Temporal changes in the spatial coupling between bentho-demersal fishes and their macrobenthic preys in the Seine estuary

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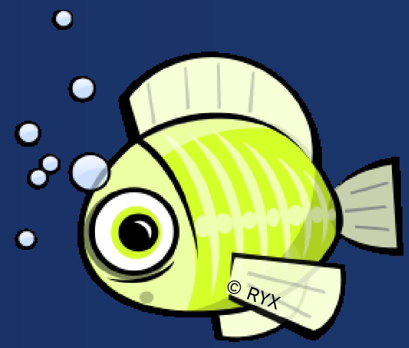
ICES ASC 20-24 September 2010, Nantes

Seine-Aval
Groupement d'intérêt public
Comprendre l'estuaire de la Seine pour mieux le gérer

Introduction



- Estuaries are essential habitats for fishes
- Fish habitat models:
  - Abiotic factors: depth, substrate, salinity, etc
  - Main biotic factors: trophic guilds
- Rarely consider the relationships between fish and their preys in a single model
- Could substantially improve fish / habitat models and our understanding of estuary functionning

- Problem:
  - Availability of “multi-sources” data
  - Differences in sampling schemes
  - Lack of appropriate methodology

Introduction

- This study is part of the multi-disciplinary project COLMATAGE (GIP Seine Aval) bridging different fields ichtyology-benthology-sedimentology to study the functioning of the Seine estuary

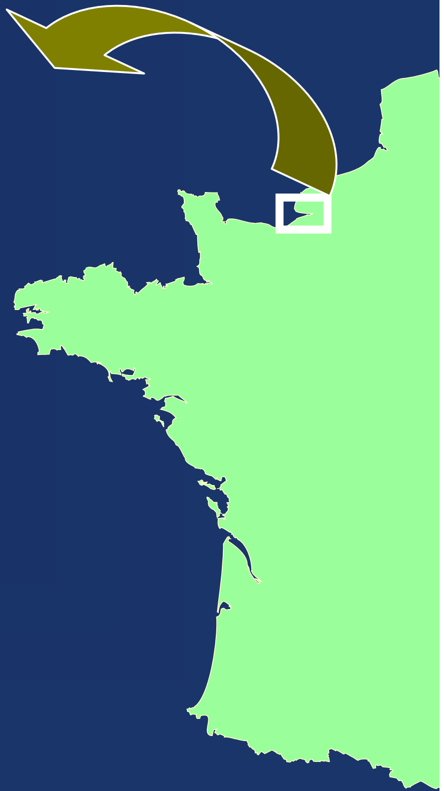
AIMS:

- Adapt a methodology to combine datasets with different sampling schemes
- Analyze spatial relationships between bentho-demersal fish and their potential benthic preys
- Assess temporal changes in time (1996-2002)

Material & Methods

Study area: Seine estuary

- Megatidal
- High river flow
- Highly modified (Port 2000: last harbour infrastructure)
- One of the most polluted estuary in Western Europe

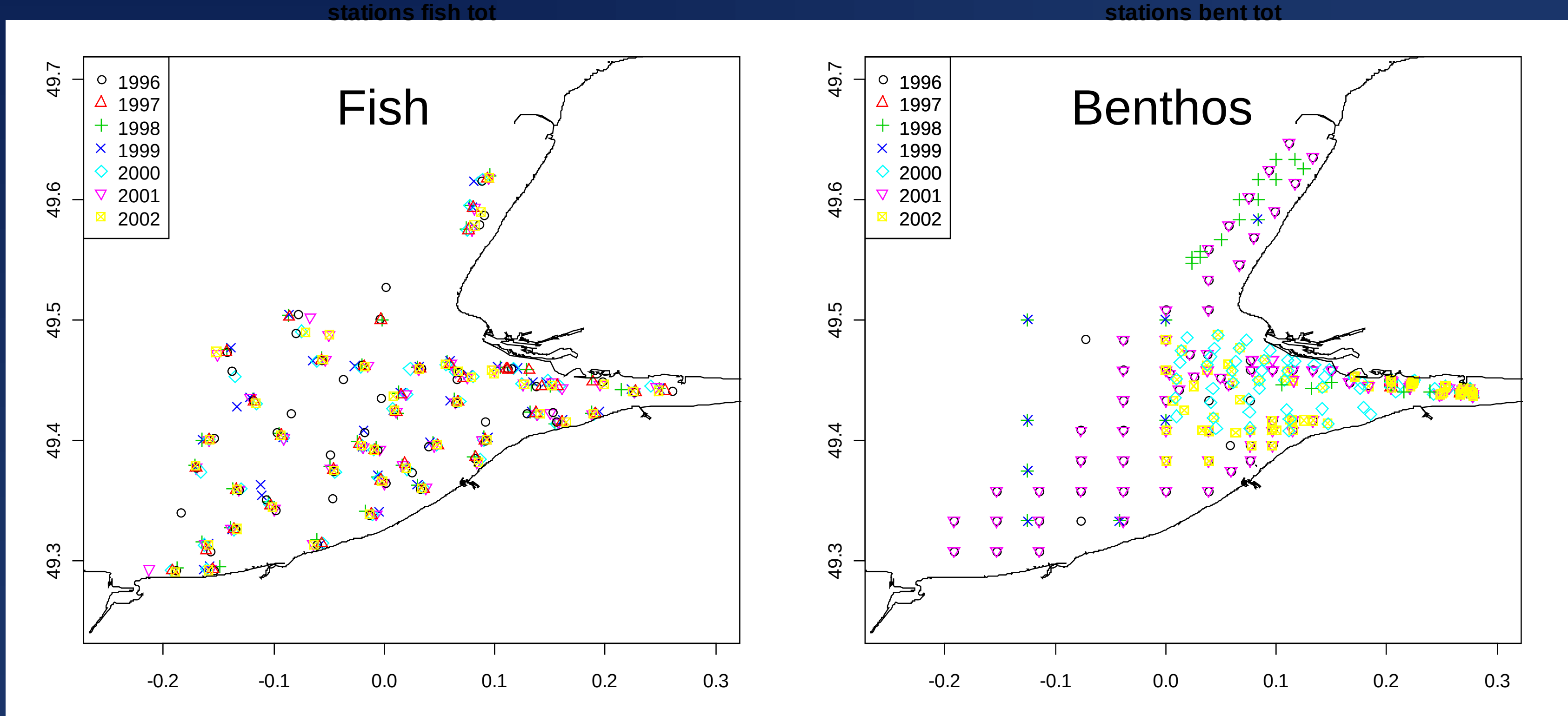


Data:

Two faunal time series (1996-2002)

With different spatial sampling design

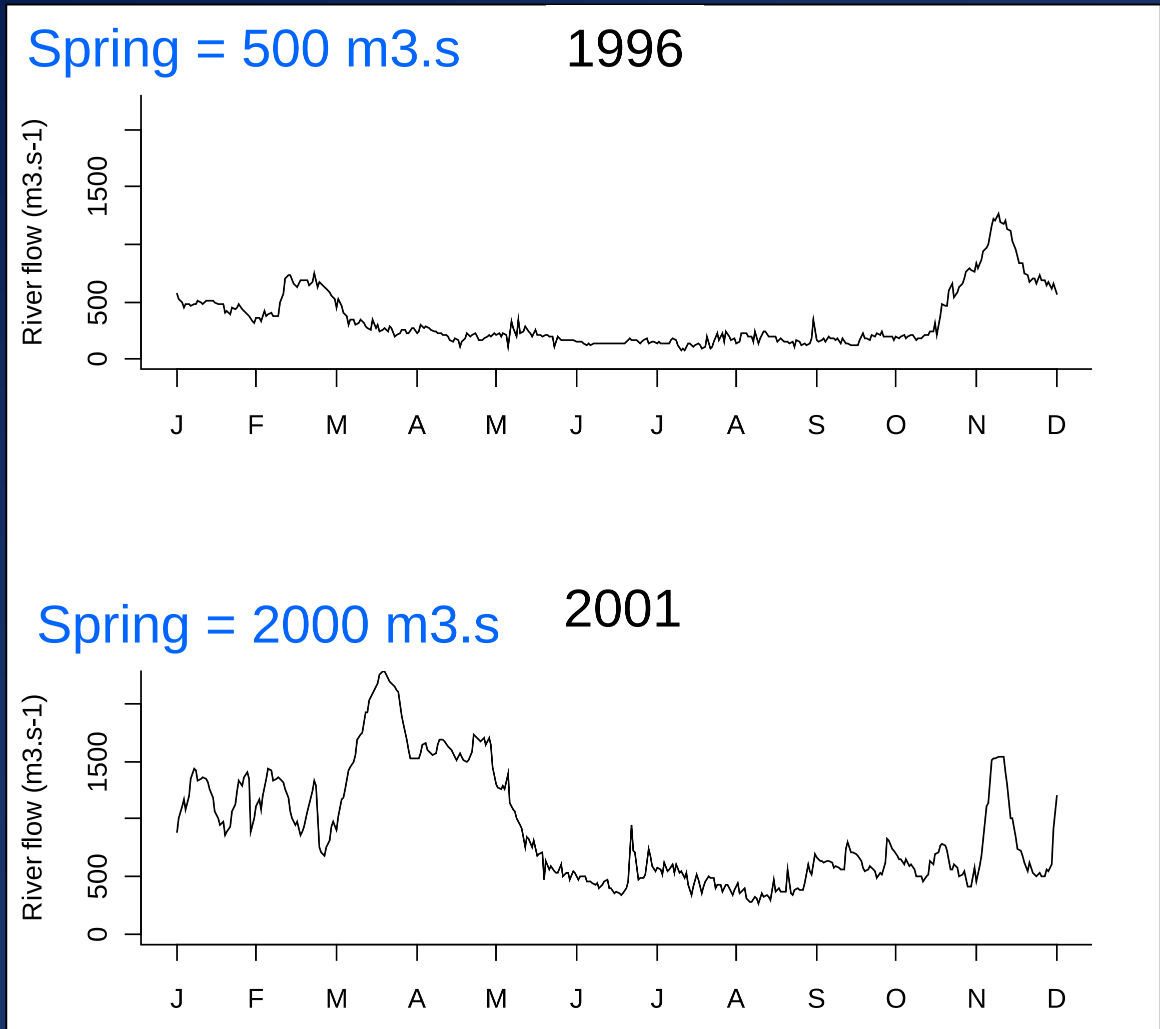
Material & Methods



➢ Focus on two years 1996 & 2001 (best spatial covering)

Material & Methods

Two contrasted years: river flow



Low (dry)

High (wet)

Material & Methods

Data summary:

	Fish	Benthos
Sampling gear	3m beam trawl	grab
Season	autumn	winter (no significant seasonal variability: non parametric manova)
Spatial sampling	systematic	systematic
Taxa selection	bentho-demersal commercial juveniles + dominant non commercial species (n=8)	>=1% occurrence potential benthic preys (based on literature) (n=24)
Metric	density	biomass

Method: Space & time variability of each compartment

(separately for fish and benthos)

Material & Methods

Space:

- Hierarchical clustering (Ward on Gower's distance)
- Identification of indicator species (Dufrêne & Legendre, 1997)

Time:

- Graphical examination
- Numerical comparison of classifications (Mantel test)

Method: Fish-benthos spatial coupling

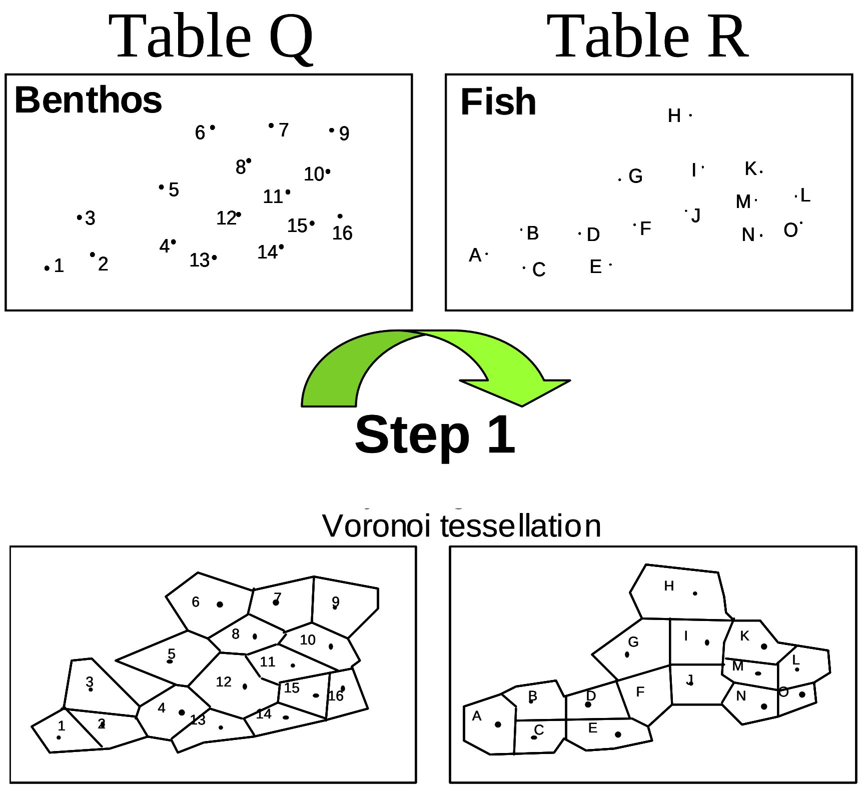
3-table approach

Linking fish and benthos data through a neighbourhood matrix

- Spatial RLQ (Dolédec, 1996; Dray *et al*, 2002)
  - ordination and spatial representation
  - Extension of co-inertia analysis taking linear combinations of variables of the two datasets which maximize the spatial cross-covariance
- Fourth corner (Legendre *et al*, 1997; Legendre & Dray, 2008)
  - correlations
  - Estimate the relationships between each couple of variables of the two datasets and test the significance using permutations

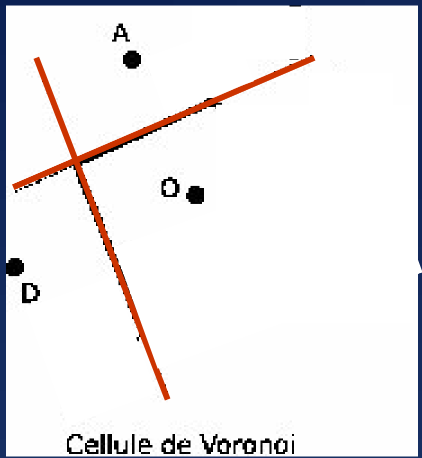
Method: Fish-benthos spatial coupling

Material & Methods



Material & Methods

Method: Voronoi tessalation



Chaque sommet du diagramme de Voronoï est le point de rencontre de trois arêtes de Voronoï

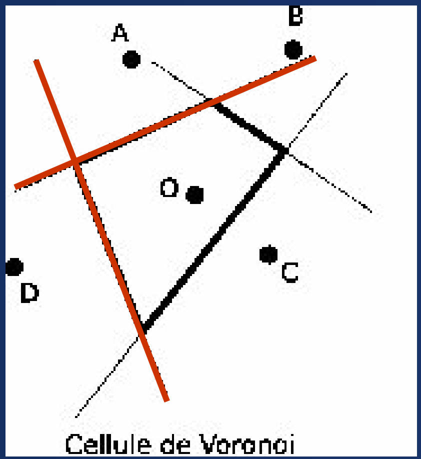


Diagramme de Voronoï : l'union des régions de Voronoï de tous les points.

Method: Fish-benthos spatial coupling

Material & Methods

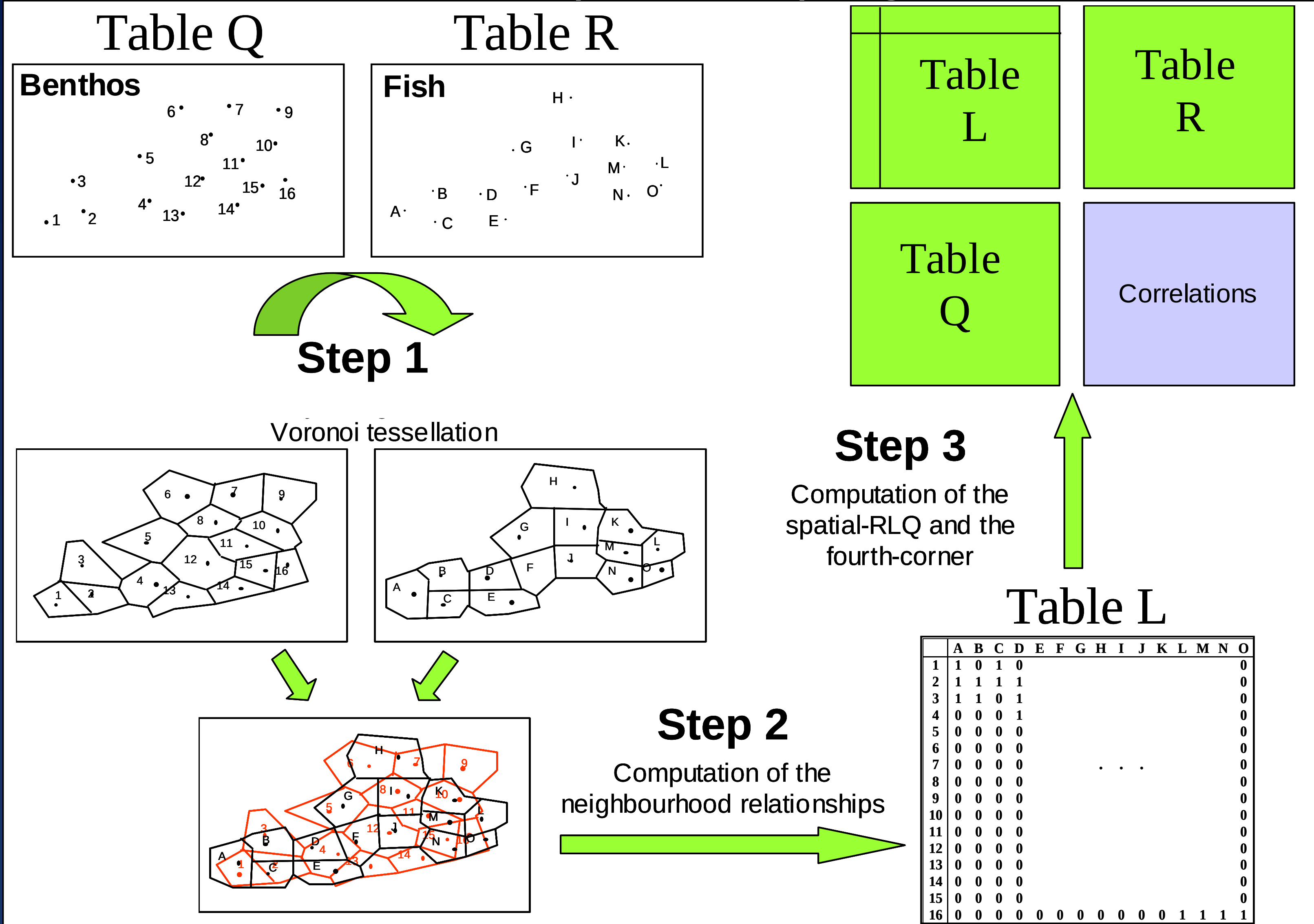
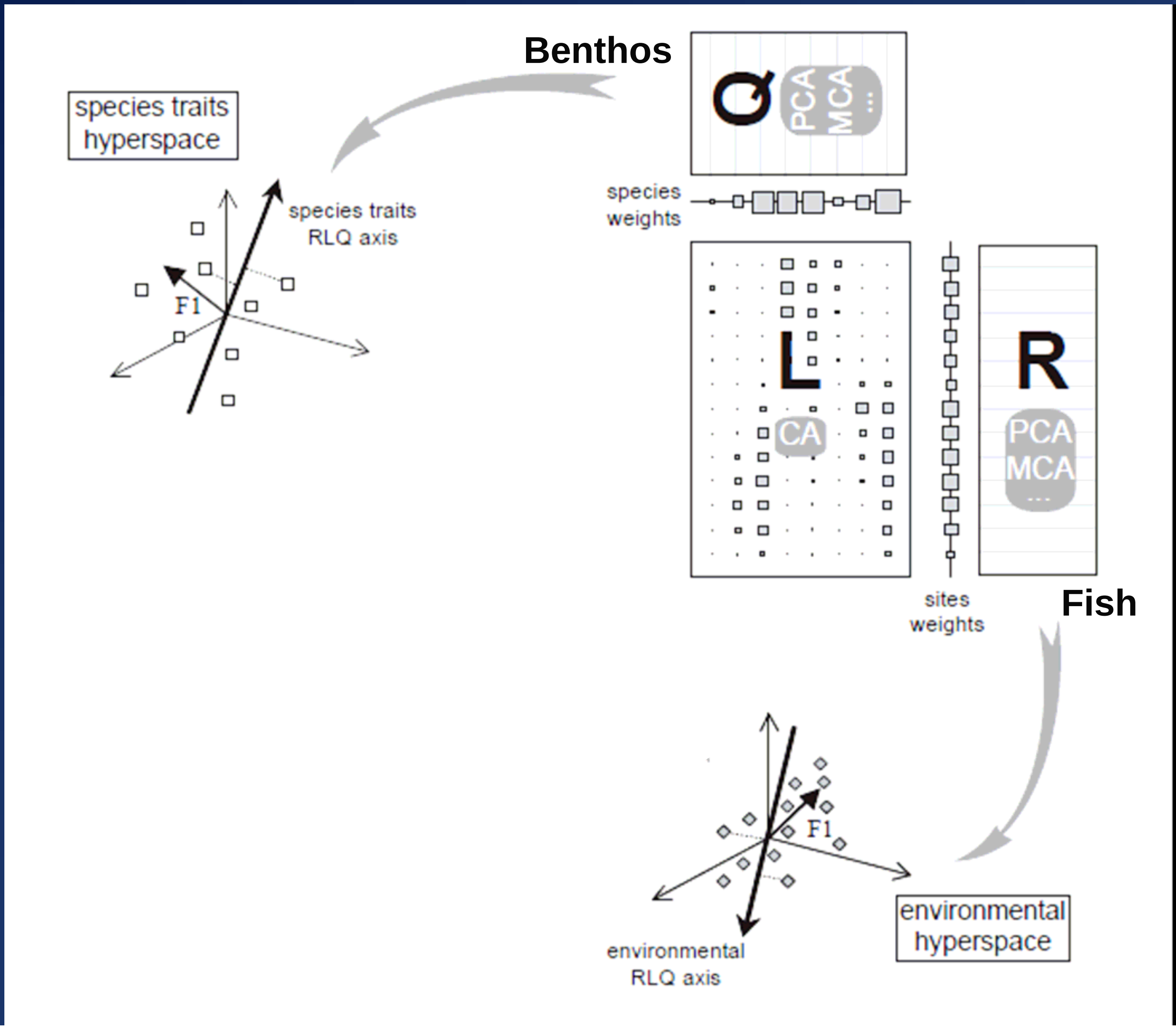


Table L

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	1	0	1	0											0
2	1	1	1	1											0
3	1	1	0	1											0
4	0	0	0	1											0
5	0	0	0	0											0
6	0	0	0	0											0
7	0	0	0	0				.	.	.					0
8	0	0	0	0											0
9	0	0	0	0											0
10	0	0	0	0											0
11	0	0	0	0											0
12	0	0	0	0											0
13	0	0	0	0											0
14	0	0	0	0											0
15	0	0	0	0											0
16	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1

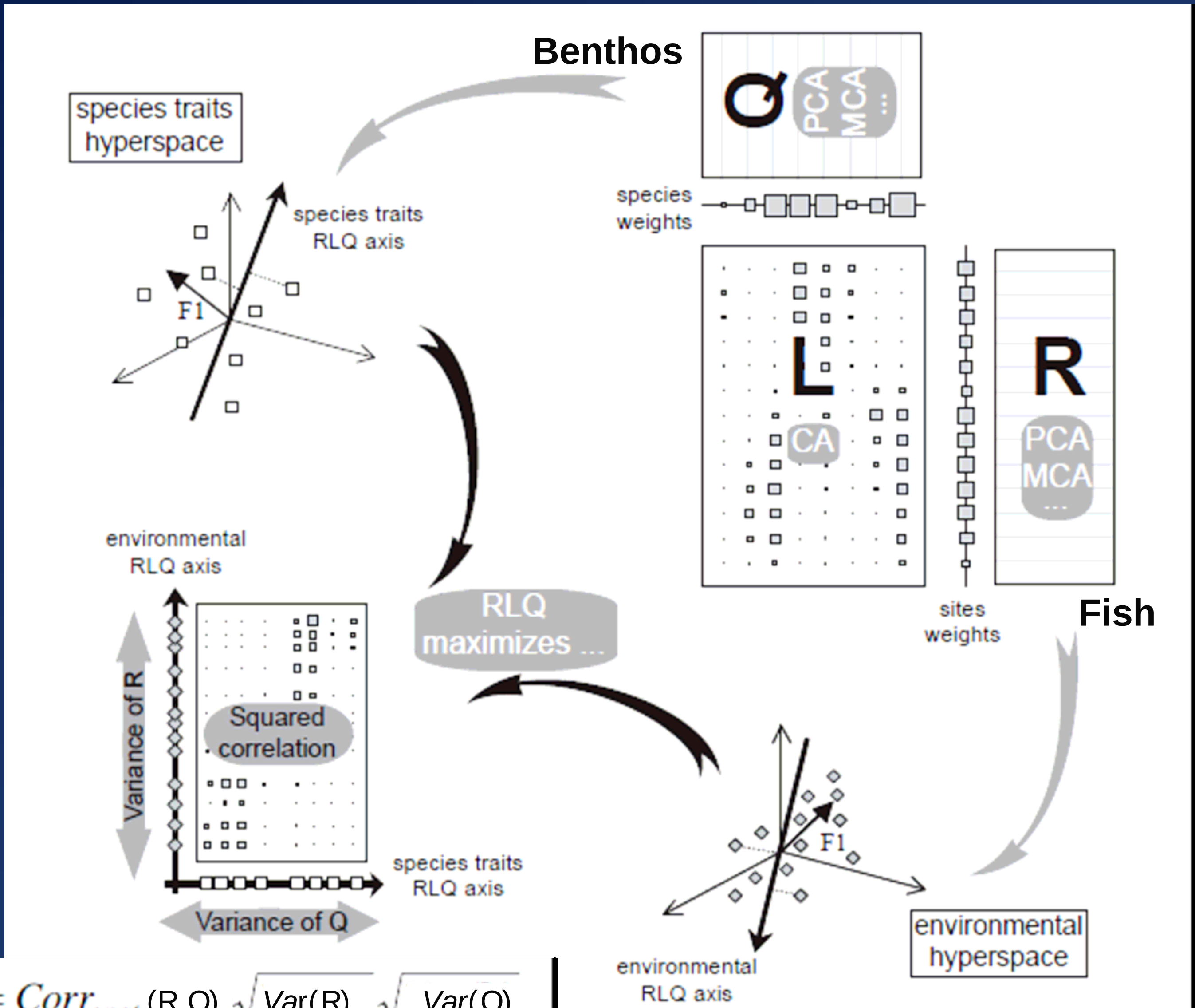
Material & Methods

Method: RLQ analysis (Dray, unpublished)



Method: RLQ analysis (Dray, unpublished)

Material & Methods



$$Cov_{spat}(R,Q) = Corr_{spat}(R,Q)\sqrt{Var(R)}\sqrt{Var(Q)}$$

Material & Methods

Method: Fourth Corner analysis (Legendre et al. 1997)

$$\begin{bmatrix} \mathbf{A}\ (k \times m) & \mathbf{B}\ (k \times n) \\ \mathbf{C}\ (p \times m) & \mathbf{D}\ (p \times n) \end{bmatrix}$$

↓

$$\mathbf{D} = \mathbf{CA'B}$$

Test case 1

	A) Stn. 1	Stn. 2	B) Herbiv.	Carniv.
Sp. 1	0	1	0	1
Sp. 2	0	1	0	1
Sp. 3	1	0	0	1
Sp. 4	1	0	0	1
Sp. 5	1	0	0	1
Sp. 6	0	1	1	0
Sp. 7	0	1	1	0
Sp. 8	0	1	1	0
Sp. 9	0	1	1	0
Sp. 10	0	1	1	0

	C) Stn. 1	Stn. 2
Live coral	1	0
Turf	0	1

(a) Inflated data table

Occurrences in test case 1	Feeding habits from B	Habitat types from C
Sp. 1 @ Stn. 2	Carnivorous	Turf
Sp. 2 @ Stn. 2	Carnivorous	Turf
Sp. 3 @ Stn. 1	Carnivorous	Live coral
Sp. 4 @ Stn. 1	Carnivorous	Live coral
Sp. 5 @ Stn. 1	Carnivorous	Live coral
Sp. 6 @ Stn. 2	Herbivorous	Turf
Sp. 7 @ Stn. 2	Herbivorous	Turf
Sp. 8 @ Stn. 2	Herbivorous	Turf
Sp. 9 @ Stn. 2	Herbivorous	Turf
Sp. 10 @ Stn. 2	Herbivorous	Turf

(b) Contingency table (**D**)

	Herbiv.	Carniv.
Live coral	0	3
Turf	5	2

Method: Fourth Corner analysis (Legendre et al. 1997)

Material & Methods

$$\begin{bmatrix} \mathbf{A}\ (k \times m) & \mathbf{B}\ (k \times n) \\ \mathbf{C}\ (p \times m) & \mathbf{D}\ (p \times n) \end{bmatrix}$$

↓

$$\mathbf{D} = \mathbf{CA'B}$$

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Sp. 5	1	0	0	1
Sp. 6	0	1	1	0
Sp. 7	0	1	1	0
Sp. 8	0	1	1	0
Sp. 9	0	1	1	0
Sp. 10	0	1	1	0

C)	Stn. 1	Stn. 2	D) Herbiv.	Carniv.
Live coral	1	0	0 − $P = 0.027$ $E = 0.03125$	3+ $P = 0.494$ $E = 0.500$
Turf	0	1	5+ $P = 0.027$ $E = 0.03125$	2− $P = 0.494$ $E = 0.500$

Contingency statistic:
$G = 5.4872$; P (9999 perm.) = 0.058

(a) Inflated data table			(b) Contingency table (D)		
Occurrences in test case 1	Feeding habits from B	Habitat types from C		Herbiv.	Carniv.
Sp. 1 @ Stn. 2	Carnivorous	Turf	Live coral	0	3
Sp. 2 @ Stn. 2	Carnivorous	Turf			
Sp. 3 @ Stn. 1	Carnivorous	Live coral	Turf	5	2
Sp. 4 @ Stn. 1	Carnivorous	Live coral			
Sp. 5 @ Stn. 1	Carnivorous	Live coral			
Sp. 6 @ Stn. 2	Herbivorous	Turf			
Sp. 7 @ Stn. 2	Herbivorous	Turf			
Sp. 8 @ Stn. 2	Herbivorous	Turf			
Sp. 9 @ Stn. 2	Herbivorous	Turf			
Sp. 10 @ Stn. 2	Herbivorous	Turf			

$$G = 2 \sum_{ij} O_{ij} \cdot \ln(O_{ij}/E_{ij})$$

- *G* statistic
- Permutations

Results

1° Space & time variability:

Fish and benthos separately

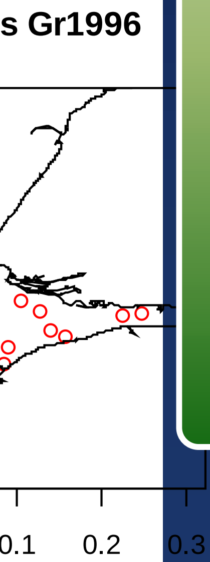
2° Fish-benthos spatial coupling:

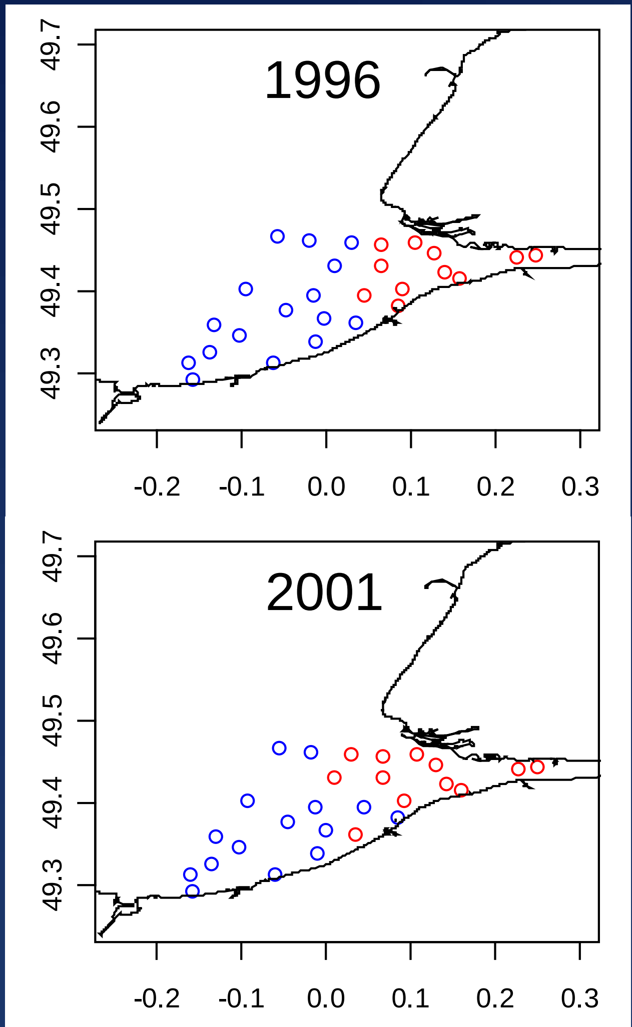
RLQ and Fourth corner results

Space & time variability: Fish

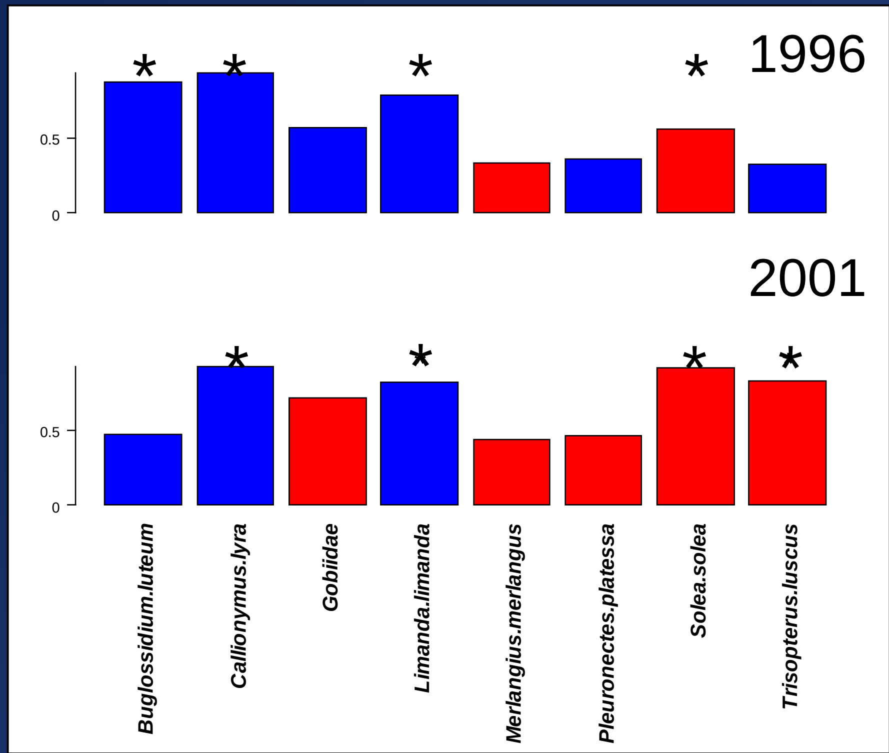
Results (1°)

No difference in total density between years





Spatial Clusters Gr2001



Mantel's statistics = 0.373; P = 0.006

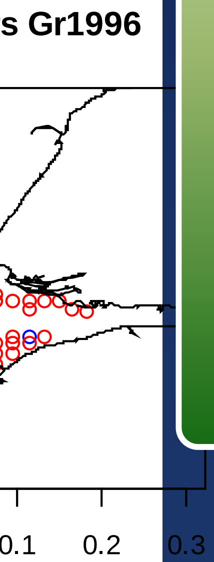
* Indicator species

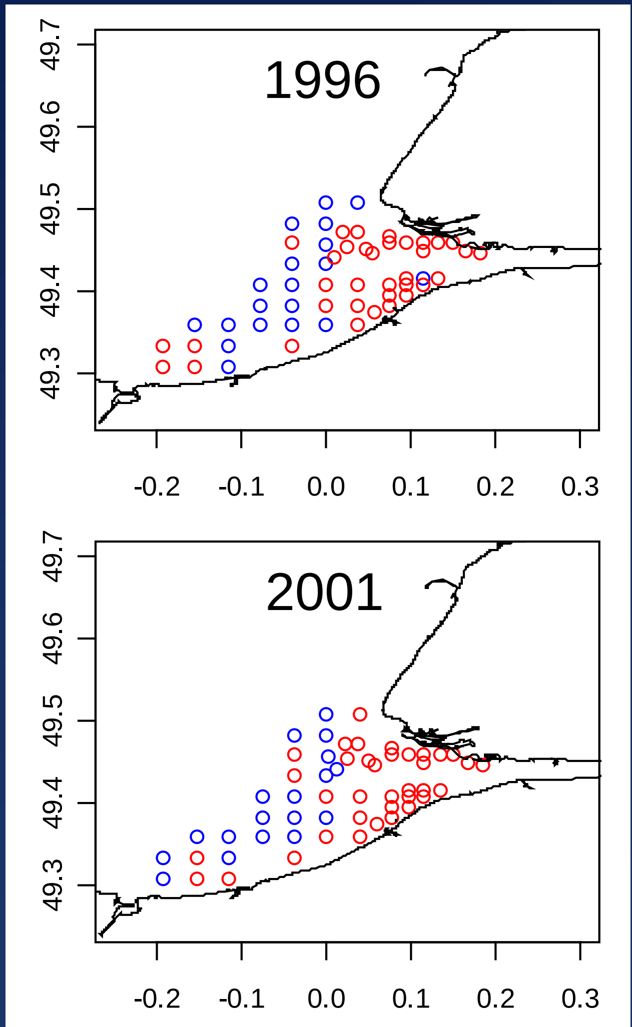
Space & time variability: Benthos

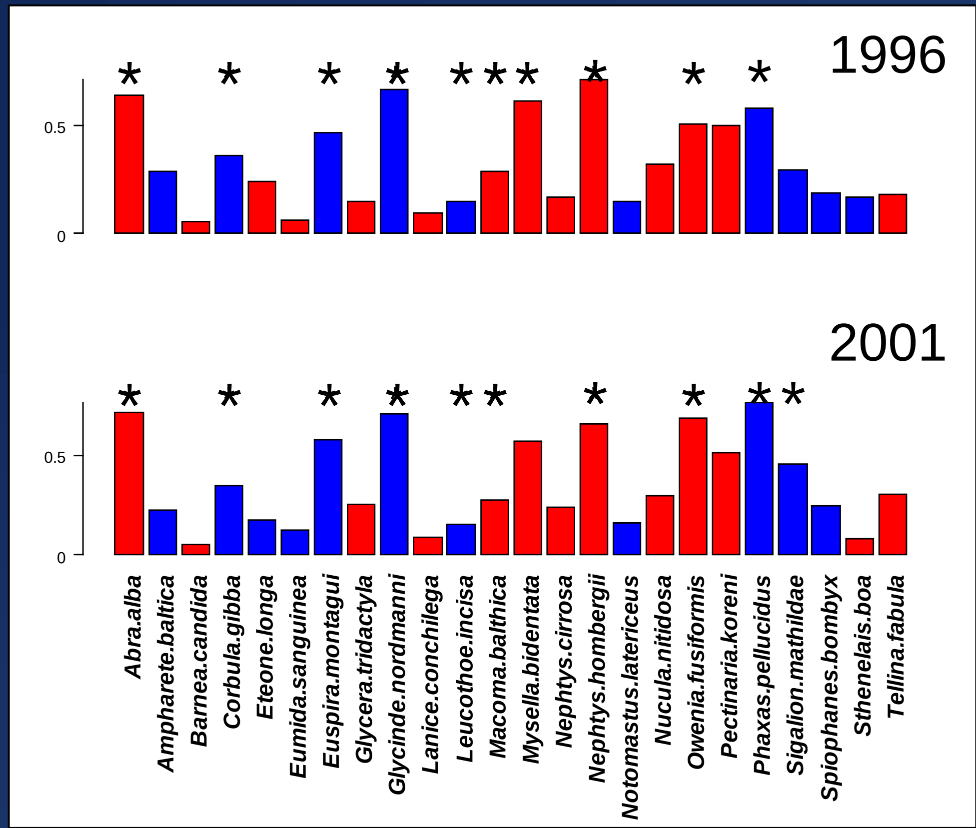
No difference in total biomass between years

Spatial Clusters Gr2001

Results (1°)







Mantel's statistics = 0.430; P = 0.001

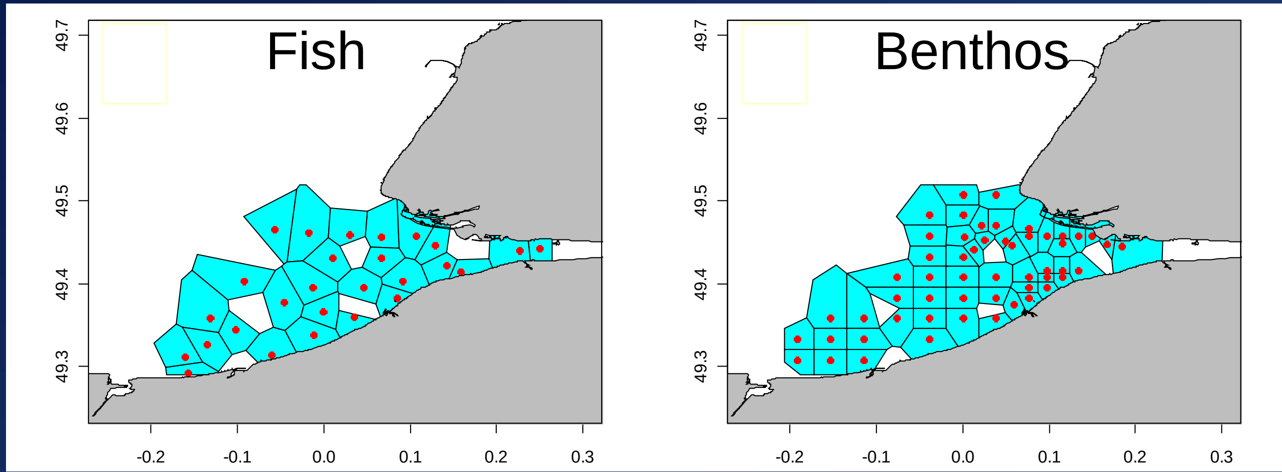
* Indicator species

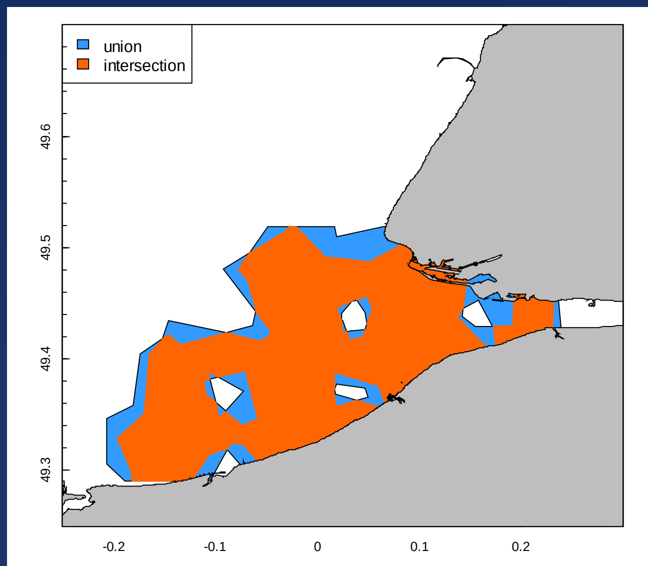
Fish-benthos spatial coupling

Years:

1996-2001

Results (2°)





percentcover.in.out = 77.83 %

Overlap: 78%

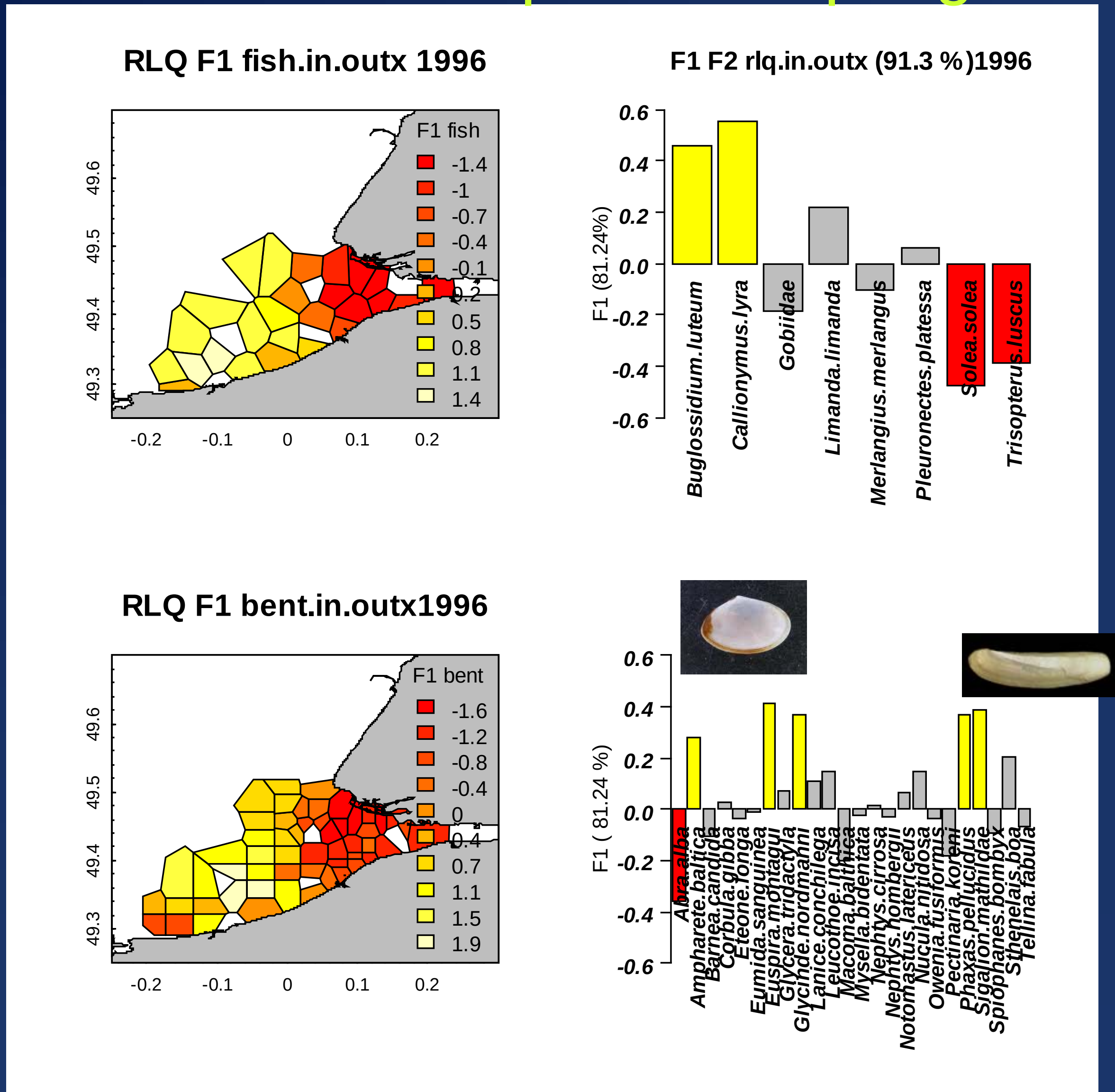
Fish-benthos spatial coupling

Spatial RLQ
1996

Results (2°)

F1: 91.3%

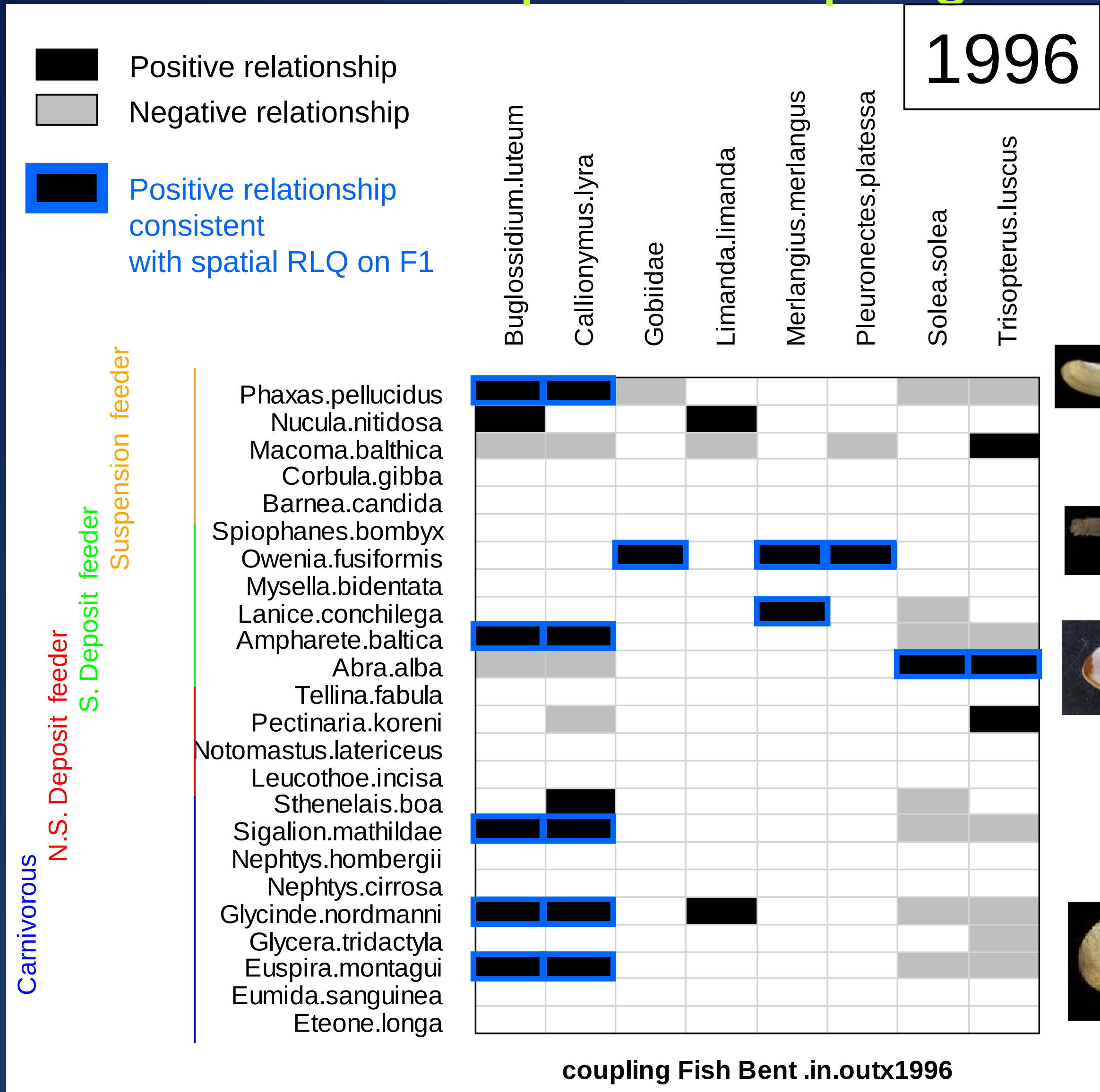
F1: 81.2%

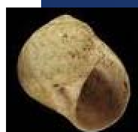


Fish-benthos spatial coupling

Fourth corner
1996

Results (2°)



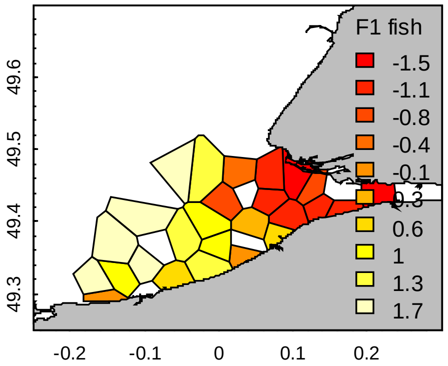


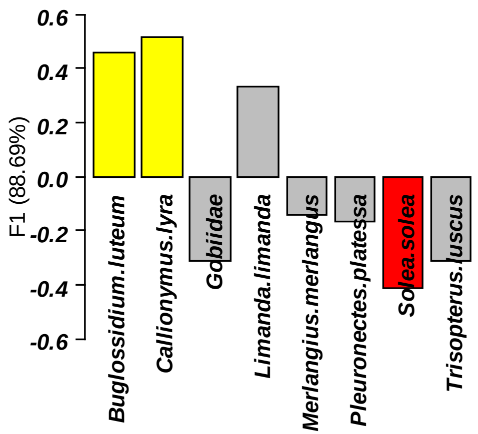
Fish-benthos spatial coupling

Spatial RLQ
2001

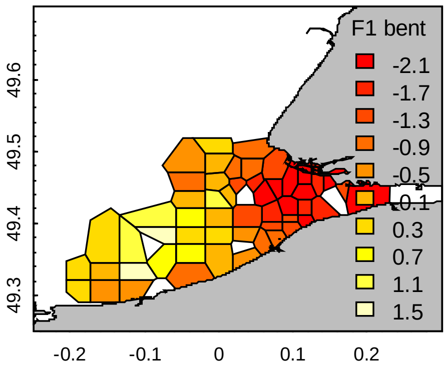
Results (2°)

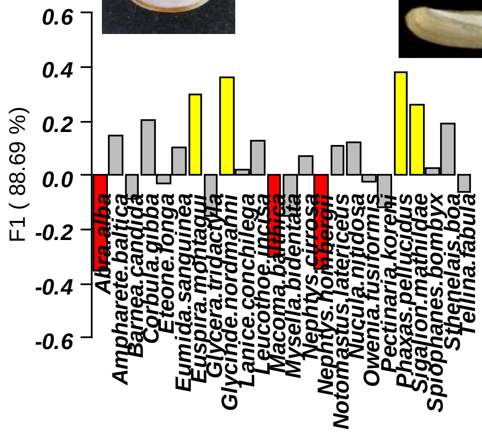
F1: 94.1%





F1: 88.7%

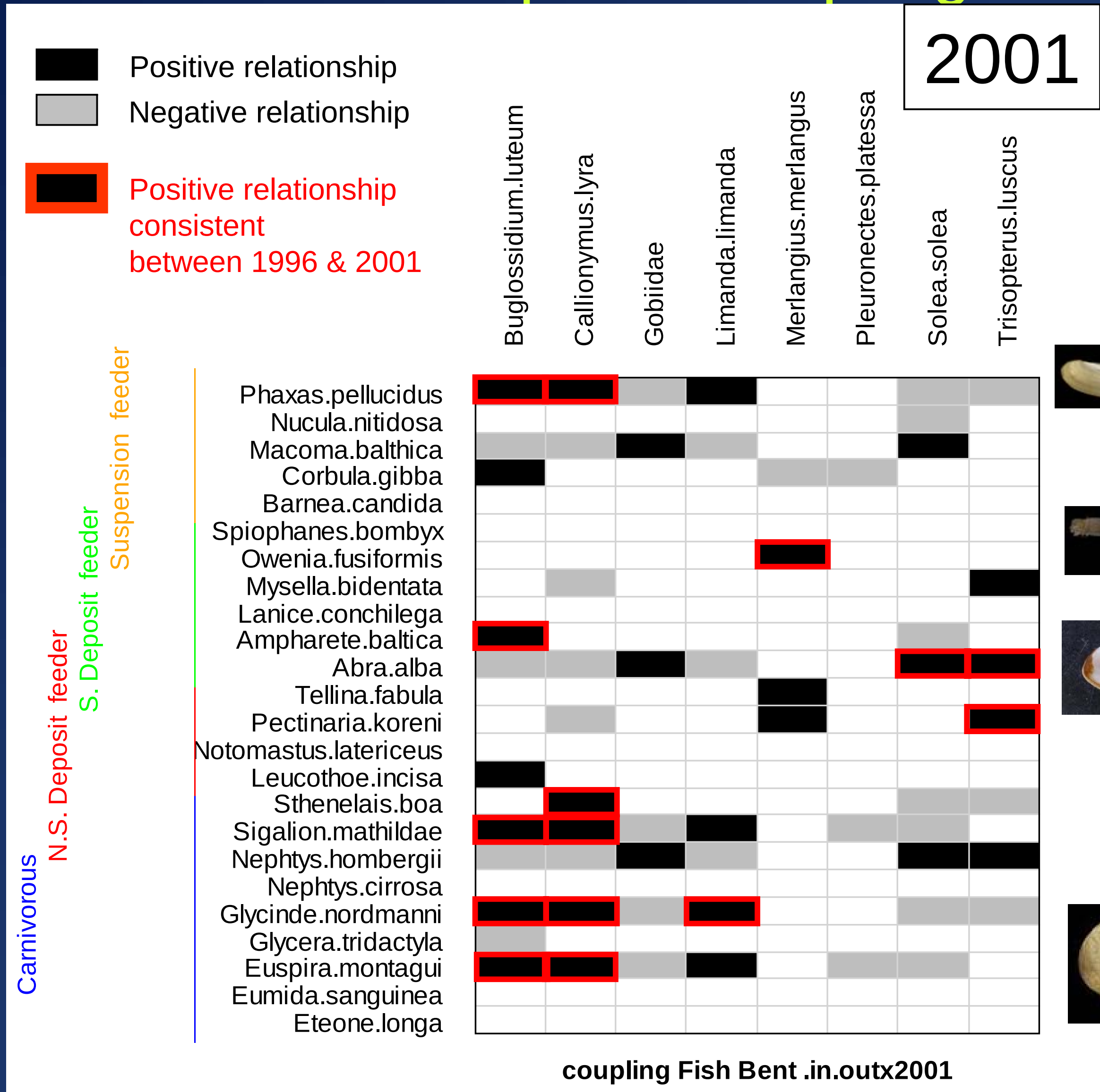


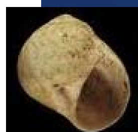


Fish-benthos spatial coupling

Fourth corner
2001

Results (2°)





Discussion - Conculsion

- Methodological interests:
  - Spatial coupling between datasets from different sampling schemes
  - Complementarity between spatial RLQ and Fourth corner outputs
  - Multivariate method: large number of variables in a synthetic way
- Limits:
  - Representativity of polygons around sampling points
- Ecology
  - Two major communities for both fish and benthos (inner and outer estuary)
  - Spatial relationships between fish (predator) and bentic preys
  - Preliminary approach before testing trophic relationships and implementing habitat models (Colmatage project)
- Perspectives:
  - Test the contribution of environmental variables on the spatial relationships
  - Ongoing functional study on habitat use and trophic interactions for 3 flatfish species

Thank you for your attention!

Limanda limanda

Callionymus lyra

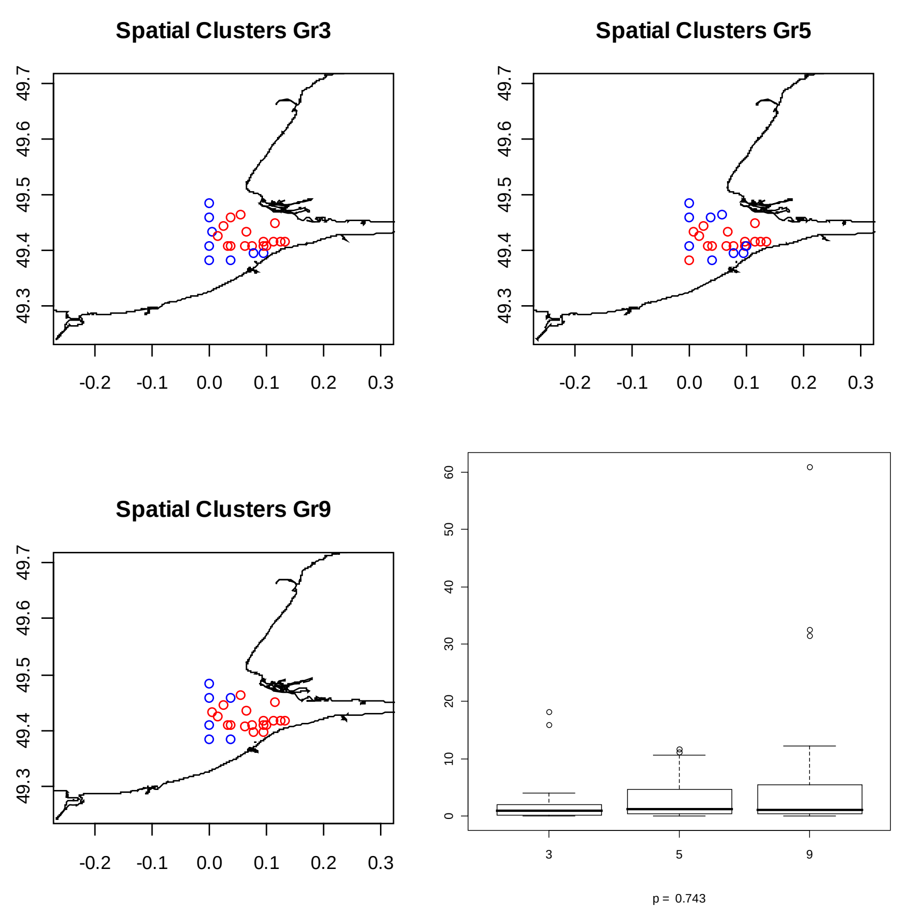
Solea solea

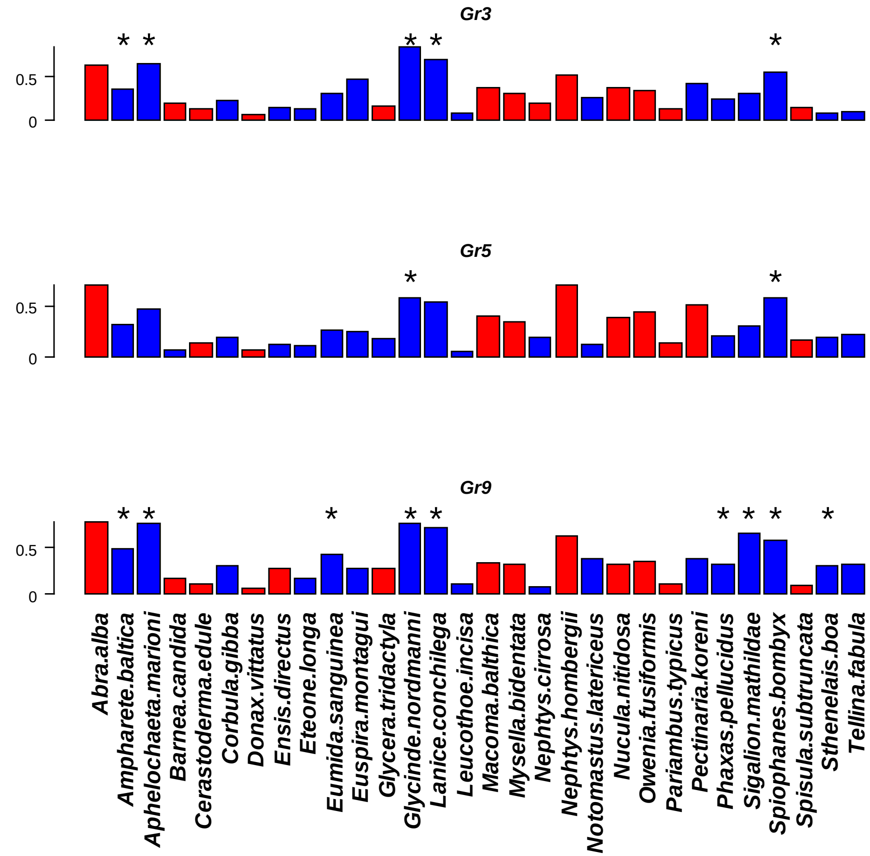
Leucothoe incisa

Nephtys hombergii

Phaxas pellucidus

Benthos seasonal variability





	Mantel.s.stat	p	sig
March vs May	0.311	0.017	*
March vs September	0.416	0.008	*
May vs September	0.314	0.019	*

Numerical comparison of classifications (Mantel test)

1) Translate each classification into a disjonctive matrix

G1: 3 1 4 2 2 1 3 1 1 4 1

	G11	G12	G13	G14
1	1	0	0	0
2	0	0	1	0
3	1	0	0	0
4	0	1	0	0
5	0	0	0	1
6	0	0	1	0
7	1	0	0	0
8	0	1	0	0
9	0	0	1	0
10	0	0	0	1
11	0	0	1	0

2) Transform disjonctive matrix in a dissimilarity matrix (Jacard's coefficient)

	1	2	3	4	5	6	7	8	9	10
2	1									
3	0	1								
4	1	1	1							
5	1	1	1	1						
6	1	0	1	1	1					
7	0	1	0	1	1	1				
8	1	1	1	0	1	1	1			
9	1	0	1	1	1	0	1	1		
10	1	1	1	1	0	1	1	1	1	
11	1	0	1	1	1	0	1	1	0	1

3) Compare the matrices with Mantel tests