Relationships between environmental parameters and the microbenthic loop of *Posidonia oceanica* meadows at small spatial scale

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Photo: A. Abadie

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P. oceanica meadow : a carbon sink?

Leaves and living rhizomes

Canopy level

Living roots and rhizomes

Dead roots and rhizomes

"Matte"
=
Carbon sink (29-36 % of *P. oceanica* primary production)

Adapted from Boudouresque *et al.*, 2015

P. oceanica meadow : a carbon sink?

- 56-86 % of sedimentary OM = Highly refractory material (Danovaro *et al.*, 1996)

- *P. oceanica* detritus:
  - Rich in structural compounds
  - Low protein content

- **But** Velimirov *et al.* (2016) questioned the carbon balance in this ecosystem...

➡ How does OM (and carbon) degradation/storage happen in this ecosystem?

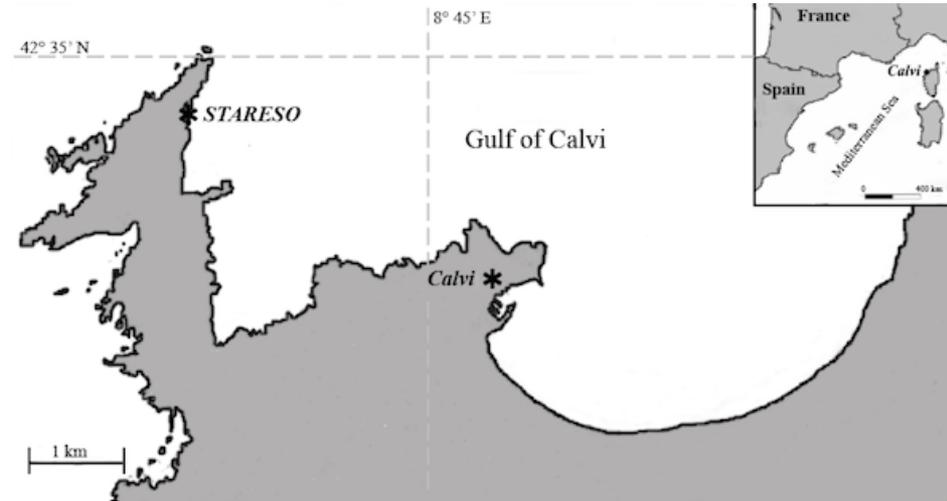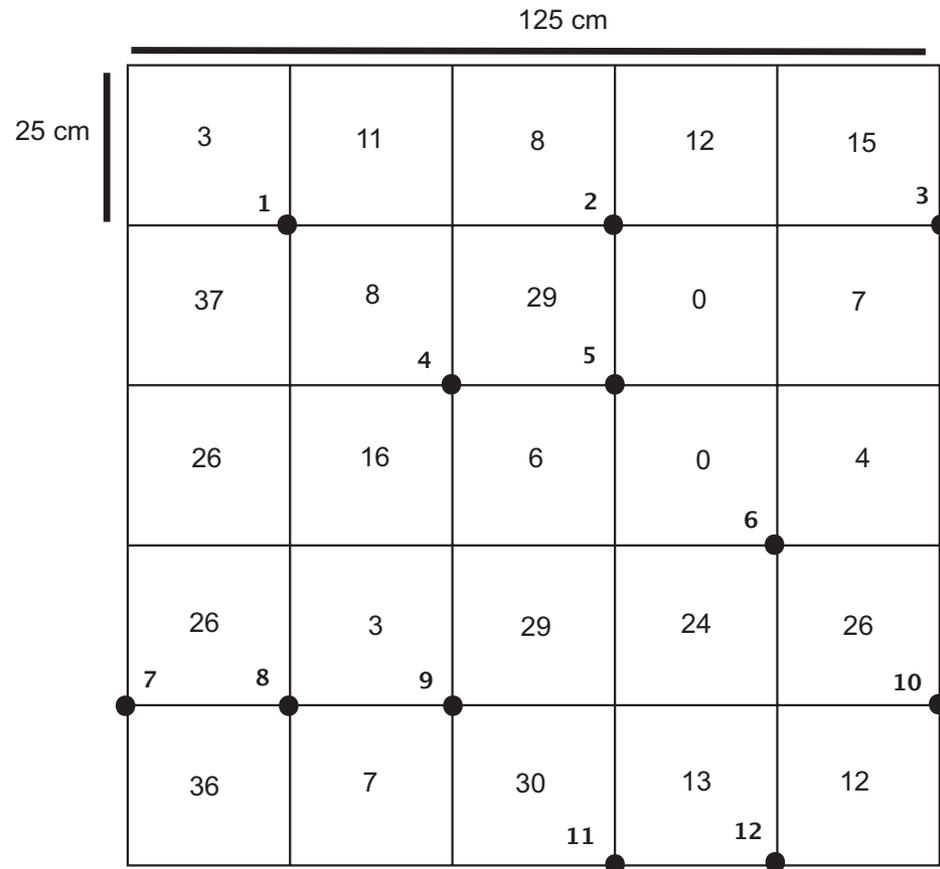# Roles of a major sub-system: the microbenthic loop?
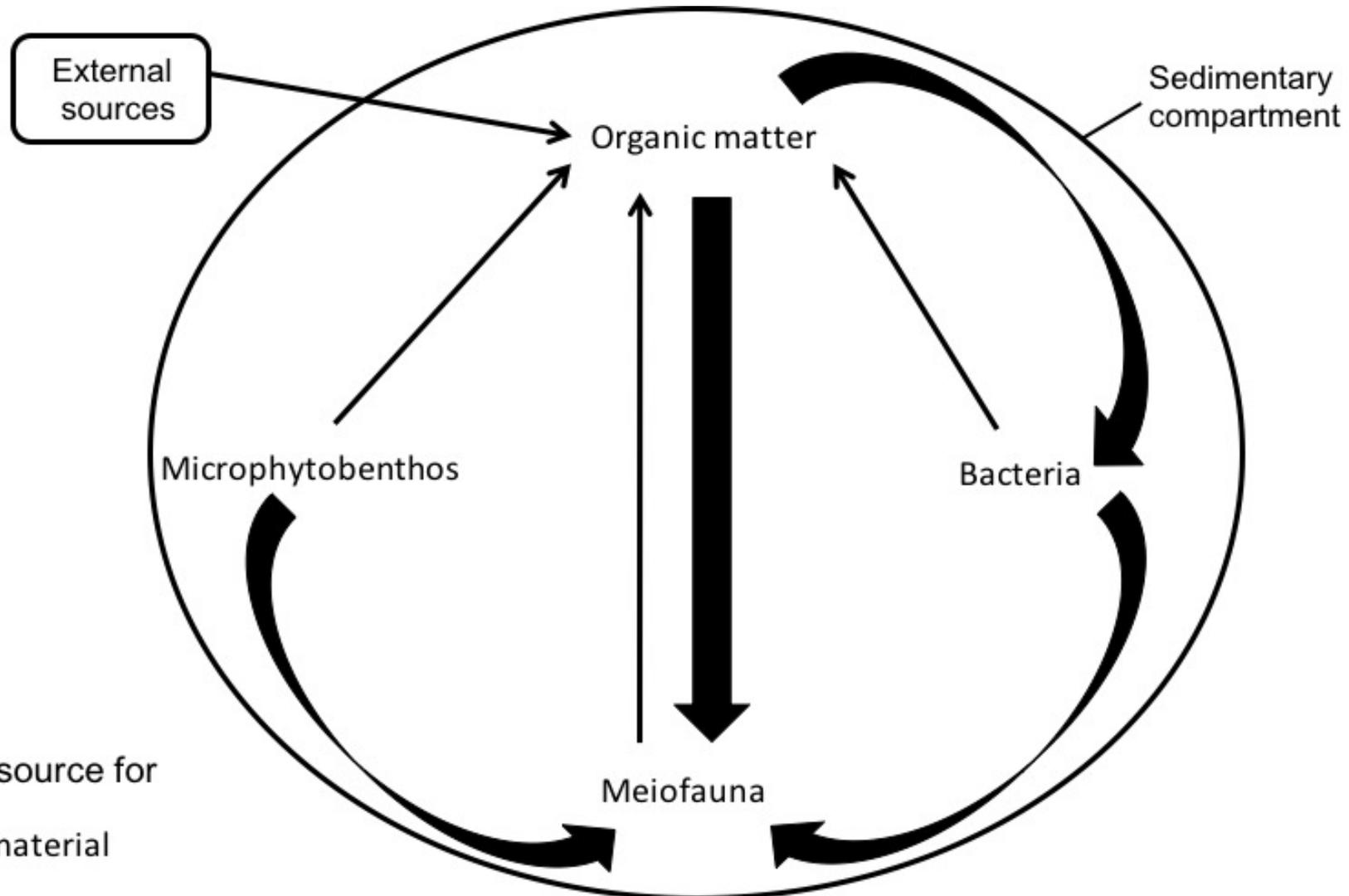
Aims of this study

Role of the microbenthic loop in OM (and carbon) degradation/storage in this ecosystem?

Aims:

- Heterogeneity at small spatial scale?
    - Role in structuring communities
    - Role in ecological processes

- Relationships between the microbenthic loop heterogeneity and environmental parameters at small scale?

Sampling strategy

125 cm

25 cm

3	11	8	12	15
				3
		1		**2**
37	8	29	0	7
		4	**5**	
26	16	6	0	4
				6
26	3	29	24	26
7	**8**	**9**		**10**
36	7	30	13	12
		11	**12**	

- 12 points randomly chosen

- *P. oceanica* shoot density inside   every 25x25 cm frames

- Pore water

- Cores

Measured parameters

Sampled	Microbenthic loop component
Core (0-2 cm)	Total Organic matter (TOM) $(mg.gDW^{-1})$
	Chlorophyll a (Chl-a) $(\mu g.gDW^{-1})$
	Total Bacteria Biomass (TBB) $(\mu gC.gDW^{-1})$
	Total Meiofauna Abundance (TMA) $(nb.gDW^{-1})$

Measured parameters

Sampled	Environmental parameters
Core (0-2 cm)	Phaeopigments (Phaeo.) (μg.gDW^{-1})
	Frequency of dividing bacteria cells (FDC) (% of total bacteria)
	Gravel (% DW)
	Sand (% DW)
	Mud (% DW)
	$\delta^{13}C$ (‰)
	Total Carbon (TC) (% DW)
	Total Organic Carbon (TOC) (% DW)
	Total Nitrogen (TN) (% DW)

Sampled	Environmental parameters
Core (0-2 cm)	TOC/TN
	Total Phosphorus (TP) (% DW)
	TOC/TP
	TN/TP
	Vegetal fibres (% DW)
	Oxygenation status
Pore water	$[NO_2^- + NO_3^-]$ (μM)
	$[NH_4^+]$ (μM)
	$[HPO_4^{2-}]$ (μM)

Measured parameters

Sampled	Environmental parameters		
Core (0-2 cm)	Phaeopigments (Phaeo.) (μg.gDW^{-1})		
	Frequency of dividing bacteria cells (FDC) (% of total bacteria)		
Grain size	Gravel (% DW)		
	Sand (% DW)		
	Mud (% DW)		
	δ^{13}C (‰)		
	Total Carbon (TC) (% DW)		
	Total Organic Carbon (TOC) (% DW)		
	Total Nitrogen (TN) (% DW)		

Sampled	Environmental parameters
Core (0-2 cm)	TOC/TN
	Total Phosphorus (TP) (% DW)
	TOC/TP
	TN/TP
	Vegetal fibres (% DW)
	Oxygenation status
Pore water	[NO$_2^-$ + NO$_3^-$] (μM)
	[NH$_4^+$] (μM)
	[HPO$_4^{2-}$] (μM)

Measured parameters

Sampled	Environmental parameters
Core (0-2 cm)	Phaeopigments (Phaeo.) (µg.gDW^{-1})
	Frequency of dividing bacteria cells (FDC) (% of total bacteria)
	Gravel (% DW)
	Sand (% DW)
	Mud (% DW)
OM and sediment quality	δ^{13}C (‰)
	Total Carbon (TC) (% DW)
	Total Organic Carbon (TOC) (% DW)
	Total Nitrogen (TN) (% DW)

Sampled	Environmental parameters
Core (0-2 cm) **OM and sediment quality**	TOC/TN
	Total Phosphorus (TP) (% DW)
	TOC/TP
	TN/TP
	Vegetal fibres (% DW)
	Oxygenation status
Pore water	[NO$_2^-$ + NO$_3^-$] (µM)
	[NH$_4^+$] (µM)
	[HPO$_4^{2-}$] (µM)

Measured parameters

Sampled	Environmental parameters
Core (0-2 cm)	Phaeopigments (Phaeo.) (μg.gDW^{-1})
	Frequency of dividing bacteria cells (FDC) (% of total bacteria)
	Gravel (% DW)
	Sand (% DW)
	Mud (% DW)
	δ^{13}C (‰)
	Total Carbon (TC) (% DW)
	Total Organic Carbon (TOC) (% DW)
	Total Nitrogen (TN) (% DW)

Sampled	Environmental parameters
Core (0-2 cm)	TOC/TN
	Total Phosphorus (TP) (% DW)
	TOC/TP
	TN/TP
	Vegetal fibres (% DW)
	Oxygenation status
Pore water	[$NO_2^- + NO_3^-$] (μM)
Nutrients	[NH_4^+] (μM)
	[HPO_4^{2-}] (μM)

Total Organic Matter (TOM)

- C.V. = 40.03 % of the mean

C.V. = SD as a percentage of the mean

TOM
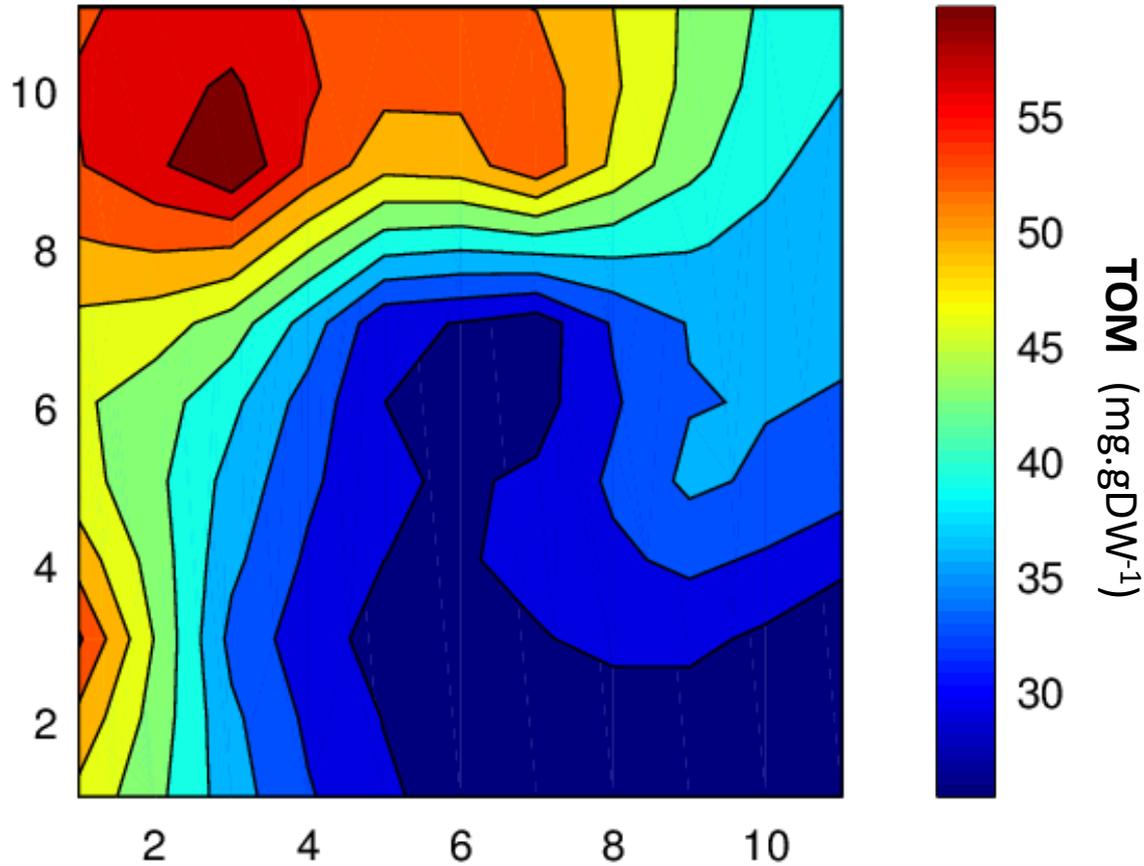
- C.V. = 40.03 % of the mean

- No relationship with microbenthic loop components

TOM

Multiple regression analysis :
- Selected parameter and regression coefficient: $[NH_4^+]$ / -1.27
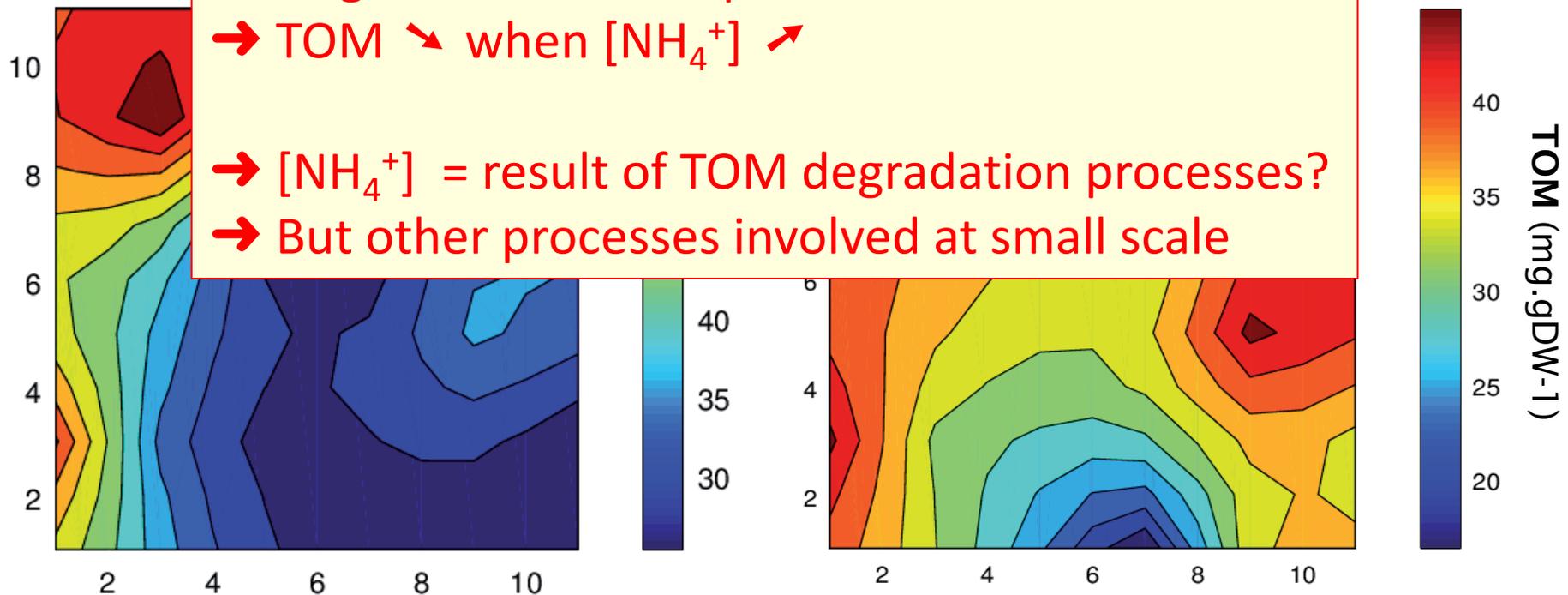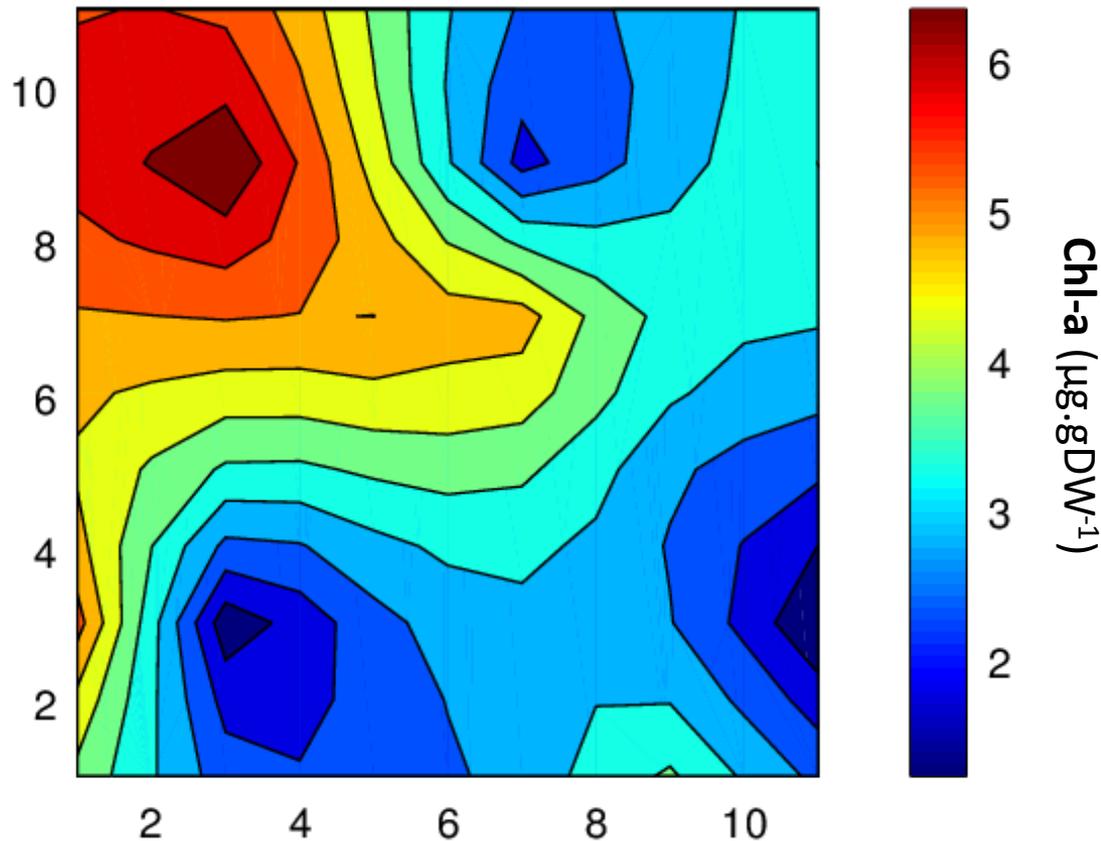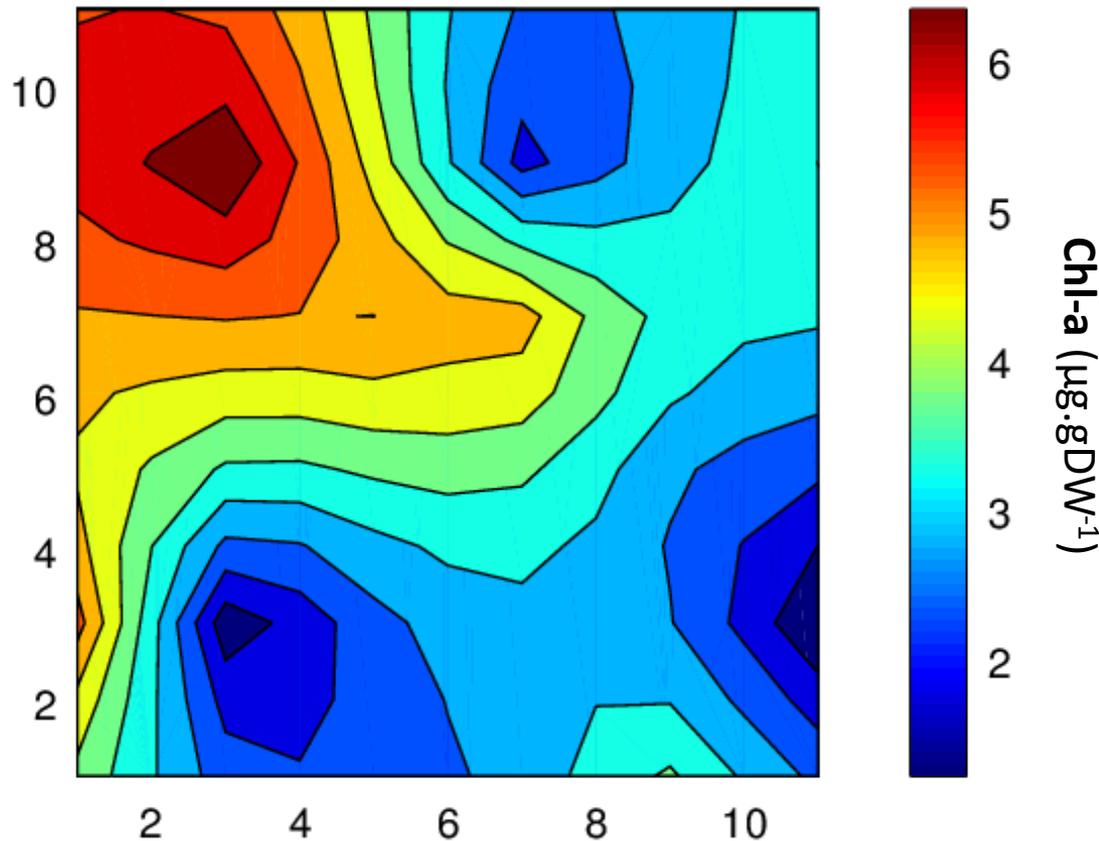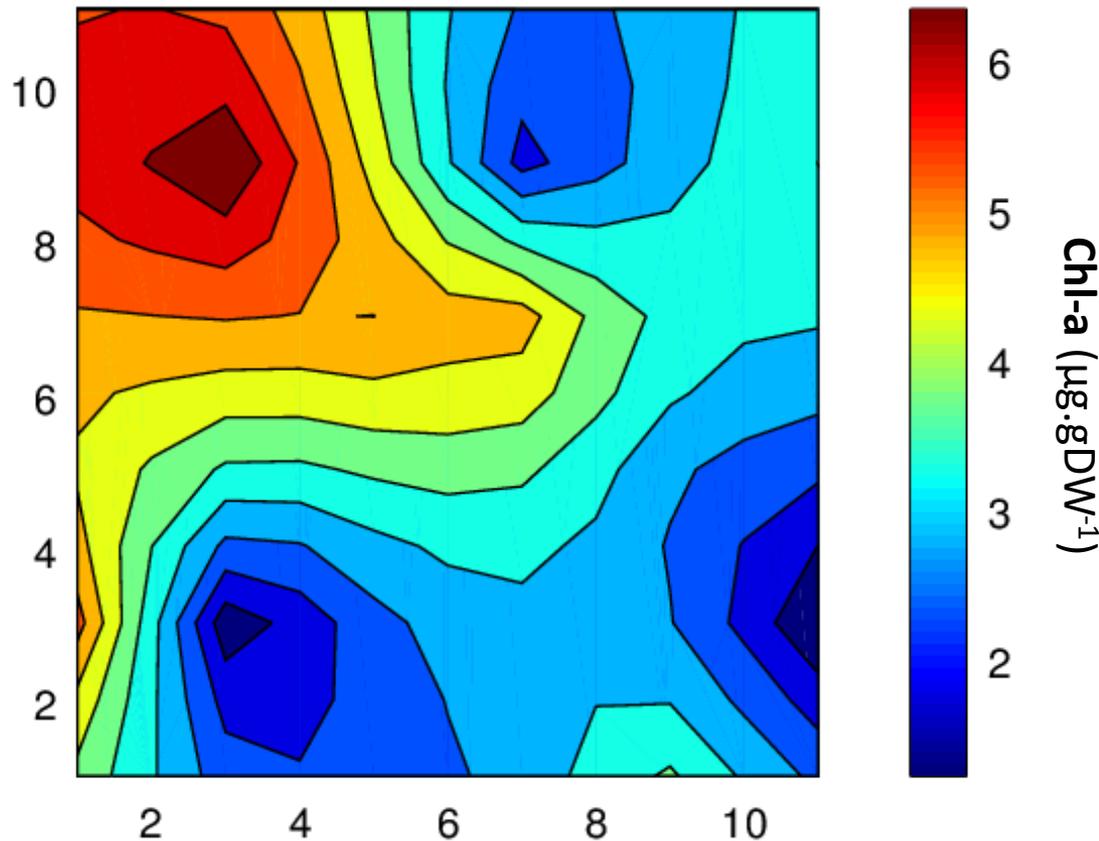- Selected model R^2 = 0.437 (p-value = 0.028)

A

B
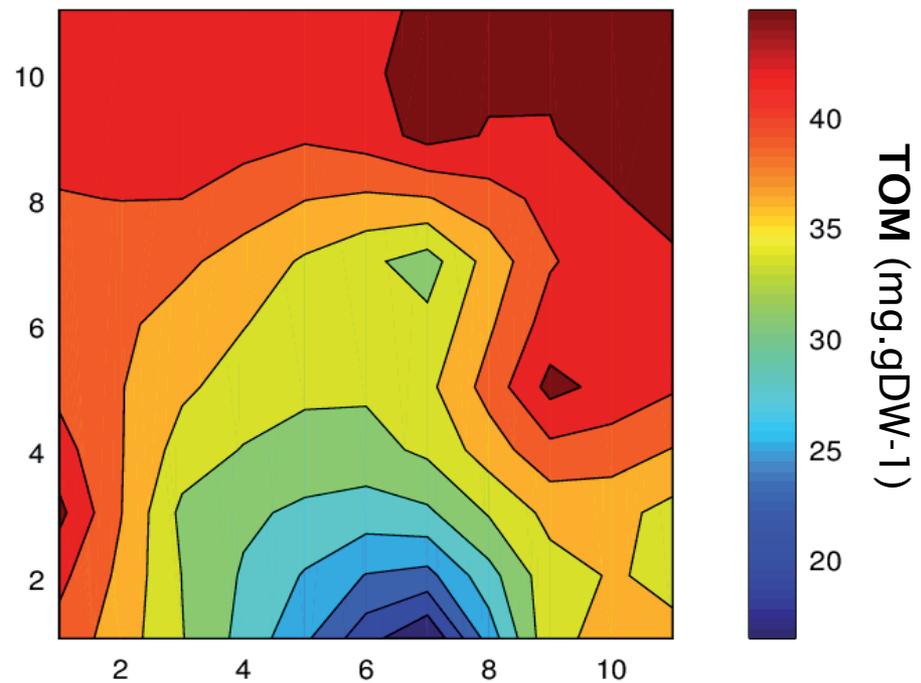
TOM (mg.gDW-1)

TOM

Multiple regression analysis :
- Selected parameter and regression coefficient: $[NH_4^+]$ / -1.27
- Selected model R^2 = 0.437 (p-value = 0.028)

A

➜ Negative relationship
➜ TOM ↘ when $[NH_4^+]$ ↗

➜ $[NH_4^+]$ = result of TOM degradation processes?
➜ But other processes involved at small scale

TOM (mg.gDW-1)

Microphytobenthos (Chl-a)

- C.V. = 53.99 % of the mean

- Highest of the microbenthic loop

Microphytobenthos (Chl-a)

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- Highest of the microbenthic loop

- No relationship with microbenthic loop components

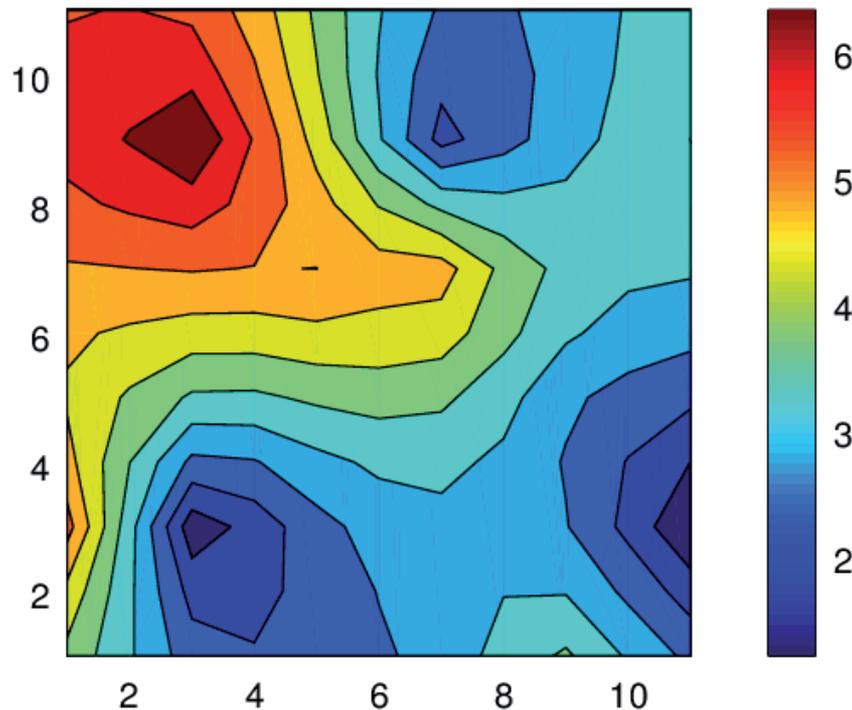# Microphytobenthos (Chl-a)

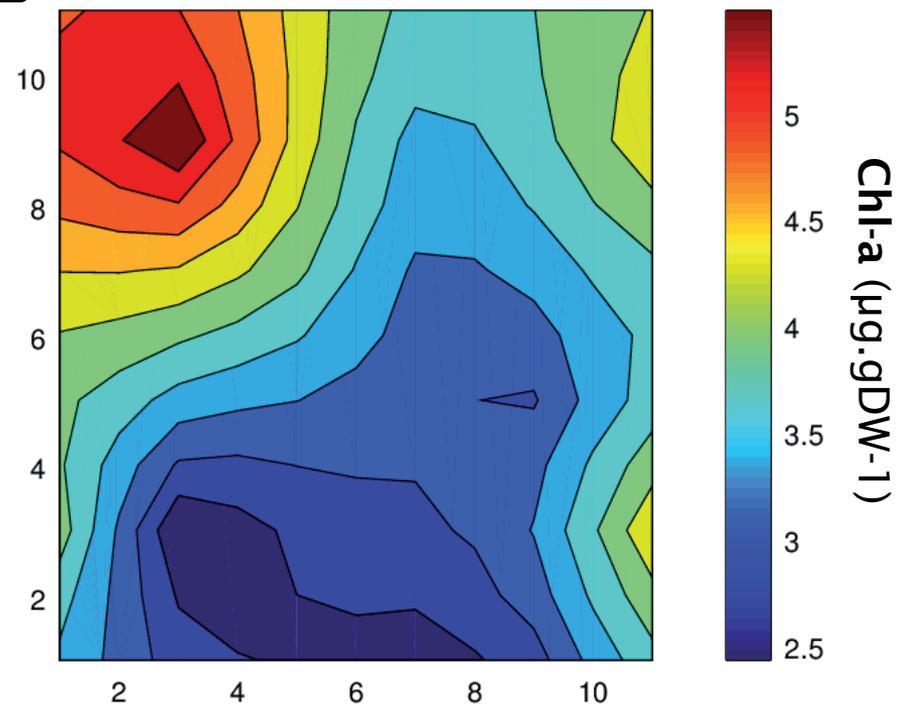- C.V. = 53.99 % of the mean

- Highest of the microbenthic loop

- No relationship with microbenthic loop components

- No significant relationship with any environmental parameter

Microphytobenthos (Chl-a)

(µg·gDW^{-1})

- C.V. = 53.99 % of the mean

- Highest of the
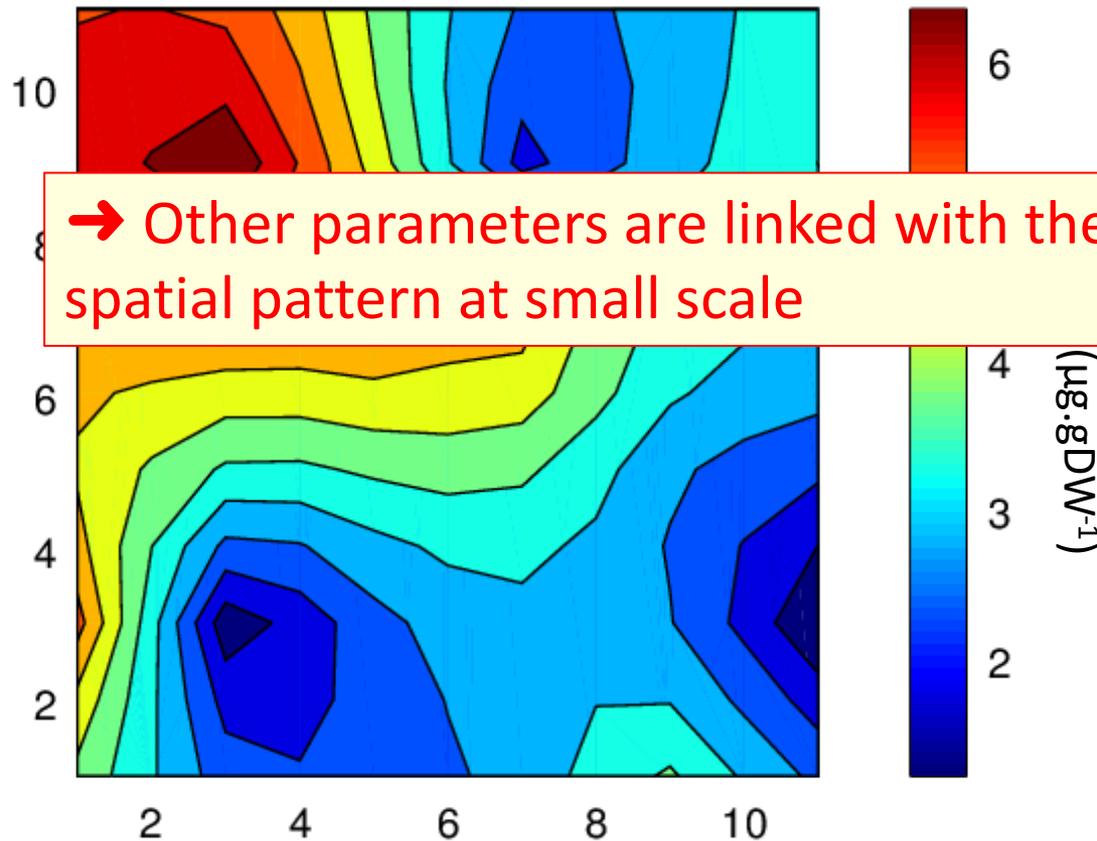
➔ Other parameters are linked with the microphytobenthos spatial pattern at small scale

- No relationship with microbenthic loop components

- No significant relationship with any environmental parameter

Microphytobenthos (Chl-a)

Multiple regression analysis :

- Selected parameter and regression coefficient: log(FDC) / 6.81
- Selected model R^2 = 0.294 (p-value = 0.085)

A

B

Chl-a (µg.gDW-1)

Microphytobenthos (Chl-a)

Multiple regression analysis :
- Selected parameter and regression coefficient: log(FDC) / 6.81
- Selected model R^2 = 0.294 (p-value = 0.085)

➜ Relationship between Chl-a and bacteria productivity in some areas
➜ Labile material amongst refractory matter
➜ Preferred food source for bacteria?
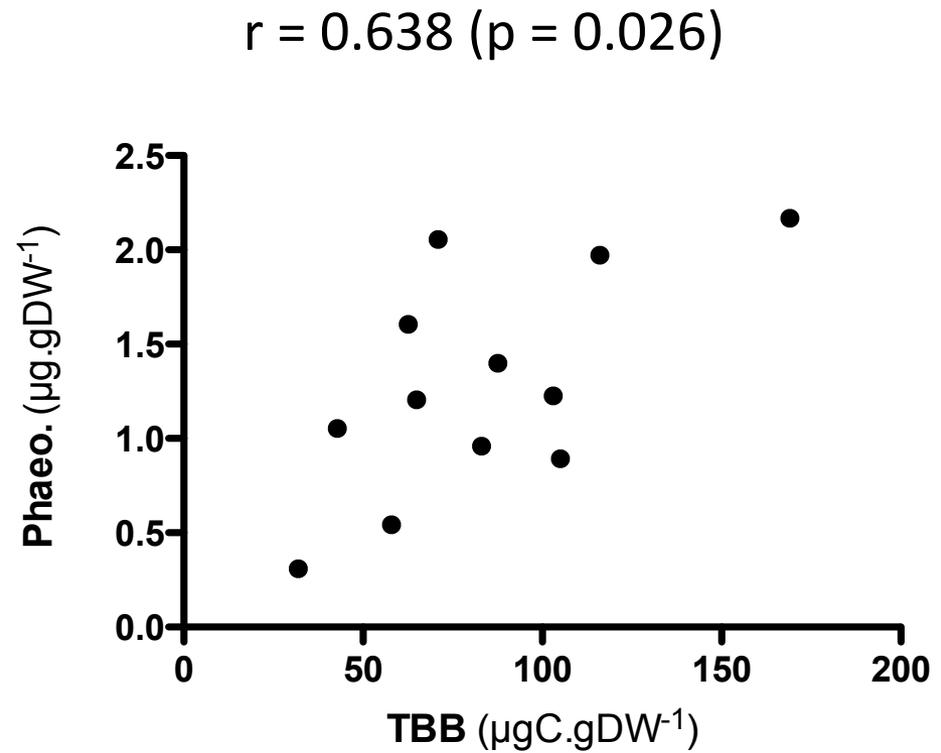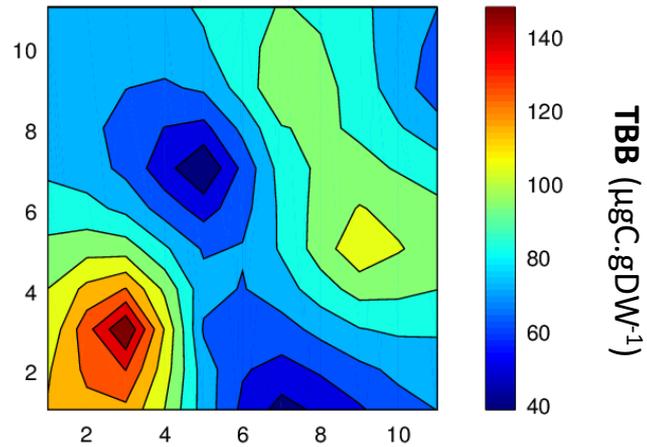
➜ Other processes probably predominant in other areas
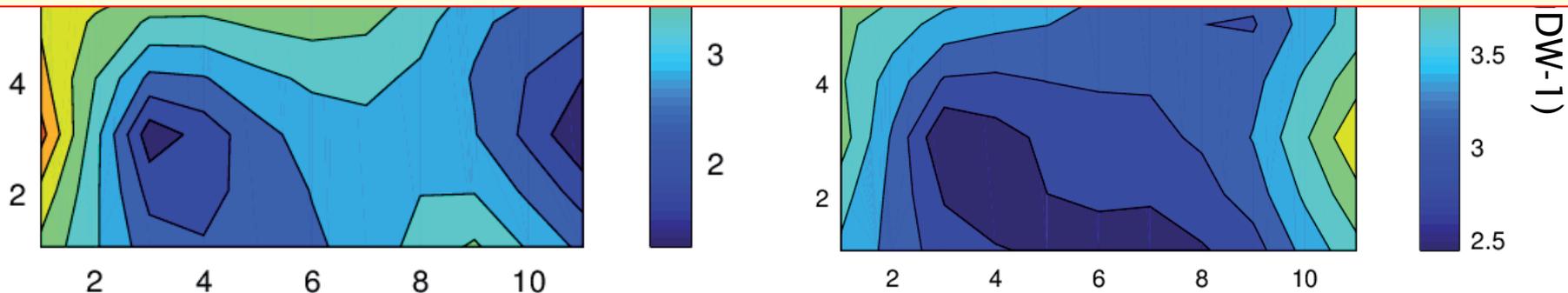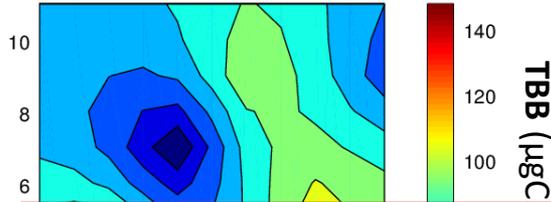
Total Bacteria Biomass (TBB)
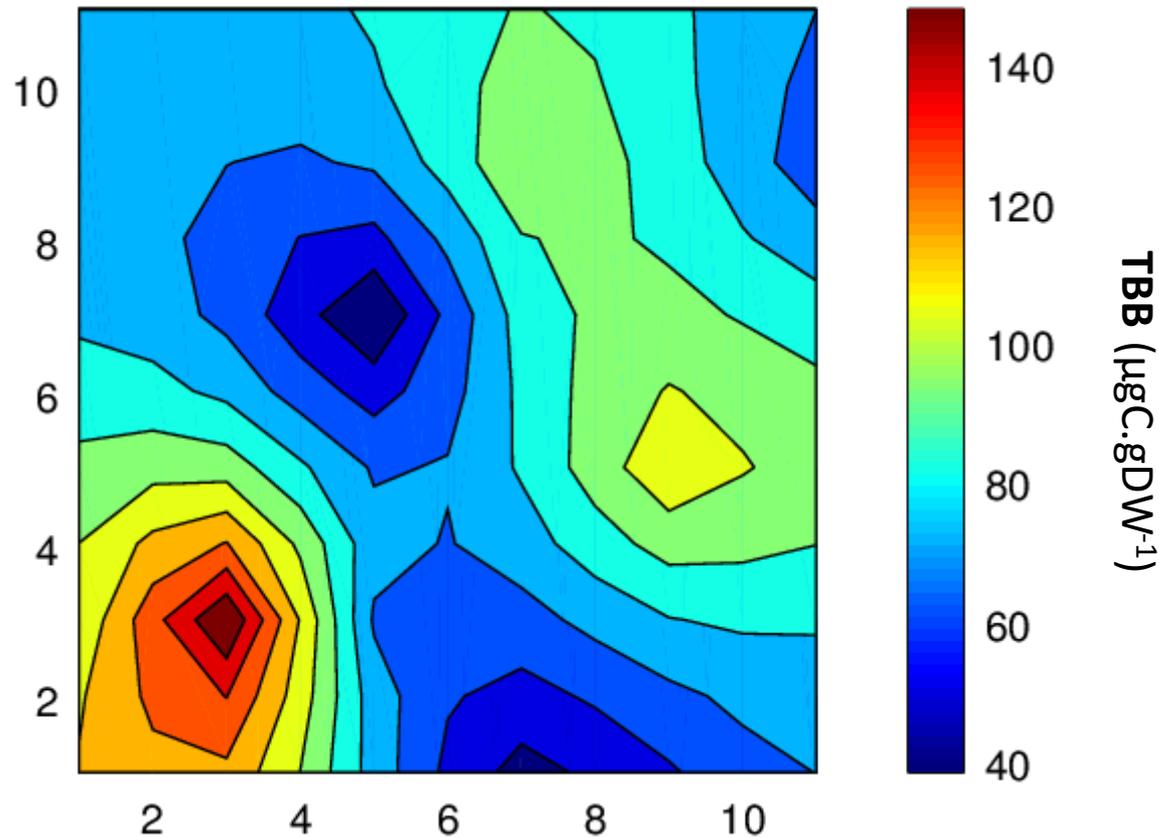
- C.V. = 44.75 % of the mean

Total Bacteria Biomass (TBB)

r = 0.638 (p = 0.026)
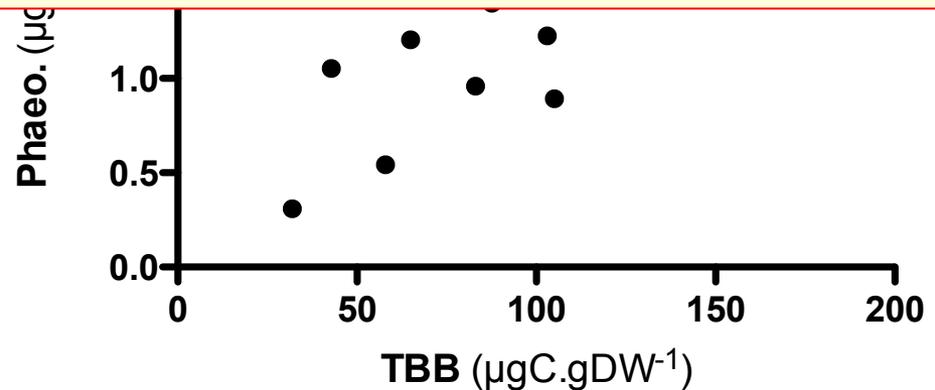
Total Bacteria Biomass (TBB)

➜ Relationship between bacteria and dead vegetal material
➜ Relationship with results obtained for Chl-a

➜ Relationship between bacteria and living and dead vegetal material
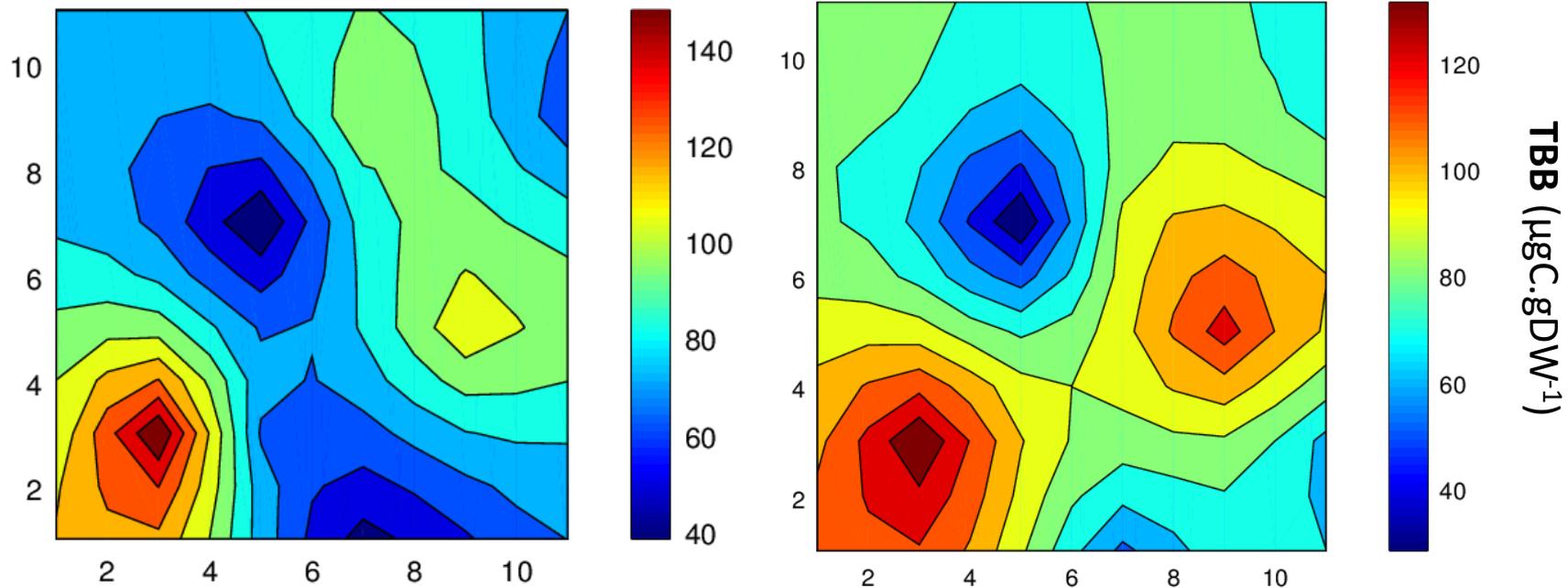
Total Bacteria Biomass (TBB)

Multiple regression analysis :

- Selected parameters and regression coefficients:
    - Log(FDC) / -301.14
    - TC / 31.98
    - Log(TOC/TN) / -184.05
    - $[NH_4^+]$ / -1.73 (N.S.)
    - Log($[HPO_4^{2-}]$) / -154.36

- Selected model R^2 = 0.839 (p-value = 0.047)

Total Bacteria Biomass (TBB)

Multiple regression analysis :
- Selected model R^2 = 0.839 (p-value = 0.047)

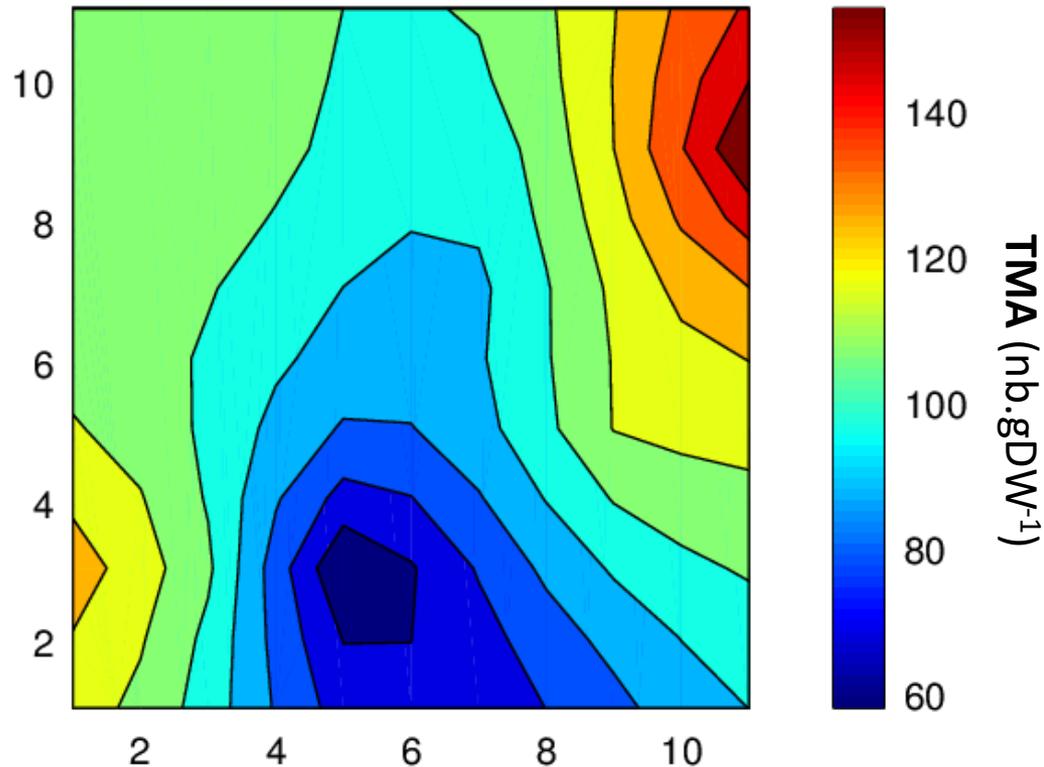## Total Bacteria Biomass (TBB)

Multiple regression analysis :

➜ Relationship between TBB and dead vegetal material

BUT

➜ TBB spatial heterogeneity is also related to a combination of FDC, sediment "quality" parameters (TC, TOC/TN) and pore water nutrient contents
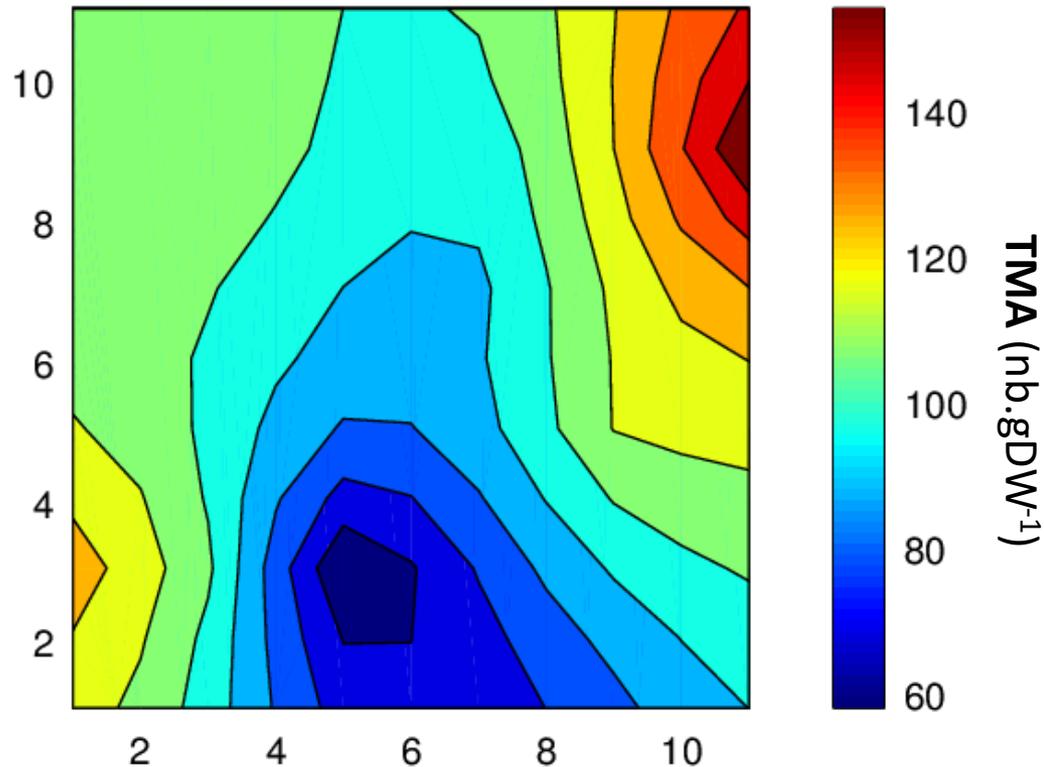
➜ Bacteria probably involved in many processes at small scale

Meiofauna (TMA)

- C.V. = 28.31 % of the mean

- Lowest of the microbenthic loop
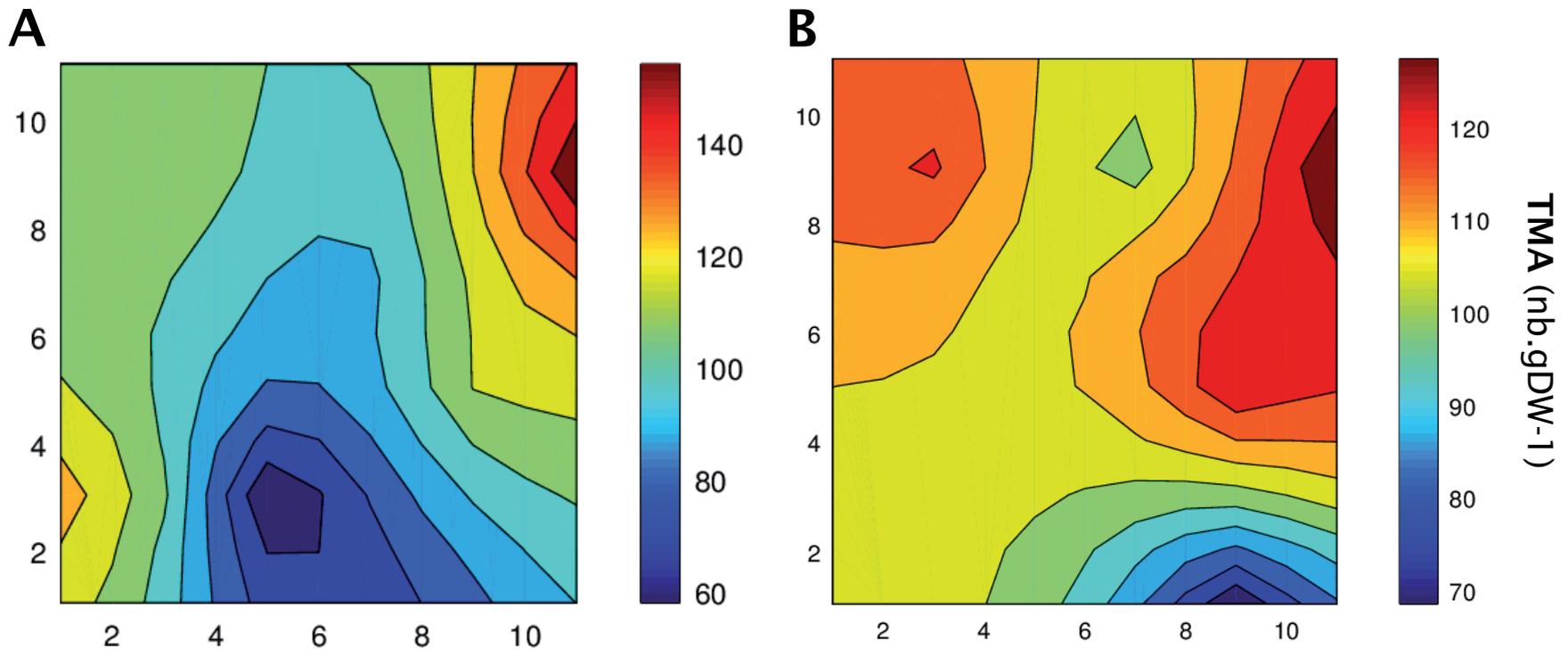
Meiofauna (TMA)

- C.V. = 28.31 % of the mean

- Lowest of the microbenthic loop

- No relationship with microbenthic loop components

Meiofauna (TMA)

Multiple regression analysis :

- Selected parameter and regression coefficient: TC / 16.03
- Selected model R^2 = 0.557 (p-value = 0.008)

A

B

TMA (nb.gDW-1)
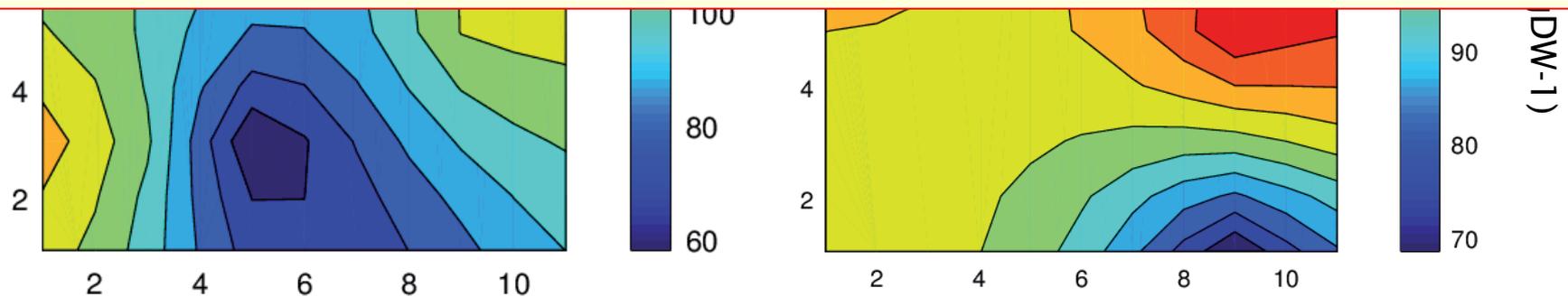
Meiofauna (TMA)

Multiple regression analysis :

- Selected parameter and regression coefficient: TC / 16.03

- Selected model R^2 = 0.557 (p-value = 0.008)

➜ Relationship with sediment "quality" parameters (TN and TP correlated with TC)

➜ Food quality?

➜ *P. oceanica* meadows = "carbonate factory" (epiphytes, particle trapping)

➜ Seems to favour meiofauna abundance at small scale

Microbenthic loop

DistLM procedure:

	Parameter	% Variability	P-value
Marginal tests	$[NH_4^+]$	26.91	0.016
	Log(FDC)	23.36	0.044
Selected models	$Log([NO_2^-+NO_3^-])$	19.74	0.060
	$[NH_4^+]$ $+ Log([NO_2^-+NO_3^-])$	26.91 43.71	0.015 0.066
	$Log(FDC)$ $+ [NH_4^+]$	23.36 41.82	0.035 0.052
	$Log(FDC)$ $+ Phaeo.$	23.36 41.16	0.032 0.069
	$Log([NO_2^-+NO_3^-])$ $+ Phaeo.$	19.74 39.82	0.071 0.051

Microbenthic loop

DistLM procedure:

	Parameter	% Variability	P-value
Marginal tests	$[NH_4^+]$	26.91	0.016

➜ Very few of the measured parameters can explain the spatial heterogeneity ($[NH_4^+]$ + FDC ∼ 42 %)

➜ Relationship with parameters related with degraded material (Phaeo.) or degradation processes linked with bacteria activities

	Parameter	% Variability	P-value
	$+ [NH_4^+]$	41.82	0.052
	Log(FDC)	23.36	0.032
	+ Phaeo.	41.16	0.069
	$Log([NO_2^-+NO_3^-])$	19.74	0.071
	+ Phaeo.	39.82	0.051

Conclusions

- Spatial heterogeneity at small scale

- No relationship between the microbenthic loop components at small scale

- Few measured environmental parameters able to explain the observed heterogeneity

- Bacteria activities seems to be related with living and dead vegetal material

- Meiofauna seems to be related with the "quality" of the sediment

- Globally the spatial heterogeneity seems to be related with degradation processes ($[NH_4^+]$, phaeo.) and bacteria activities

Conclusions

- Spatial heterogeneity at small scale

- No relationship between the microbenthic loop components at small scale

➜ The microbenthic loop seems to be related with degradation processes at small spatial scale

But only a small part of the observed variability was explained by the measured parameters

- Meiofauna seems to be related with the "quality" of the sediment

- Globally the spatial heterogeneity seems to be related with degradation processes ([NH$_4^+$], phaeo.) and bacteria activities

Thank you for your attention!