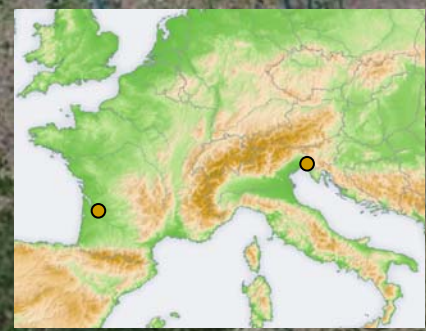
Inverse Matrix: an easy tool to test interactions in a trophic network

Application to the Gironde Estuary (France)

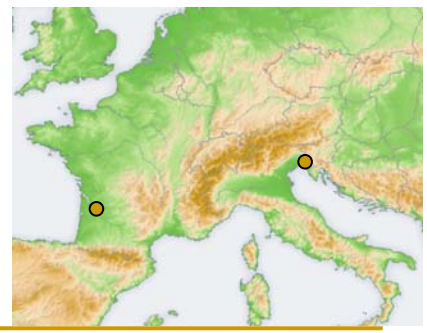
Sébastien Rochette, Jérémy Lobry,
Mario Lepage & Philippe Boët

Cemagref-Bordeaux, France



Outline

- Trophic food webs modelling
  - To approach the functioning of ecosystems
  - To calculate trophodynamic indicators
  - To compare different ecosystems



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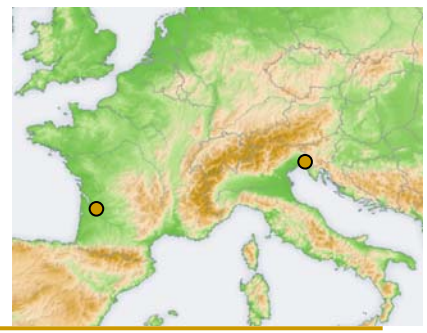
- How to make forecasts ?
  - Under compartment or human pressure modifications



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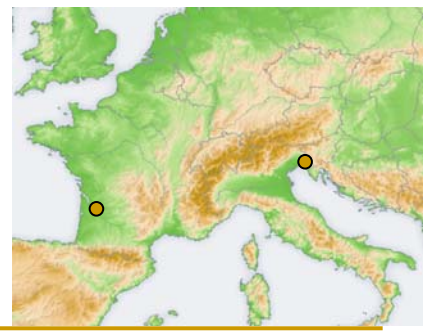

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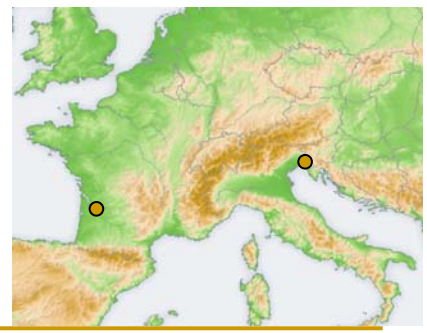
- Qualitative approaches are attractive (Levins loop analysis)
  - Direct and indirect interactions taken into account
  - Not only biological compartments (e.g. fishermen or power plant)
  - Easy to use



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  - Direct and indirect interactions taken into account
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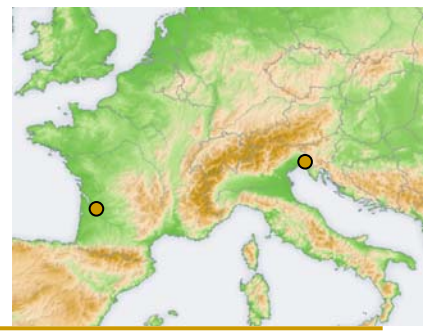
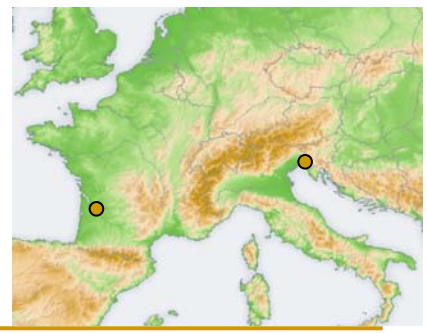
  - Easy to use
- A test on the Gironde case
  - A comparison with an existing Ecopath model *(Lobry et al. 2004)*



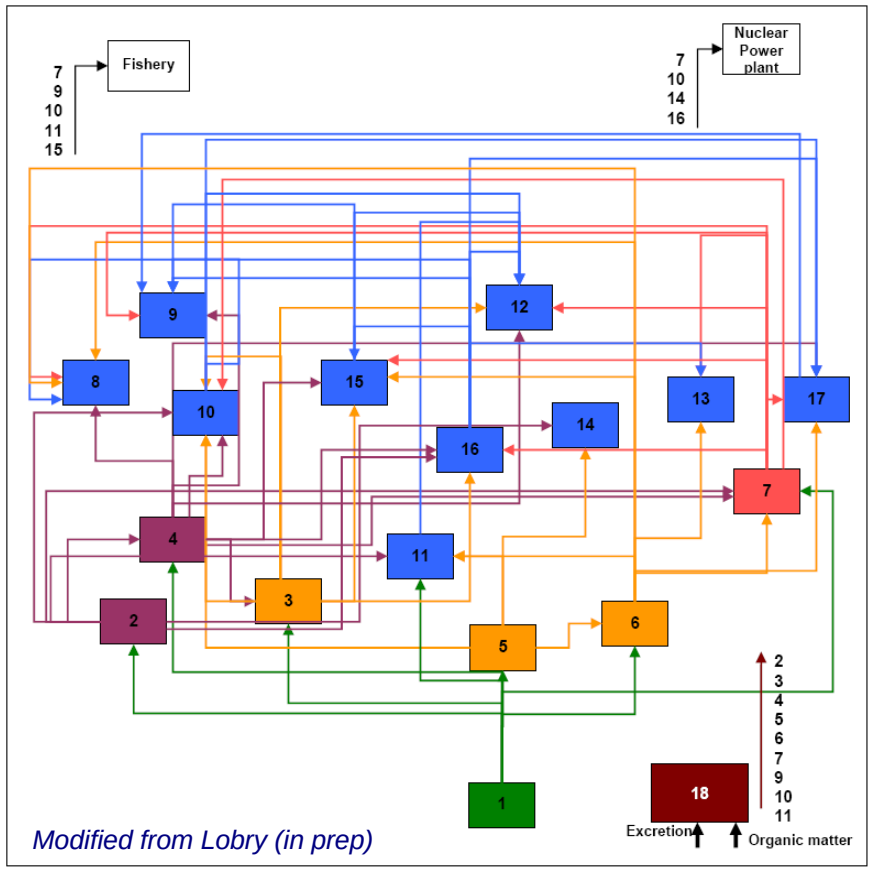
Plan

- Reasons for the implementation
- Using a sensitivity analysis to perform Community matrix inversion
- Interpretation of the results and similarities with Ecopath



Using a known trophic network: The Gironde estuary food web

1.	Primary producers	11.	Mulets
2.	Copepods	12.	Big marine fish
3.	Suprabenthos	13.	Big pelagic fish
4.	Mysids	14.	Pipe fish
5.	Meiobenthos	15.	Flat fish
6.	Macrobenthos	16.	Gobids
7.	Shrimps	17.	Freshwater fish
8.	Sturgeons	18.	Detritus
9.	Eels	19.	Fishery
10.	Small pelagic fish	20.	Nuclear power plant



Modified from Lobry (in prep)

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- Many trophic interaction links, strong and weak ones

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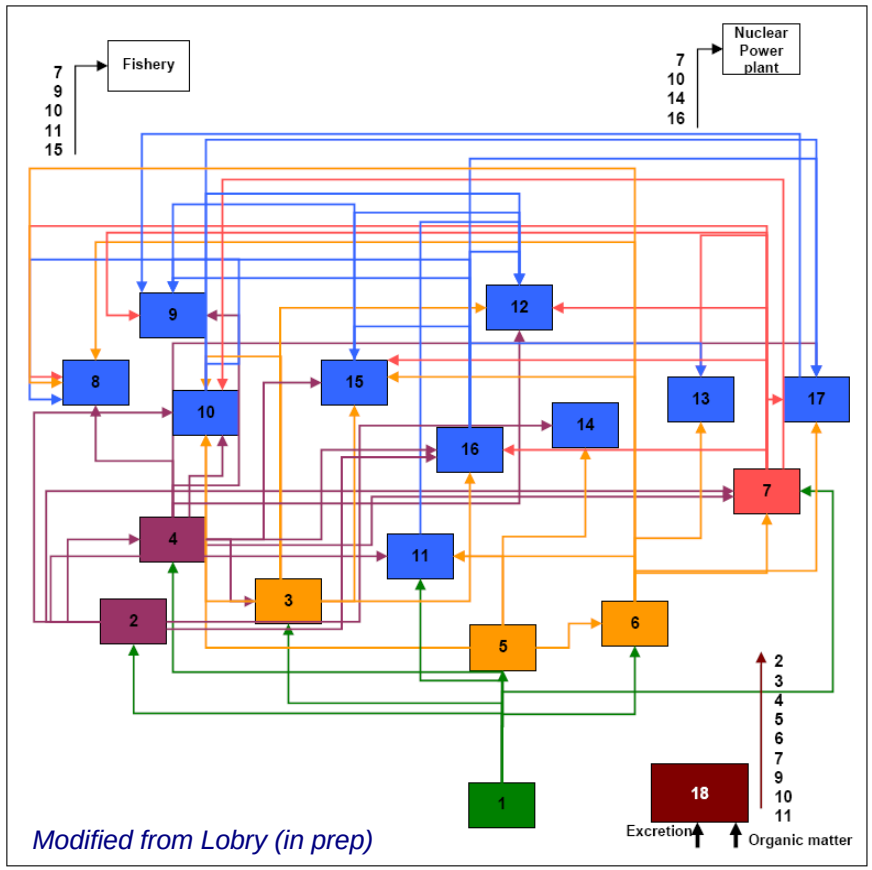

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Using a known trophic network: The Gironde estuary food web

- Many trophic interaction links, strong and weak ones

- Ecopath model considered as a reference for our inverse matrixes study

1.	Primary producers	11.	Mulets
2.	Copepods	12.	Big marine fish
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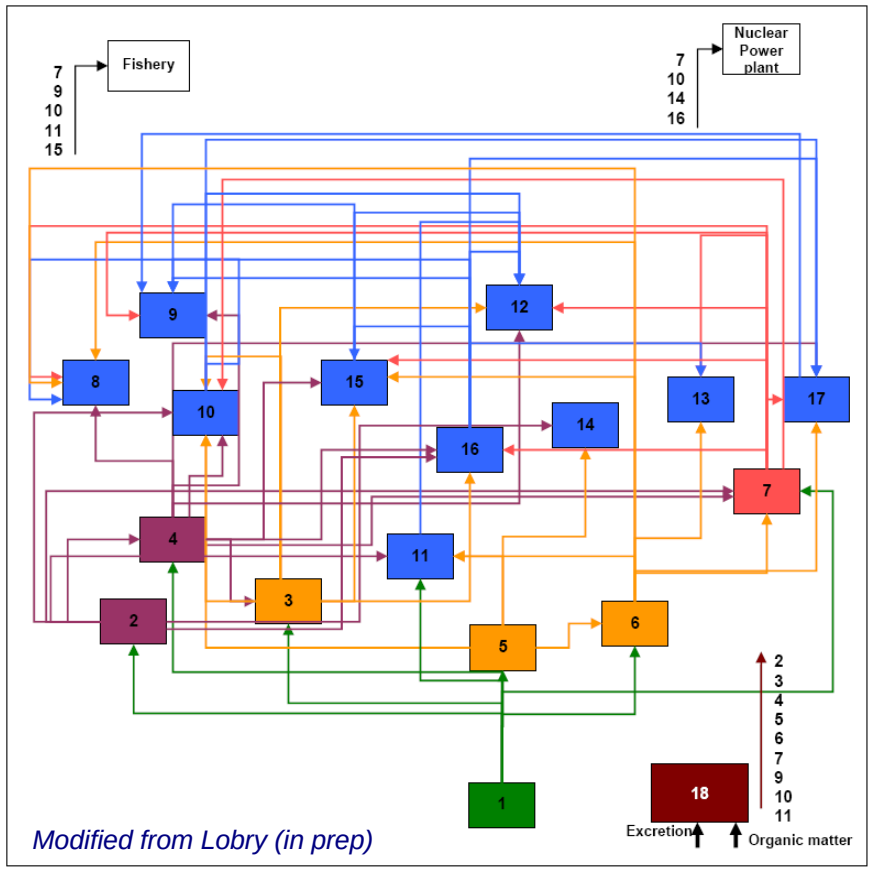

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Loop Analysis

- First step: construction of the "Community matrix"

1.	Primary producers	11.	Mulets
2.	Copepods	12.	Big marine fish
3.	Suprabenthos	13.	Big pelagic fish
4.	Mysids	14.	Pipe fish
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	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	-1	-1	-1	-1	-1	-1	0	0	0	-1	0	0	0	0	0	0	0	0	0	0
2	1	-1	-1	0	0	0	0	0	-1	0	0	0	0	0	-1	0	0	1	0	0
3	1	1	-1	0	0	0	-1	-1	-1	0	-1	0	-1	0	-1	-1	0	1	0	0
4	1	0	0	-1	-1	0	0	0	-1	-1	0	0	-1	0	0	0	0	1	0	0
5	1	0	0	1	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	-1	0	1	0	0
6	1	0	0	0	1	-1	-1	-1	-1	0	-1	-1	0	-1	-1	-1	0	1	-1	-1
7	0	0	1	0	1	1	-1	0	0	0	0	0	0	0	1	0	0	0	0	0
8	0	0	1	0	1	1	0	-1	1	0	0	0	0	1	1	1	1	1	-1	0
9	0	1	1	1	1	1	0	-1	-1	0	-1	-1	0	0	0	-1	0	1	0	-1
10	1	0	0	1	0	0	0	0	0	-1	-1	0	0	0	0	0	0	1	-1	0
11	0	0	1	0	1	1	0	0	1	1	-1	0	0	1	1	0	0	1	-1	0
12	0	0	0	0	1	1	0	0	1	0	0	-1	0	0	0	0	0	0	0	0
13	0	0	1	1	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	-1
14	0	0	0	0	1	1	0	-1	0	0	-1	0	0	-1	1	0	0	0	-1	0
15	0	1	1	0	0	1	-1	-1	0	0	-1	0	0	-1	-1	-1	0	1	0	-1
16	0	0	1	0	1	1	0	-1	1	0	0	0	0	0	1	-1	0	0	0	0
17	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	-1	0	-1	-1
18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	1	1
19	0	0	0	0	0	1	0	1	0	1	1	0	0	1	0	0	1	0	-1	0
20	0	0	0	0	0	1	0	0	1	0	0	0	1	0	1	0	1	0	0	-1

Loop Analysis

- First step: construction of the "Community matrix"
- Second step: calculation of the "Adjoint matrix" with an inversion *(Dambacher, 2001)*

1.	Primary producers	11.	Mulets
2.	Copepods	12.	Big marine fish
3.	Suprabenthos	13.	Big pelagic fish
4.	Mysids	14.	Pipe fish
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	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	-1	-1	-1	-1	-1	-1	0	0	0	-1	0	0	0	0	0	0	0	0	0	0
2	1	-1	-1	0	0	0	0	0	-1	0	0	0	0	0	-1	0	0	1	0	0
3	1	1	-1	0	0	0	-1	-1	-1	0	-1	0	-1	0	-1	-1	0	1	0	0
4	1	0	0	-1	-1	0	0	0	-1	-1	0	0	-1	0	0	0	0	1	0	0
5	1	0	0	1	-1	-1	-1	-1	-1	0	-1	-1	0	-1	0	-1	0	1	0	0
6	1	0	0	0	1	-1	-1	-1	-1	0	-1	-1	0	-1	-1	-1	0	1	-1	-1
7	0	0	1	0	1	1	-1	0	0	0	0	0	0	0	1	0	0	0	0	0
8	0	0	1	0	1	1	0	-1	1	0	0	0	0	1	1	1	1	1	-1	0
9	0	1	1	1	1	1	0	-1	-1	0	-1	-1	0	0	0	-1	0	1	0	-1
10	1	0	0	1	0	0	0	0	0	-1	-1	0	0	0	0	0	0	1	-1	0
11	0	0	1	0	1	1	0	0	1	1	-1	0	0	1	1	0	0	1	-1	0
12	0	0	0	0	1	1	0	0	1	0	0	-1	0	0	0	0	0	0	0	0
13	0	0	1	1	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	-1
14	0	0	0	0	1	1	0	-1	0	0	-1	0	0	-1	1	0	0	0	-1	0
15	0	1	1	0	0	1	-1	-1	0	0	-1	0	0	-1	-1	-1	0	1	0	-1
16	0	0	1	0	1	1	0	-1	1	0	0	0	0	0	1	-1	0	0	0	0
17	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	-1	0	-1	-1
18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	1	1
19	0	0	0	0	0	1	0	1	0	1	1	0	0	1	0	0	1	0	-1	0
20	0	0	0	0	0	1	0	0	1	0	0	0	1	0	1	0	1	0	0	-1

Loop Analysis

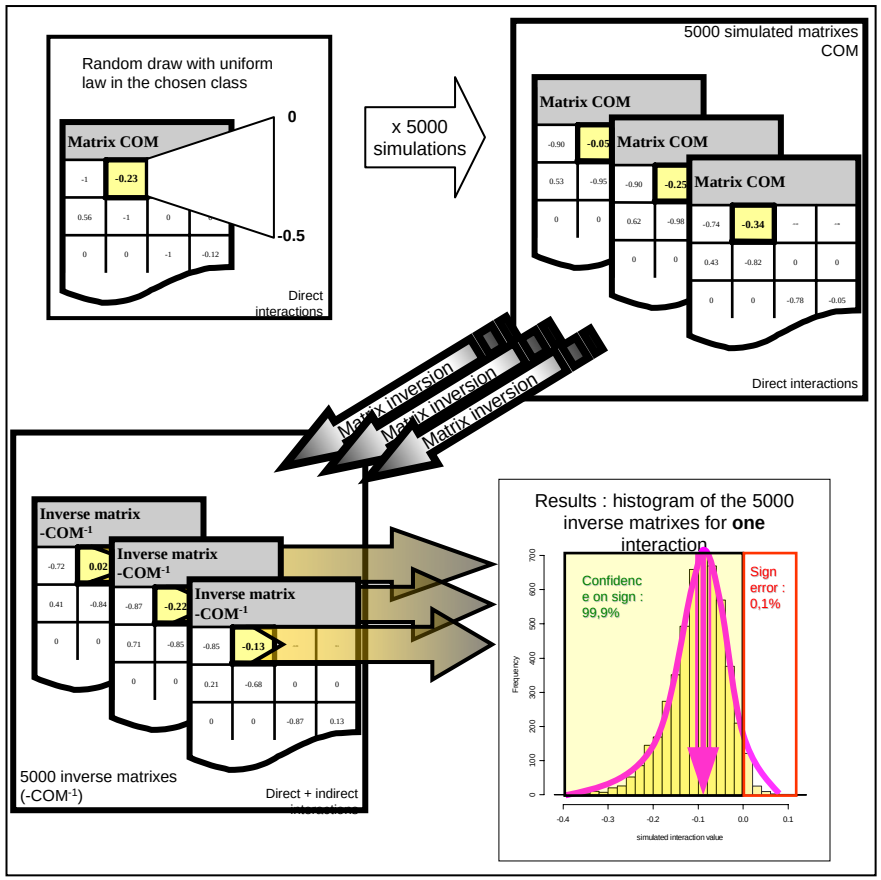
- Most of results are uncertain due to
  - Many trophic interaction links
  - Taking weak interaction into account

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	NN																			
2		NNN			PP															
3	NN		NNN											NN						
4				NNN																
5					NNN	PP														
6						NN														
7							NNN									PP				
8								NNN												
9									NN									NNN		
10										NNN										
11	NNN										NNN							NNN		
12												NNN							PP	
13													NNN							
14														NNN						PP
15										PP					NNN					
16																NNN				
17									PP								NNN			
18	NNN									NNN				NNN				NNN		PPP
19	NN														NN				NNN	
20														NN						NNN

- Effects of one component (columns) on the others (row). After inversion. Sum of direct and indirect interactions
  - Colour indicates: confidence > 90%
  - Green PP: positive effect
  - Red NNN, NN: strong or medium negative effect

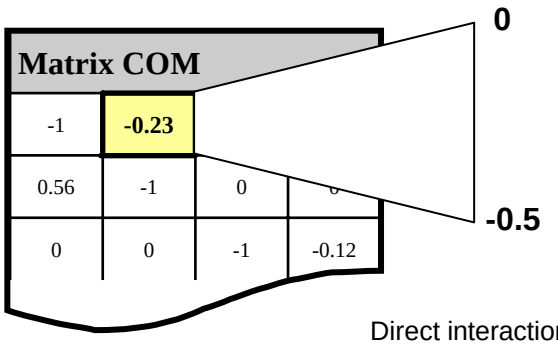
Inverse matrixes and sensitivity analysis

- Method:
  - Distinct data by classes
  - Evaluate uncertainty on the results



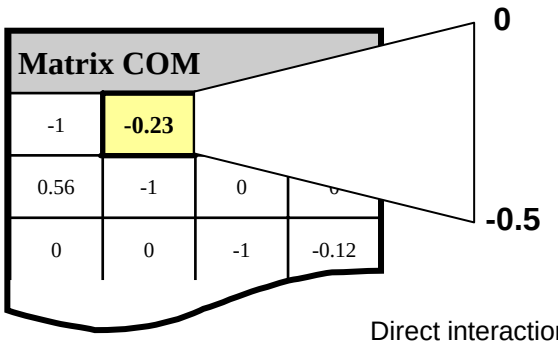
➢ Method to assess uncertainty on the results

Random draw with uniform law in the chosen class



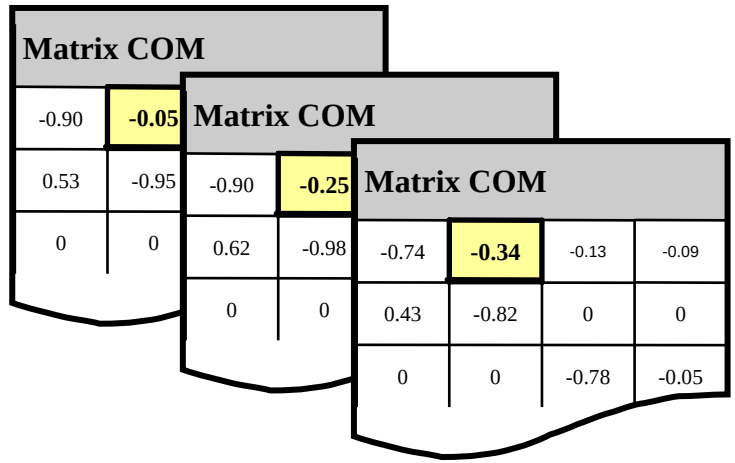
Direct interactions

Random draw with uniform law in the chosen class

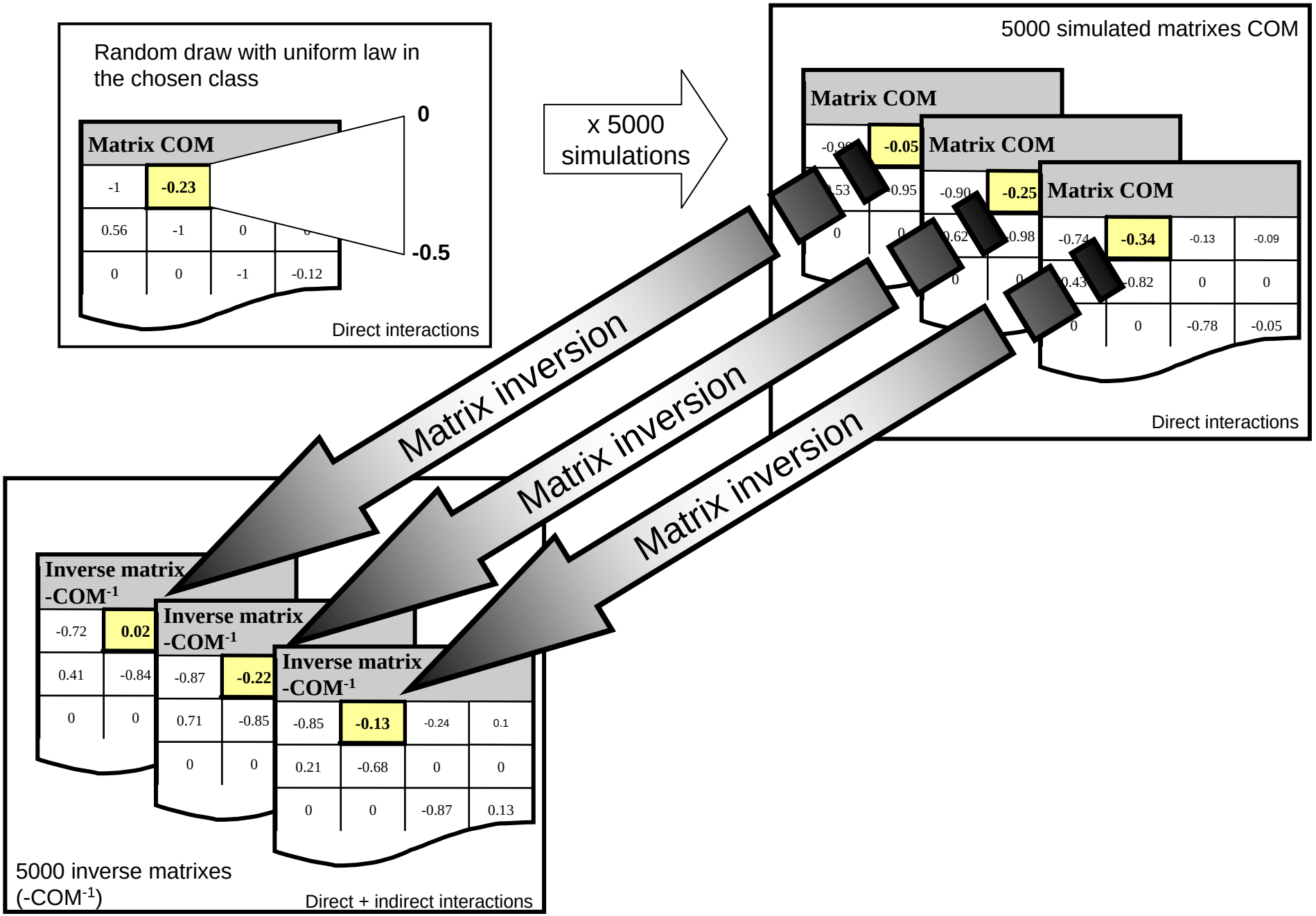


x 5000 simulations

5000 simulated matrixes COM



Direct interactions


Random draw with uniform law in the chosen class
0
-0.5
Matrix COM
-1
-0.23
0.56
-1
0
0
0
-1
-0.12
Direct interactions
x 5000 simulations
5000 simulated matrixes COM
Matrix COM
-0.05
0.53
0.95
0
0
Matrix COM
-0.90
-0.25
0.62
0.98
0
0
Matrix COM
-0.74
-0.34
-0.13
-0.09
0.43
-0.82
0
0
0
0
-0.78
-0.05
Direct interactions
Matrix inversion
Matrix inversion
Matrix inversion
Inverse matrix -COM-1
-0.72
0.02
0.41
-0.84
0
0
Inverse matrix -COM-1
-0.87
-0.22
0.71
-0.85
0
0
Inverse matrix -COM-1
-0.85
-0.13
-0.24
0.1
0.21
-0.68
0
0
0
0
-0.87
0.13
5000 inverse matrixes (-COM-1)
Direct + indirect interactions

Random draw with uniform law in the chosen class

Matrix COM

-1	**-0.23**		
0.56	-1	0	
0	0	-1	-0.12

0

-0.5

Direct interactions

x 5000 simulations

5000 simulated matrixes COM

Matrix COM

-0.90	**-0.05**	-0.90	**-0.25**	-0.74	**-0.34**	-0.13	-0.09
0.53	-0.95	0.62	-0.98	0.43	-0.82	0	0
0	0	0	0	0	0	-0.78	-0.05

Direct interactions

Matrix inversion

Matrix inversion

Matrix inversion

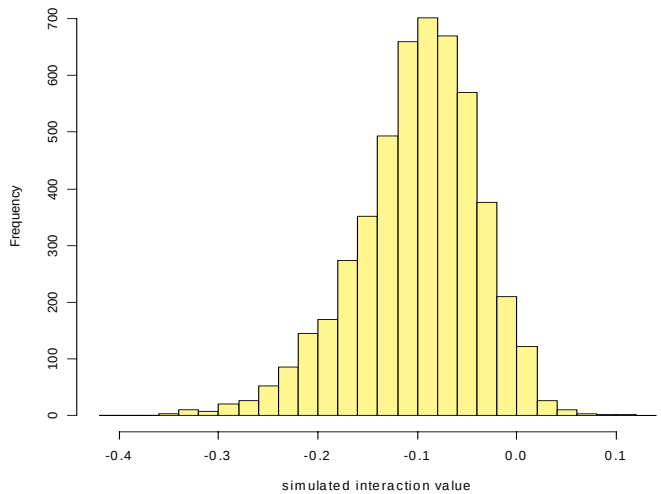
Inverse matrix -COM^{-1}

-0.72	**0.02**	-0.87	**-0.22**	-0.85	**-0.13**	-0.24	0.1
0.41	-0.84	0.71	-0.85	0.21	-0.68	0	0
0	0	0	0	0	0	-0.87	0.13

5000 inverse matrixes (-COM^{-1})

Direct + indirect interactions

Results : histogram of the 5000 inverse matrixes for **one** interaction



Random draw with uniform law in the chosen class

Matrix COM

-1	**-0.23**		
0.56	-1	0	
0	0	-1	-0.12

0

-0.5

Direct interactions

x 5000 simulations

5000 simulated matrixes COM

Matrix COM

-0.90	**-0.05**	-0.90	**-0.25**	-0.74	**-0.34**	-0.13	-0.09
0.53	-0.95	0.62	-0.98	0.43	-0.82	0	0
0	0	0	0	0	0	-0.78	-0.05

Direct interactions

Matrix inversion

Matrix inversion

Matrix inversion

Inverse matrix -COM^{-1}

-0.72	**0.02**	-0.87	**-0.22**	-0.85	**-0.13**	-0.24	0.1
0.41	-0.84	0.71	-0.85	0.21	-0.68	0	0
0	0	0	0	0	0	-0.87	0.13

5000 inverse matrixes (-COM^{-1})

Direct + indirect interactions

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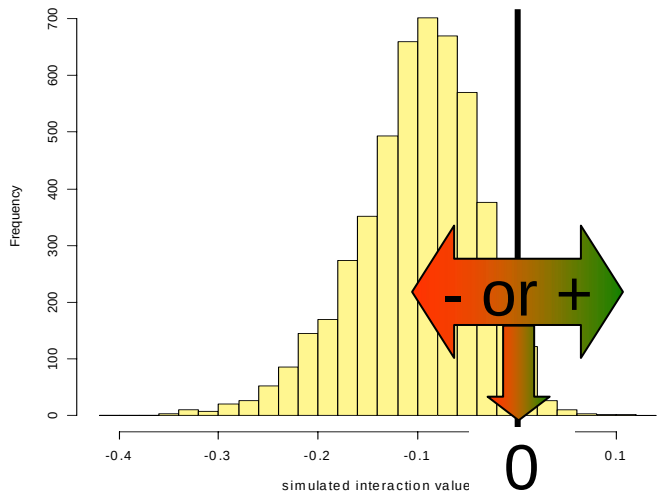
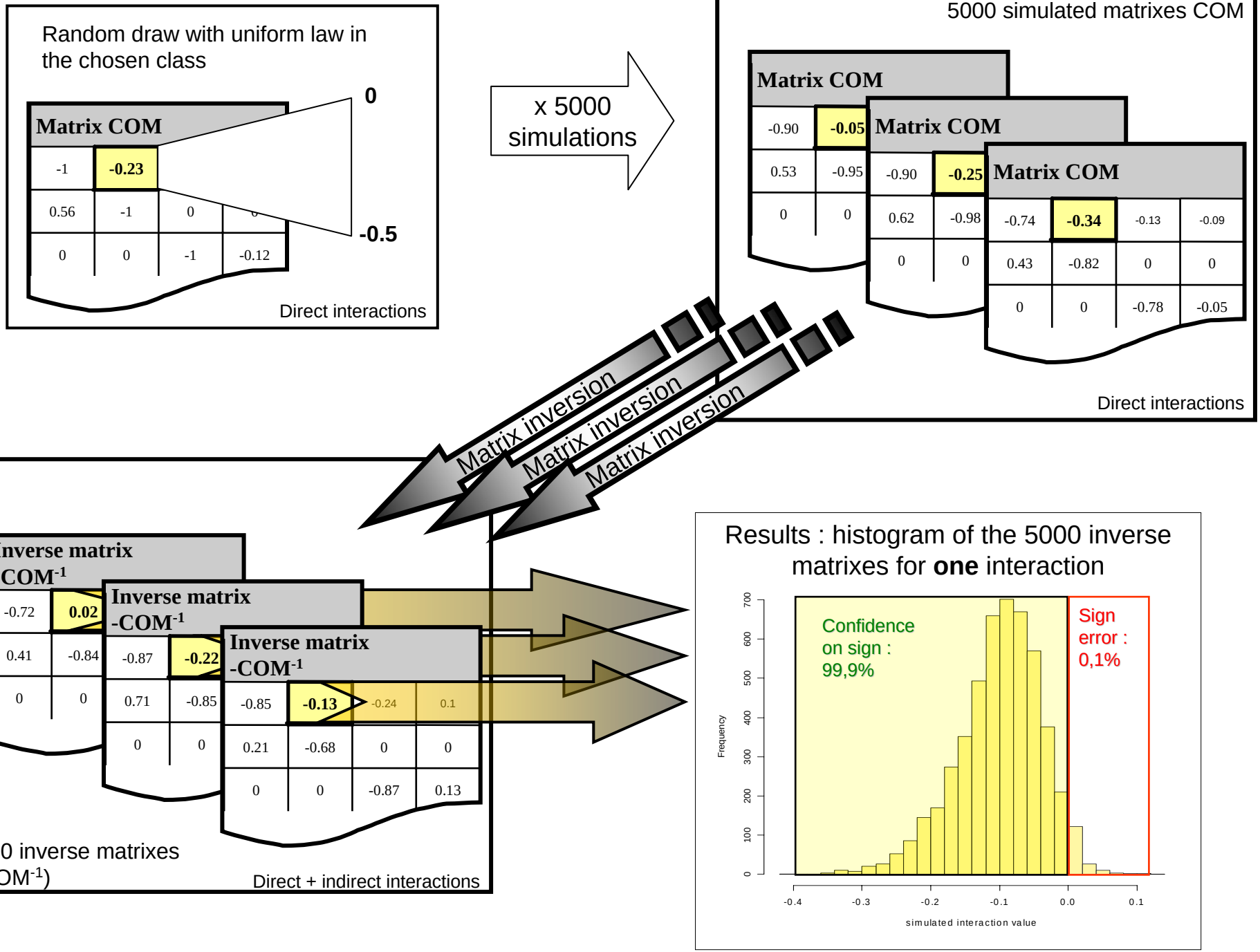



Random draw with uniform law in the chosen class
Matrix COM
-1
-0.23
0.56
-1
0
0
0
-1
-0.12
0
-0.5
Direct interactions
x 5000 simulations
5000 simulated matrixes COM
Matrix COM
-0.90
-0.05
0.53
-0.95
0
0
Matrix COM
-0.90
-0.25
0.62
-0.98
0
0
Matrix COM
-0.74
-0.34
-0.13
-0.09
0.43
-0.82
0
0
0
0
-0.78
-0.05
Direct interactions
Matrix inversion
Matrix inversion
Matrix inversion
Inverse matrix -COM-1
-0.72
0.02
0.41
-0.84
0
0
Inverse matrix -COM-1
-0.87
-0.22
0.71
-0.85
0
0
Inverse matrix -COM-1
-0.85
-0.13
-0.24
0.1
0.21
-0.68
0
0
0
0
-0.87
0.13
5000 inverse matrixes (-COM-1)
Direct + indirect interactions
Results : histogram of the 5000 inverse matrixes for one interaction
Confidence on sign : 99,9%
Sign error : 0,1%
Frequency
0
100
200
300
400
500
600
700
-0.4
-0.3
-0.2
-0.1
0.0
0.1
simulated interaction value

Random draw with uniform law in the chosen class

Matrix COM

-1	**-0.23**		
0.56	-1	0	
0	0	-1	-0.12

0

-0.5

Direct interactions

x 5000 simulations

5000 simulated matrixes COM

Matrix COM

-0.90	**-0.05**	-0.90	**-0.25**	-0.74	**-0.34**	-0.13	-0.09
0.53	-0.95	0.62	-0.98	0.43	-0.82	0	0
0	0	0	0	0	0	-0.78	-0.05

Direct interactions

Matrix inversion

Matrix inversion

Matrix inversion

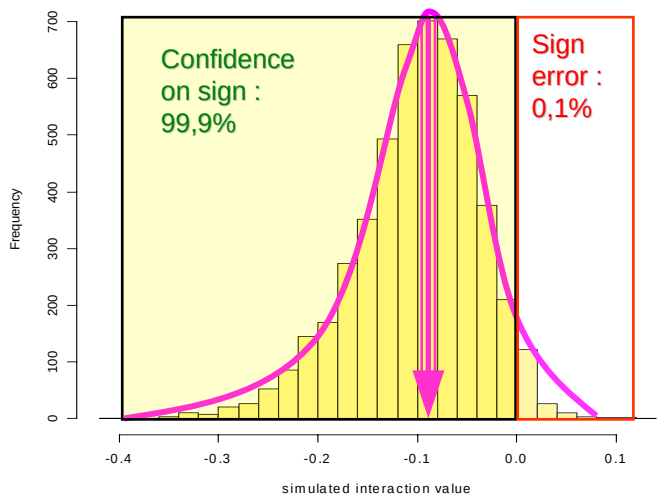
Inverse matrix -COM^{-1}

-0.72	**0.02**	-0.87	**-0.22**	-0.85	**-0.13**	-0.24	0.1
0.41	-0.84	0.71	-0.85	0.21	-0.68	0	0
0	0	0	0	0	0	-0.87	0.13

5000 inverse matrixes (-COM^{-1})

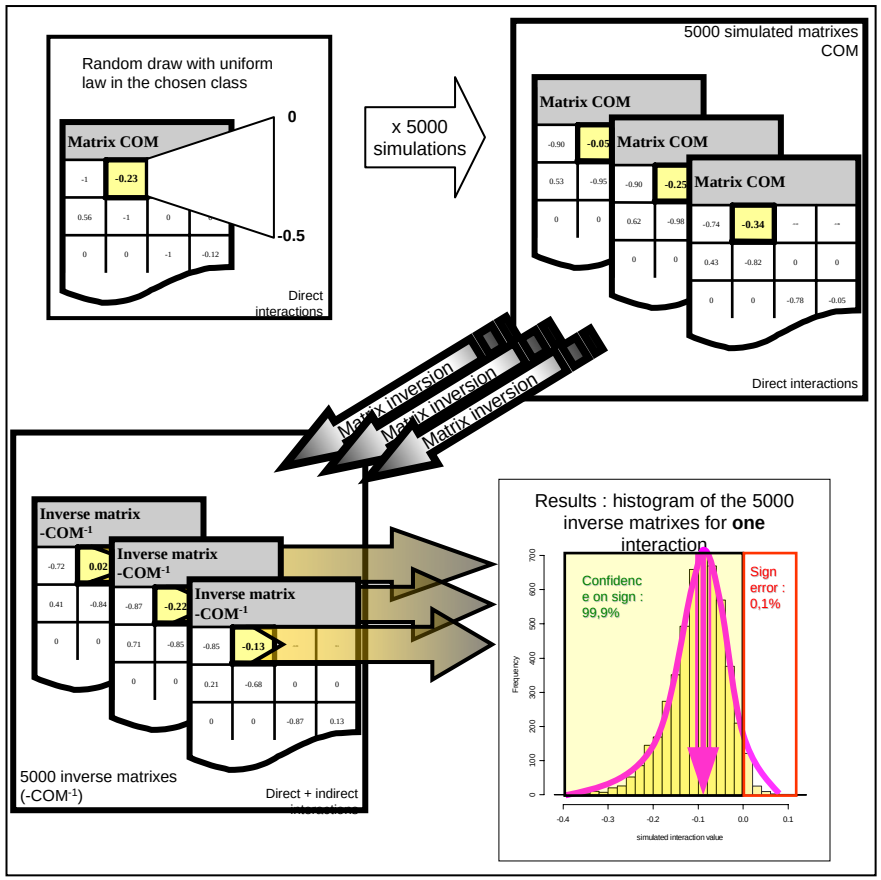
Direct + indirect interactions

Results : histogram of the 5000 inverse matrixes for **one** interaction



Inverse matrixes and sensitivity analysis

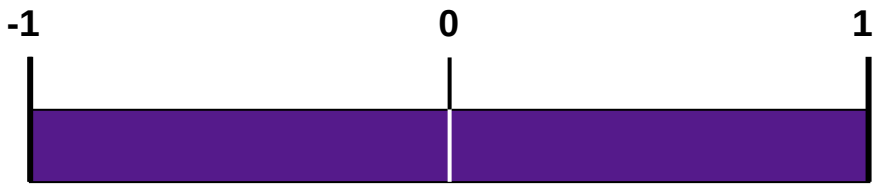
- Method:
  - Rank data by classes
  - Evaluate uncertainty on the results
- How many classes do we need?



➢ Method to assess uncertainty on the results

Community matrix: to put data in classes

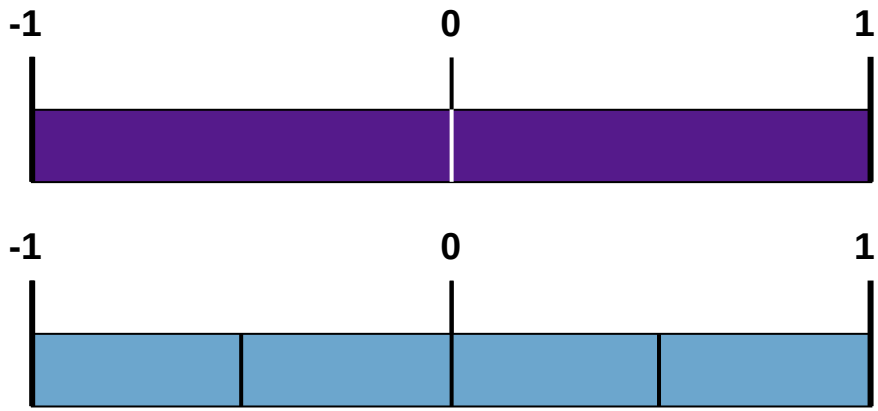
- Four different tested cases:
  - Equivalent to Loop Analysis



➢ Representation of the different cases

Community matrix: to put data in classes

- Four different tested cases:
  - Equivalent to Loop Analysis
  - Weak and strong interactions, distinguished for both signs in 2 classes…



➢ Representation of the different cases

Community matrix: to put data in classes

- Four different tested cases:
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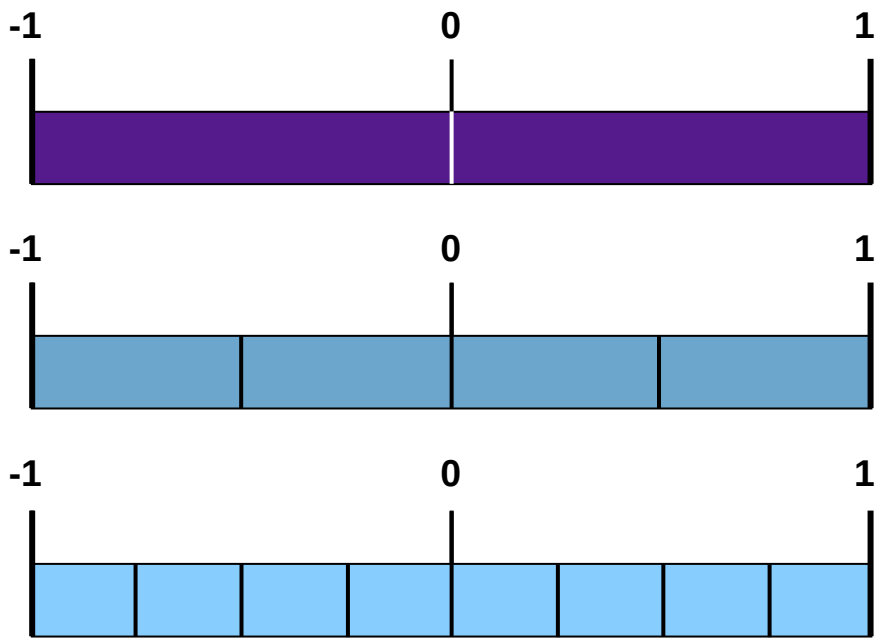
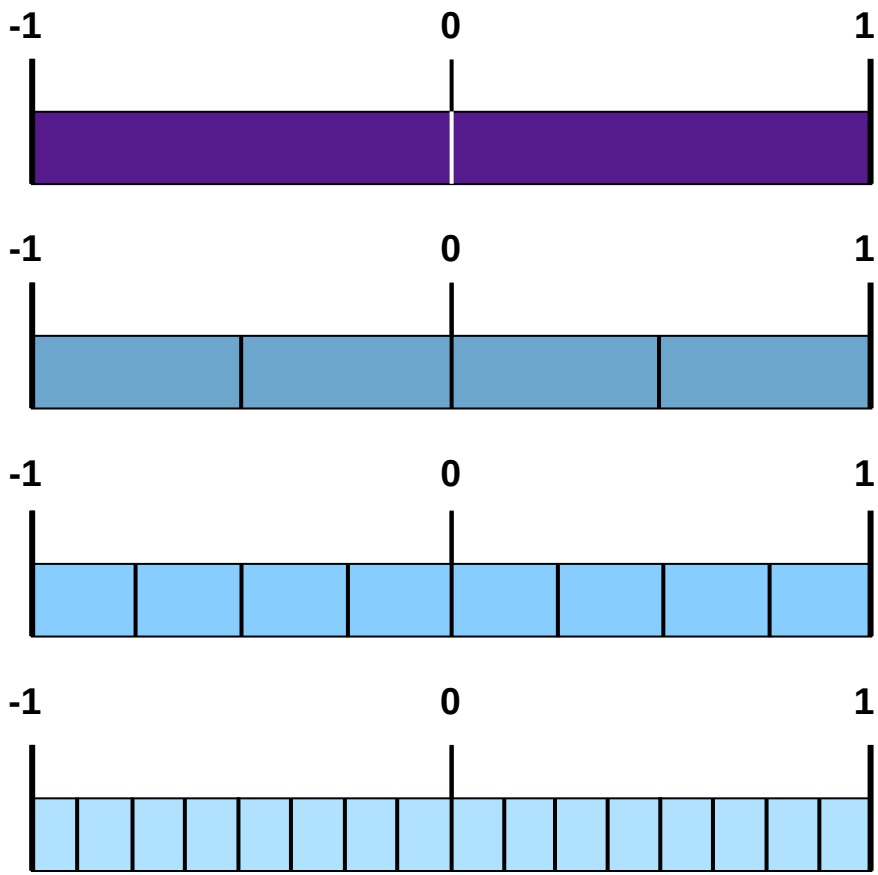
  - Weak and strong interactions, distinguished for both signs in 2 classes…
  - … or in 4 classes



➢ Representation of the different cases

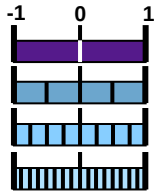
Community matrix: to put data in classes

- Four different tested cases:
  - Equivalent to Loop Analysis
  - Weak and strong interactions, distinguished for both signs in 2 classes…
  - … or in 4 classes
  - … or in 8 classes

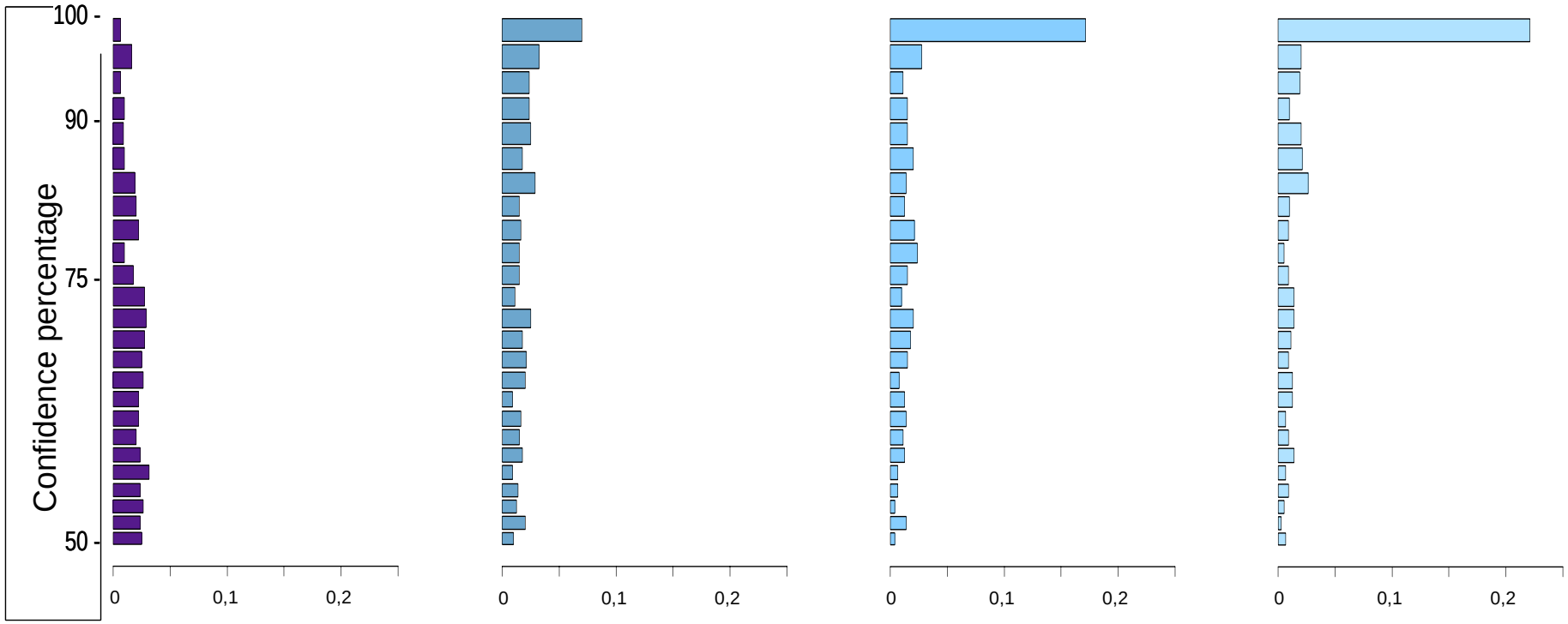


➢ Representation of the different cases

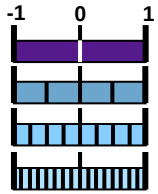
Inverse matrixes: results of the sensitivity analysis



- Using interaction classes in the Community matrix
  - increases precision on the results of the inverse matrixes…



Inverse matrixes: results of the sensitivity analysis



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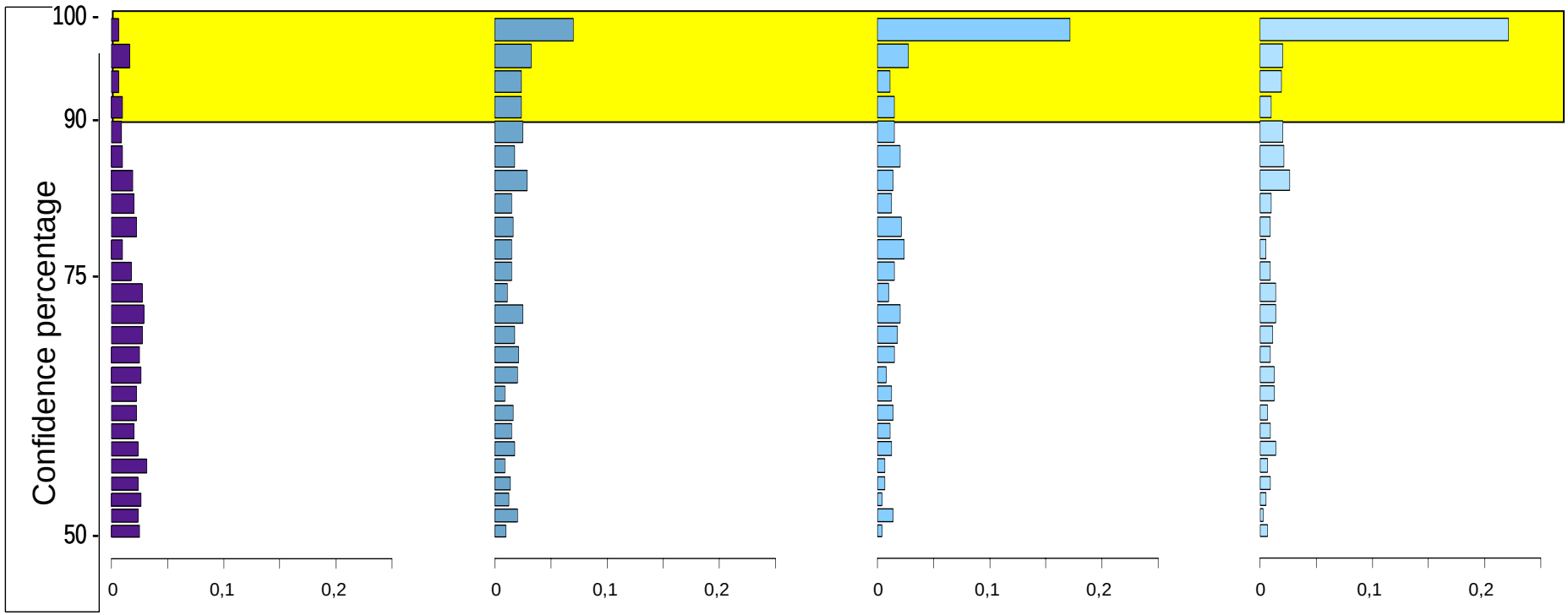

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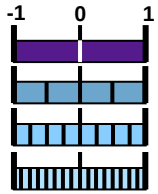

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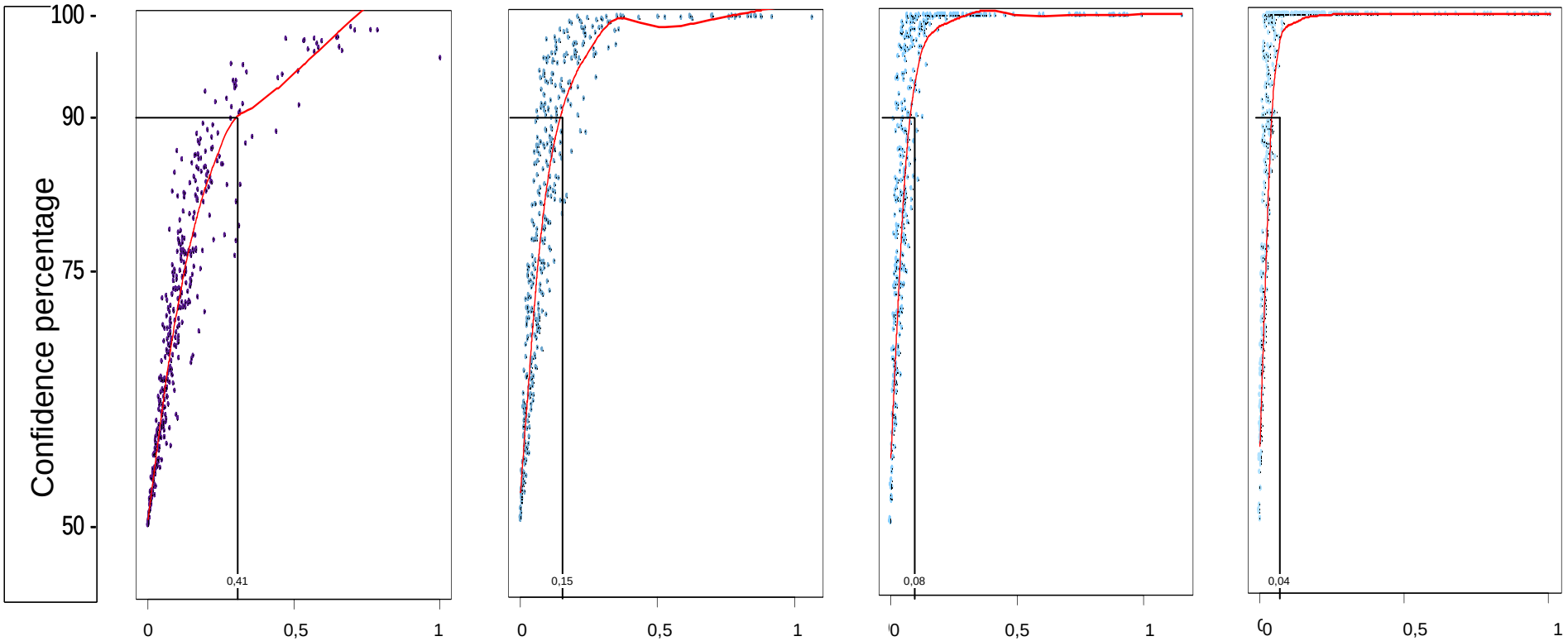
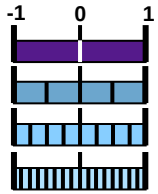


Inverse matrixes: results of the sensitivity analysis



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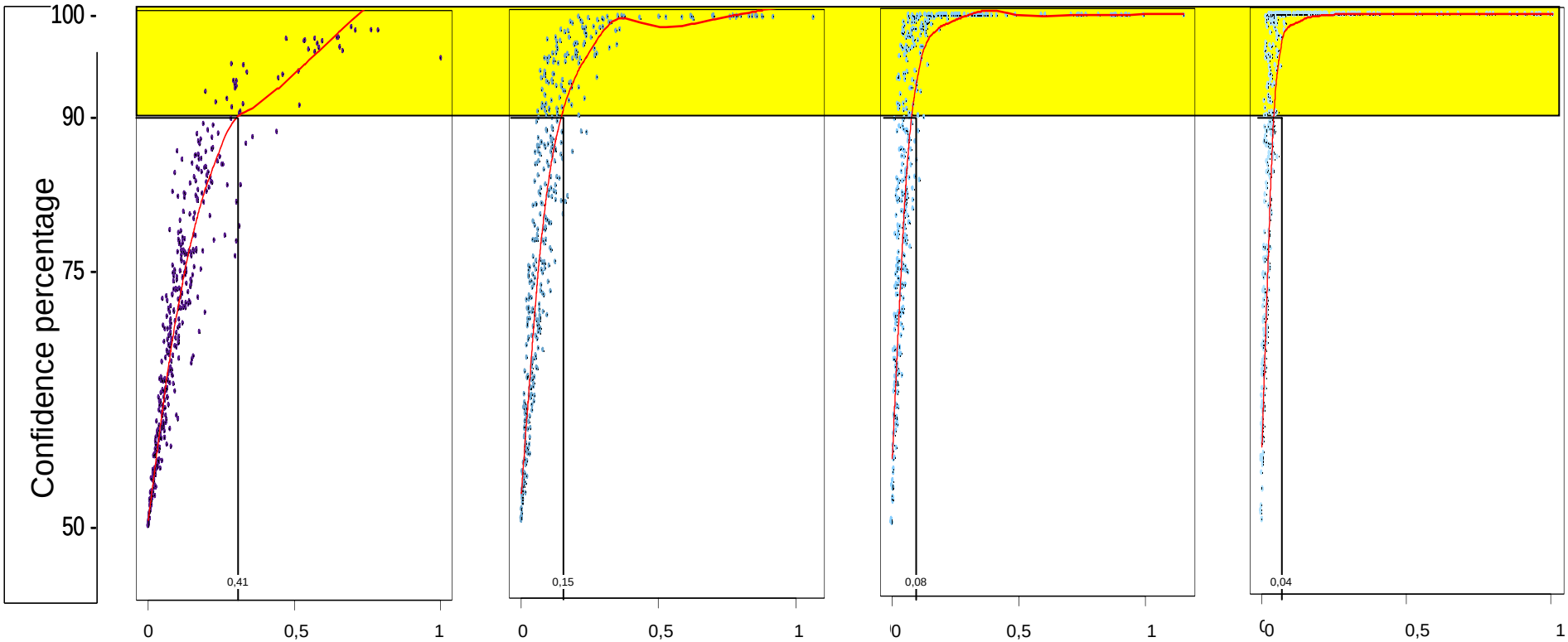

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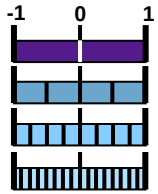
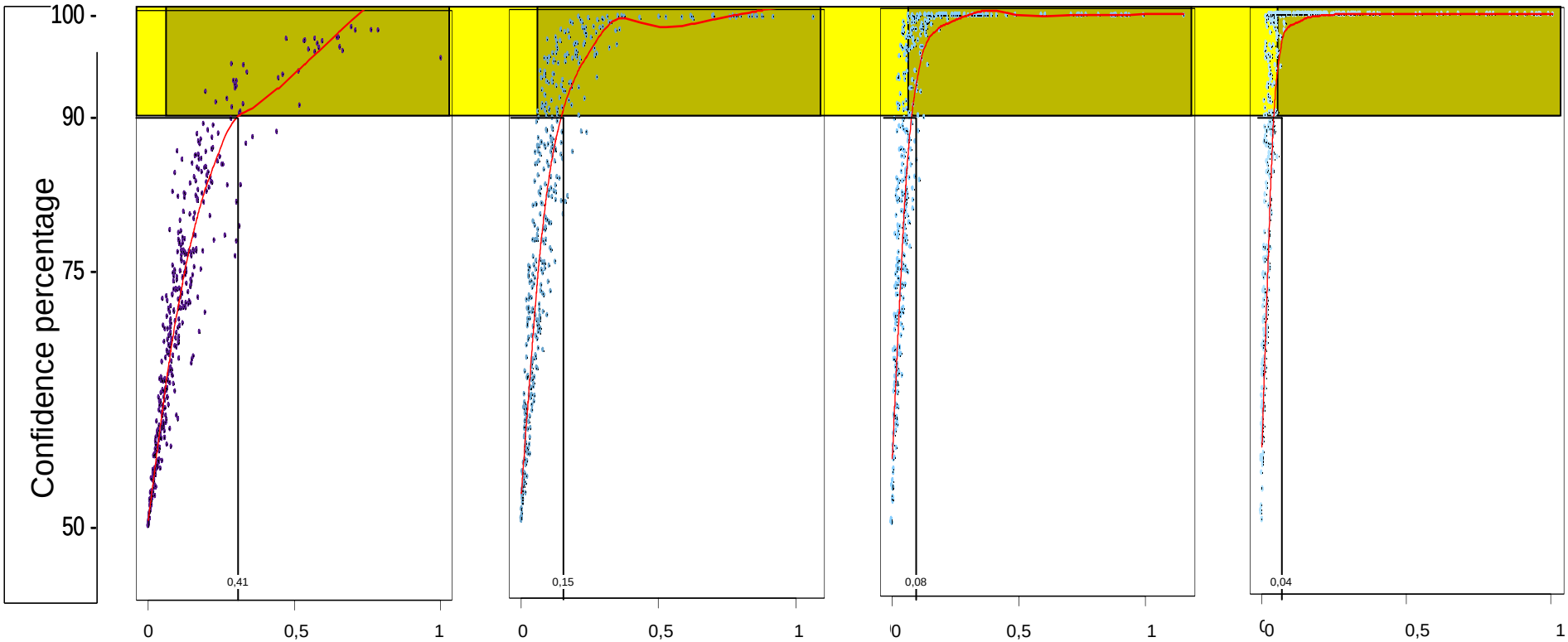
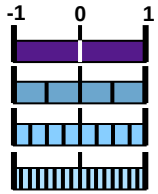


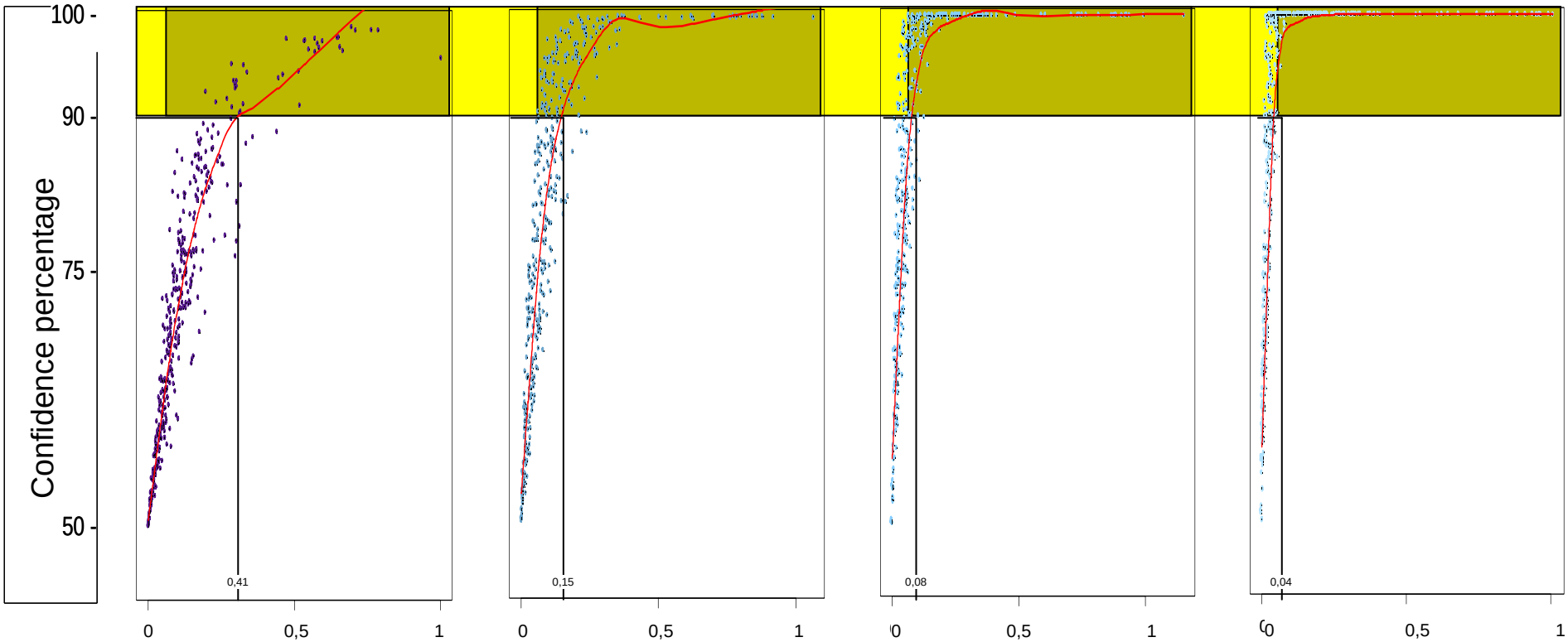
- Using interaction classes in the Community matrix
  - increases precision on the results of the inverse matrixes…
  - …particularly on the strong values of them.



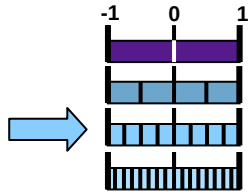
Inverse matrixes: results of the sensitivity analysis

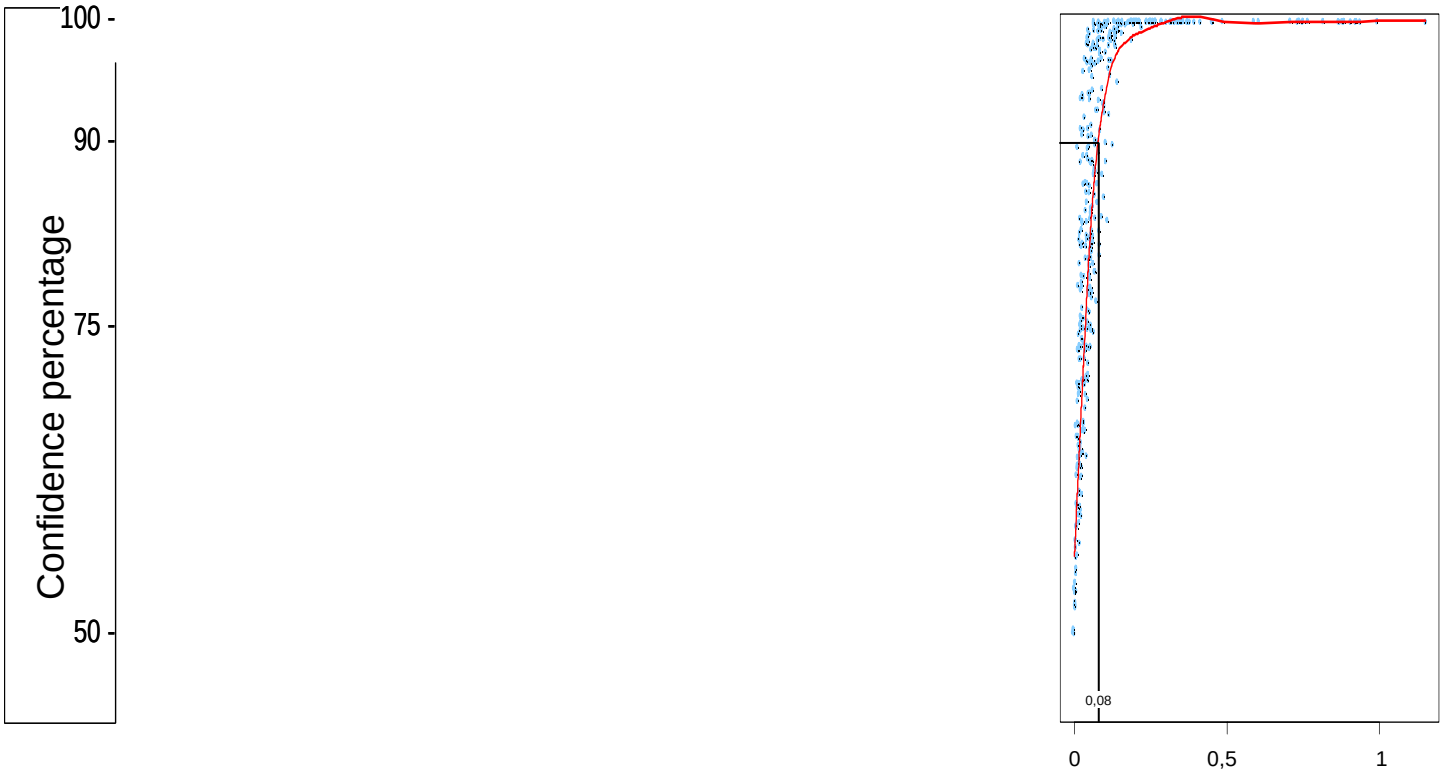


- Using interaction classes in the Community matrix
  - increases precision on the results of the inverse matrixes…
  - …particularly on the strong values of them.
  - Highlights influent and sensitive components

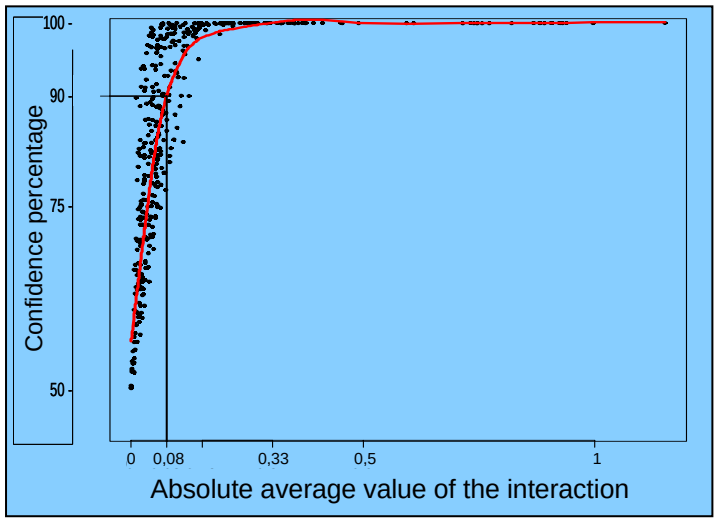


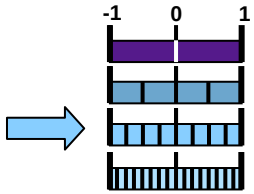
Inverse matrixes: results and interpretation





Inverse matrixes: results and interpretation





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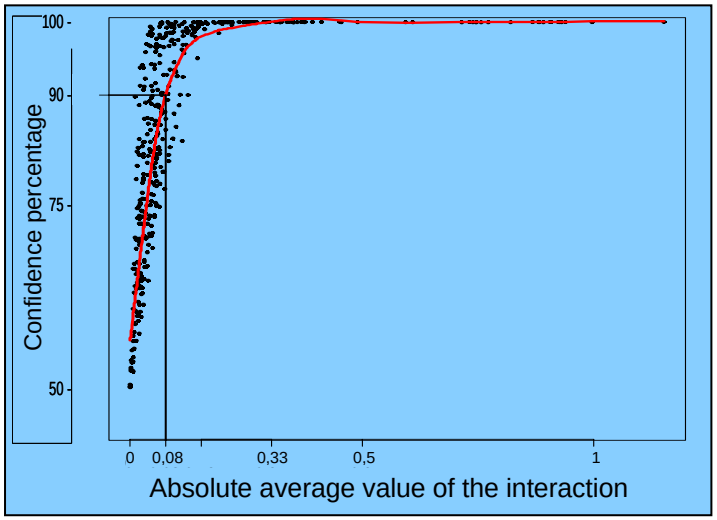
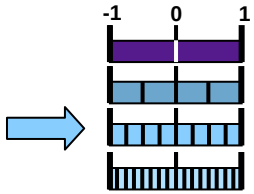
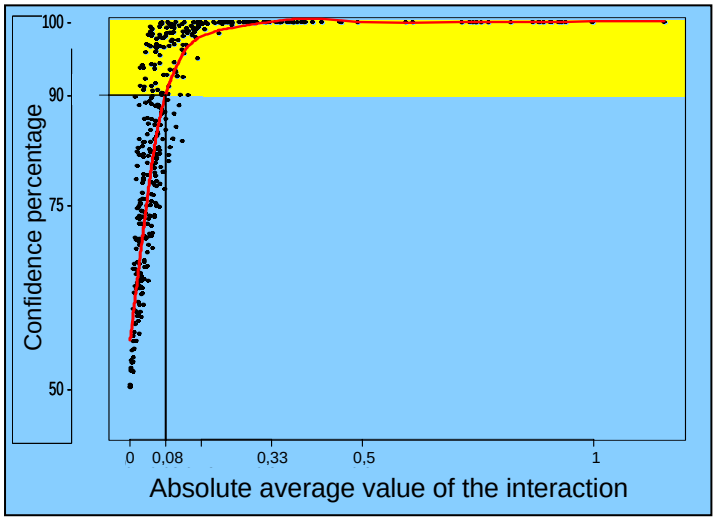
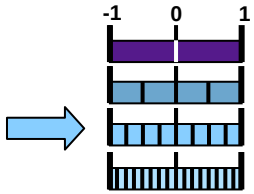




	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	NNN	PP				+	+											PPP	-	
2	NN	NNN		PP	+	-		-							-		-	NNN		
3	NNN	PP	NNN	-		-		-					-	-		PPP	-	NNN		
4	NN	NNN	+	NNN	+	+	PP						-						-	-
5	NN		+	-	NNN		-						-			-		NNN		
6	NN	+	+			NNN						-		-		-		NNN		
7			PP		+		NNN			+						PP			+	
8	NN		+	-		NNN		NNN				-		-		-		NNN		+
9	NN		+	-		NN	NNN		NNN		+	+		-				NNN	PPP	+
10	NN	NN	NN					-		NNN						PP		NNN		+
11	NNN		+			-					NNN			-		-		NNN	+	+
12	NN			-	+		NNN				-	NNN				+		NN	PP	+
13	NN					NNN							NNN	-		-		NNN		+
14	NN	NNN	+	+	NN			-		+		-	-	NNN	-		-	NNN	+	PPP
15	-					NN			+	+	+	PPP			NNN					
16	-	NN	NN		+	PP	-			+					+	NNN		-		+
17	NN					NNN			PPP			-		-		-	NNN	NN	-	
18	NN		+	NN			NN							-		-		NNN	+	+
19	-			-			NNN				-	NN		-	-			NN	NNN	+
20	-	NN	-			+	-			NN		+		-		NN		NN		NNN

Inverse matrixes: results and interpretation

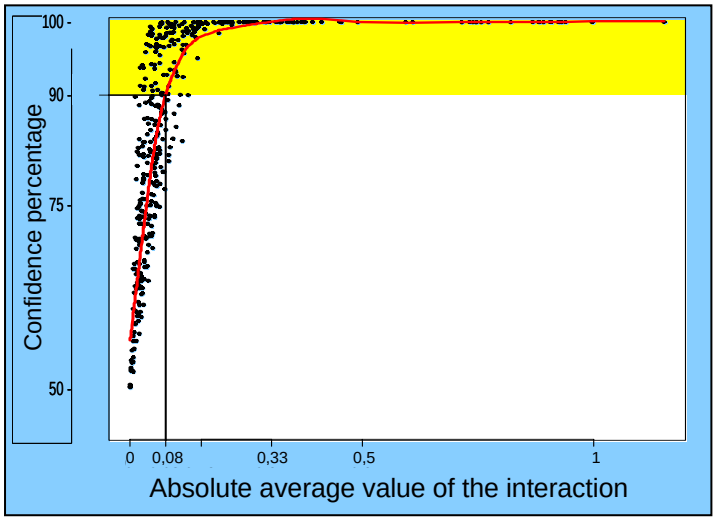


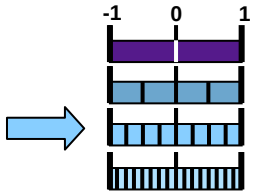


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	NNN	PP				+	+											PPP	-	
2	NN	NNN		PP	+	-		-							-		-	NNN		
3	NNN	PP	NNN	-		-		-					-	-		PPP	-	NNN		
4	NN	NNN	+	NNN	+	+	PP						-						-	-
5	NN		+	-	NNN		-						-			-		NNN		
6	NN	+	+			NNN						-		-		-		NNN		
7			PP		+		NNN			+						PP			+	
8	NN		+	-		NNN		NNN				-		-		-		NNN		+
9	NN		+	-		NN	NNN		NNN		+	+		-				NNN	PPP	+
10	NN	NN	NN					-		NNN						PP		NNN		+
11	NNN		+			-					NNN			-		-		NNN	+	+
12	NN			-	+		NNN				-	NNN				+		NN	PP	+
13	NN					NNN							NNN	-		-		NNN		+
14	NN	NNN	+	+	NN			-		+		-	-	NNN	-		-	NNN	+	PPP
15	-					NN			+	+	+	PPP			NNN					
16	-	NN	NN		+	PP	-			+					+	NNN		-		+
17	NN					NNN			PPP			-		-		-	NNN	NN	-	
18	NN		+	NN			NN							-		-		NNN	+	+
19	-			-			NNN				-	NN		-	-			NN	NNN	+
20	-	NN	-			+	-			NN		+		-		NN		NN		NNN

- Effects of one component (columns) on the others (row). After inversion. Sum of direct and indirect interactions
  - Colour indicates: confidence > 90%

Inverse matrixes: results and interpretation





	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	NNN	PP				+	+											PPP	-	
2	NN	NNN		PP	+	-		-							-		-	NNN		
3	NNN	PP	NNN	-		-		-					-	-		PPP	-	NNN		
4	NN	NNN	+	NNN	+	+	PP						-						-	-
5	NN		+	-	NNN		-						-			-		NNN		
6	NN	+	+			NNN						-		-		-		NNN		
7			PP		+		NNN			+						PP			+	
8	NN		+	-		NNN		NNN				-		-		-		NNN		+
9	NN		+	-		NN	NNN		NNN		+	+		-				NNN	PPP	+
10	NN	NN	NN					-		NNN						PP		NNN		+
11	NNN		+			-					NNN			-		-		NNN	+	+
12	NN			-	+		NNN				-	NNN				+		NN	PP	+
13	NN					NNN							NNN	-		-		NNN		+
14	NN	NNN	+	+	NN			-		+		-	-	NNN	-		-	NNN	+	PPP
15	-					NN			+	+	+	PPP			NNN					
16	-	NN	NN		+	PP	-			+					+	NNN		-		+
17	NN					NNN			PPP			-		-		-	NNN	NN	-	
18	NN		+	NN			NN							-		-		NNN	+	+
19	-			-			NNN				-	NN		-	-			NN	NNN	+
20	-	NN	-			+	-			NN		+		-		NN		NN		NNN

- Effects of one component (columns) on the others (row). After inversion. Sum of direct and indirect interactions
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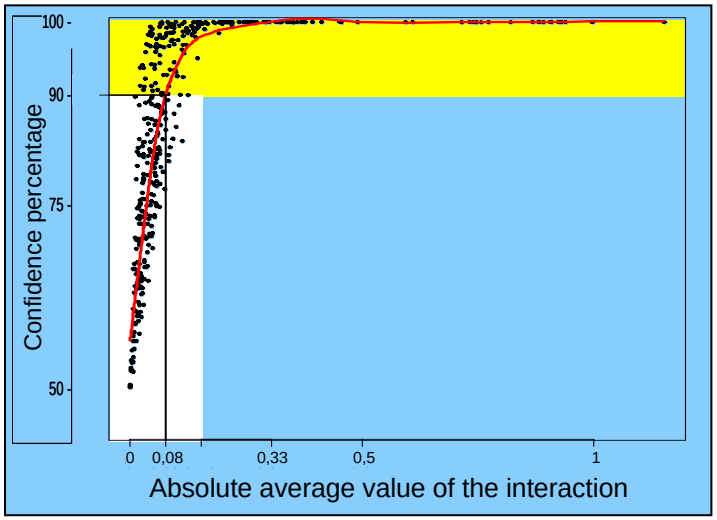
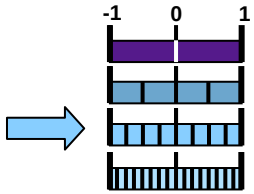
Inverse matrixes: results and interpretation





	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	NNN	PP				+	+											PPP	-	
2	NN	NNN		PP	+	-		-							-		-	NNN		
3	NNN	PP	NNN	-		-		-					-	-		PPP	-	NNN		
4	NN	NNN	+	NNN	+	+	PP						-						-	-
5	NN		+	-	NNN		-						-			-		NNN		
6	NN	+	+			NNN						-		-		-		NNN		
7			PP		+		NNN			+						PP			+	
8	NN		+	-		NNN		NNN				-		-		-		NNN		+
9	NN		+	-		NN	NNN		NNN		+	+		-				NNN	PPP	+
10	NN	NN	NN					-		NNN						PP		NNN		+
11	NNN		+			-					NNN			-		-		NNN	+	+
12	NN			-	+		NNN				-	NNN				+		NN	PP	+
13	NN					NNN							NNN	-		-		NNN		+
14	NN	NNN	+	+	NN			-		+		-	-	NNN	-		-	NNN	+	PPP
15	-					NN			+	+	+	PPP			NNN					
16	-	NN	NN		+	PP	-			+					+	NNN		-		+
17	NN					NNN			PPP			-		-		-	NNN	NN	-	
18	NN		+	NN			NN							-		-		NNN	+	+
19	-			-			NNN				-	NN		-	-			NN	NNN	+
20	-	NN	-			+	-			NN		+		-		NN		NN		NNN

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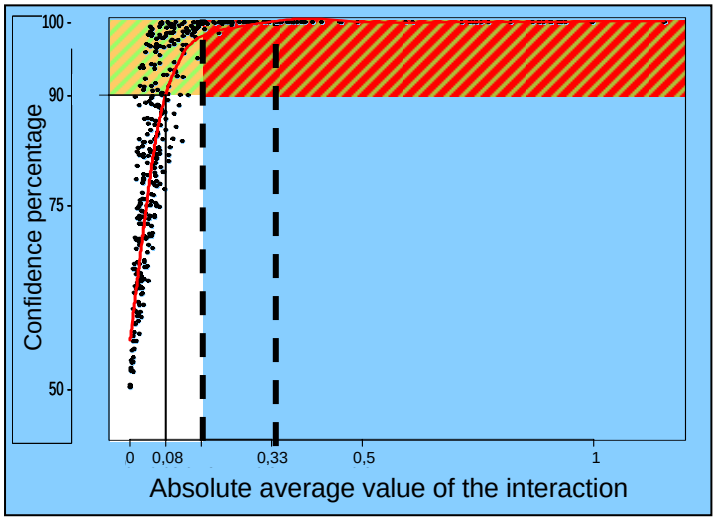
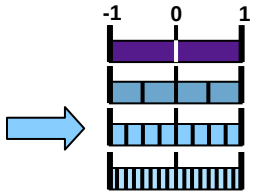
Inverse matrixes: results and interpretation





	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	NNN	PP				+	+											PPP	-	
2	NN	NNN		PP	+	-		-							-		-	NNN		
3	NNN	PP	NNN	-		-		-					-	-		PPP	-	NNN		
4	NN	NNN	+	NNN	+	+	PP						-						-	-
5	NN		+	-	NNN		-						-			-		NNN		
6	NN	+	+			NNN						-		-		-		NNN		
7			PP		+		NNN			+						PP			+	
8	NN		+	-		NNN		NNN				-		-		-		NNN		+
9	NN		+	-		NN	NNN		NNN		+	+		-				NNN	PPP	+
10	NN	NN	NN					-		NNN						PP		NNN		+
11	NNN		+			-					NNN			-		-		NNN	+	+
12	NN			-	+		NNN				-	NNN				+		NN	PP	+
13	NN					NNN							NNN	-		-		NNN		+
14	NN	NNN	+	+	NN			-		+		-	-	NNN	-		-	NNN	+	PPP
15	-					NN			+	+	+	PPP			NNN					
16	-	NN	NN		+	PP	-			+					+	NNN		-		+
17	NN					NNN			PPP			-		-		-	NNN	NN	-	
18	NN		+	NN			NN							-		-		NNN	+	+
19	-			-			NNN				-	NN		-	-			NN	NNN	+
20	-	NN	-			+	-			NN		+		-		NN		NN		NNN

- Effects of one component (columns) on the others (row). After inversion. Sum of direct and indirect interactions
  - Colour indicates: confidence > 90%
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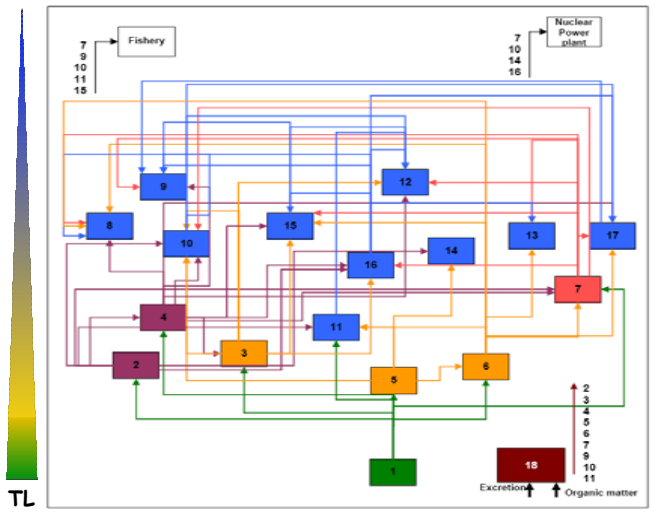
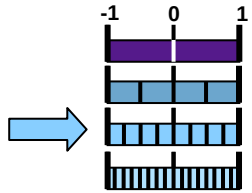
  - Red NNN, NN: strong or medium negative effect

Inverse matrixes: results and interpretation





TL

	18	1	2	3	6	5	11	4	7	14	10	8	13	17	16	15	9	12	19	20
18	NNN	NN		+				NN	NN	-					-				+	+
1	PPP	NNN	PP		+				+										-	
2	NNN	NN	NNN		-	+		PP				-		-		-				
3	NNN	NNN	PP	NNN	-			-		-		-	-	-	PPP					
6	NNN	NN	+	+	NNN					-					-			-		
5	NNN	NN		+		NNN		-	-						-					
11	NNN	NNN		+	NN		NNN			-					-				+	+
4		NN	NNN	+	+	+		NNN	PP				-						-	-
7				PP		+			NNN		+				PP				+	
14	NNN	NN	NNN	+		NN		+		NNN	+	-	-	-		-		-	+	PPP
10	NNN	NN	NN	NN							NNN	-			PP					+
8	NNN	NN		+	NNN			-		-		NNN			-					+
13	NNN	NN			NNN					-			NNN		-					+
17	NN	NN			NNN					-				NNN	-		PPP	-	-	
16	-	-	NN	NN	PP	+			-		+				NNN	+				+
15		-			NN		+				+					NNN	+	PPP		
9	NNN	NN		+	NN		+	-	NNN	-							NNN	+	PPP	+
12	NN	NN				+	-	-	NNN						+			NNN	PP	+
19	NN	NN					-	-	NNN	-						-		NN	NNN	+
20	NN	NN	NN	-	+				-	-	NN				NN			+		NNN

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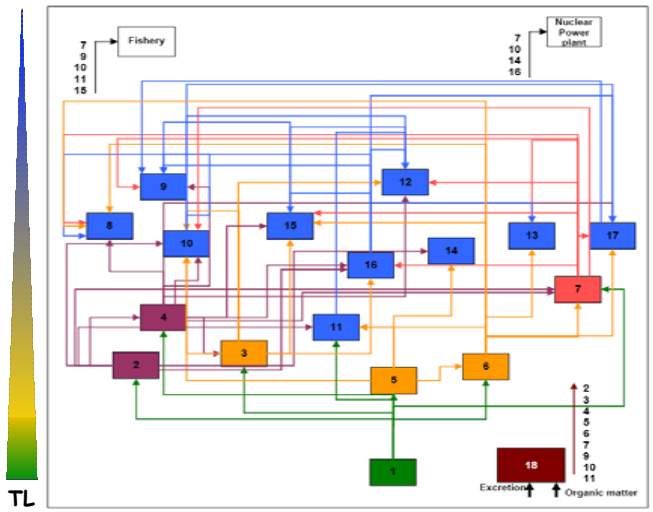

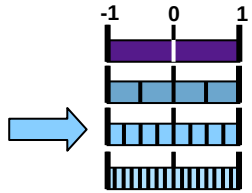

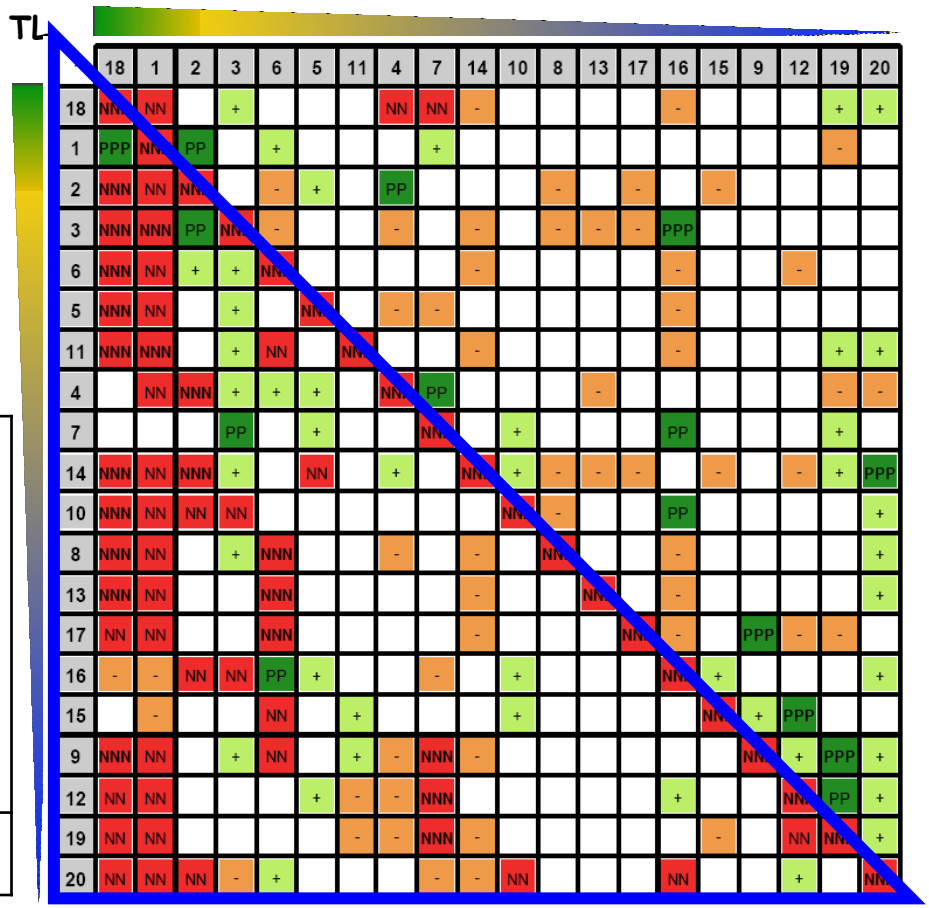

1.	Primary producers	11.	Mulets
2.	Copepods	12.	Big marine fish
3.	Suprabenthos	13.	Big pelagic fish
4.	Mysids	14.	Pipe fish
5.	Meiobenthos	15.	Flat fish
6.	Macrobenthos	16.	Gobids
7.	Shrimps	17.	Freshwater fish
8.	Sturgeons	18.	Detritus
9.	Eels	19.	Fishery
10.	Small pelagic fish	20.	Nuclear power plant

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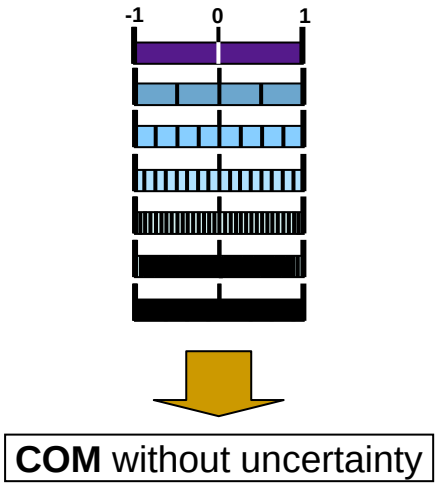
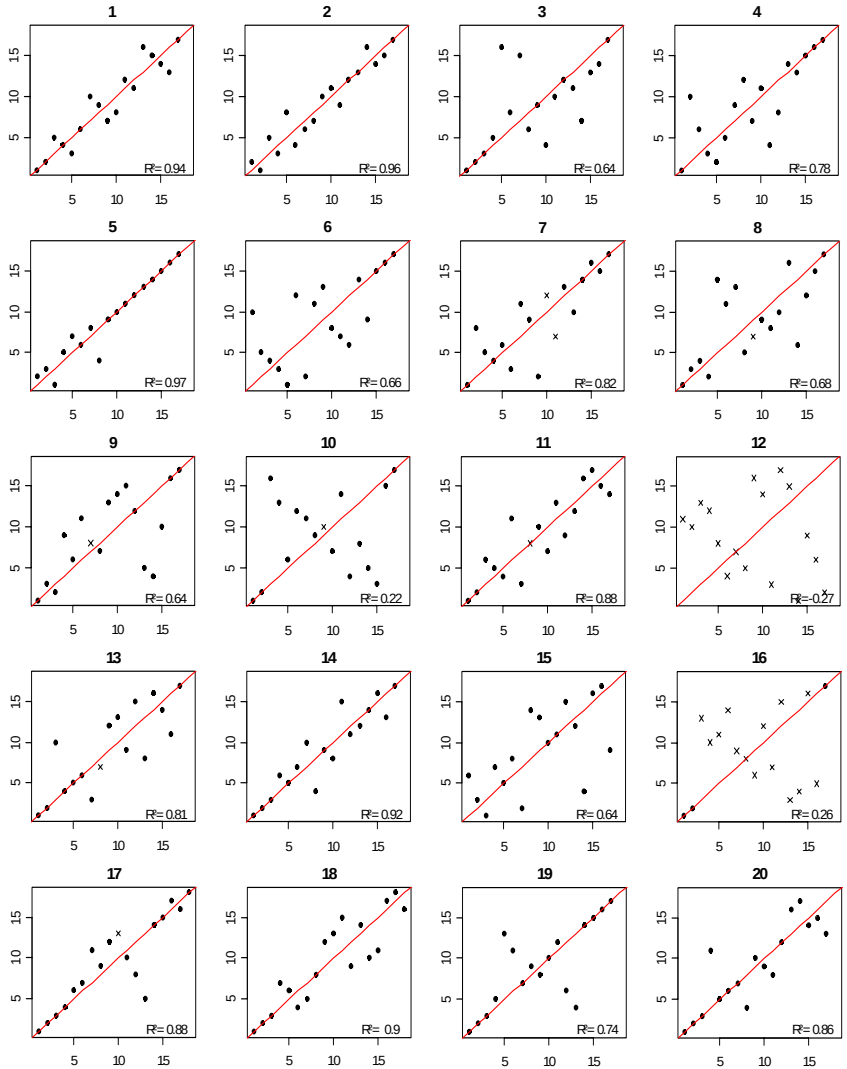
Correlation with « Mixed Trophic Impact »

- Increasing number of classes tends towards a Community matrix, free of uncertainty (COM)



Correlation with « Mixed Trophic Impact »

- Increasing number of classes tends towards a Community matrix, free of uncertainty (COM)
- COM correlated with the “Mixed Trophic Impact” matrix



COM without uncertainty

⇕

Mixed Trophic Impact

Conclusions and perspectives

- A simple way
  - to assess indirect interactions
  - to identify influent or sensitive components

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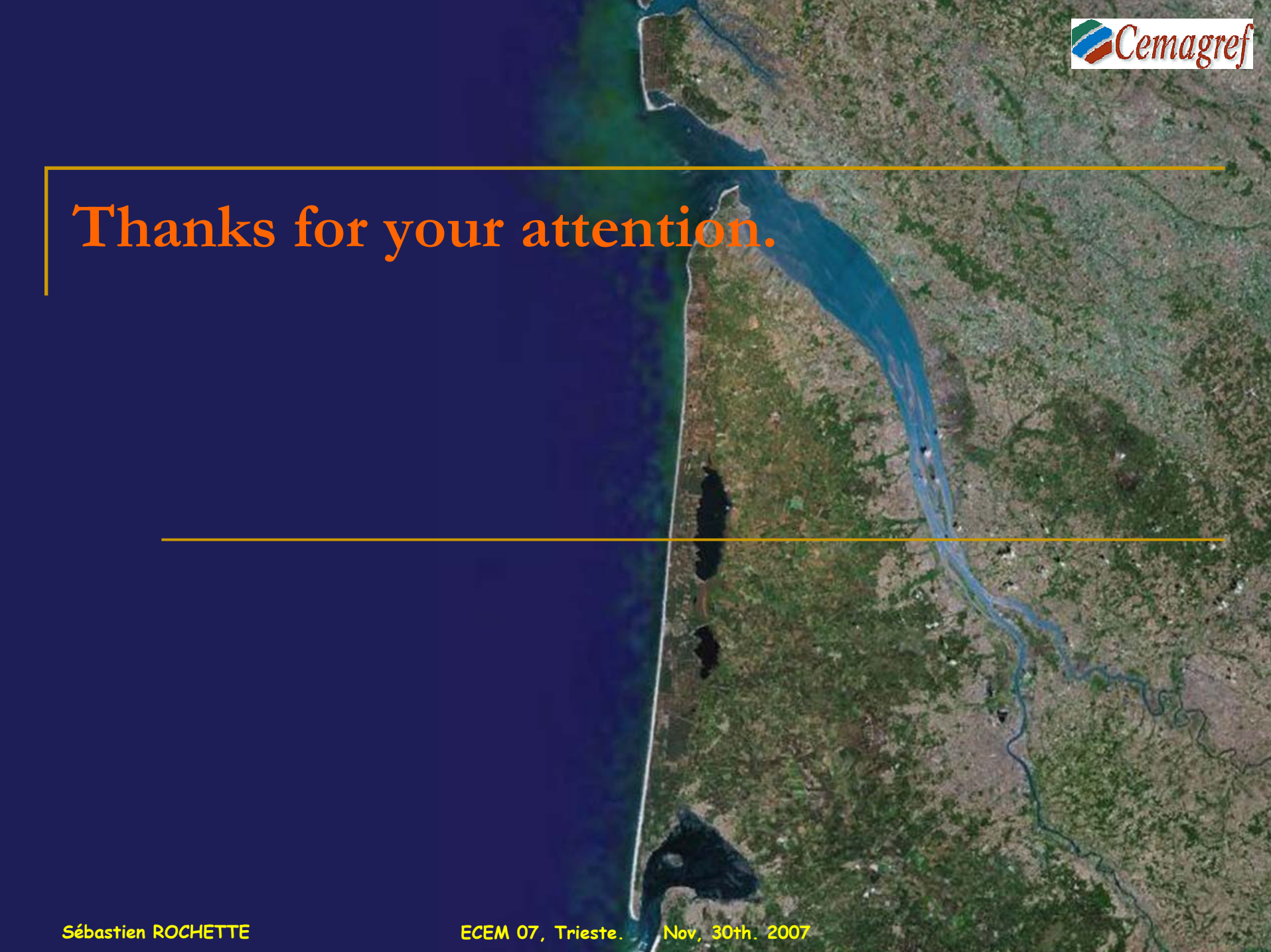
- A simple way
  - to assess indirect interactions
  - to identify influent or sensitive components
- An intermediate approach between loop analysis & Ecopath (“Mixed Trophic Impact”)
- Offering
  - simulation possibilities with confidence percentages
  - comparison means of several ecosystems, poorly-known as well
  - Possible improvement of MTI in order to add confidence intervals on results



Thanks for your attention.