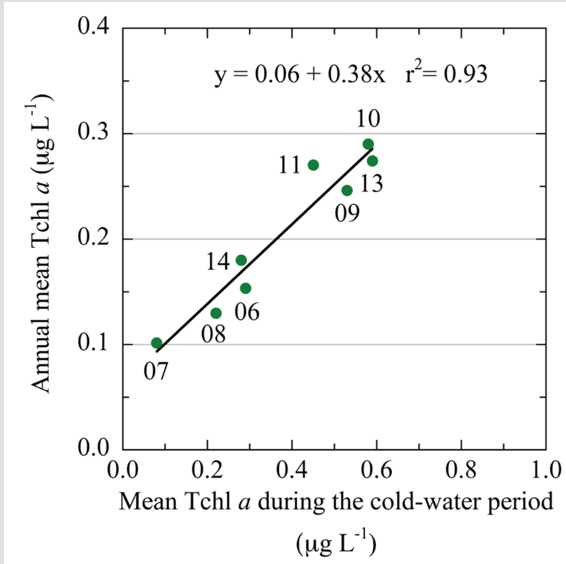
NUTRIENTS AND TCHL *a* VS WII DURING THE COLD-WATER PERIOD

The plots of nitrate and Tchl *a* averaged over the cold-water periods as function of WII show highly significant relationships (Goffart et al., 2015).



RELATIONSHIPS BETWEEN COLD-WATER PERIOD AND ANNUAL MEAN CONCENTRATIONS

When nutrient and phytoplankton were sampled over the entire year, strong positive correlations are observed between cold-water period and annual mean concentrations.



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Link between WII and phytoplankton

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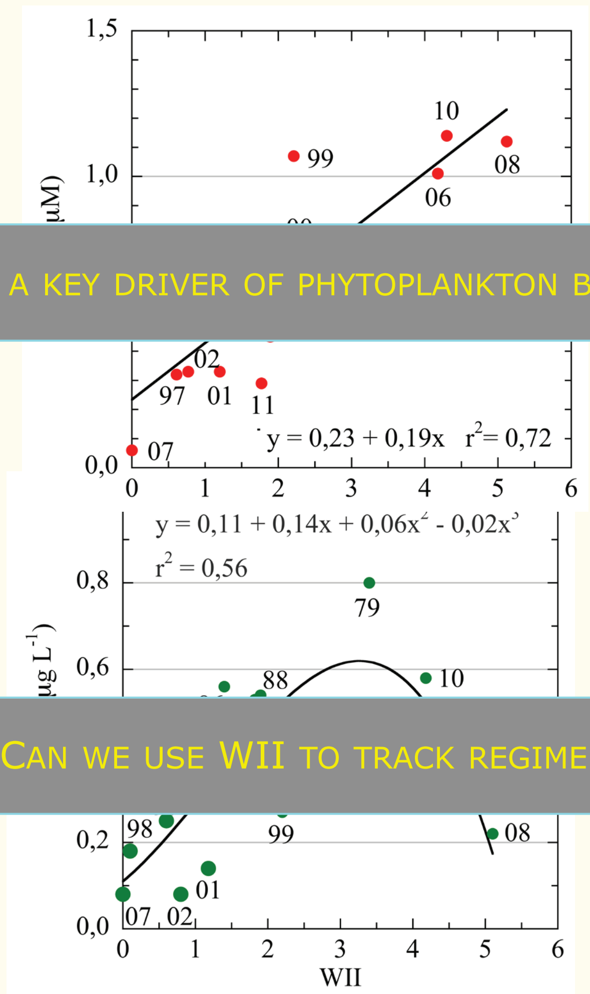
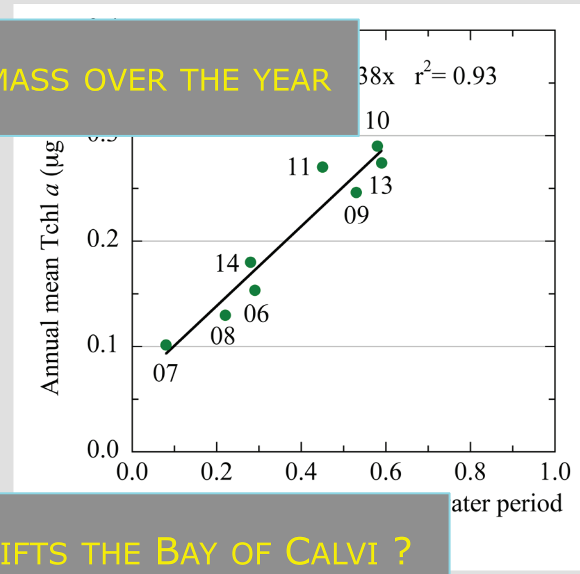


WINTER INTENSITY IS A KEY DRIVER OF PHYTOPLANKTON BIOMASS OVER THE YEAR

RELATIONSHIPS BETWEEN COLD-WATER PERIOD AND ANNUAL MEAN CONCENTRATIONS

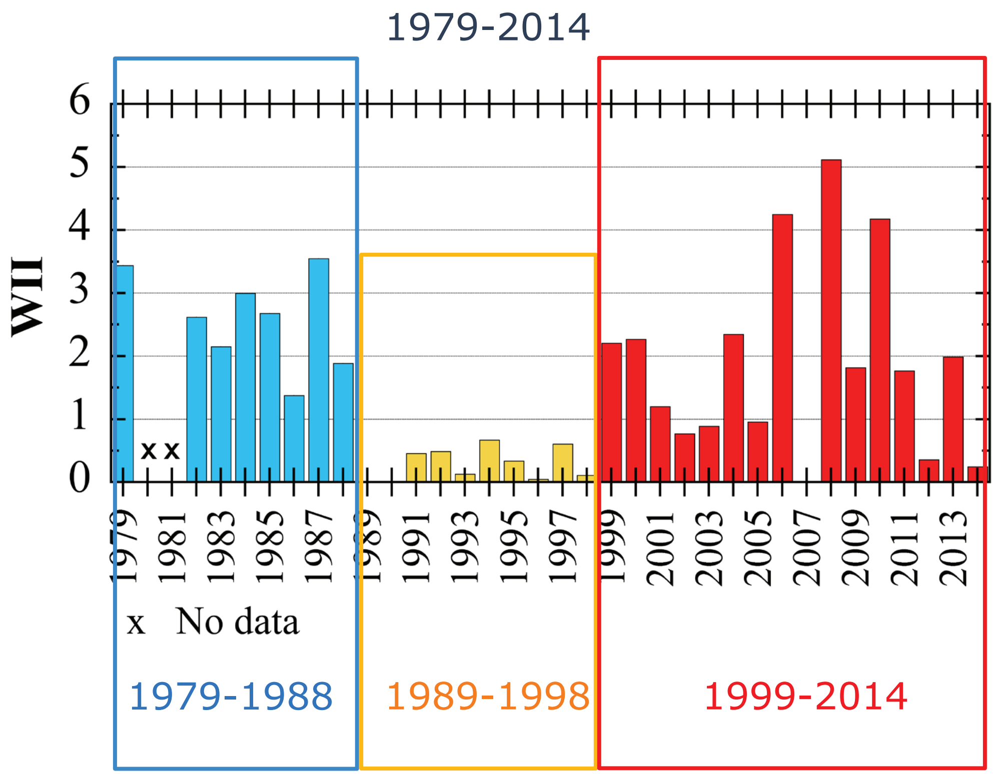
In years when nutrient and phytoplankton were sampled over the entire year, strong positive correlations are observed between cold-water period and annual mean concentrations.



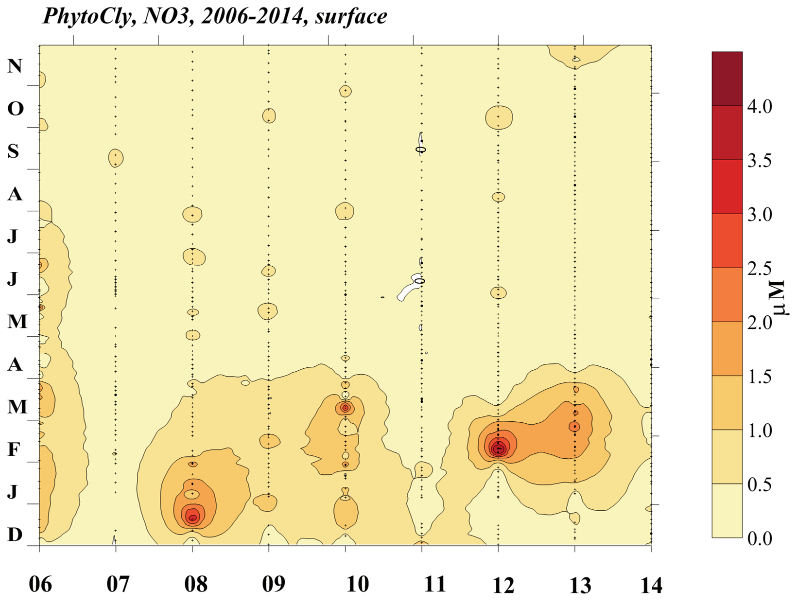
CAN WE USE WII TO TRACK REGIME SHIFTS THE BAY OF CALVI ?

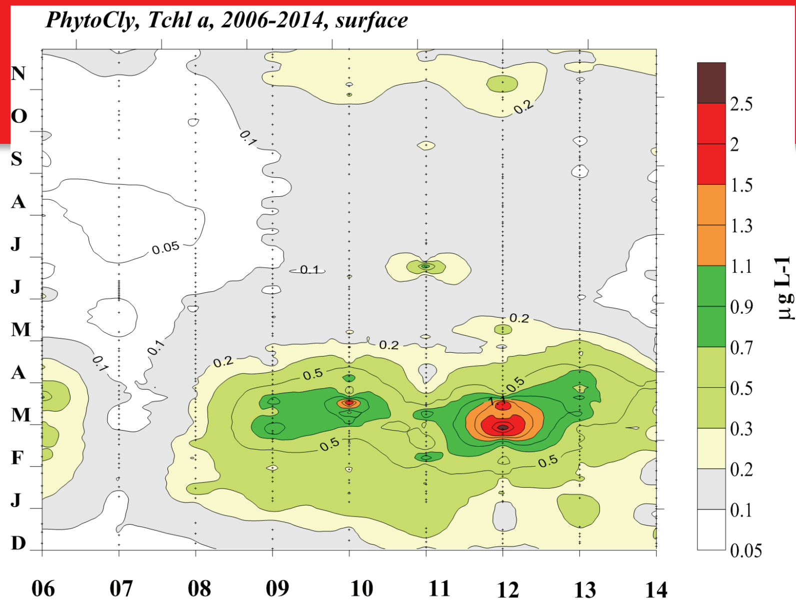
Decadal changes in WII

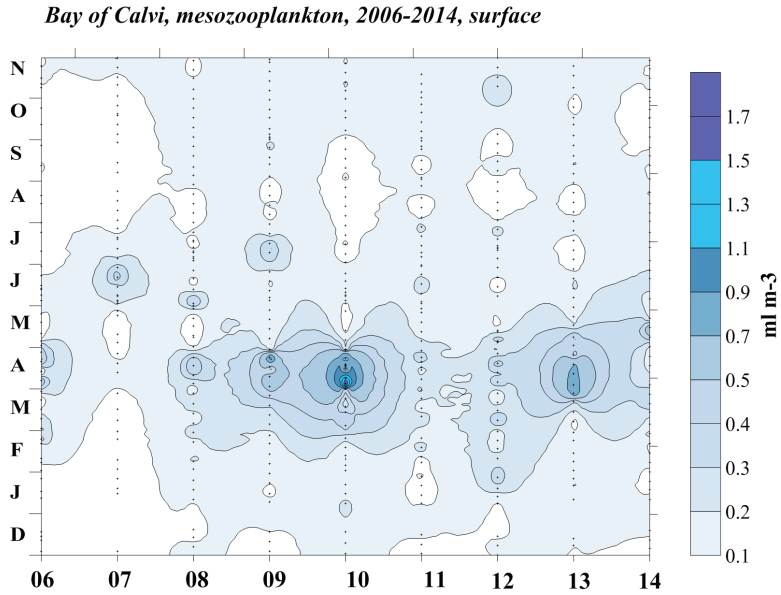
- The Bay of Calvi has undergone regime shifts (*i.e.* sudden, substantial and temporally persistent changes) in the late 1980s and in the late 1990s.
- Extreme WII values were observed in two consecutive winters during the last decade (2007 and 2008, respectively). Abnormal and exceptional climatic events occurred during winter 2012.



Control of plankton composition by winter intensity







A non bloom year : 2007

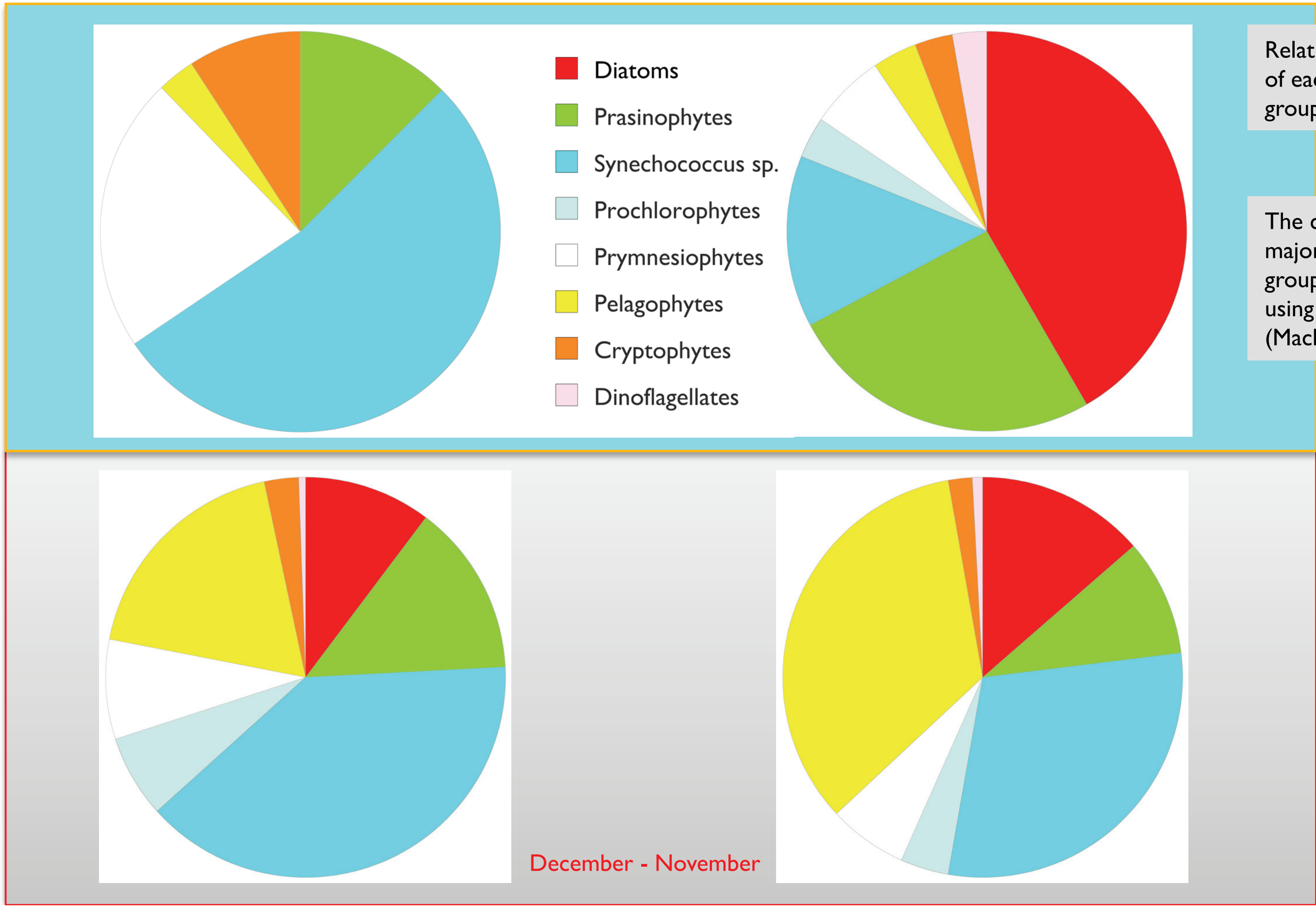
A bloom year : 2010

Control of phytoplankton composition by winter intensity

2007 : a non bloom year **2010 : a bloom year**

COLD-WATER PERIOD (≤13.5°C)

WATER > 13.5°C



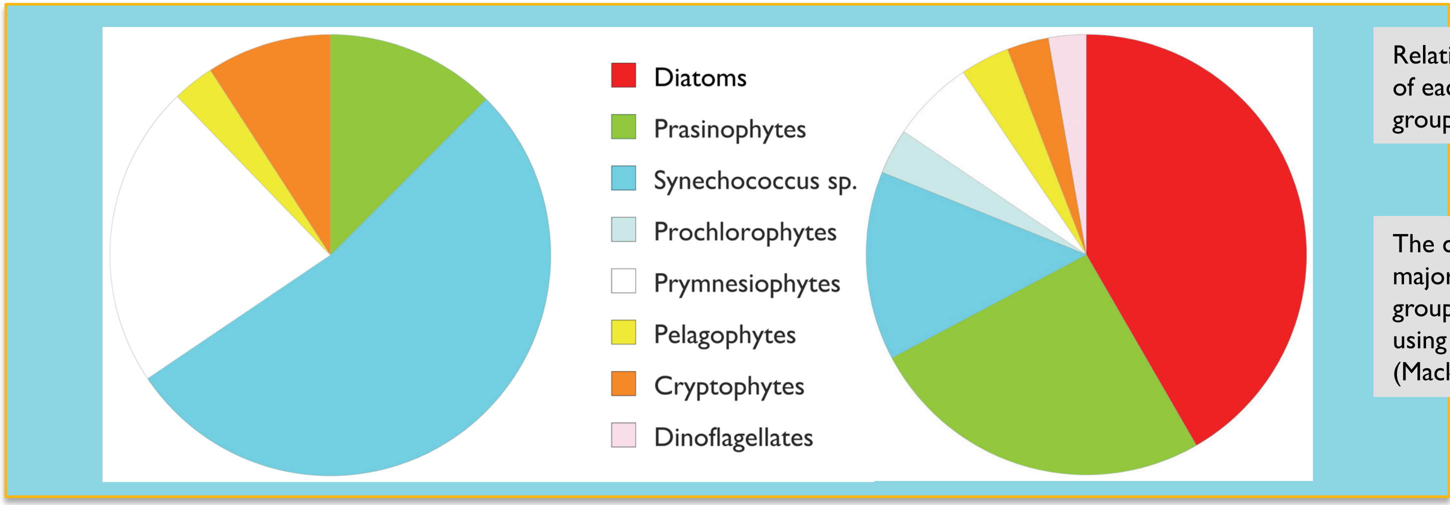
Relative contribution (%) of each phytoplankton group at the surface

The contribution of major phytoplankton groups was quantified using CHEMTAX (Mackley et al. 1996).

Control of phytoplankton composition by winter intensity

COLD-
WATER
PERIOD
(≤13.5°C)

2007 : a non bloom year **2010 : a bloom year**



Relative contribution (%) of each phytoplankton group at the surface

The contribution of major phytoplankton groups was quantified using CHEMTAX (Mackley et al. 1996).

WINTER INTENSITY IS A KEY DRIVER OF PHYTOPLANKTON BIOMASS,
COMPOSITION AND SIZE-FRACTIONS
OVER THE YEAR

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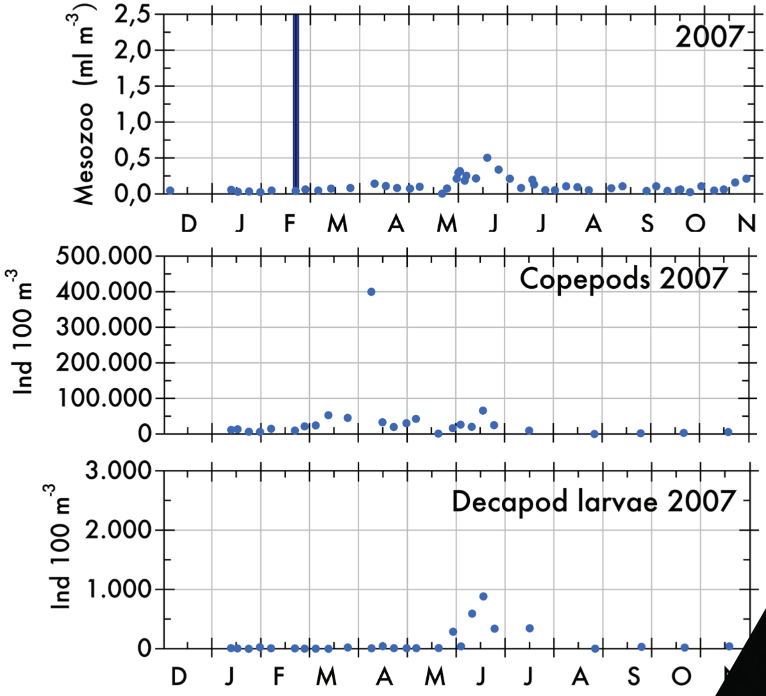
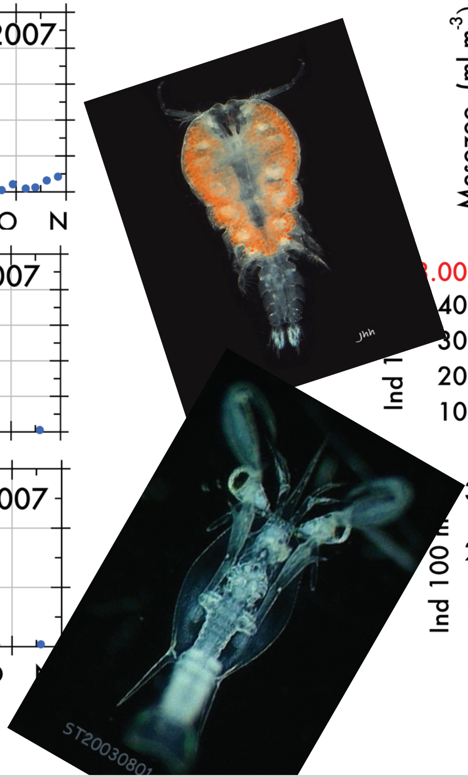
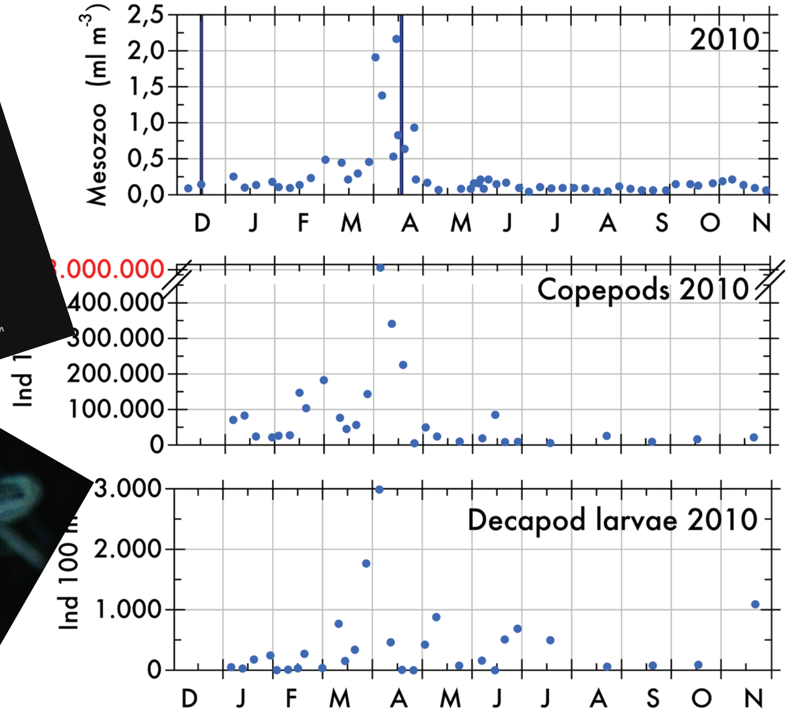
Control of zooplankton composition by winter intensity

2007 : a non bloom year





2010 : a bloom year



Winter intensity is a key driver of herbivorous zooplankton biomass over the year. It is likely to affect abundance of some groups (*e.g.* meroplanktonic Crustaceans) through food (detritus) availability.

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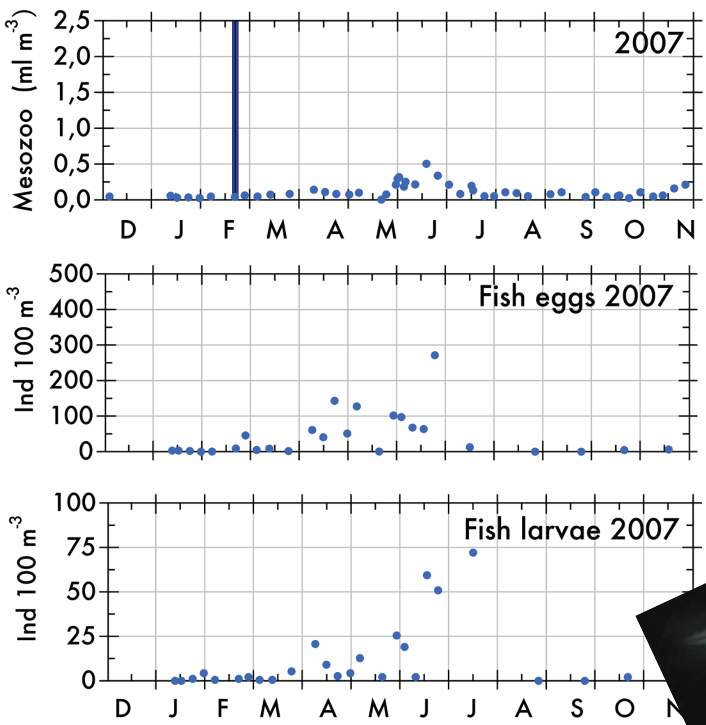
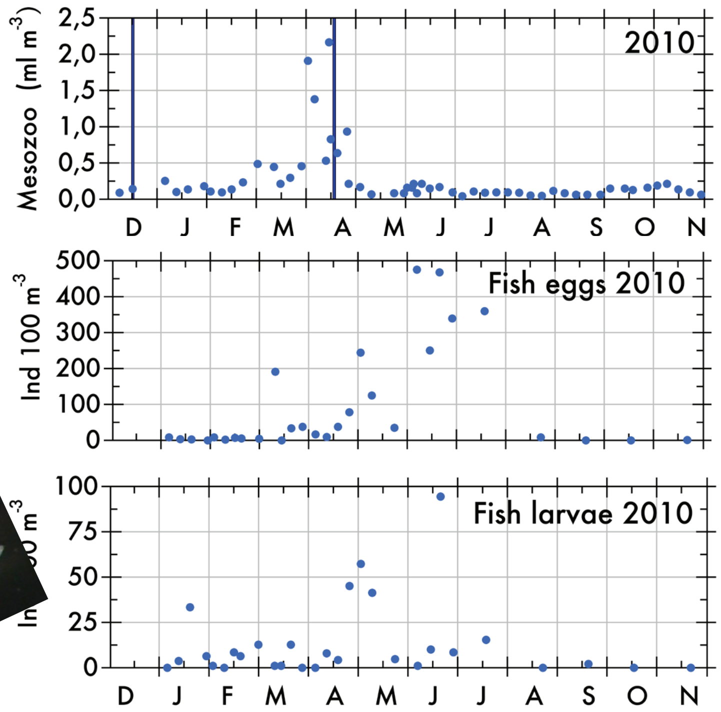
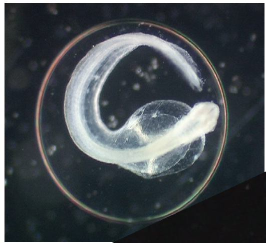
Control of zooplankton composition by winter intensity

2007 : a non bloom year



2010 : a bloom year





Abundance of fish larvae is NOT directly affected by winter intensity, but effective recruitment could be limited by food availability (mismatch between food recruitment and food availability).

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Conclusions and perspectives

Based on the results provided by the long-term time series conducted at the PhytoCly station, we showed that :

- the Bay of Calvi has undergone regime shifts in the late 1980s and in the late 1990s;
- winter intensity is a key driver for phytoplankton dynamics;
- winter intensity affects herbivorous zooplankton by direct control and is likely to influence higher trophic levels, including marine resources, via food limitation.

The next step will be to use our WII to characterize/forecast ranges of plankton abundance and composition from spring to late autumn. This could help to characterize food resources available for consumers, and to improve our knowledge of recruitment variability.


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Thank you for your attention !