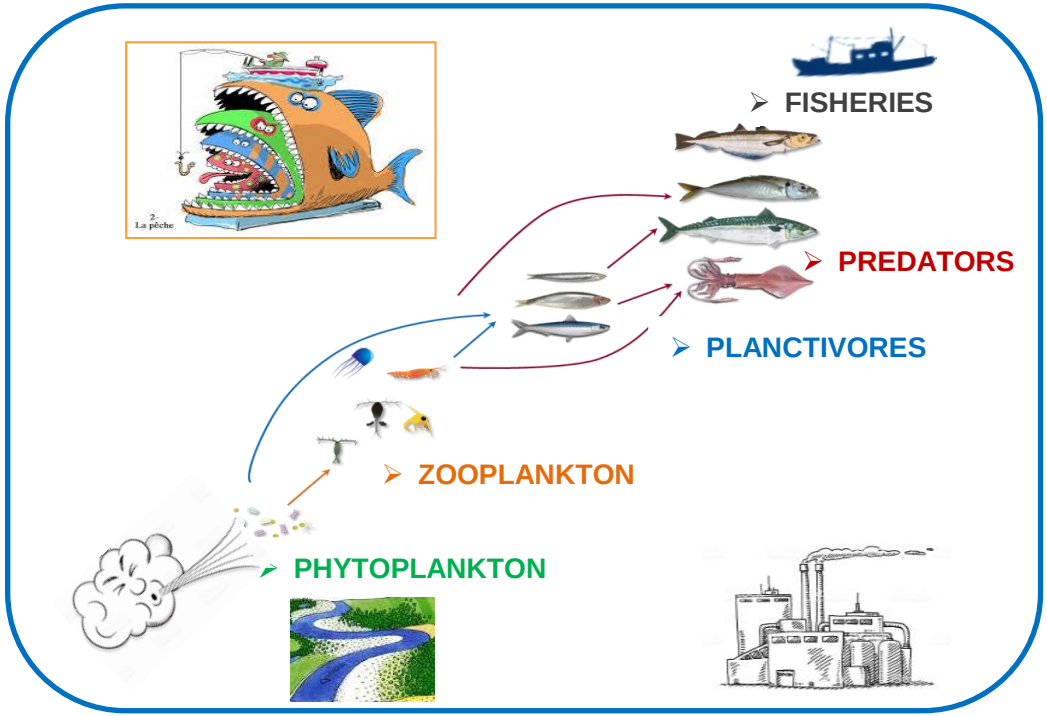
Oligotrophy in the Mediterranean Sea: functioning of ecosystems, impact on fisheries and contamination of food webs

Daniela.Banaru@univ-amu.fr
Assistant Professor Aix-Marseille University
Mediterranean Institute of Oceanology

MED-AC - FG West Med video conference
22 February 2022 14:00 – 16:00



- **Ecosystem approach to studying the functioning of marine ecosystems**
  « End-to-End »
- Planktonic production and impact on fisheries
- Impact of oligotrophy on the contamination of food webs, example of Hg

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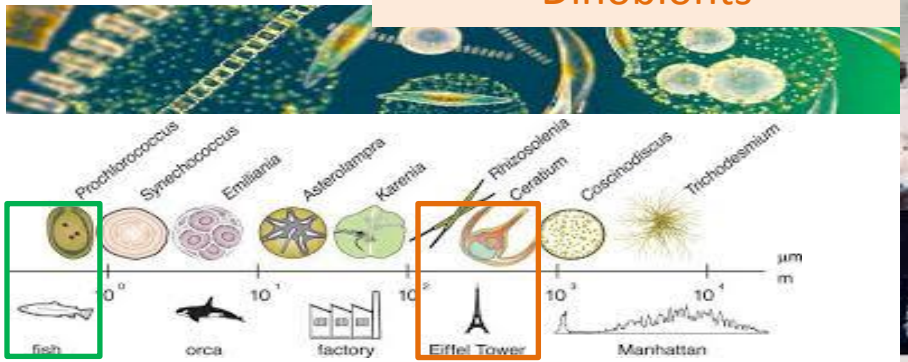
Plankton: diversity of sizes, species and trophic regimes

Phytoplankton ⇒ **Zooplankton** ⇨ 

Pico –	Nano –	Micro –	Meso –	Macro-
0,0002-0,002	0,002-0,02	0,02-0,2	0,2-2	>2 **mm**

Bacteria -> Diatoms

Dinobionts



Copepods, larvae, eggs …

Carnivorous (III+)

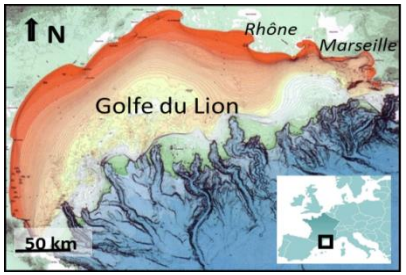
Herbivorous and omnivorous (II+)

Primary producers (I)

⇨ *Increasing trophic levels*

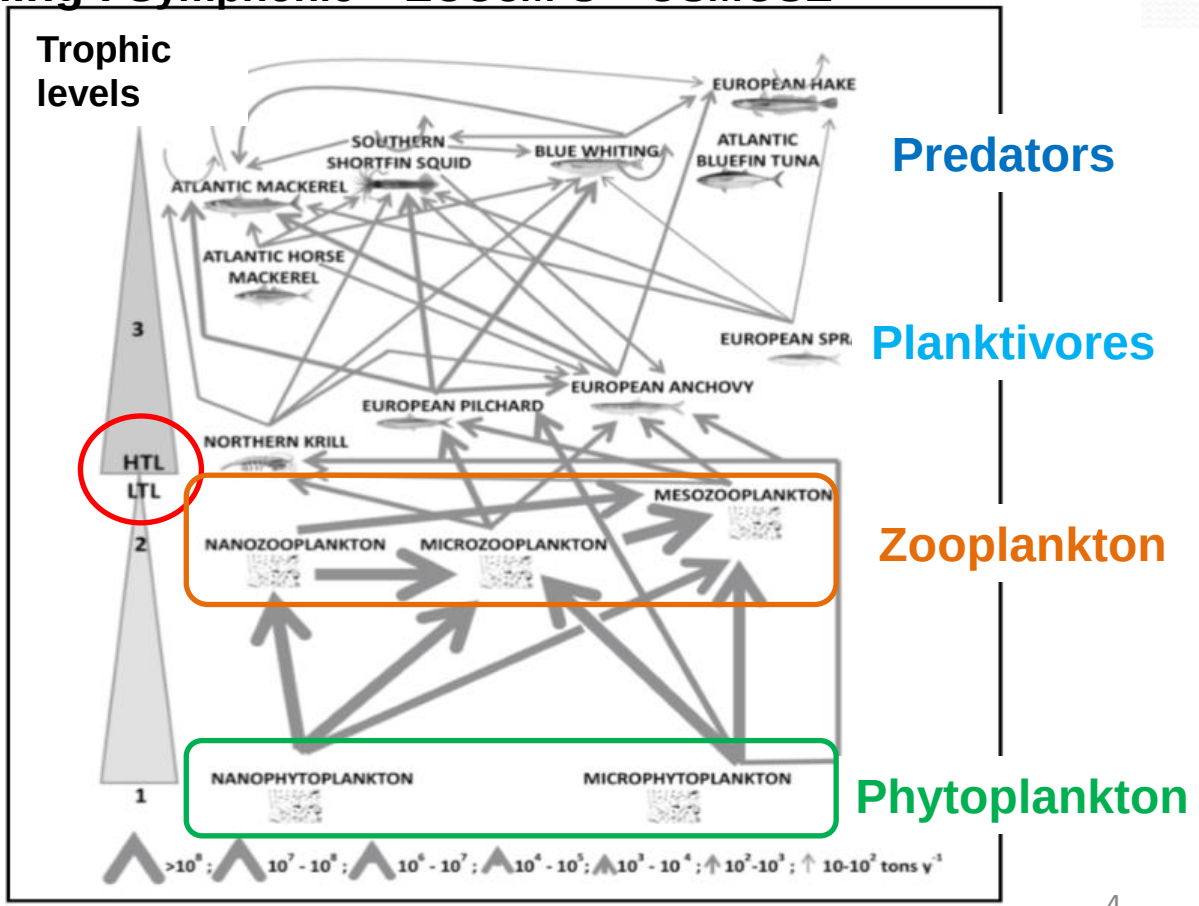
Coupled ecosystem modeling : Symphonie – ECO3M-S – OSMOSE

NW Mediterranean sea



(2001-2004)

Flows of organic matter (OM) that nourish the food web of the main species in the Gulf of Lion (>70% biomass)



Bănaru et al., 2013 ; Bănaru et al., 2019; Diaz et al., 2019

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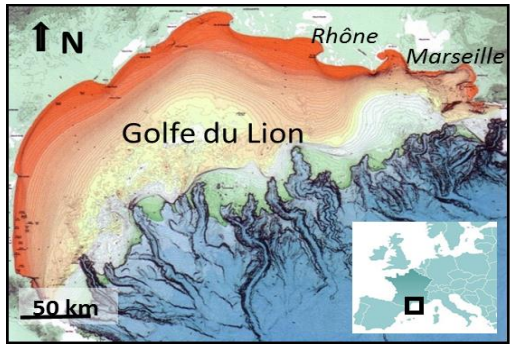
Isotope tracers($\delta^{13}C$ & $\delta^{15}N$) of trophic flows

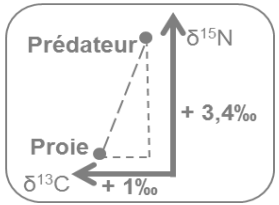
NW Mediterranean sea



2011-2012, 2015 (GoL-spatial)
Bănaru et al., in prep.

Isotope tracers - where does the OM that feeds these organisms come from?

Recent campaigns:
Hippocampe and Contampump



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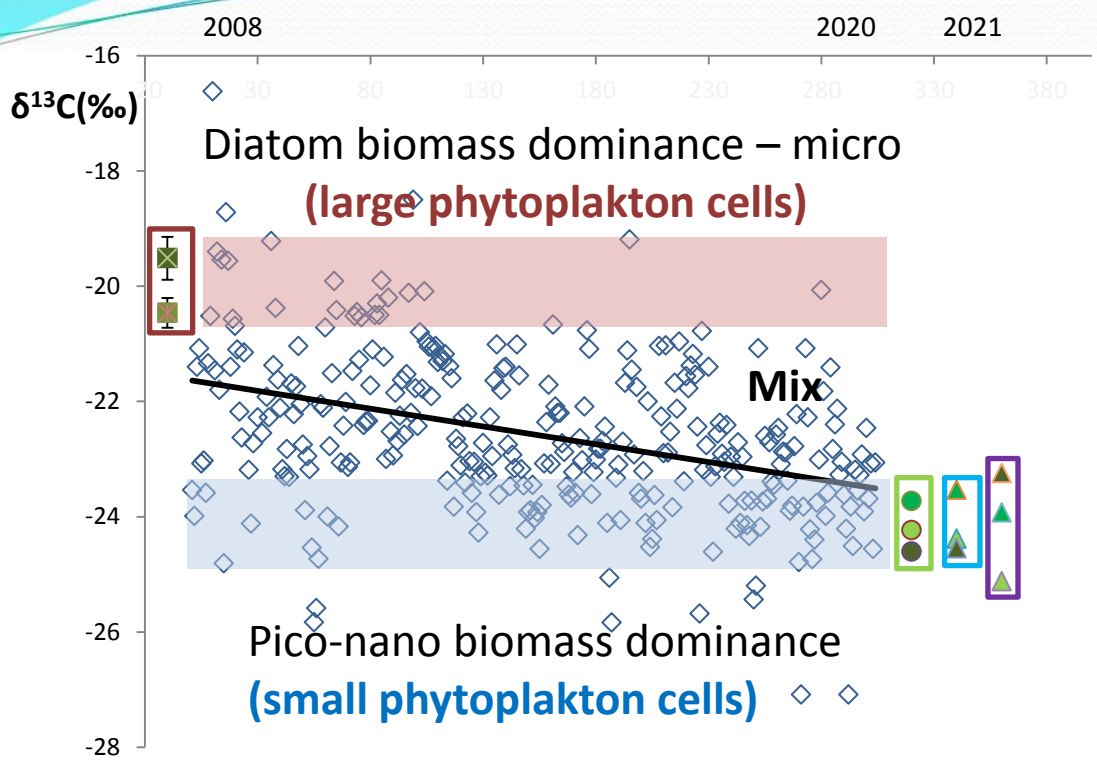
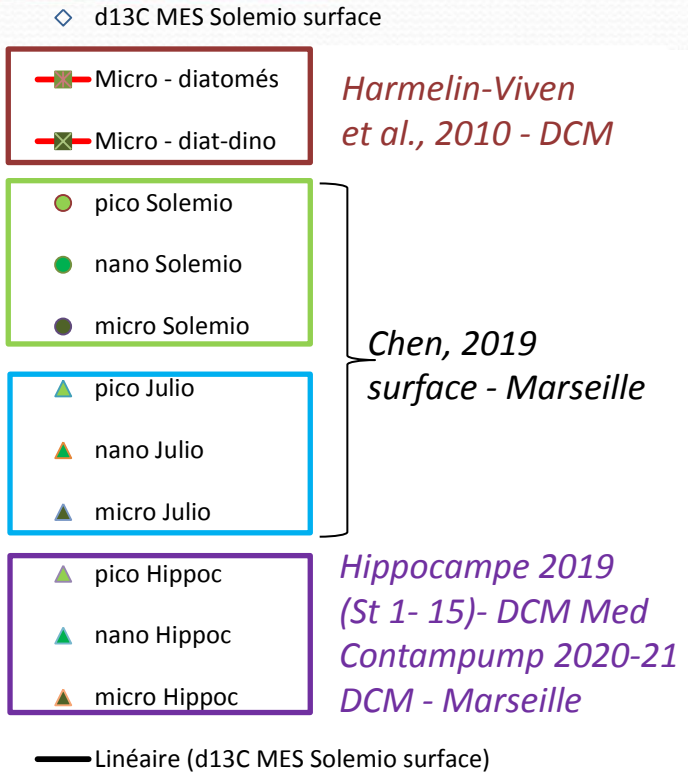
Interactions : environment ⟷ plankton ⟷ small pelagic planktivores

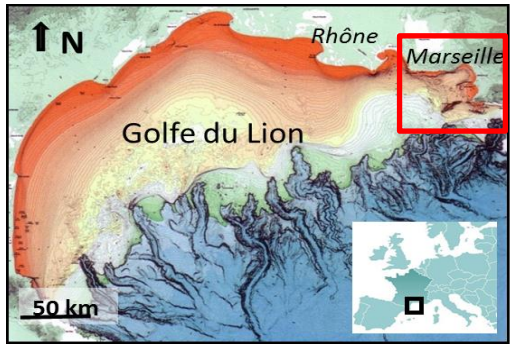




Since 2008, δ13C(‰) values of "phytoplankton" suspended matter at SOMLIT (Solemio) show a change in the source of OM at the base of the food web which may reflect a depletion of nutrients from the system and/or link with seawater temperature

Stomach contents and isotopic tracers ($\delta^{13}C$ & $\delta^{15}N$) of trophic flows

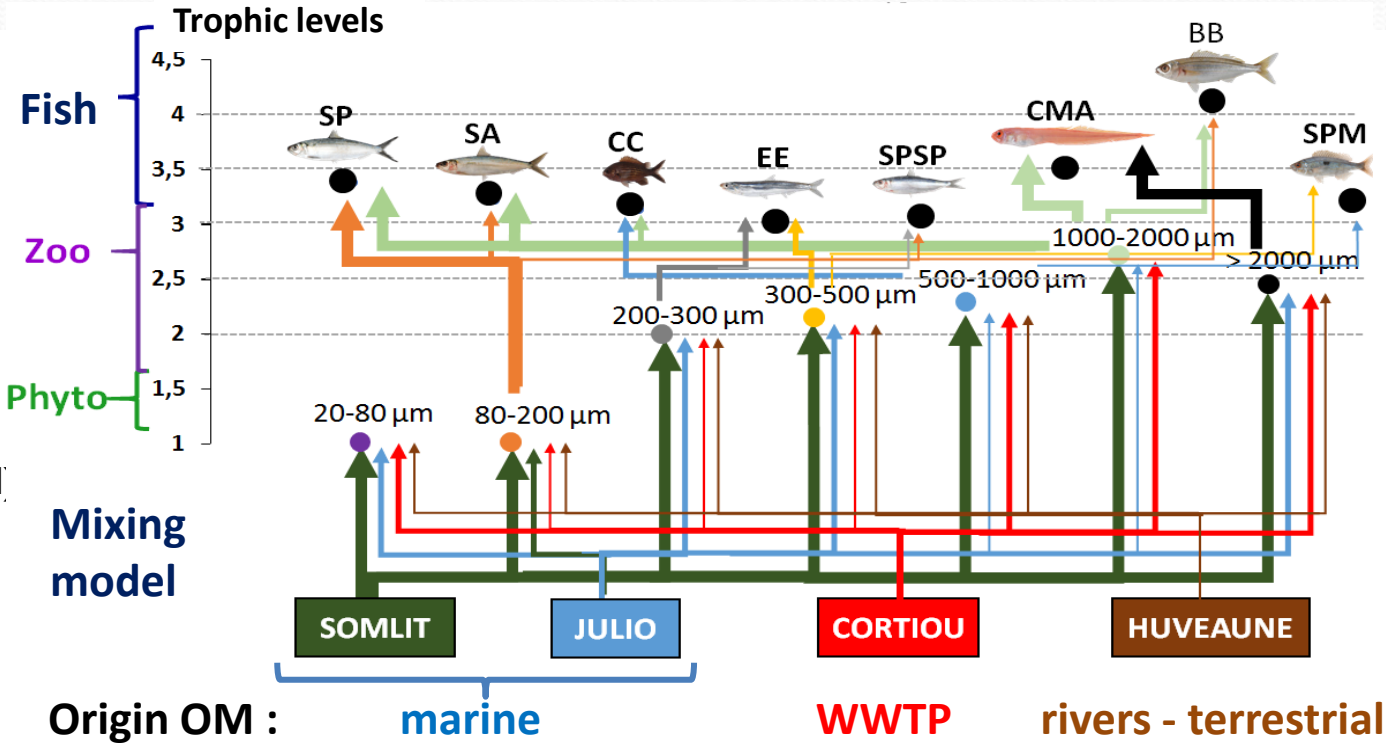
NW Mediterranean sea



2016-2018 (Marseille-temporel)

Isotope tracers - where does the OM that feeds these organisms come from?

(PhD Chen, 2019; Chen et al., in prep.)



Flows from OM sources to the pelagic food web of 8 planktivorous fish species

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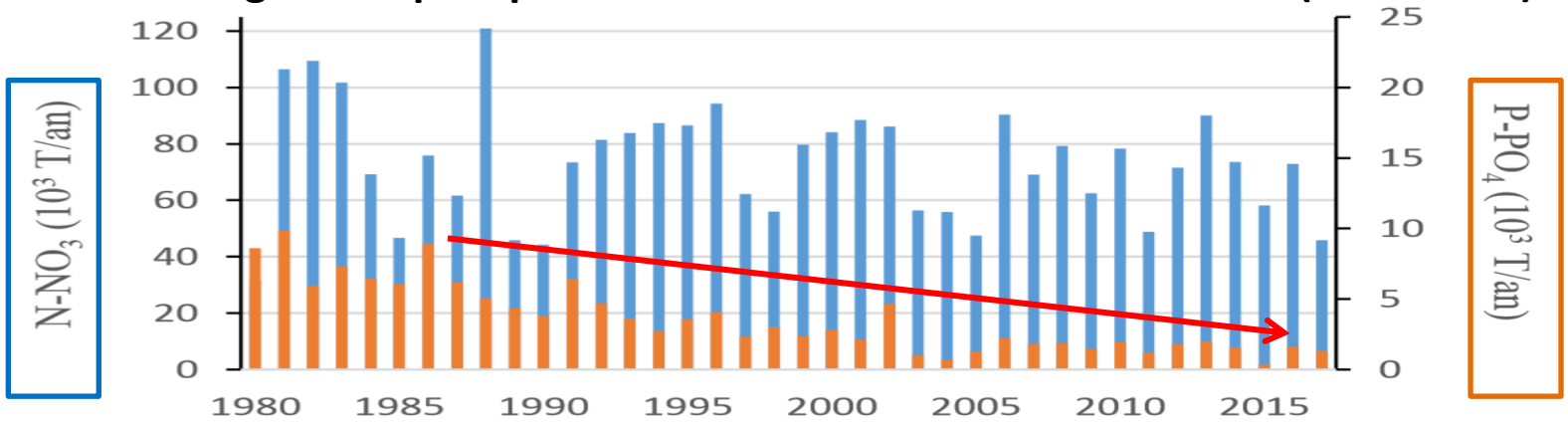
Interactions : environment ⟷ plankton ⟷ small pelagic planktivores

Nitrogen and phosphorus at the mouth of the Rhône river (1980-2017)



Castille, 2018 – report M2, SOMLIT 1994-2017

Pages et al., 2020 : **PO_4 reduction in rivers -> reduction in size of copepods in the Mediterranean**

Improvement in wastewater treatment plant (WWTP) in Marseille -> decrease in the biomass of planktonophages and their relative proportion compared to other trophic groups

(Cresson et al., 2019; Ourgaud, 2015)

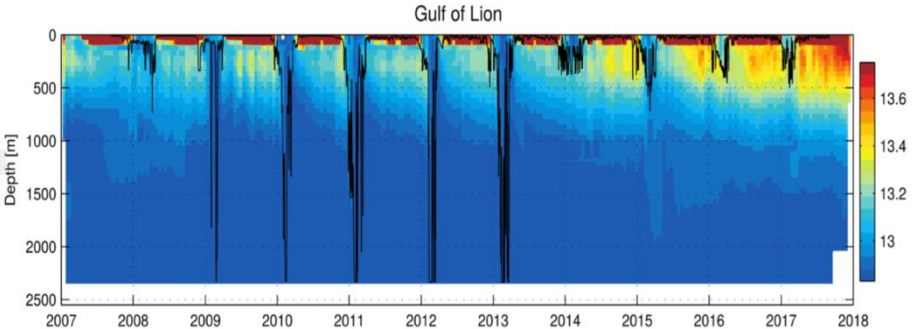
Daniela.banaru@univ-amu.fr

Interactions : environment ⟷ plankton ⟷ small pelagic planktivores

Climate influences:

Convection zone off the Gulf of Lion – strong primary production which can sometimes extend over the shelf

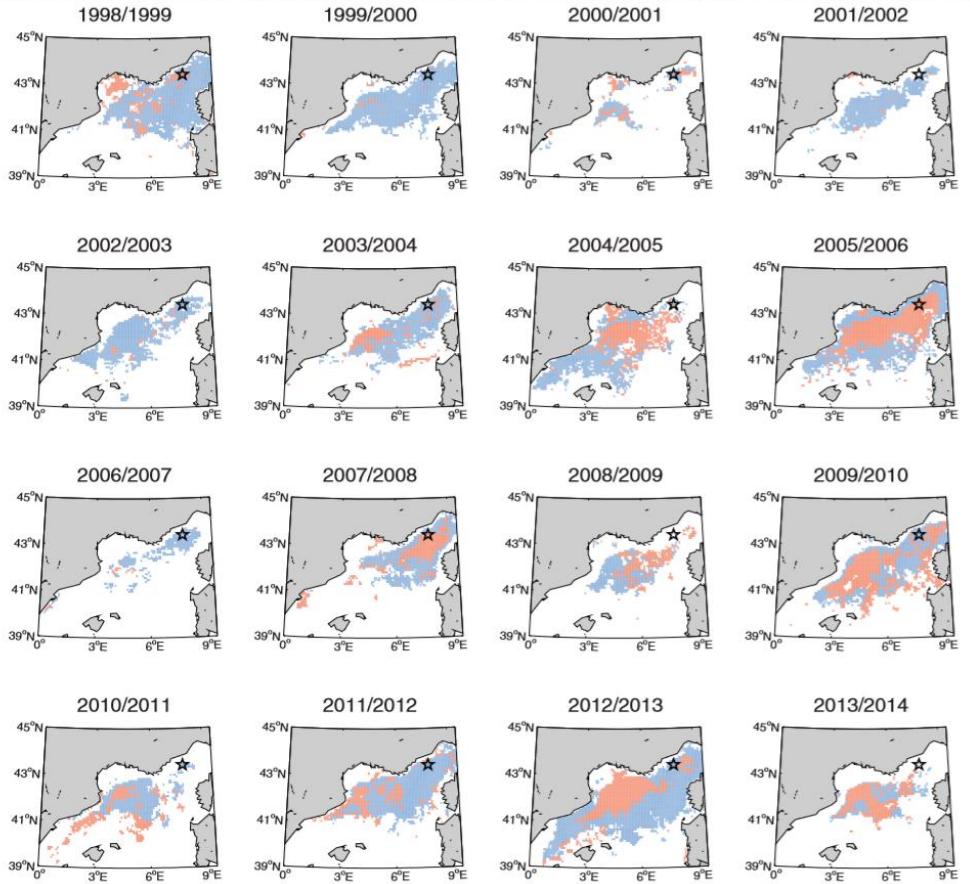
(Mayot et al., 2017)



2007 2014 2018

Higher surface temperatures, higher stratification and less mixing, less nutrients, less planktonic production, smaller cells

(Margirier et al., 2020)



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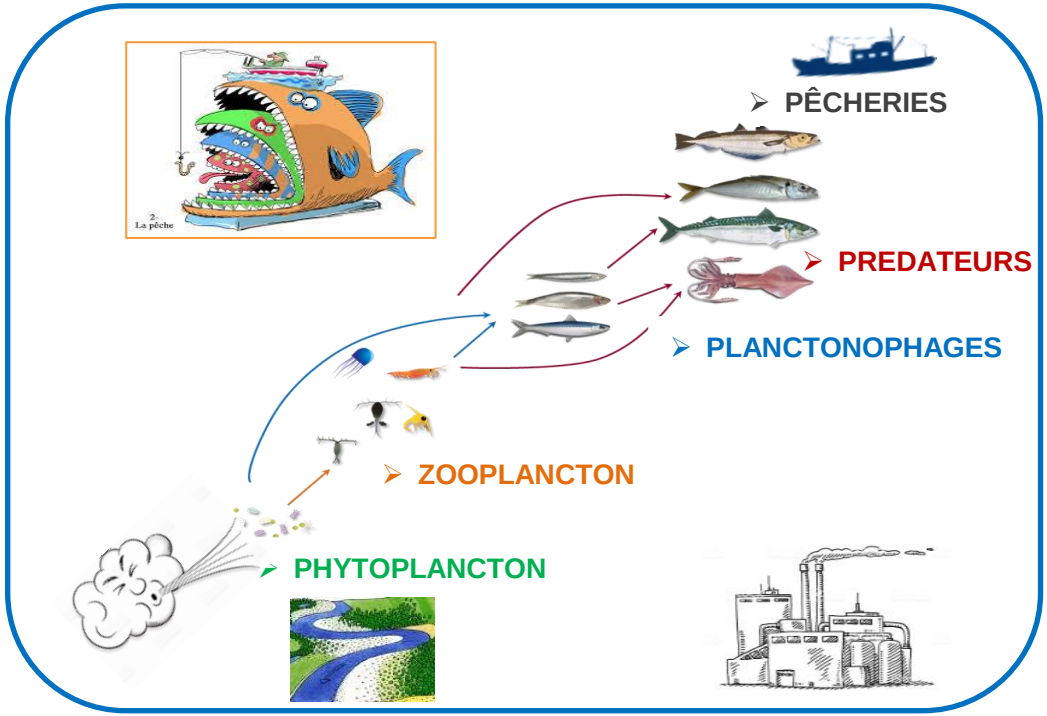

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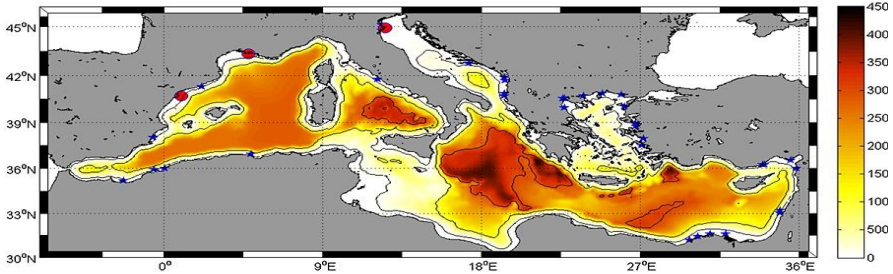
Plankton and fisheries in the French Mediterranean

Fisheries

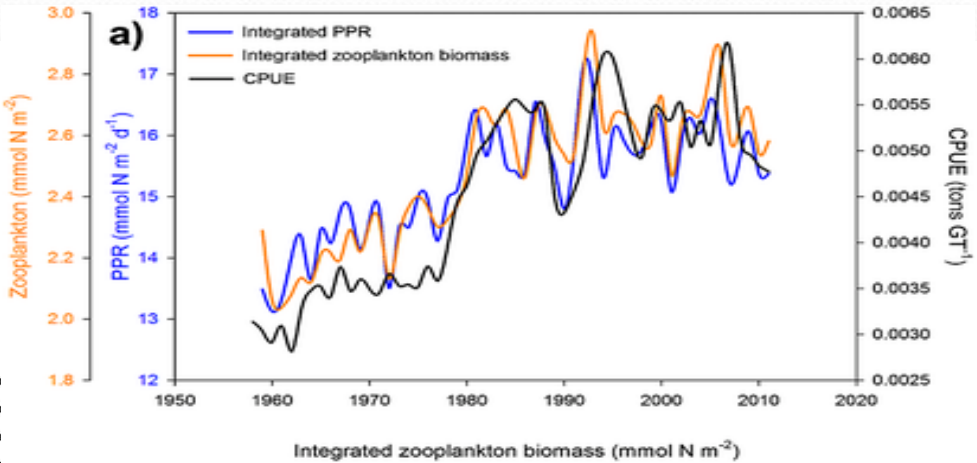
Zooplankton

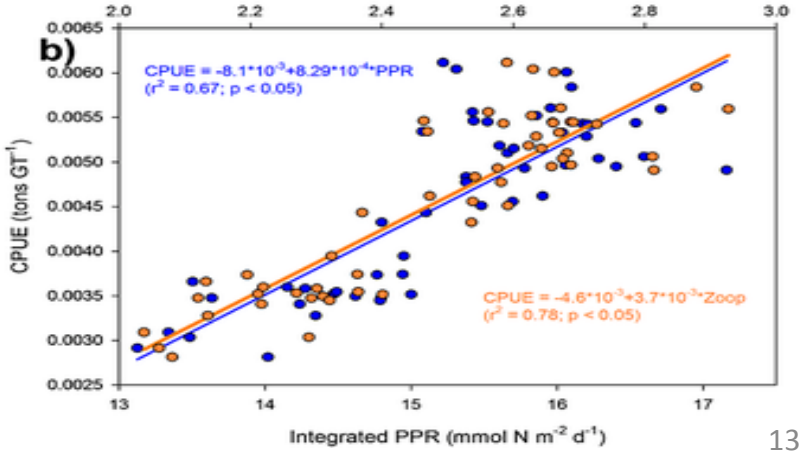
Phytoplankton

River inputs
- nutriments



Coupled 3-D hydrodynamic biogeochemical model (1957 -2012) *(Macias et al., 2014)*





PPR = primary production required to sustain fisheries
CPUE = catch by unit of effort

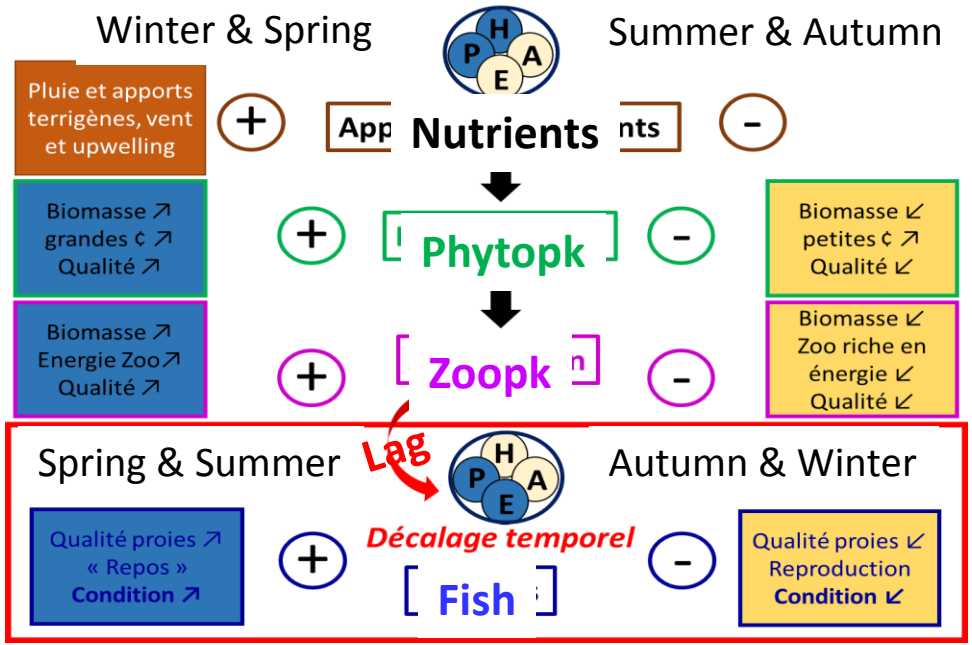
Daniela.banaru@univ-amu.fr

Interactions : environment ⟷ plankton ⟷ small pelagic planktivores

Project APREM – PhD C.T. Chen (2016-2019) « Feeding of planktivors fish in Marseille region»

Monthly survey – SOMLIT (2016-2018)

- **"Marine" and "terrestrial" sources supply the pelagic food web of the Bay of Marseille**
- **Quantity and quality of plankton related to inputs and the environment**
- **Plankton quality depends on size and group of organisms**
- **Fish are able to select quality prey**
- **Relative body condition of fish related to food quality and reproduction**



Funding MRT & PNC

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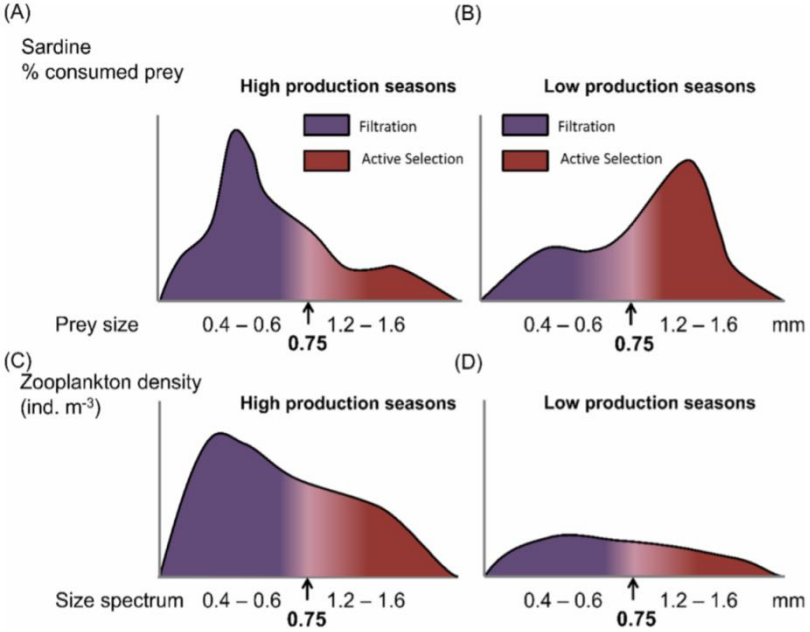
Interactions : environment ⟷ plankton ⟷ small pelagic planktivores

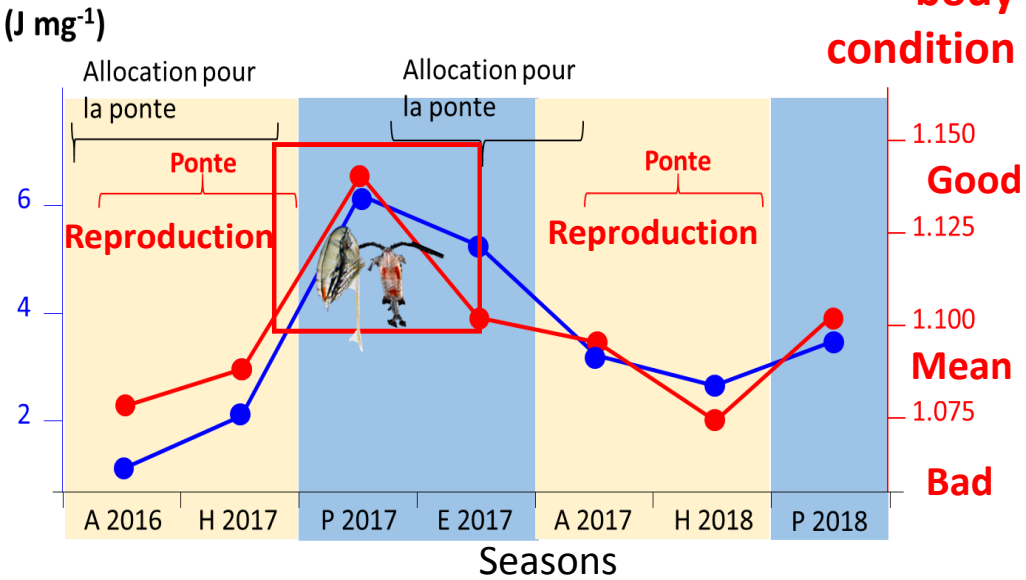
Temporal variation of plankton and sardine food selection



Chen et al., 2021

Energy value of plankton - diet

Chen et al., 2019

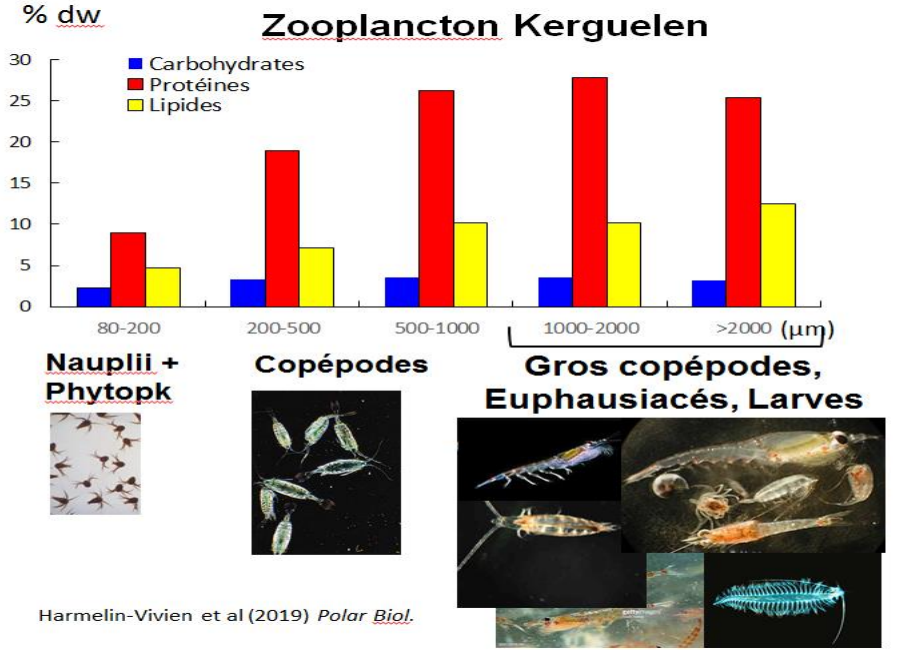


Spring & Summer: **large prey**
no reproduction -> **Good Kn**

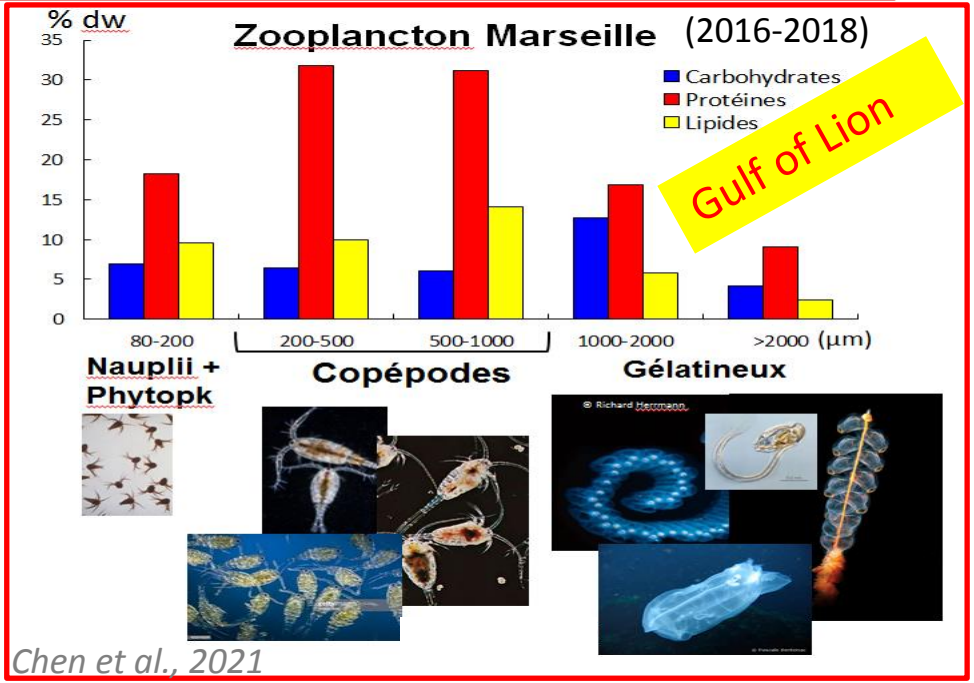
Daniela.banaru@univ-amu.fr

Interactions : environment ↔ plankton ↔ small pelagic planktivores

Biochemical composition and energy value of zooplankton vary with the size of the organisms and the composition of the fractions



Harmelin-Vivien et al (2019) *Polar Biol.*

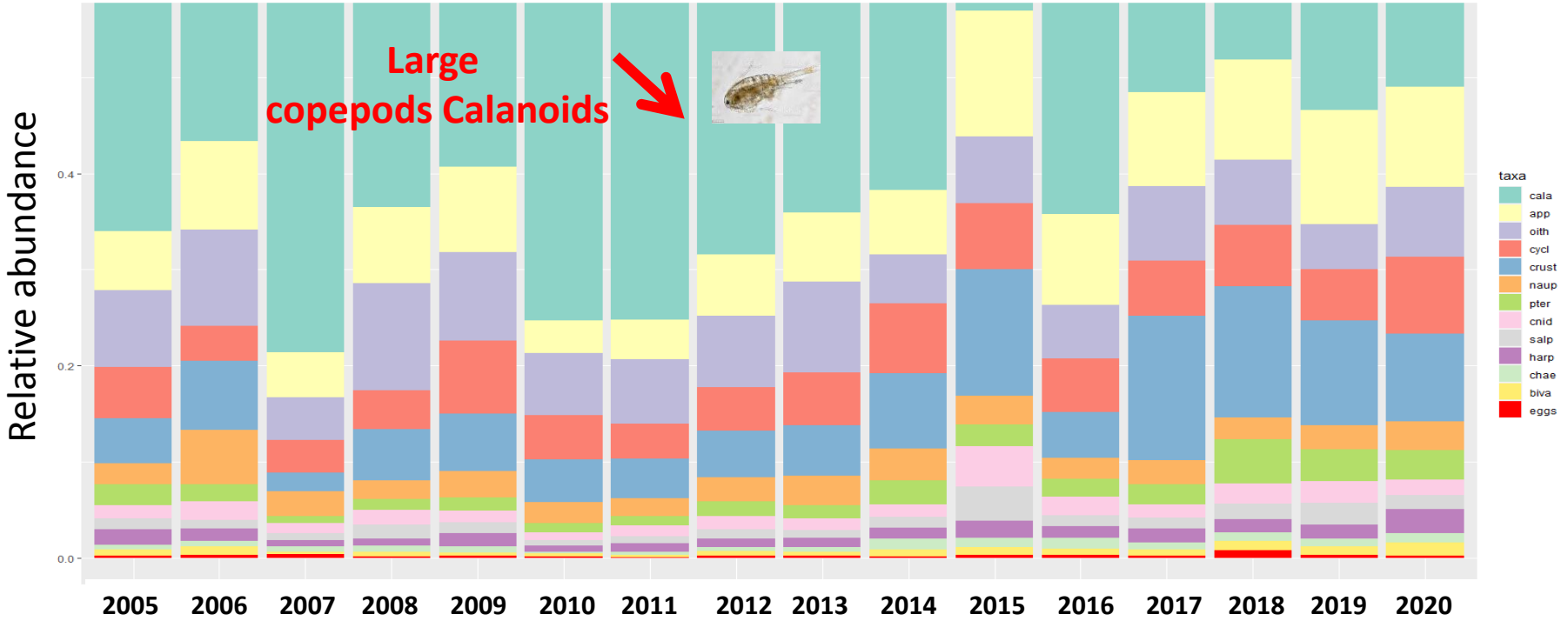


Chen et al., 2021

Where have the larger, more energetic prey gone?

Daniela.banaru@univ-amu.fr

Project ZOO-INDEX – PhD T. Garcia (2020-2023) « Changes in zooplankton in the Bay of Marseilles over the past two decades and impact on the functioning of the ecosystem »



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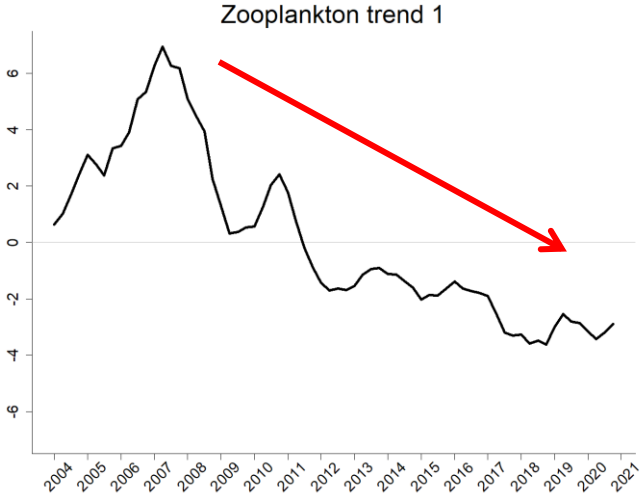
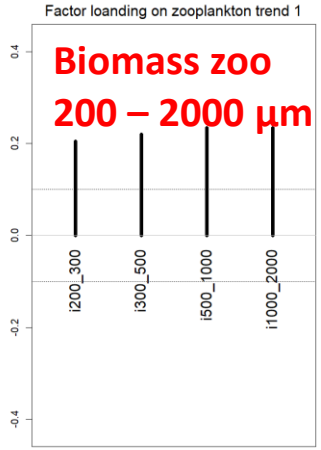
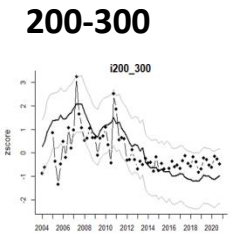
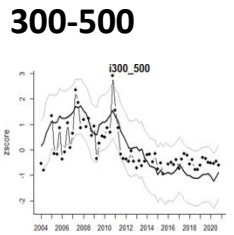
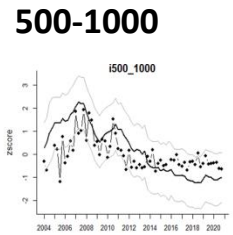
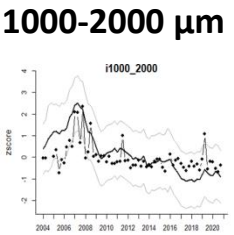






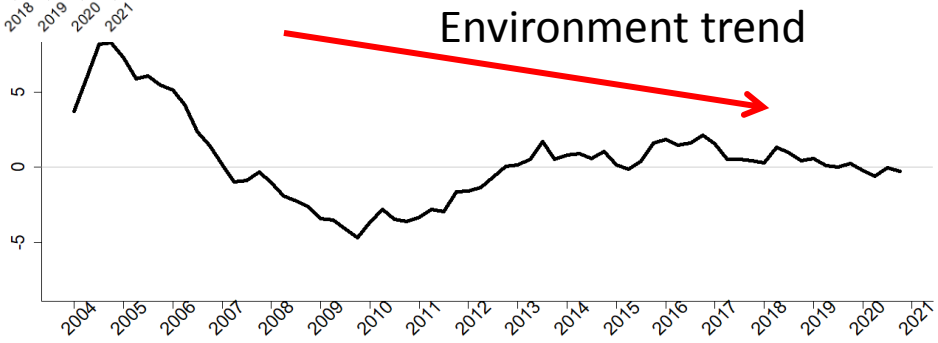


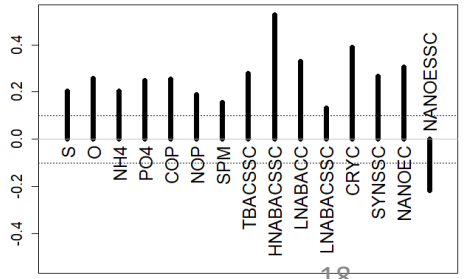




2004-2021

Nutrients, organic particles, size of pico-nano plankton





Région Provence-Alpes-Côte d'Azur

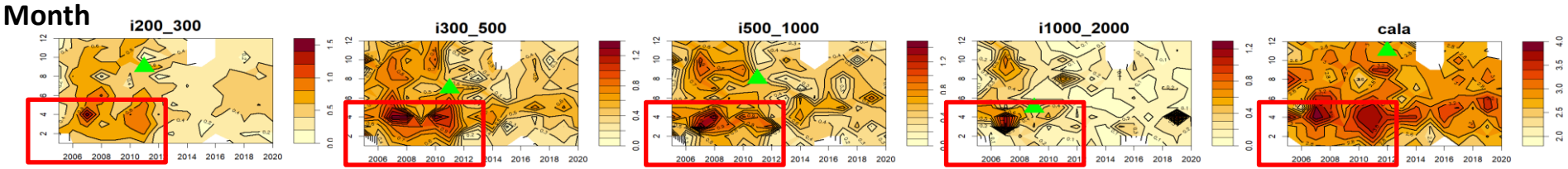
Parc national des Calanques

CRPMEM PACA

Interactions : environment ⟷ plankton ⟷ small pelagic planktivores

Project ZOO-INDEX – PhD T. Garcia (2020-2023) « Changes in zooplankton in the Bay of Marseilles over the past two decades and impact on the functioning of the ecosystem »

Seasonal changes **Biomass zooplankton 200 – 2000 µm** **Calanoides**

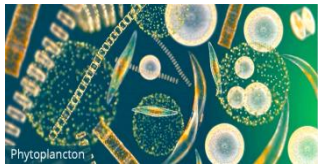


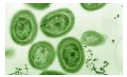
Year 2004-2020

- Decrease in the biomass of zooplankton size classes and the abundance of Calanoides copepods more marked in spring
- Change in diet of planktivorous fish that adapt to available resources (size & species) (Le Bourg et al., 2015; Chen, 2019; Chen et al., 2021)
- At the end of winter and at the beginning of spring, sardines are more vulnerable to starvation conditions (Queiros et al., 2021)
- Decrease in size and relative body condition of planktivorous fish (Van Beveren et al, 2014) -> impact on fishing activities

Daniela.banaru@univ-amu.fr

Less nutrients, smaller phytoplankton
less zooplankton and probably less energetic

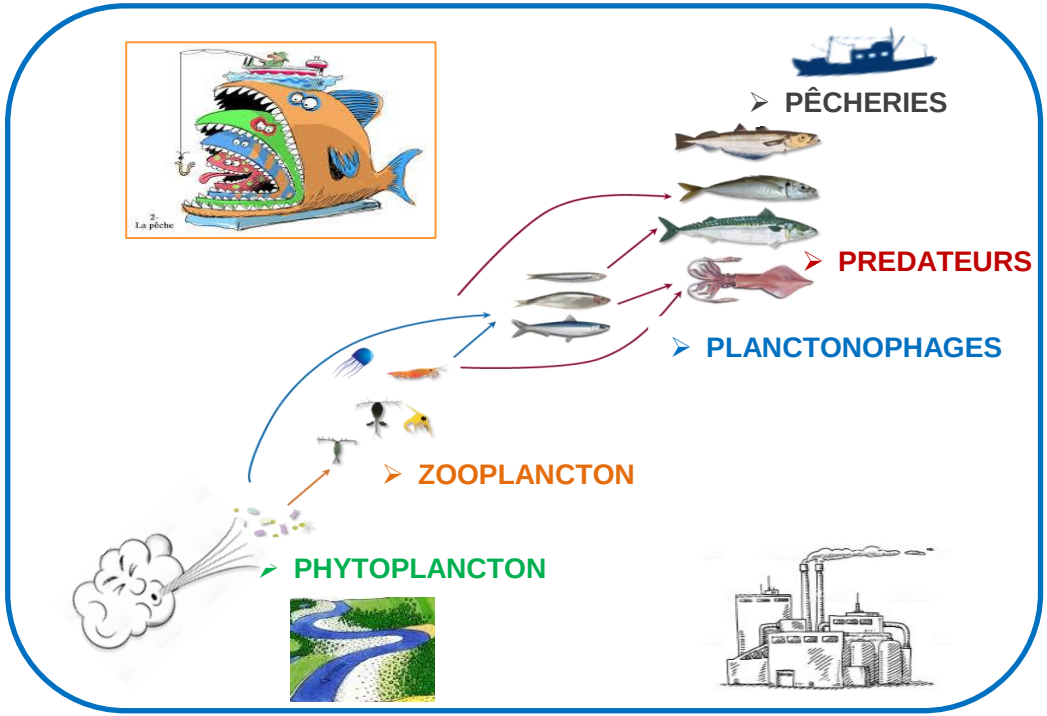



Planktivorous fish on a diet (lower relative body condition, smaller average size)


Fisheries crisis in the NW Mediterranean sea

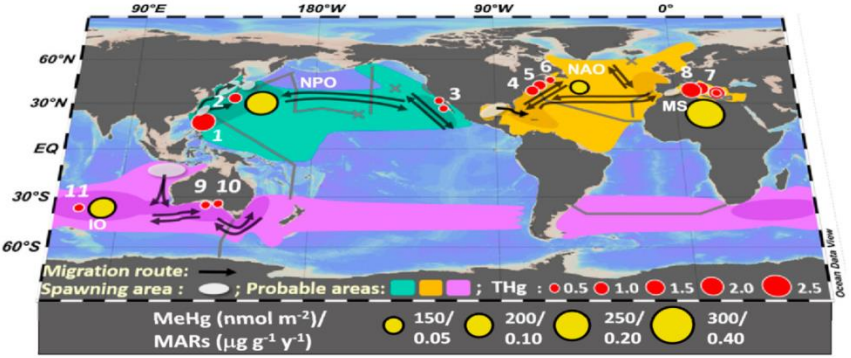
Daniela.banaru@univ-amu.fr



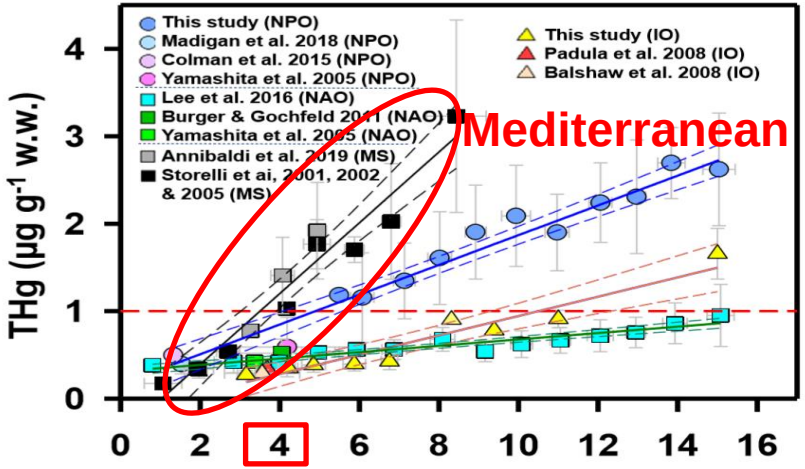
- Approche écosystémique d'étude du fonctionnement des écosystèmes marins « End-to-End »
- Production planctonique et impact sur les pêcheries
- **Impact de l'oligotrophie sur la contamination des réseaux trophiques, example du Hg**

Daniela.banaru@univ-amu.fr

Mediterranean: high accumulation of THg and MeHg in top predators, example of bluefin tuna:



Other species: hake, plaice, mullet, dolphin (*André et al. 1991 ; Andral et al. 2004; Harmelin-Vivien et al. 2009; Cossa et al. 2012; Chouvelon et al. 2012*)



Mediterranean >

North Pacific > Indian > North Atlantic

Tseng et al., 2021

0.16 - 2.59 mg kg^{-1} (moy = 1.18 mg kg^{-1} w.w.)

Storelli et al., 2002

WHO health threshold exceeded in the Mediterranean for mature individuals > 4 years (>61% indiv.)

-> influence of size /age (bioaccumulation)

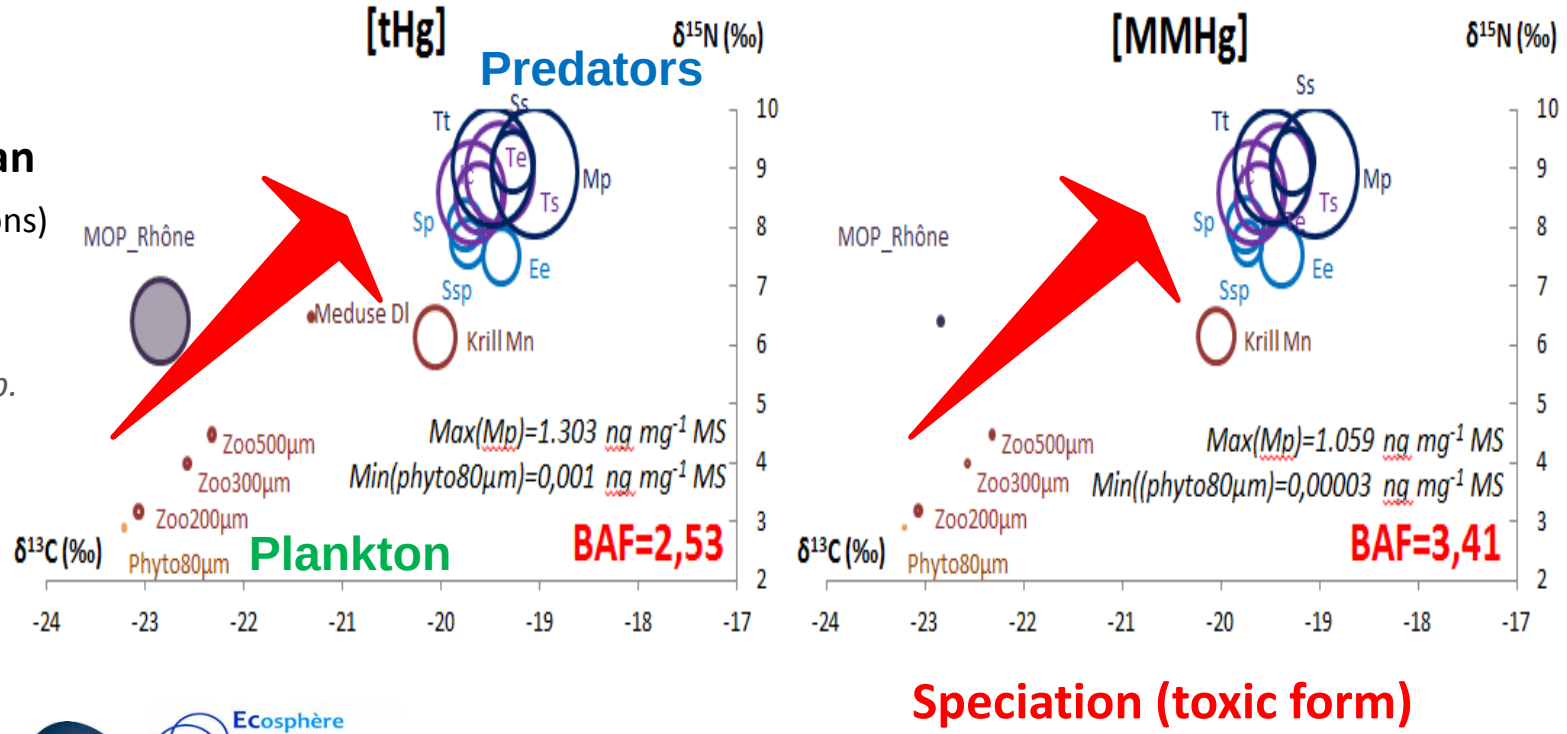
Food webs and contamination

Influence of the trophic level (biomagnification in the food web)

NW Mediteranean

2011-2012 (Gulf of Lions)

Bănaru et Harmelin-Vivien, 2019;
Bănaru et al., en prép.



Speciation (toxic form)

Project PARME
CNRS – EC2CO

Ecosphère Continentale et Côtière

Daniela.banaru@univ-amu.fr

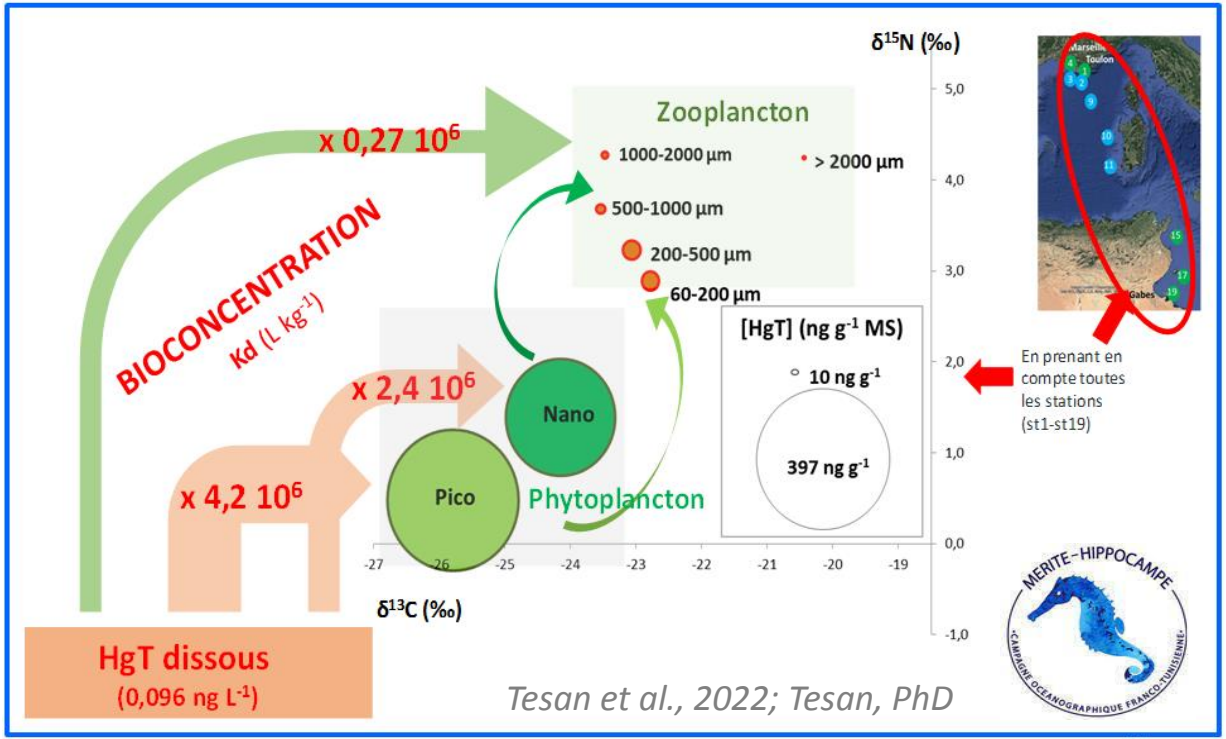
Food webs and contamination

Plankton: biological PUMP of CONTAMinants in marine ecosystems (ANR JCJC CONTAMPUMP)?

- **Plankton:**
  - Basis of marine food webs
  - Multitude of organisms
  - Biological carbon pump

- **Contaminants:**
  - Traces in sea water
  - High levels in marine organism

Major role of plankton in trophic transfer of contaminants

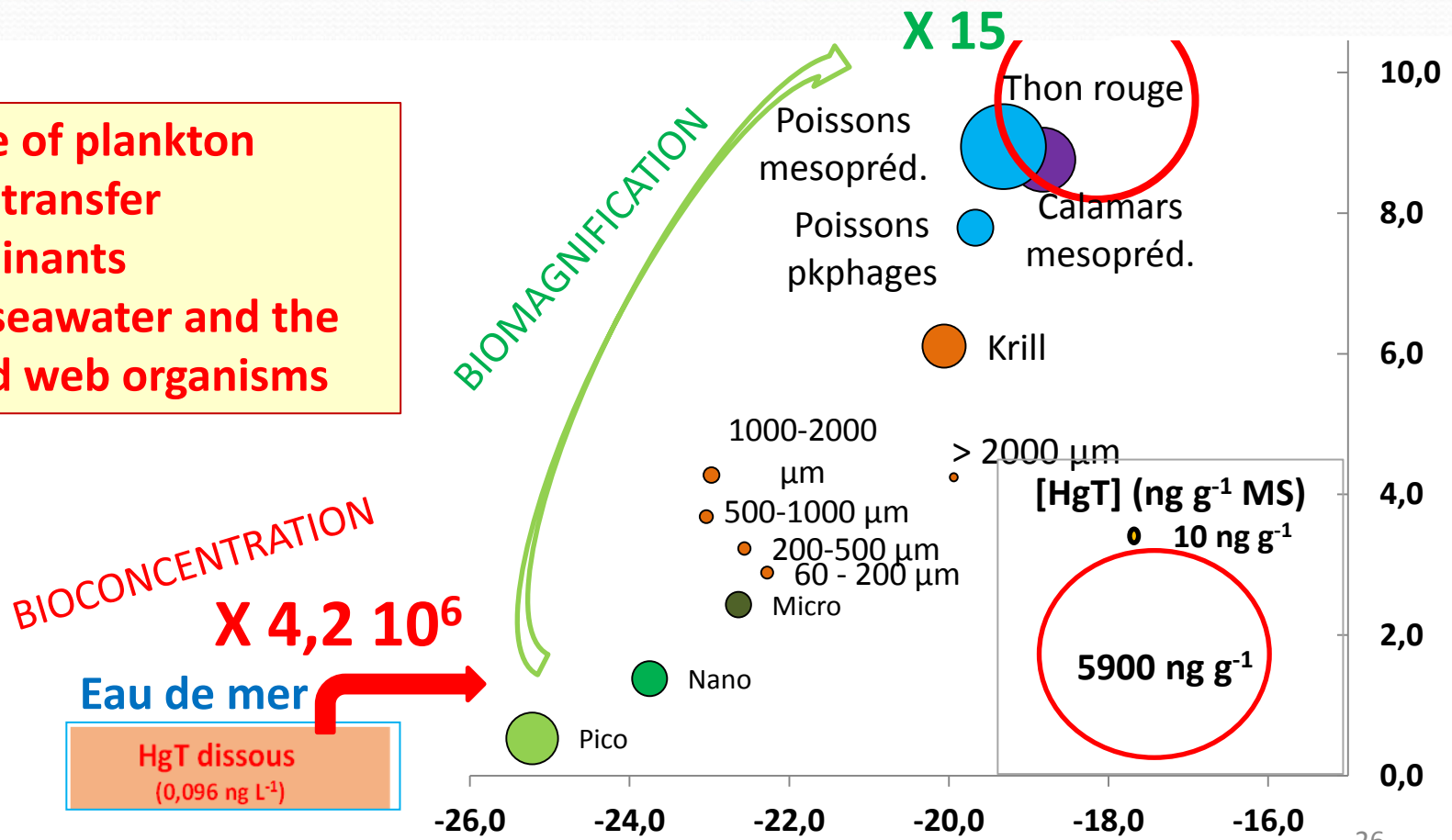


Tesan et al., 2022; Tesan, PhD

Daniela.banaru@univ-amu.fr

Food webs and contamination

Major role of plankton in trophic transfer of contaminants between seawater and the other food web organisms



Daniela.banaru@univ-amu.fr

Conclusions

- Mediterranean: a sea with high biodiversity, but naturally poor in nutrients
- Reducing nutrient inputs from rivers and WWTPs further accentuates this oligotrophy (+ drought and use of water for agriculture)
- Global warming and stratification reduce vertical mixing and deplete the water column

-> less plankton production to support fisheries production

-> more bioconcentration of contaminants at the base of food webs

Daniela.banaru@univ-amu.fr