Brest, Océan, climat et vulnérabilité, 22-23 juin 2010

Groupements d'Intérêt Scientifique

Europôle Mer et Climat-Environnement-Société

Ecological impact of nutrient watershed deliveries at the coastal zone.

Effect of environmental measures in the continuum Seine-Somme-Scheldt-North Sea and economic effectiveness

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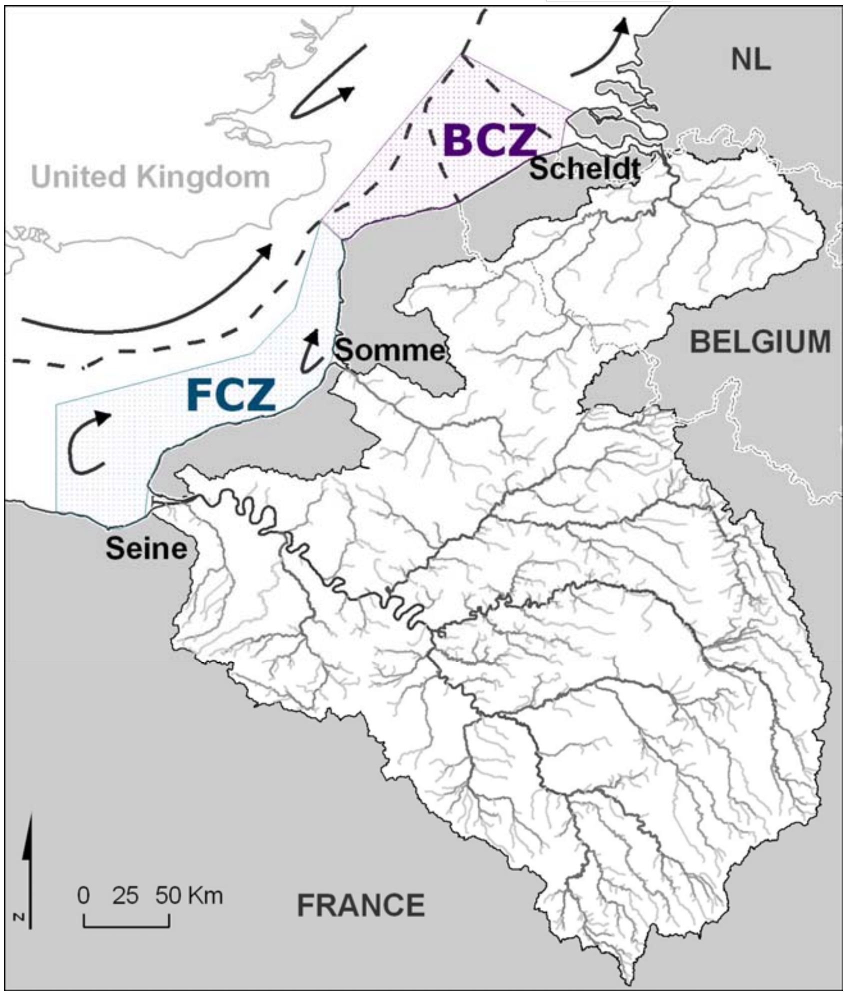
14h30-15h, le 23 juin

Content

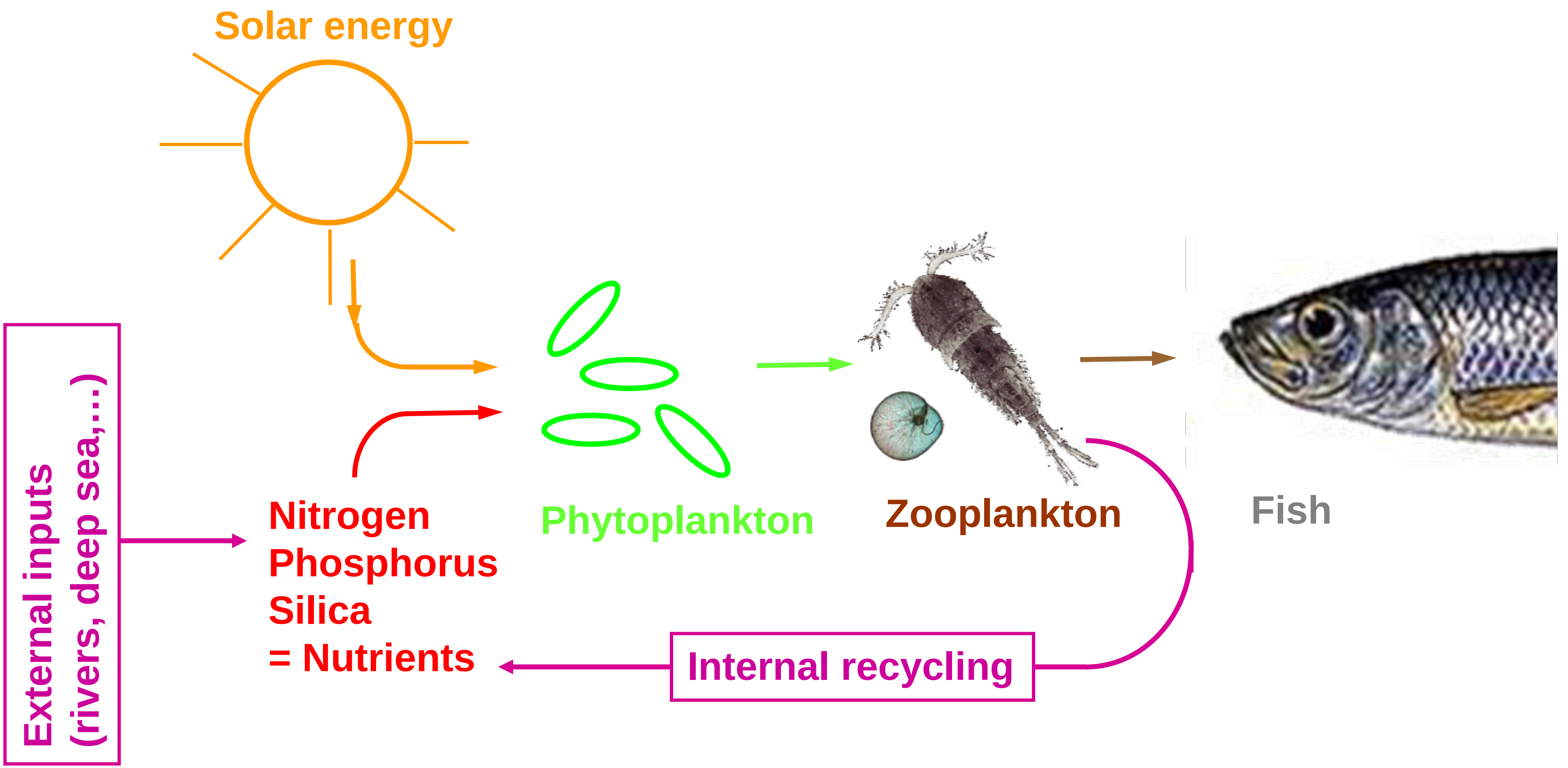
- Background
- Modelling approach for the 3S-North Sea Case study
- Validation & Scenarios of nutrient reductions
- Impact at the coastal zone
- Cost-effectiveness analysis

Eutrophication, a disease from which the sea is suffering …



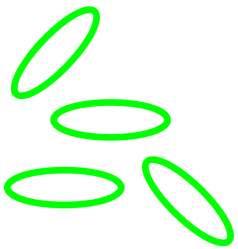
Nitrogen load delivered to the coastal sea is responsable for coastal eutrophication, and HAB blooms (Phaeocystis foam, toxic dinoflagellates, etc.)

Nutrient inputs lead to an efficient food web…

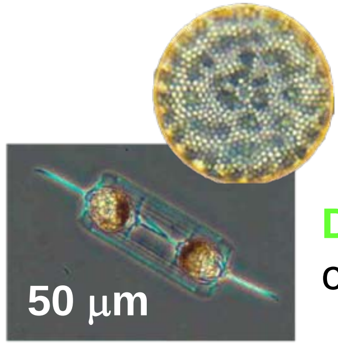


... when their ratio follow the algae requirement !

Silica, a non-anthropogenic key nutrient, limiting with P, N excess



Phytoplankton



Diatoms (preferred algae for large zooplankton)
convey primary production to fish

require Si

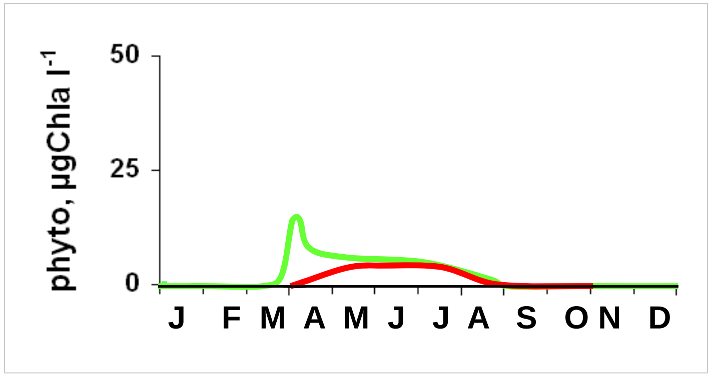
Internal recycling

Flagellates (non siliceous small algae not ingested by large zooplankton)
Grow rapidly on recycled nitrogen and phosphorus
Rapidly decomposed through microbial action)

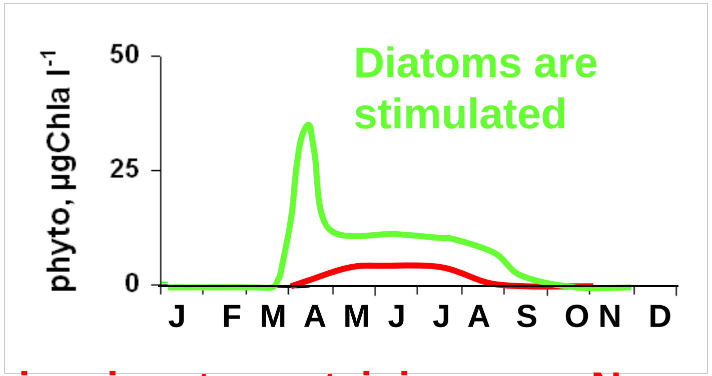
do not require Si

How river input of nutrient controls coastal zone ecosystems ?

No river:
Diatoms grow first, use all available N, P, Si
Flagellates bloom later, using recycled N and P
(Si is more slowly recycled)

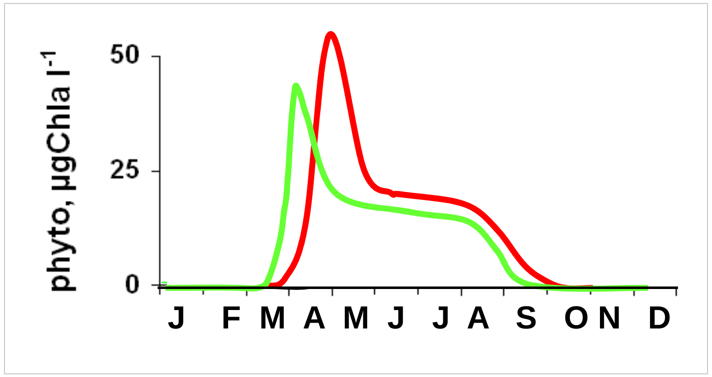


Pristine river:
Bring more silica than nitrogen and phosphorus
Diatoms are stimulated, fish production is enhanced

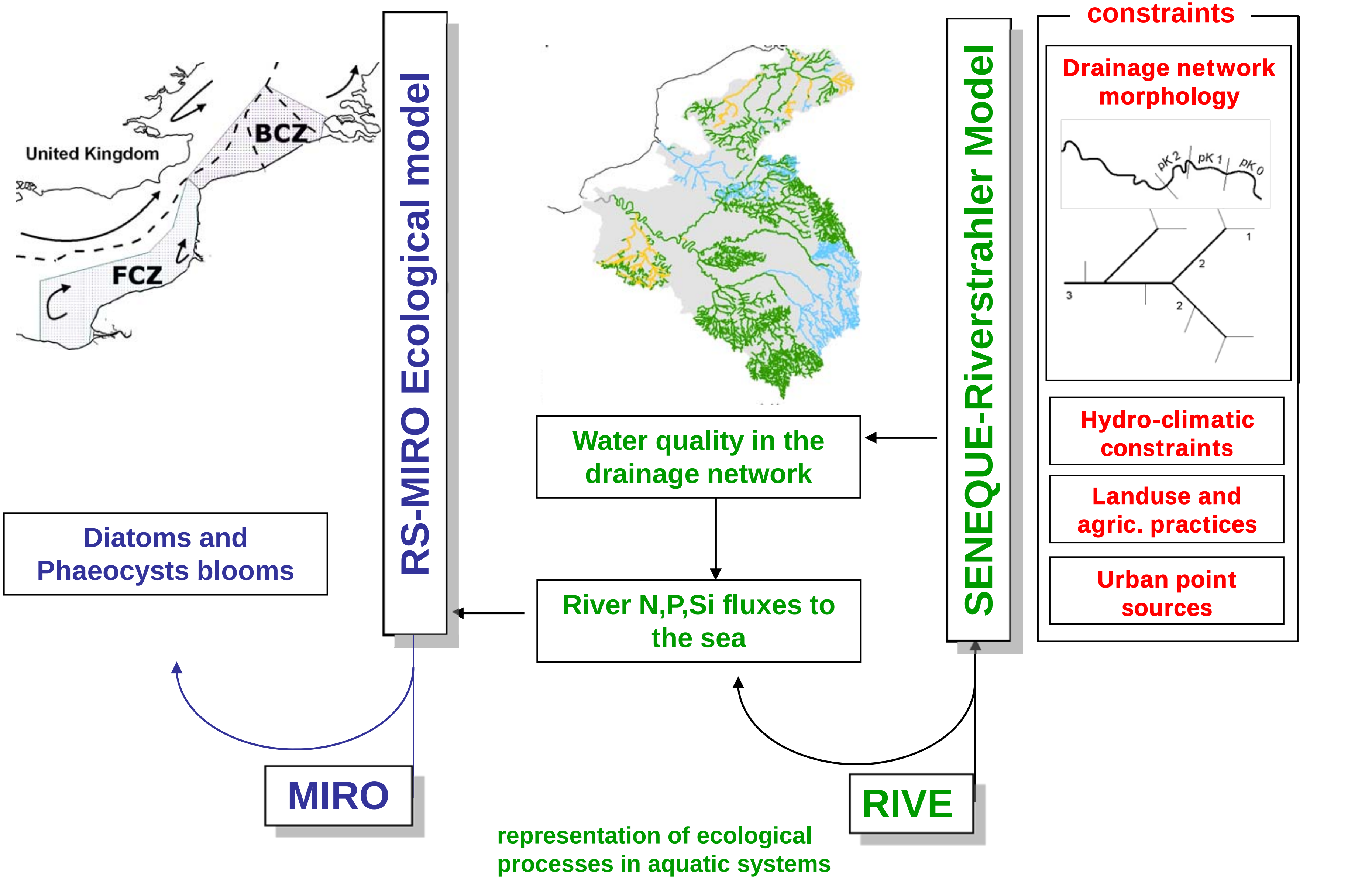


‘Bad algae’ are stimulated by river inputs containing more N and P than Si with respect to the requirements of diatoms

‘Anthropic’ rivers:
Bring more nitrogen and phosphorus than silica
Non-siliceous micro- or macroalgae are favoured instead of diatoms, with undesirable effects

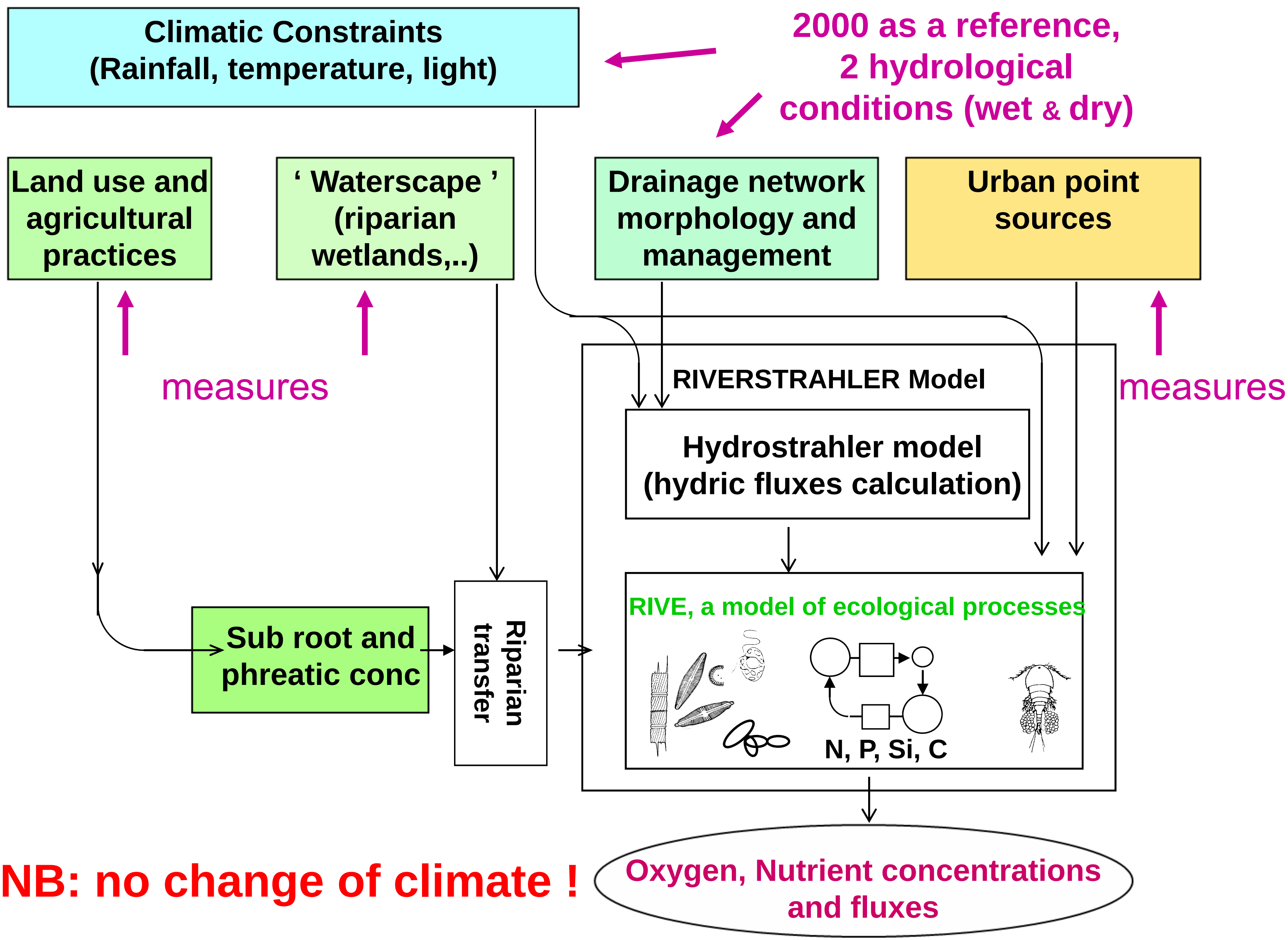


Chaining watershed and coastal zone models for predicting the effect on water quality of measure programmes or scenarios in the watersheds



The Riverstrahler Model

Billen et al., 1994; Garnier et al., 1995; Billen & Garnier, 1999; Garnier et al. 2002, Thieu et al., 2009, WR; Thieu et al, 2010,



➔ **NB: no change of climate !**

Spatial implementation of the 3 S Model :

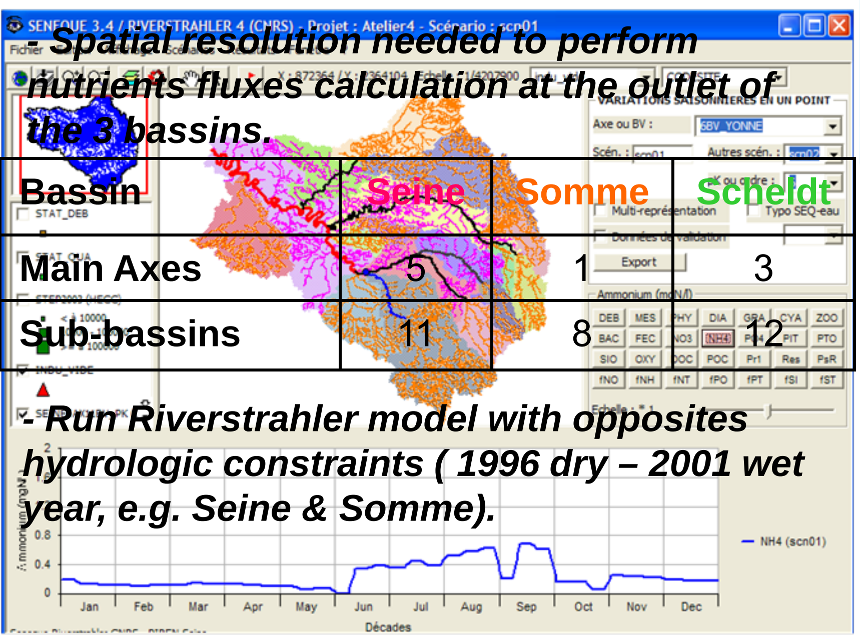
❑ Definition of the drainage networks

Seine: 76000 km²; Somme: 6200 km²; Scheldt : 19860 km

❑ Compilation of a complete domestic & industrial inputs for the 3S (release localization, incomes fluxes, treatment efficiency)

Bassin	Seine	Somme	Scheldt
Indus. sources	4428	190	317

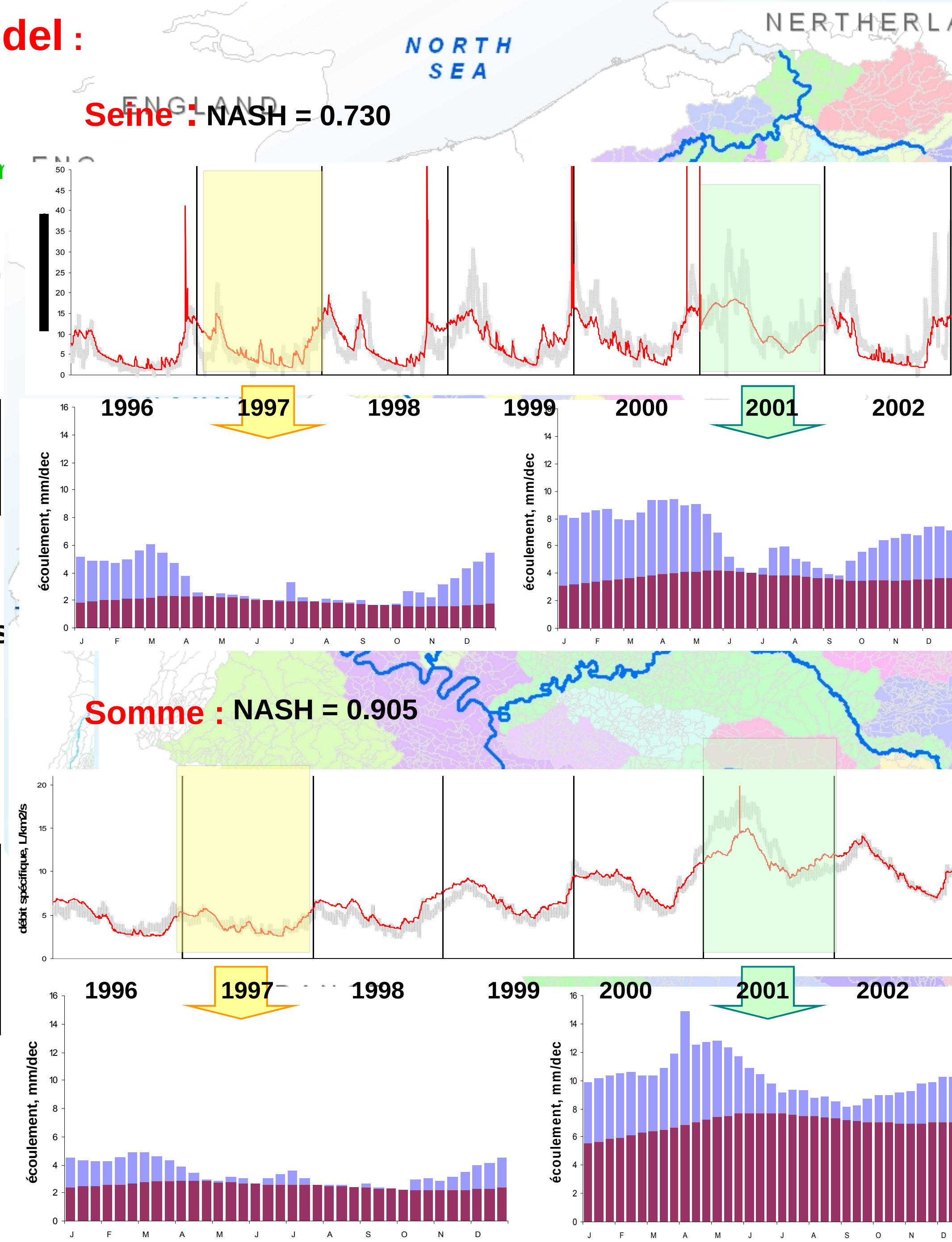
❑ Assumptions made to assess coastal impacts



- Spatial resolution needed to perform nutrients fluxes calculation at the outlet of the 3 bassins.

Bassin	Seine	Somme	Scheldt
Main Axes	5	1	3
Sub-bassins	11	8	12

- Run Riverstrahler model with opposites hydrologic constraints (1996 dry – 2001 wet year, e.g. Seine & Somme).



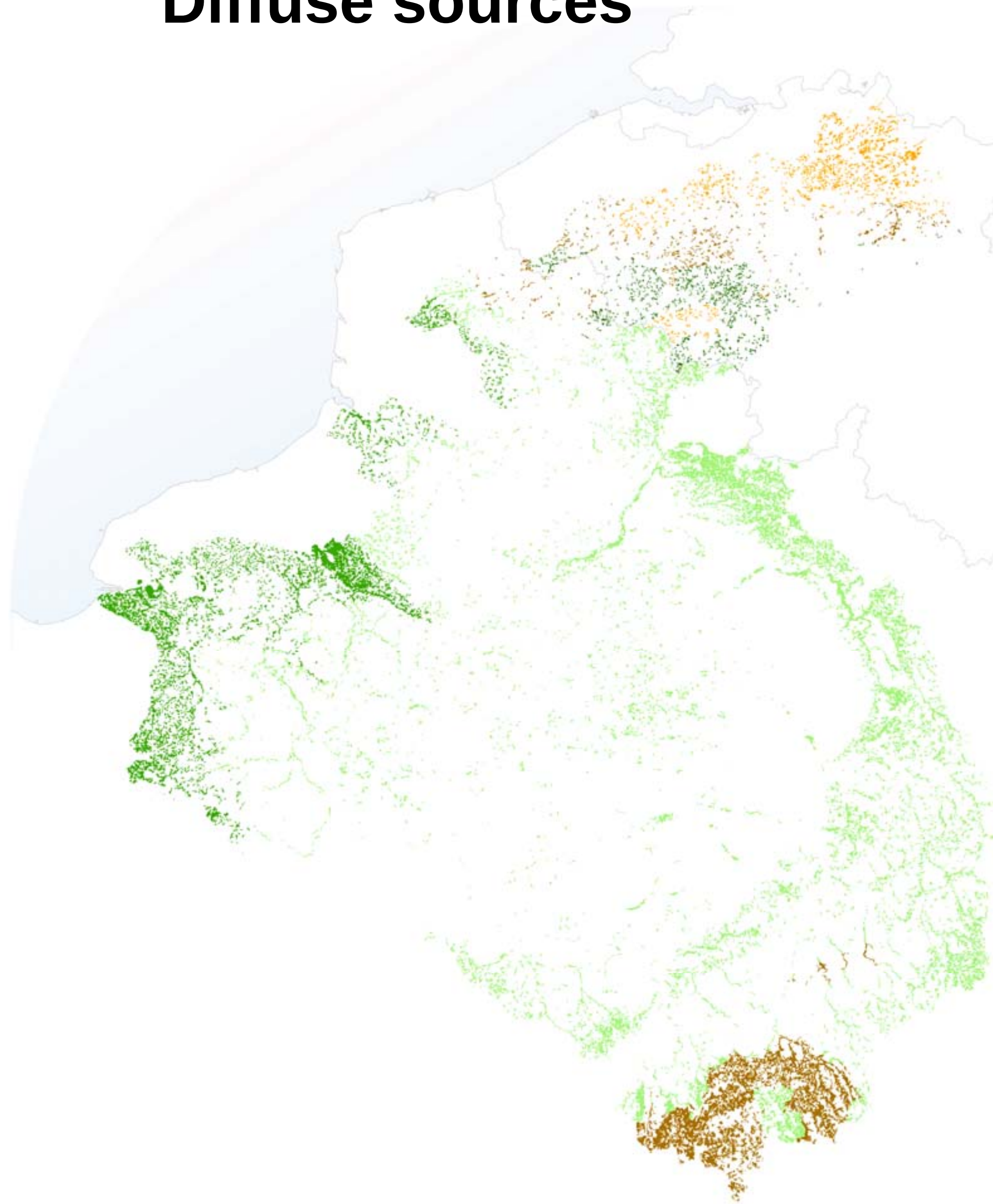
Diffuse sources

Seine | Somme | Escaut

10% | 5 % | 8%

ut

- type argonnne
- type linomeuse
- type morvan
- type normande
- type sableuse
- type sablo-limoneuse
- champagne humide
- depression yonne
- limon riche
- morvan
- perche auge bray
- plateau jurassique
- plateau normand
- vignoble
- campine
- campine hennuyere
- region limoneuse
- region sableuse
- region sablo-limoneuse



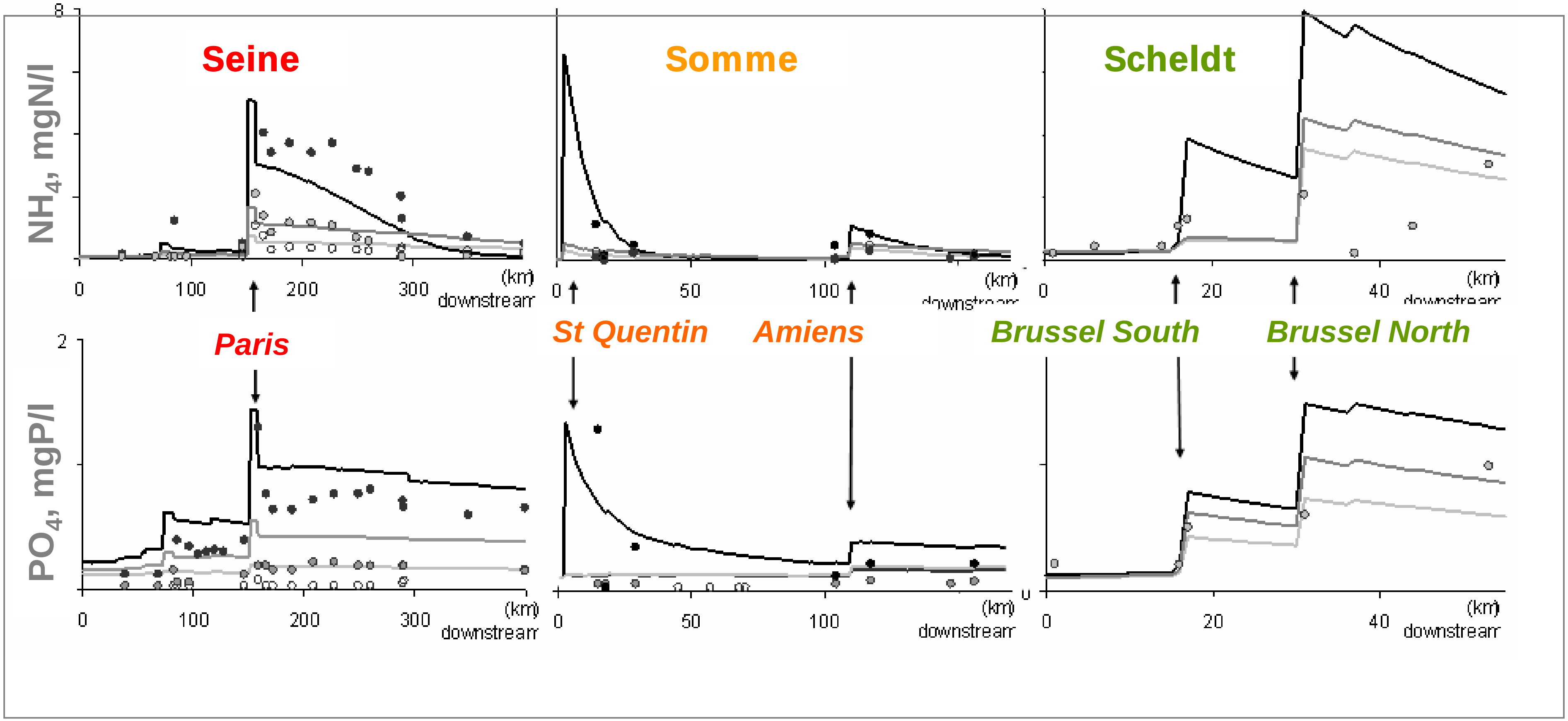
Ph-D Vincent Thieu, 2009;

Thieu et al., 2009, Water Res.

Validation of the Riverstrahler model

3 years (1996, 2000, 2001)

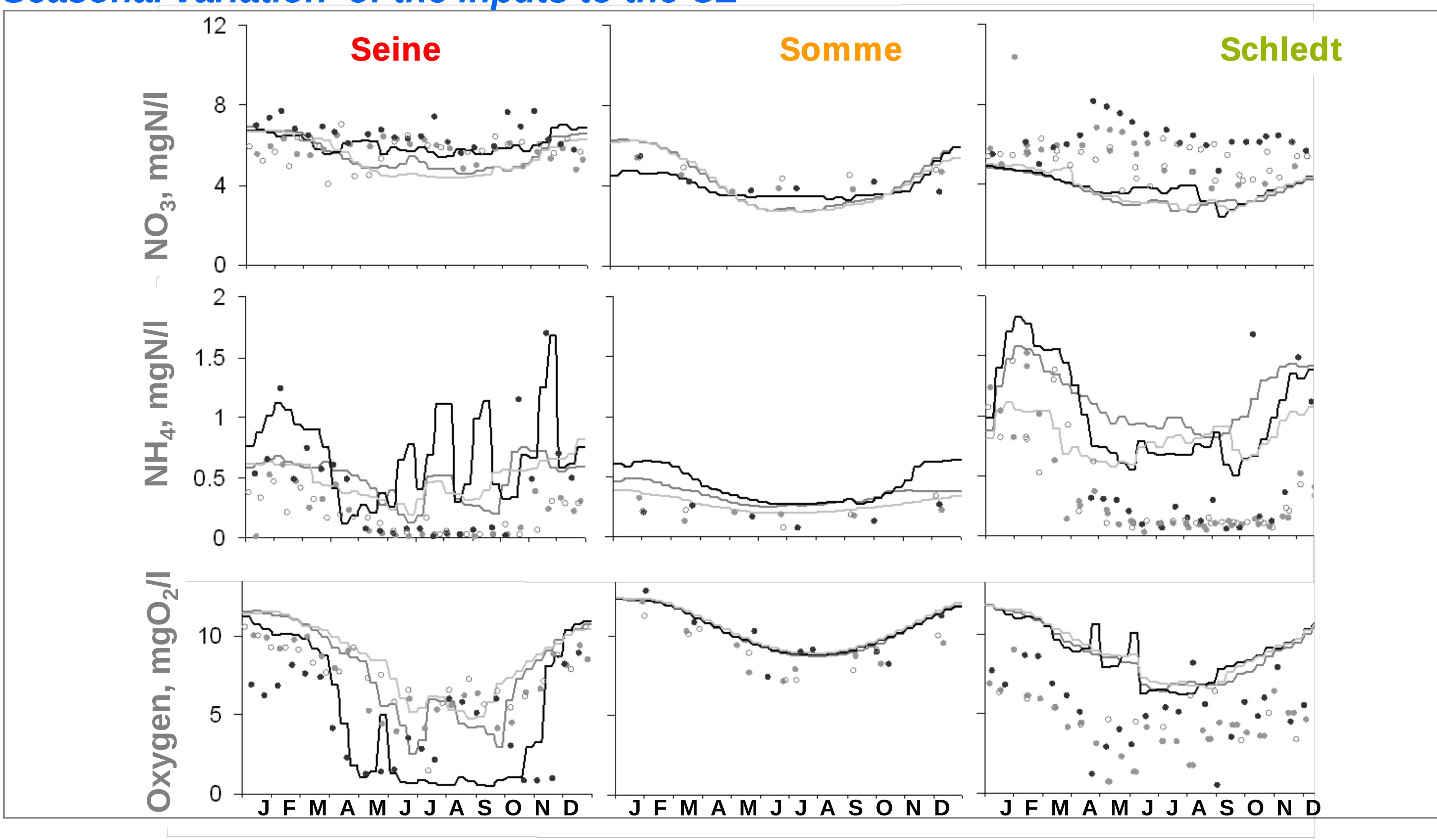
Concentration profiles downstream from large urban zones



Validation of the Riverstrahler model

3 years (1996, 2000, 2001)

Seasonal variation of the inputs to the CZ



Scenarios implementation of nutrient (N, P) reductions

Short term, 2015

+ Waste Water treatement plant (WFD, 2015), > *20000 Inhab. Eq.*

Reference 2000 + upgrading treatment in WWTPs, both phosphorus and nitrogen treatment (or implementation of new treatment)

- up to 73% of N removal (nitrification + denitrification)
- up to 90% of P removal (dephosphatation process)

+ Good agricultural practice (WFD, 2015)

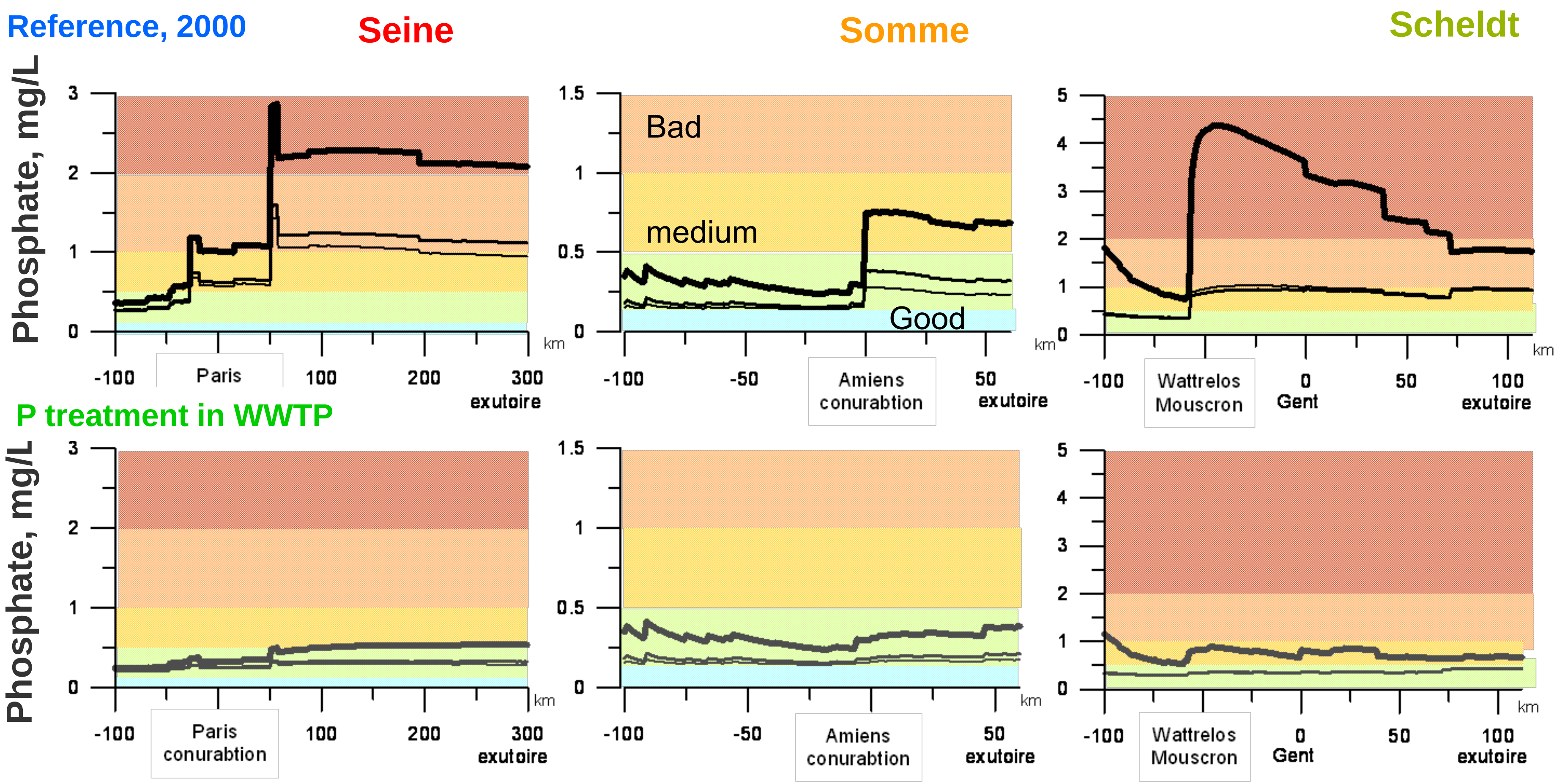
Reduction of the input of nitrogen and phosphorus fertilizers (-5 to 20 %)
Implementation of nitrogen trapping winter crops on arable land (- 5 to 35%)
Conversion of fodder corn crop into meadows (- ≈ 30-50 % N leaching)
Ground water release considered unchanged (NB: - 25% in 2050)

Long term, 2050

+ Long term eco-agricultural scenario (a new CAP ???)

Use of organic fertizers
Legume cropping (N fixation)
Complementarity between cropping and animal farming (0.7 LU/ha)
➔ *Subroot concentrations 3-6 mgN/L (against 10-20 mgN/L)*
Equilibrium between NO_3 surface and groundwater concentrations

Effect of P treatment in WWTPs (> 20 000 inhab. Eq.) of the 3S-WS

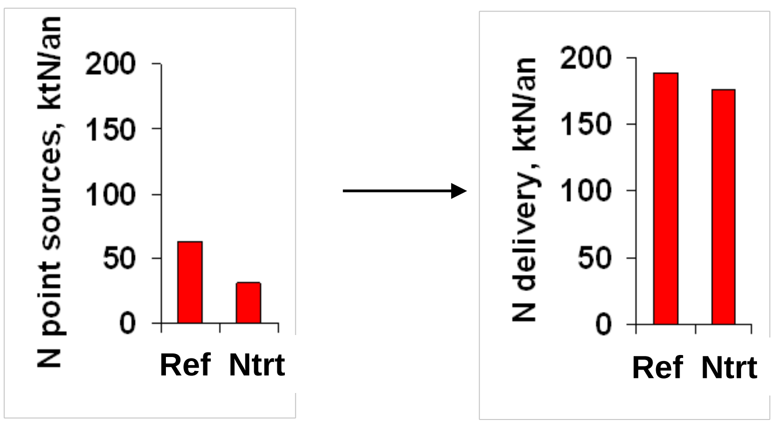


Improving wastewater treatment

Upgrading N treatment in WWTPs :

Available technology, although expensive, allows WWTP to eliminate 70% of the N load treated.

If applied to all WWTP >20 000 inhab equiv:

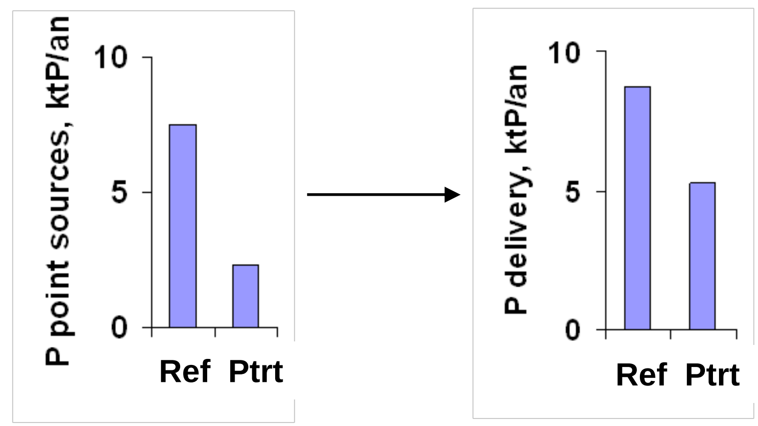


Total N riverine delivery decrease by 10 %

Upgrading P treatment in WWTPs :

Available technology, rather simple to implement, allows WWTP to eliminate 90% of the P load treated.

If applied to all WWTP >20 000 inhabequiv:



Total P riverine delivery decrease by 40 %

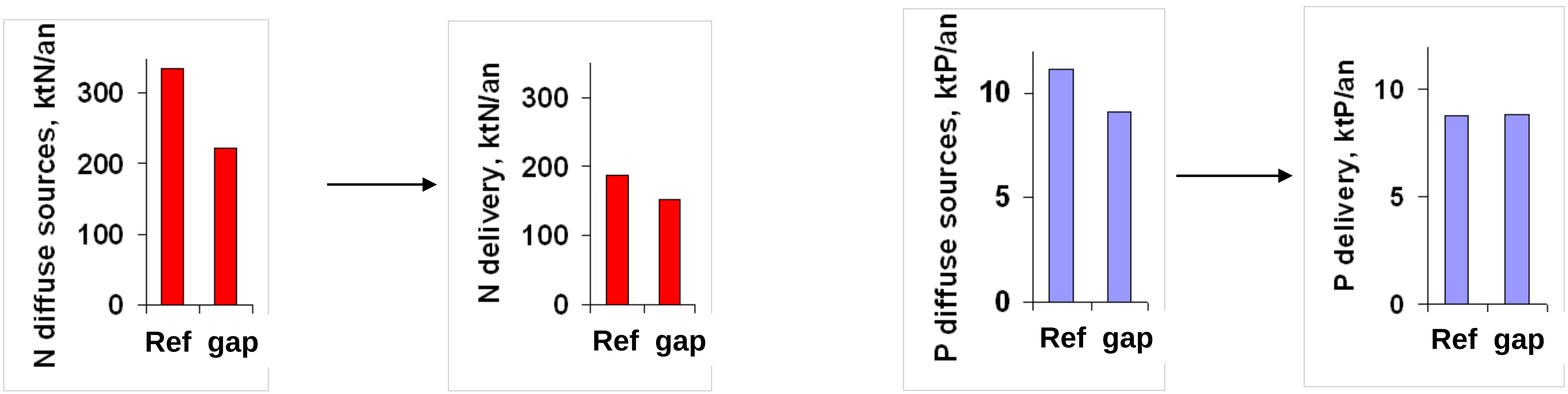
➔ Only P treatment in WWTP has a significant effect

Thieu et al., 2010, STOTEN

Agricultural measures «good agricultural practices» (gap)

NB:

Converting maïze crop land into grasslands
Reducing N fertiliser application
Introducing winter N-catch crops (to avoid bare soils during winter)



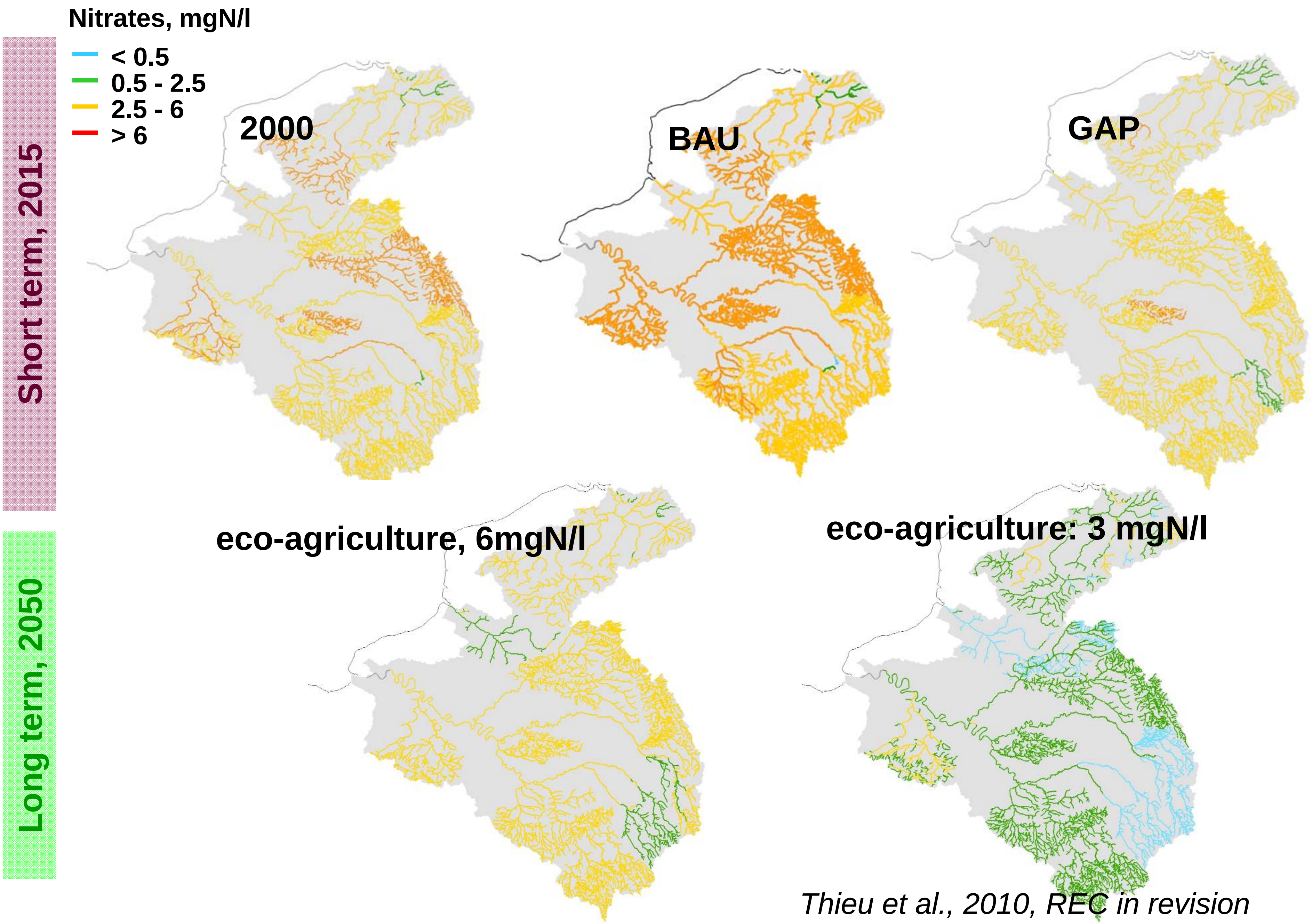
N : maximum effect with

- 50 % conversion Arable to Grasslands
- reduction of N fertilisers + N trapping winter crops

P : no major effects

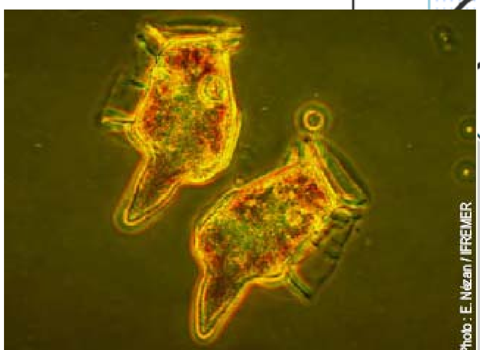
➔ Good agricultural practices (winter catch crop introduction and conversion of fodder crops to grassland) allows 25%reduction of N delivery

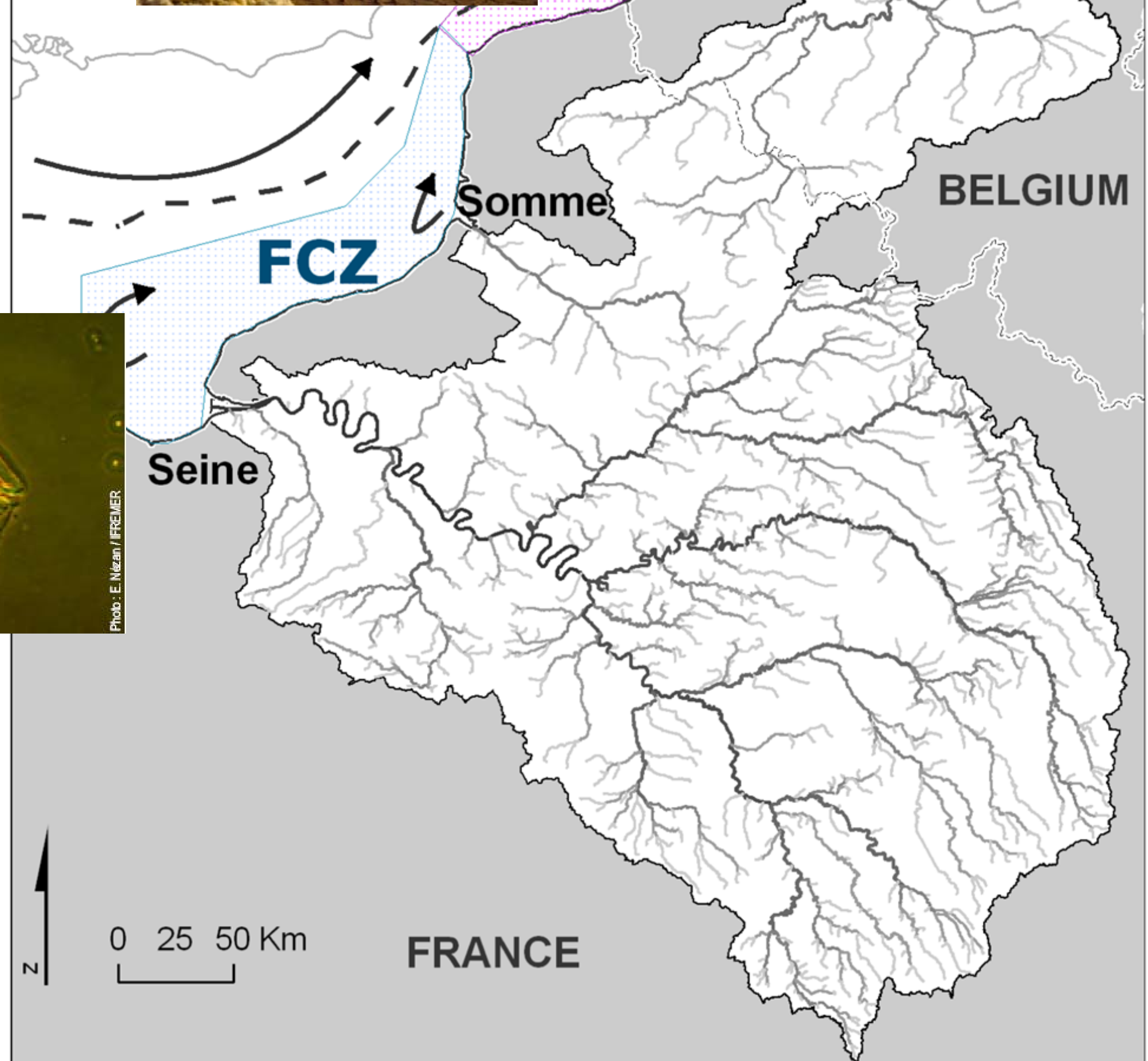
Agricultural measures: eco-agriculture



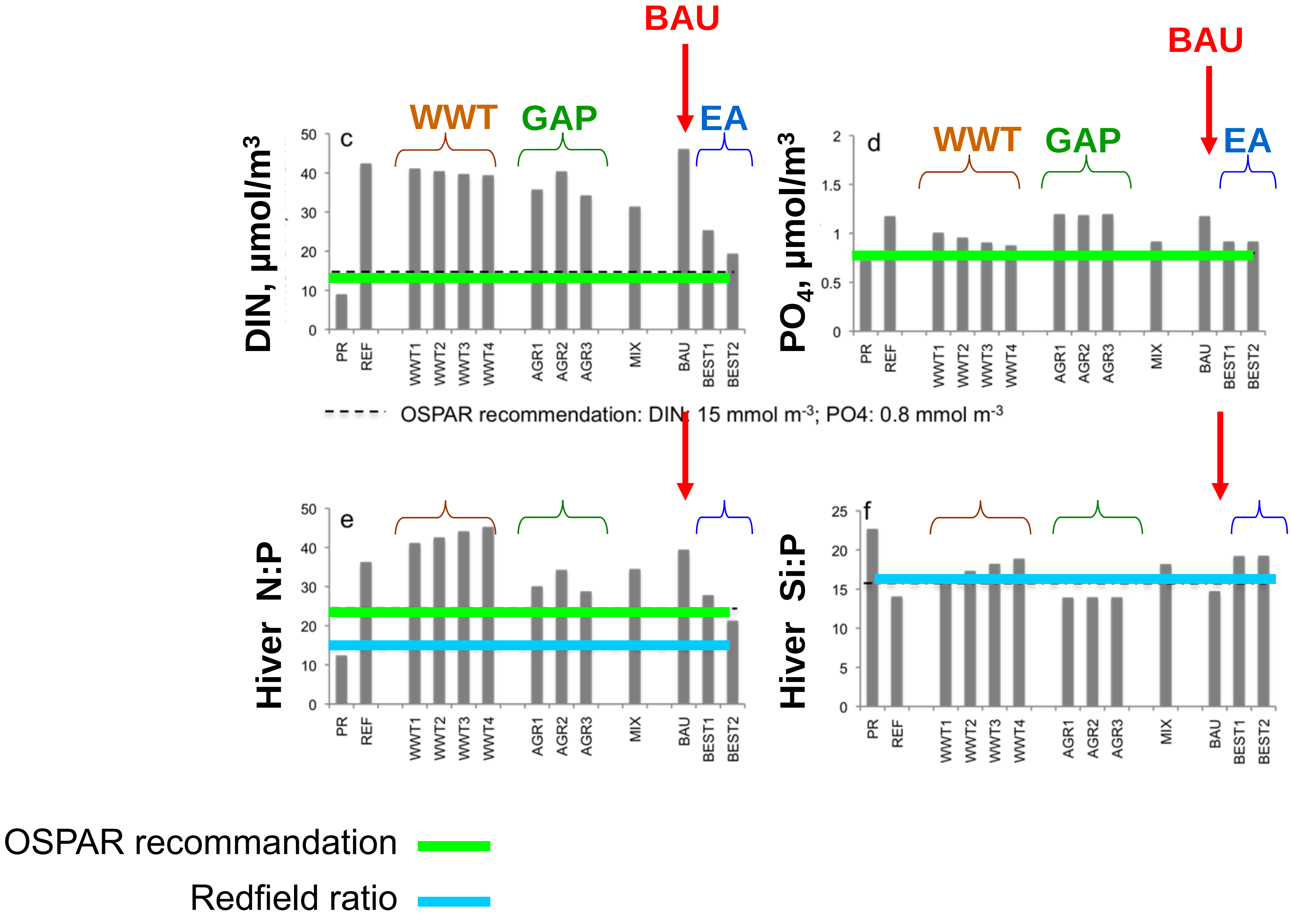
Thieu et al., 2010, REC in revision

Effect at the coastal zone



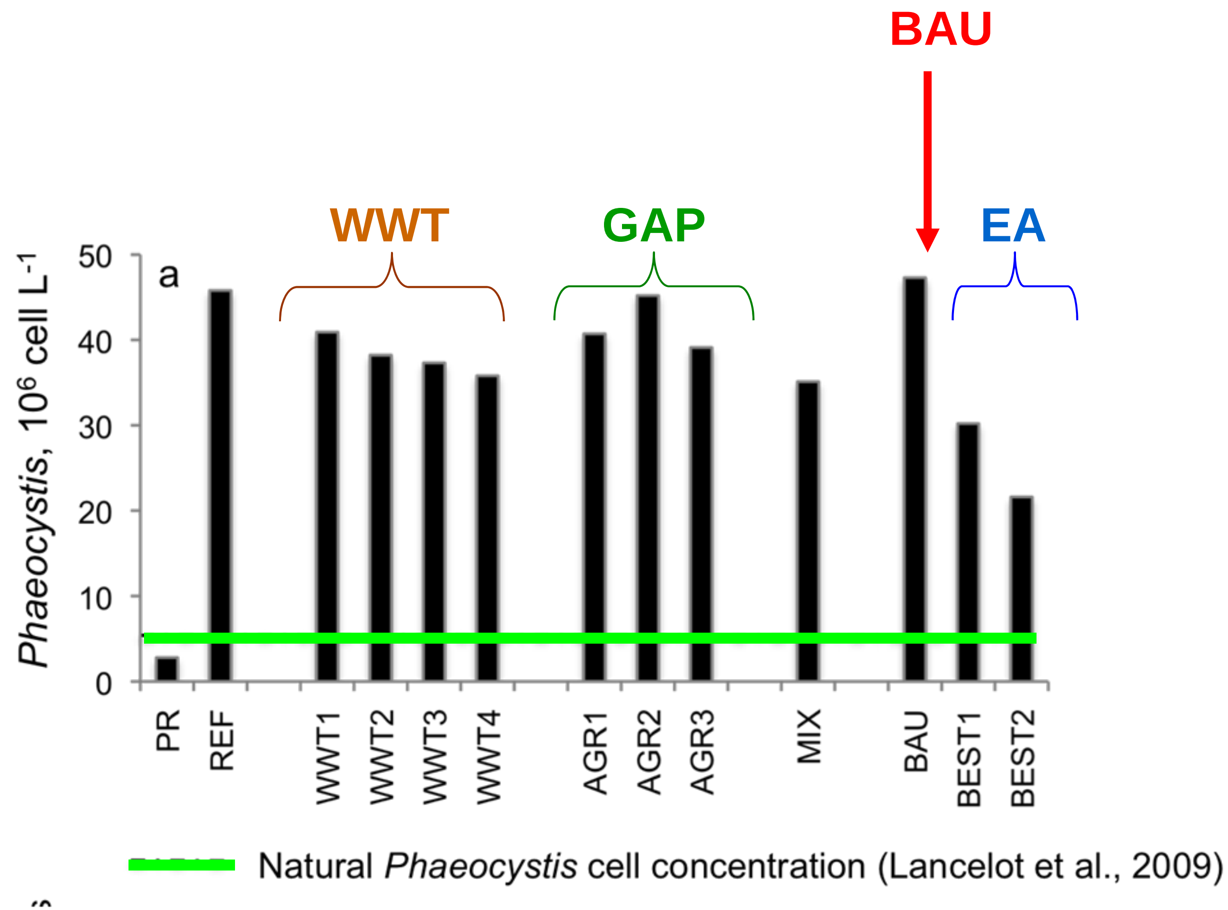


Effect on nutrients

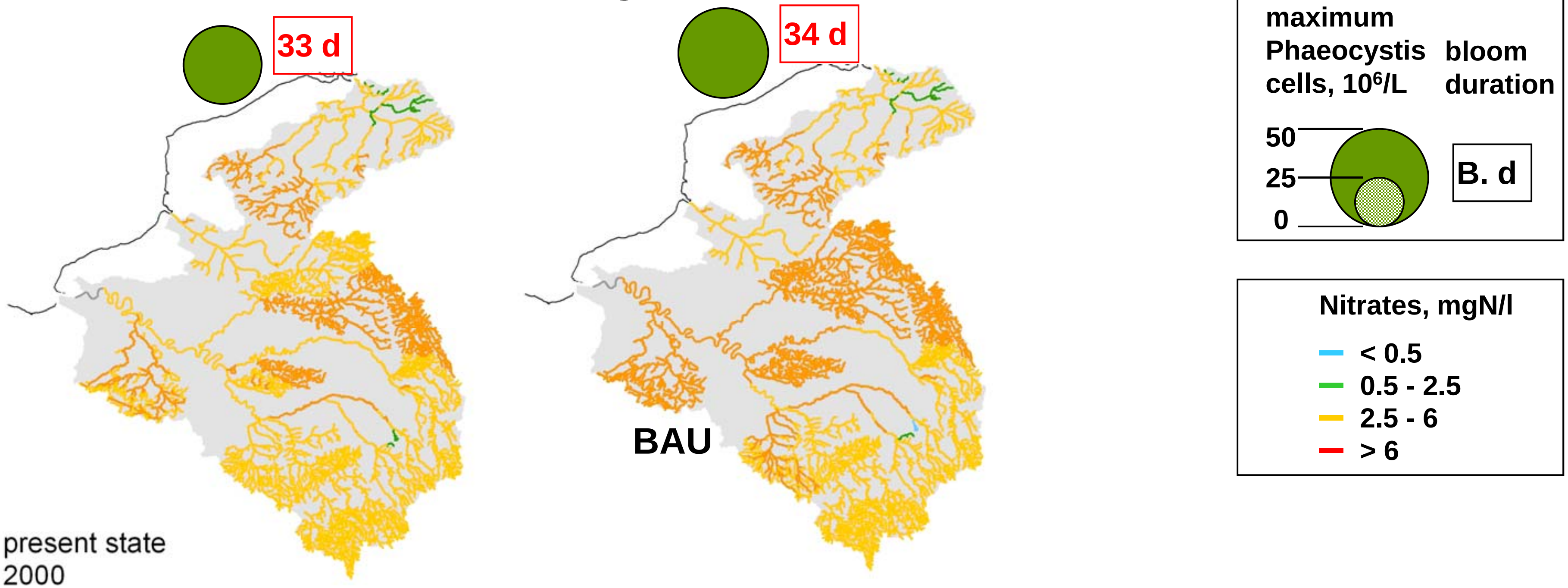


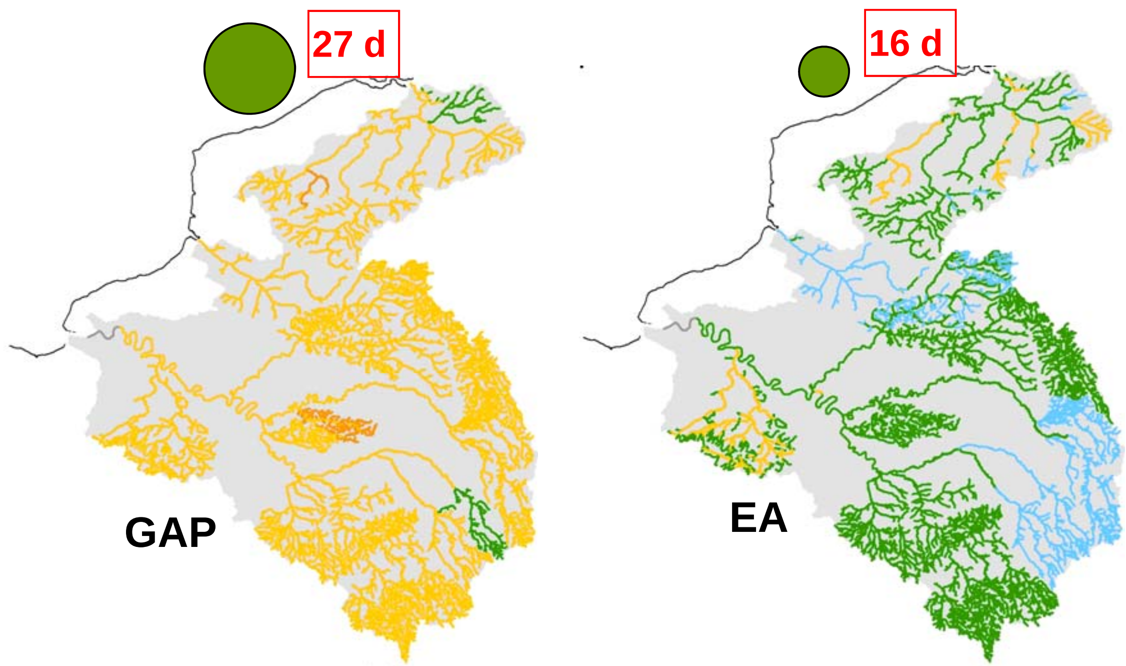
Lancelot et al., 2010, in revision

Effect on Phaeocystis abundance



Effect on Bloom intensity and duration





Thieu et al., 2010;

Thieu et al., 2010, in revision

Lancelot et al., 2010, in revision

Economical Effectiveness

- A cost-effectiveness analysis is performed for each nutrient reduction scenario

- The reduction obtained for *Phaeocystis* blooms is assessed by comparison with ecological indicators (bloom magnitude and duration).

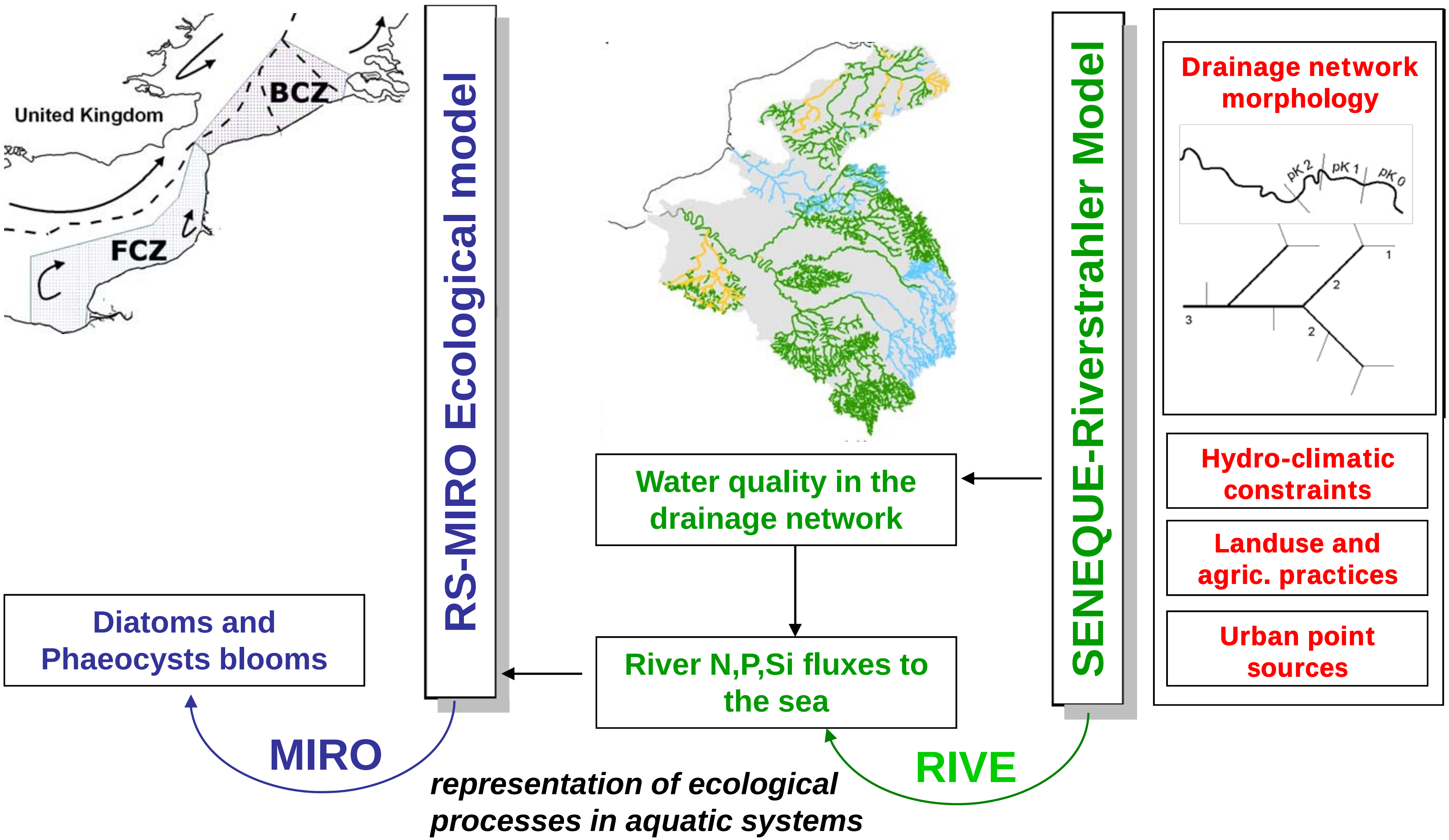
An integrated biogeochemical and cost and effectiveness approach

Impacts

cost-effectiveness (CEESE-ULB)

Emission agriculture & wastewater

Cost mitigation/effectiveness (CEESE-ULB)



Mitigation cost and effectiveness of nutrient reductions

SR-MIRO Scenarios	Mitigation costs, M€			Cost effectiveness, €/kg N			Cost effectiveness, €/kg P		
	Seine	Somme	Scheldt	Seine	Somme	Scheldt	Seine	Somme	Scheldt
WWTP-Upgrading N,P (>20000 IE)	307	9	135	31	65	66	107	154	251
Agro-environmental measures	63	7.5	16	2.3	3	3			
WWT + Agro-environ measures	*370*	*16.5*	*151*	*10*	*8*	*20*	*127*	*259*	*287*

➔ Costs of mitigation not directly related to effectiveness, as they depend on the level of ref. treatments, etc.

➔ Agricultural measures are more cost-effective than implementation in WWT for N reduction (e.g. 2.3 €/ kgN <<< 31 €/ kgN)

Mitigation cost and effectiveness for HAB

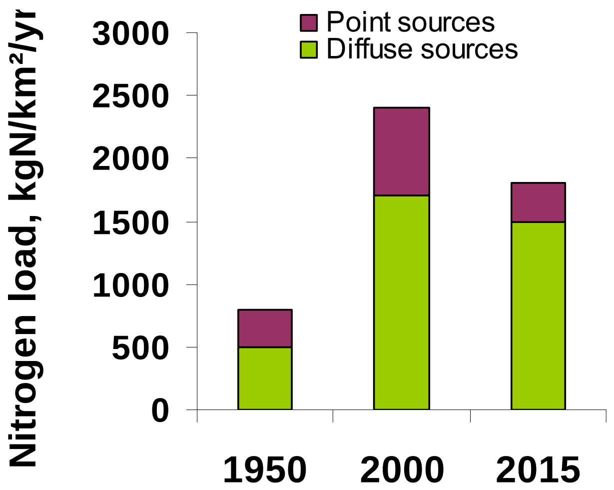
***Phaeocystis* bloom max (ref. 46 10^6 cell) *vs* duration (ref. 33 days)**

SR-MIRO Scenarios	*Phaeocystis* colonies		ΣCost 3S	Cost-effectiveness	
	Maximum 10^6 *cell/L (% reduction)*	***Duration*** *Day, (% reduction.)*	*M €*	*M €/ 10^6 cell/L*	*M €/ day*
WWTP-Upgrading N,P (>20000 IE)	37.3 *(19)*	28 *(15)*	451	53	90
Agro-environmental measures	39.1 *(15)*	30 *(9)*	88	13	29
WWT + Agro-environ measures	35.1 *(23)*	27 *(18)*	538	50	89

- WWTs reduce more *Phaeocystis* than agro-environemental measures (19% against 15 % and 15 % against 9 %, but the cost is much higher

- Agricultural measures are however cheaper per unit of cell abundance reduced or number of days of the bloom duration lowered

Does the WFD really target the good ecological state ?



- Nitric contamination, a problem not well taken into account by the WFD

- A new objective for the coastal zone water quality would be to tend towards N:Si equilibrium

➔ Nitrate: an agricultural problem… what kind of agriculture for the future ?

- A reduction of nitrate input as fertilizers *vs* engineering (construction of ponds, buffer strips) or restauration (rehabilitation of wetlands, etc.)
- Conventional *vs* ecological agriculture, using knowledge in agronomy and soil sciences (≠obsessive productivity)

➔ What about reducing our meat consumption ?

- Today, in Belgium and France more than 60% of our protein intake are from animal products
- To produce 1 kgN as vegetal proteins ➔ 0.3 kgN leached
- To produce 1 kgN as animal proteins ➔ >2 kgN leached

➔ What are the issues of agriculture *vs* new climate constraints ?

Conclusions and perspectives on the land to sea modelling

1. A chain of models able to test management scenarios

An original integrated impact assessment methodology to quantify the ecological impact of human activity along a continuum from land to sea

2. An implementation of costs effectiveness analysis

A economic cost effectiveness of realistic nutrient mitigation scenarios:

- exploring the benefits for the coastal ecosystems
- taking into account the feasibility of nutrient reduction to the sea

3. In the nearby future ➔ capability to take into account changing hydrology under climate changes

Thank you for attention !

Acknowledgements

EU FP6: 2006-2009
Thresholds of Environmental sustainability

IAP TIMOTHY: 2007-2011

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Programme interdisciplinaire de Recherche en Environnement

CNRS & UPMC, since 2007, FR-3020 FIRE
Fedération Ile-de-France de Recherche sur l'environnement

Reference by the teams

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