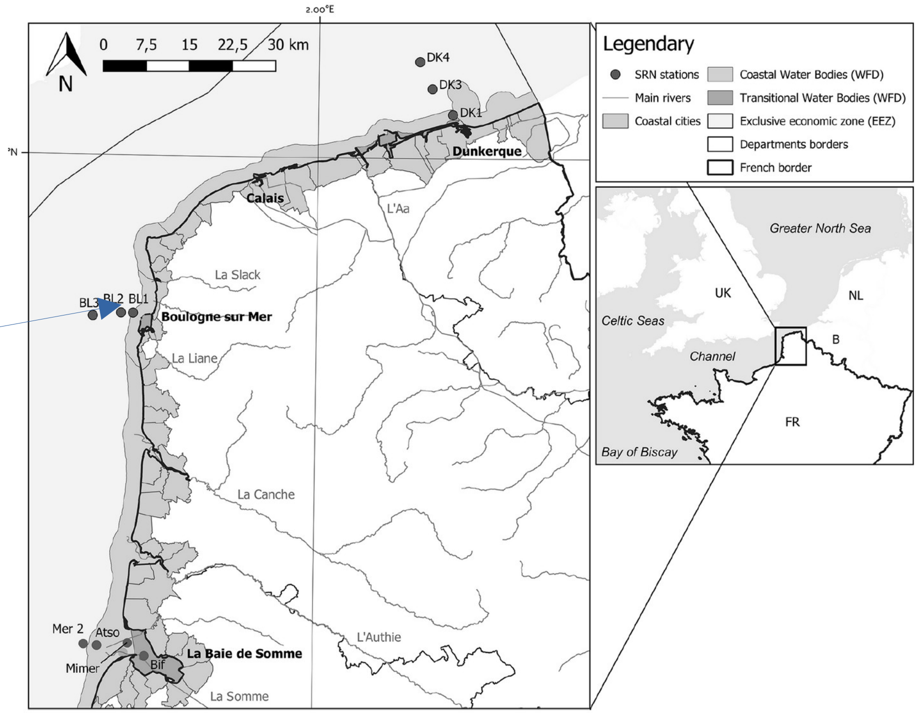
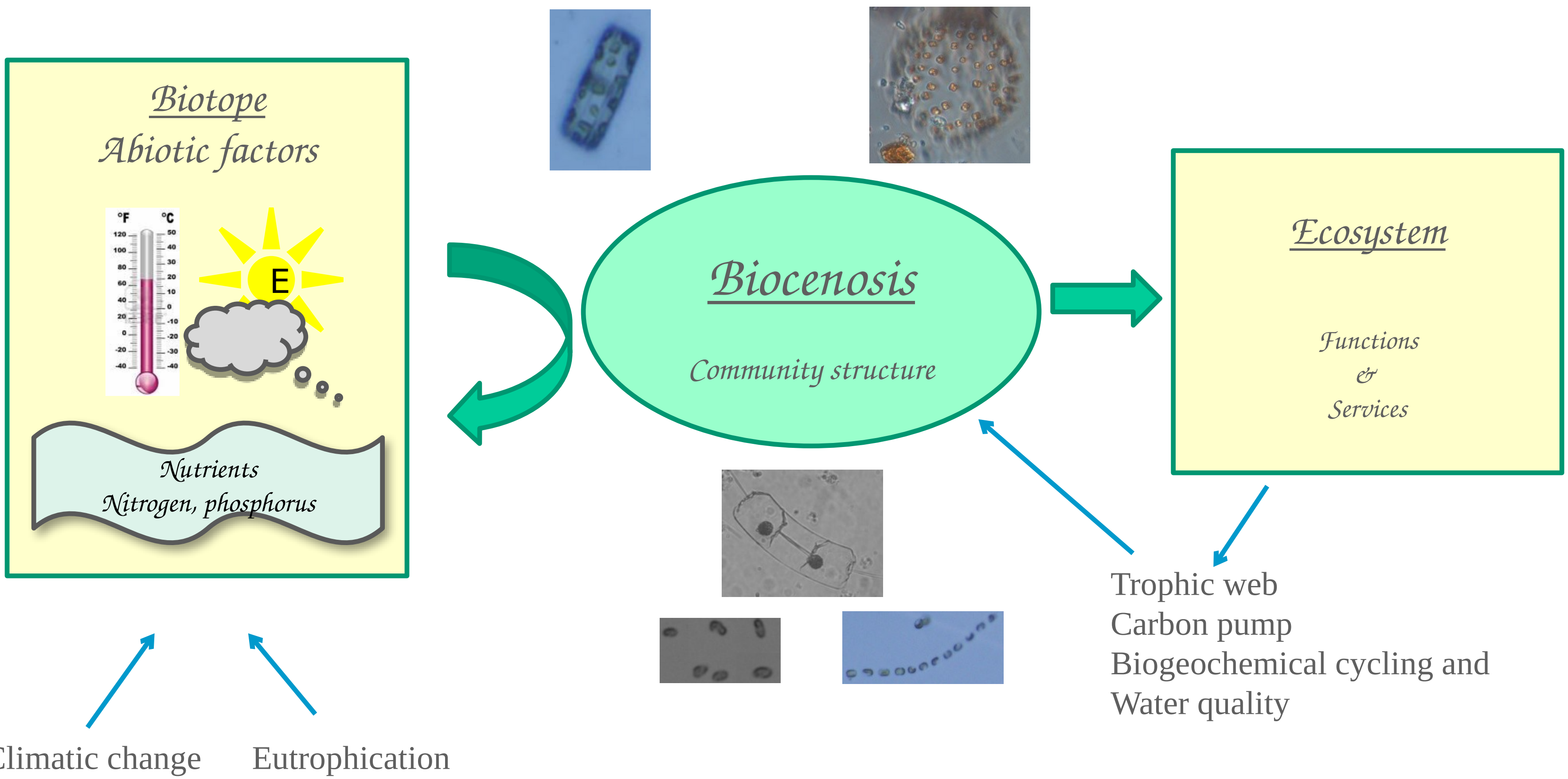
Interactions dynamiques dans le plancton marin

Sébastien Lefebvre

Professeur en écologie marine



Biodiversity and ecosystem functioning



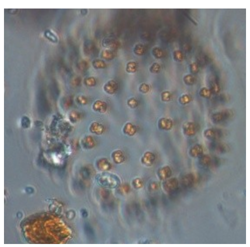
Introduction

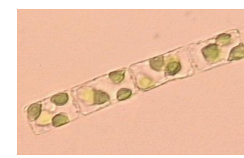
Marine phytoplanktonic microalgae

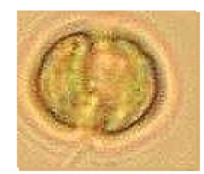
0,2 % of global photosynthetic biomass

High diversity
(phylogenetic, morphologic …)

45-50% of global carbon fixation

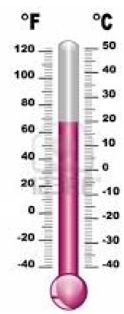






Critical role in trophic webs, carbon pump and climate
Biogeochemical cycles and water quality

Microalgae nutrient requirements



Lumière

Température

Sels nutritifs inorganiques
CO_2, NH_4^+, NO_3^-, PO_4^{3-}, SiO_4^-

Quantité et qualité

Autotrophie

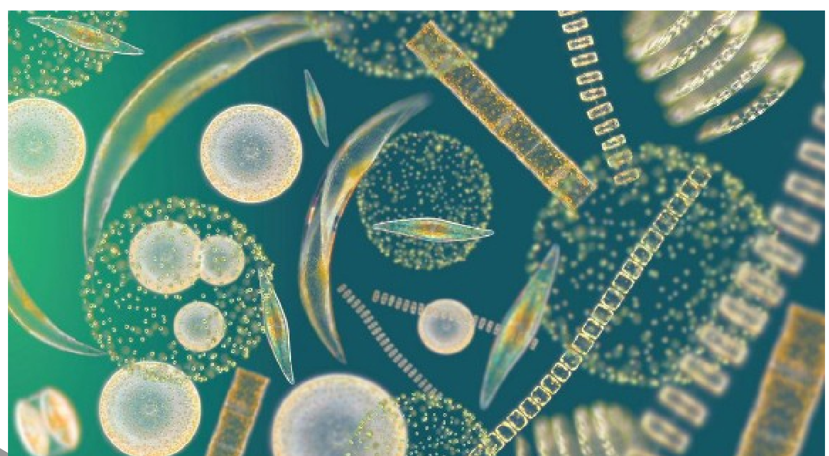
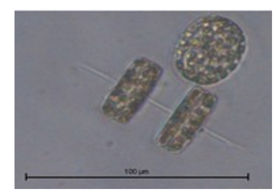
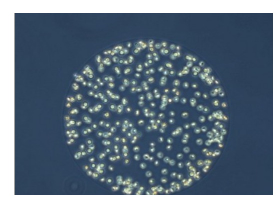


Photo SERC



Diatomées
N/P/Si
16/1/16

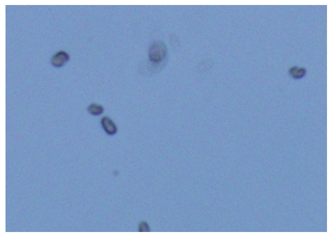


Prymnésiophycées
N/P/~~Si~~
25/1

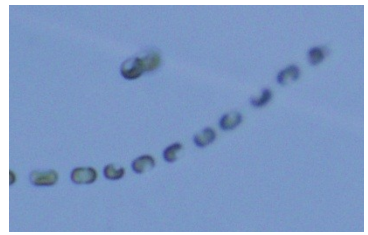
Microalgae diversity

Five species from English channel (spring bloom)

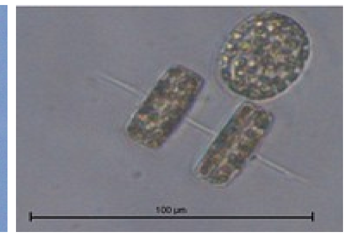
Phaeocystis globosa



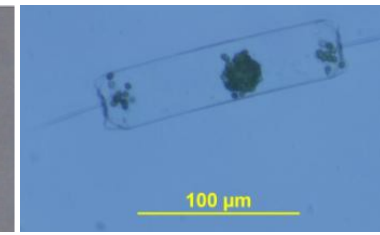
Hemiselmis rufescens



Skeletonema marinoi



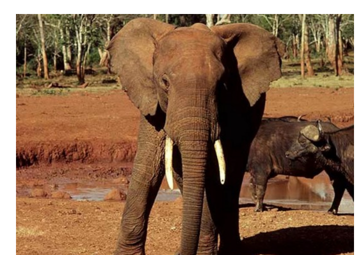
Thalassiosira rotula



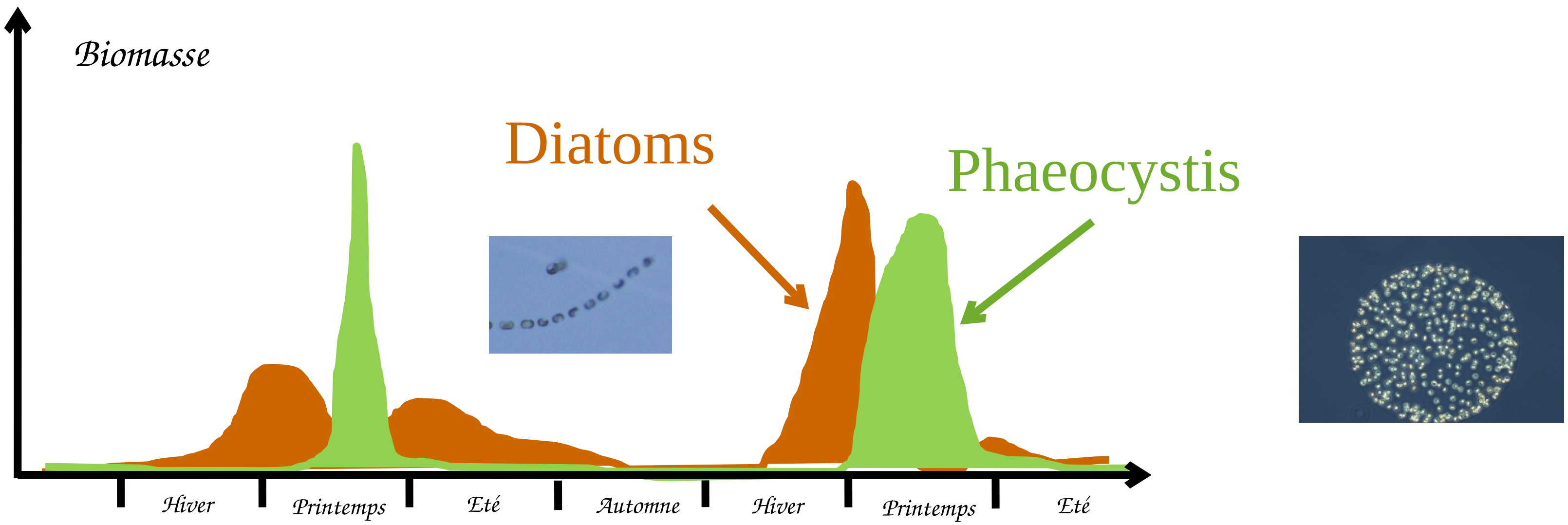
Ditylum brightwellii

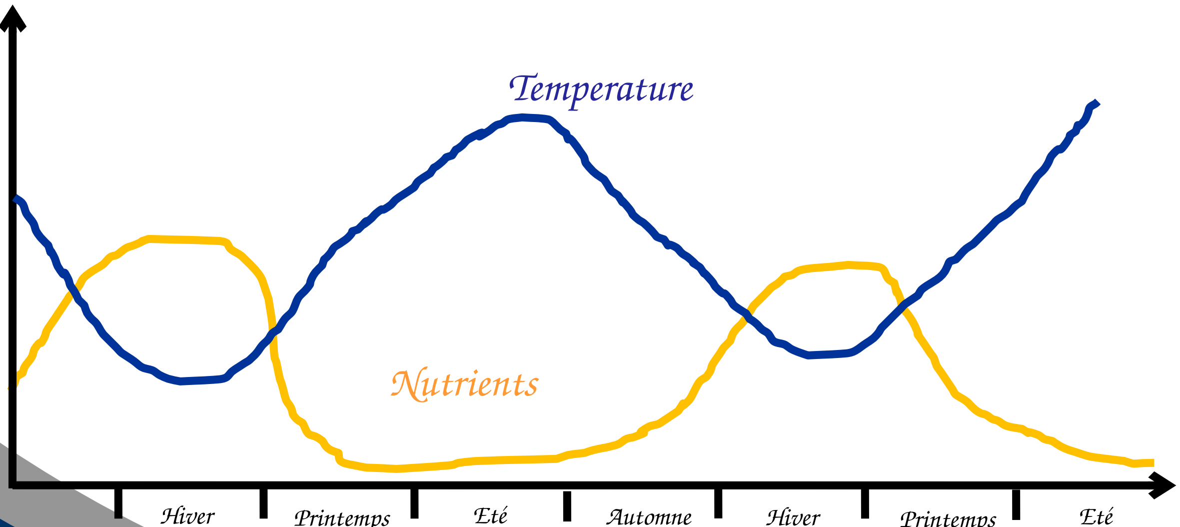
3 µm — 3-10 µm — 5-15 µm — 20-40 µm — 70-200 µm

Size gradient = differential response to environmental variability



Ecological niche: Correlative approach





« Mousse de mai » 2010

Etude de la niche écologique de microalgues à l'aide de la méthode WitOMI pour une meilleure compréhension des interactions entre espèces

Sébastien Lefebvre[1] & Stéphane Karasiewicz[2]

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FST Station marine de Wimereux
[2]Laboratoire environnement ressources de Boulogne sur mer, IFREMER

Séminaire UMR Cristal
21 juin 2021

Ecological niche: Correlative approach

PeerJ

Within outlying mean indexes: refining the OMI analysis for the realized niche decomposition

Stéphane Karasiewicz[1], Sylvain Dolédec[2] and Sébastien Lefebvre[1,3]

Harmful Algae 72 (2018) 1–13

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journal homepage: www.elsevier.com/locate/hal

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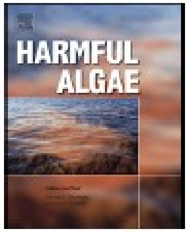


Realized niche analysis of phytoplankton communities involving HAB: *Phaeocystis* spp. as a case study

Check for updates

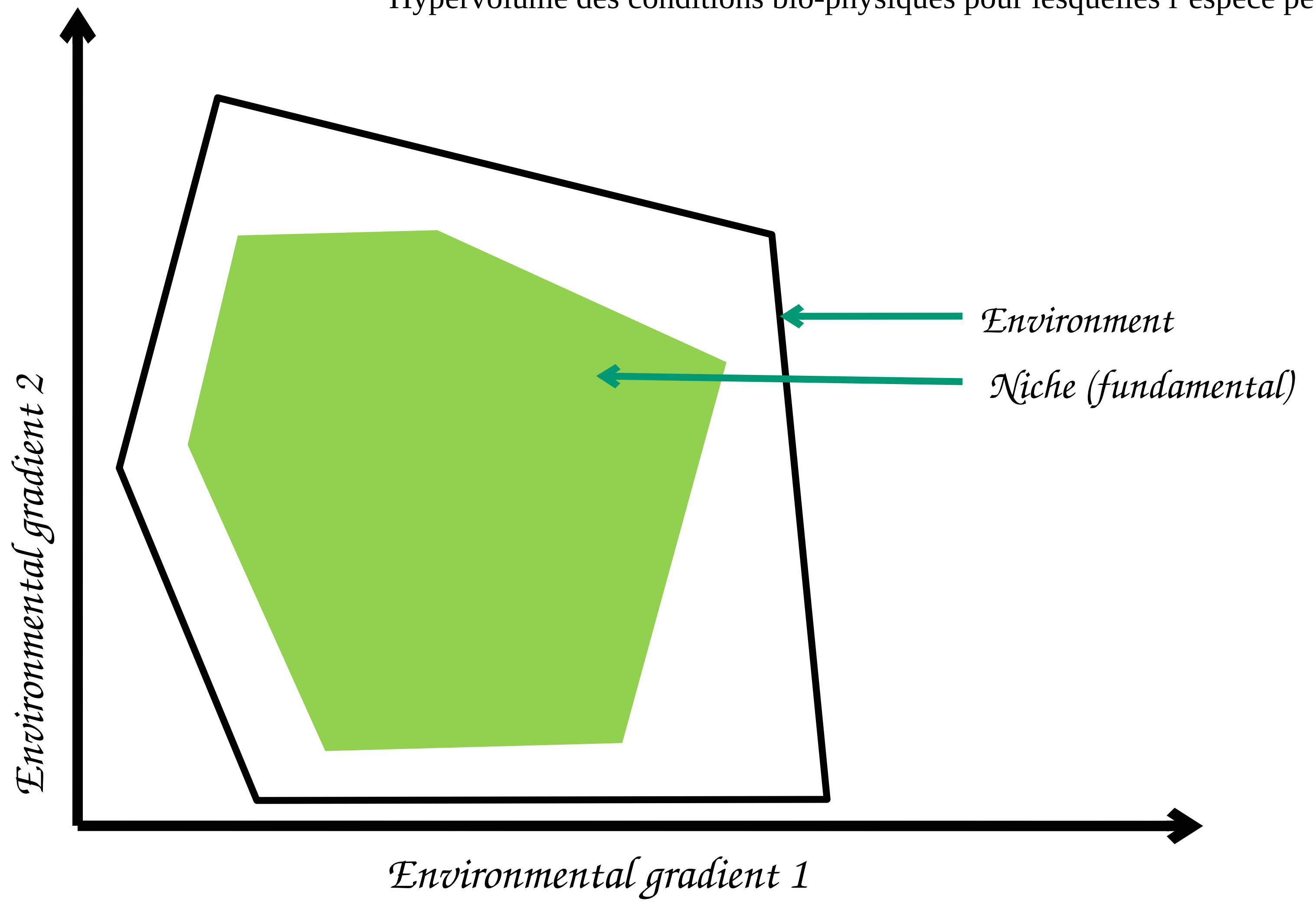
Stéphane Karasiewicz[a,*], Elsa Breton[a], Alain Lefebvre[b], Tania Hernández Fariñas[c], Sébastien Lefebvre[a,d]

State of the Art on P. globosa appearance

Appearance of P. globosa	References
- N:P	(Riegman & Van Boekel,1996)
- Si	(Cadée and Hegeman, 1986)
+ N:Si	(Lancelot et al., 1987; Lancelot, 1990)
+ N leftover by diatoms	(Bradley et al., 2010; Lundgren & Granéli, 2010)
+ Light	(Peperzak 1993)
+ salinity	(Borkman et al., 2016)

Niche concept

Hypervolume des conditions bio-physiques pour lesquelles l'espèce peut vivre



Hutchinson 1957, Soberon et al.,2011

Outlying mean index (OMI) analysis

Environment vs time

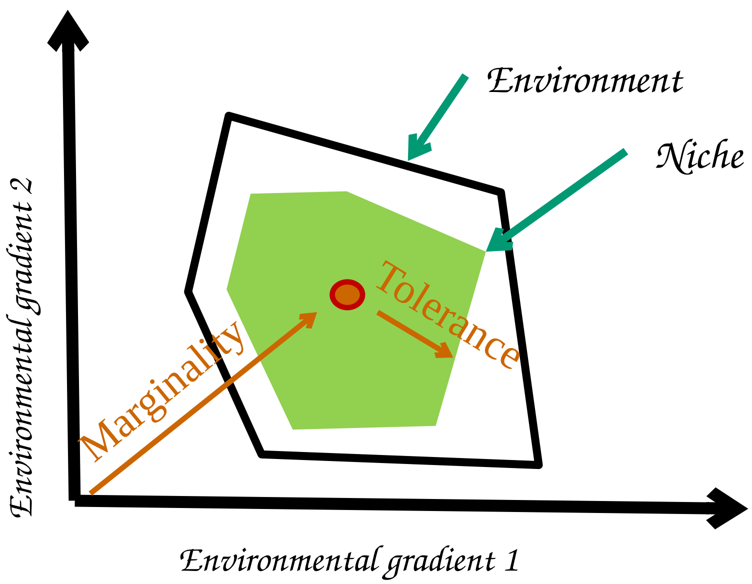
	VarE1	VarE2	VarE3	…
Date 1				
Date 2				
…				

Species (sp) vs time

	Sp1	Sp2	Sp3	…
Date 1				
Date 2				
…				

Species (sp) vs environment

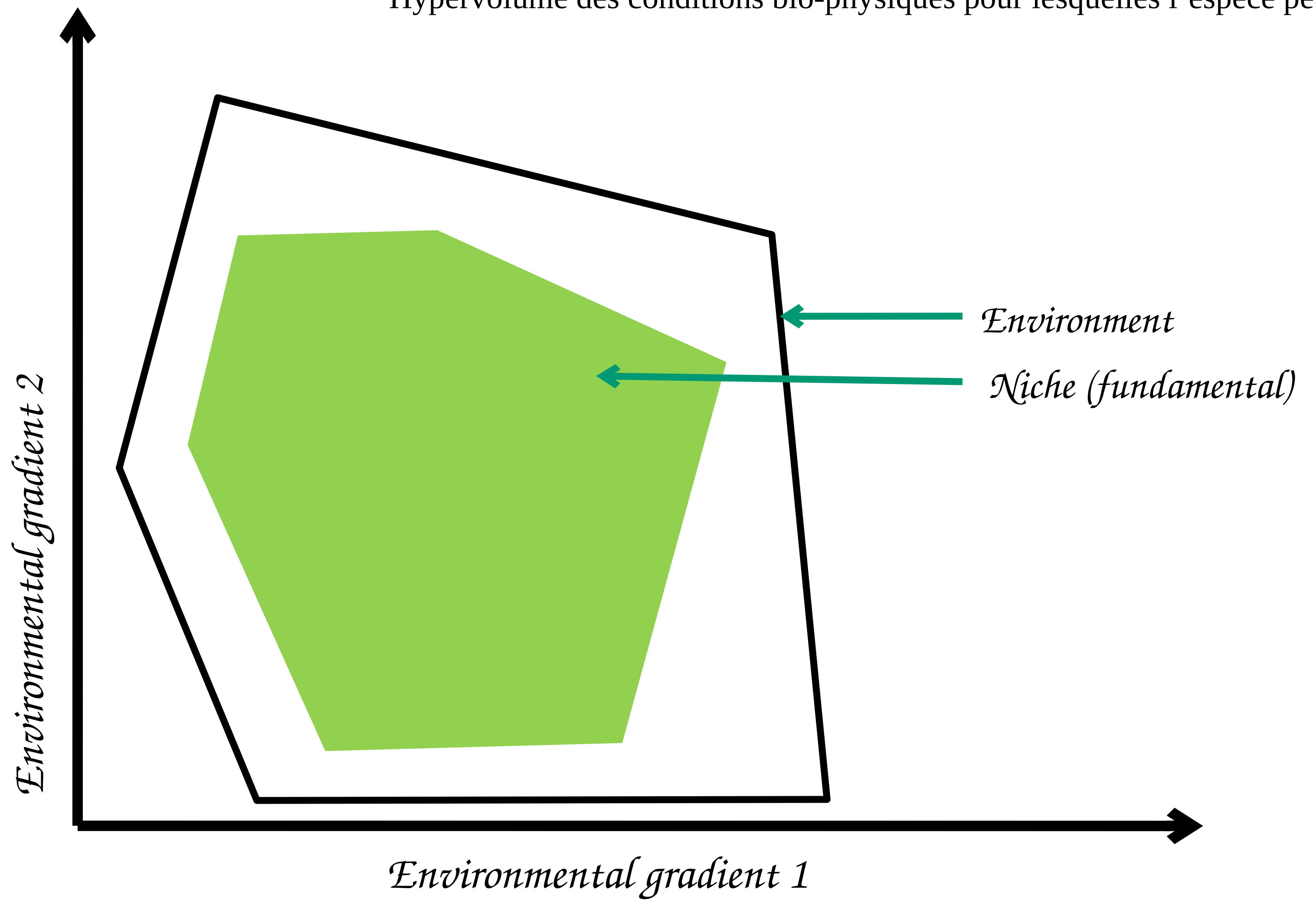
	Sp1	Sp2	Sp3	…
VarE1				
VarE2				
…				



- Ordination (Correspondance analysis)
  - Calculation of marginality and tolerance

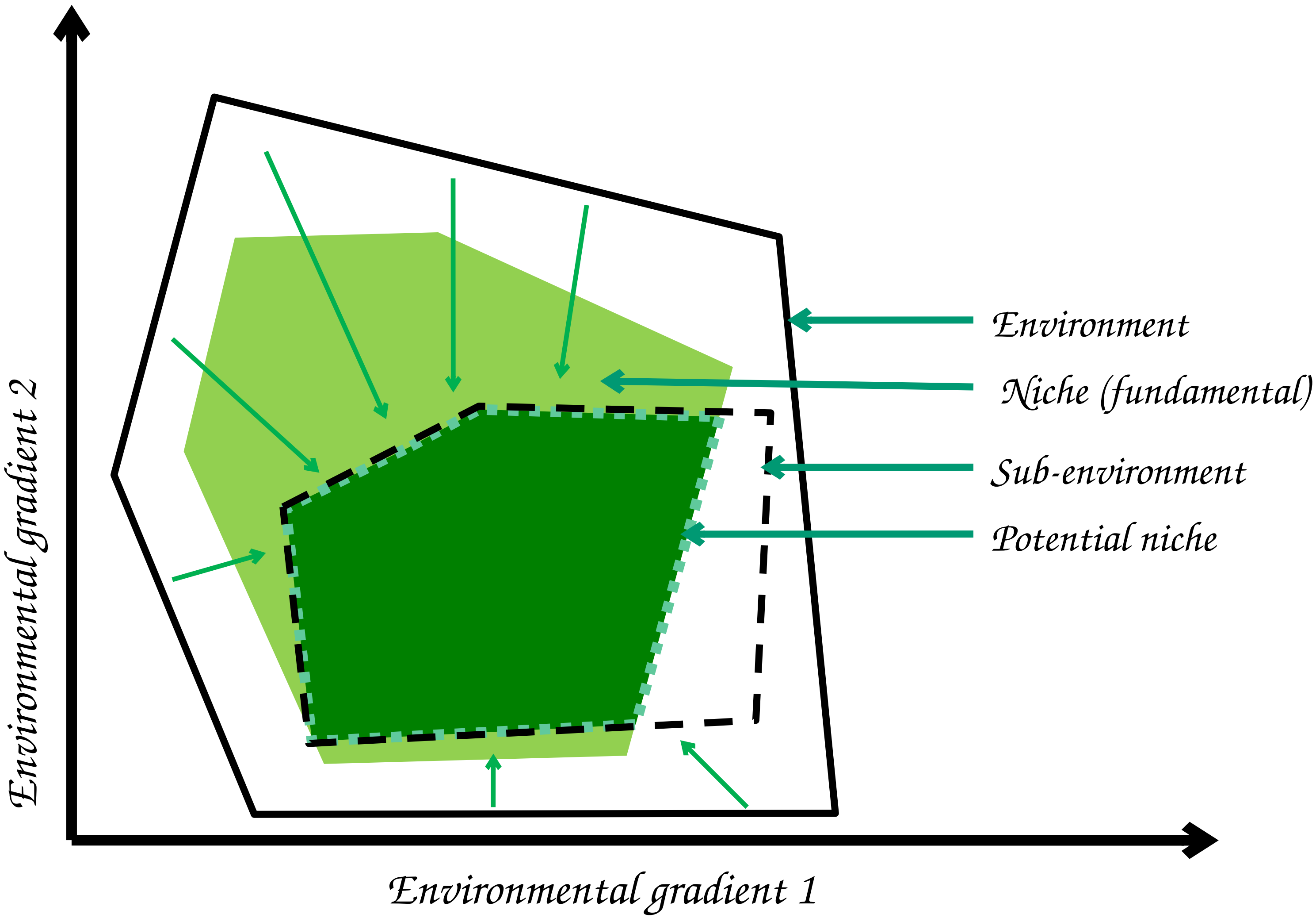
Niche concept

Hypervolume des conditions bio-physiques pour lesquelles l'espèce peut vivre



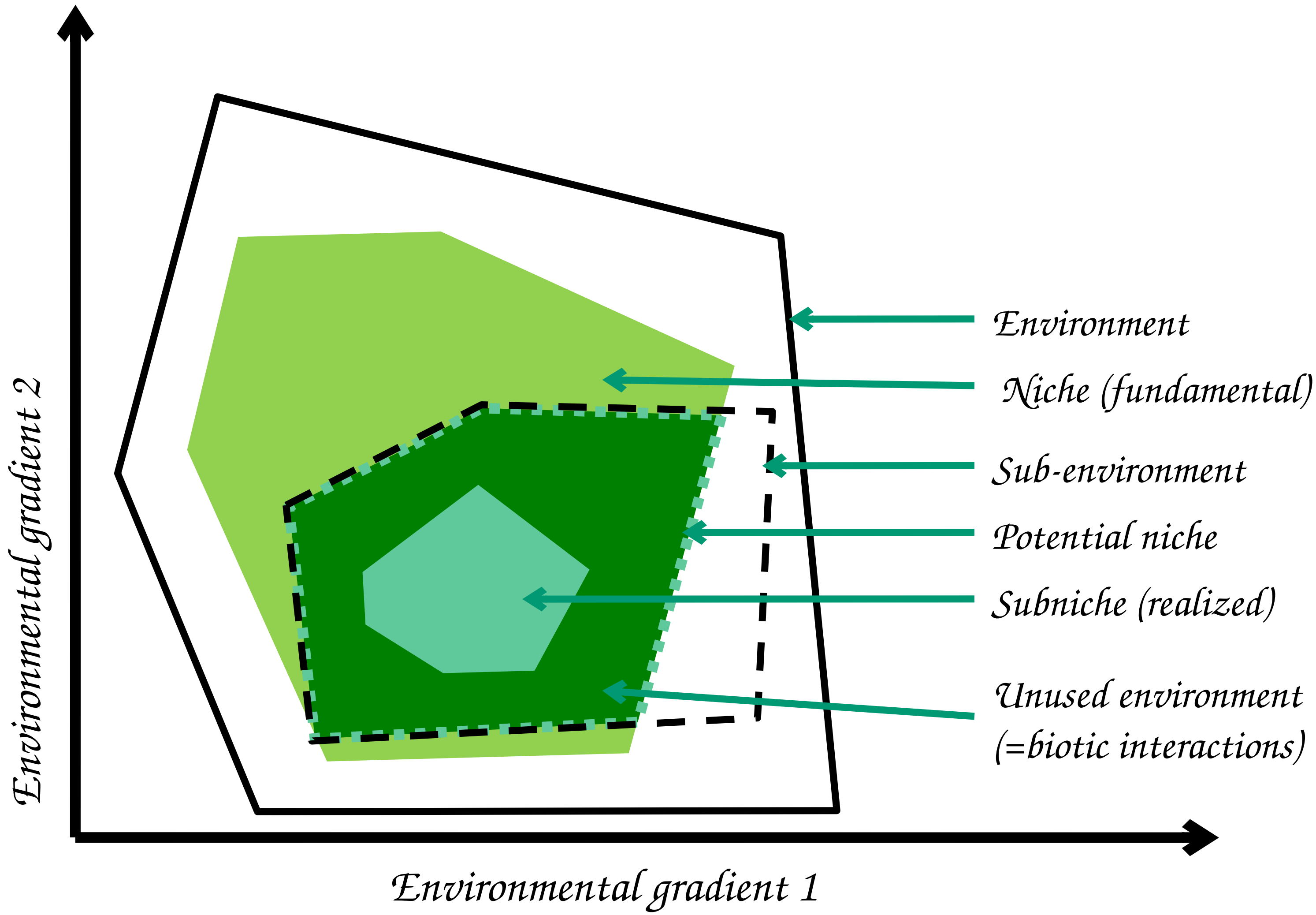
Hutchinson 1957, Soberon et al.,2011

Niche concept



Hutchinson 1957, Soberon et al.,2011

Niche concept

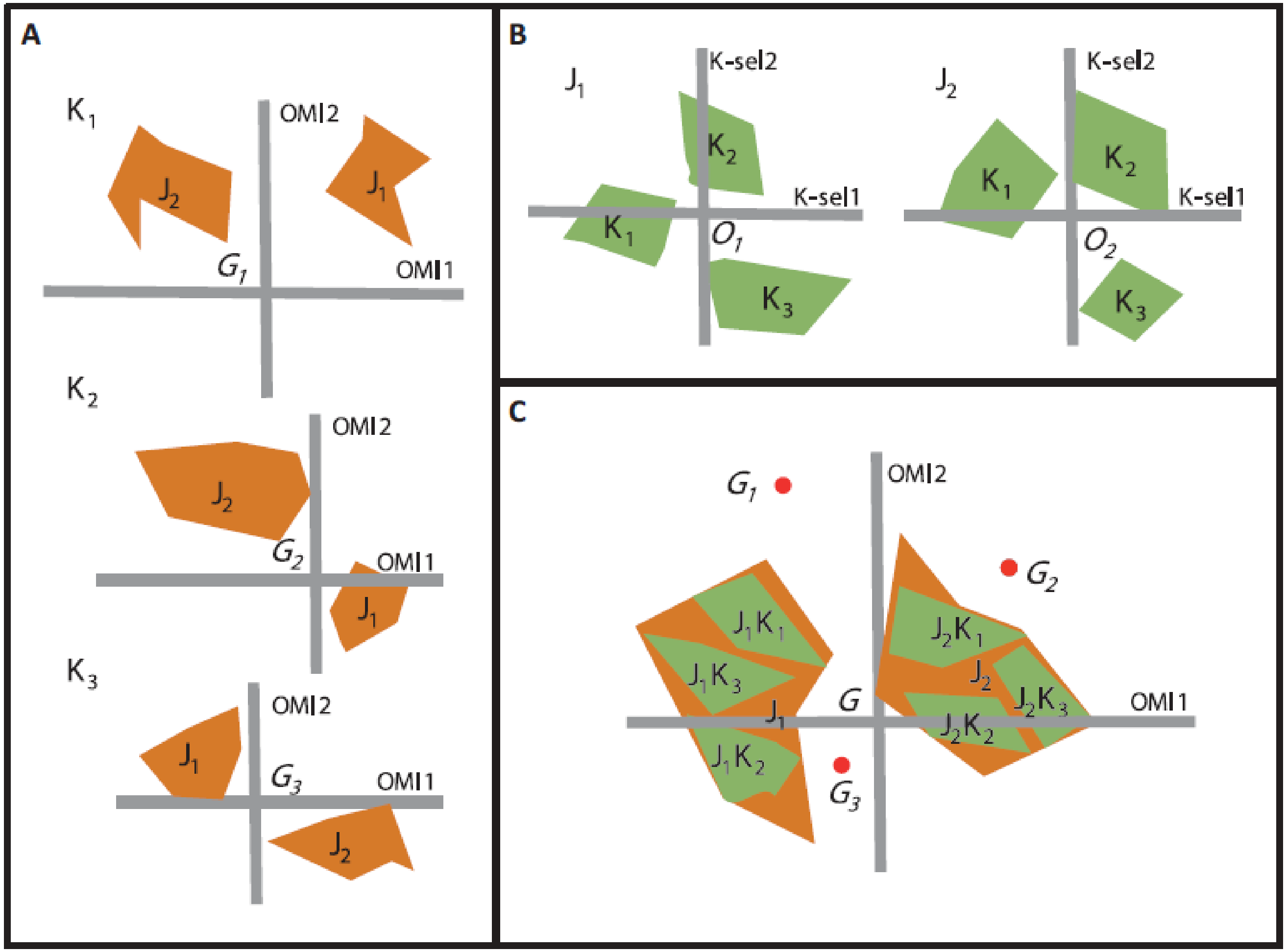


Hutchinson 1957, Soberon et al.,2011

Within OMI analysis

K select

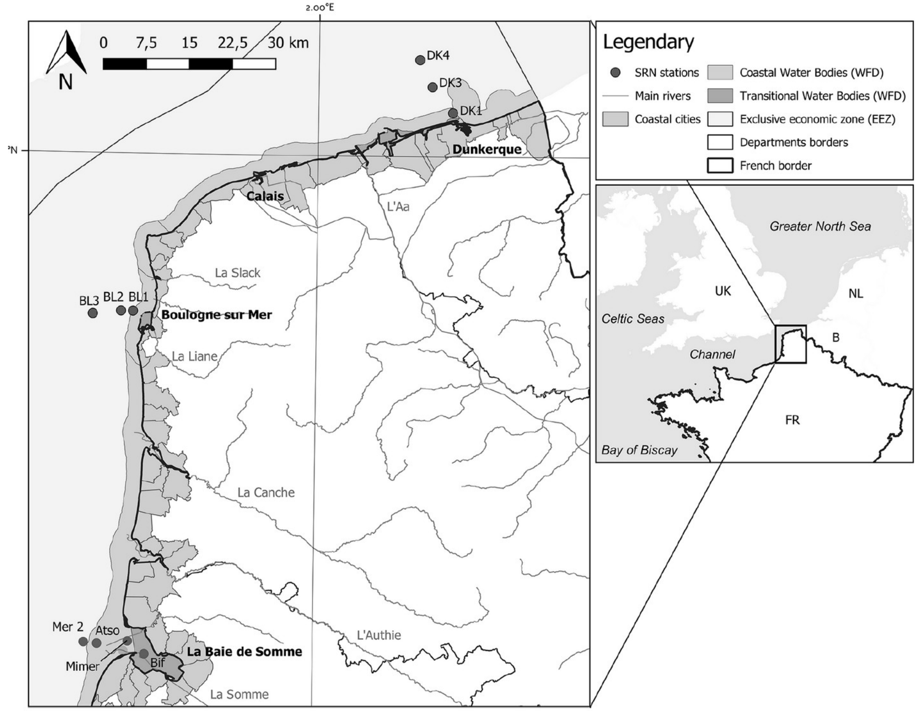
OMI



WitOMI

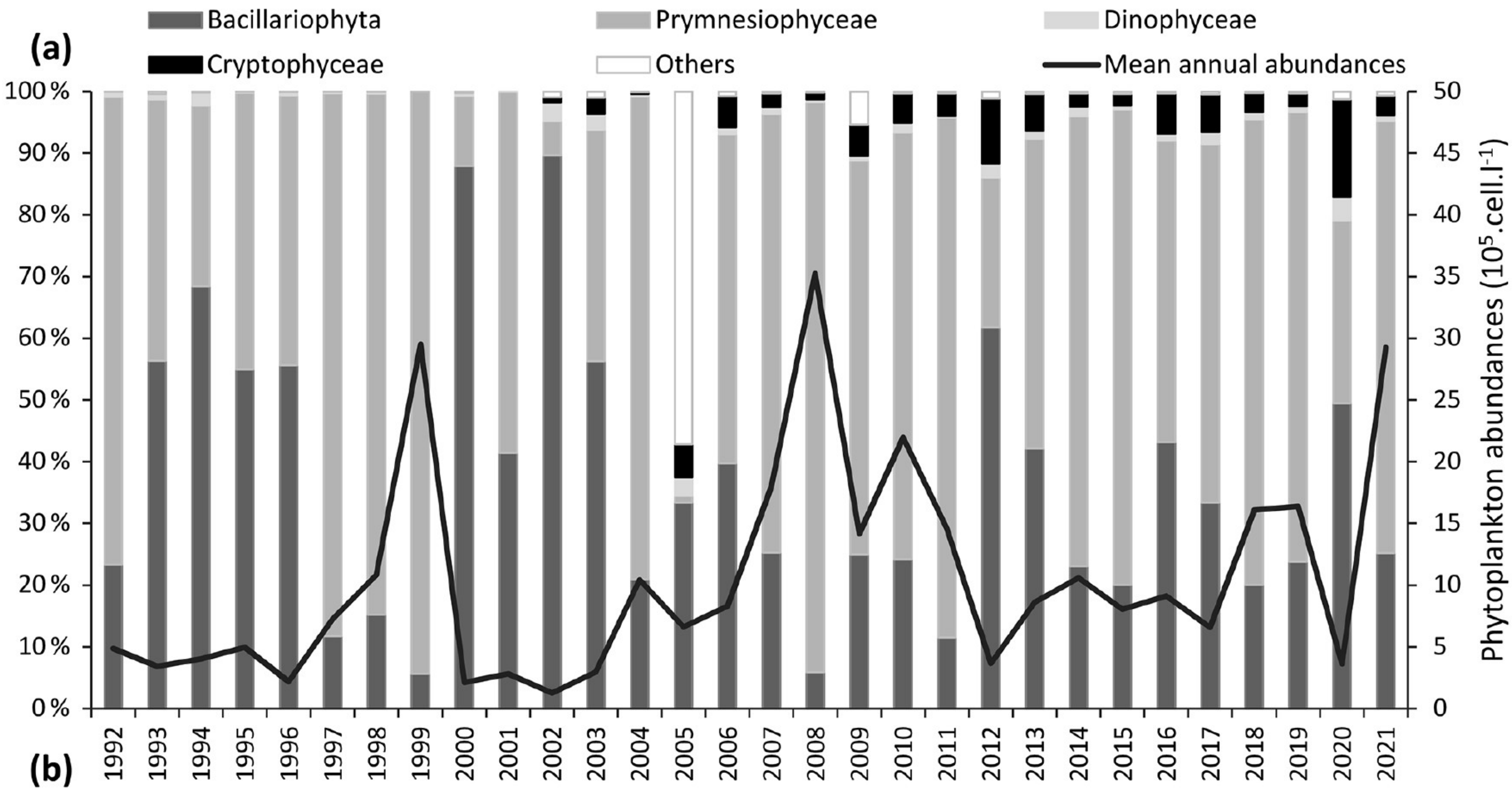
Data set

- Combination of Rephy (Ifremer) and SRN data
- 17 years (1996 to 2012)
- 24 diatom species and P. Globosa
  (but 11 diatom species studied)
- 8 environmental variables
- 269 sampling dates
- 1 sampling site only (for now …)



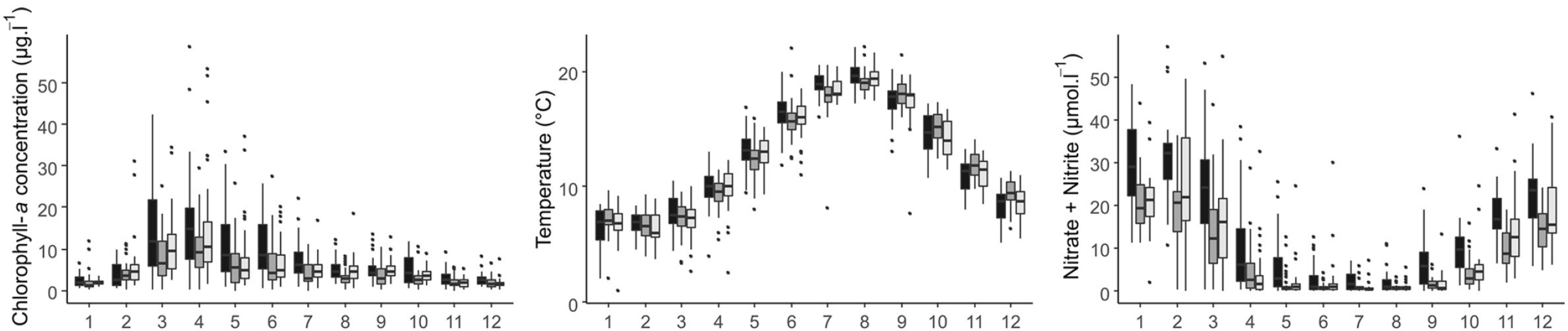
Lefebvre et Devrecker, 2023

Dynamique des communautés



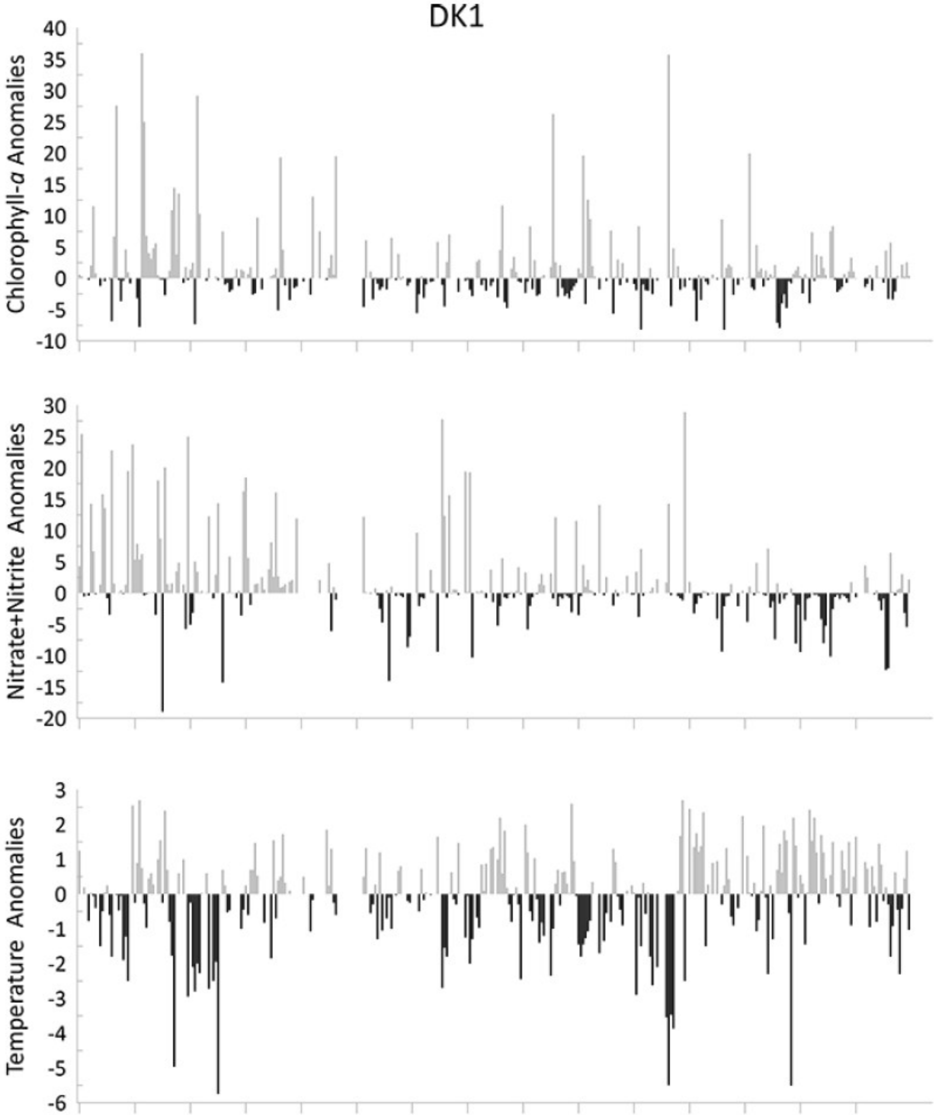
Lefebvre et Devrecker, 2023

Saisonnalité



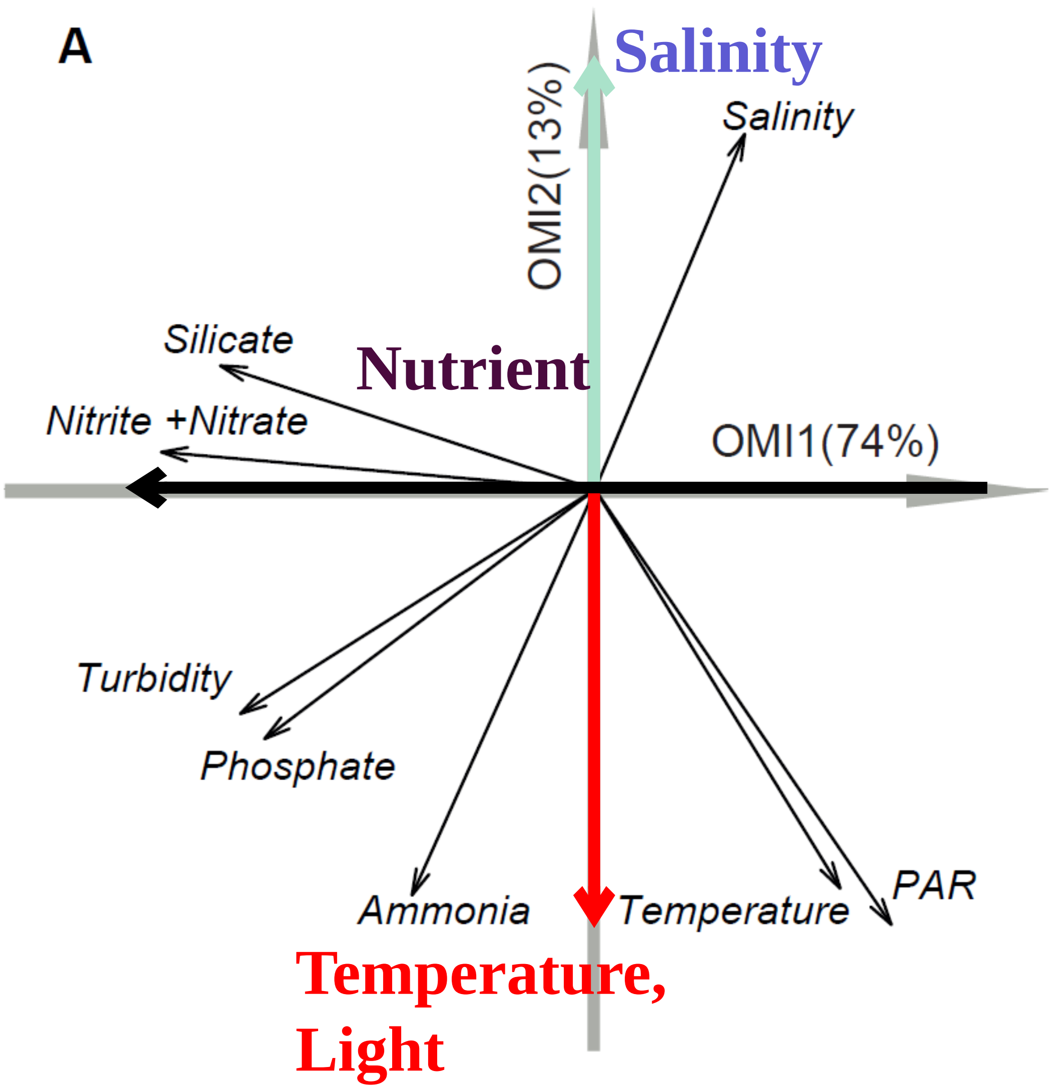
Lefebvre et Devrecker, 2023

Dynamique biomasse et ressources

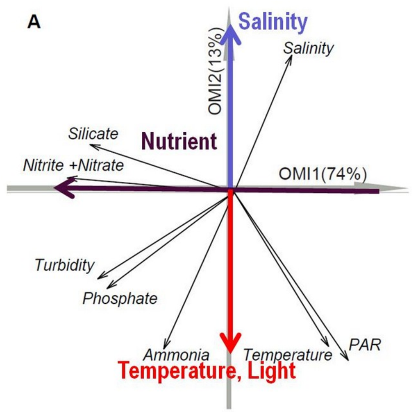


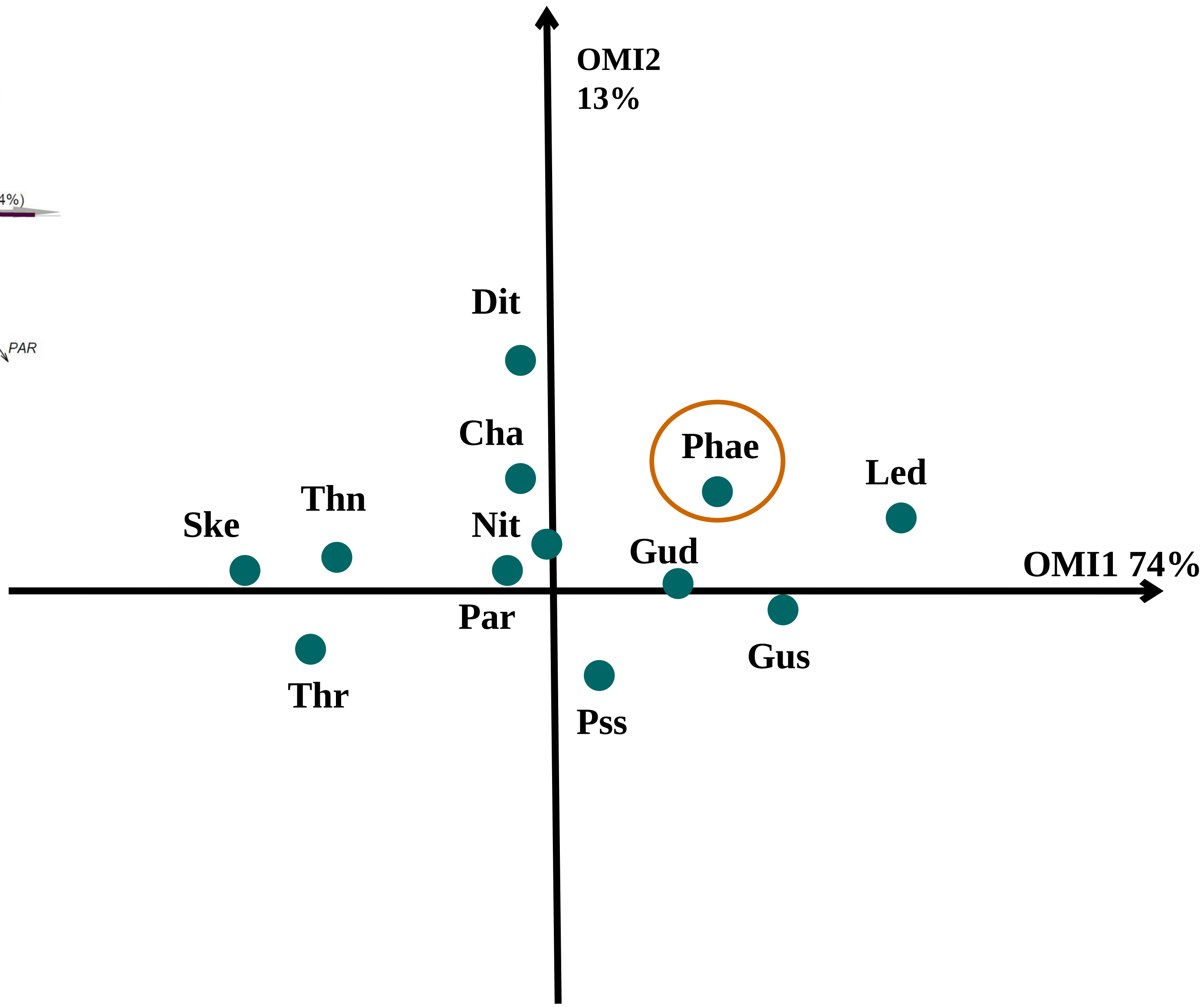
Lefebvre et Devrecker, 2023

OMI analysis (overall niche)

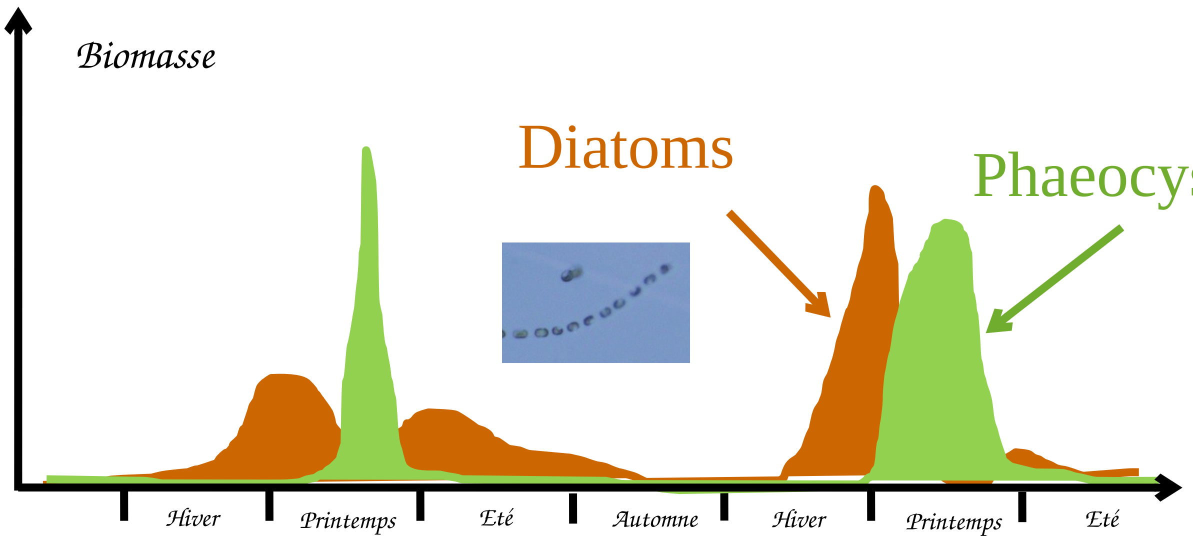


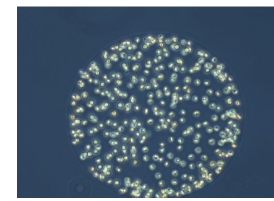
OMI analysis (overall niche)

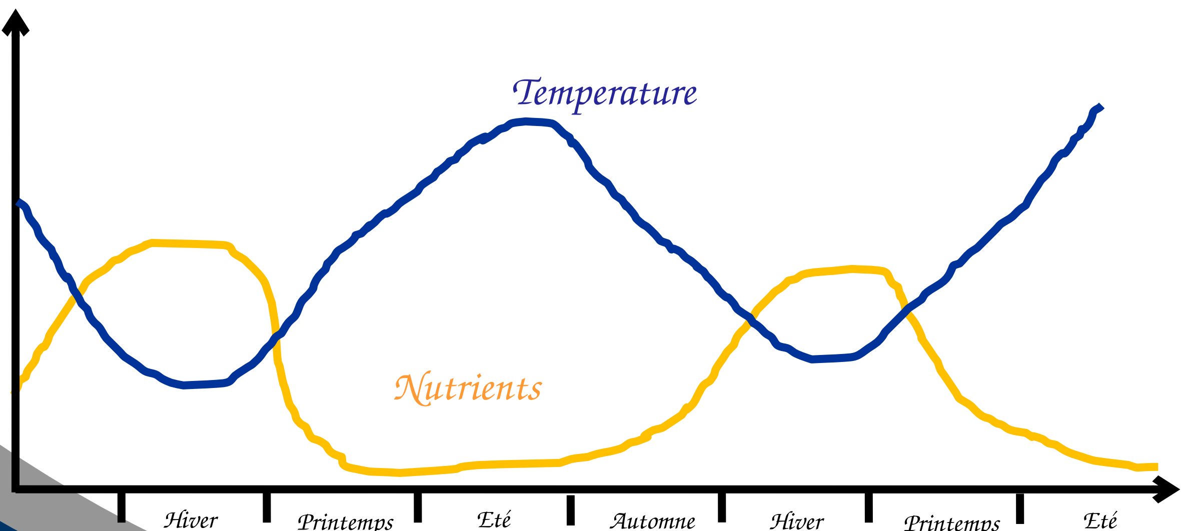




Species successions

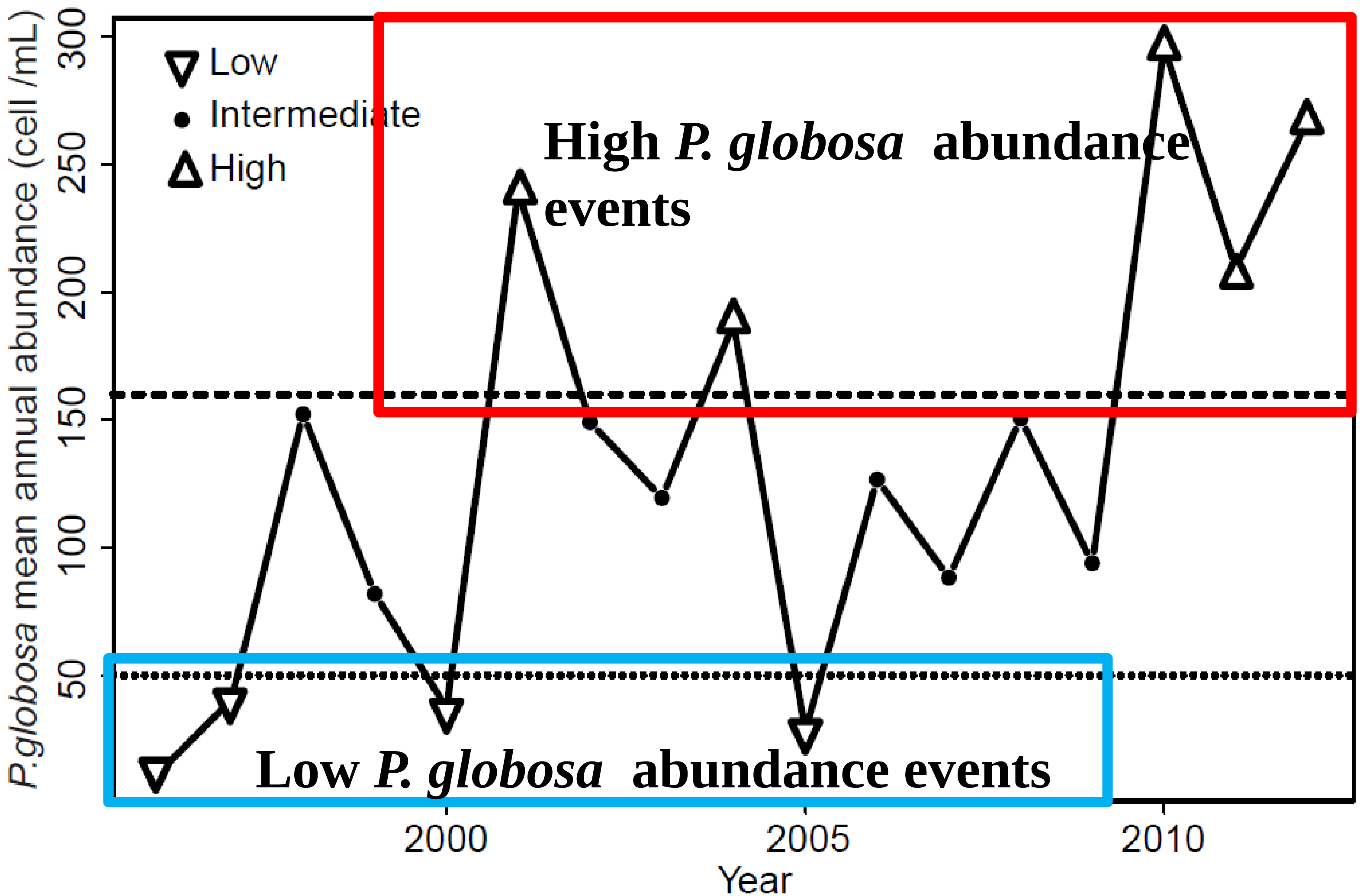




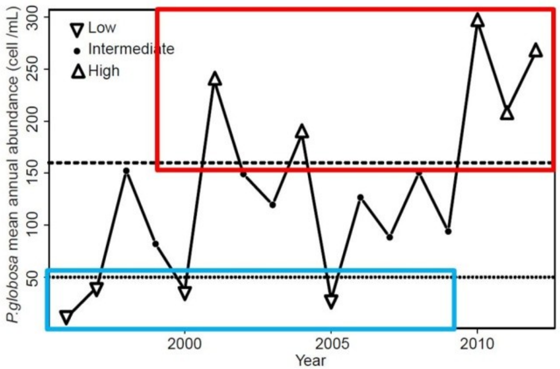


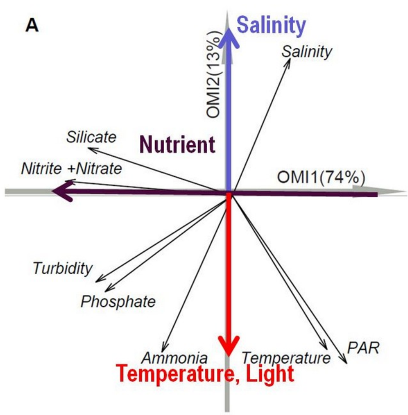
« Mousse de mai » 2010

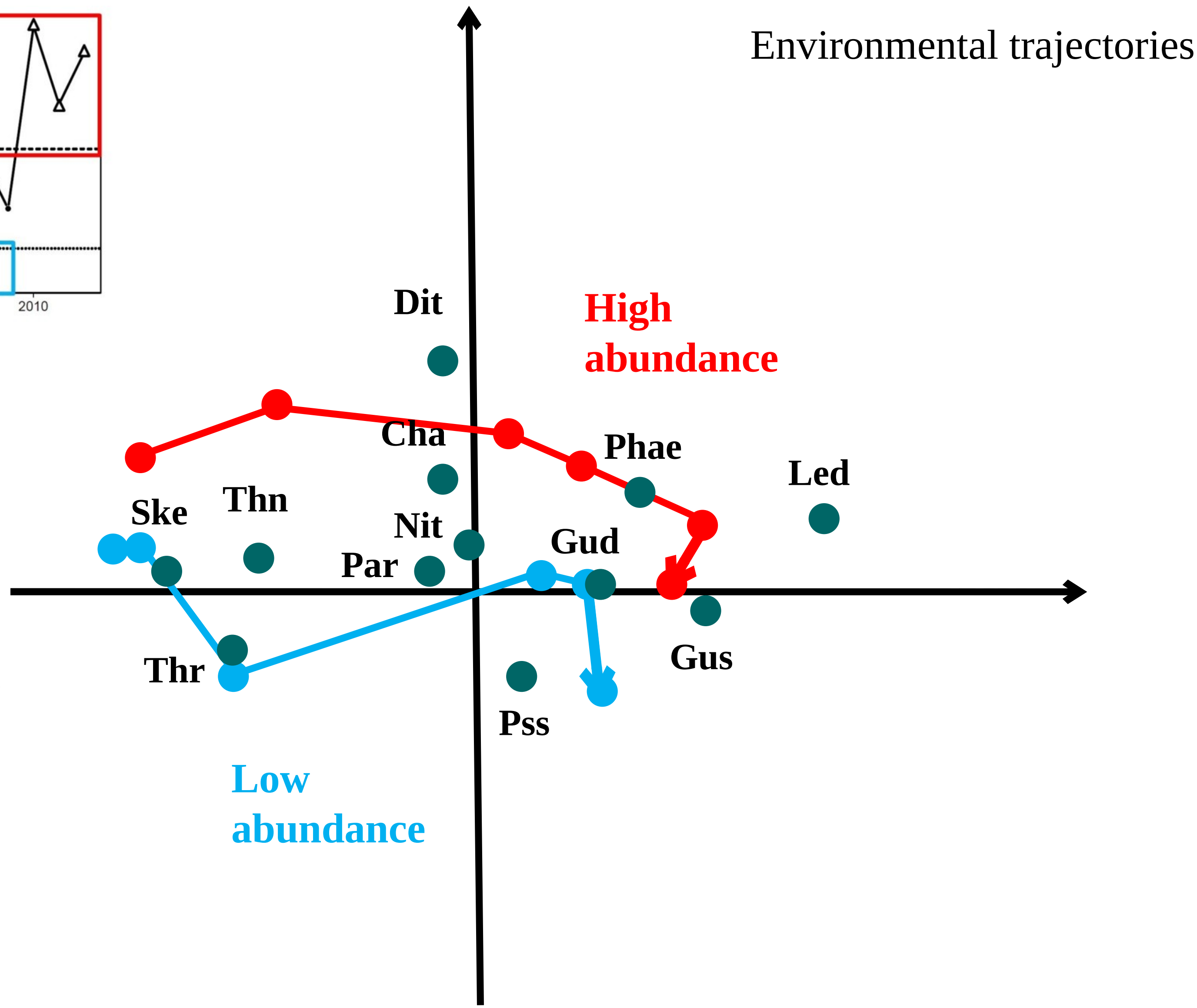
WitOMI analysis (subniche)



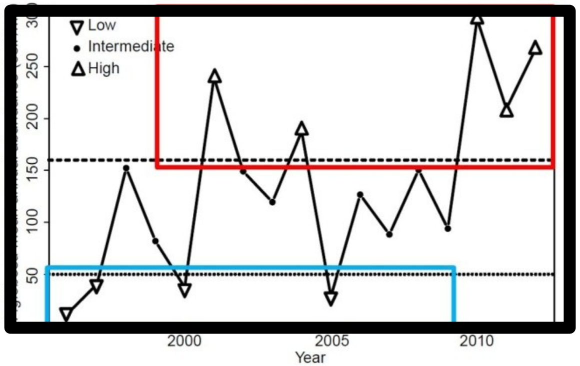
OMI analysis (overall niche)





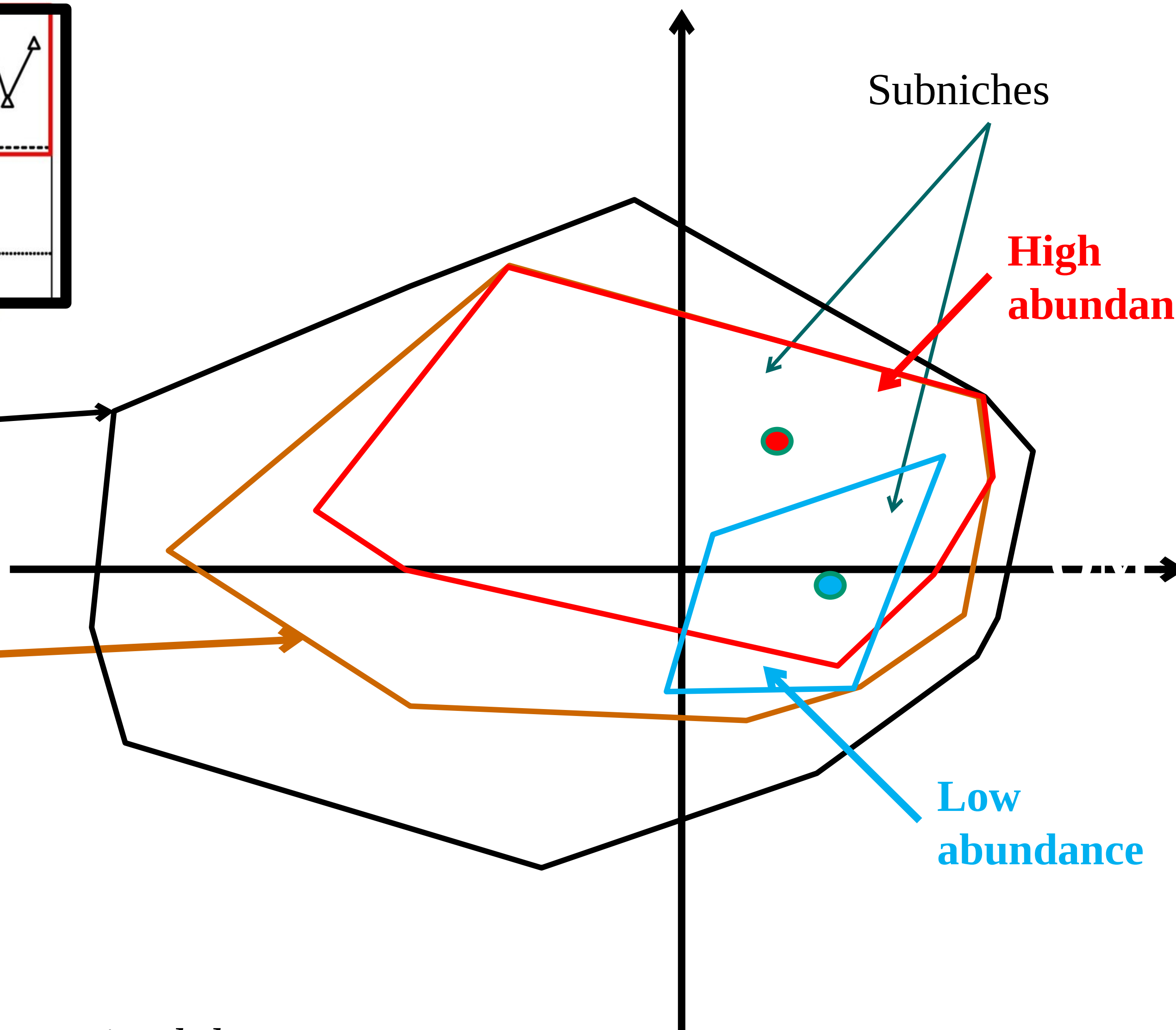


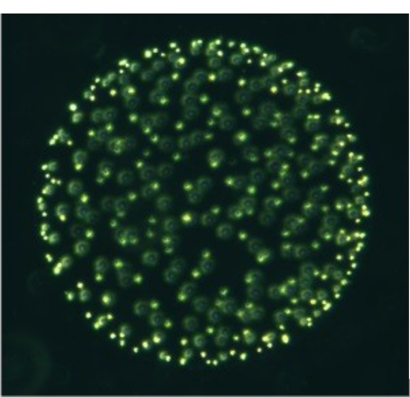
WitOMI analysis (subniche)



Overall Environmental constraint

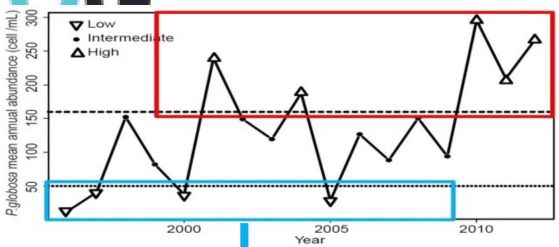
Niche





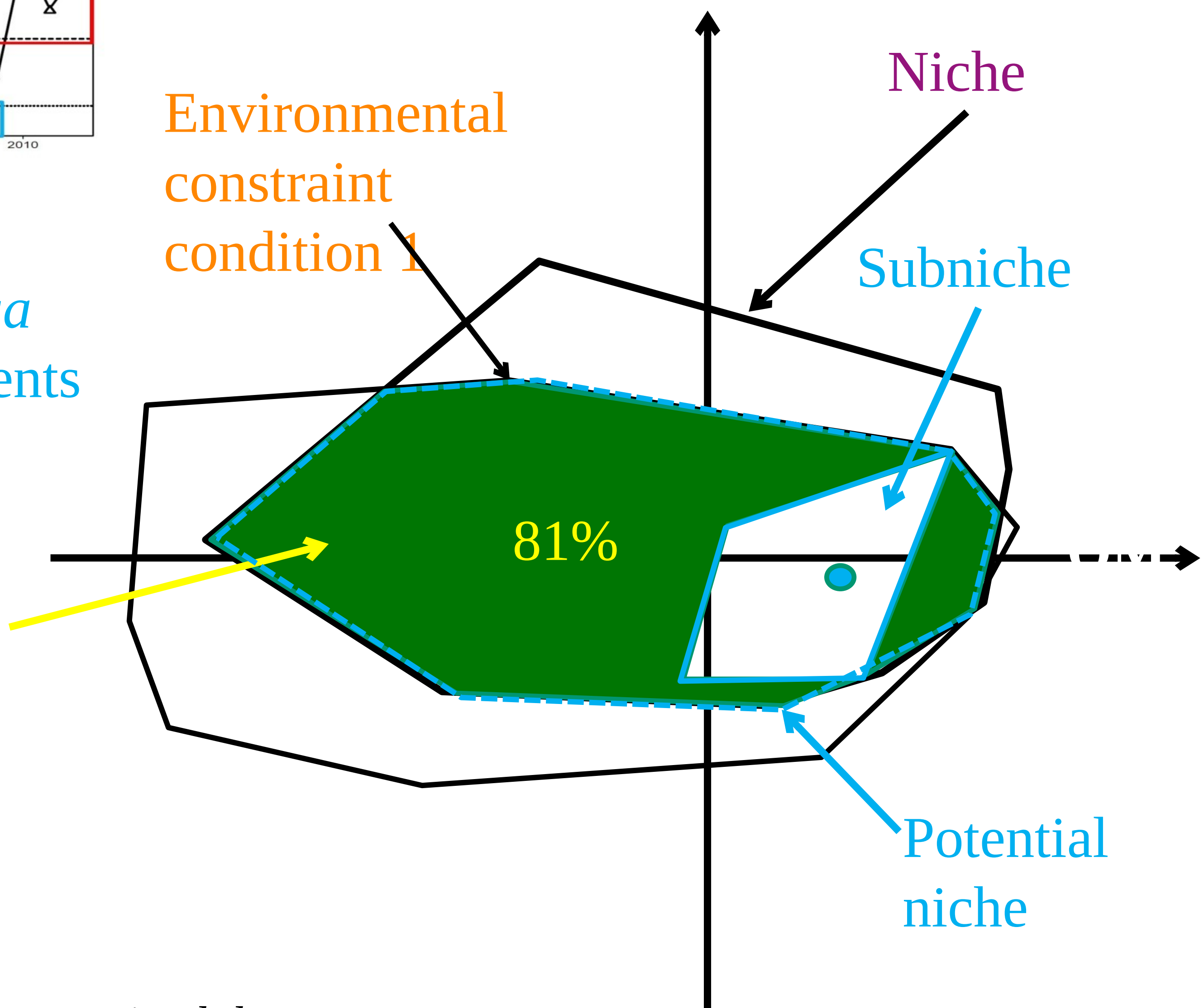
Phaeocystis globosa

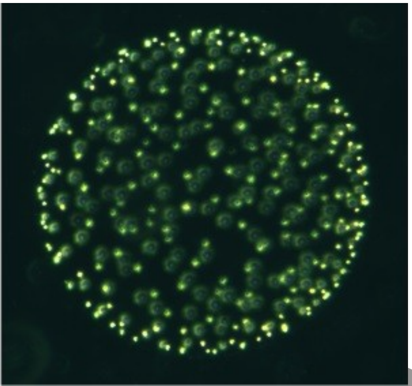
WitOMI analysis (subniche)



Low *P. globosa* abundance events

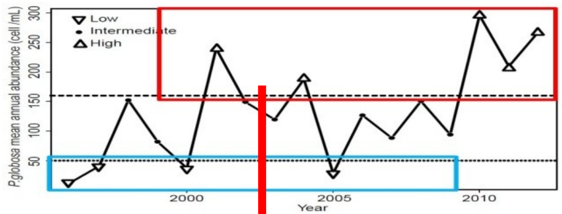
Unused environment





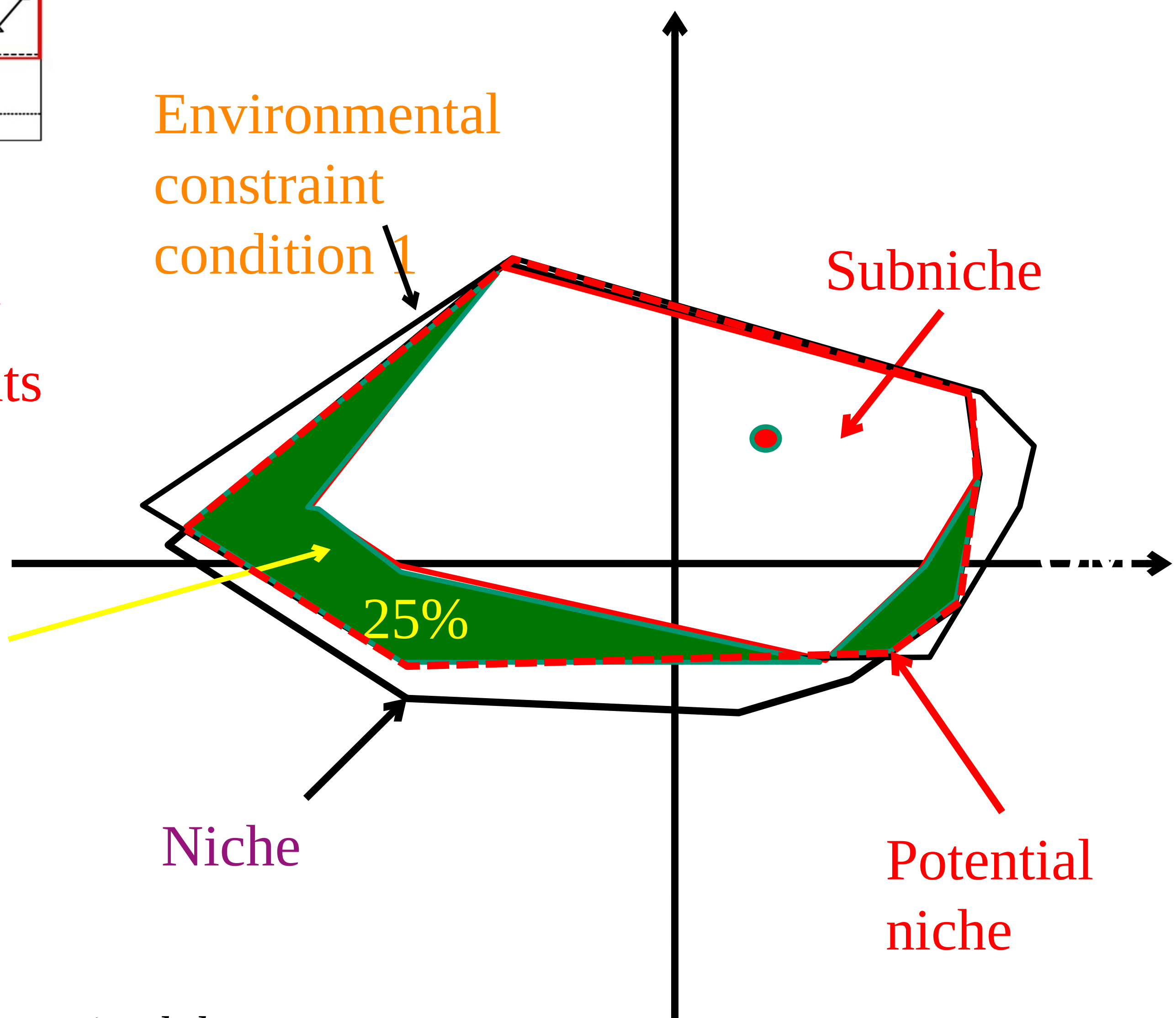
Phaeocystis globosa

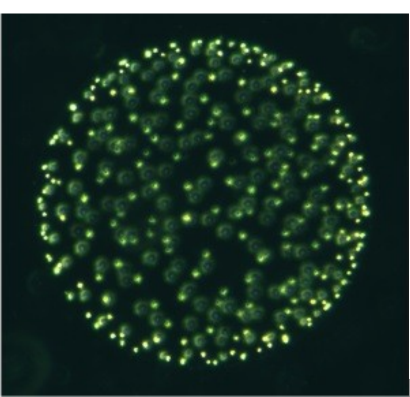
WitOMI analysis (subniche)



High *P. globosa* abundance events

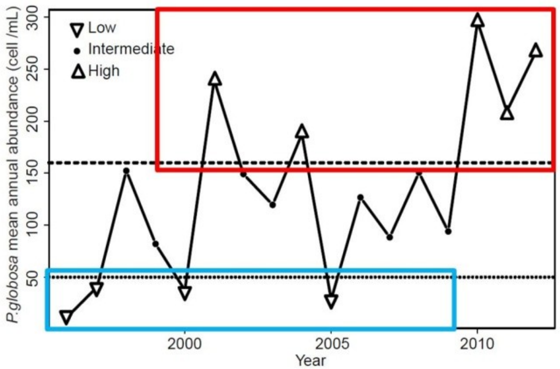
Unused environment

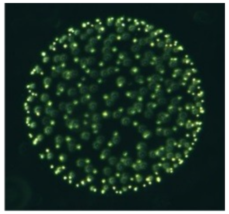


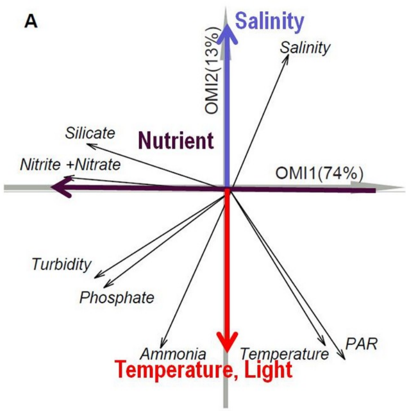


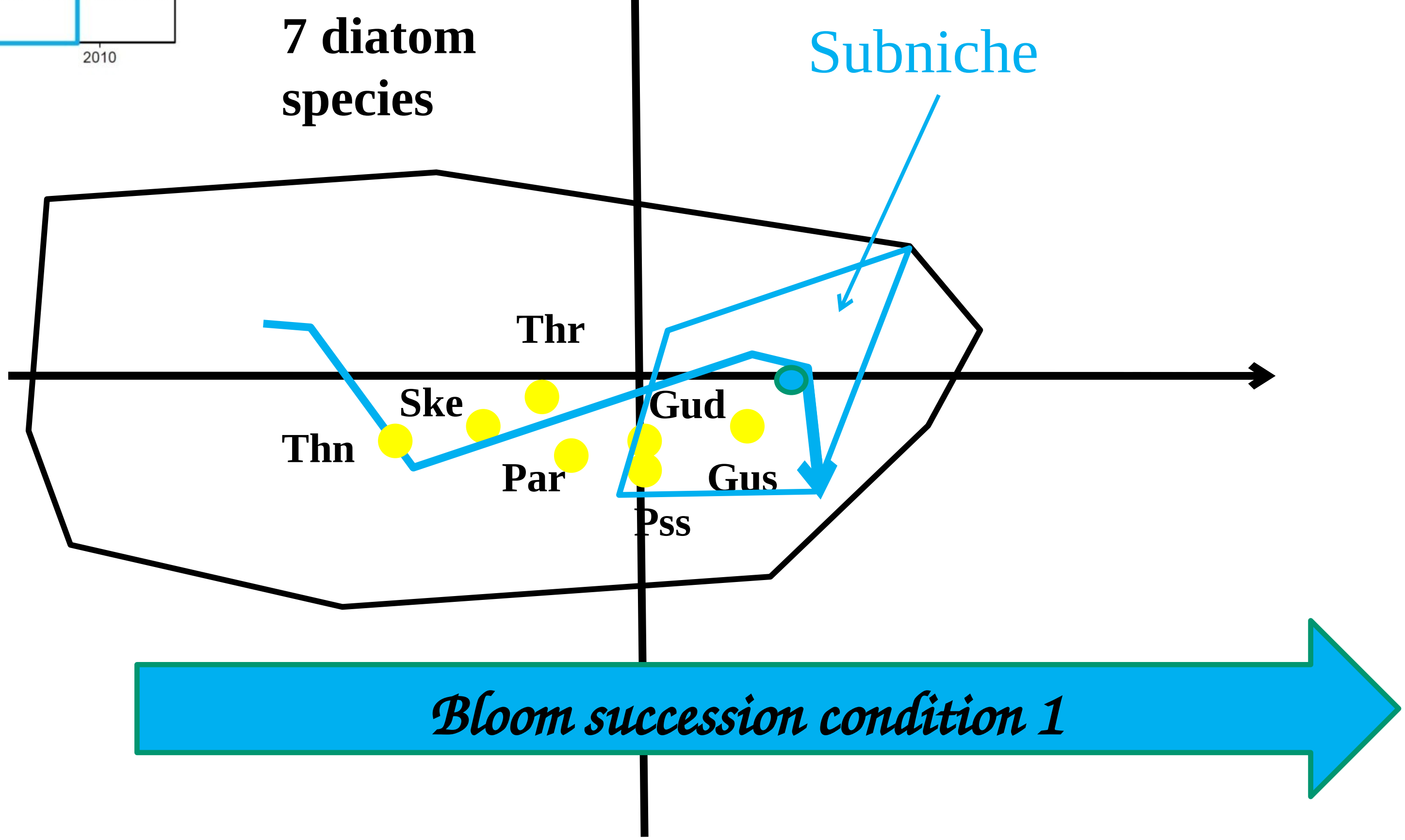
Phaeocystis globosa

Pourquoi?

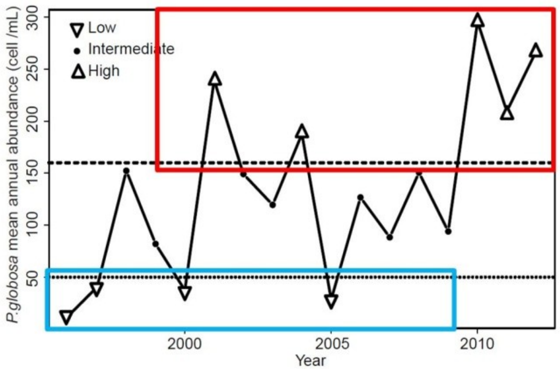

Low
Intermediate
High
P.globosa mean annual abundance (cell /mL)
300
250
200
150
100
50
2000
2005
2010
Year




A
Salinity
Salinity
OMI2(13%)
Silicate
Nutrient
Nitrite +Nitrate
OMI1(74%)
Turbidity
Phosphate
Ammonia
Temperature
PAR
Temperature, Light


7 diatom species
Subniche
Thr
Ske
Thn
Gud
Par
Gus
Pss
Bloom succession condition 1

Pourquoi?



Low
Intermediate
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P.globosa mean annual abundance (cell /mL)
50
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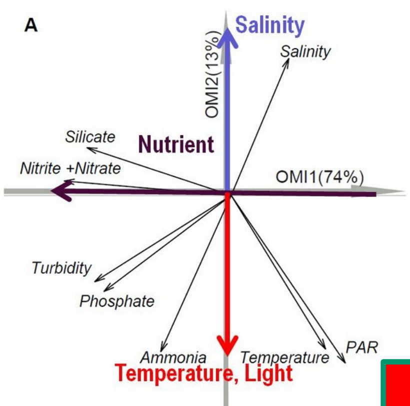
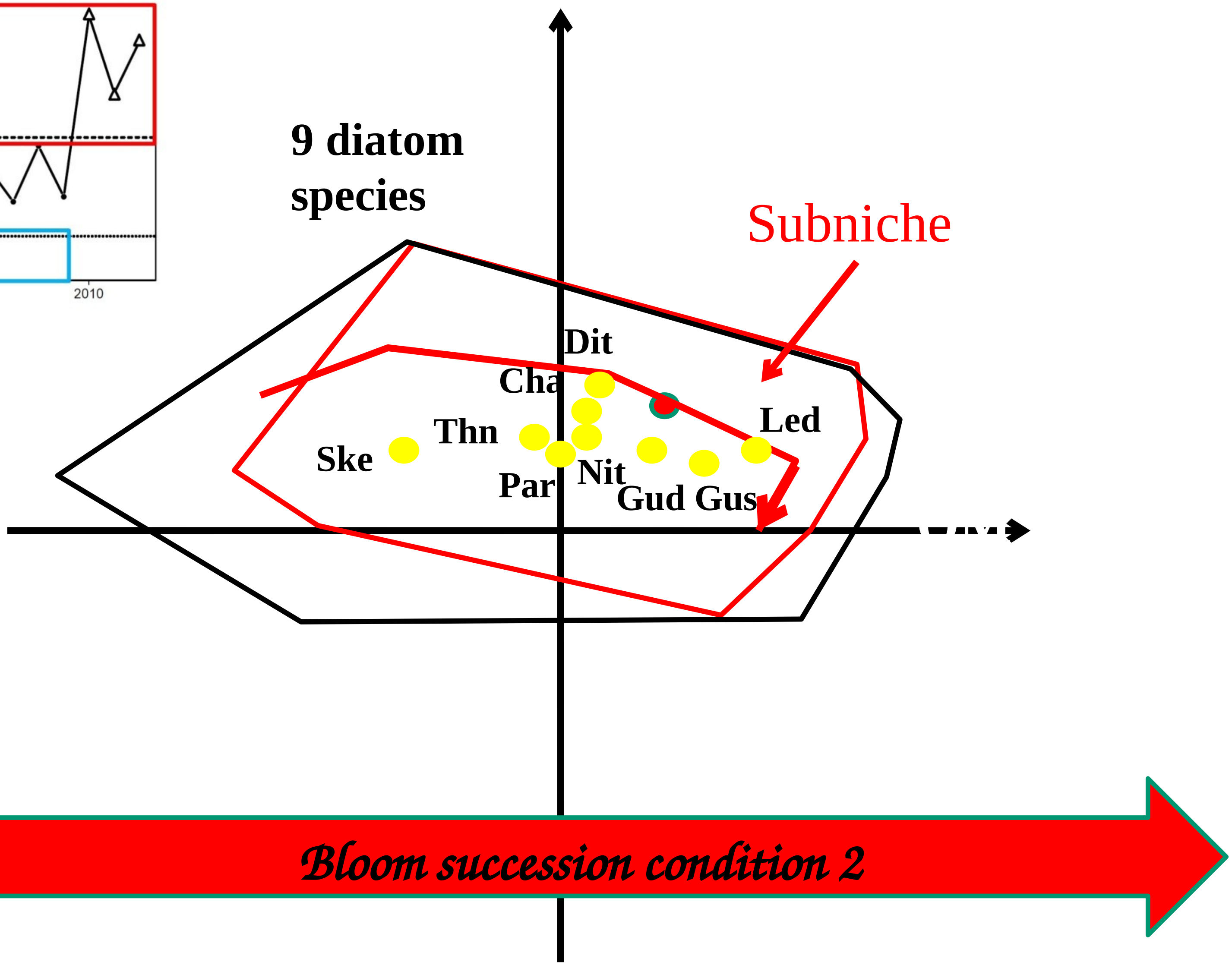
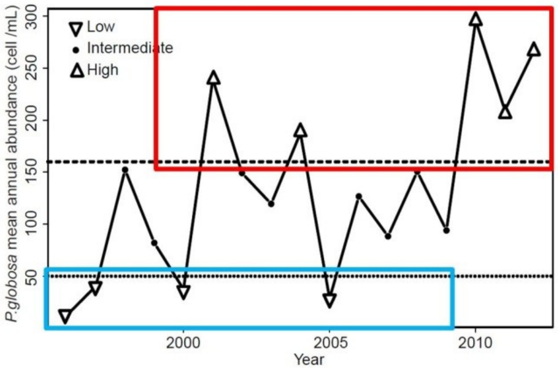


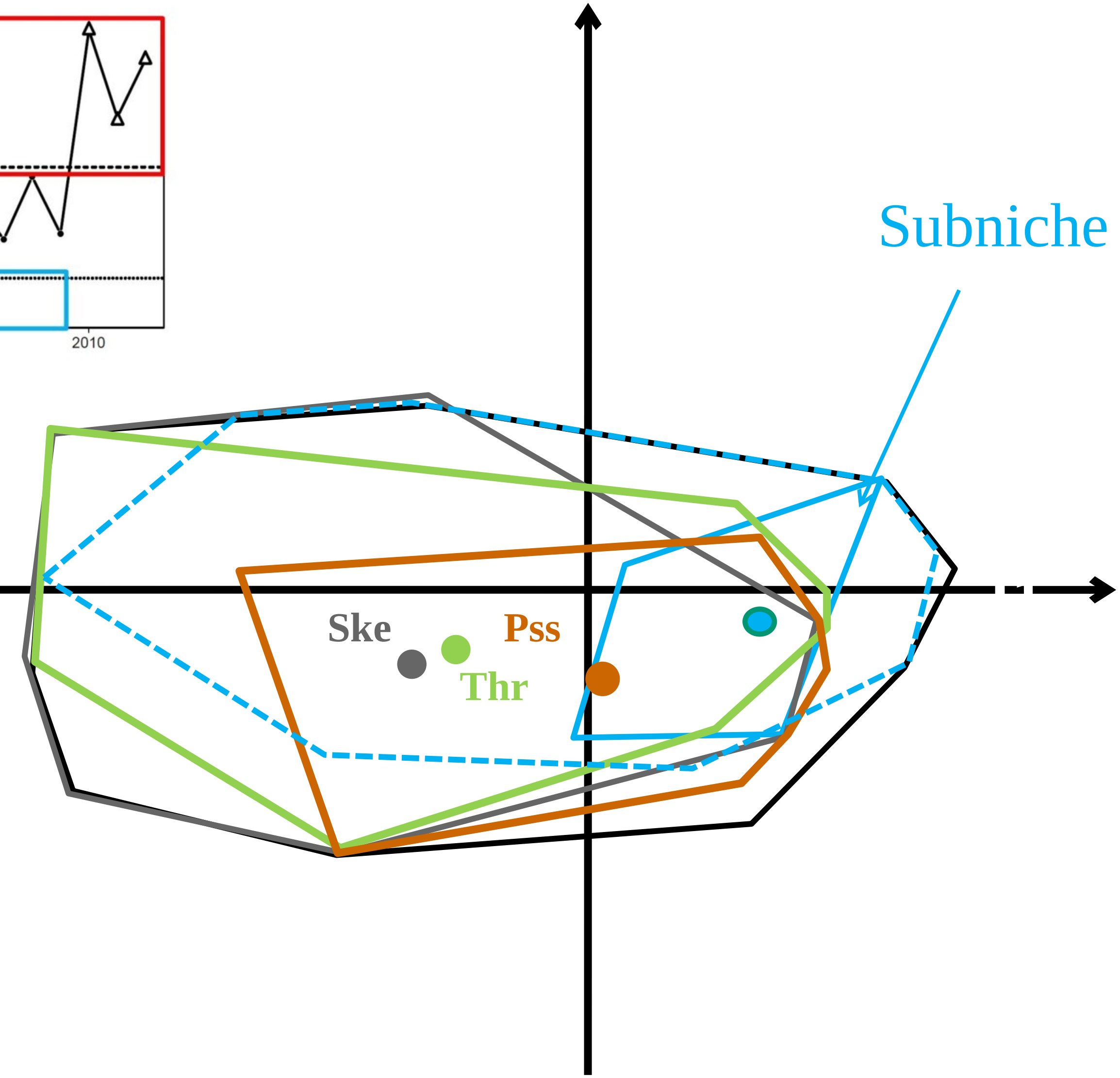
A
Salinity
Salinity
OMI2(13%)
Silicate
Nutrient
Nitrite +Nitrate
OMI1(74%)
Turbidity
Phosphate
Ammonia
Temperature
PAR
Temperature, Light

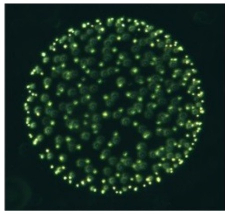


9 diatom species
Subniche
Dit
Cha
Thn
Ske
Par
Nit
Led
Gud
Gus
Bloom succession condition 2

DIATOM COMPETITION







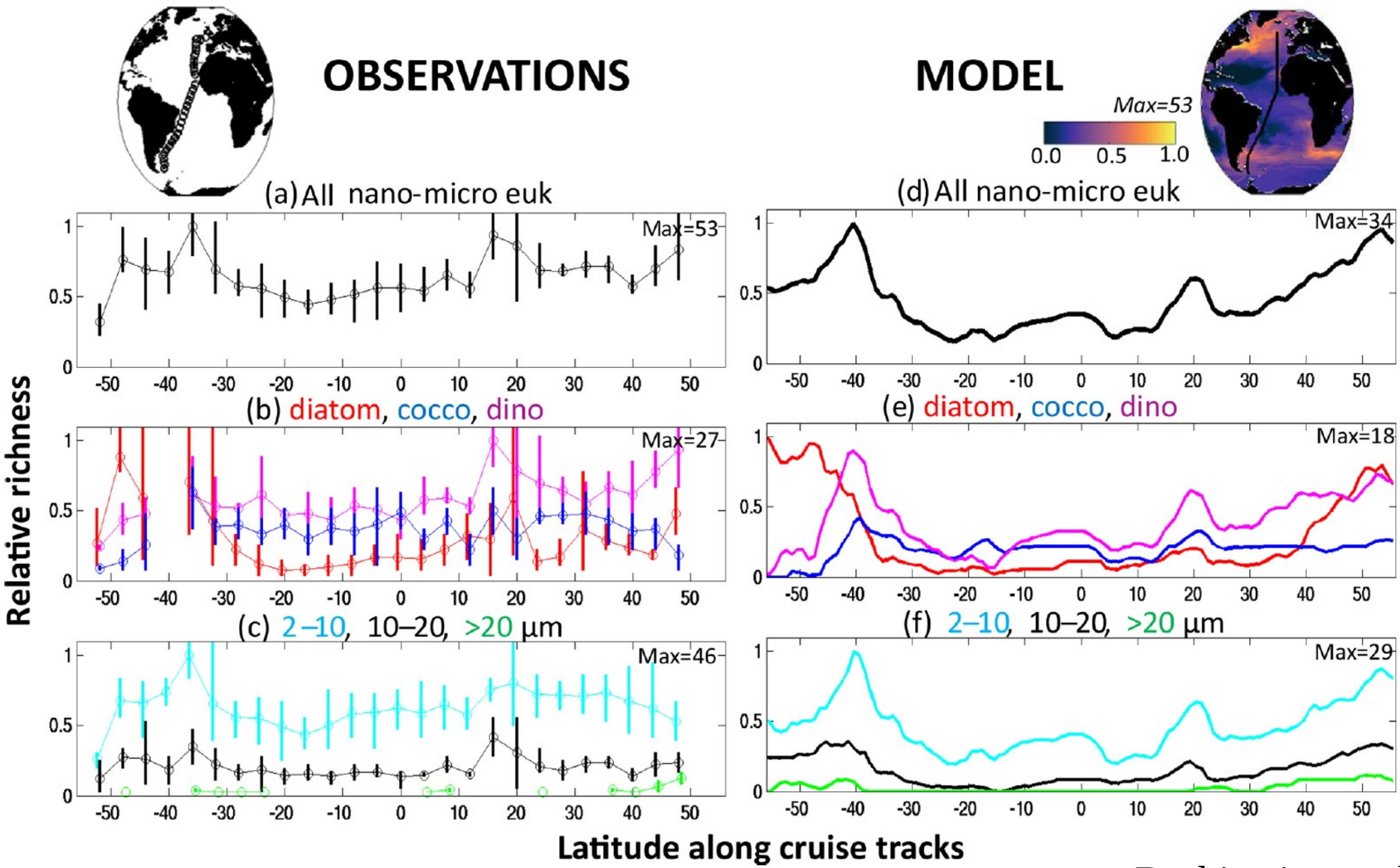
Take home messages

- *Mise en évidence des interactions biotiques et quantification*
- *WitOMI temporelle mais peut-être aussi spatiale*
- *Réduction du nombre de variables environnementales par ordination*
- *Peut-on affiner la compréhension par d'autres types d'analyses ? interdisciplinarité*

Merci

Ecosystemic model: infinite biodiversity

- *35 Plankton functional types (i.e. pseudo species)*



Dutkiewicz et al., 2020

A1.1 Grazing allows coexistence

If we now consider a system of J phytoplankton (B_j) and K zooplankton (Z_k), where each phytoplankton has a specific grazer, we can write the loss rate now as $M = m + g_{kj} Z_k$. Here g_{kj} is the per biomass grazing rate of zooplankton k on phytoplankton j, and m is a linear loss rate (resolving cell death and other losses). In this case

$$R_j^* = \frac{k_{Rj}\,(m + g_{kj} Z_k)}{\mu_{\max j} - (m + g_{kj} Z_k)}. \tag{A4}$$

Dutkiewicz et al., 2020

A1.2 Multiple limiting resources allow coexistence

If we now consider a system of two phytoplankton (B_j, where j is 1 or 2) limited by different resources (R_i where i is A or C), we suggest that this system can allow for coexistence. To explore when the two types can coexist we expand Eqs. (A1) and (A2) (where the biomass is in units of element A) such that

$$\frac{\mathrm{d}R_A}{\mathrm{d}t} = -\mu_{\max 1}\frac{R_A}{R_A + k_{R_{A1}}}B_1 - \mu_{\max 2}\frac{R_C}{R_C + k_{R_{C2}}}B_2 + S_{R_A}, \tag{A5}$$

$$\frac{\mathrm{d}R_C}{\mathrm{d}t} = -\mu_{\max 1}\frac{R_A}{R_A + k_{R_{A1}}}\Upsilon_{AC1}B_1 - \mu_{\max 2}\frac{R_C}{R_C + k_{R_{C2}}}\Upsilon_{AC2}B_2 + S_{R_C}, \tag{A6}$$

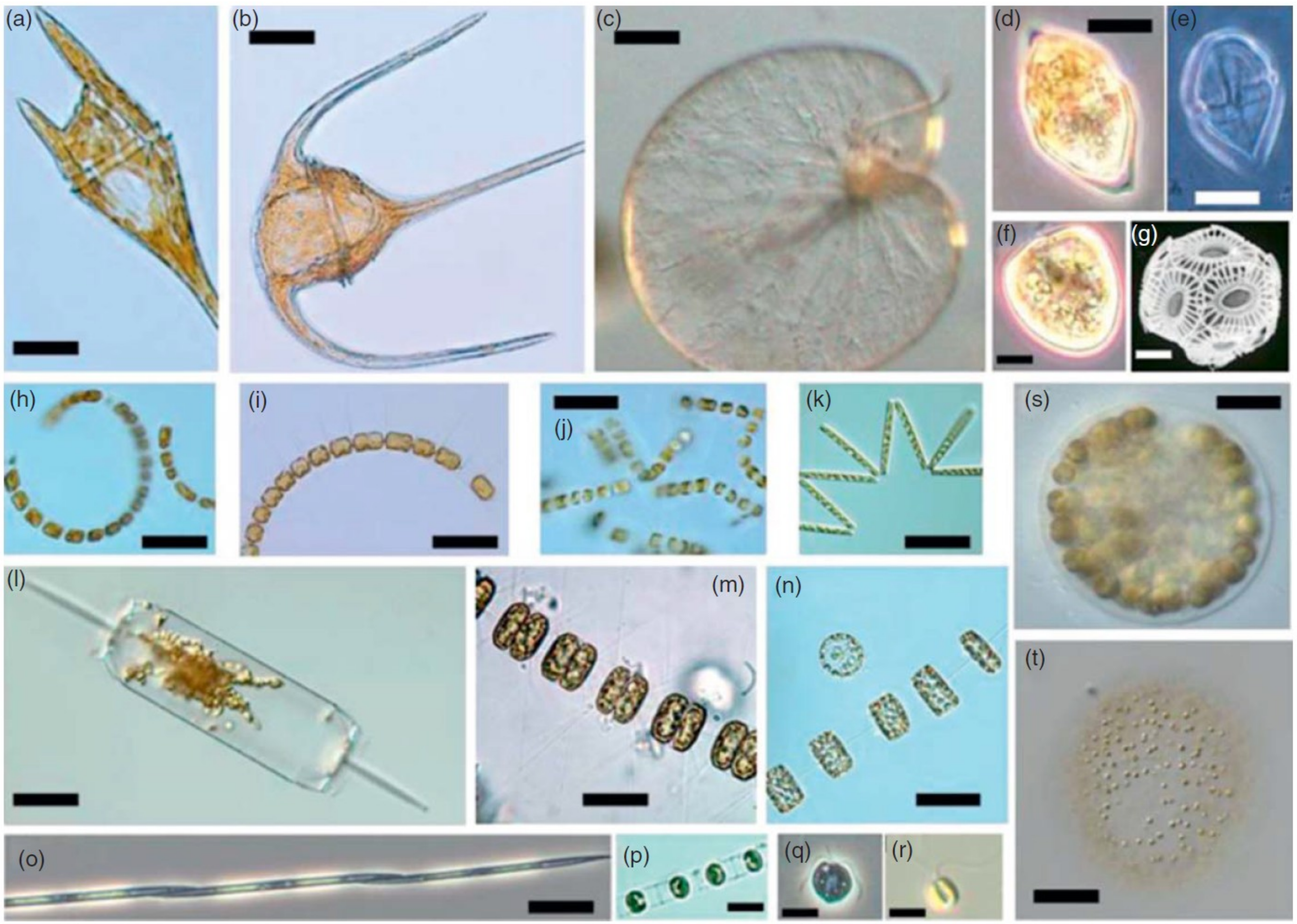
$$\frac{\mathrm{d}B_1}{\mathrm{d}t} = \mu_{\max 1}\frac{R_A}{R_A + k_{R_{A1}}}B_1 - M_1 B_1, \tag{A7}$$

$$\frac{\mathrm{d}B_2}{\mathrm{d}t} = \mu_{\max 2}\frac{R_C}{R_C + k_{R_{C2}}}B_2 - M_2 B_2, \tag{A8}$$

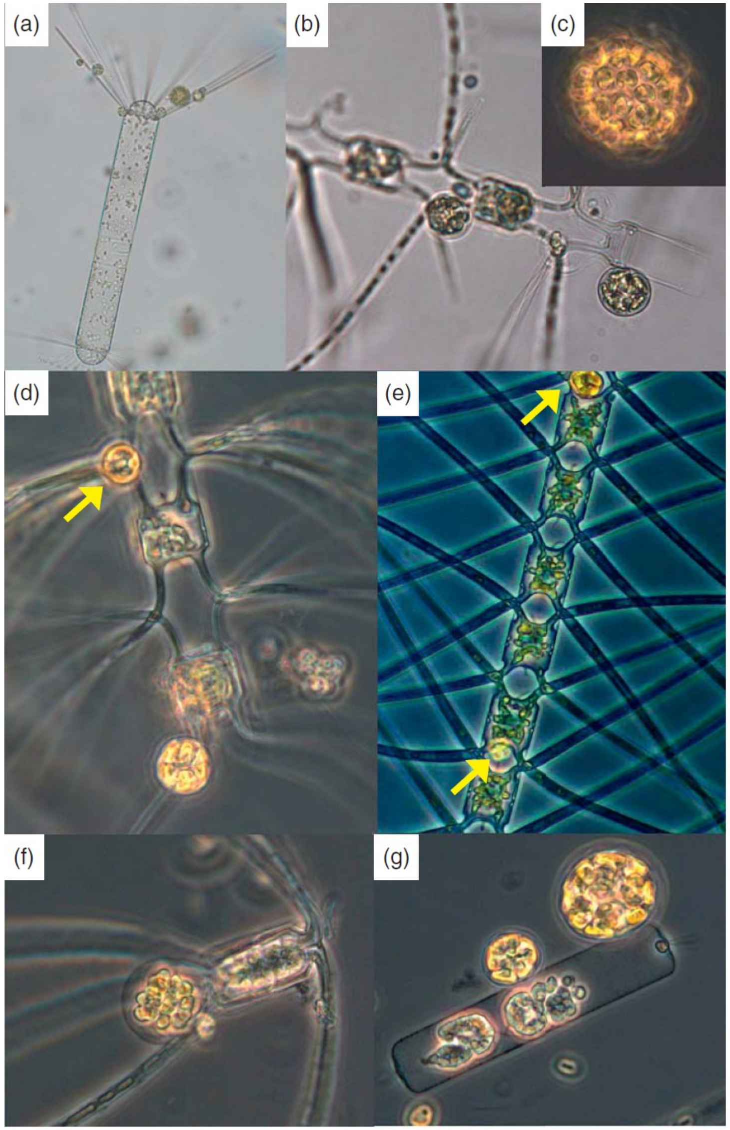
Allelopathy ? Facilitation?

Infinite biodiversity… !

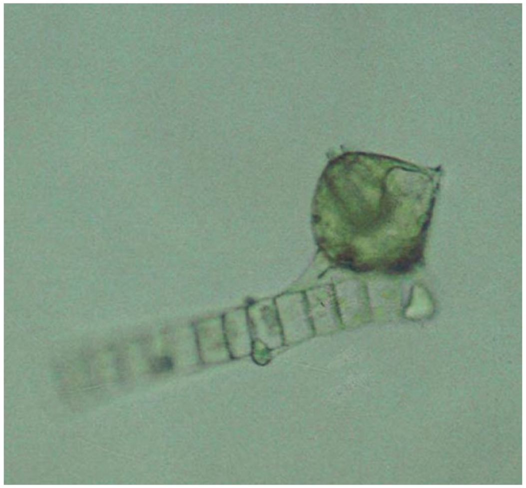
- *> 100 000 species !!*



De nombreuses interactions : Facilitation…

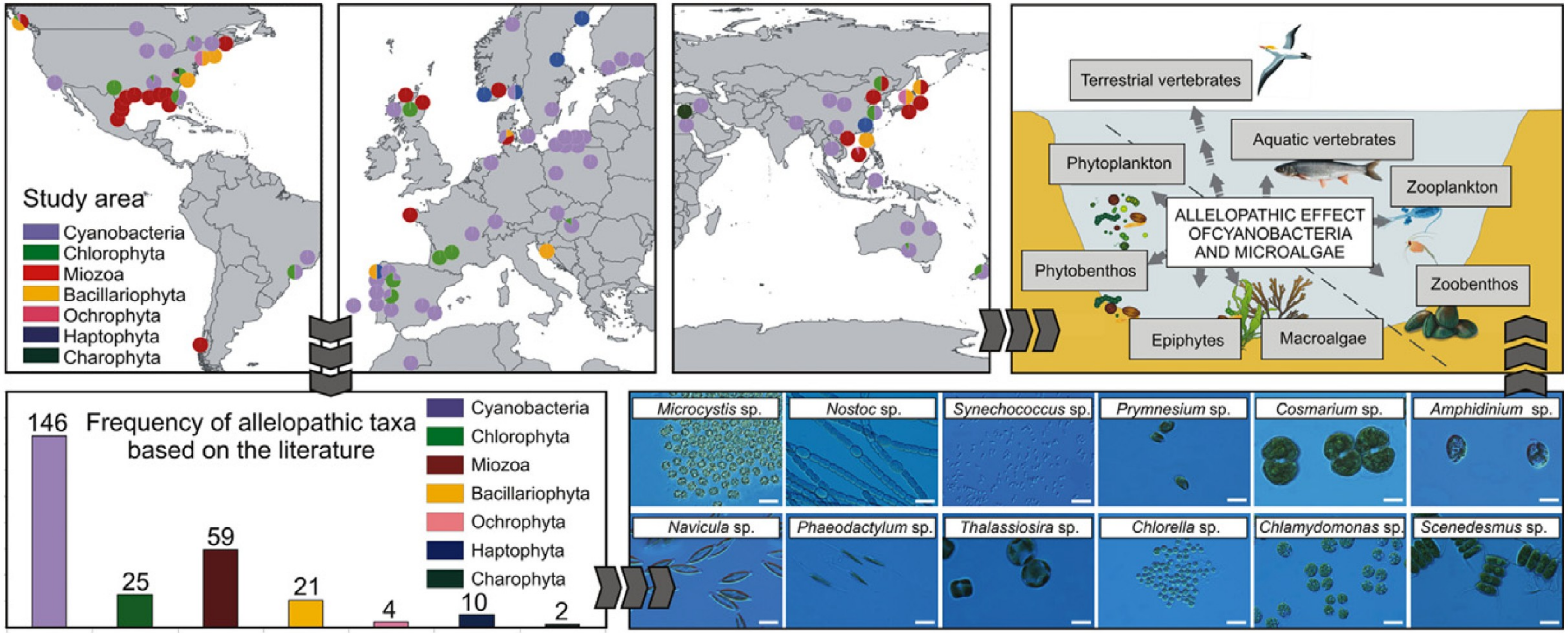


- *Colonial forms of Phaeocystis linked to diatoms*
- *And also predation, parasitism, symbiosis*

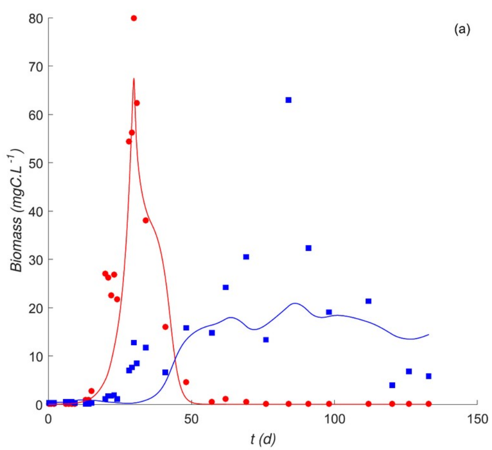


Assmy & Smetacek, 2009

De nombreuses interactions : Allelopathy…!



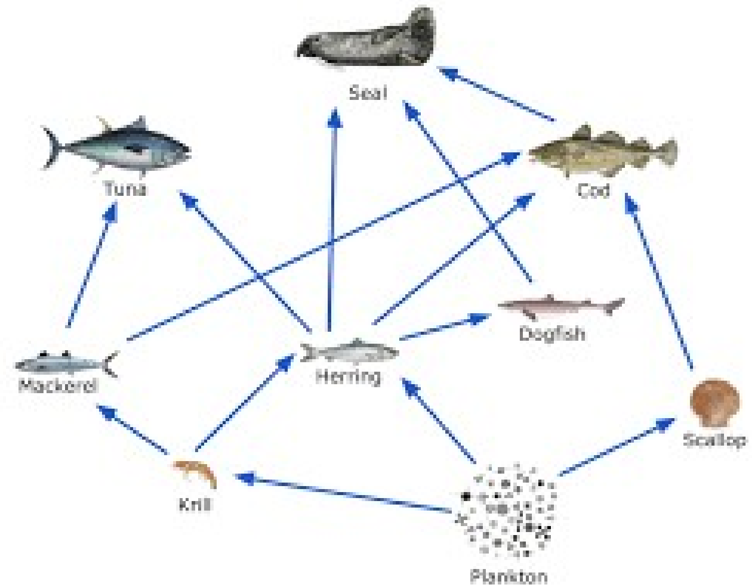
Śliwińska-Wilczewska et al., 2021



Krichen et al., 2019

Projet en cours

- *Ph D thesis Madeleine Eyrault with Maxime and Cédric*
- *ANR Rebon : Use of infinite biodiversity models to challenge Boolean bioreaction networks ?*
- *Food webs ?*



Merci merci