Upscaling the impact of coastal hypoxia from species to ecosystem functions. The case of bioturbation in the Black Sea

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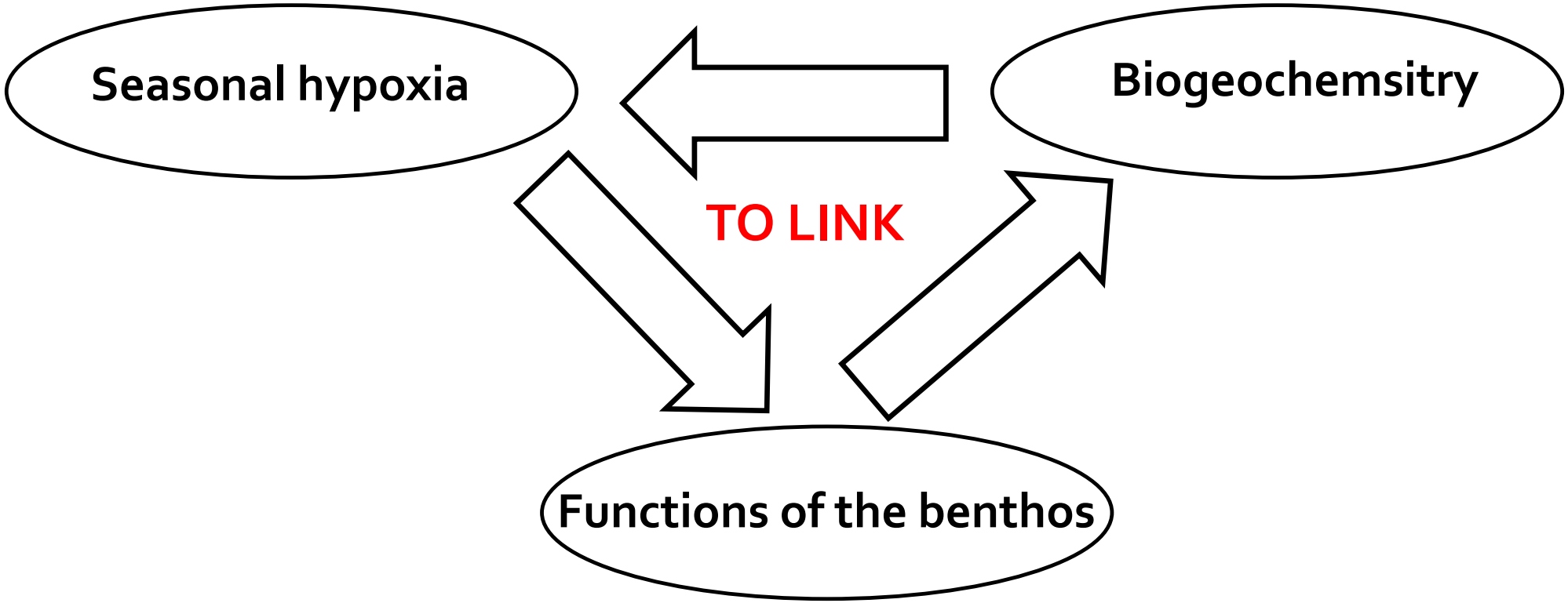
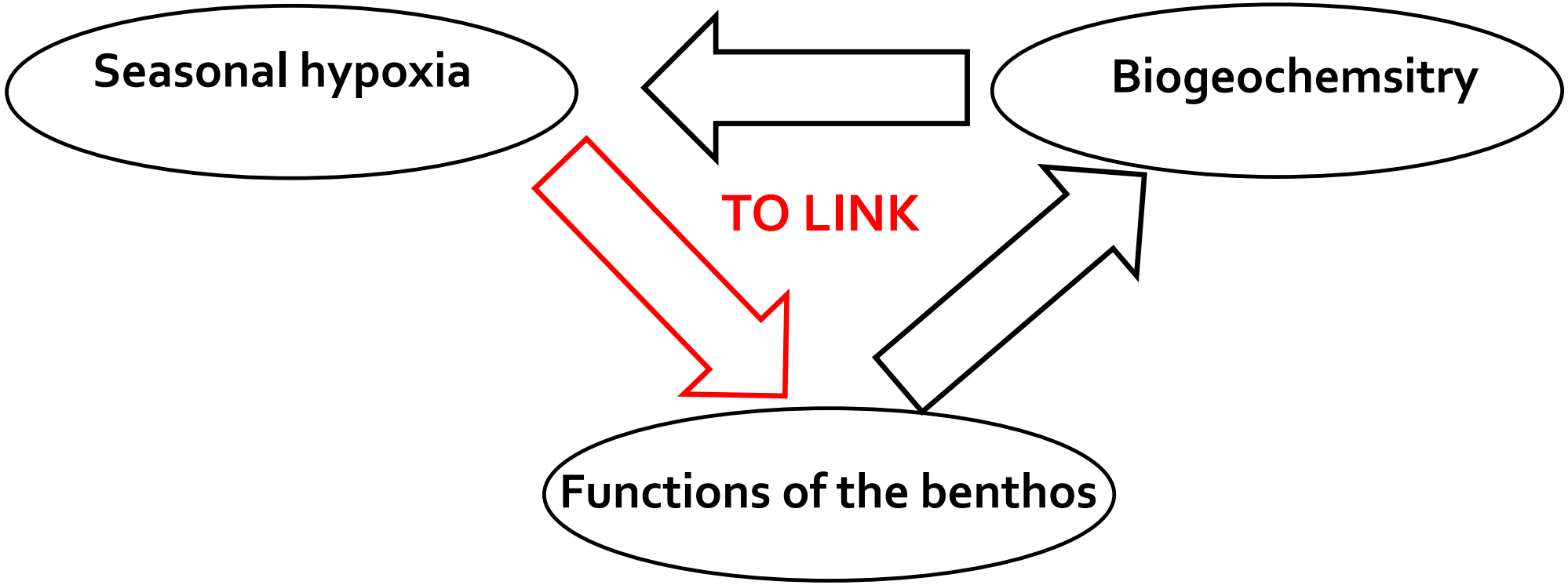
2. *Chemical Oceanography and Water Geochemistry,University of Brussels, Belgium*
3. *Laboratoire de géochimie des argiles*
4. *GeoEcoMar, Romania*

Objectives


Seasonal hypoxia
Biogeochemsitry
TO LINK
Functions of the benthos

Objectives


Seasonal hypoxia
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Objectives

Seasonal hypoxia

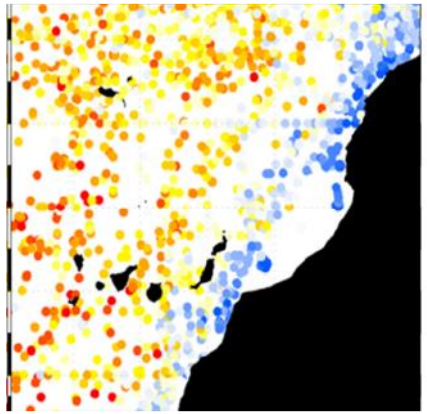
Biogeochemsitry

TO LINK

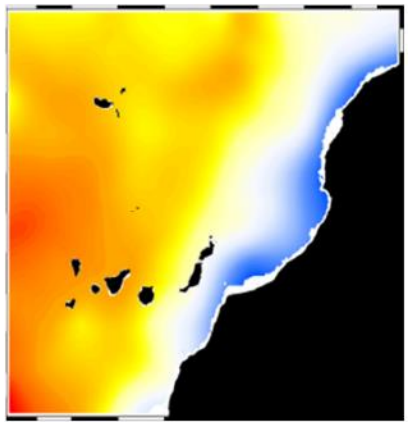
Functions of the benthos

Species

Field experiments



UPSCALE

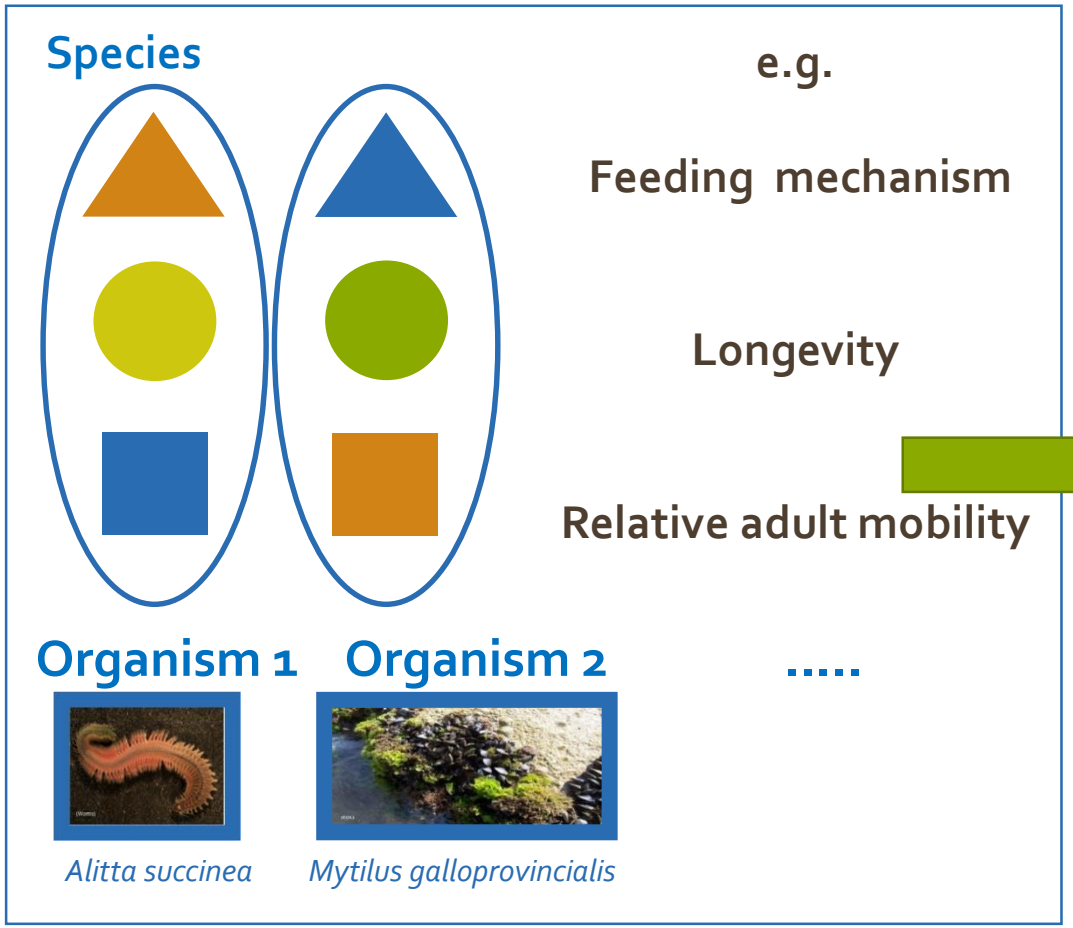


Ecosystem

Scales of management

A Functional approach of biodiversity

TRAITS : "Morphological, physiological or phenological caracteristics defined at the level of the species " (Violle et al., 2007 Oikos)



SPECIES

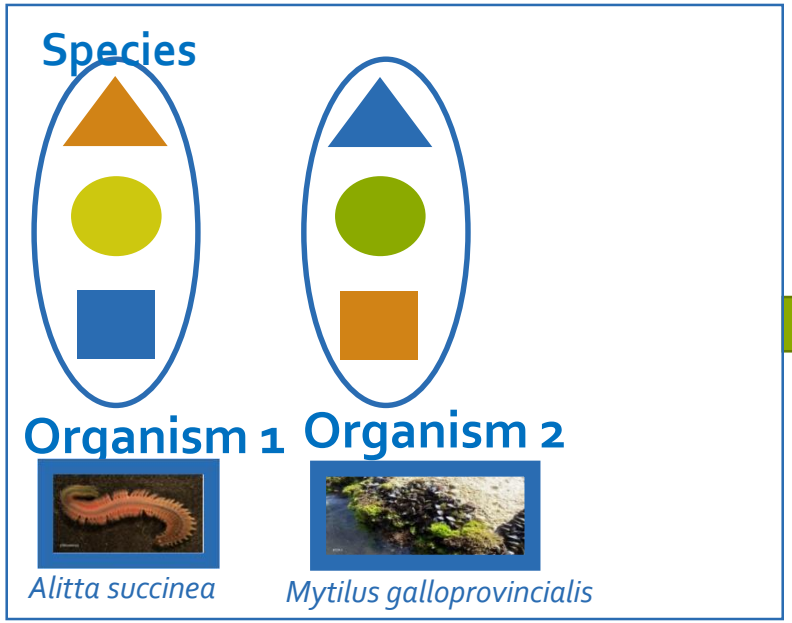
TRAITS

Biological Traits Species	Feeding mechanisms			Adult Longevity			Relative Adult Mobility			
	SF	DF	GB	<2	2-5	>5	None	Low	Mediu m	High
Mya arenaria	2	1	0	0	1	3	0	3	0	0
Mytilius galloprovincialis	3	0	0	0	1	3	3	1	0	0
Nereis rava	0	0	3	3	0	0	0	0	1	2
Terebellides stroemii	0	3	0	0	0	3	3	1	0	0
Lagis koreni	0	3	0	3	1	0	2	1	0	0
...										

Traits are the variables of our approach

A Functional approach of biodiversity

TRAITS : "Morphological, physiological or phenological caracteristics defined at the level of the species " (Violle et al., 2007 Oikos)



SPECIES

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Mytilius galloprovincialis	3	0	0	0	1	3	3	1	0	0
Nereis rava	0	0	3	3	0	0	0	0	1	2
Terebellides stroemii	0	3	0	0	0	3	3	1	0	0
Lagis koreni	0	3	0	3	1	0	2	1	0	0
...										

Traits are the variables of our approach

Southwood hypothesis (1977) : *"The habitat provides the templet on which evolution forges characteristic life history strategy. This means that* ***biological traits can be related to the physical and biogeochemical properties of the environment****".*

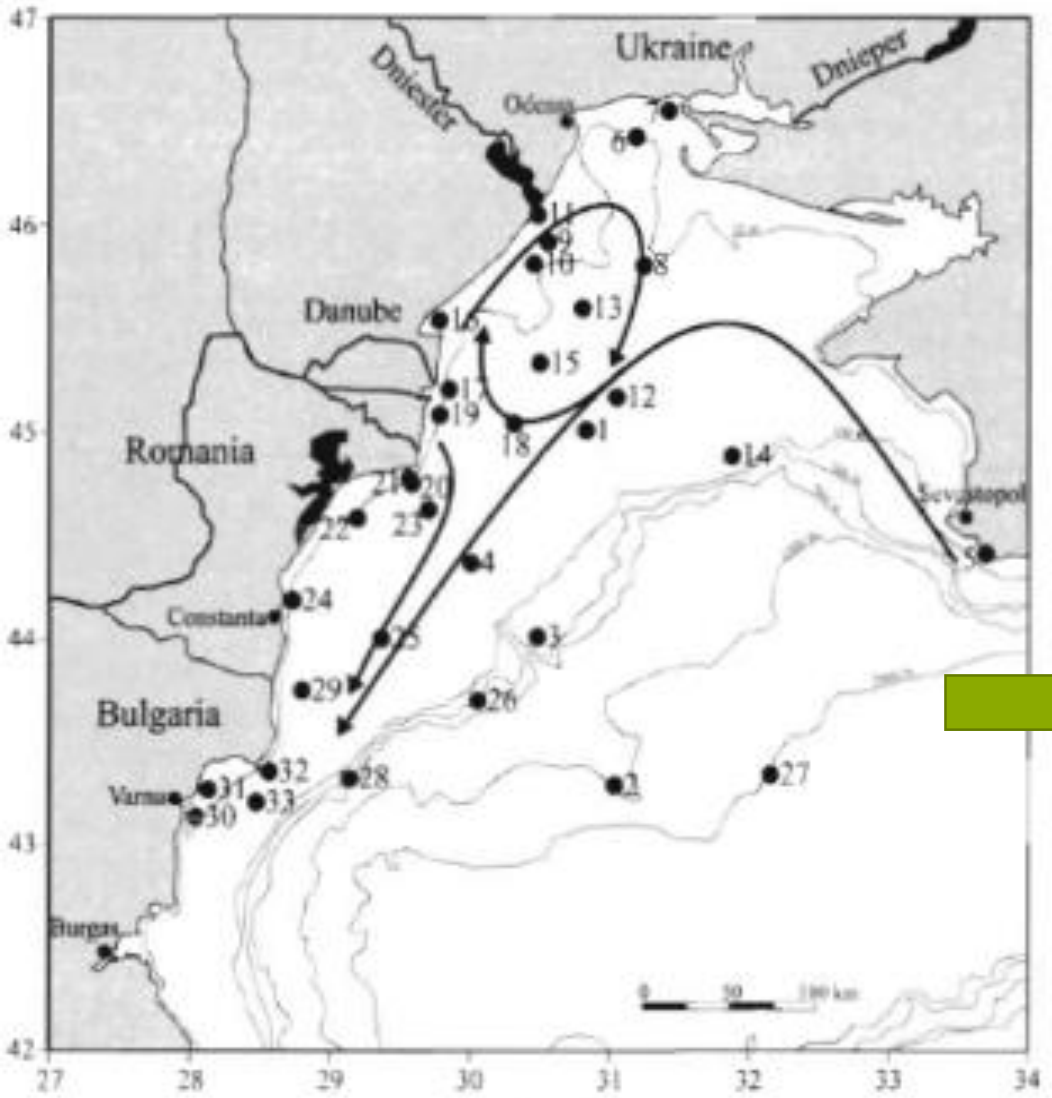
Selected Traits

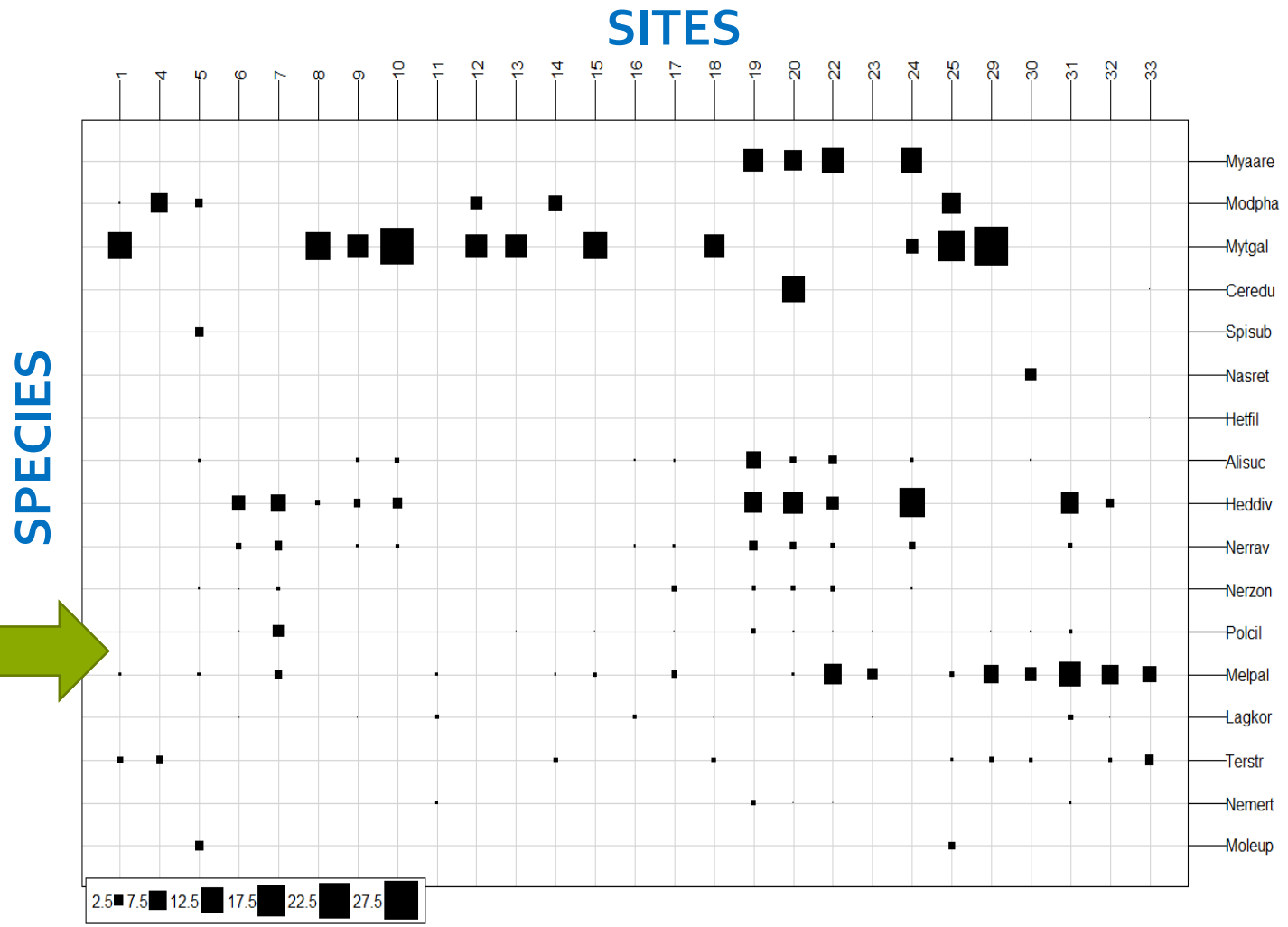
- Method of sediments reworking
- Propensity to move through the sediment
- Max sediment dwelling depth
- Feeding mechanisms
- Diet
- Larval development mechanisms
- Propagule dispersal
- Larval type
- Degree of attachment
- Relative adult mobility
- Adult life habitLongevity
- Maximum adult size
- Tolerance to disturbance

Methodology

- Local data sets
- Mechanistic models
- Biogeographic functional models (Viollet et al., 2014)

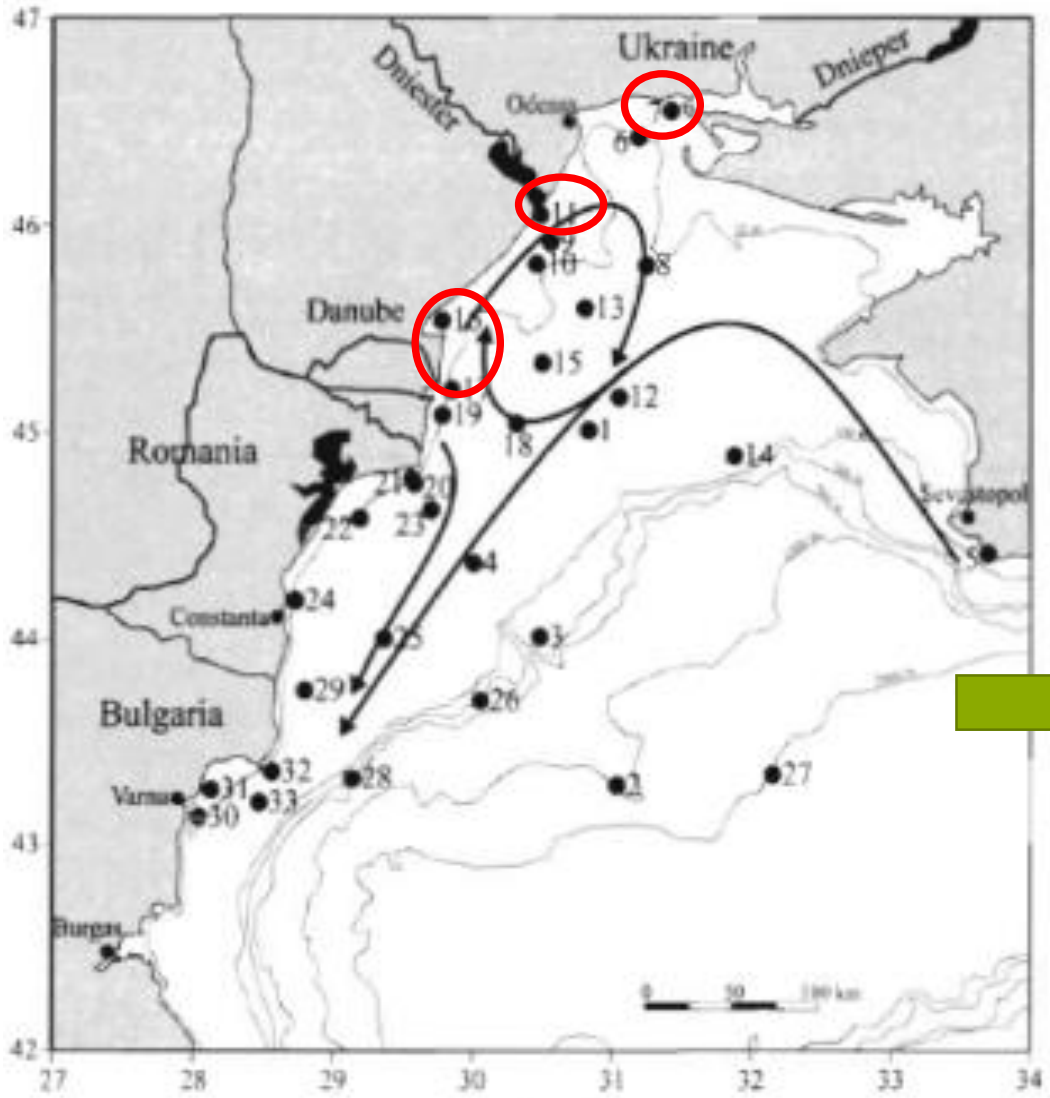
Macrobenthos data set





EROS data set, August 1995. Wijsman et al., 1999.

Macrobenthos data set



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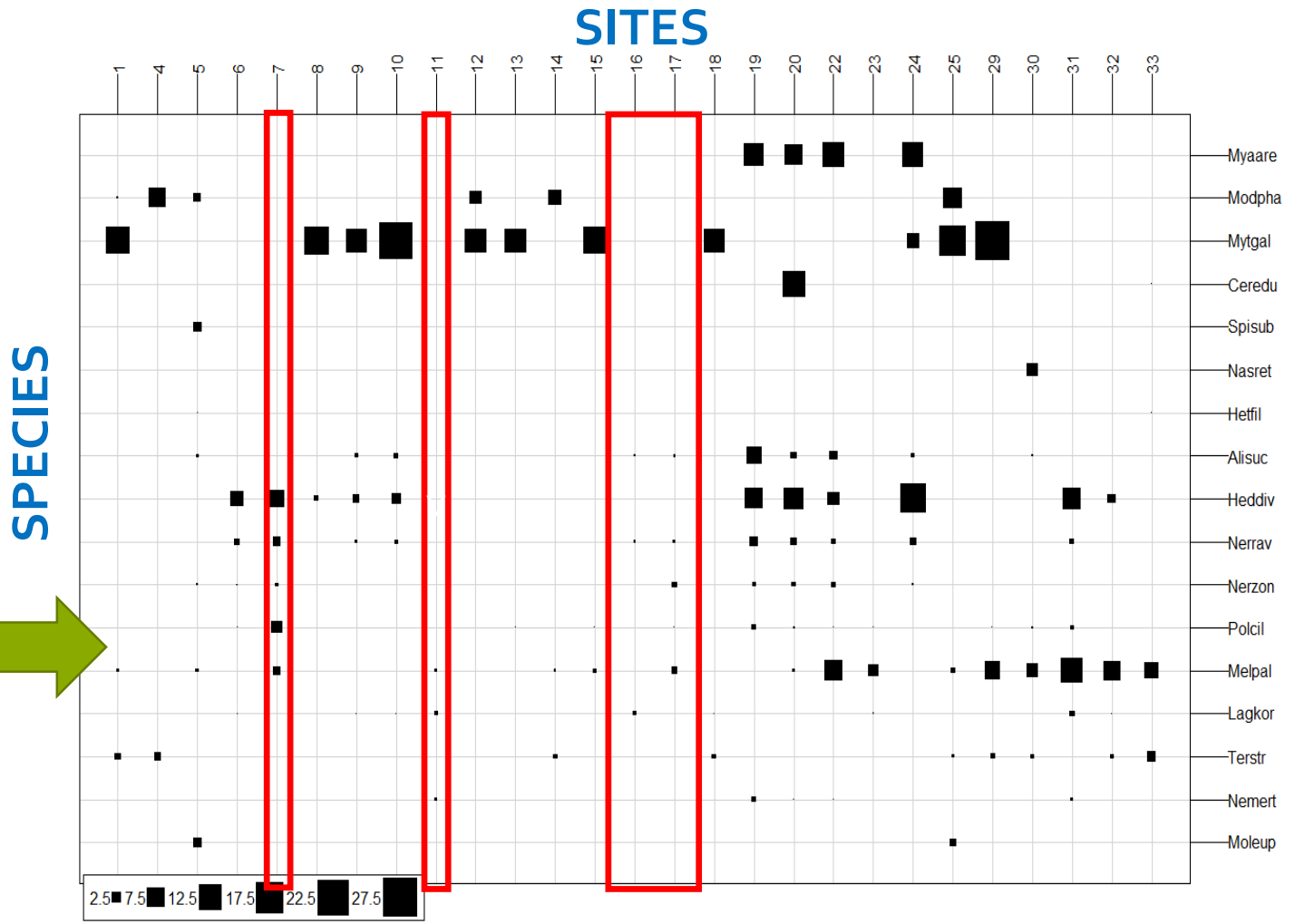
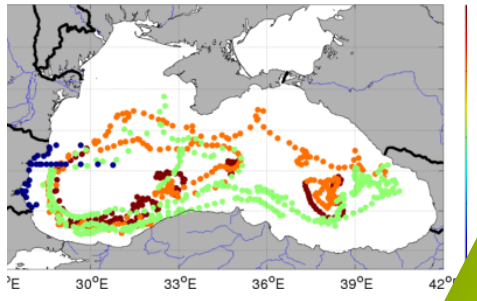


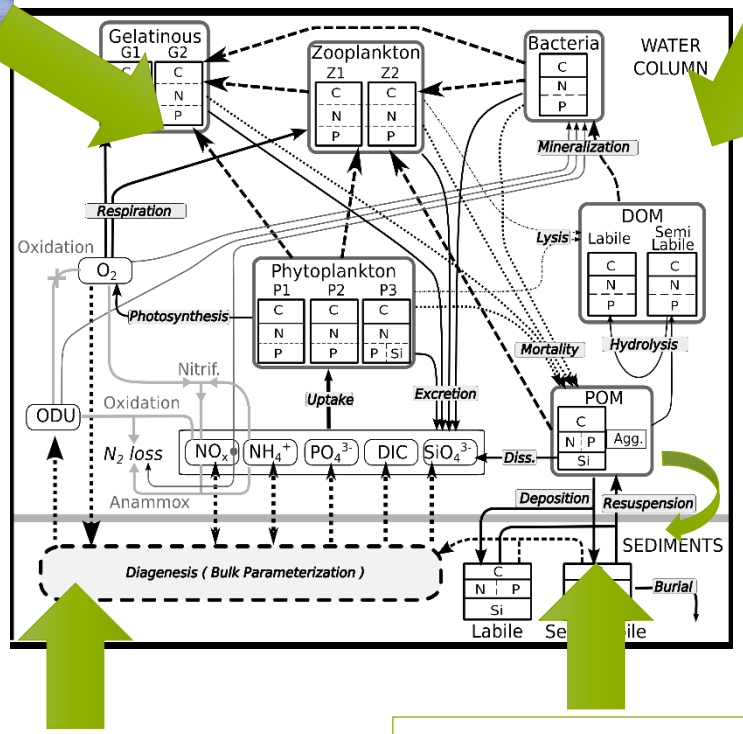
Hypoxia is especially critical at stations 16 and 11

The CMEMS Black Sea forecasting Center

Black Sea Forecasting center

ARGO oxygen





PU-BIO ULiege

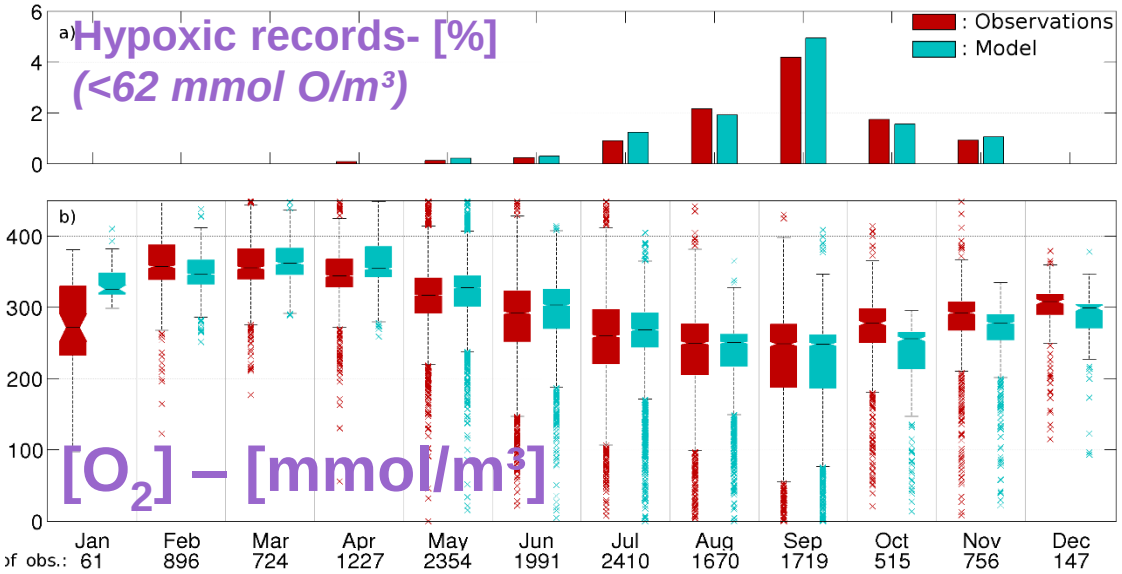
Grégoire et al., 2008; 2011

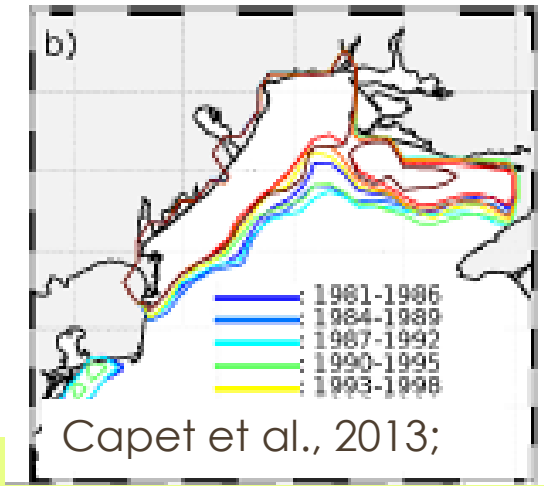
Capet et al., 2016

PU-PHYSICS (CMCC, USOFIA)

HZG PU-WAVES

Quality control procedure (QUID)





Capet et al., 2013;

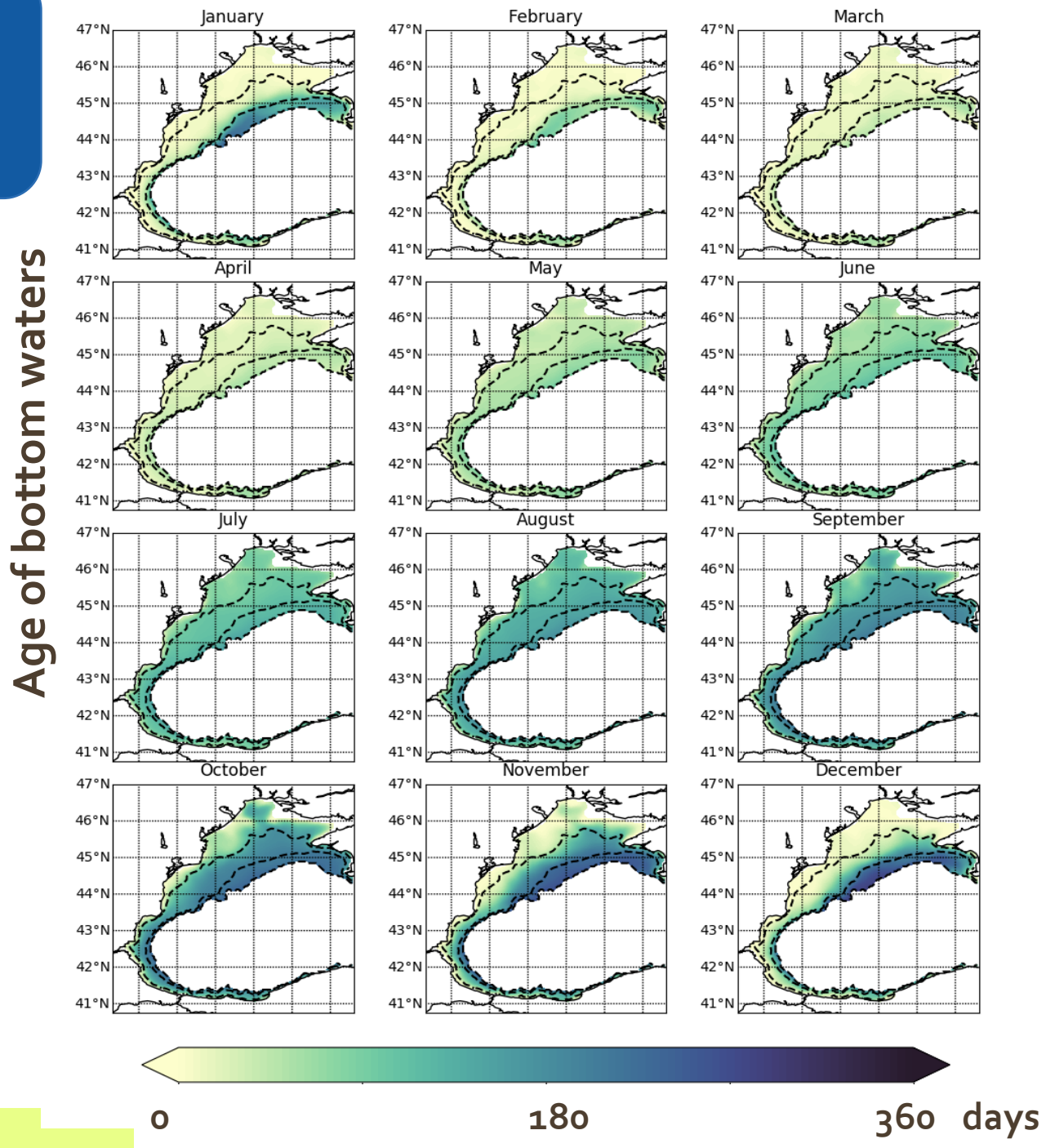
Copernicus
Europe's eyes on Earth

COPERNICUS · MARINE ENVIRONMENT MONITORING SERVICE
CMEMS BLACK SEA MFC
Contract BS - MFC
Until April 30 2018

Seasonal hypoxia events occur on the northern part of the shelf

- Age of bottom waters (number of days since the water leaves the surface) increases to 70-90 days in summer in the NW shelf.

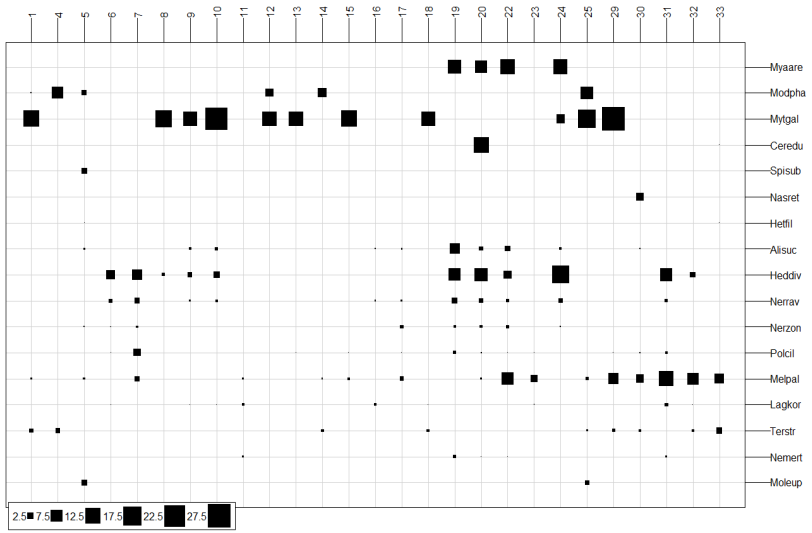
- 40 % of the NW-shelf oxygen consumption in summer is related to benthic degradation.



Species-Traits-Environment

STATIONS

SPECIES



R

TRAITS

SPECIES

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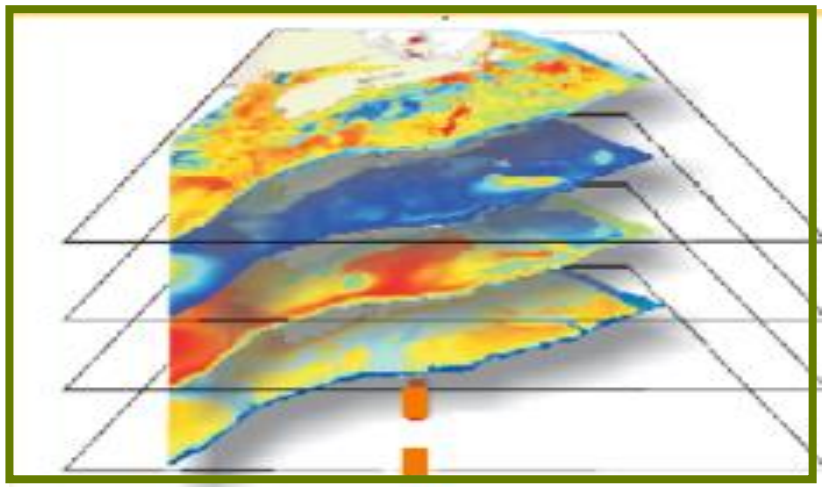
Mytilius galloprovincialis	3	0	0	0	1	3
Nereis rava	0	0	3	3	0	0
Terebellides stroemii	0	3	0	0	0	3
Lagis koreni	0	3	0	3	1	0
...						

L

ENVIRONMENT

STATIONS



Q

?

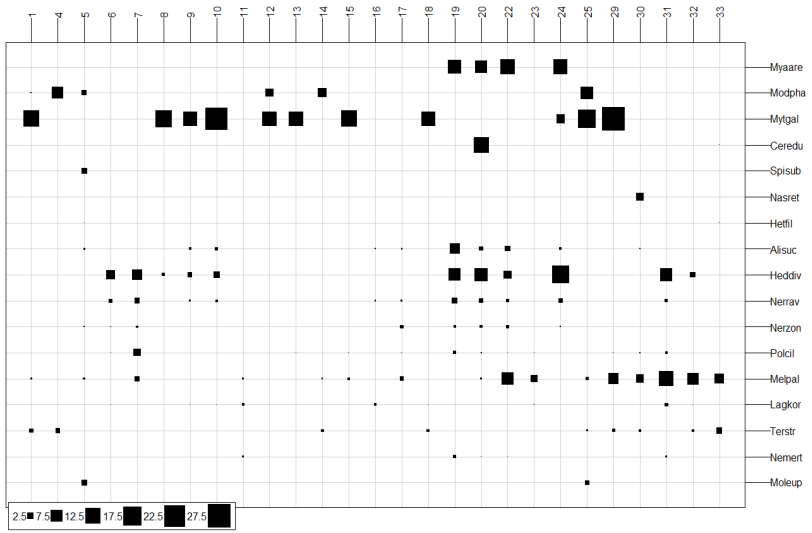
ENVIRONMENT

TRAITS

Species-Traits-Environment

STATIONS

SPECIES



R

TRAITS

SPECIES

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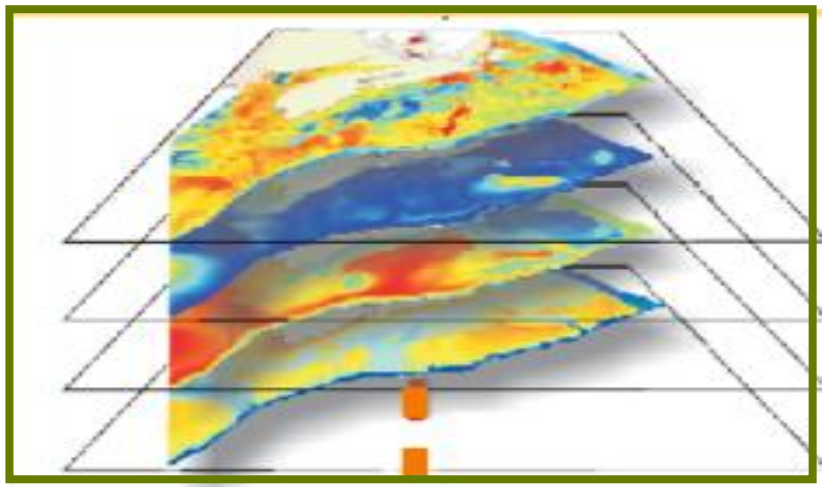
Lagis koreni	0	3	0	3	1	0
...						

L

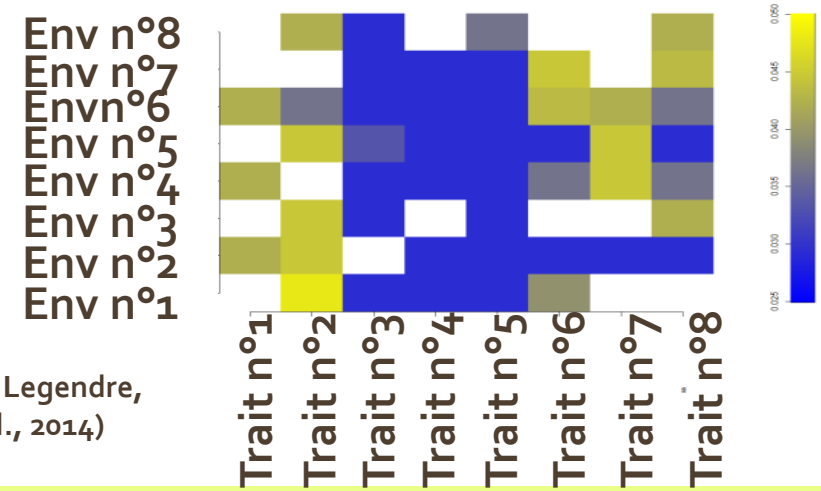
ENVIRONMENT

STATIONS



Q

Fourthcorner matrix



(Legendre and Legendre, 2012 Dray et al., 2014)

RLQ

Environmental variables

In-situ data: grain size, silt content, OrgC, TotN, Tot P (Wijsman et al., 1995).

Model variables:

Physical variables:

- Température,
- Salinity,
- Total shear stress (current+wave)
- Water age (time since the water leaves the sea surface)
- Turbuelnt Kinetic Energy

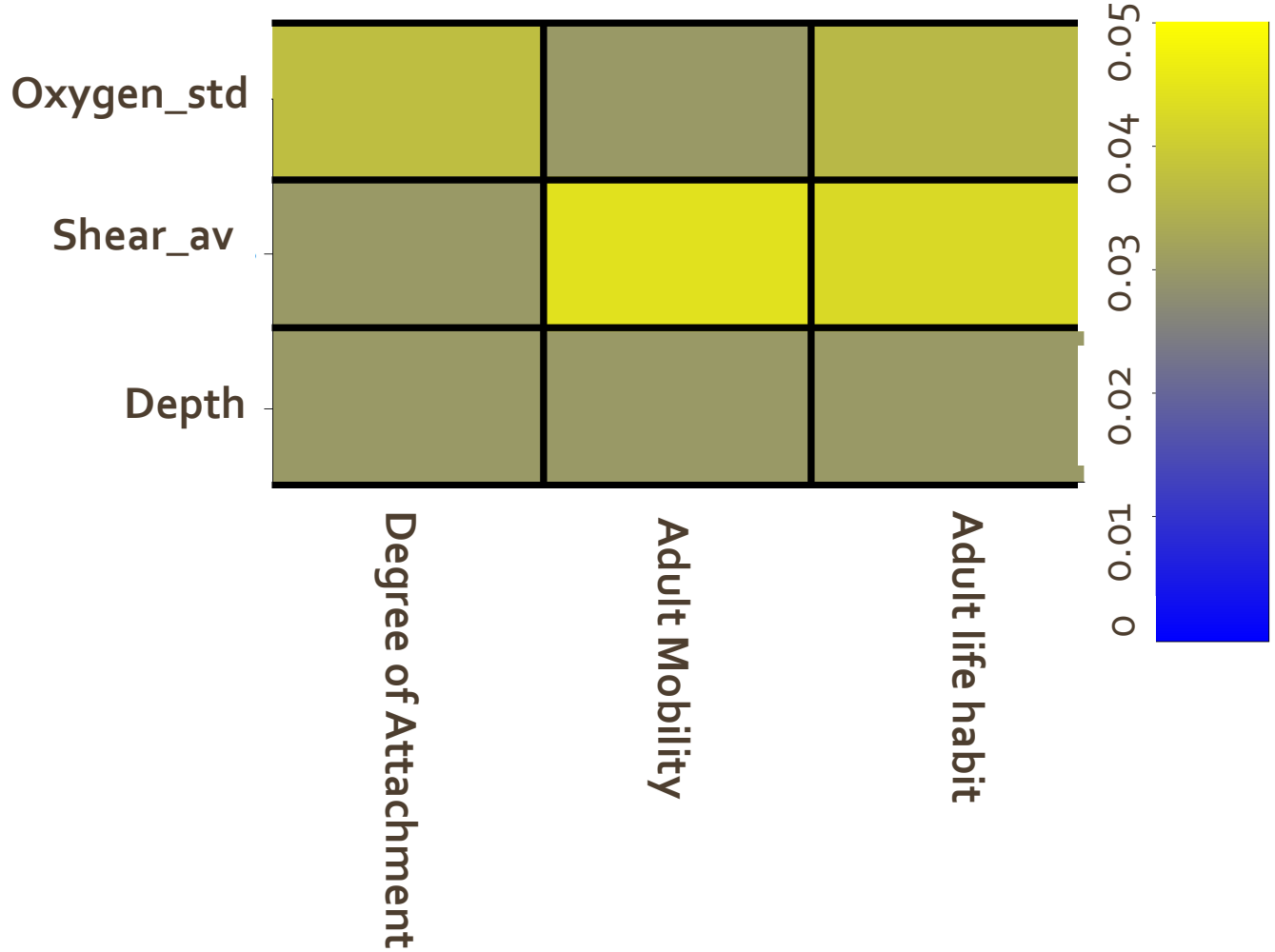
Biogeochemical variables

- Oxygen
- Hypoxia index
- Flux of POC to the bottom
- Carbon in the sediment (two pools)
- PAR

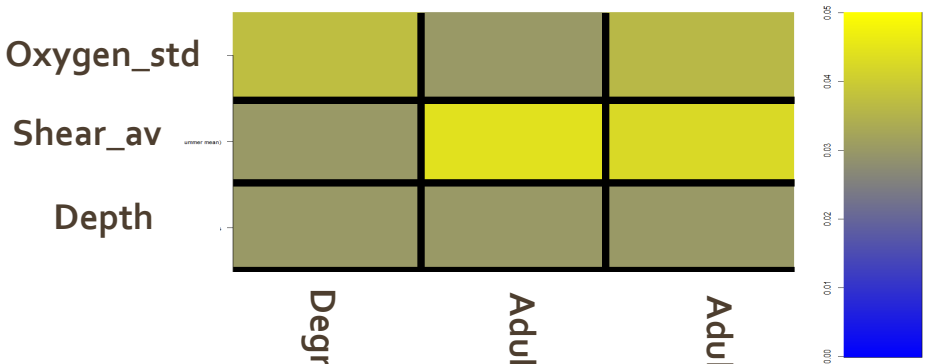
Average, std, min, max bottom values computed at seasonal and annual scale.

Mobility-Environment

Significance (pvalue) of the bivariate associations between traits and environmental variables (results from the fourth-corner tests). Significant associations correspond to p values <0.05

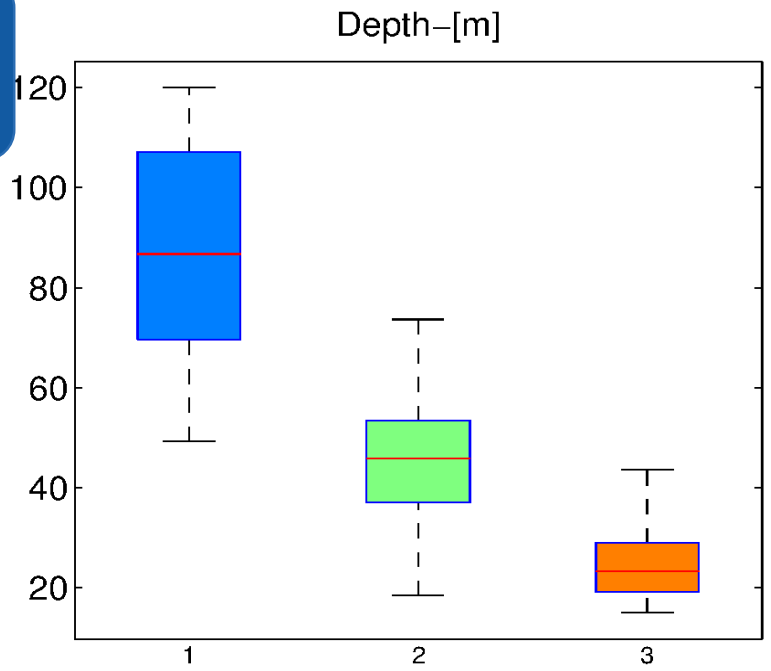


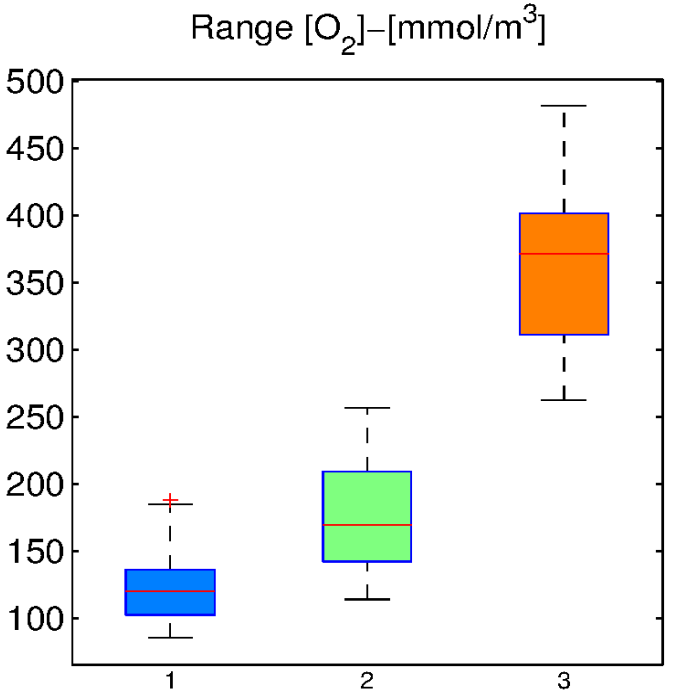
Mobility-Environment

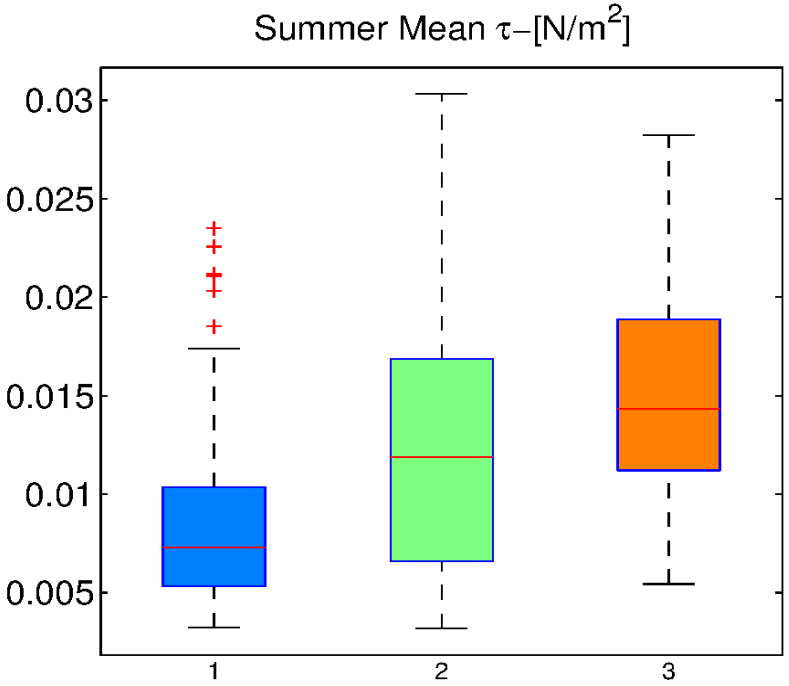


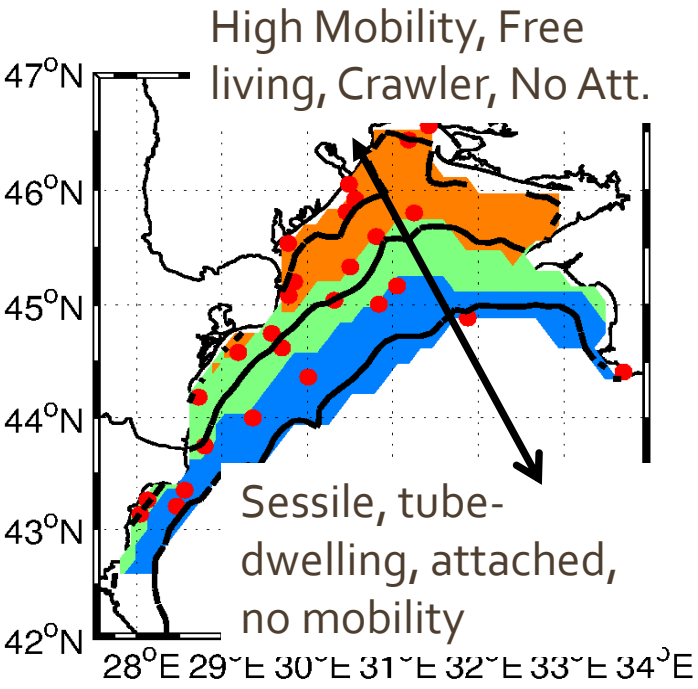
3D Ocean model

SOM Analysis
of significantly correlated variables

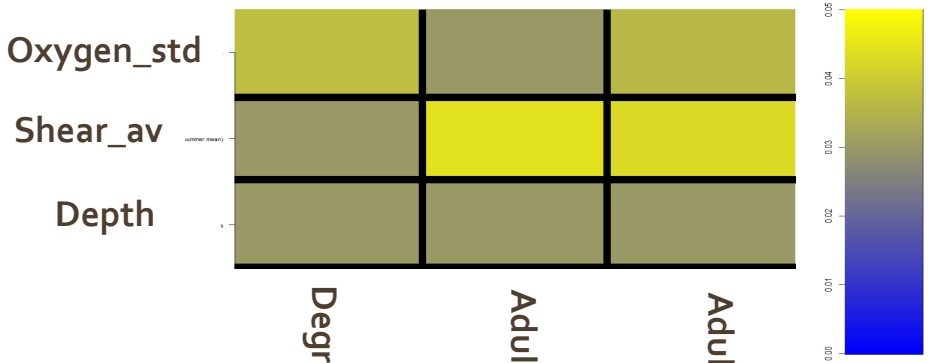








Mobility-Environment



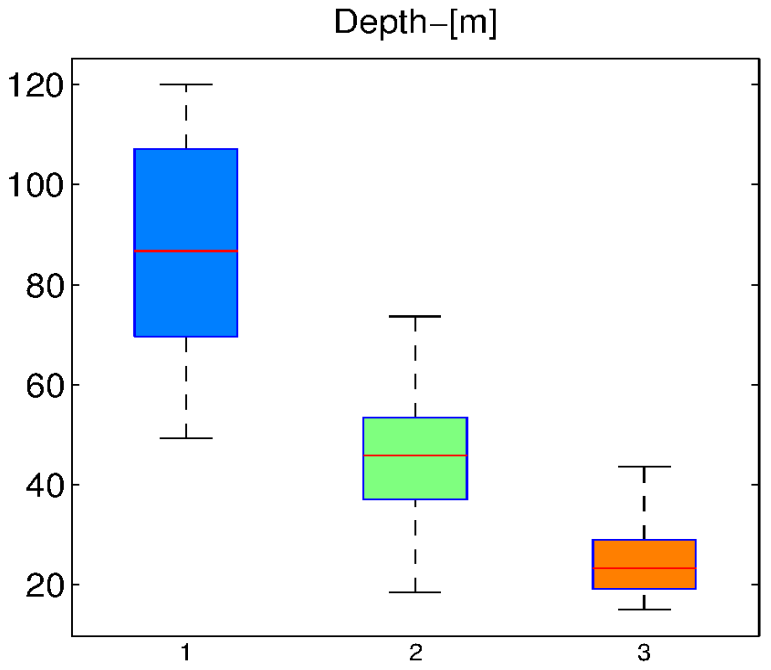
Degree of Attachment

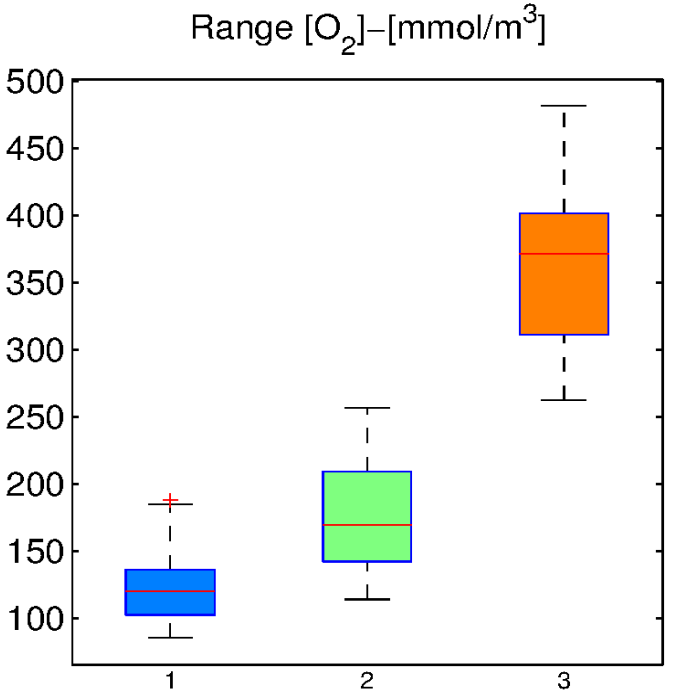
Adult Mobility

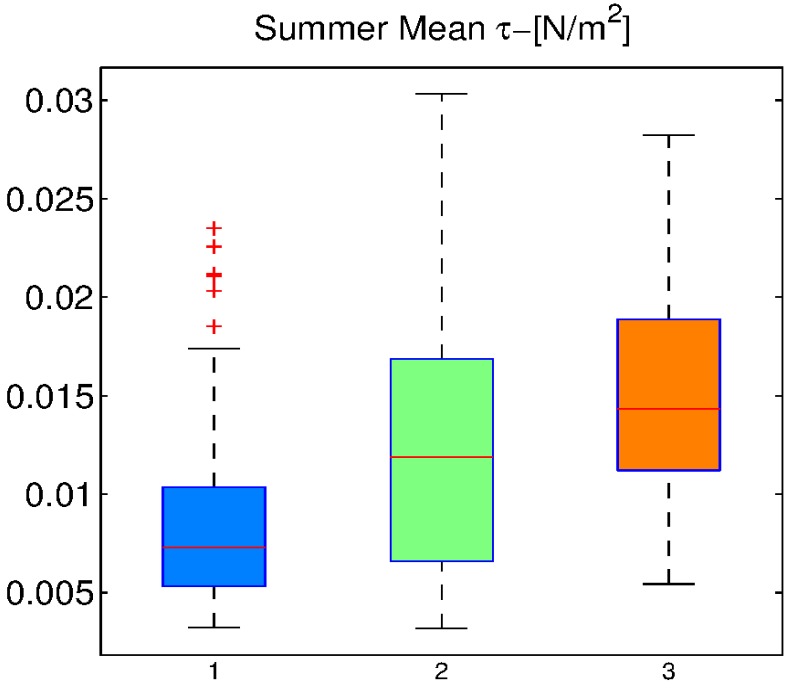
Adult life habit

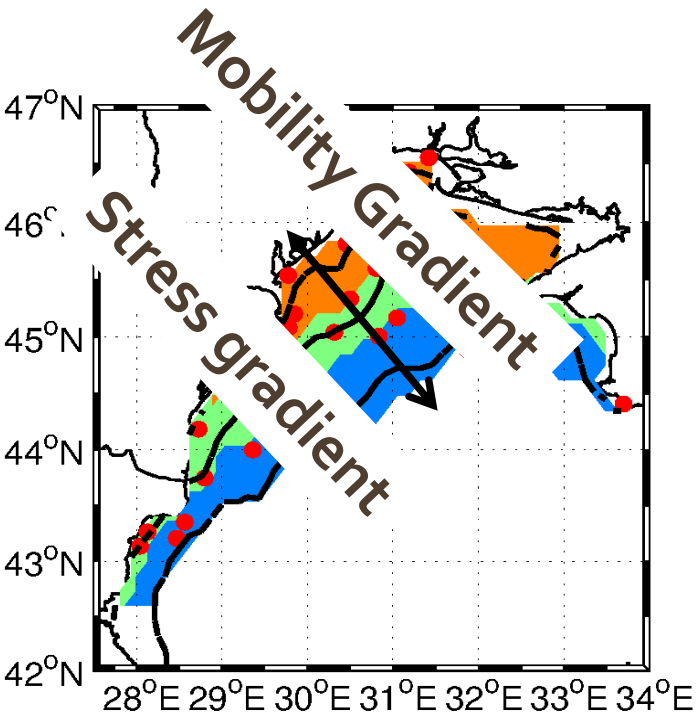
3D Ocean model

SOM Analysis
of significantly correlated variables









Bioturbation Traits

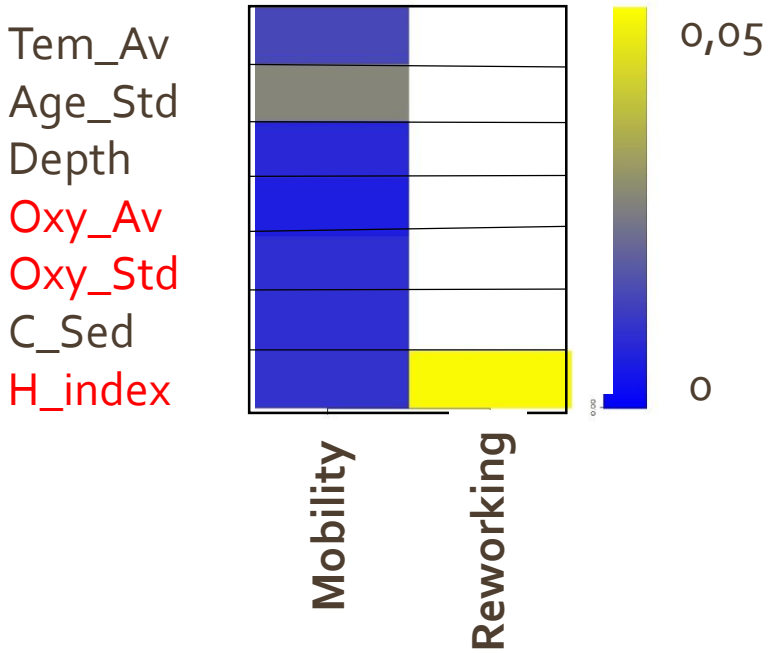
TRAIT	Modalities
Method of sediments reworking **(Reworking mode: Ri)** **Ri**	(1) Epifauna that bioturbate at the sediment-water interface, (2) surficial modifiers (<1-2cm) (3) upward/downward conveyors that actively transport sediment to/from the sediment surface (4) Biodiffusors
Propensity to move through the sedimentary matrix **(Mobility :Mi)** **Mi**	(1) in a fixed tube (2) limited movement, sessile, but not in a tube (3) slow movement (4) free movement via burrow system

Increasing activity

Increasing impact on the sediment turnover

Traits estimated for the 72 species from Queiros et al., 2013

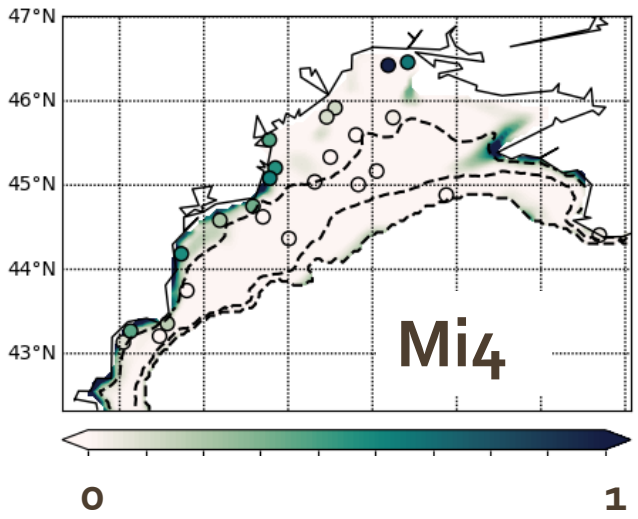
Bioturbation-Environment



- Mi and Ri 's presence-absence is significantly clustered by the environment.
- The degree of significance of clustering is higher for Mi.

Mapping the trait (ponderated by the biomass)

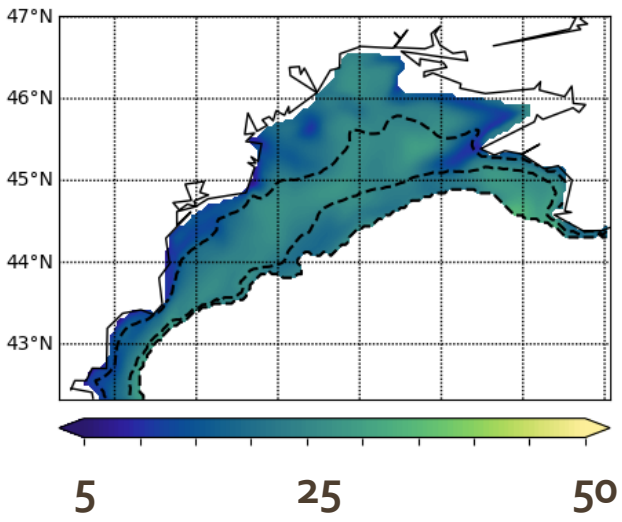
Multiple Linear Regression



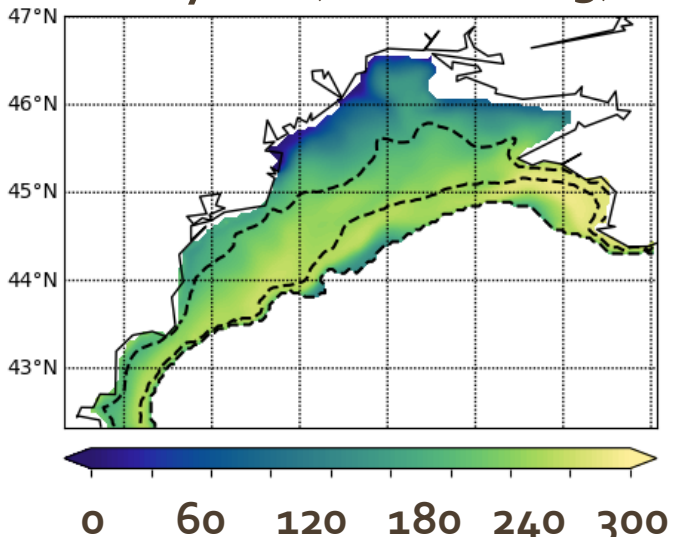
f(Age_std, oxy_av, depth, oxy_std, H_index)
R2= 0.7938, Adjusted R2= 0.7446

Mi4: free movement, burrower

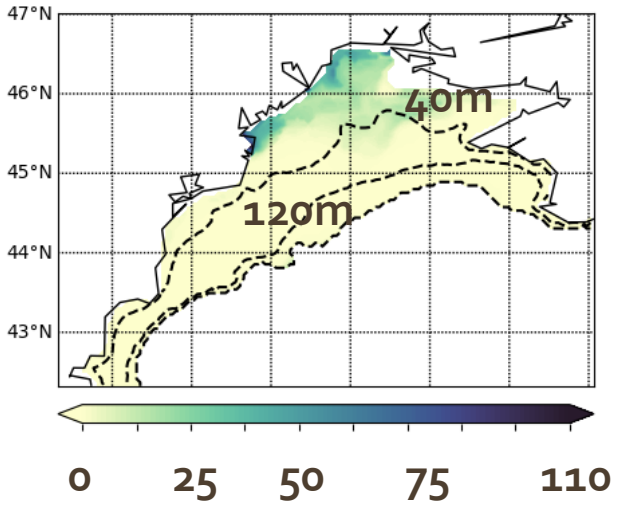
Age_std (in days)



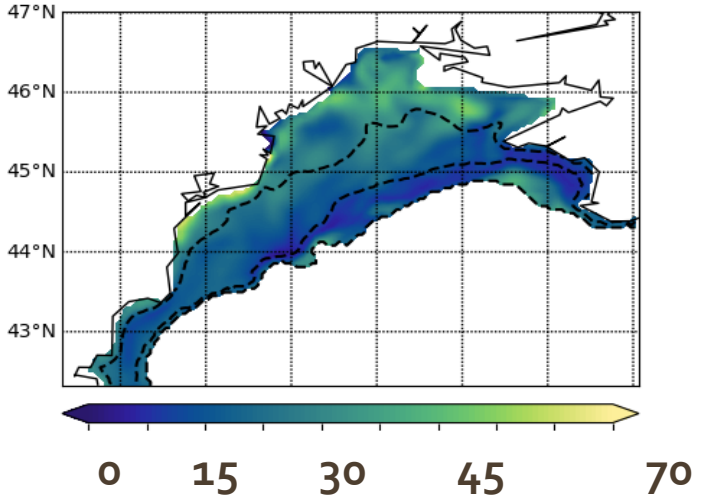
Oxy_Av (in mmol/m3)



H_index

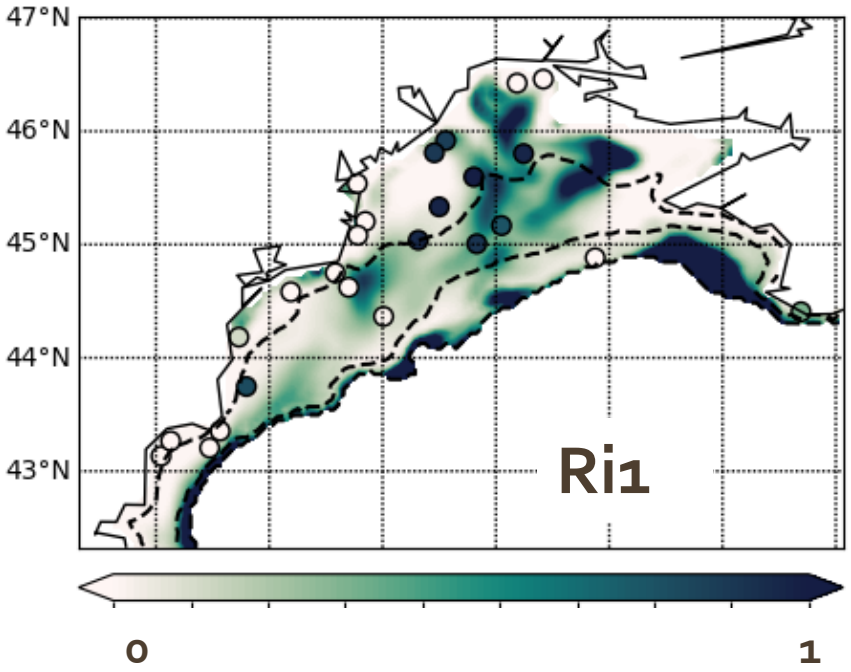


Oxy_std (in mmol/m3)



+DEPTH

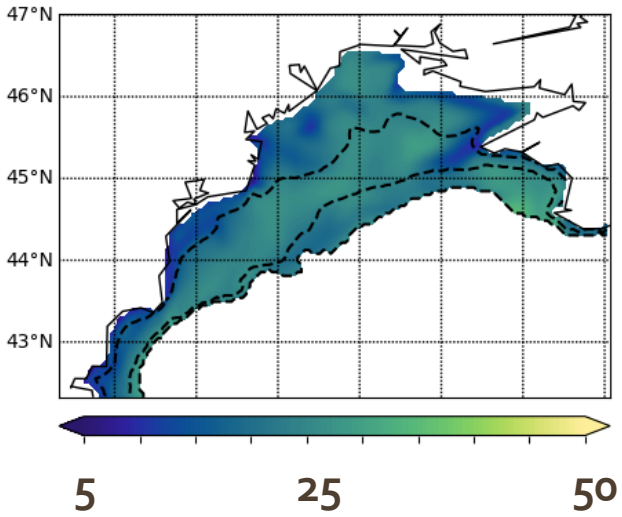
Mapping the trait



f(Age_std, oxy_std, depth)
R2= 0.41, Adjusted R2= 0.3428

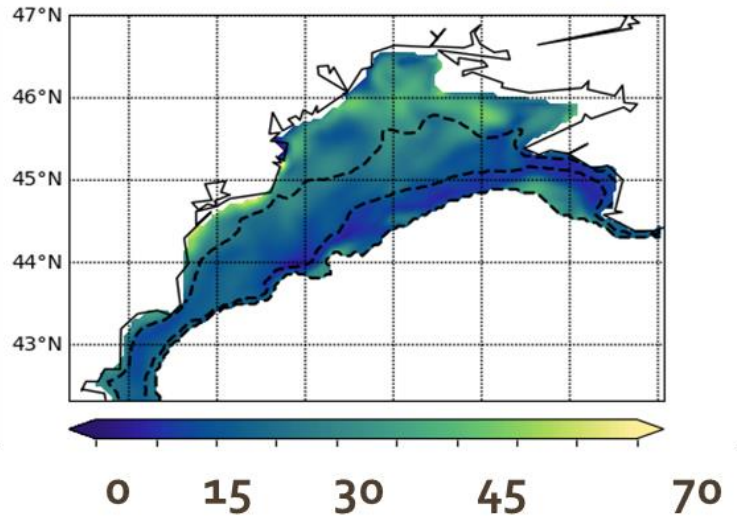
Ri1: Epifauna

Age_Std (in days)



+DEPTH

Oxy_std (in mmol/m3)



Bioturbation Potential of the community (BPc)

TRAIT	Modalities
Method of sediments reworking **(Reworking mode: Ri)**	(1) Epifauna that bioturbate at the sediment-water interface, (2) surficial modifiers (<1-2cm) (3) upward/downward conveyors that actively transport sediment to/from the sediment surface (4) biodiffusors
Propensity to move through the sedimentary matrix **(Mobility :Mi)**	(1) in a fixed tube (2) limited movement, sessile, but not in a tube (3) slow movement (4) free movement via burrow system

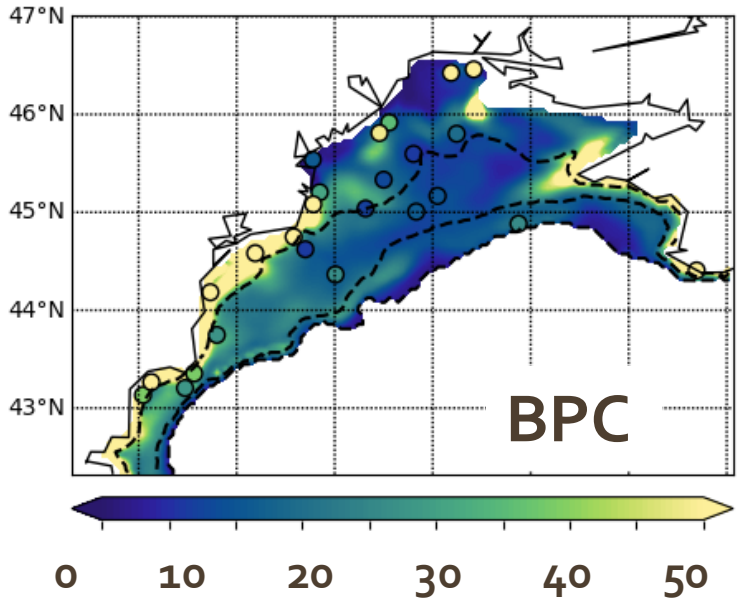
Per capita effect of **each species** on sediment mixing

(Solan et al., 2004 Science).

$$BPi = Bi^{0,5} * Mi * Ri$$

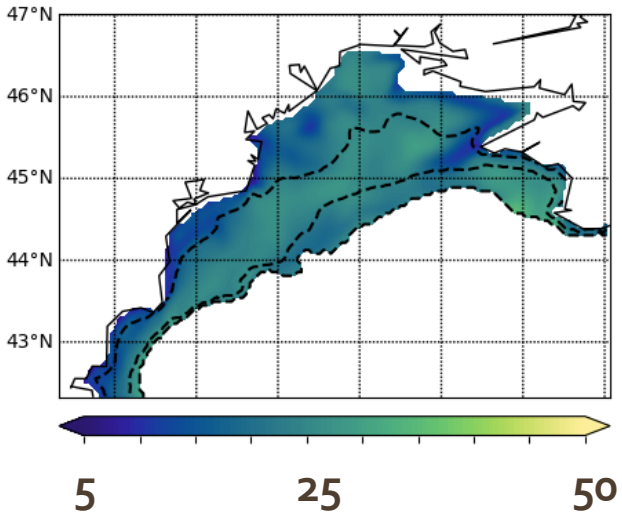
Bioturbation-Environment

Multiple Linear Regression

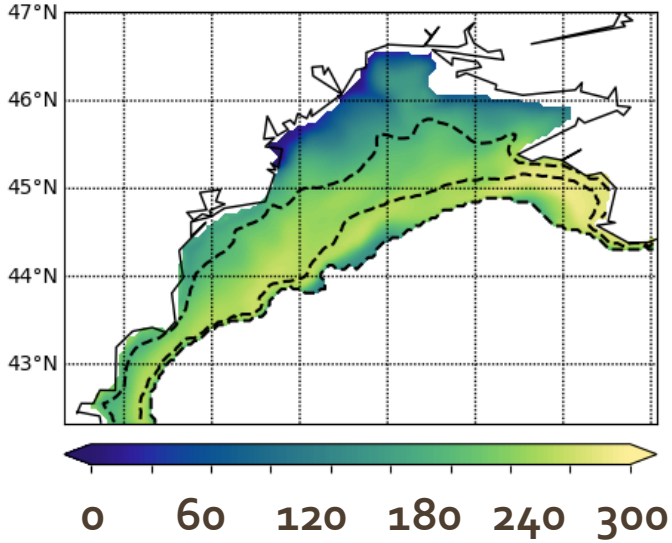


f(Age_Std,Oxy_Av,Depth, C_sed, H_index)
(R2=0,72, adjusted R2=0,65)

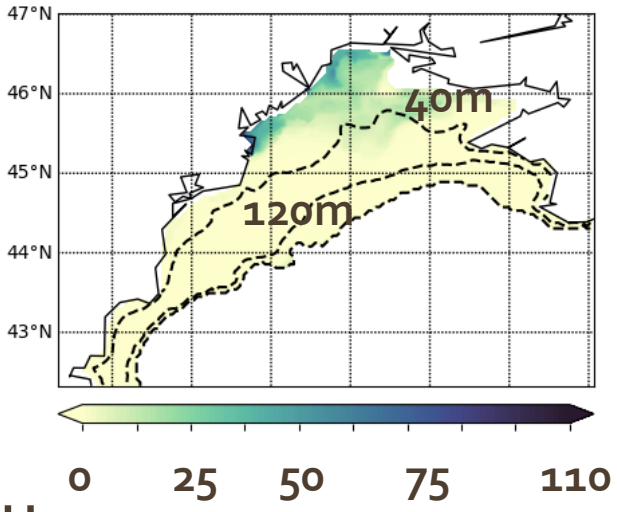
Age_Std (in days)



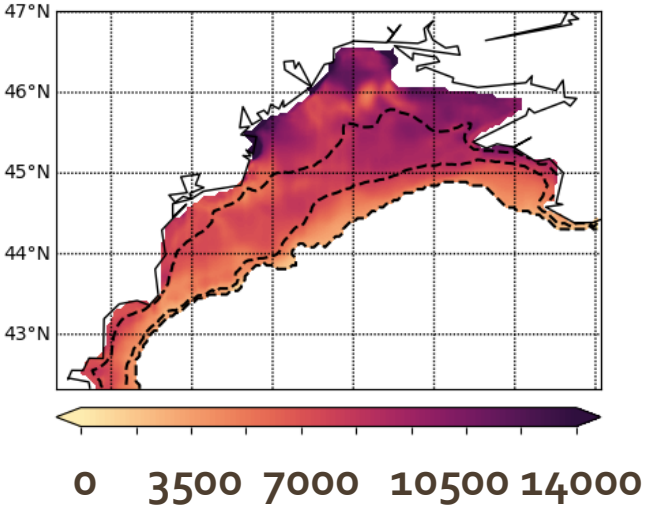
Oxy_Av (in mmol/m3)



H_index

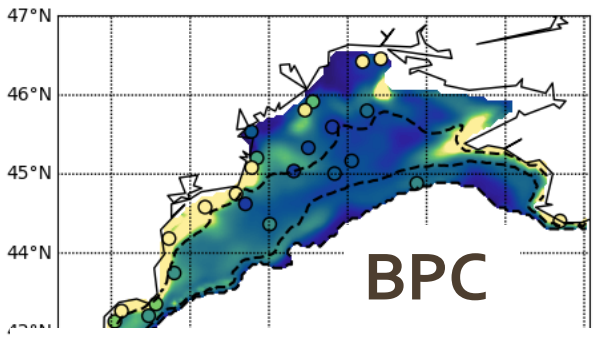


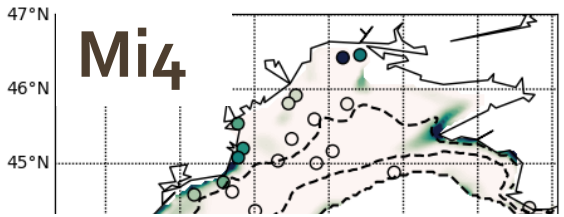
C_sed (mmol/m2)

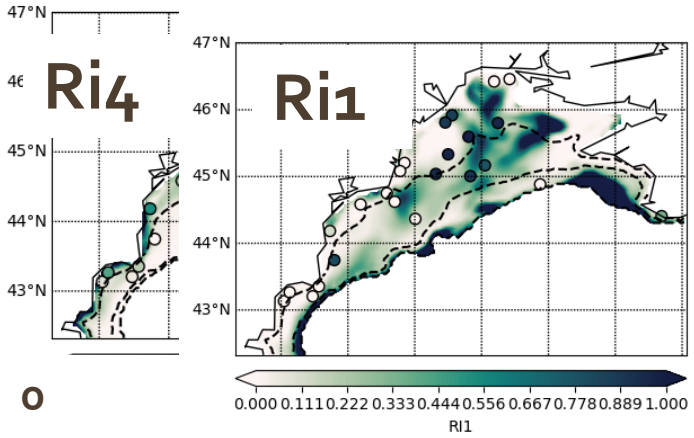


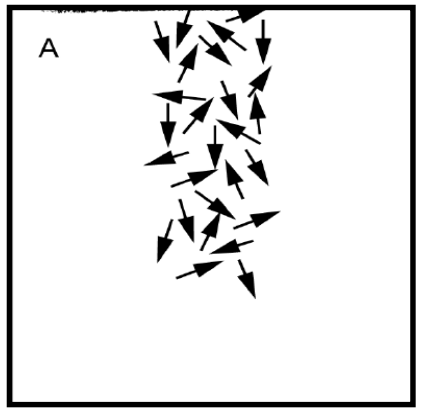
+DEPTH

Mapping of bioturbation to feed biogeochemical models

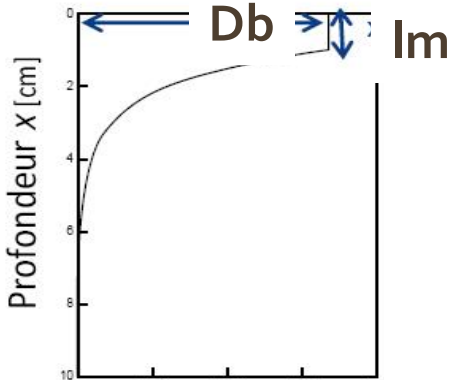








Local random transport of particles



Sediment mixing paramters (Db, lm)

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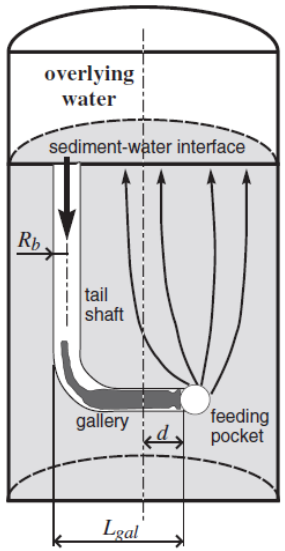
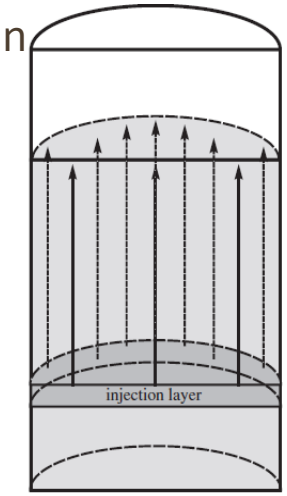
Model parameterization



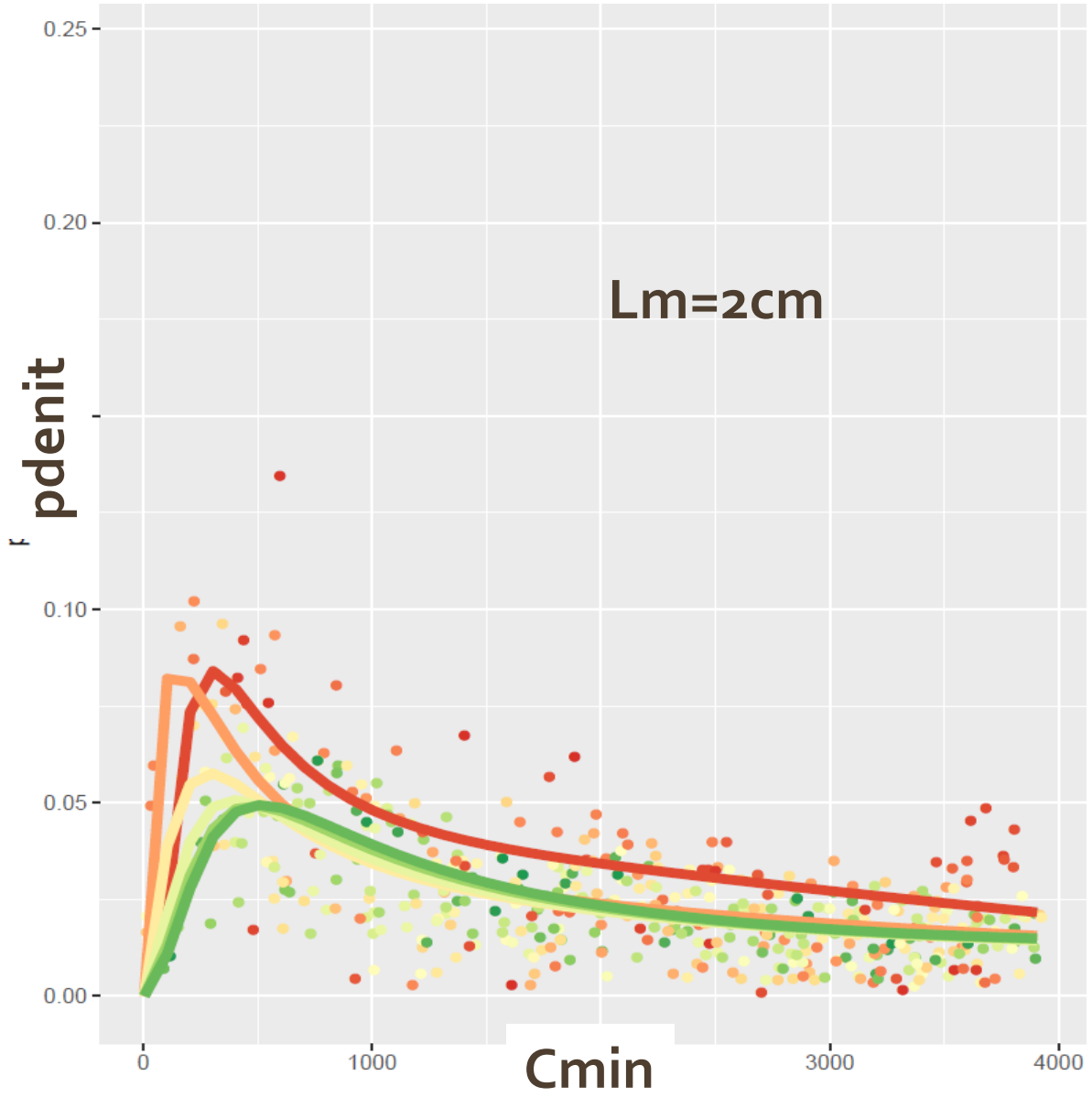
Meysman et al., 2016

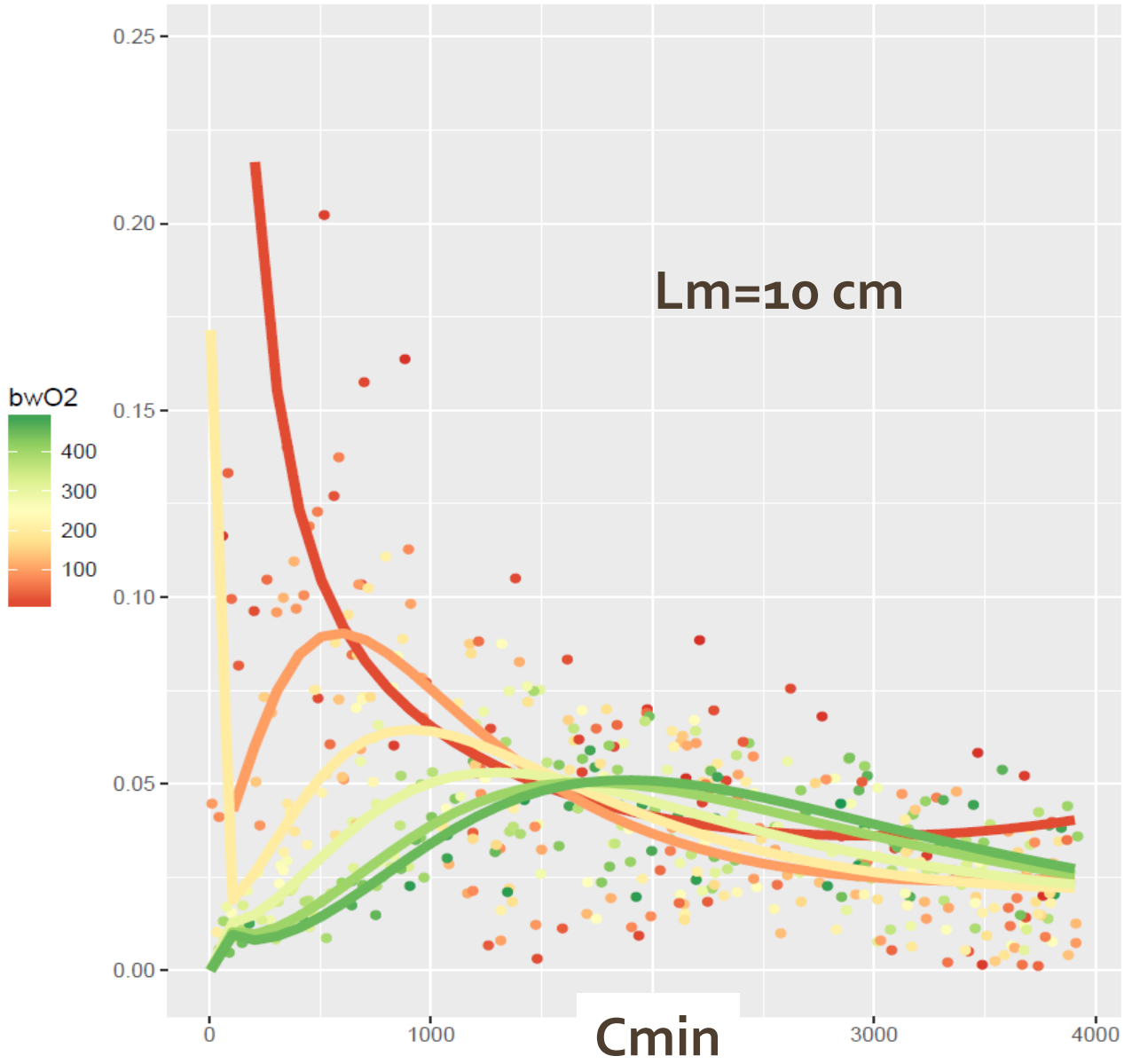
Non-local and local transport of particles and solutes (ventilation)
Li=injection pocket depth



Li=injection pocket , pumping rate, diffusion enhancement factor,

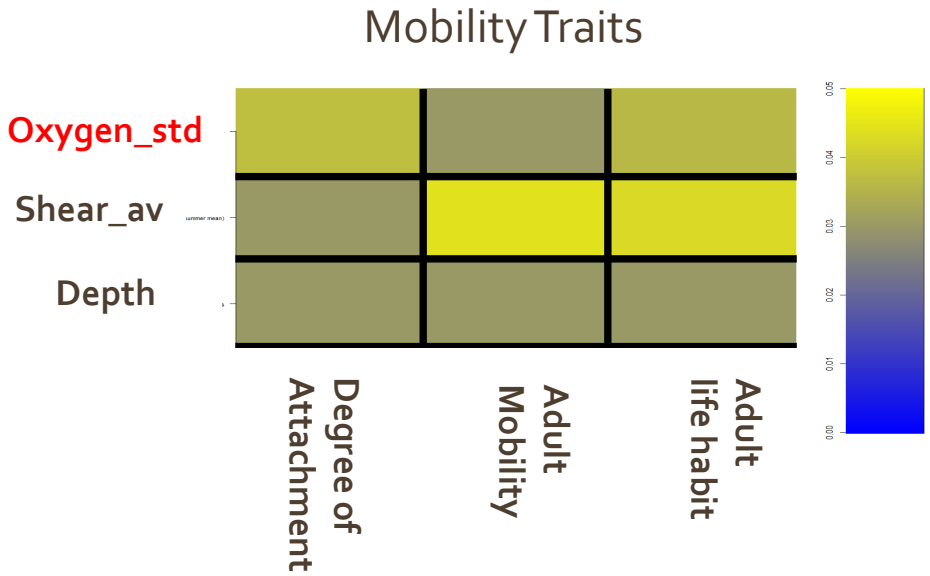
Sensitivity of the benthic model parameters to changing lm

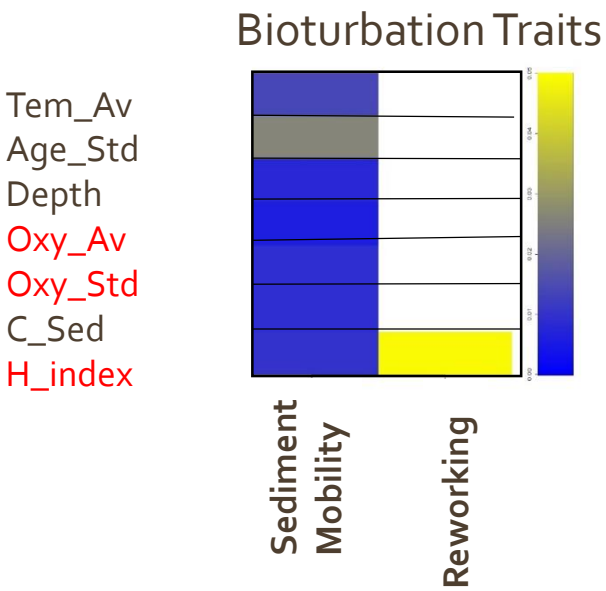




Main outcomes

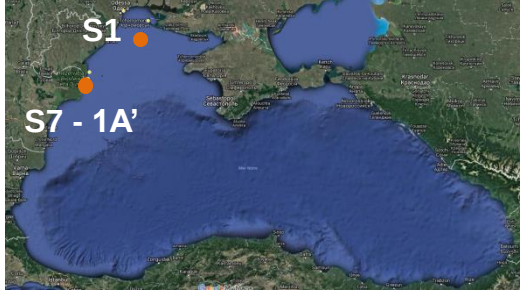
- Macrobenthos traits are significantly clustered by the environment.





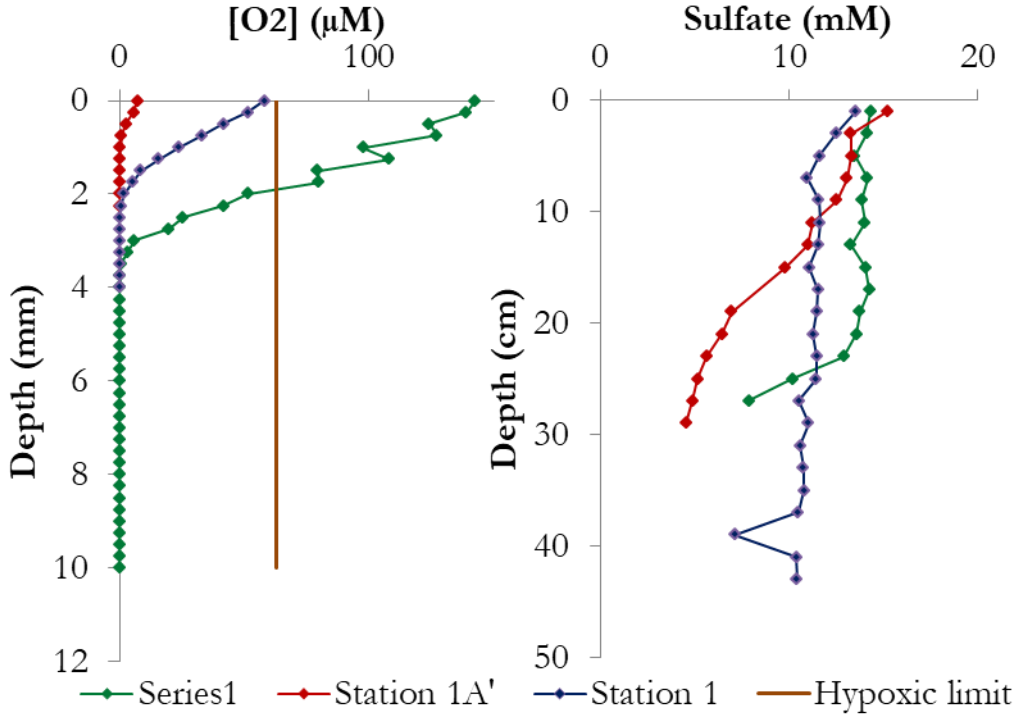
- Regions of low oxygen conditions, high shear stress are regions with highly mobile species and active bioturbators. But this does not reflect in the mapping of the BPC because the biomass is lower.
- The age of the bottom waters is a dominant variables for explaining the variability of the intensity of traits.
- The coupling of functional biogeographic models and mechanistic biogeochemical models offers the way to couple environment, biodiversity and biogeochemistry at the ecosystem scale.

Hypoxia on the northwestern shelf



Station	Date	Location	Bottom water condition	Oxygen penetration depth (mm)
7	May 2016	Danube Delta	Oxic	3.2
1A'	August 2017	Danube Delta	Hypoxic	1.5
1	August 2017	Shelf	Hypoxic	2.5

EMBLAS
Environmental monitoring in the Black sea



Diagenetic processes impacted by hypoxia:

Oxic respiration

$$CH_2O + O_2 \rightarrow CO_2 + H_2O$$

Sulfate reduction

$$2\,CH_2O + SO_4^{2-} \rightarrow H_2S + 2\,HO_3^-$$

#Poster: Plante et al., ID91

GO$_2$NE
Global Ocean Oxygen NEtwork

XIAMEN UNIVERSITY

United Nations Educational, Scientific and Cultural Organization

Intergovernmental Oceanographic Commission

GO$_2$NE SS2019: GO$_2$NE Summer School
2-7 September 2019

THANK YOU!

BenthOx

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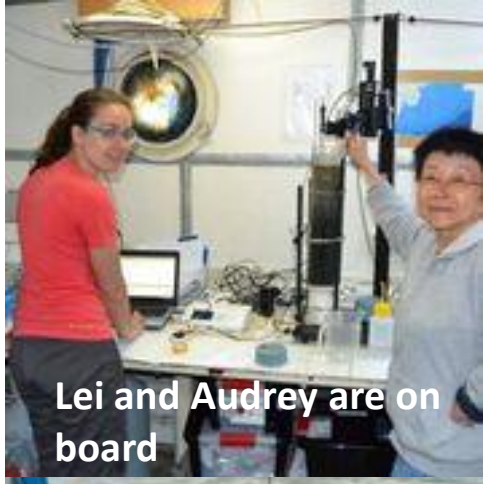
UNDP

EMBLAS
Environmental monitoring in the Black sea


The MARE Nigrum the Romanian research vesse (GeoEcoMar)


Lei and Audrey are on board


Deployment of the multi-corer


The long core is sliced by the EMBLAS team


The short sediment cores


Pore waters are extracted from the sediment