Wetlands at the catchment scale: from monitoring to management

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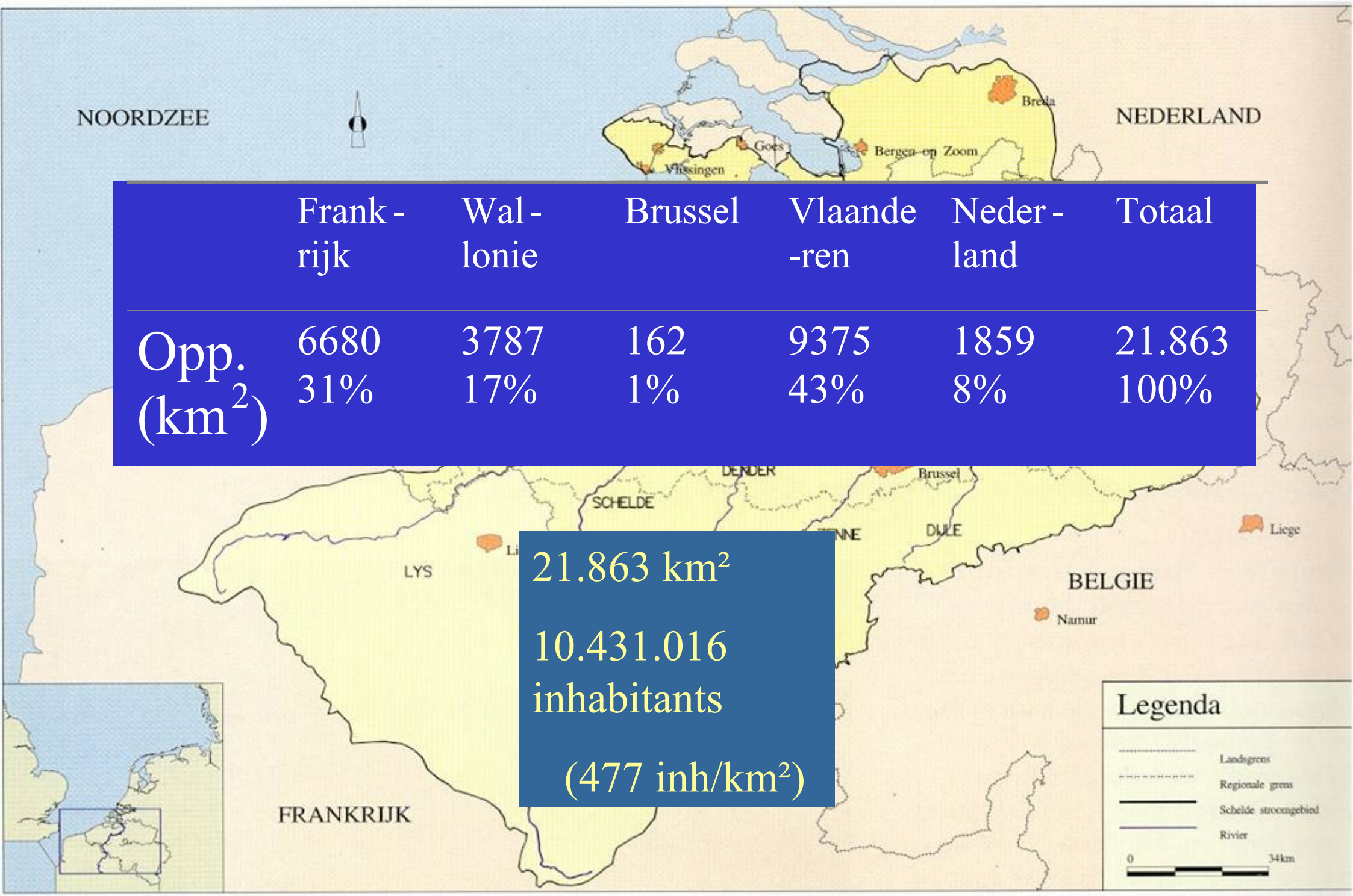
ECOSYSTEM MANAGEMENT RESEARCH GROUP

Aim

- The aim of this presentation is to put foreward some ideas developed and applied in recent years in Flanders concerning wetland restoration and river basin management.
- Put emphazis on monitoring, modeling and management as well as on a functional approach



	Frank-rijk	Wal-lonie	Brussel	Vlaande-ren	Neder-land	Totaal
Opp. (km^2)	6680 31%	3787 17%	162 1%	9375 43%	1859 8%	21.863 100%

21.863 km²

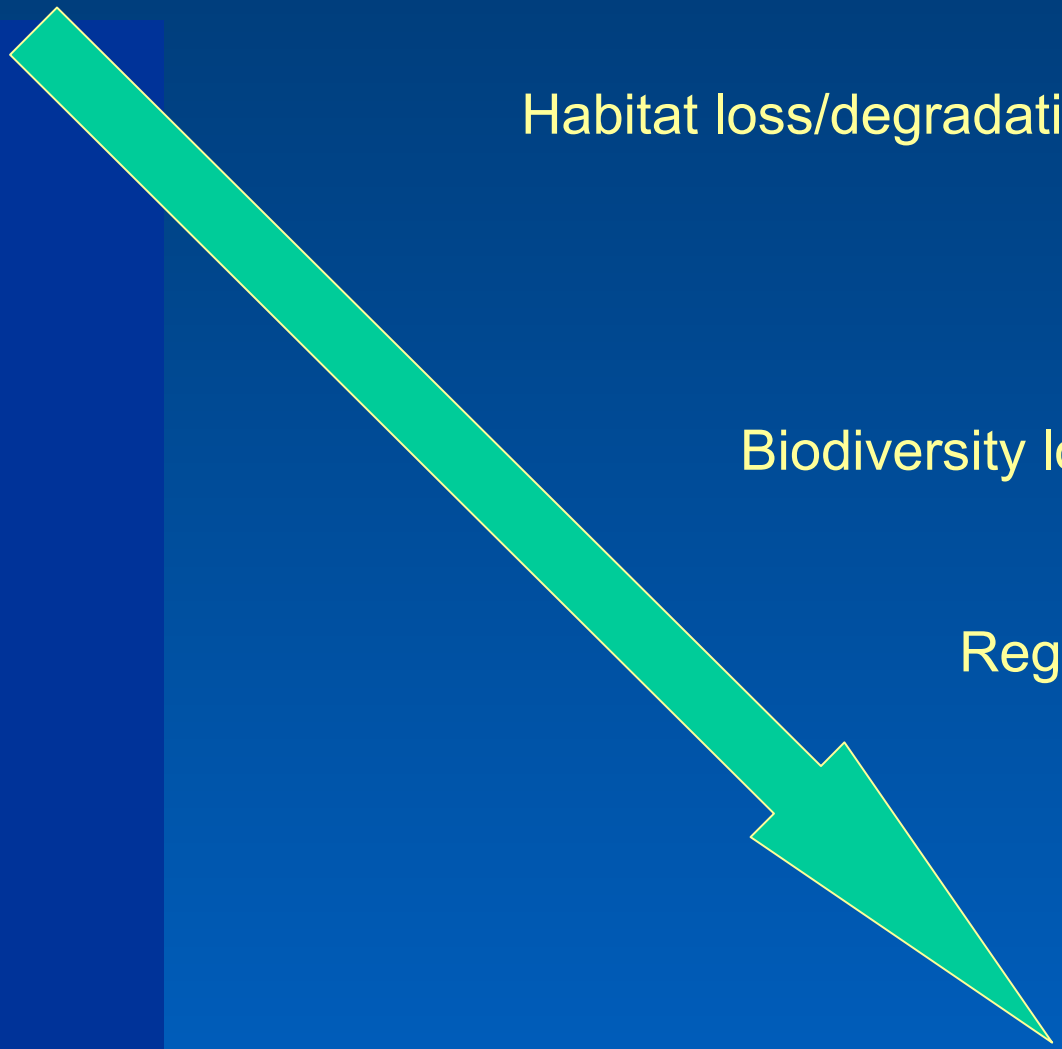
10.431.016 inhabitants

(477 inh/km²)

intro

- Detoriation of Wetlands and their biodiversity is a world wide phenomena
- Many actions have been undertaken to stop further losses and to try to restore wetlands

The nature conservation Approach



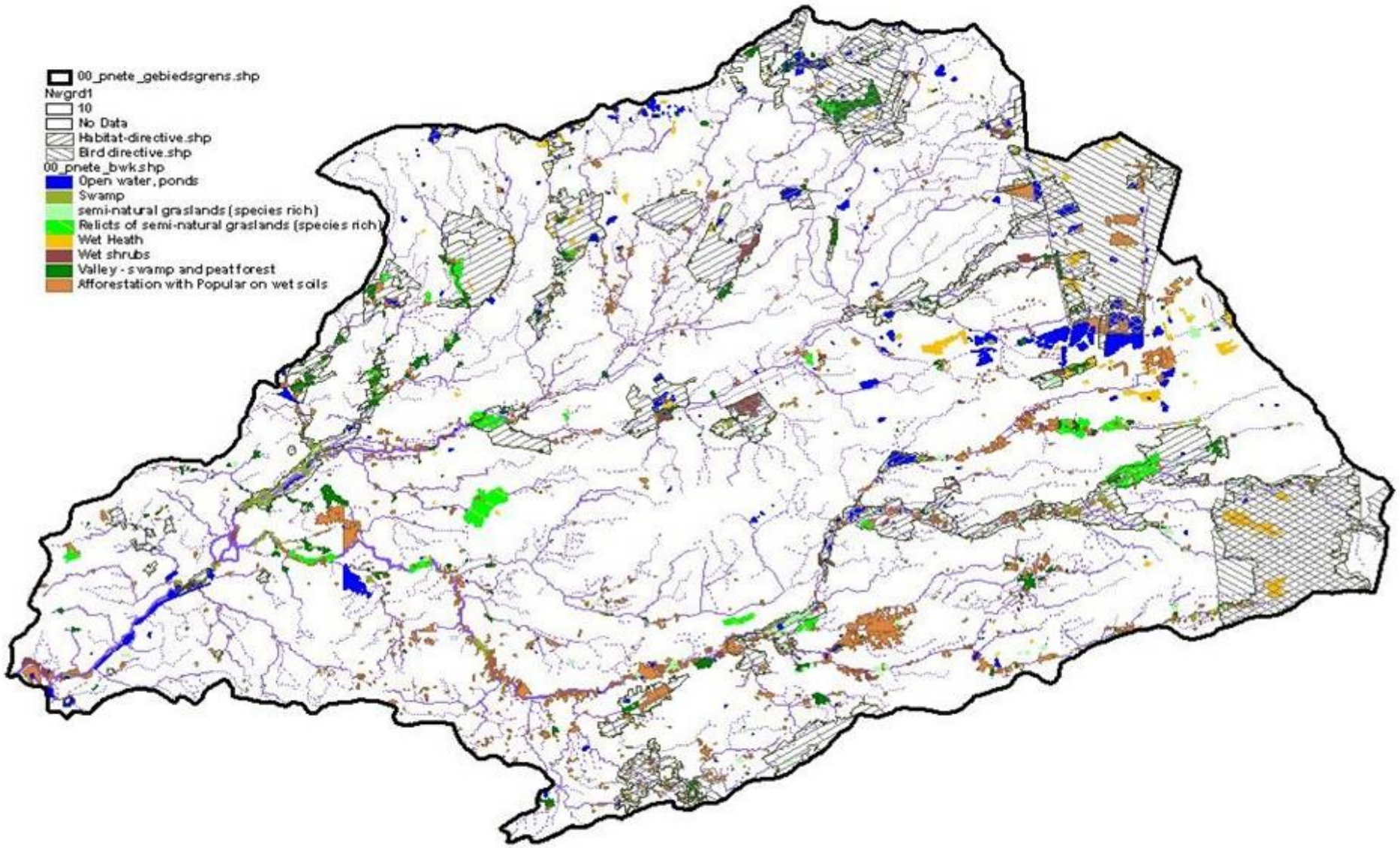
Regulations

- RAMSAR convention
- EU Bird directive
- EU Habitat directive
- …
- National regulations

✂➔ designation of sites

✂➔ management

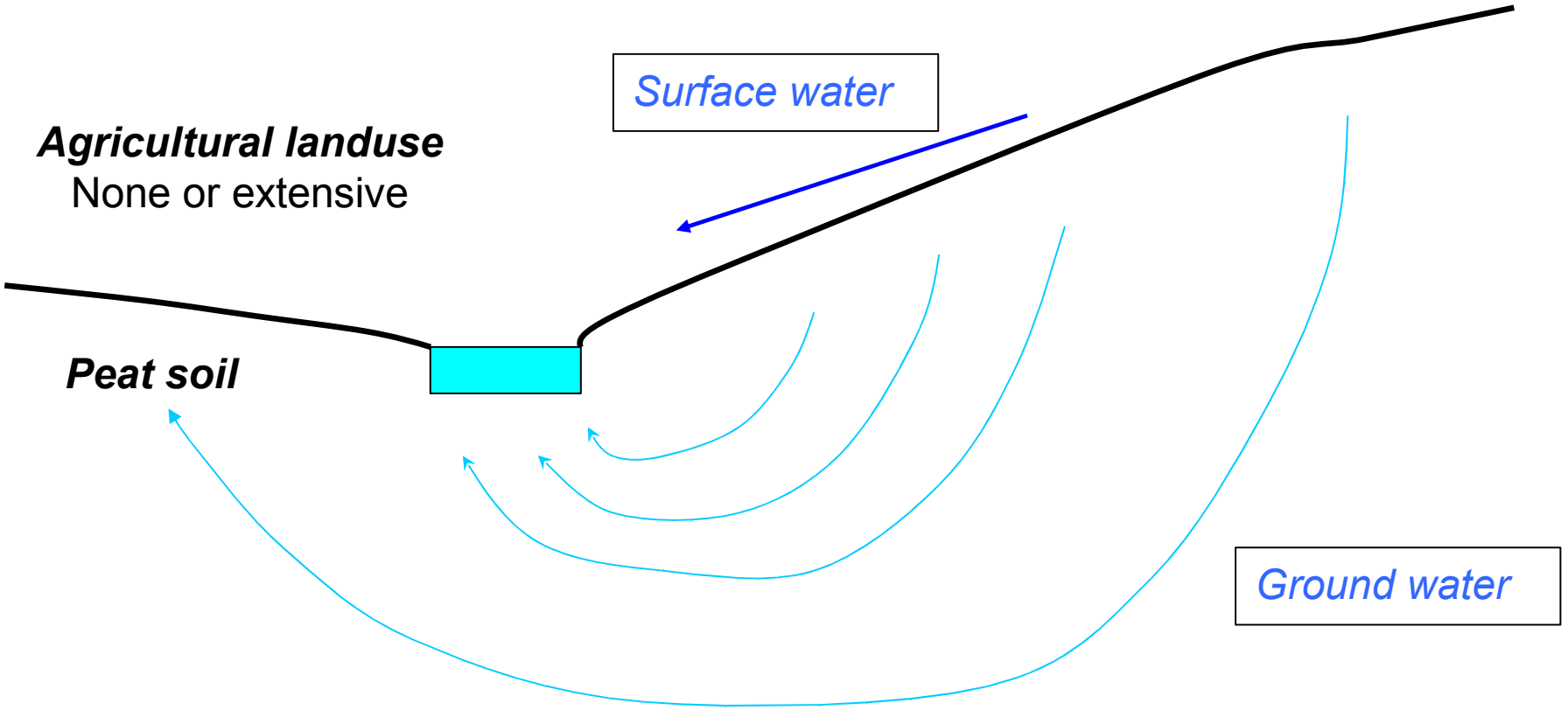
Water dependent ecosystems

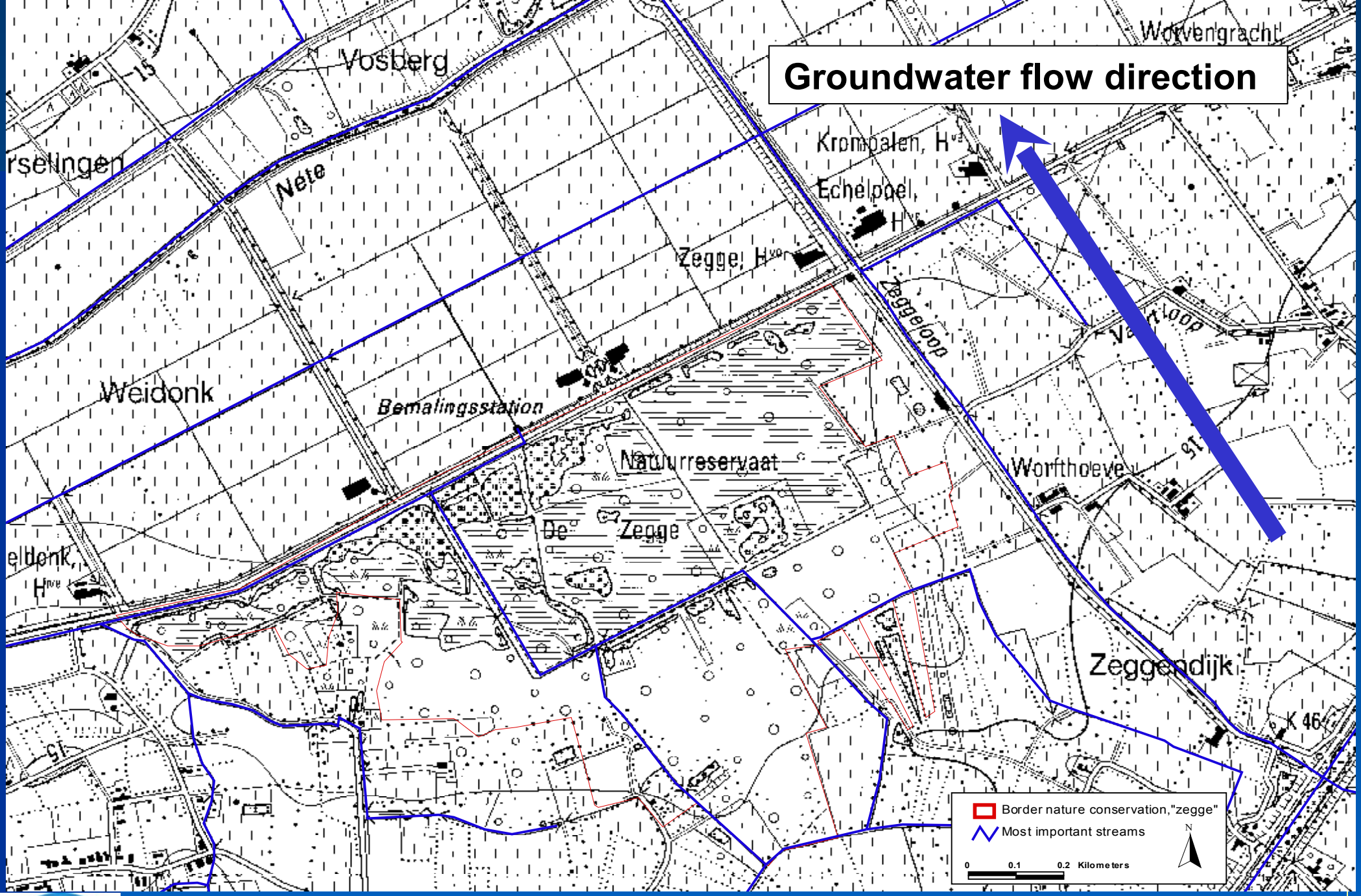


- But:
  - Not all sites are protected
  - protection is not a guarantee for safeguarding the area

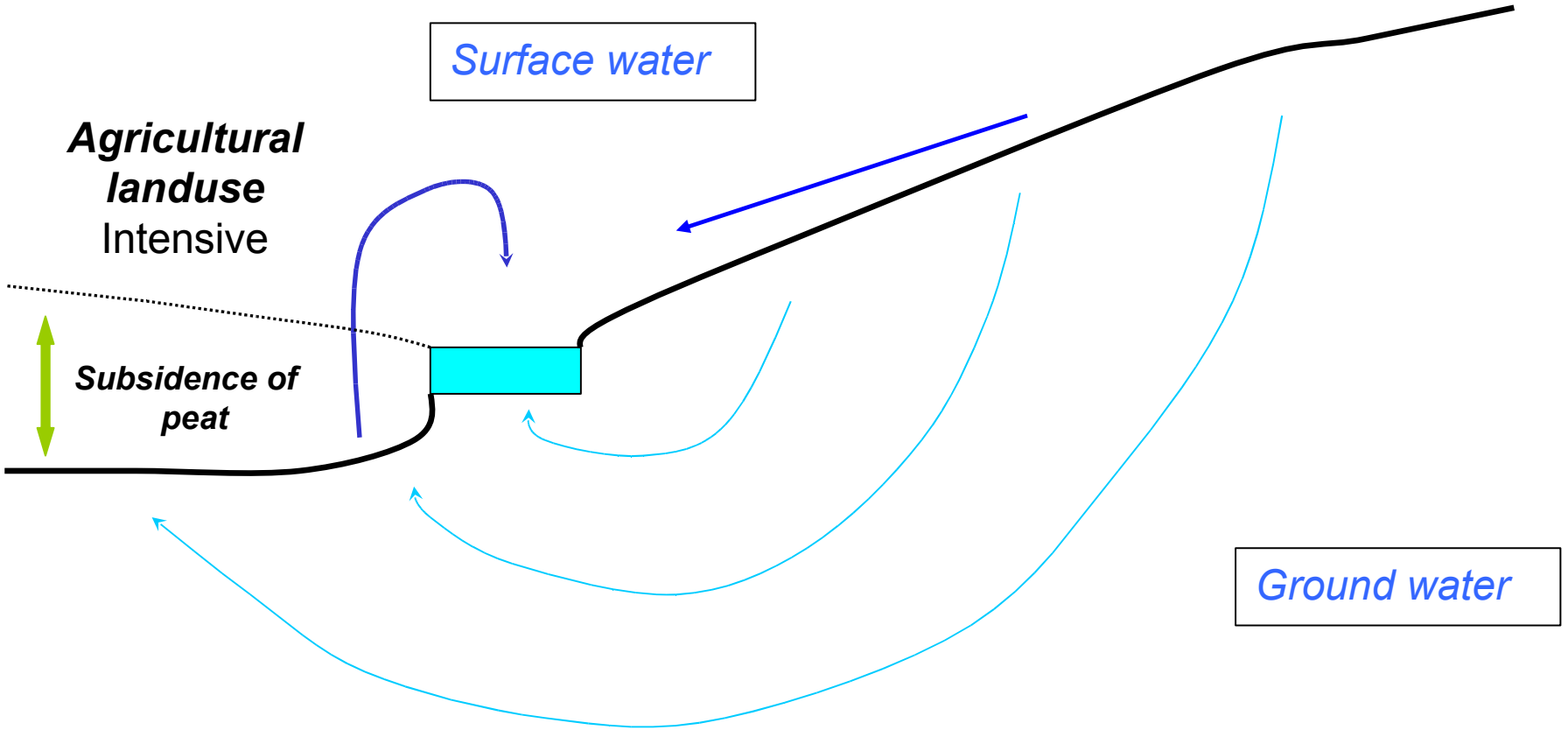
- "De Zegge" (106.7 ha), is a nature conservation area, and harbors many rare plant-, bird and reptile species, for several of them is the last population in Flanders.
- dependent on groundwater !!!!!

- *Original situation*

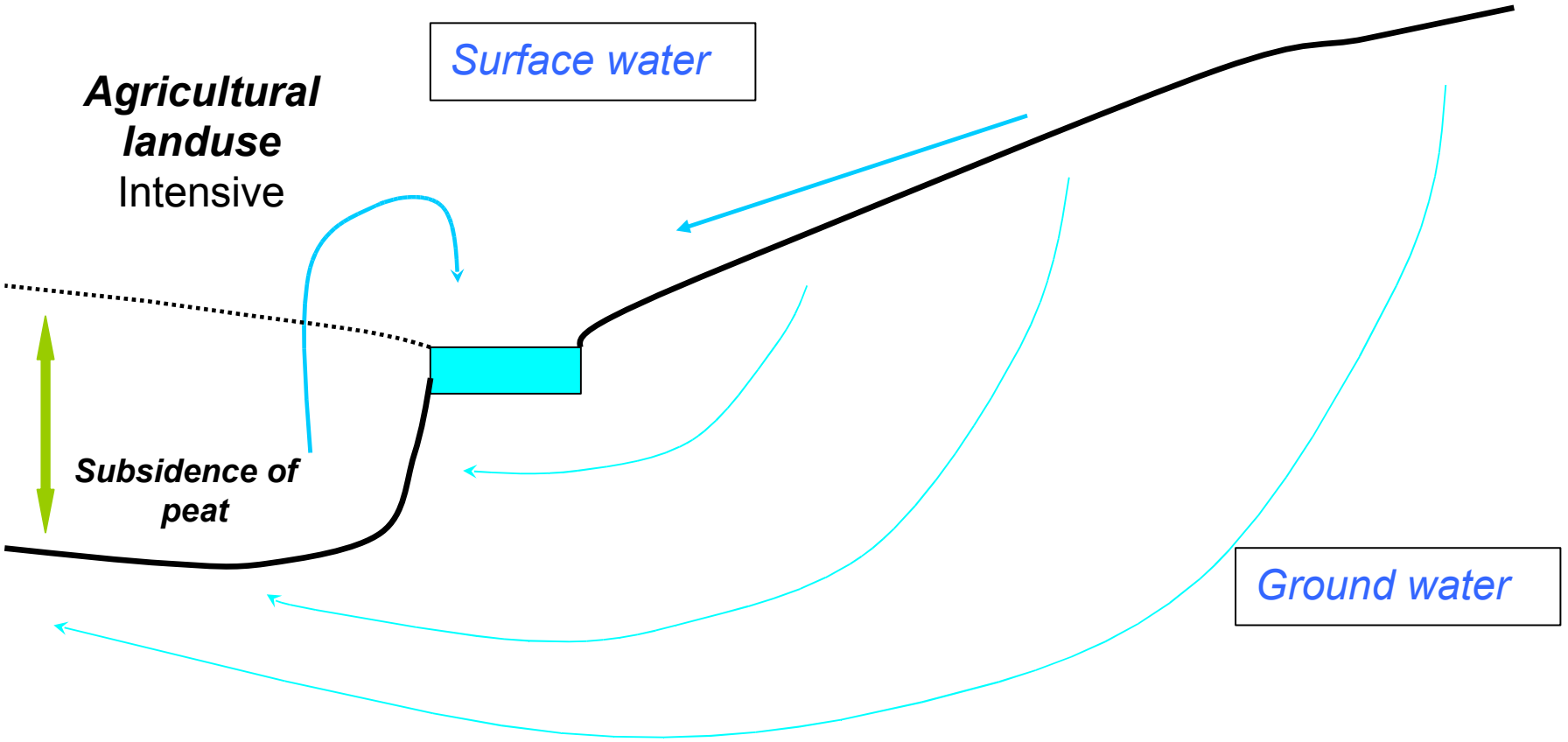



Groundwater flow direction
Vosberg
Nete
Weidonk
Bemalingsstation
Natuurreservaat
De Zegge
Zeggeloop
Krompalen, H
Echelpoel, H
Zegge, H
Worfthoeve
Zeggendijk
Wolvengracht
Border nature conservation,"zegge"
Most important streams
N
0 0.1 0.2 Kilometers

- *Current situation*



- **Future situation???**



Conclusion 2

- Although the "nature conservation approach" is essential, there remains major problems:
  - Safeguarding the necessary abiotic conditions
  - Success of restoration
  - Mainly based on structural aspects and not on functional ones

The nature conservation Approach

Habitat loss/degradation

Biodiversity loss

Regulations

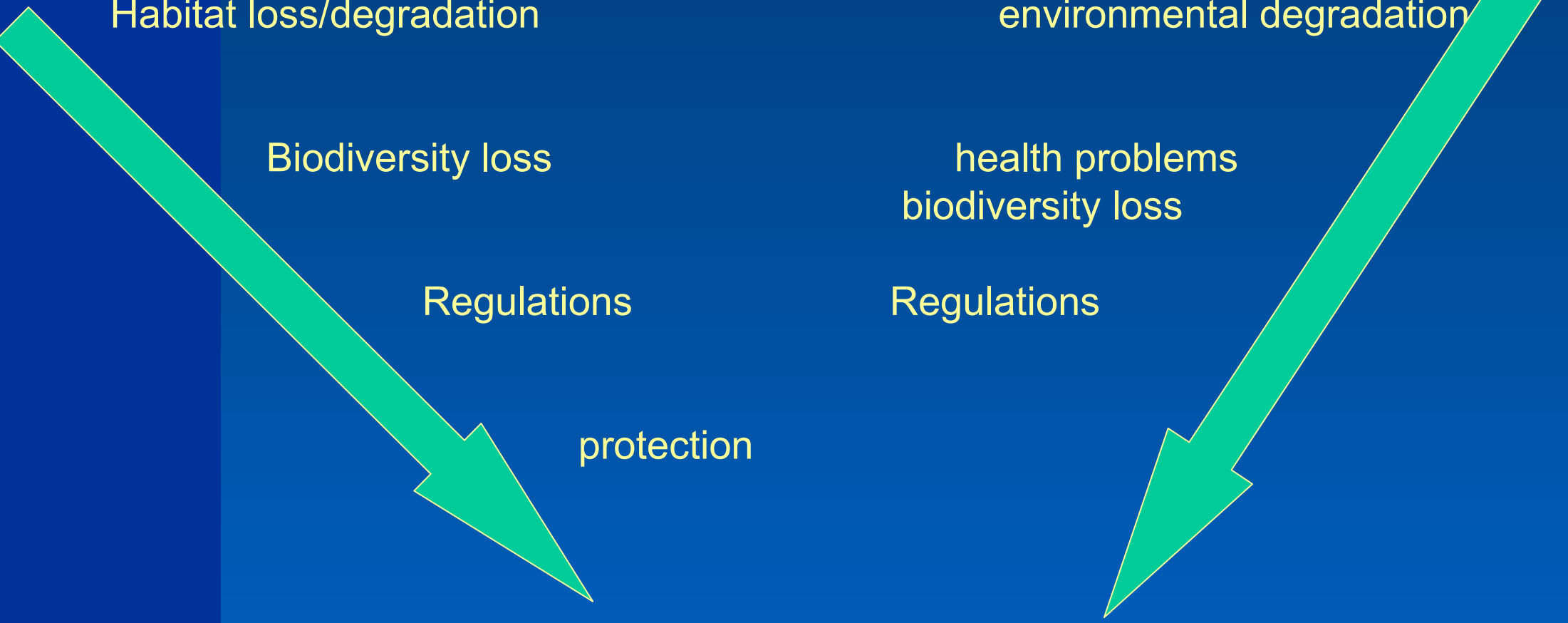
protection

The environmental Approach

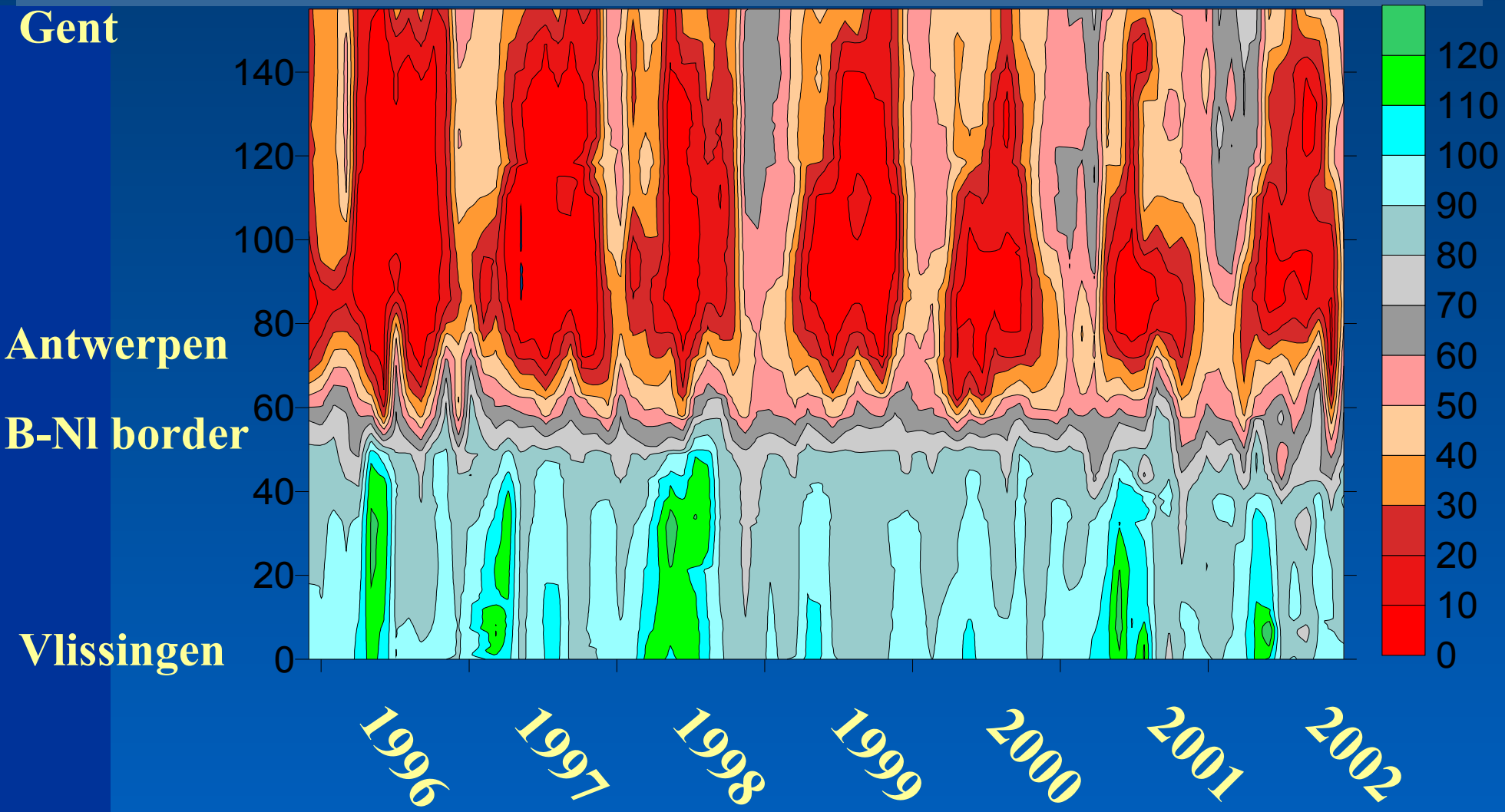
environmental degradation

health problems
biodiversity loss

Regulations



Oxygen saturation (%)



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Percentage of the load that reaches the North Sea

1974 Billen et al. 1985	1985 Soetaert & Herman, 1995	2002 Cox et al. in prep.
48% 55.000 t	77% 66.000	74% 70.000

RISK OF EUTROFICATION, POLLUTION

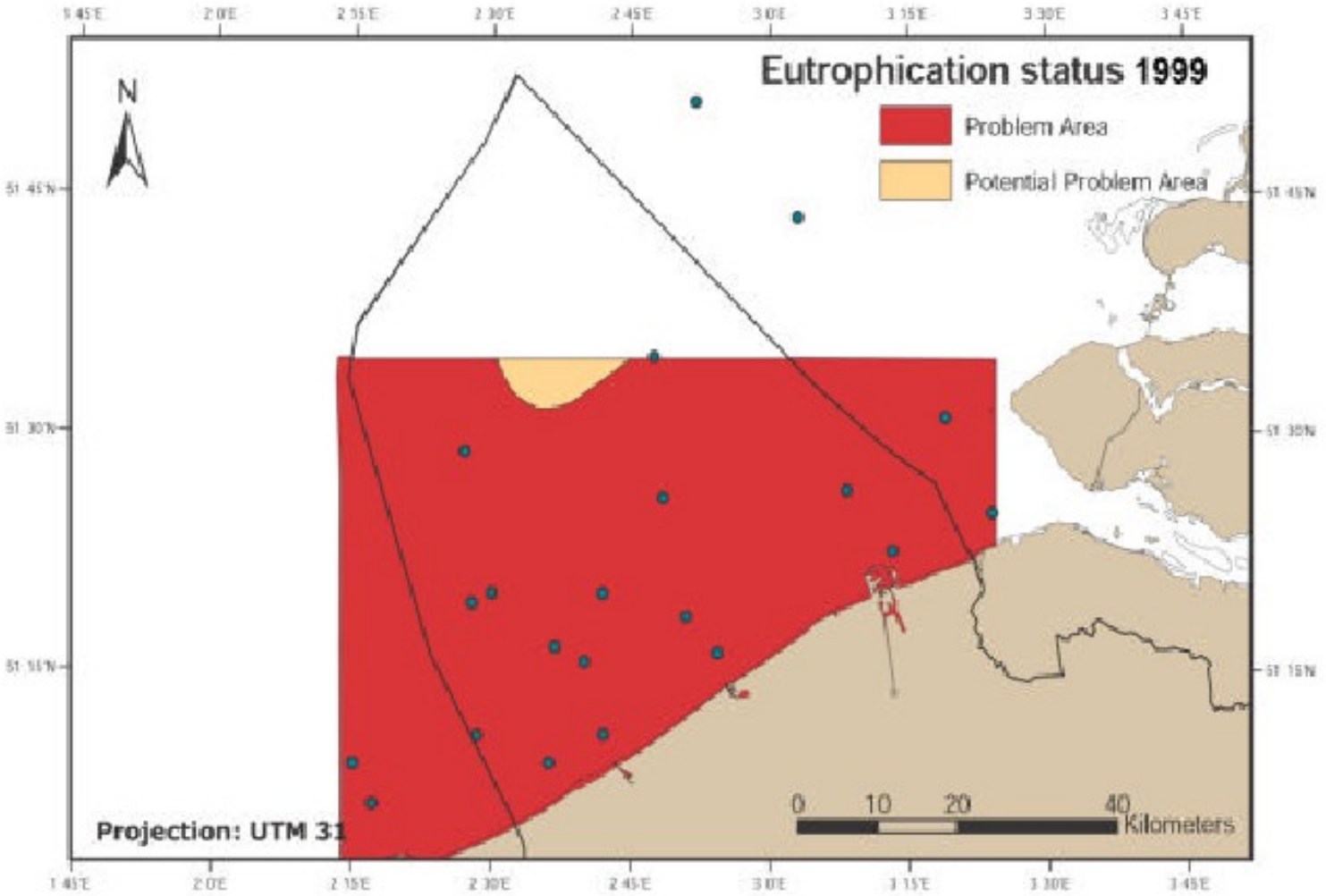
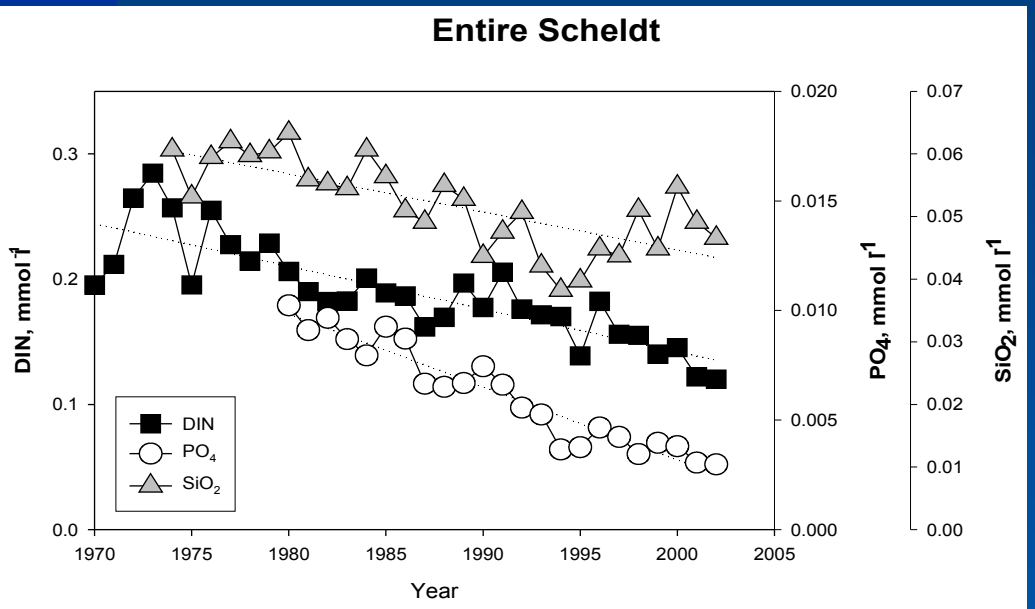
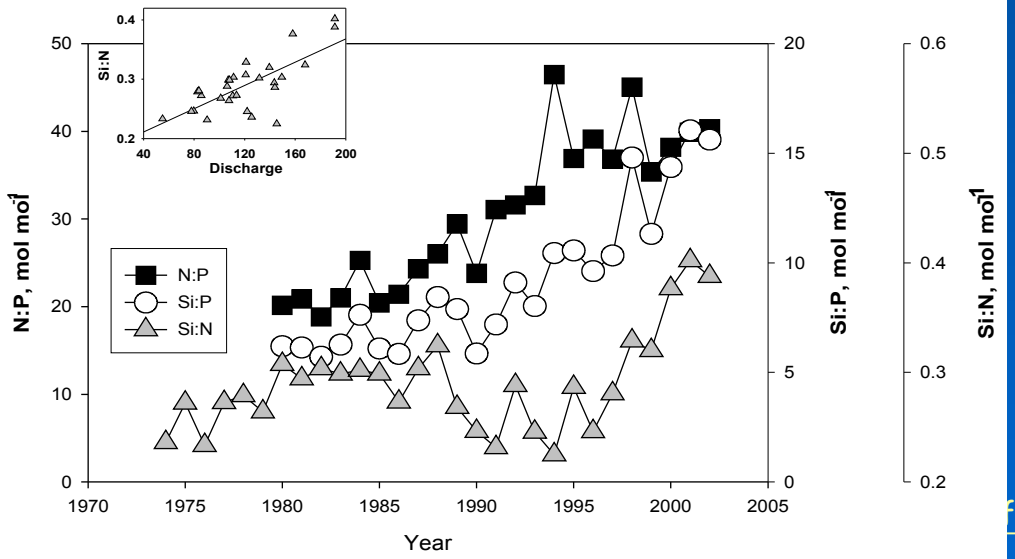


Figure 9 Assessment of the Eutrophication status of the BCS in 1999. Monitoring stations are indicated.

Nutrient availability partly reflects waterquality management in the catchment!





Indication of possible limitation of phytoplankton by P and not by N!

Soetaert et al., in press

Conclusion 3

- Although important improvements are achieved, the environmental regulations did not result in good water quality, the role of natural processes has not been included
- An element by element approach is inadequate as their ratio's is very important for the system!

- An enormous loss of ecosystem goods & services, the functionality of the landscape has been lost due to impacts starting already several 100 years ago

- What is the solution???

EU Water framework directive

- A major breaktrough as it is an important step to a more holistic approach
- But:
  - incorporation of wetlands still unclear although they should be included
  - Still structure and less functional oriented

Habitat directive

The Birds (79/109/EEG) and Habitats Directive (92/43/EEG) aim to conserve natural habitats and wild flora and fauna in the EU through the **designation, protection and management of special conservation areas.**

Member states are obligated to ensure that the habitattypes and species for which these special conservation areas were designated are being preserved and restored (article 6 of the habitat directive).

The instruments to do this, **conservation objectives**, can freely be adopted by every member state.

Conservation objectives

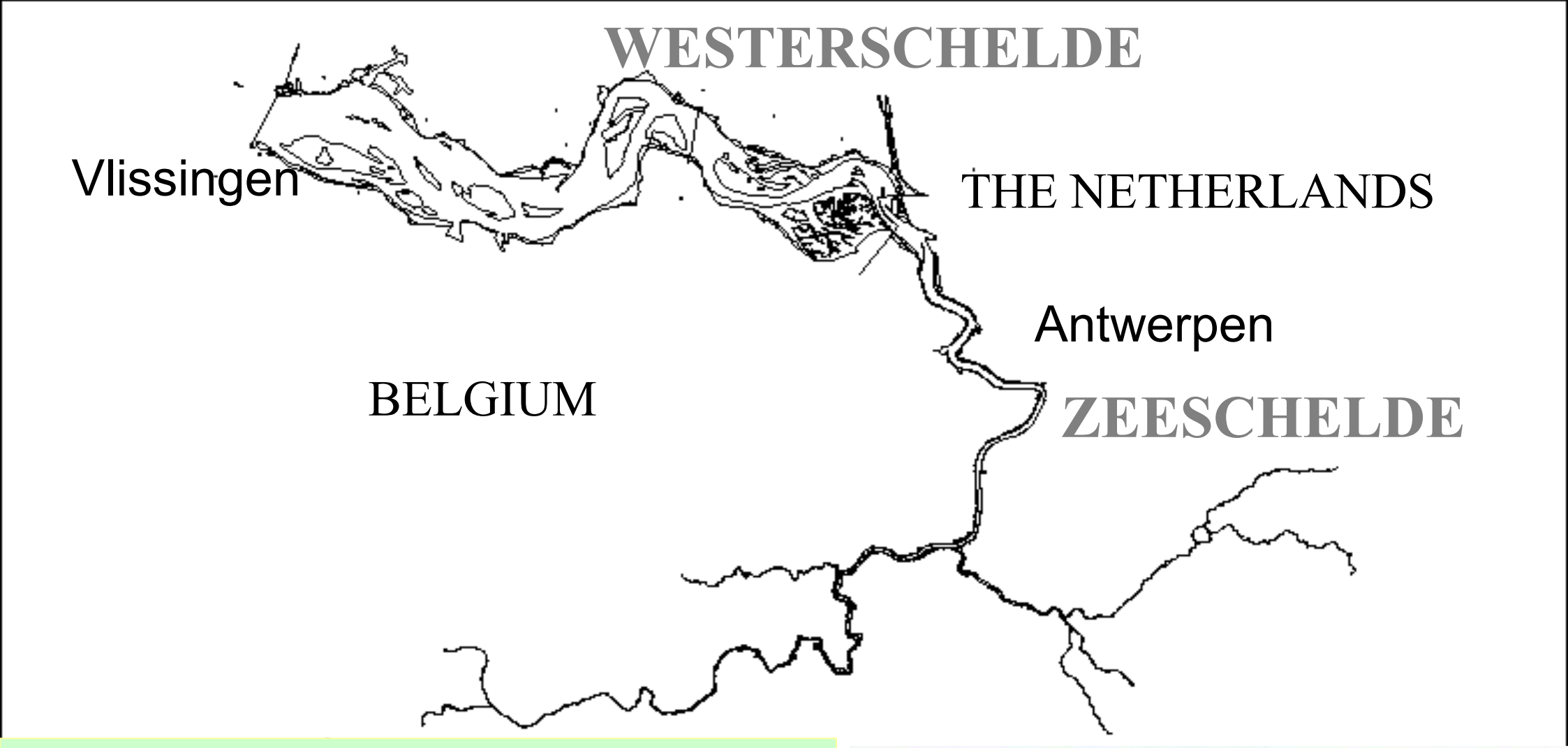
The only direct reference to Conservation Objectives in the text of the Directive is in Article 6.3, which states that any plan or project, likely to significantly affect a site, shall be subject to an appropriate assessment in view of the site's **Conservation Objectives**.

According to the Habitats Directive Art. 1 conservation means "a series of measures required to maintain or restore the natural habitats and the populations of species of wild fauna and flora at a favourable status". As a consequence COs should also provide information on what should be considered as "favourable status " of habitats, species and populations.

Conservation objectives

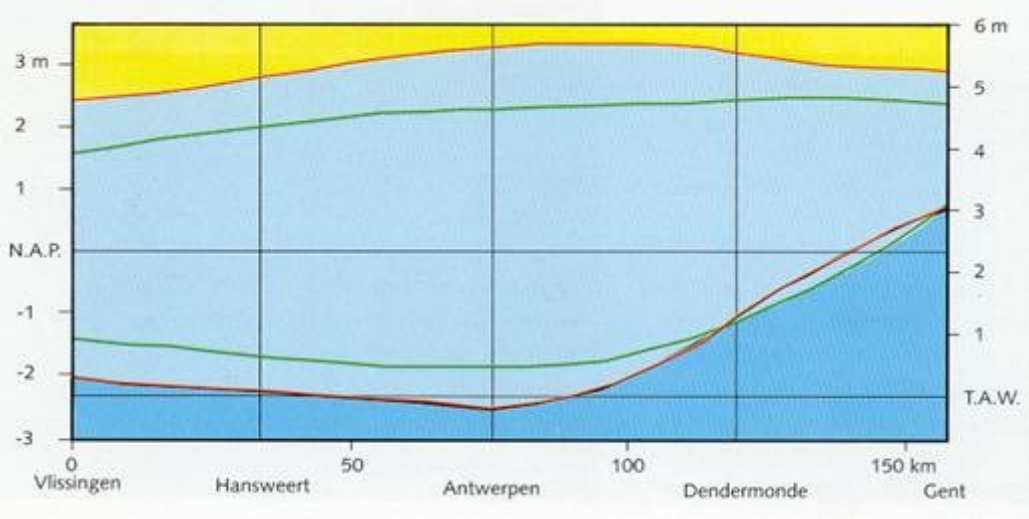
The conservation status of a natural habitat will be taken as 'favourable' when:

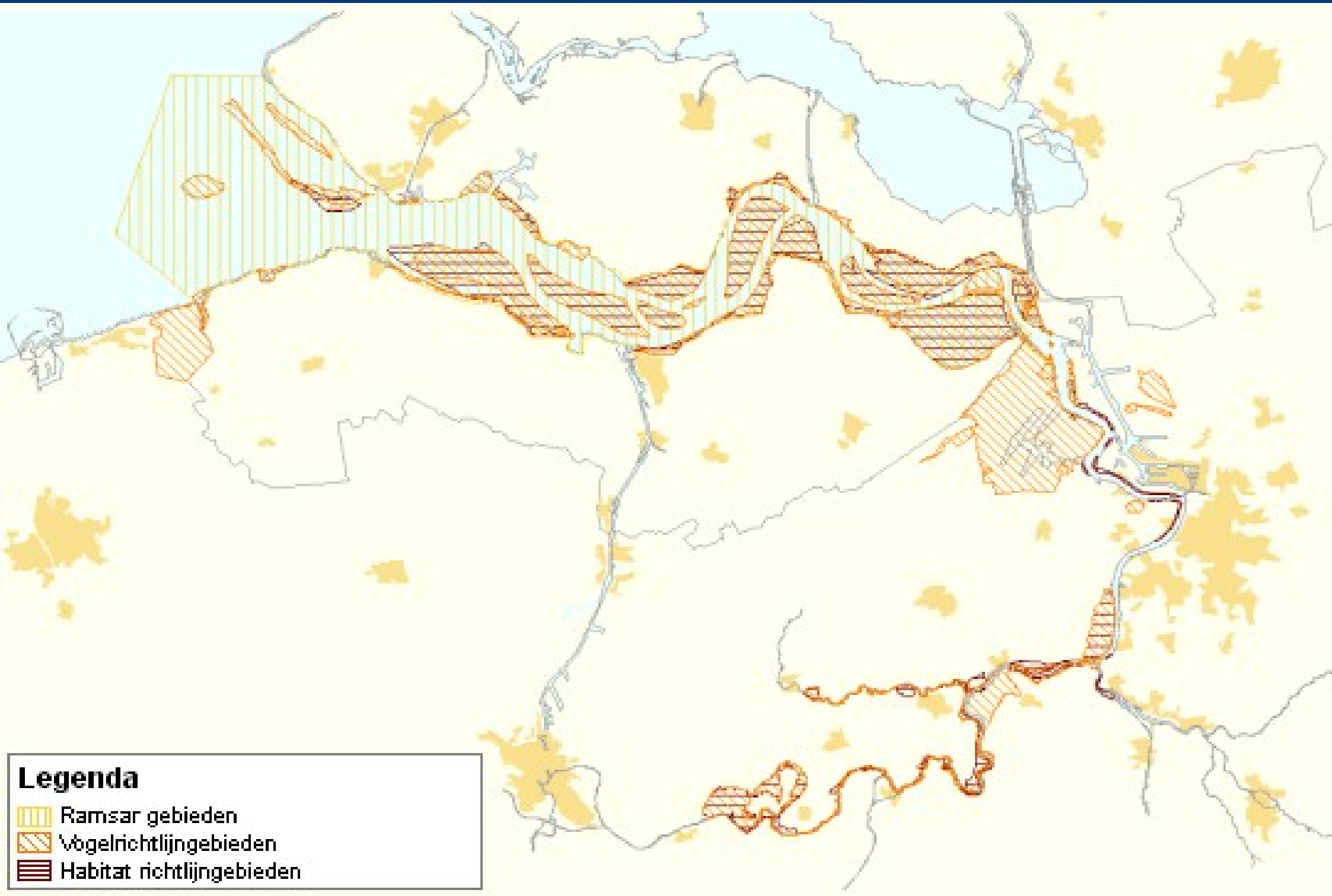
- its natural range and areas it covers within that range are stable or increasing, and
- the specific **structure and functions** which are necessary for its long-term maintenance exist and are likely to continue to exist for the foreseeable future, and
- the conservation status of its typical species is favourable;



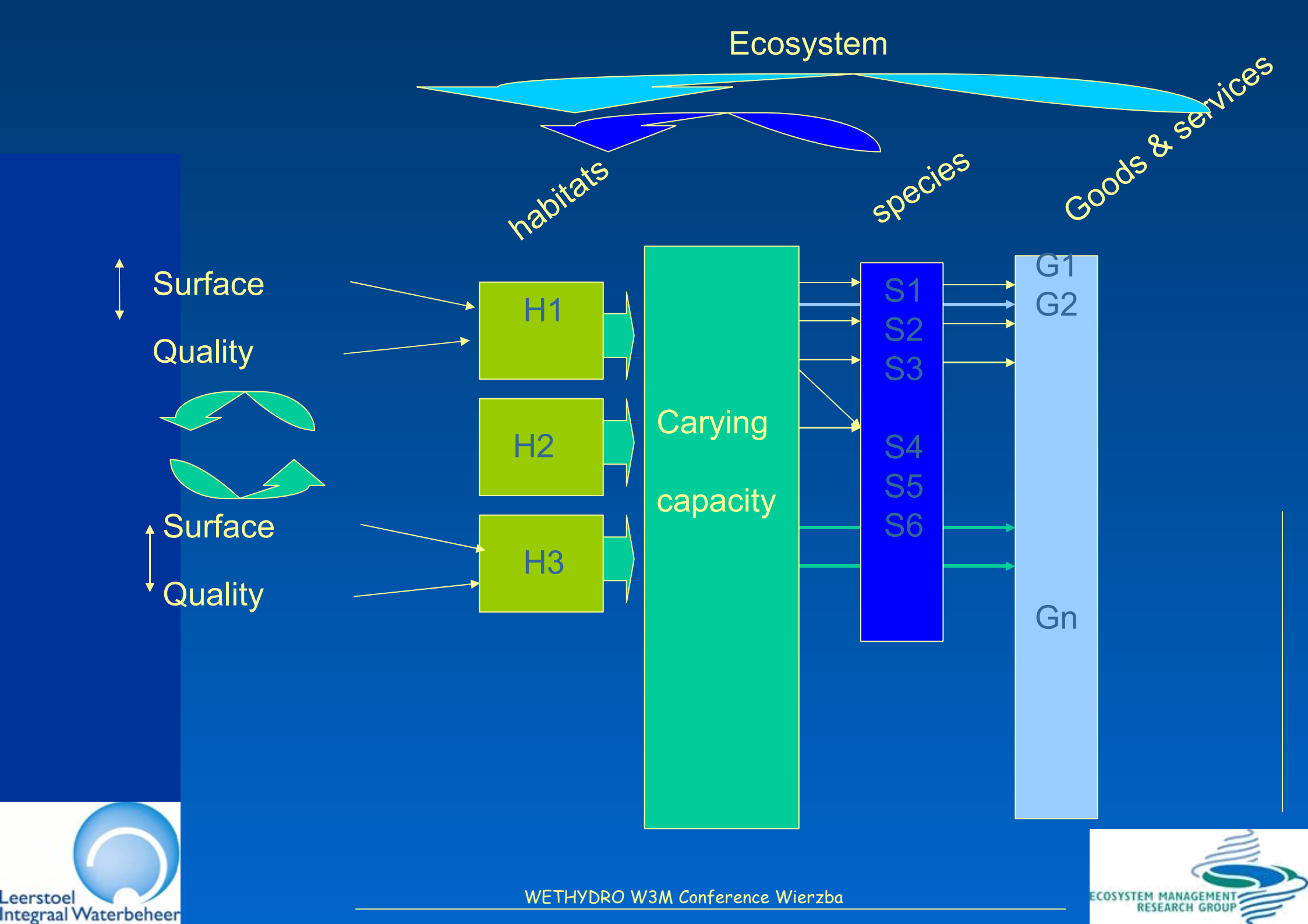
The Schelde estuary:

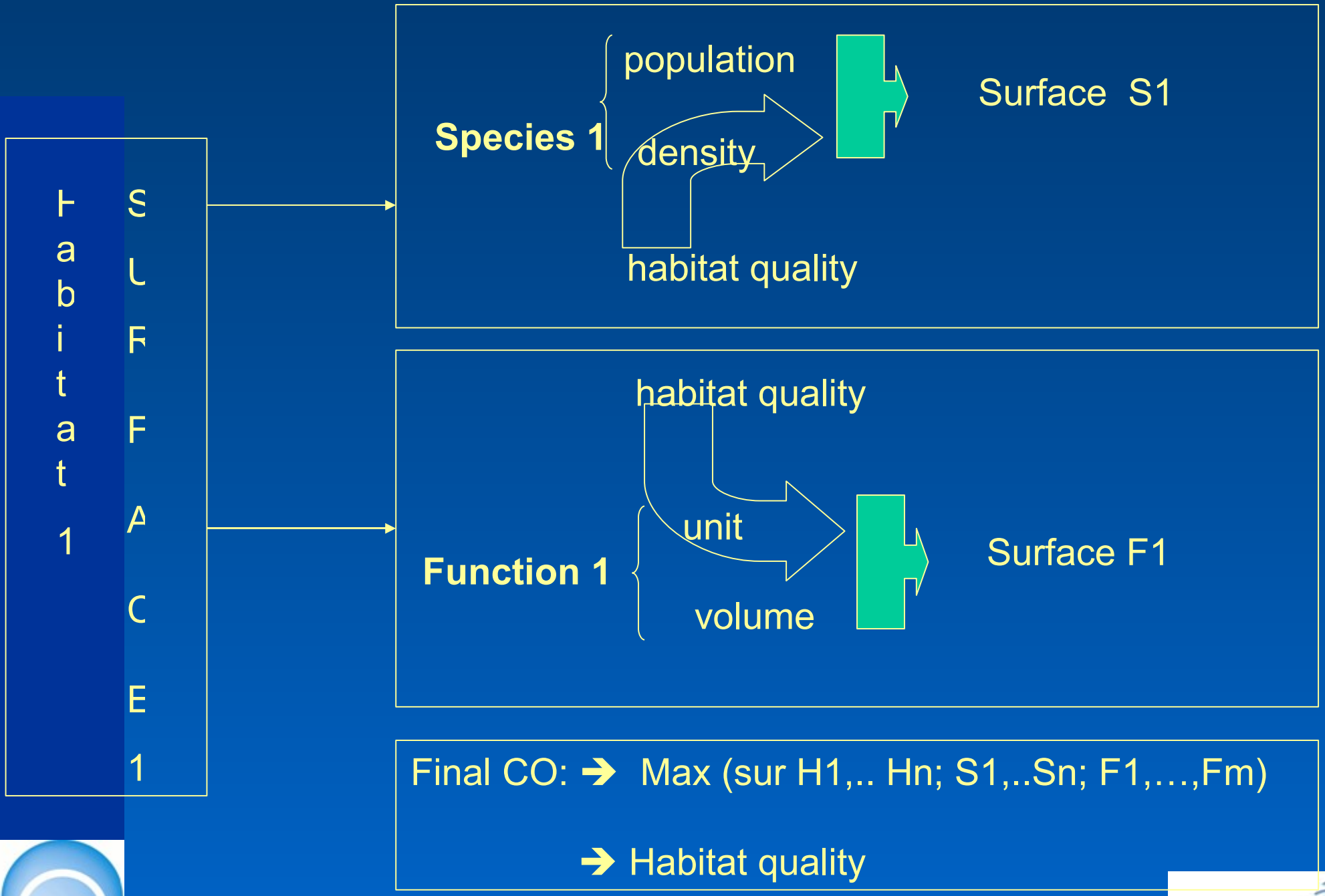
- 160 km long and macro-mesotidal
- Entire salinty gradient from fresh to salt




Legenda
Ramsar gebieden
Vogelrichtlijngebieden
Habitat richtlijngebieden

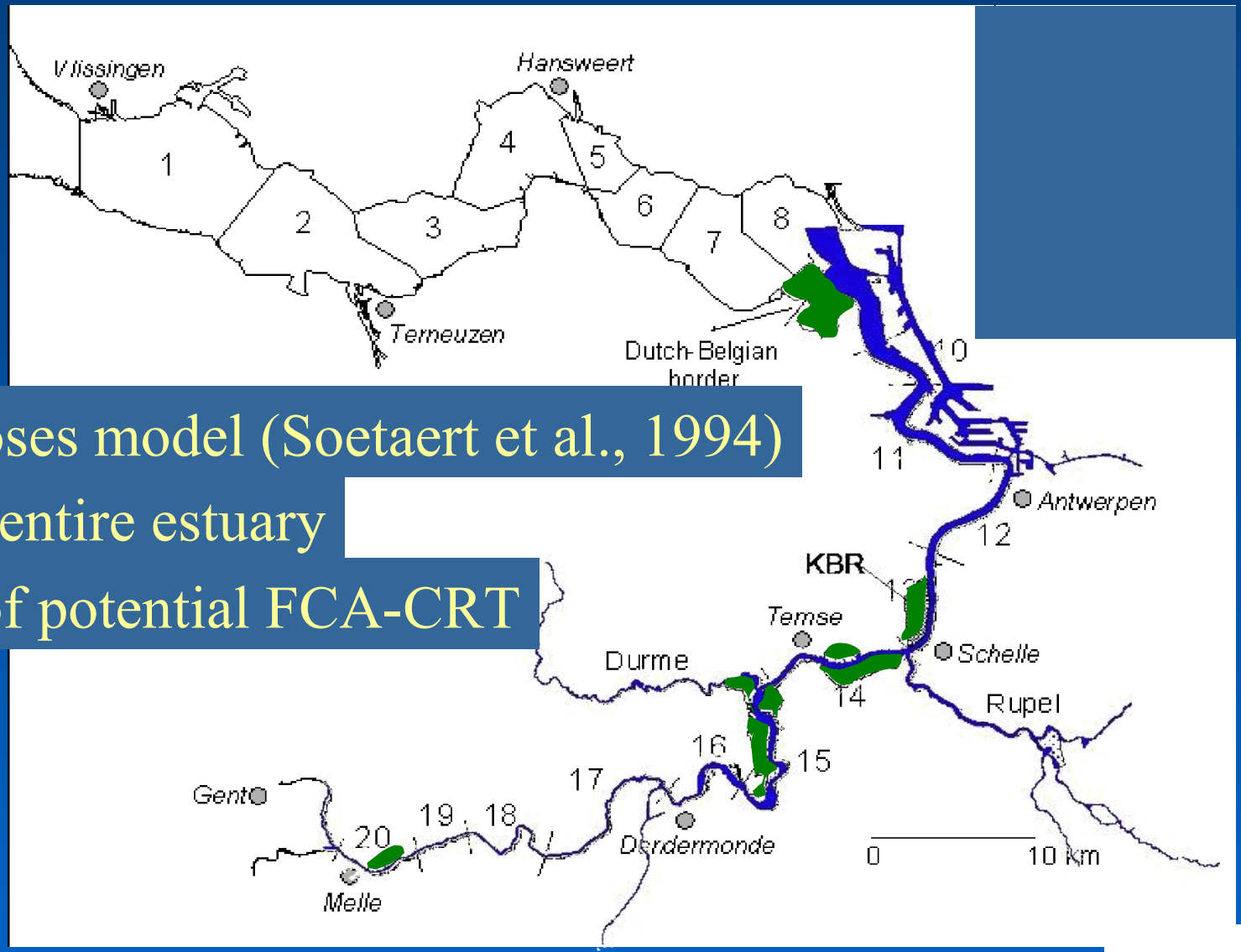
- Due to large scale impacts (dredging, deepening, embankments etc.) the elaboration of a compensation plan was necessary.
- The basis for it had to be the conservation objectives
- They must be quantitative to be included in an overall plan.


Ecosystem
habitats
species
Goods & services
Surface
Quality
Surface
Quality
H1
H2
H3
Carying
capacity
S1
S2
S3
S4
S5
S6
G1
G2
Gn


Habitat 1
SURFACE 1
Species 1
population
density
habitat quality
Surface S1
Function 1
habitat quality
unit
volume
Surface F1
Final CO: ➔ Max (sur H1,.. Hn; S1,..Sn; F1,…,Fm)
➔ Habitat quality

- Crucial tool:
- Ecosystem model of Schelde

Tidally averaged advection dispersion model (19 boxes)



- based on Moses model (Soetaert et al., 1994)
- extented for entire estuary
- attachment of potential FCA-CRT

OMES Biochemistry

- Biochemical **state variables**: NH4,NO3+NO2,DSi,BSi,O2, Fdet,Sdet
- Biochemical **processes**: oxygenation, mineralisation (oxic, anoxic, denitrification), nitrification
- Typically modelled as 'first order':

$$dX/dt = kX$$

$$k = k(T).\Lambda.\gamma$$

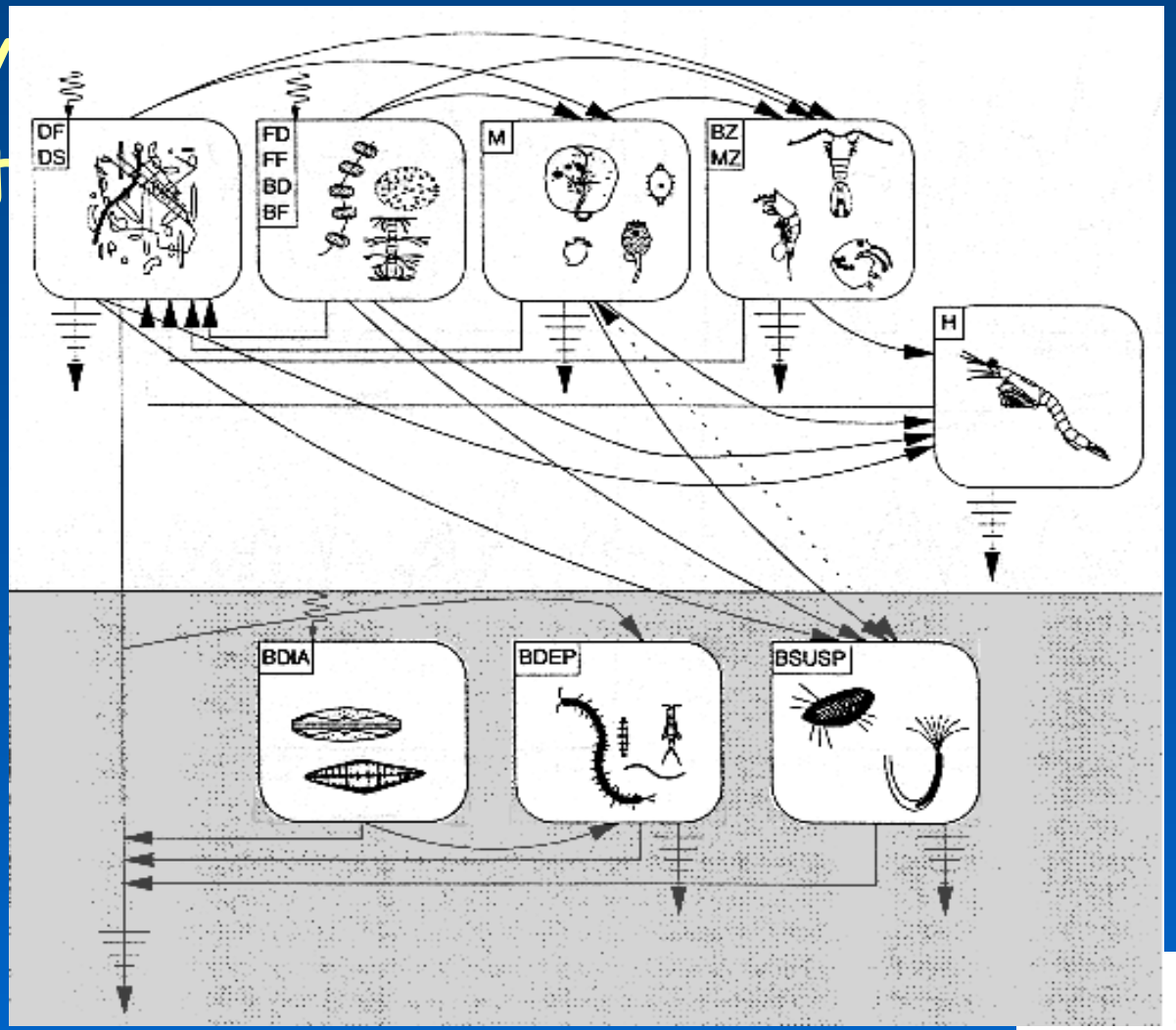
$$k(T) = k(T0).\exp(\beta(T-T0)$$

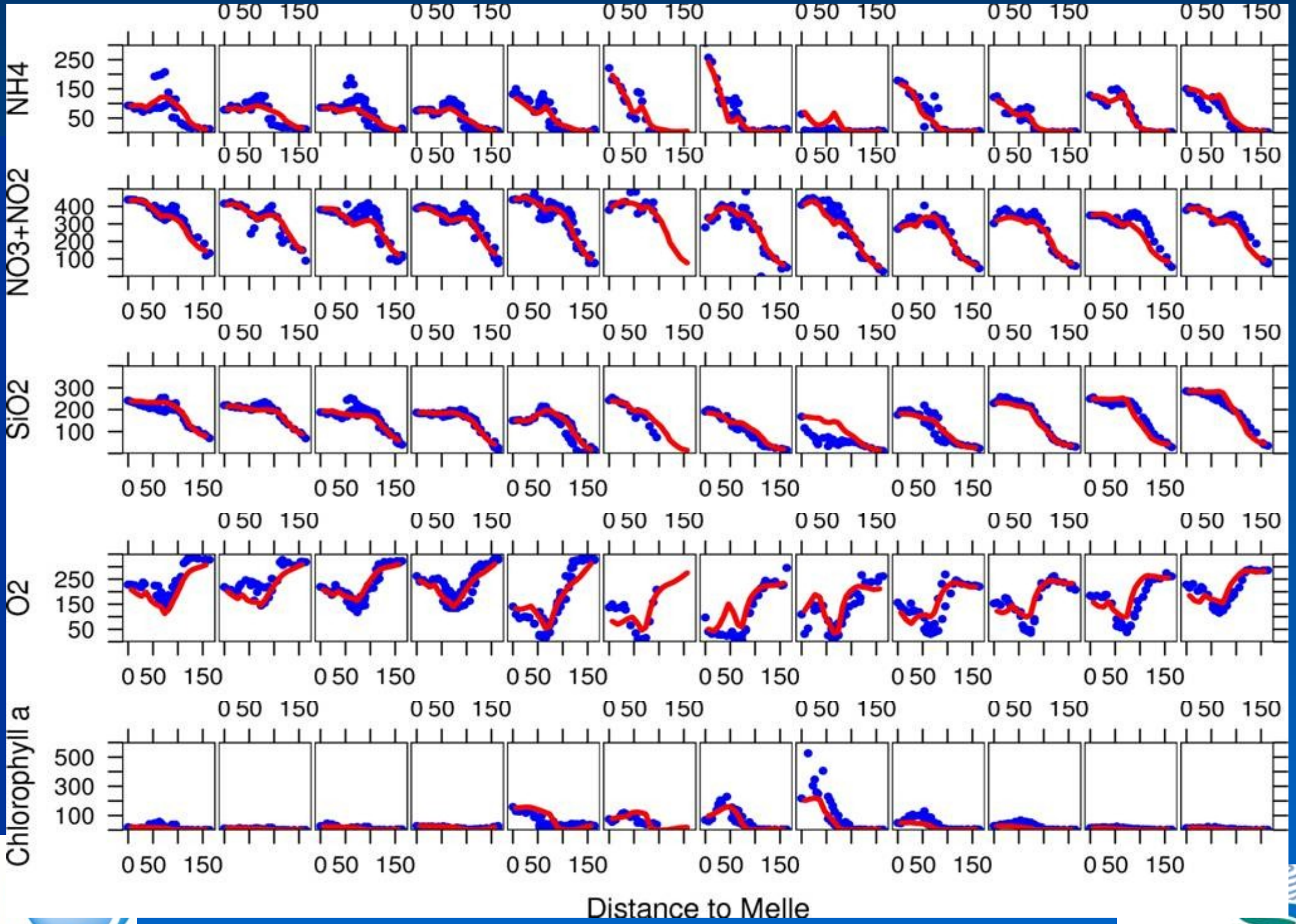
OMES pelagic biology

- Major state variables: FrDia, BrDia,FrAlg,BrAlg
- Major processes: gross production, respiration, mortality, excretion
- Also modelled first-order (depth integration and light attenuation is explicitly performed)
- Production is mainly light limited

Other ingredients

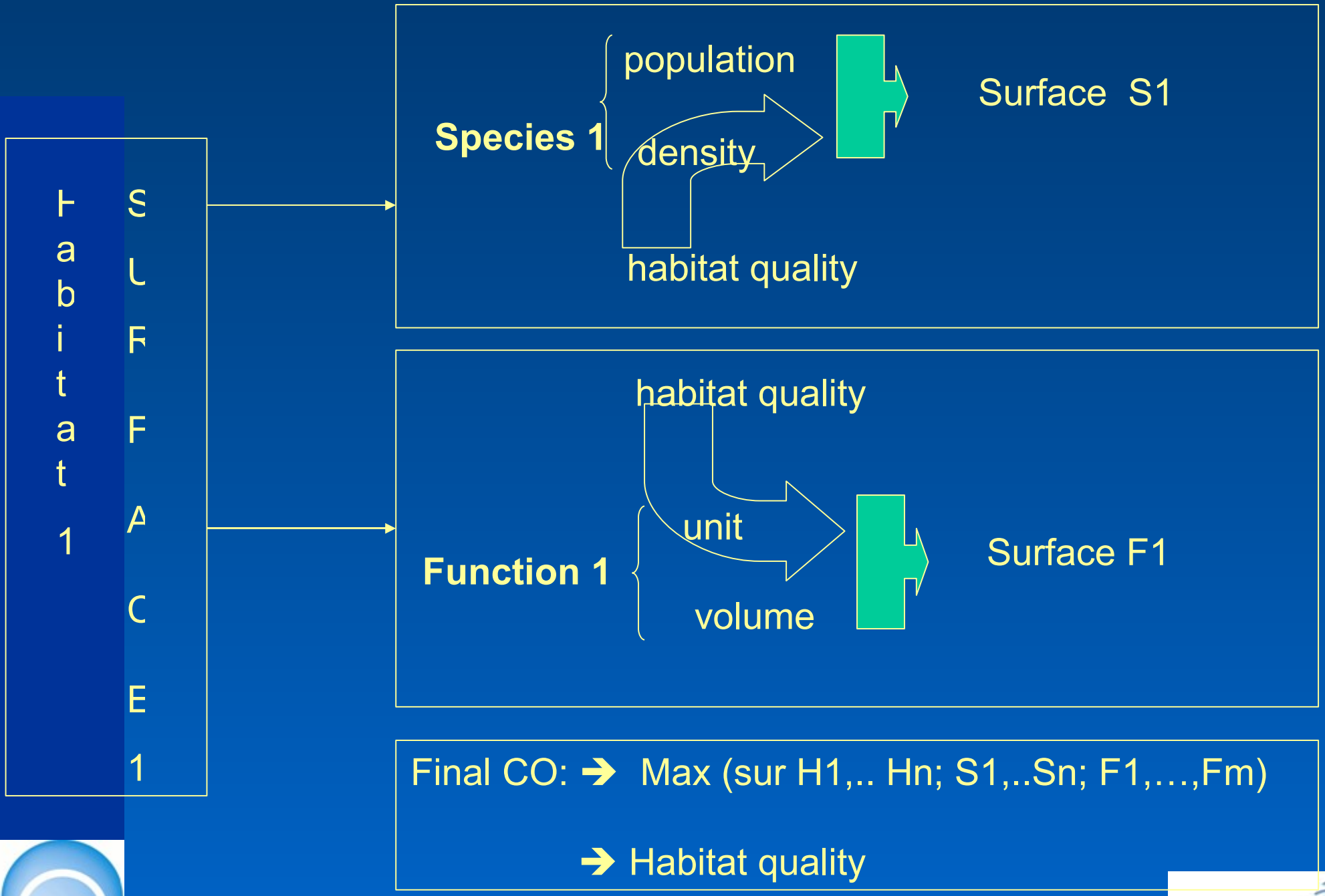
- Sediment biochemistry model (Lancelot&Billen 1985)
- Higher biology
- Intertidal flat




NH4
NO3+NO2
SiO2
O2
Chlorophyll a
Distance to Melle

OMES

- Integrated measurements of all different aspects of the pelagic during monthly campaigns with the Veremans and Scaldis
- Plan monitoring in relation with modeling


Habitat 1
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population
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Function 1
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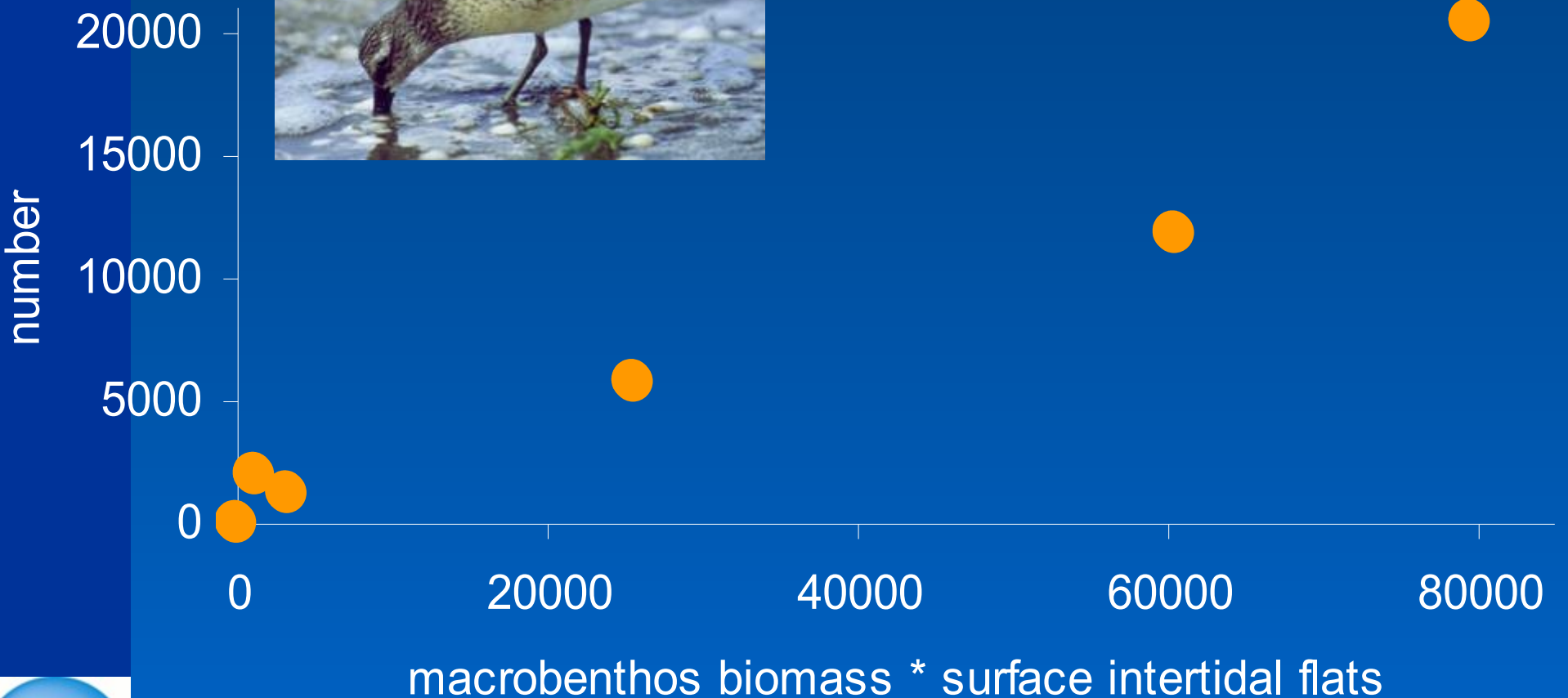
unit
volume
Surface F1
Final CO: ➔ Max (sur H1,.. Hn; S1,..Sn; F1,…,Fm)
➔ Habitat quality

- Conservation objectives for tidal flats
- Required surface based on
  - Historical reference?
  - Geographical reference?

- Crucial habitat for birds

Conservation objectives

Birds and their food



Data Tom Ysebaert NIOO- CEMO

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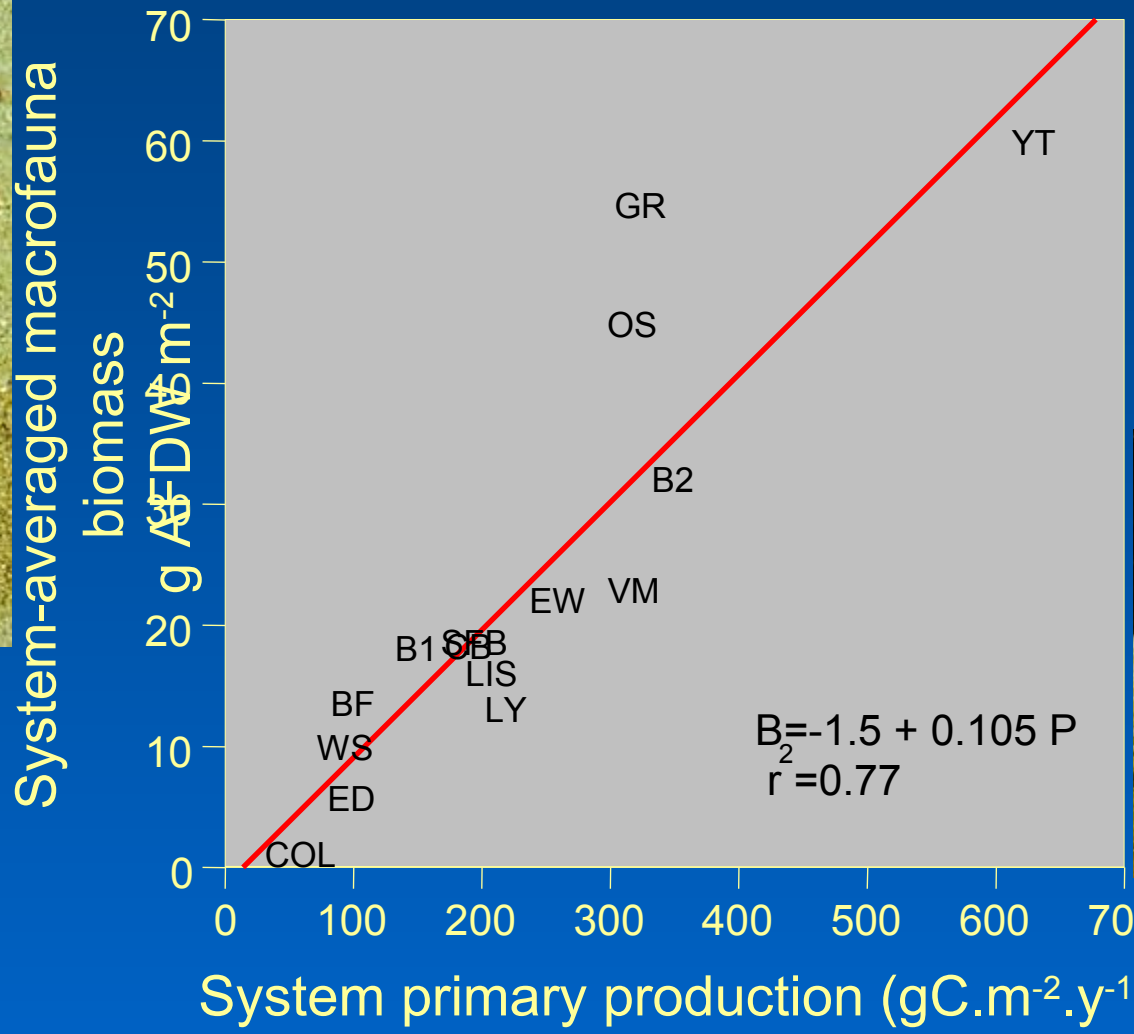
Benthos and its food



Source: P. Herman NIOO-CEMO

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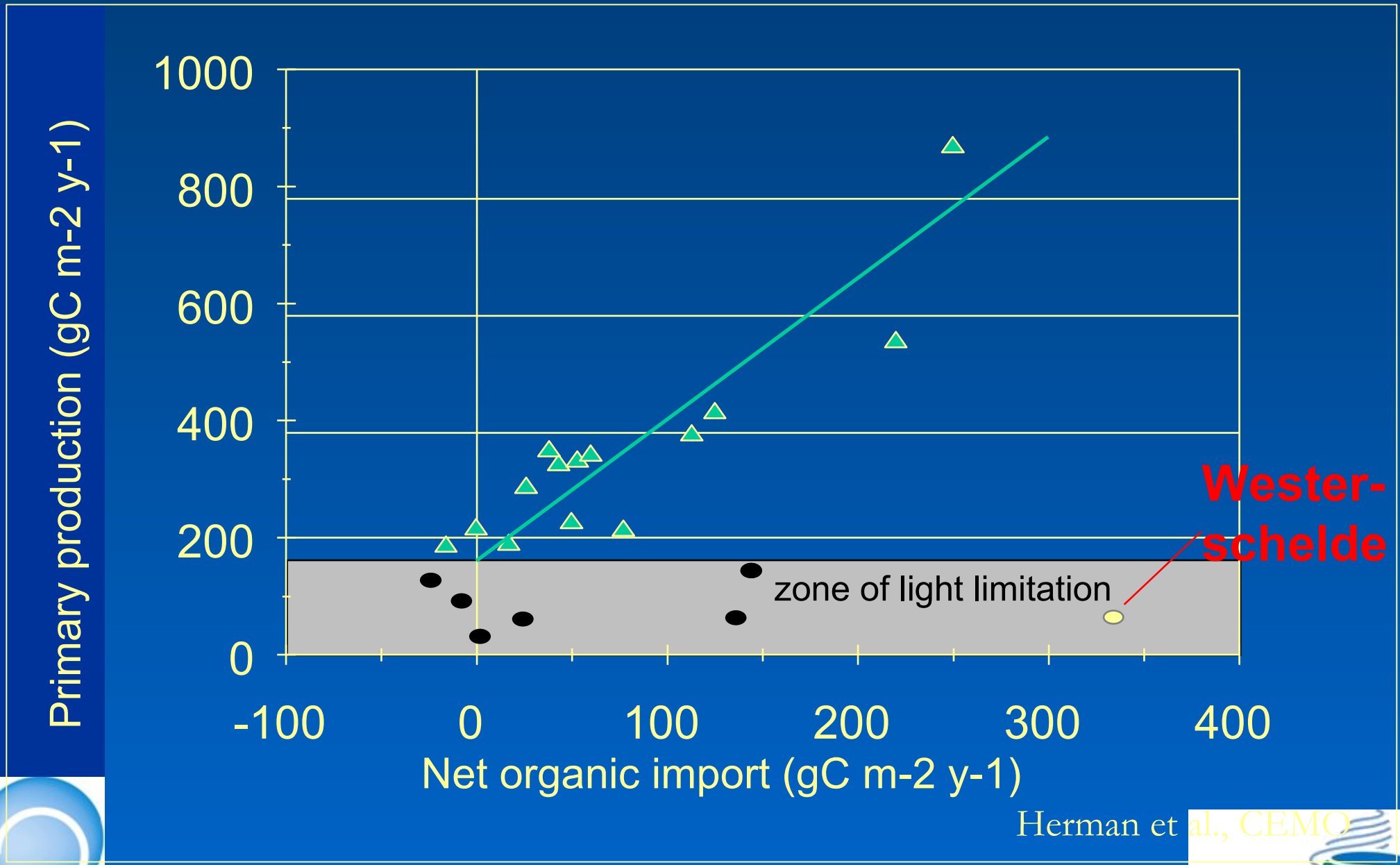
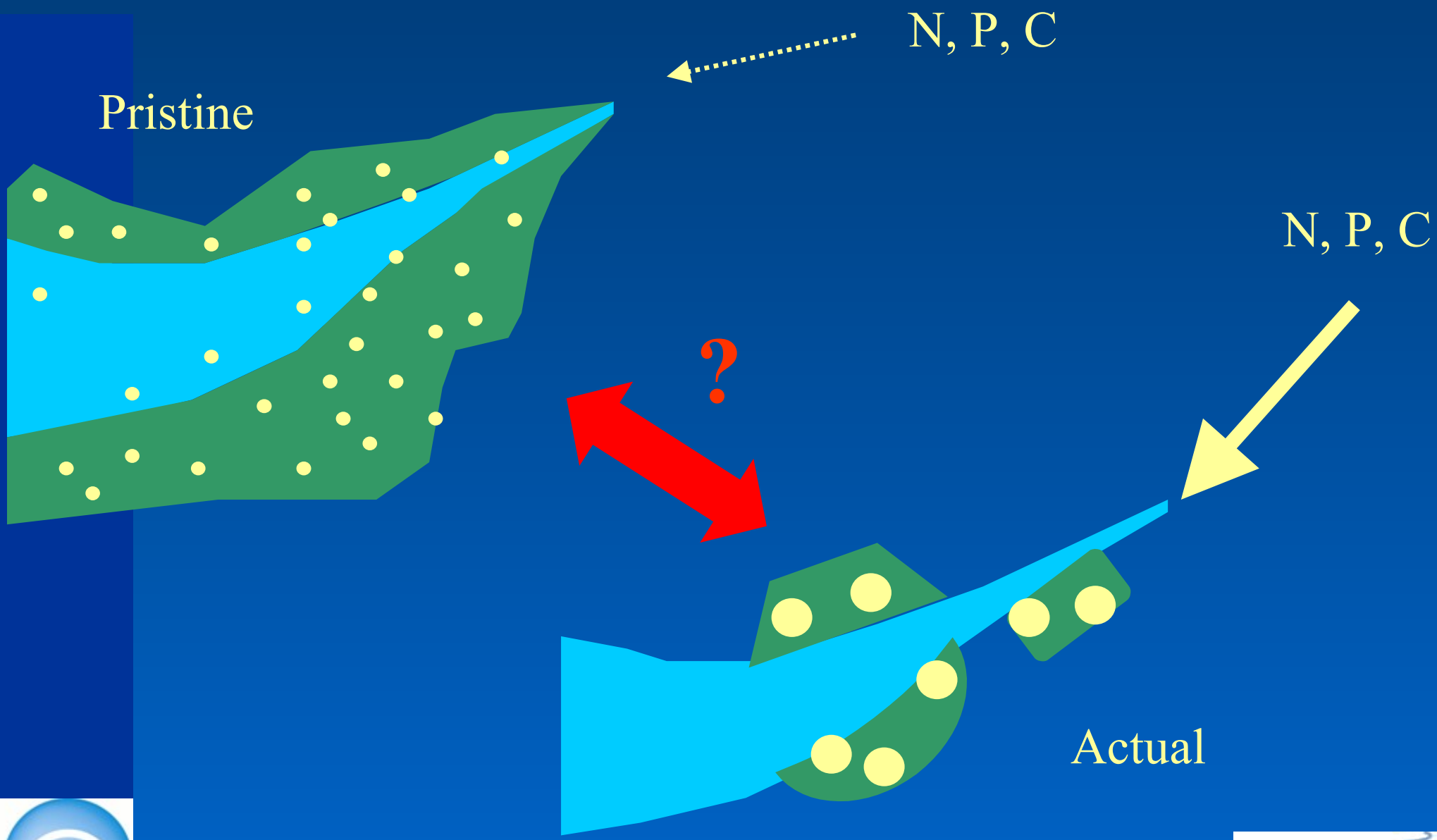
Phytoplankton and organic load

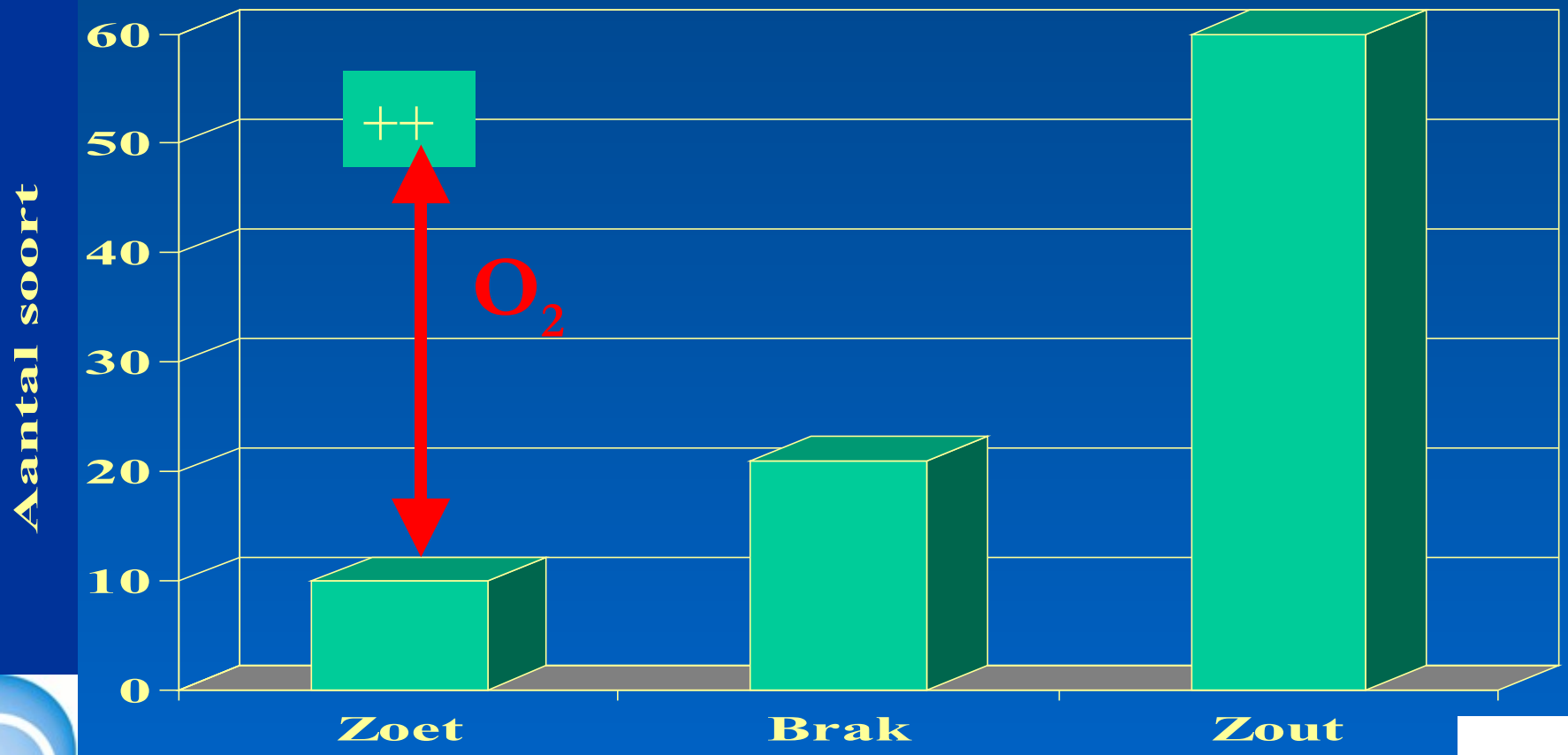


Herman et al., CEMO

Carrying capacity



Benthic diversity under pressure



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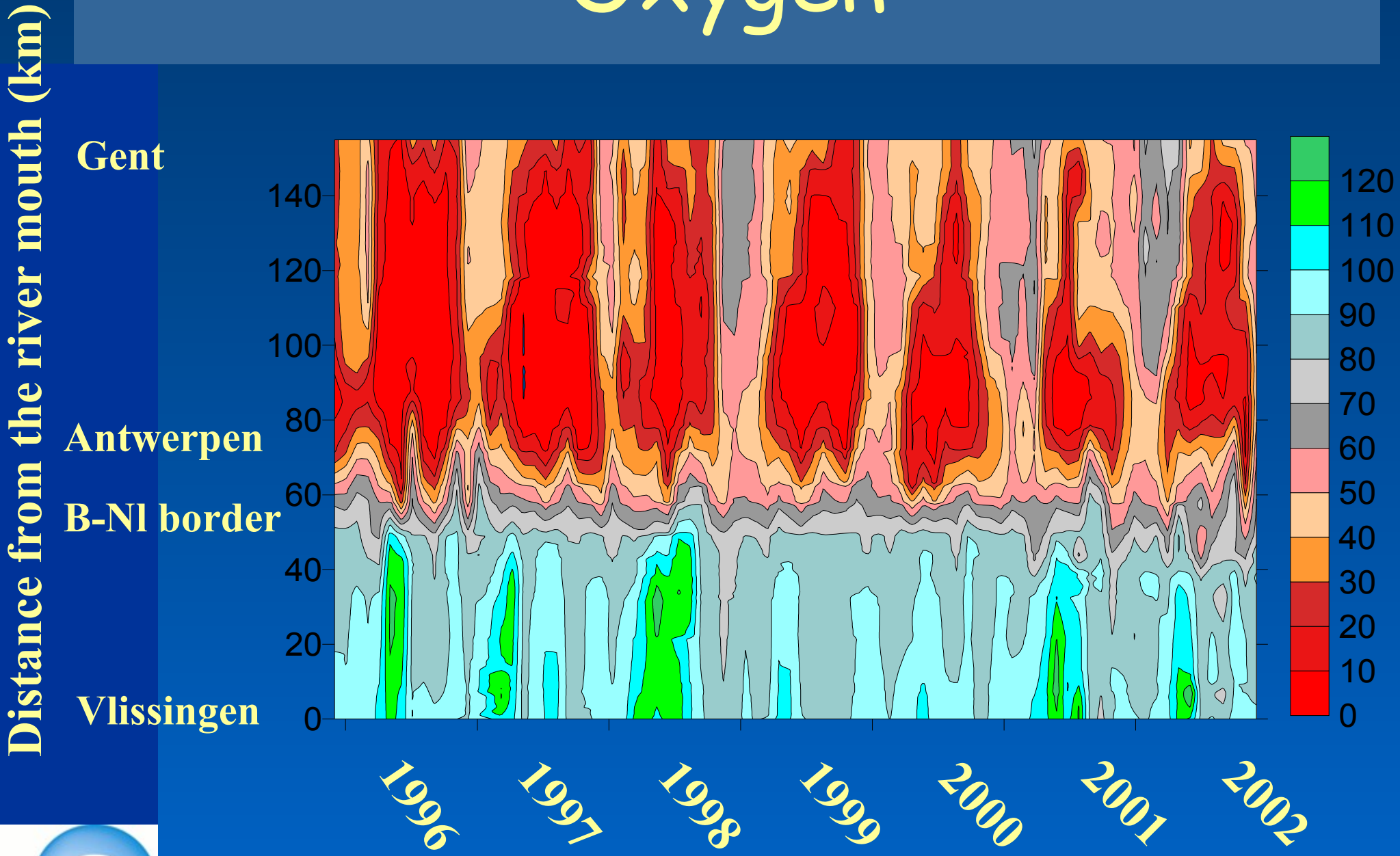
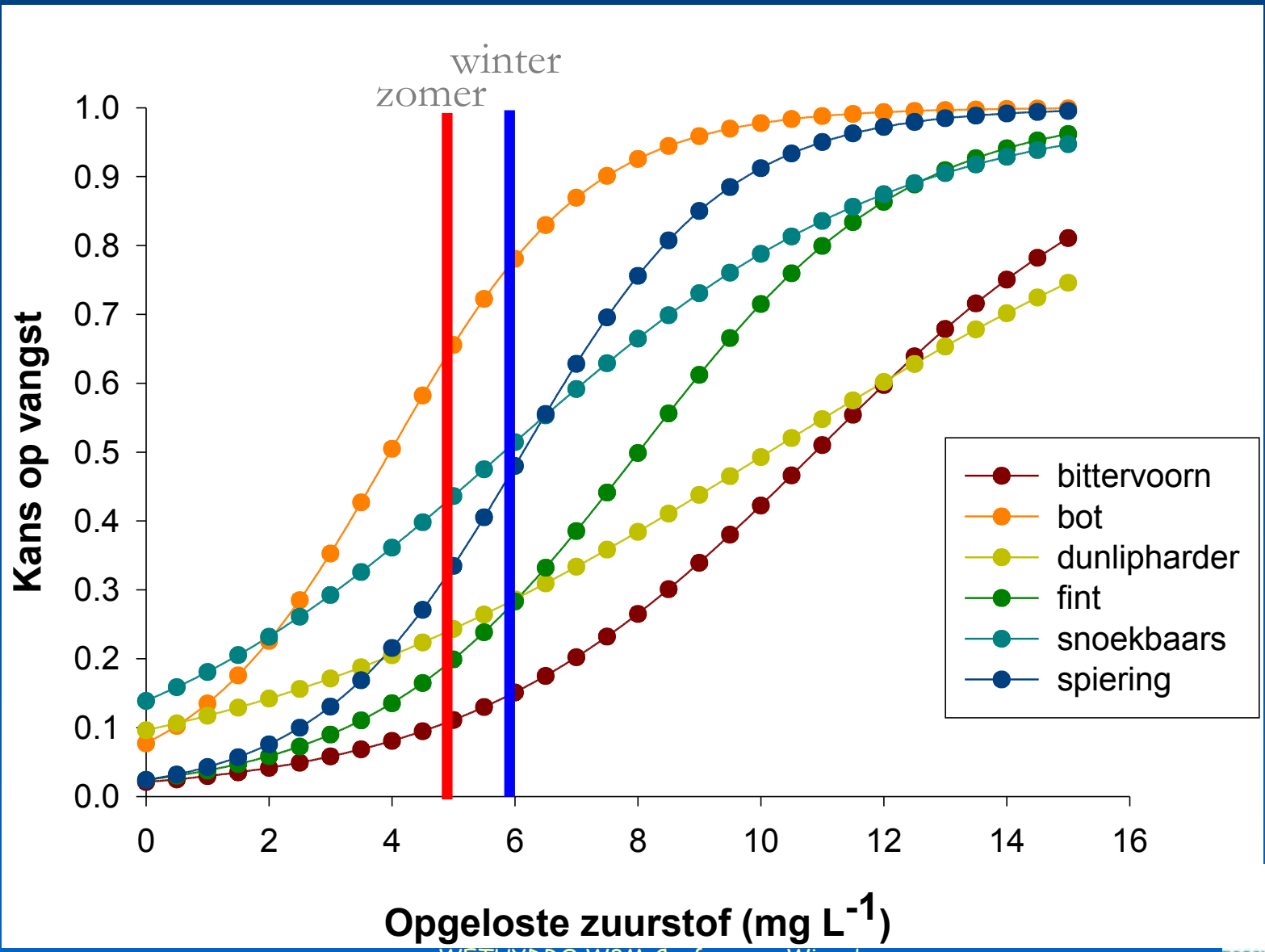
Oxygen


Distance from the river mouth (km)
Gent
Antwerpen
B-Nl border
Vlissingen
140
120
100
80
60
40
20
0
120
110
100
90
80
70
60
50
40
30
20
10
0
1996
1997
1998
1999
2000
2001
2002

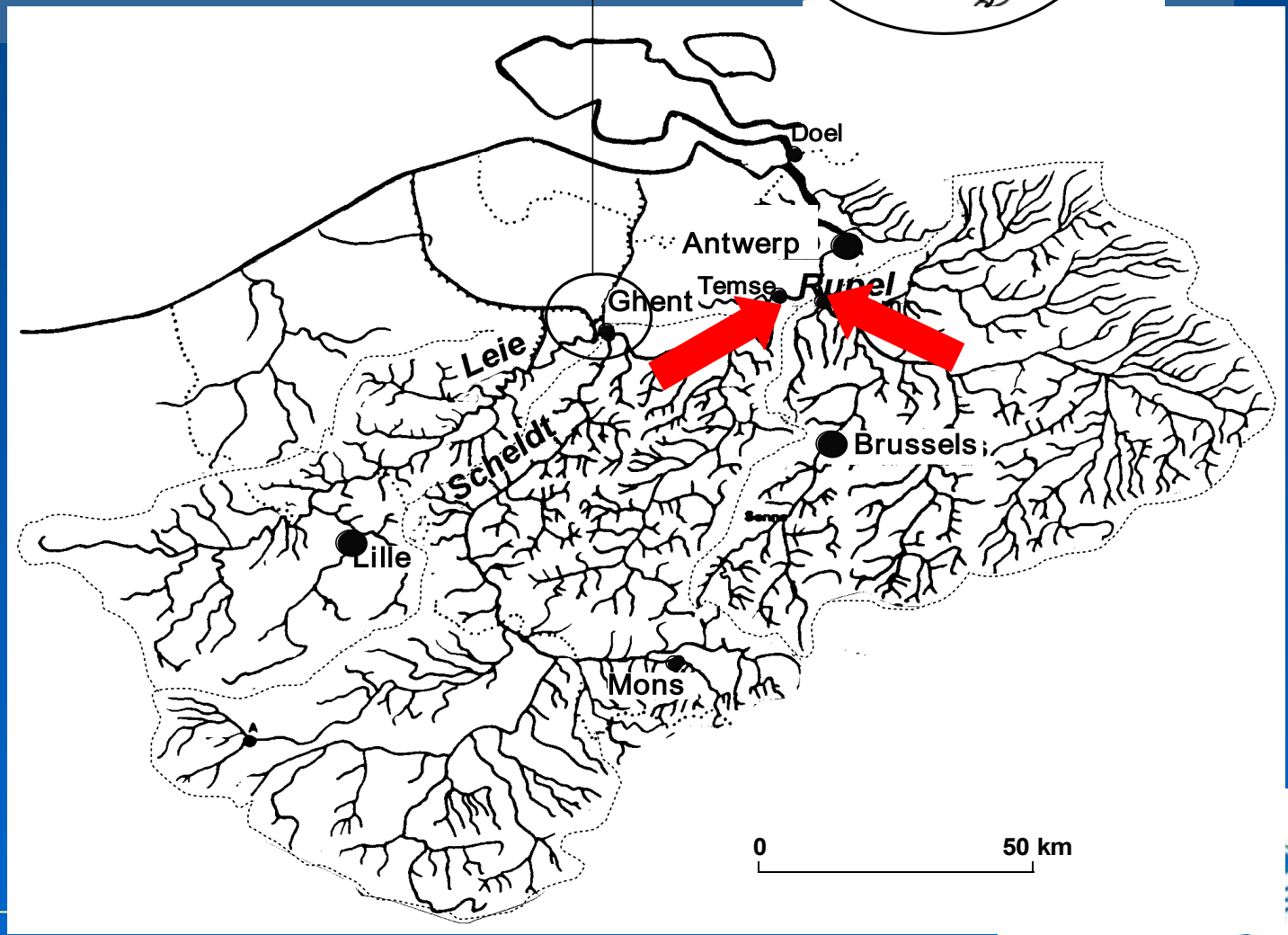
Responce fish on O_2



- Oxygen is depend on:
  - Physical rearation
  - Oxygen consumption due to respiration and mineralisation
  - Oxygen production by primary production

✂➔ How was this in the past??

Reconstruction historic emission from the catchm



Billen & Garnier,
University of Paris

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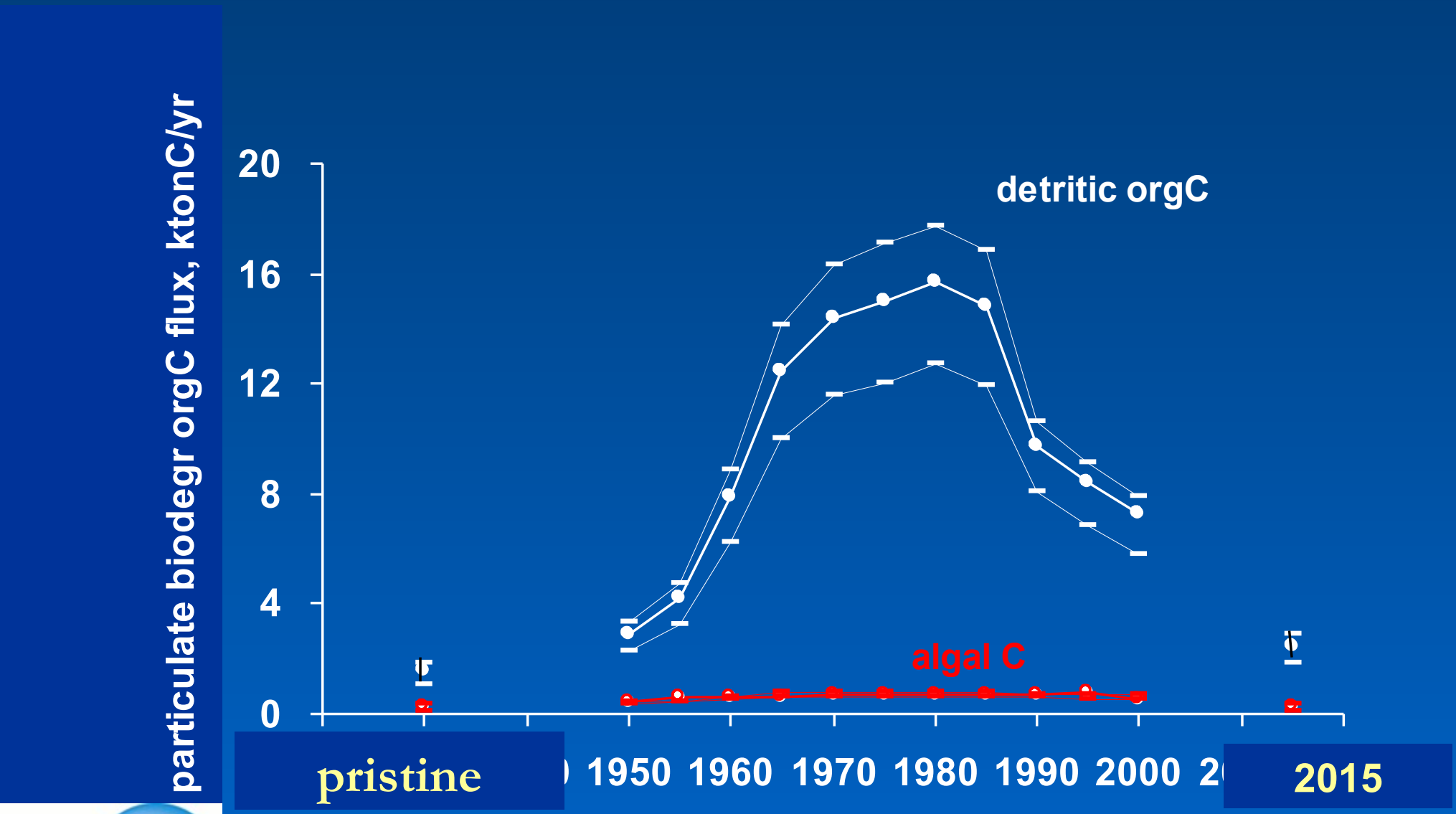
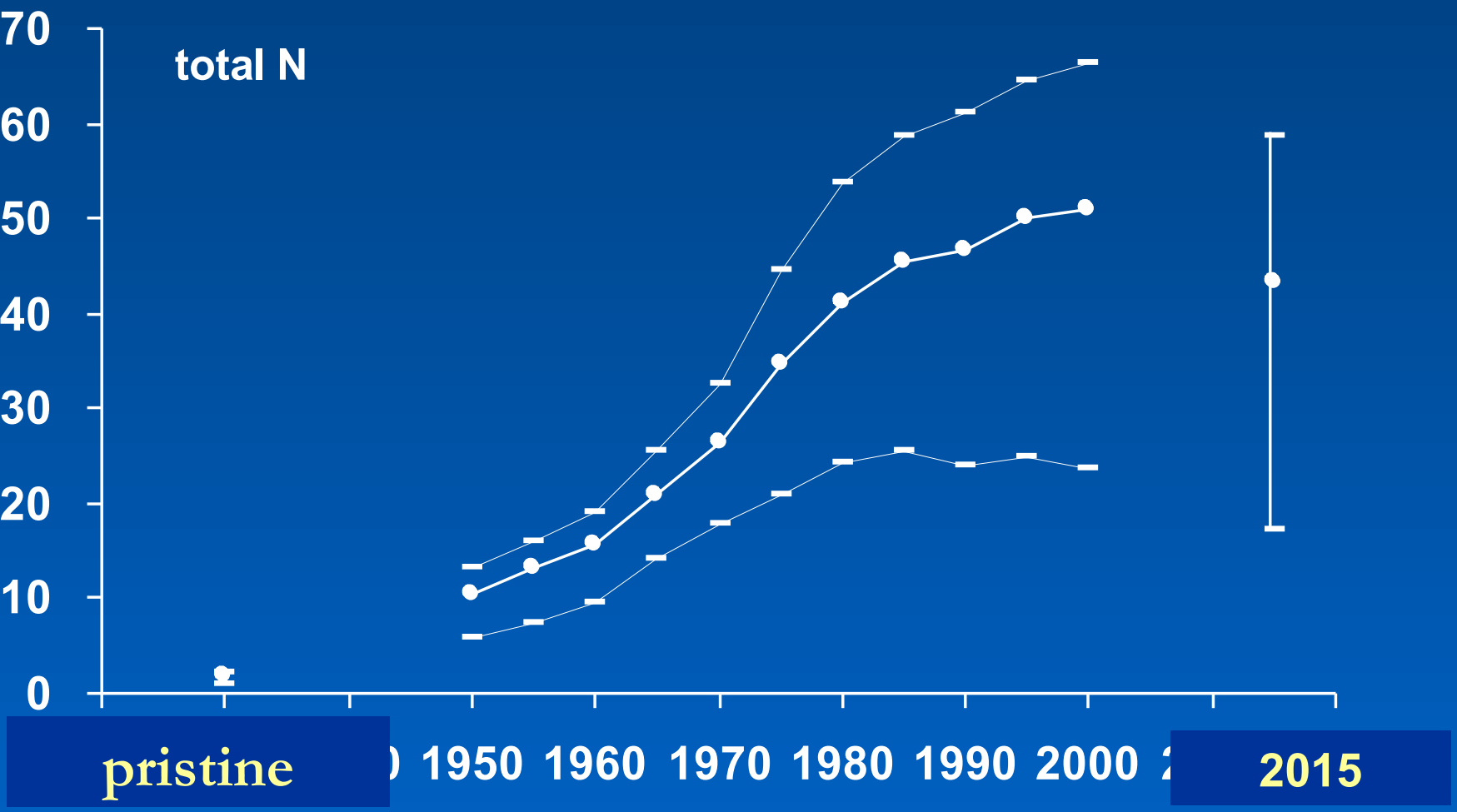

particulate biodegr orgC flux, ktonC/yr
20
16
12
8
4
0
detritic orgC
algal C
pristine
1950
1960
1970
1980
1990
2000
2015



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Billen & Garnier, Univ. de Paris

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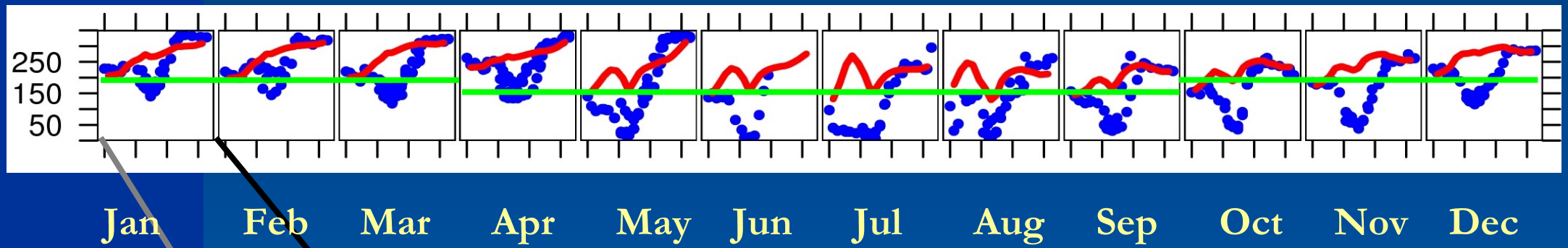
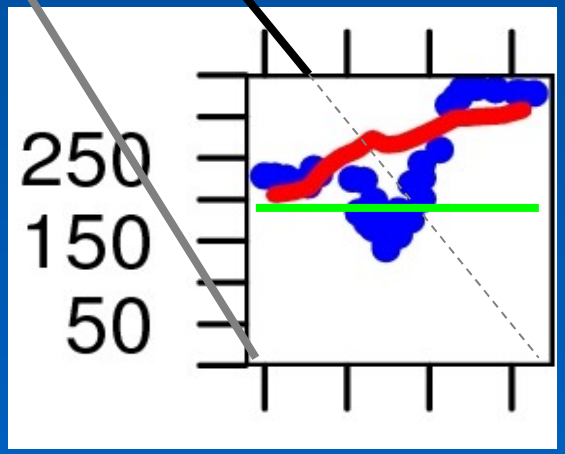
Reconstruction estuarine quality





Dissolved O^2 (µM)

1950 (modelled)

2001 (data)

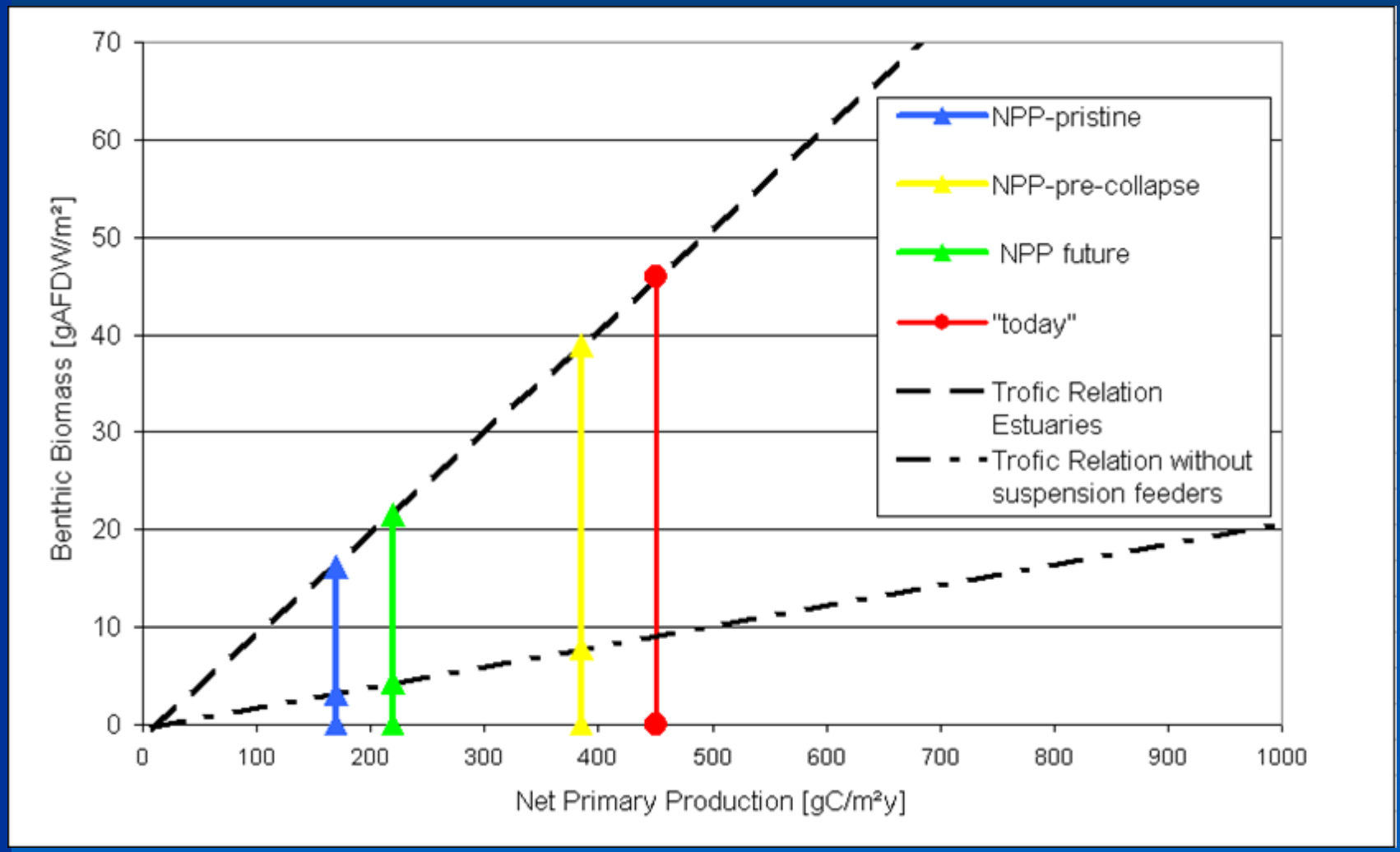
Conservation goal

Gent Vlissingen

Distance (km)

- From load to primary production and oxygen conditions
- From Primary production back to benthic productivity

Up again from plankton to benthos



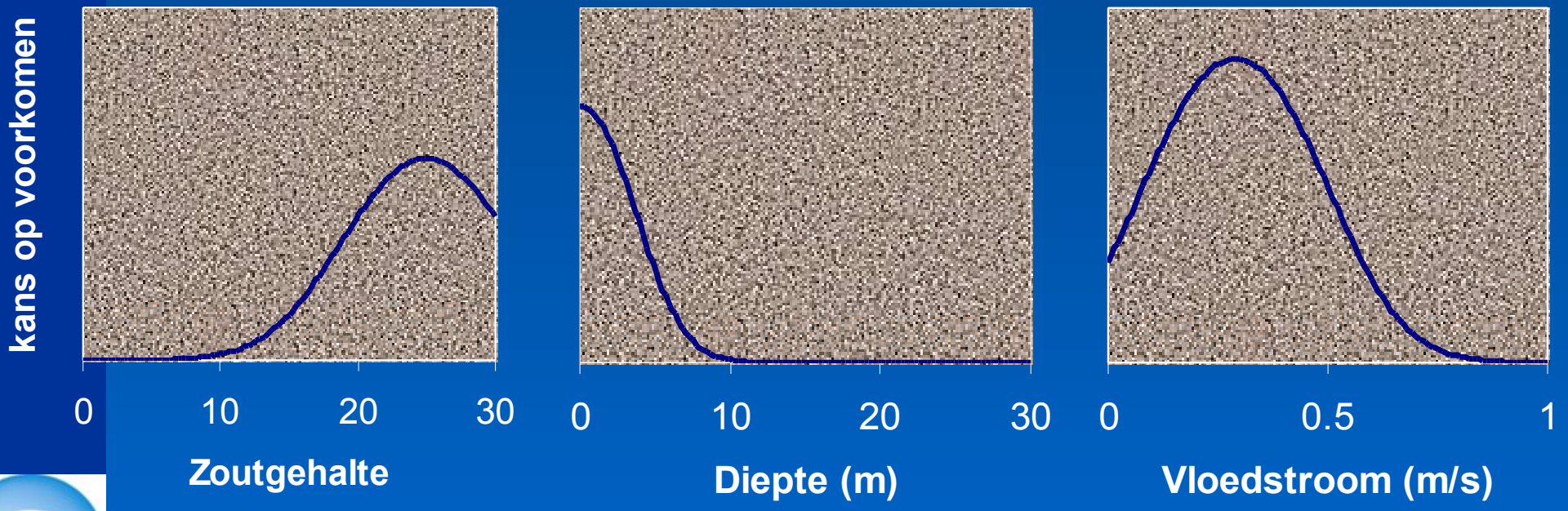
Carrying capacity: all elements

- Calculation formula:
- $Bi * Ai = Bj * (Aj + Sj)$

  - B = system averaged benthos biomass (in g AFDW.m-2)
  - A = natural area surface (in ha)
  - S = required area
  - i = scenario i
  - j = scenario j
- For the Belgian part of the Scheldt this results in a required extra area of **500 ha** of mudflats, **suitable for benthos, fish and birds.**

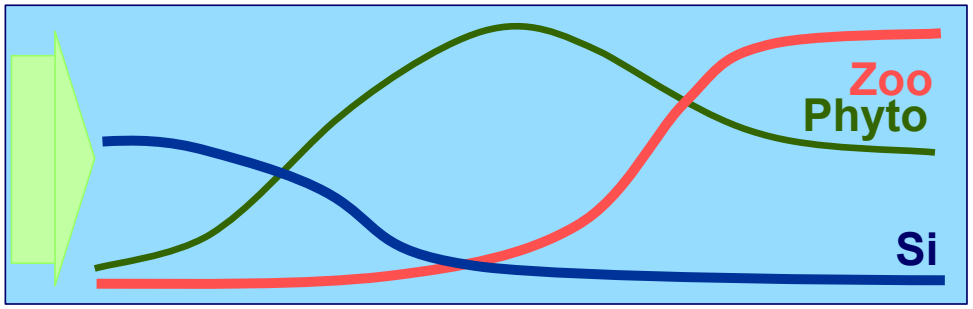
Benthic animals have demands !

E.g. Cockle



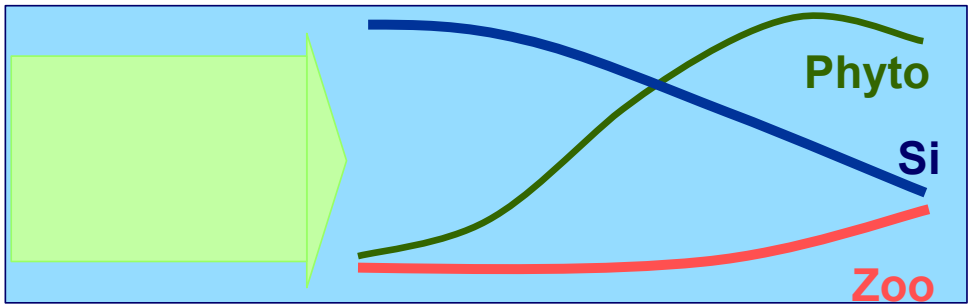
Regulation of phytoplankton by river discharge

low river discharge



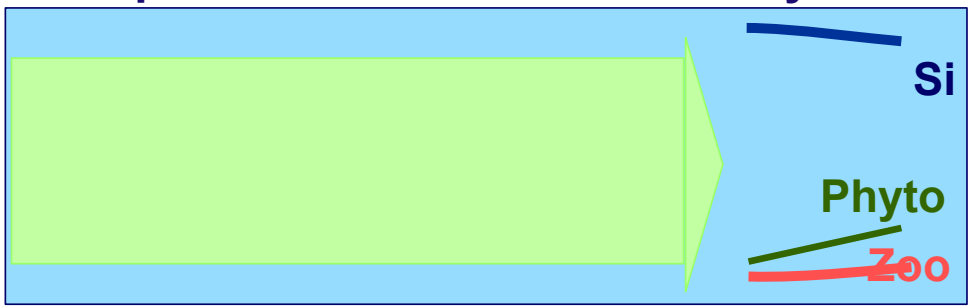
limitation of phytoplankton by grazers or silicium

Partial wash out of the estuary

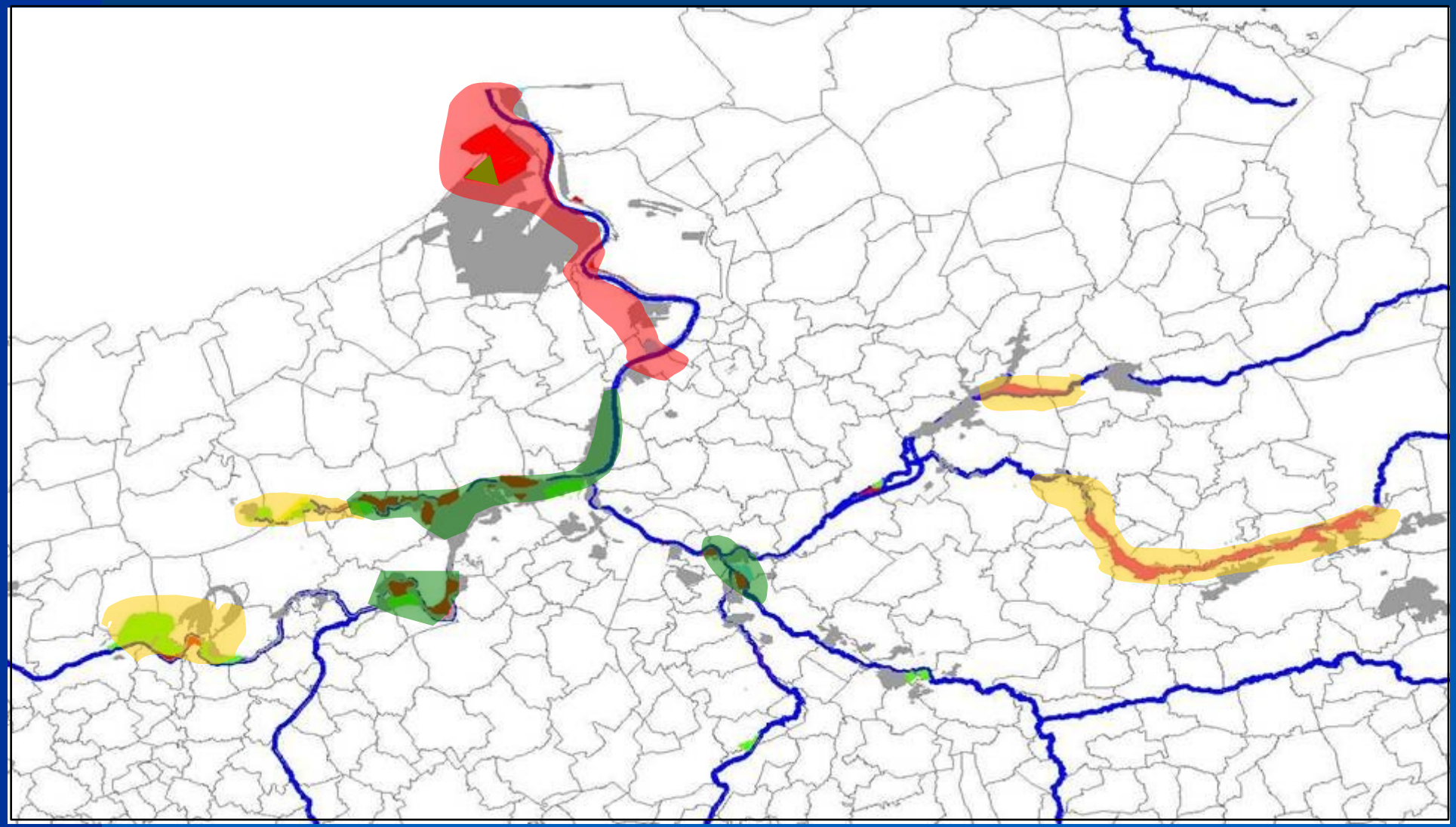


growth of phytoplankton due to removal of limitation

Complete wash out of the estuary



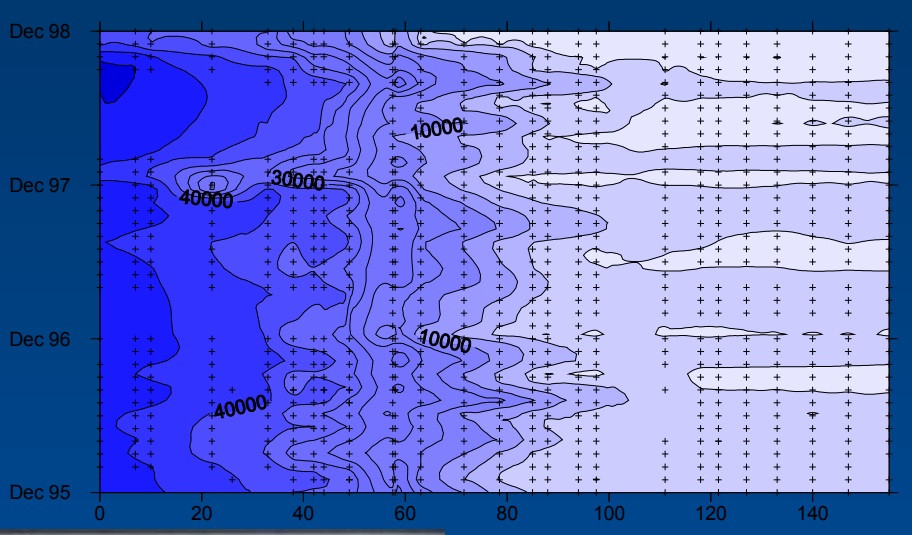
phytoplankton is washed out of the estuary



Conservation objectives

- Formulated as:
  - Required area
  - Required conditions concerning
    - Water quality
    - Water quantity
    - ..
  - Include clear spatial aspects

- Conservation objectives tidal marshes



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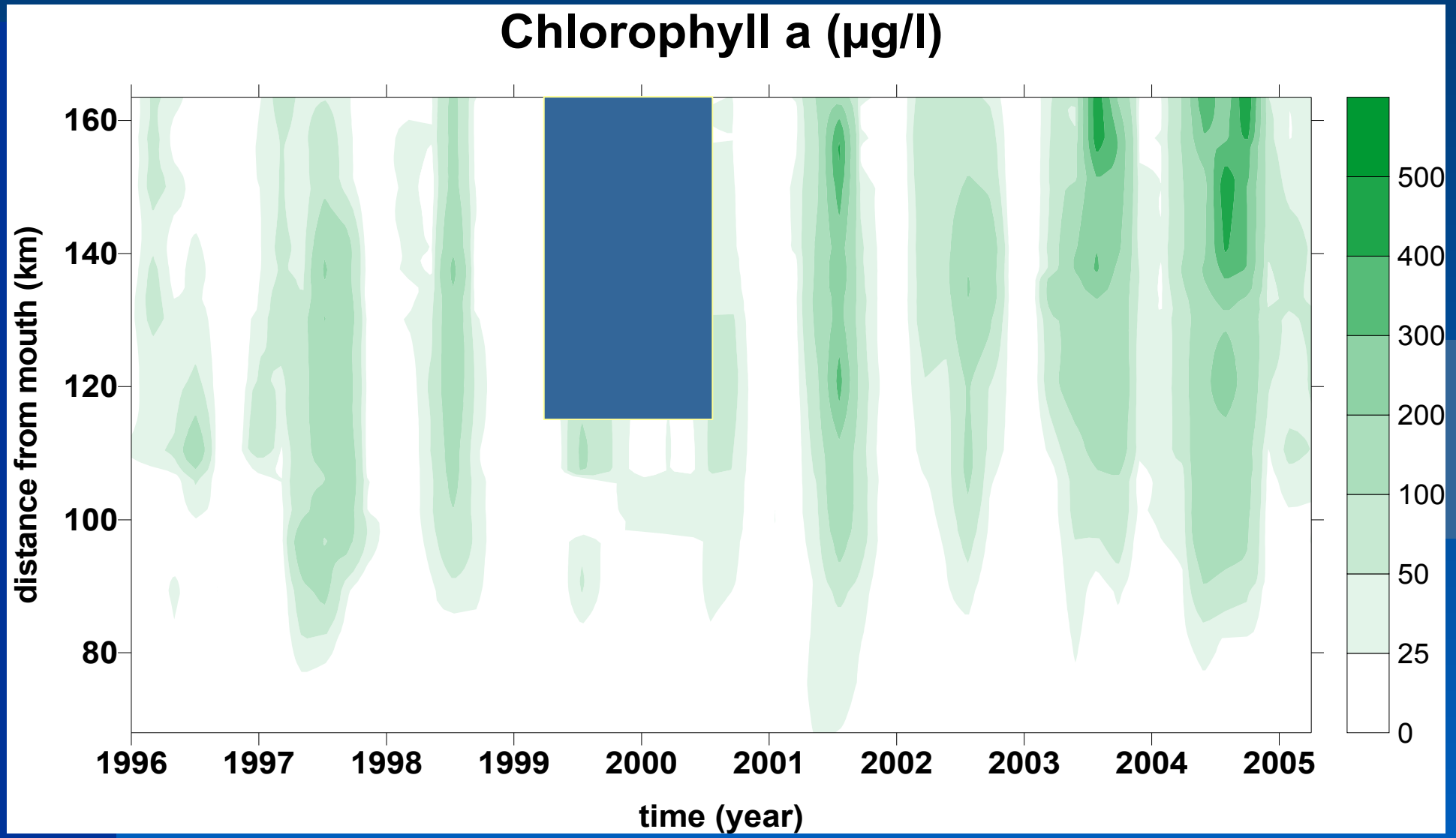
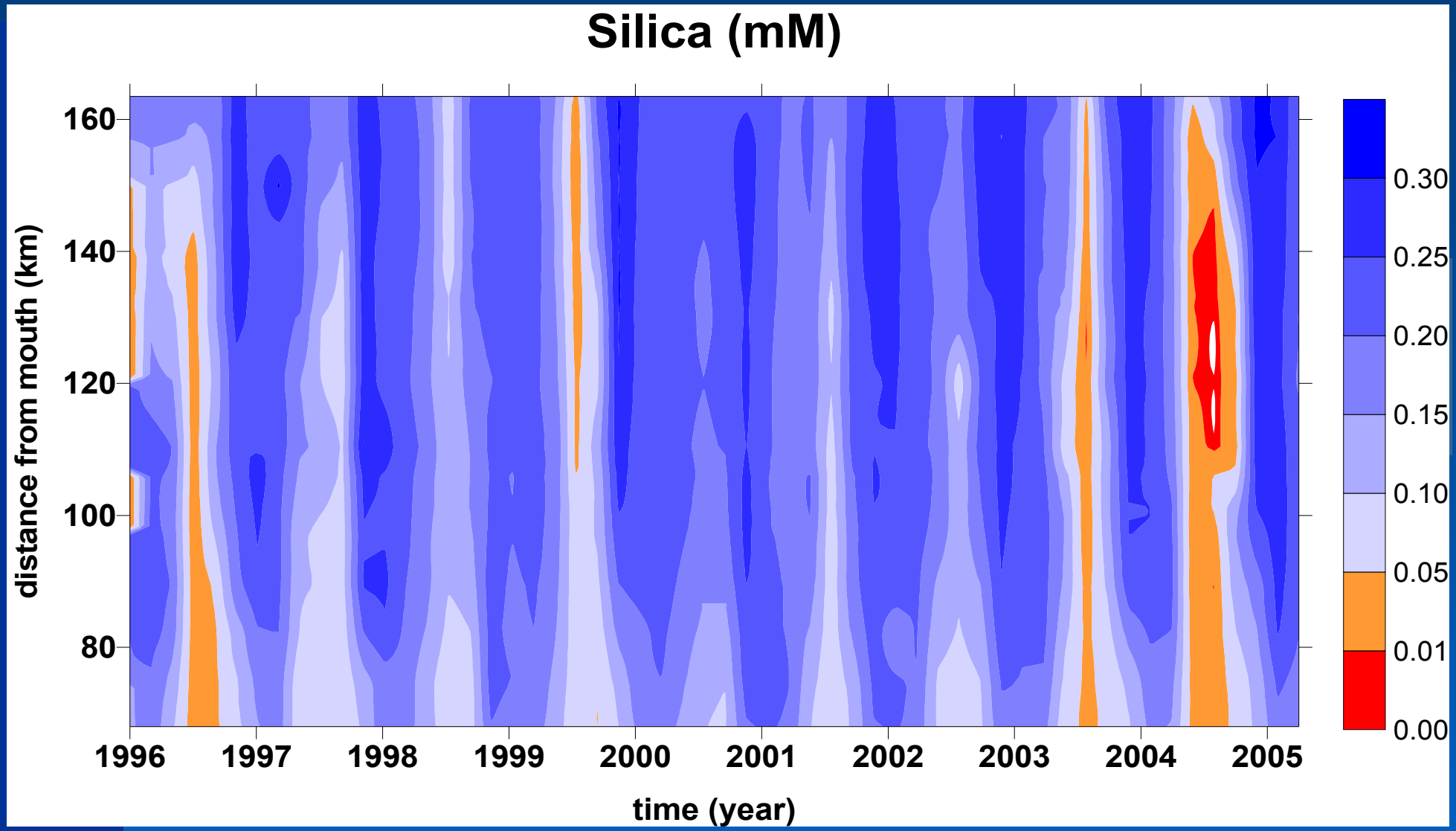
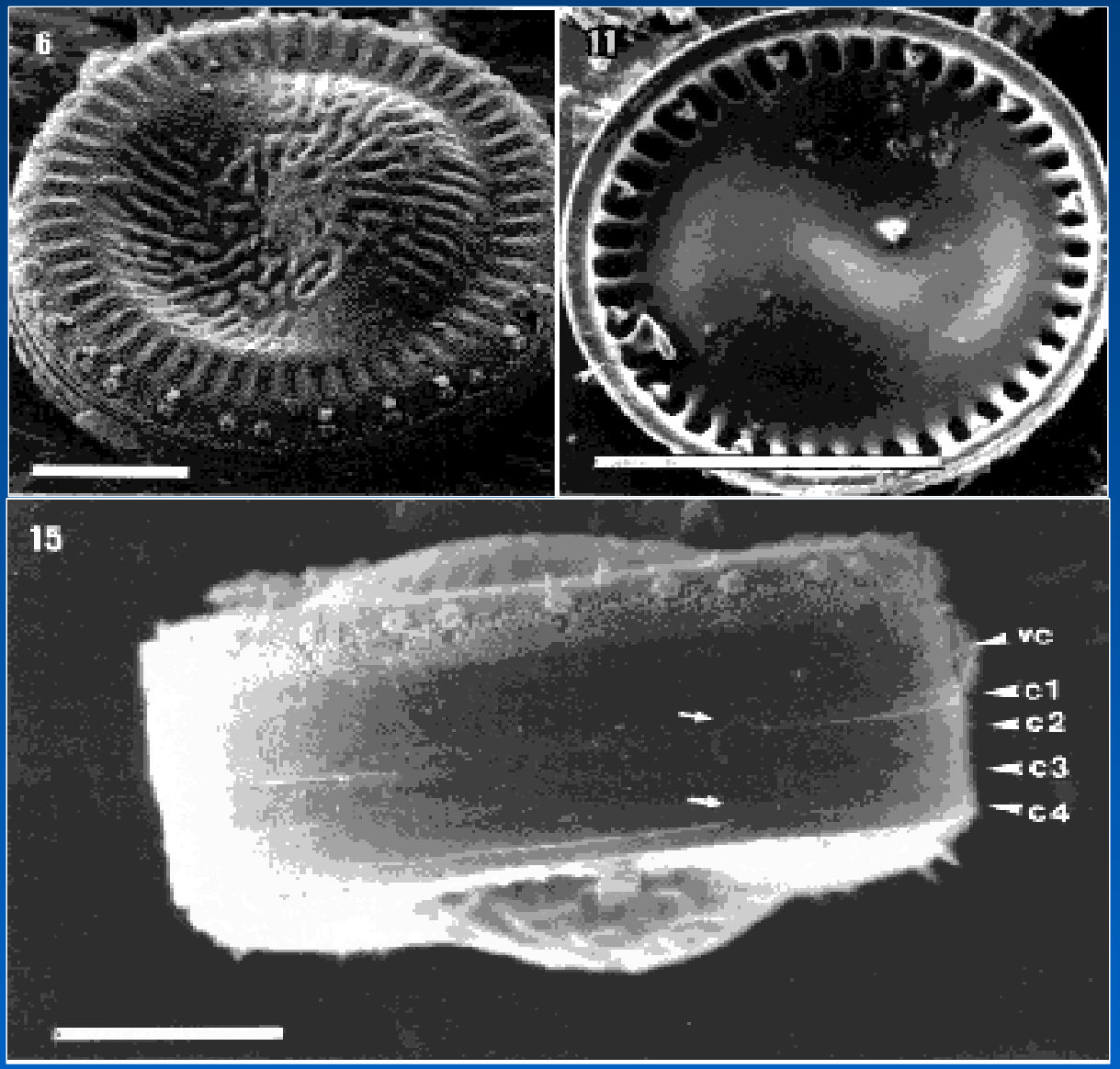
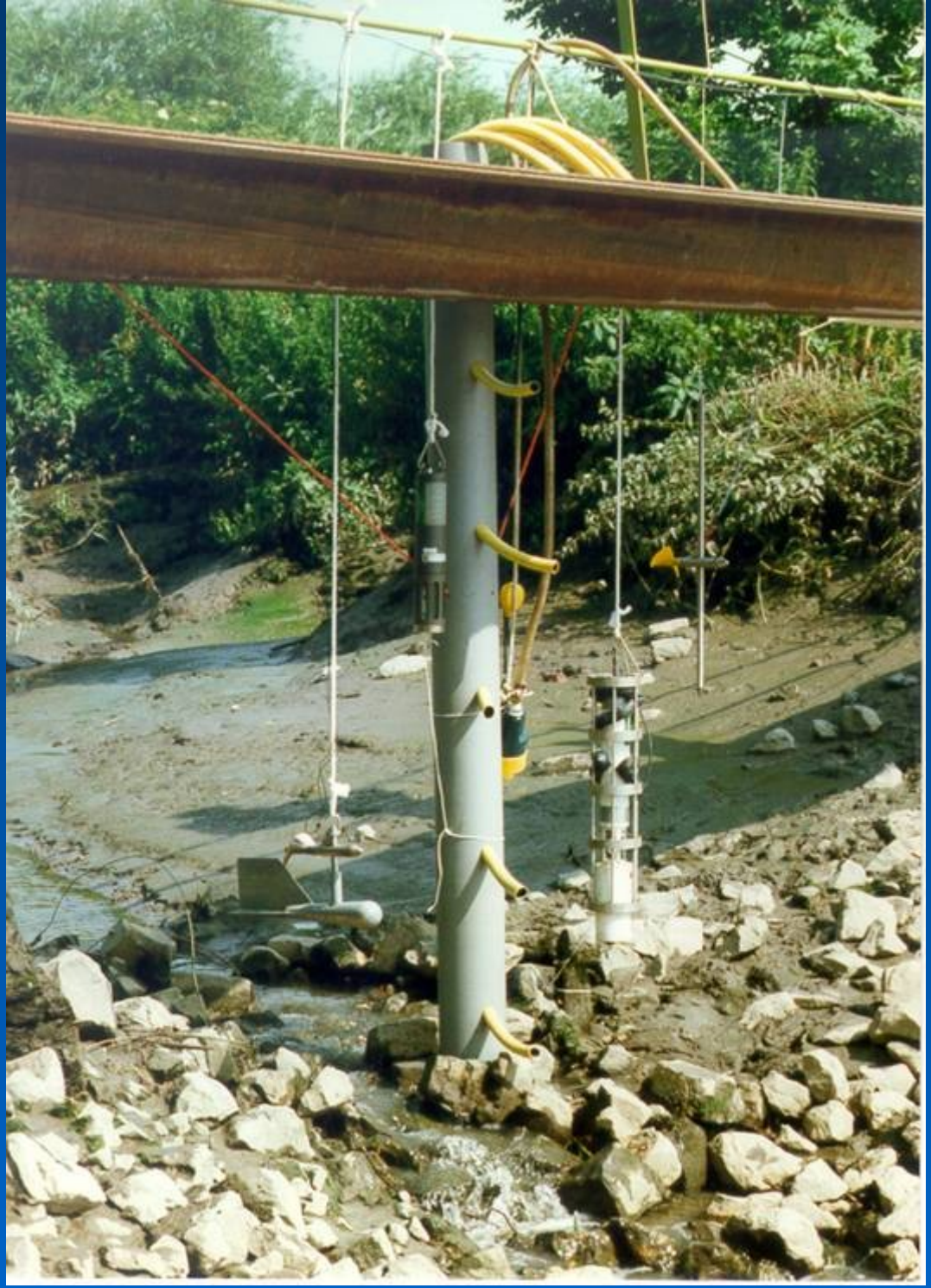
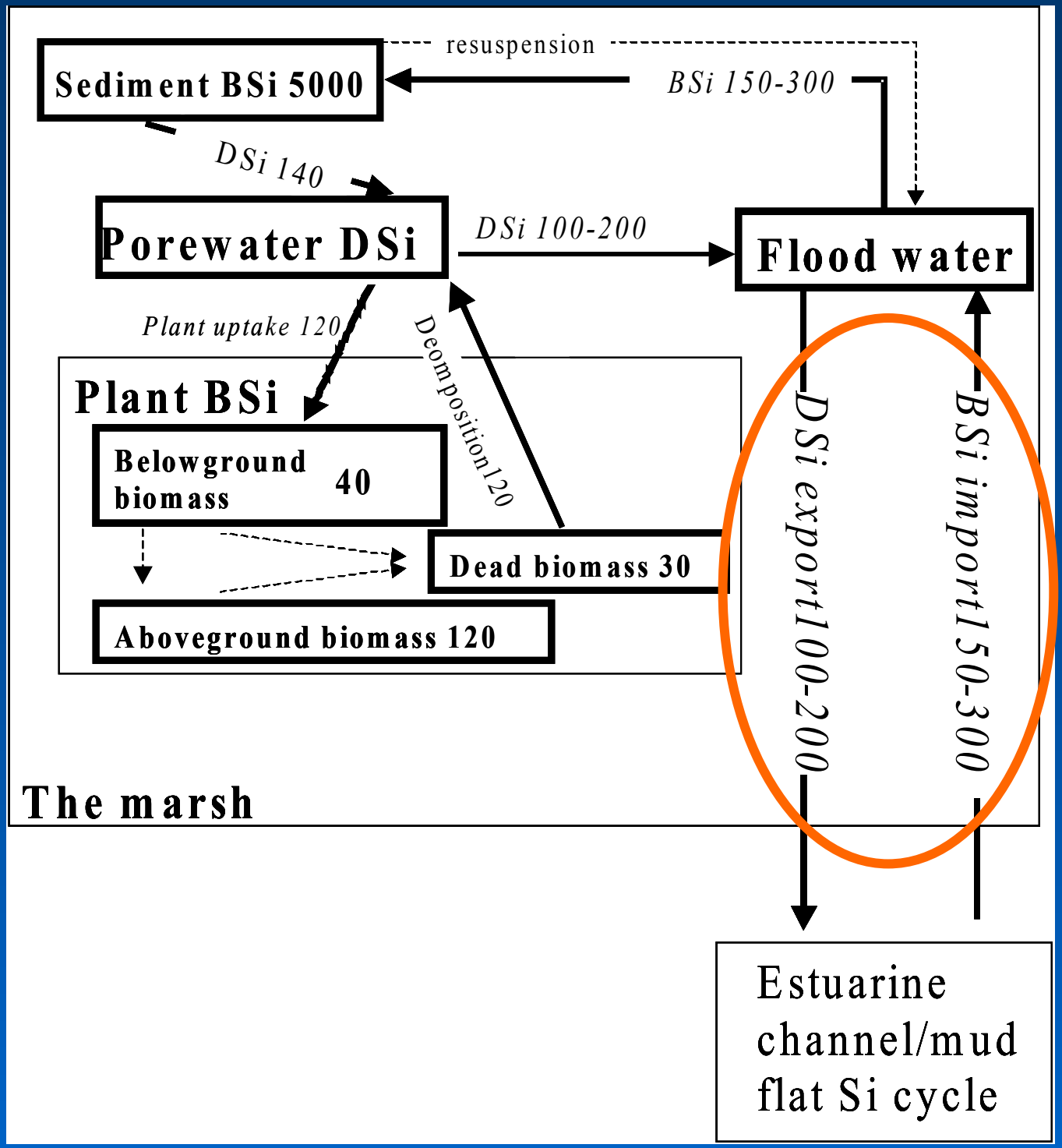

Chlorophyll a (µg/l)
distance from mouth (km)
160
140
120
100
80
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
time (year)
500
400
300
200
100
50
25
0


Silica (mM)
distance from mouth (km)
160
140
120
100
80
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
time (year)
0.30
0.25
0.20
0.15
0.10
0.05
0.01
0.00

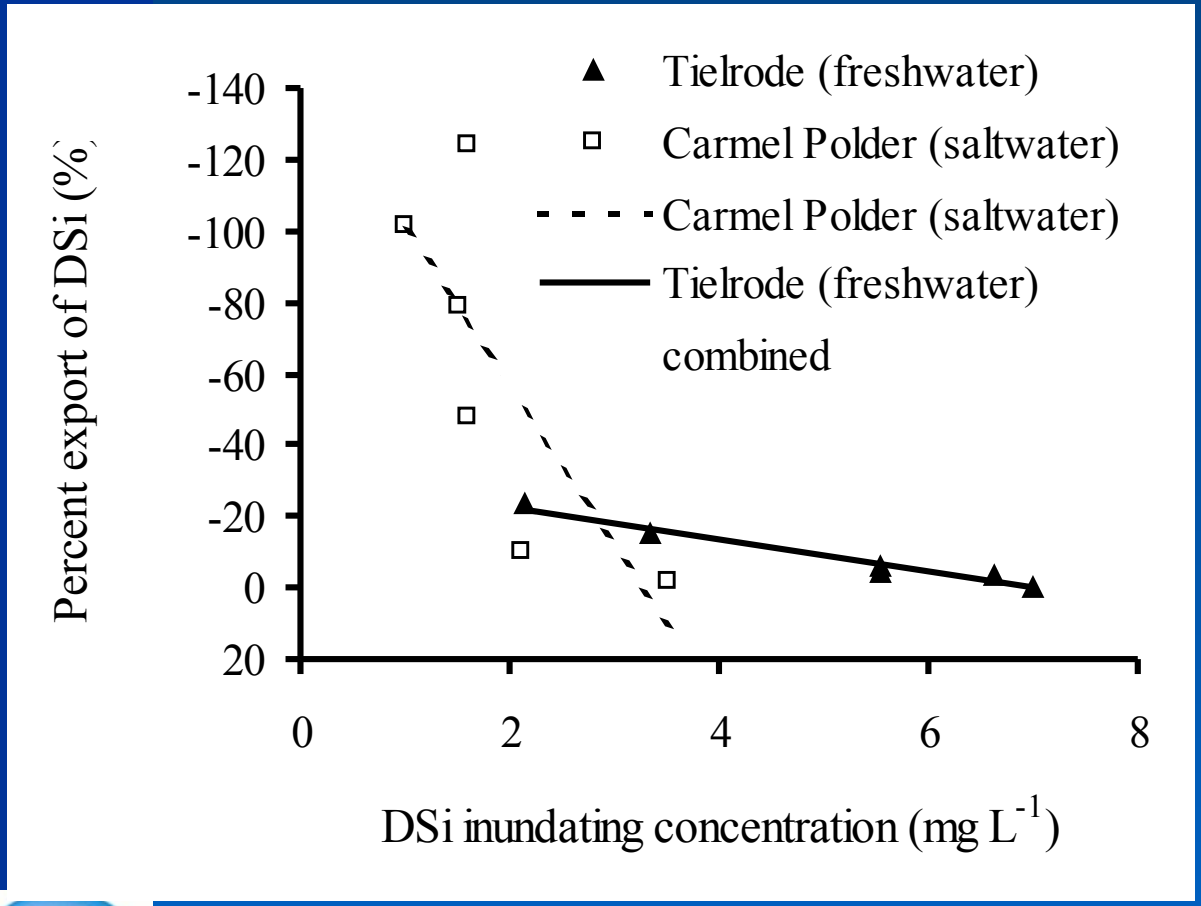
Cyclotella scaldensis, een nieuwe diatomeeënsoort





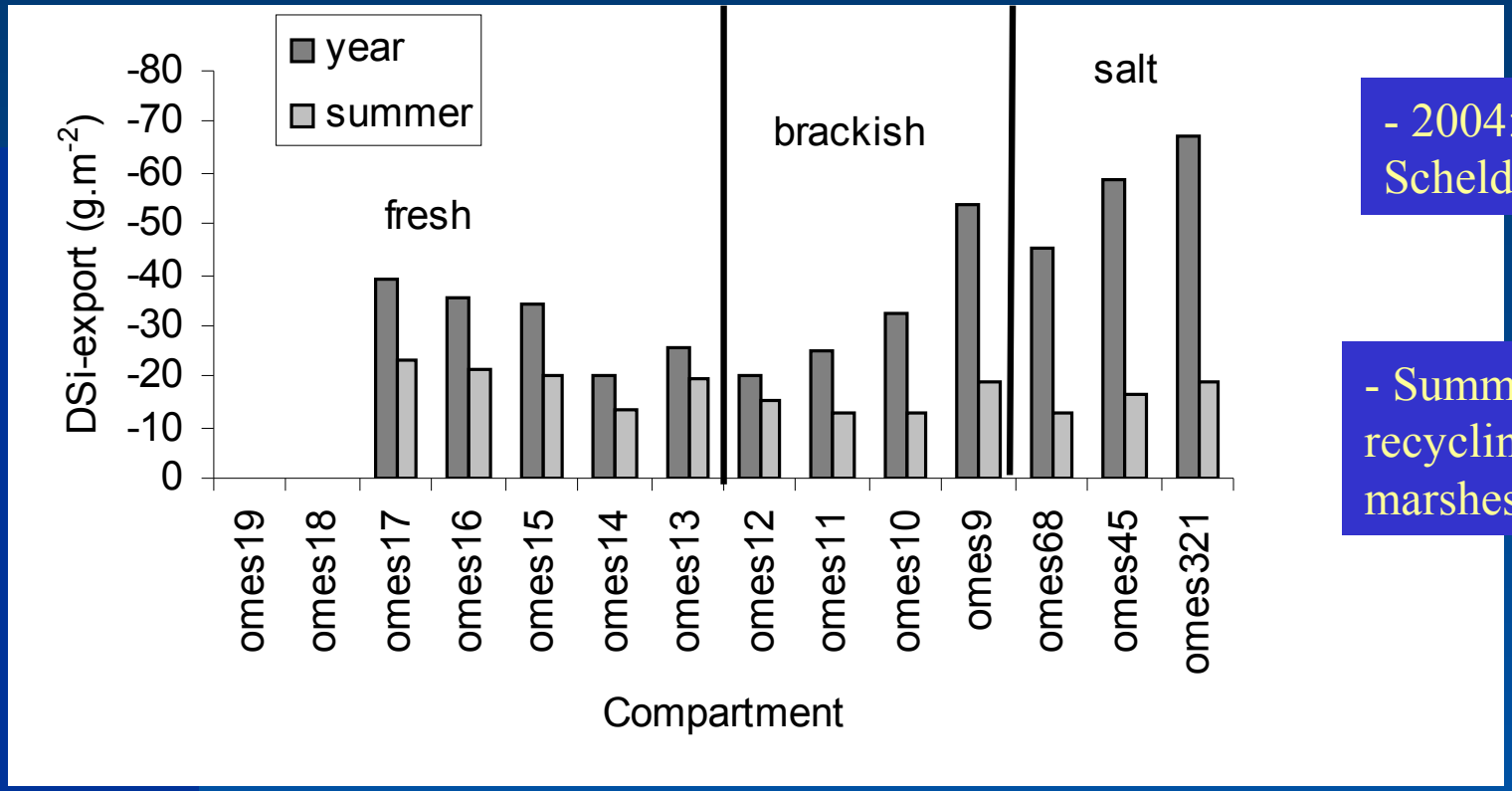

resuspension
Sediment BSi 5000
BSi 150-300
DSi 140
Porewater DSi
DSi 100-200
Flood water
Plant uptake 120
Deomposition120
Plant BSi
Belowground biomass 40
Dead biomass 30
Aboveground biomass 120
DSi export100-200
BSi import150-300
The marsh
Estuarine channel/mud flat Si cycle

Marshes import biogenic Si, and export dissolved Si



BSi is imported along with suspended matter

Relative DSi export is highest, when DSi concentrations in inundation water are low



- 2004: low DSi concentrations in Scheldt freshwater

- Summer months: comparable recycling of BSi to DSi in marshes along salinity gradient

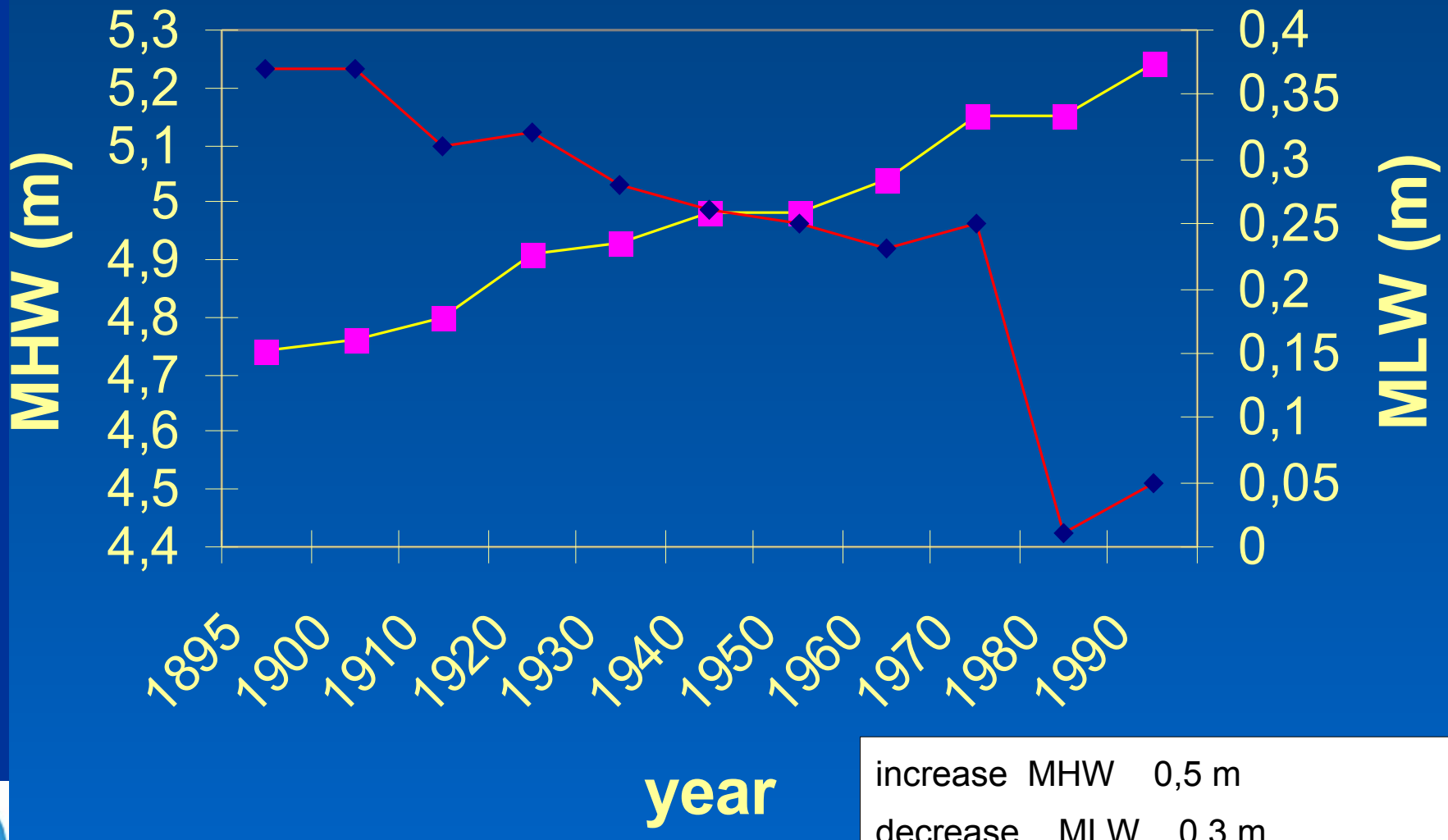
- In the period 1996-2000, 6 "problem months" in Dendermonde: molar DSi-DRP ratio < 3

- 1500 ha of restored marsh enhances DSi load in such a way, that Si-limitation in the Scheldt freshwater is prevented

Remarks:
- marshes might also import DRP (less ha needed)
- young marshes might have lower recycling capacity

- Starting from safety problems

Changing tidal heights

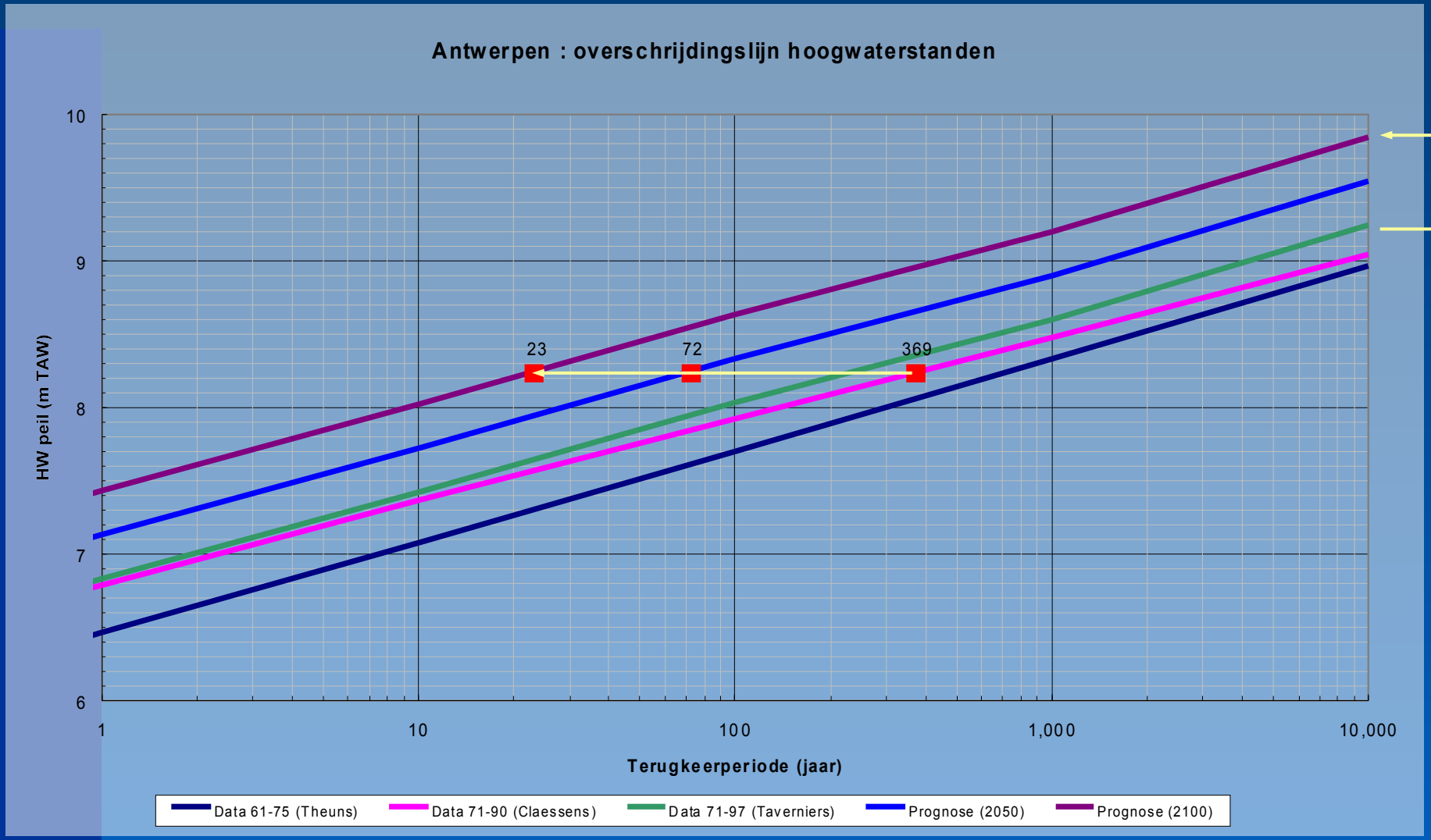


increase MHW 0,5 m

decrease MLW 0,3 m

total increase tidal amplitude 0,8m

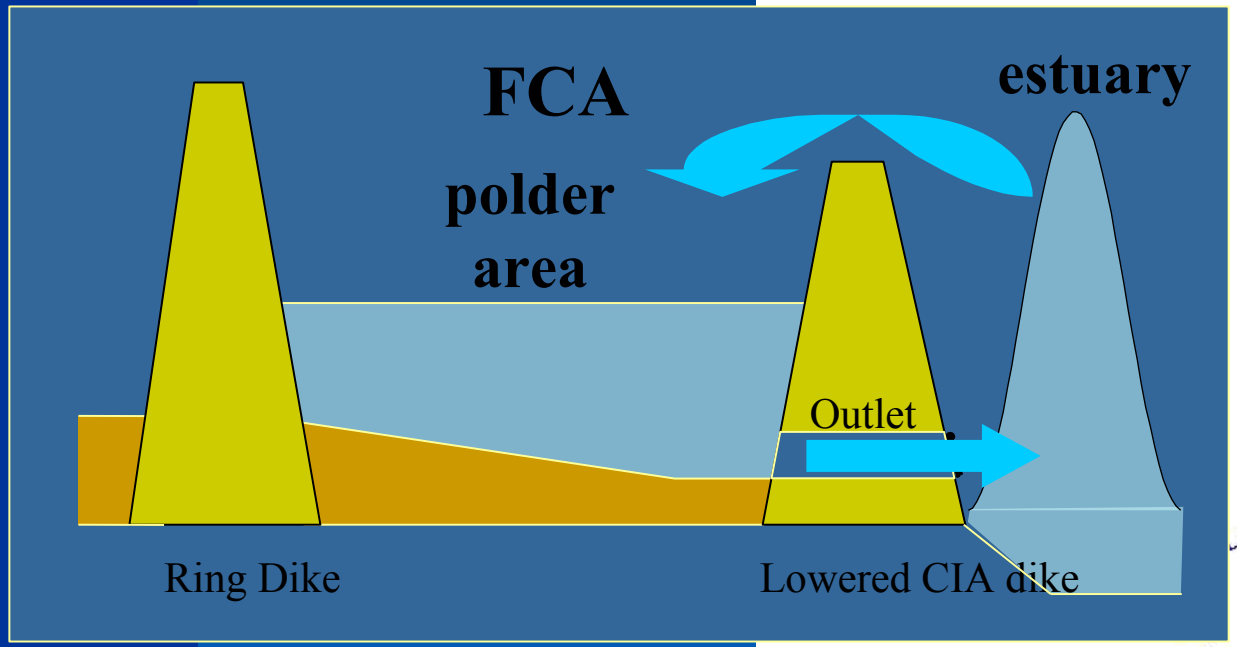
Actualisation is necessary

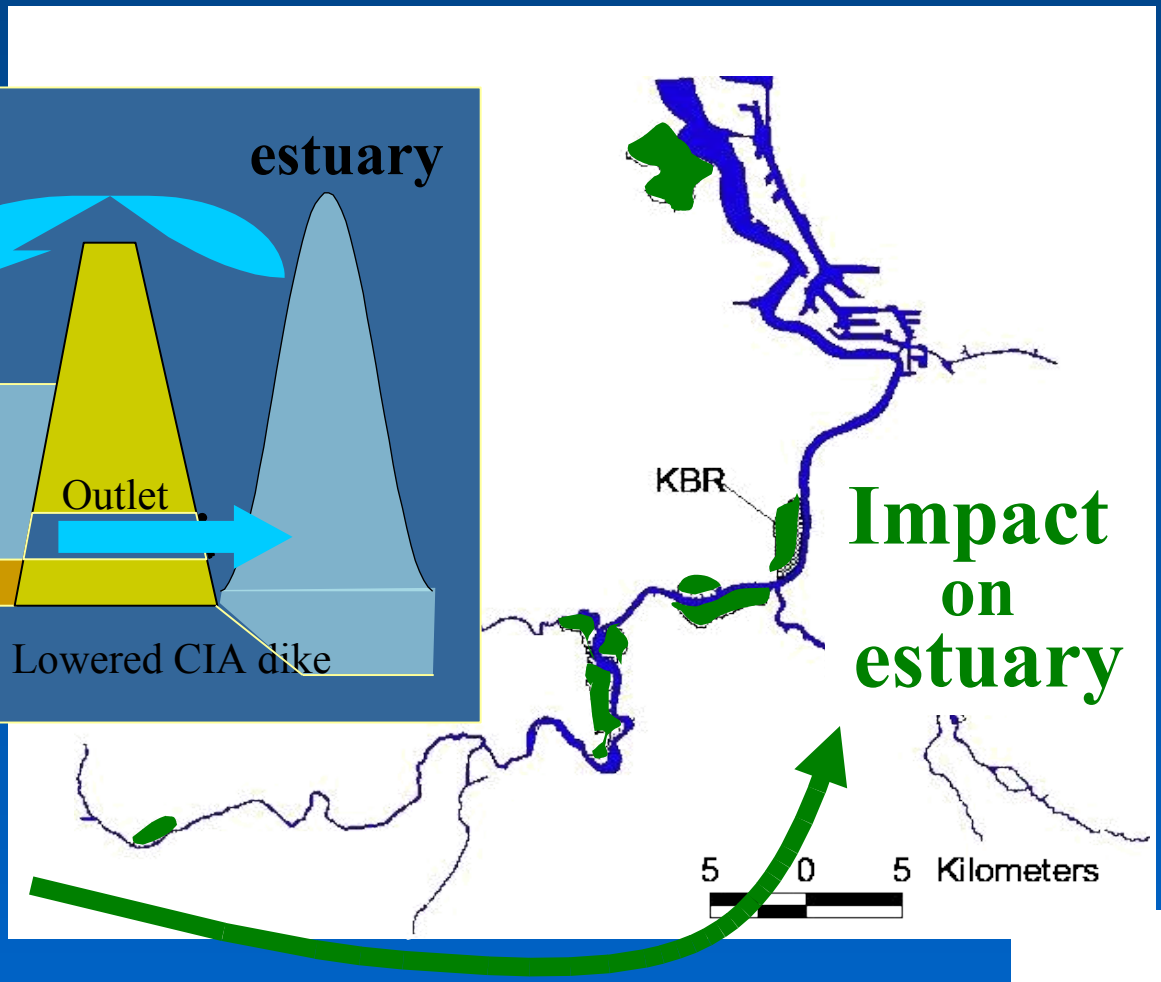


1 / 70 jaar (7,83 m TAW) : situation now

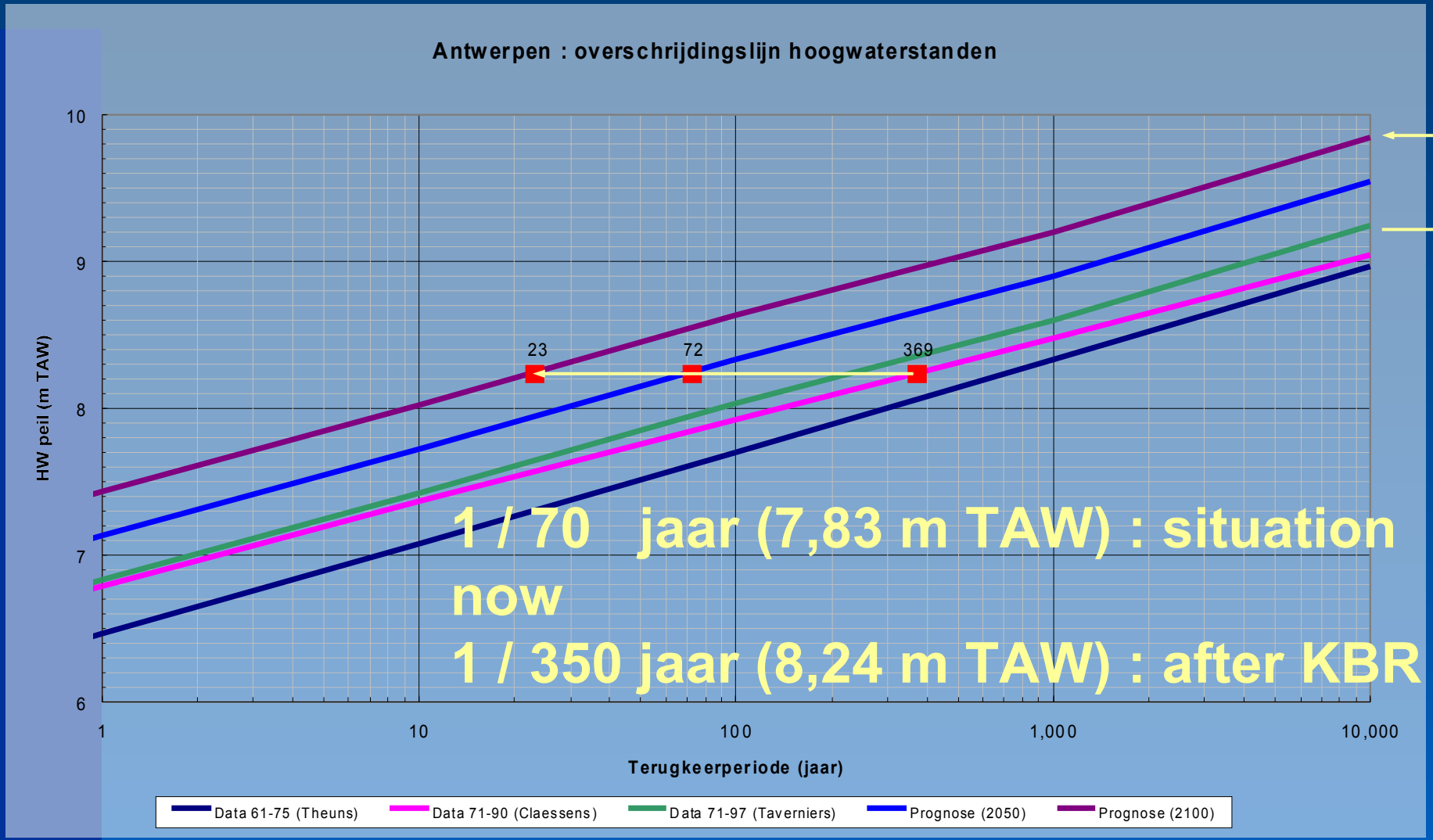
The SIGMAPLAN 1977

Flood Control Areas (FCA)
Controlled Reduced Tide (CRT)





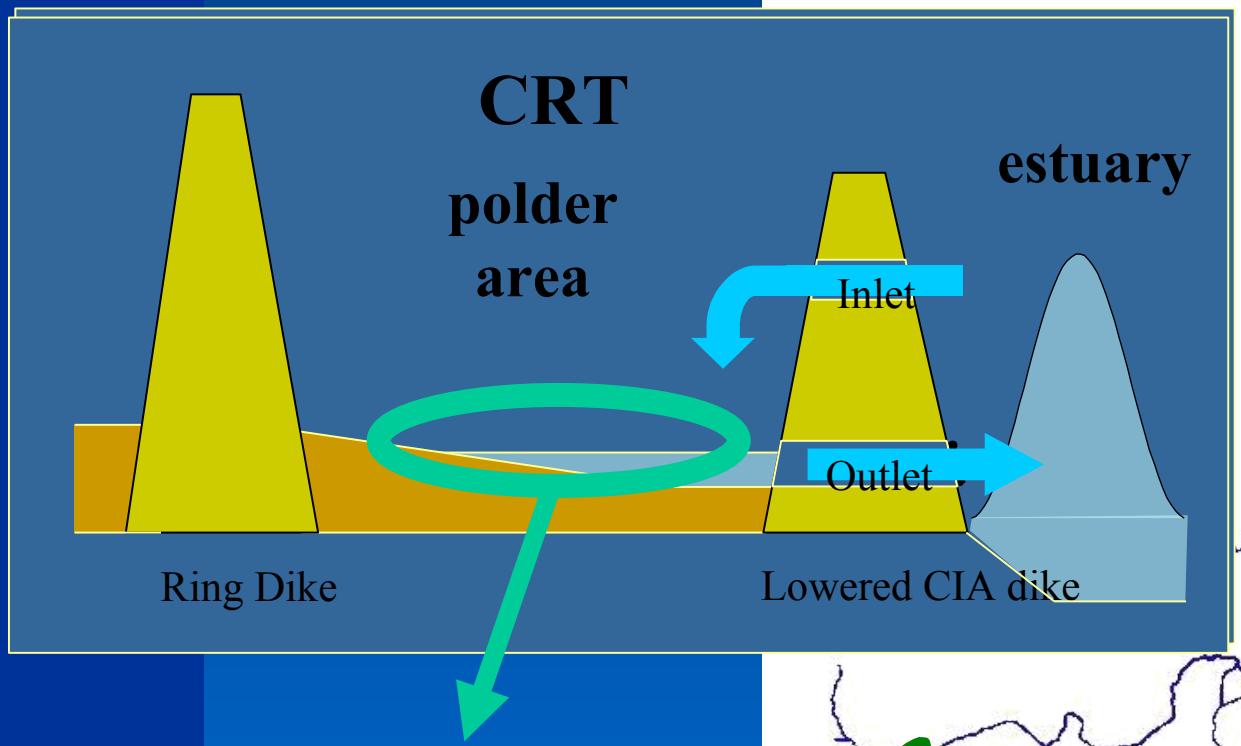
Actualisation is necessary

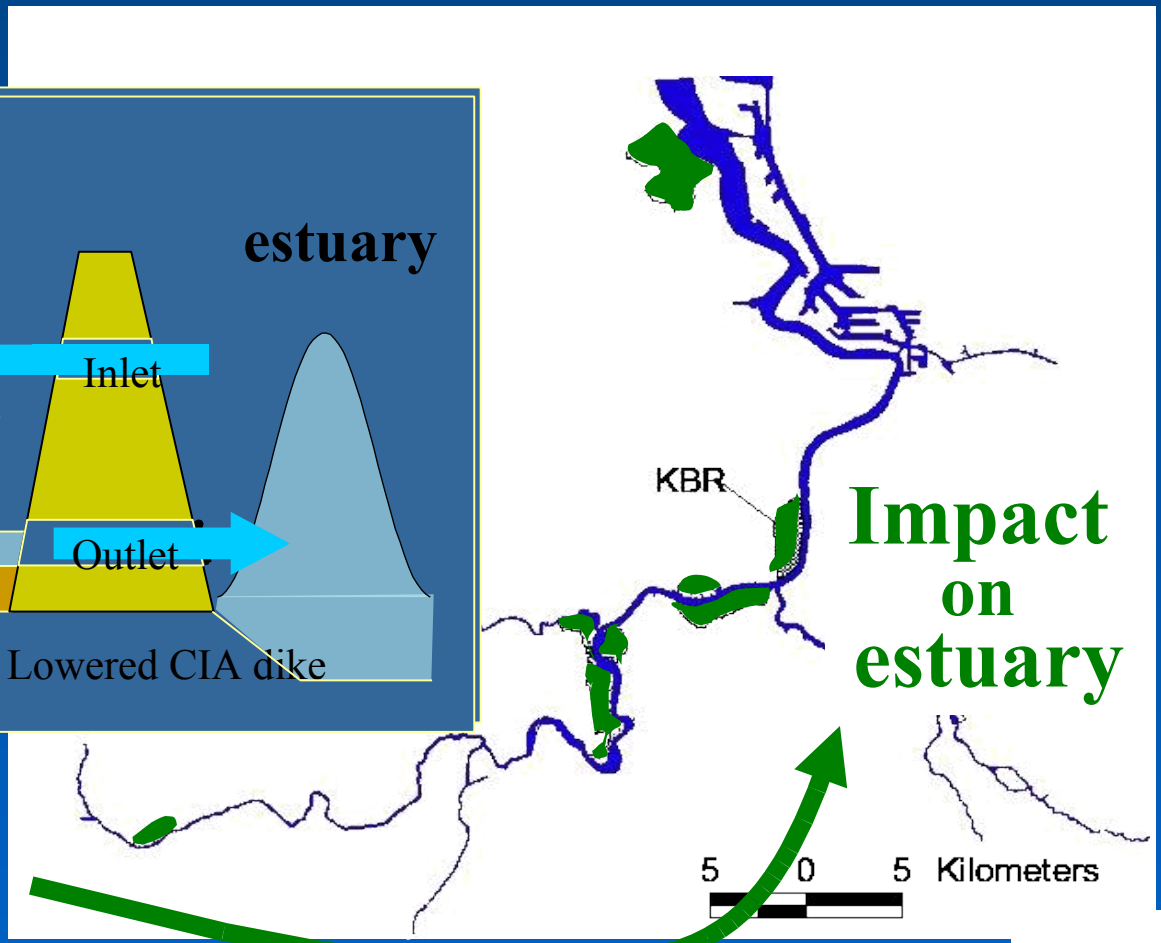


- Based on optimization (minimizing the damage of flooding)
- 1800 ha of flood control area needed

- Is there a combination possible with the area needed for marshes?

Flood Control Areas (FCA)
Controlled Reduced Tide (CRT)

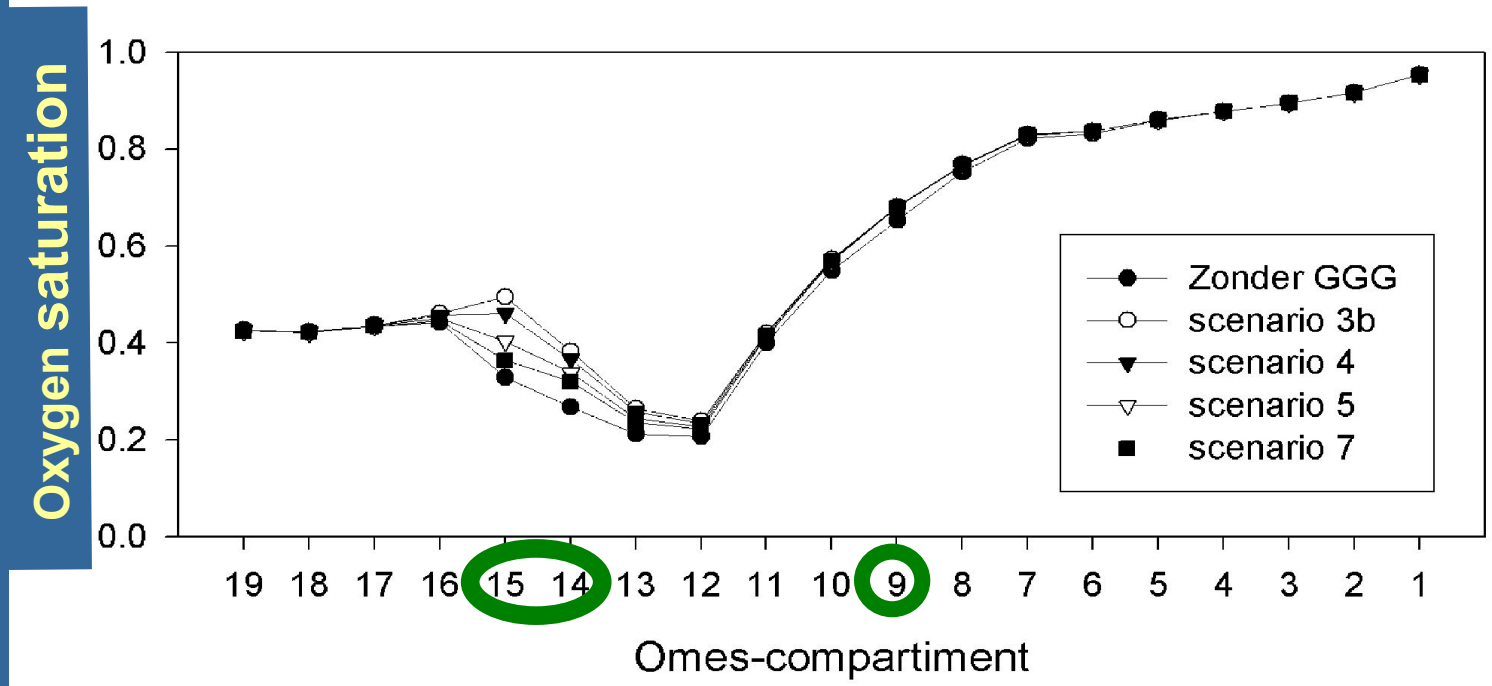




Impact on estuary

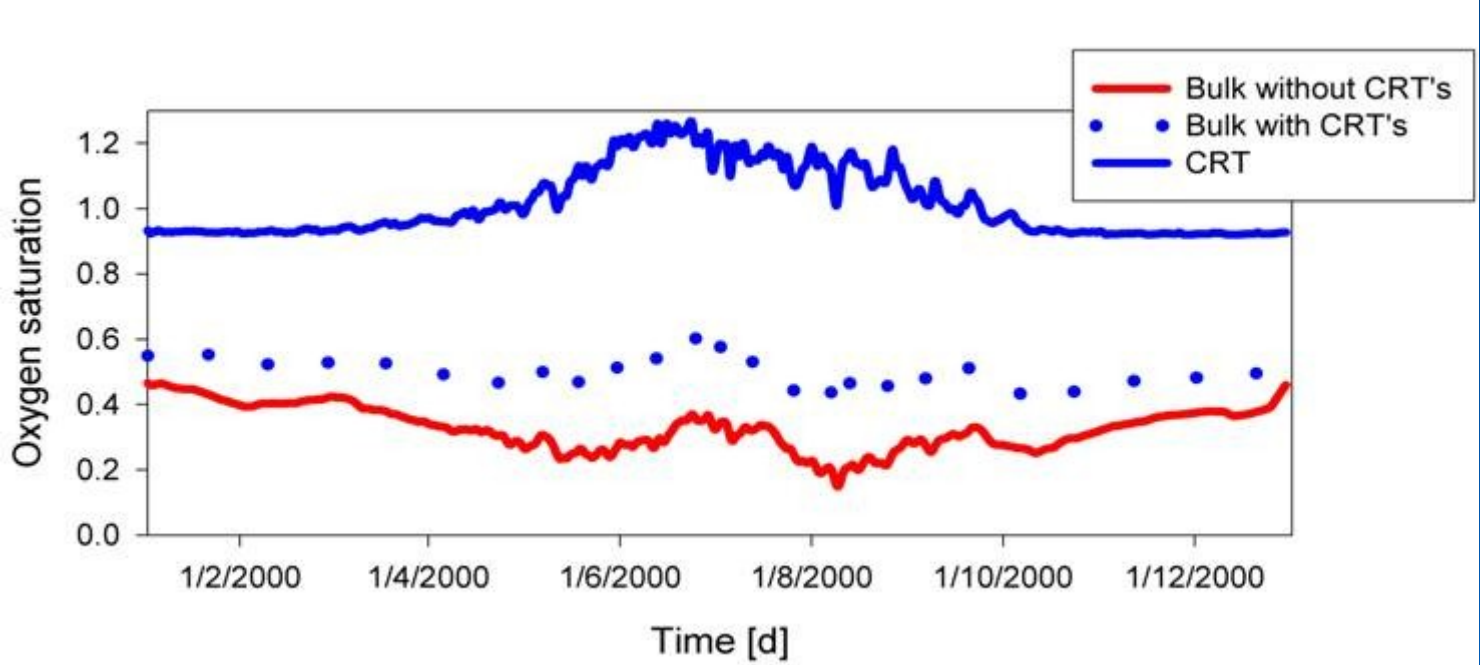
Estuarine functions

Oxygen Saturation



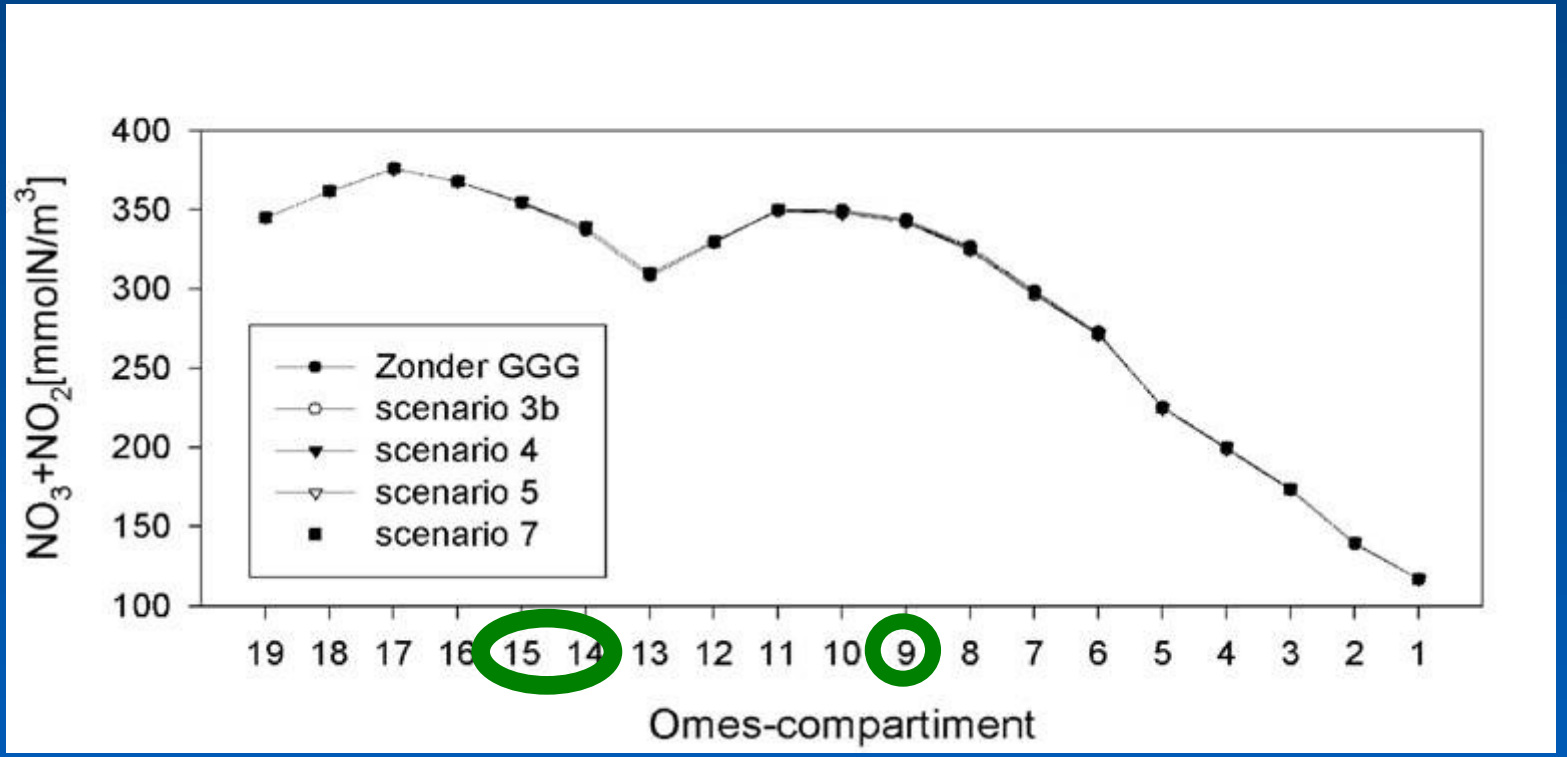
yearly averaged oxygen saturation (data 2000)

Oxygen Saturation



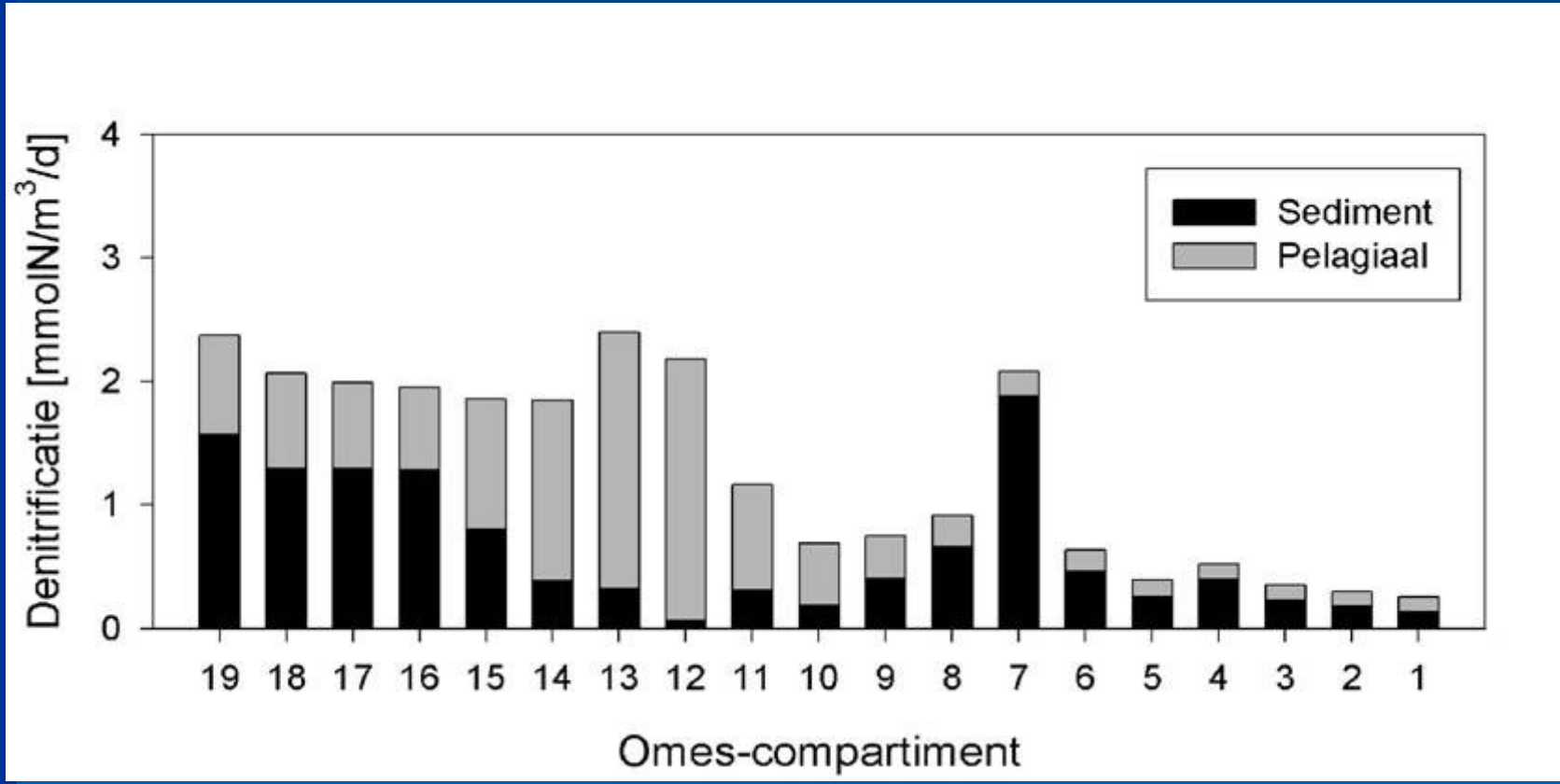
averaged oxygen saturation (data 2000) in compartment 15

Nitrate + Nitrite



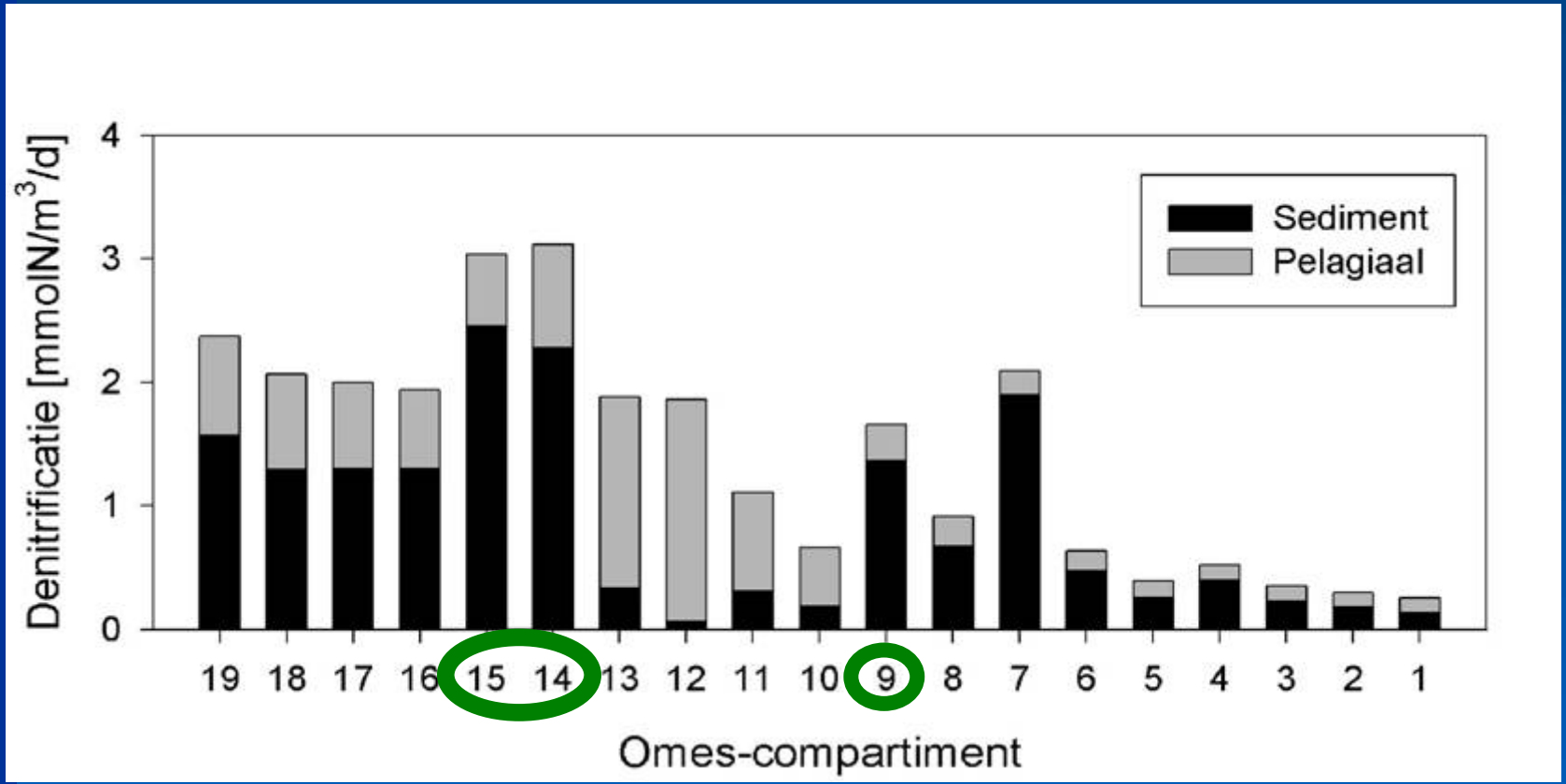
Yearly averaged nitrate + nitrite profile (data 2000)

Denitrification



Denitrification in water column and sediment (data 2000)

Denitrification



Denitrification in water column and sediment (data 2000)

Pionneer controlled inundation with reduced tide

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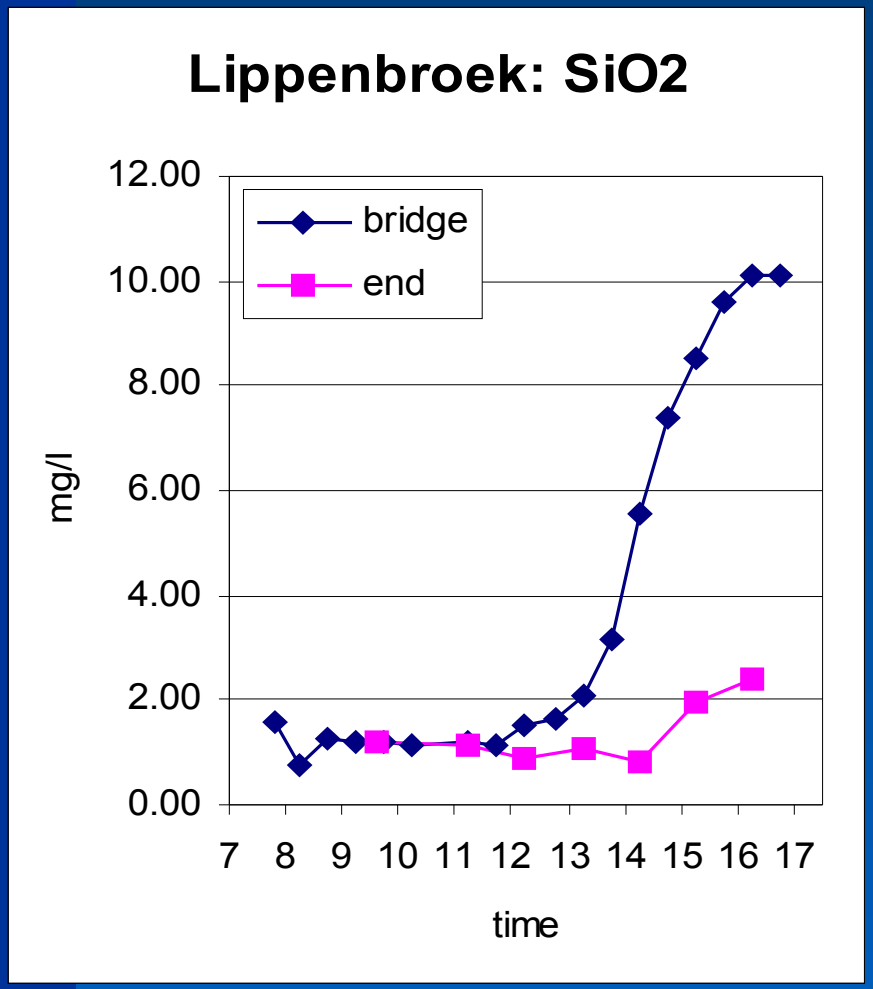
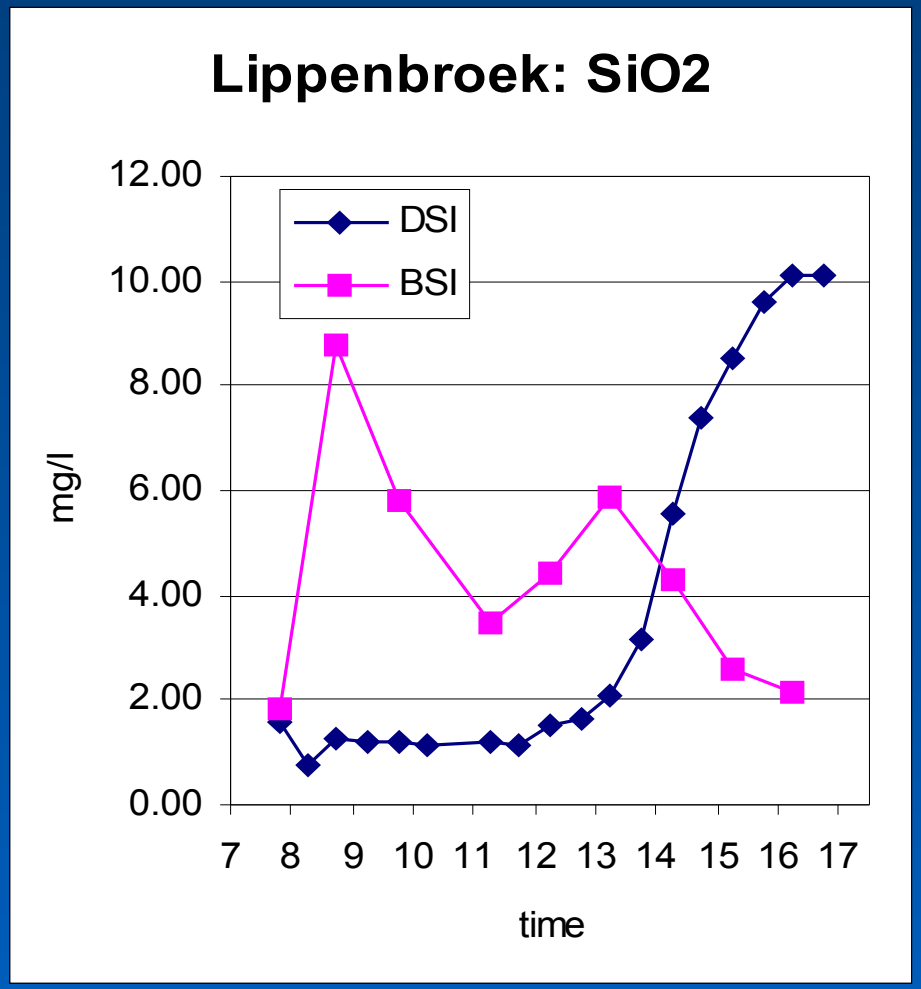
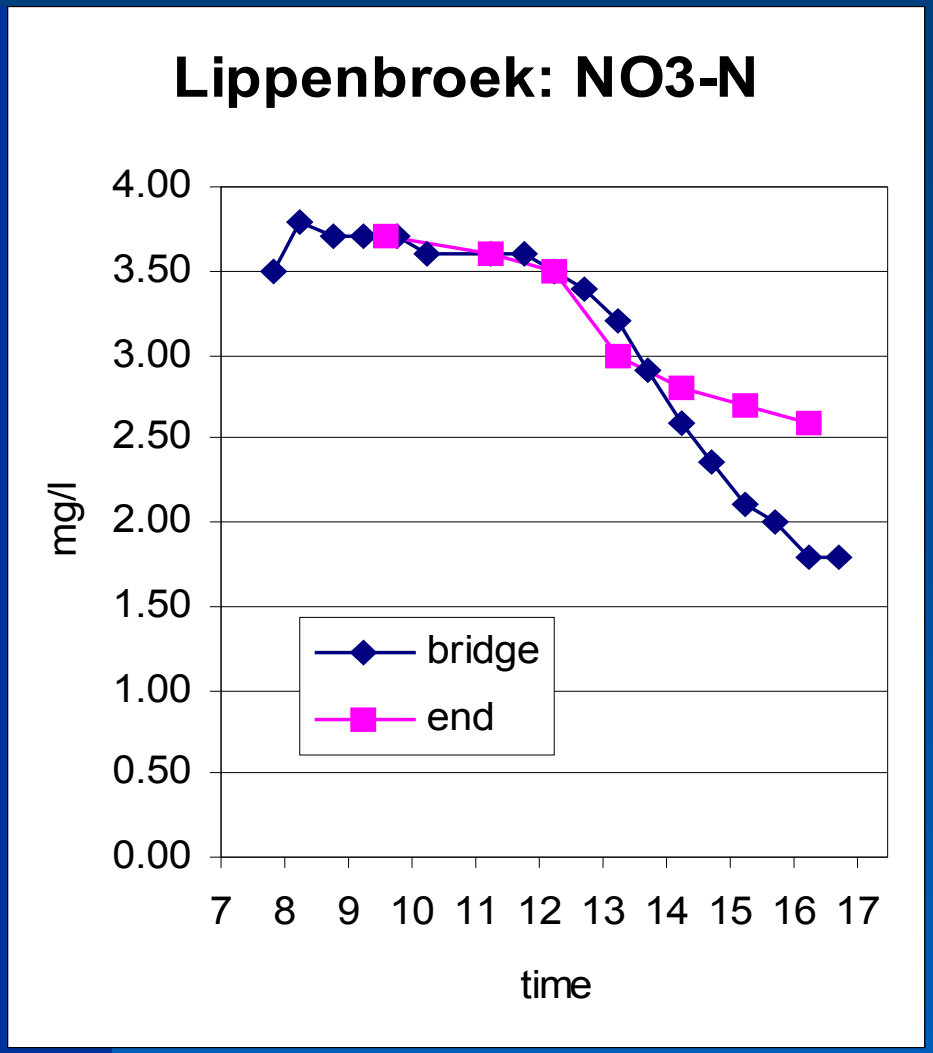
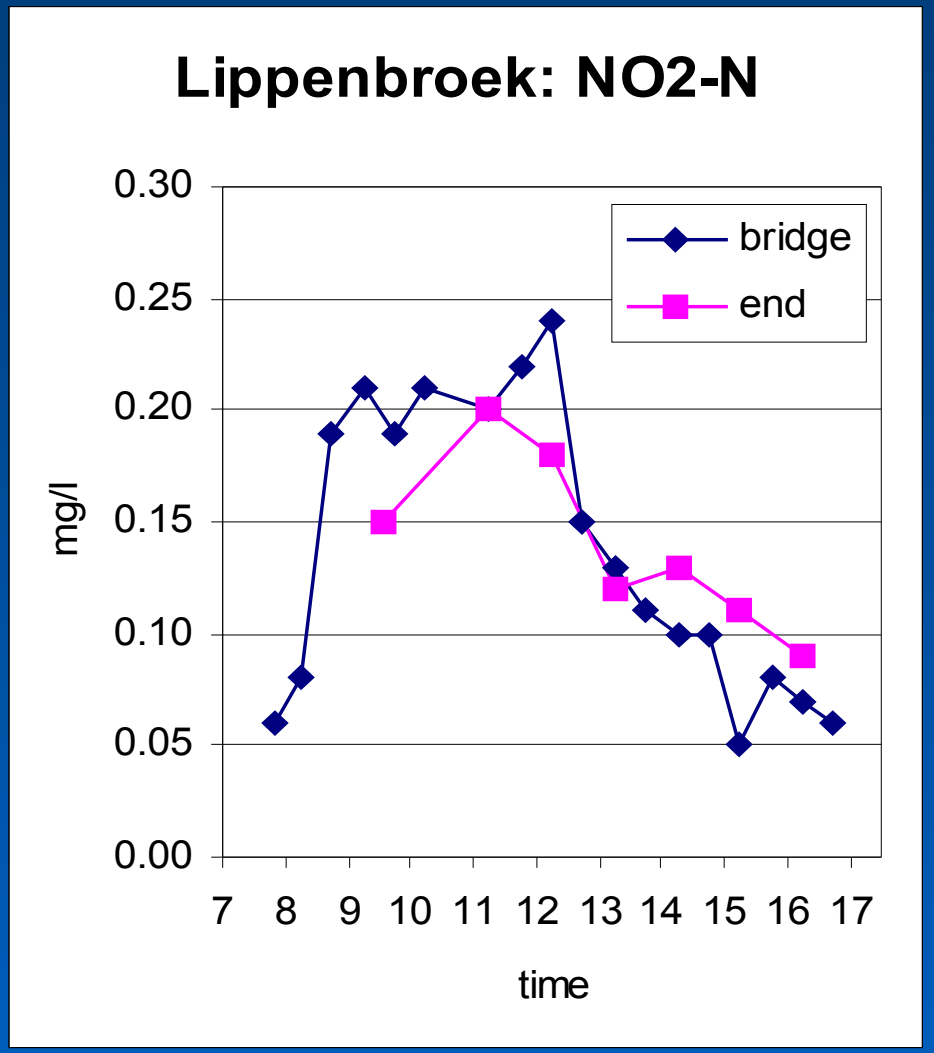

Lippenbroek: SiO2
12.00
10.00
8.00
6.00
4.00
2.00
0.00
mg/l
bridge
end
7 8 9 10 11 12 13 14 15 16 17
time


Lippenbroek: SiO2
12.00
10.00
8.00
6.00
4.00
2.00
0.00
mg/l
DSI
BSI
7 8 9 10 11 12 13 14 15 16 17
time


Lippenbroek: NO3-N
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
mg/l
7 8 9 10 11 12 13 14 15 16 17
time
bridge
end


Lippenbroek: NO2-N
0.30
0.25
0.20
0.15
0.10
0.05
0.00
mg/l
7 8 9 10 11 12 13 14 15 16 17
time
bridge
end

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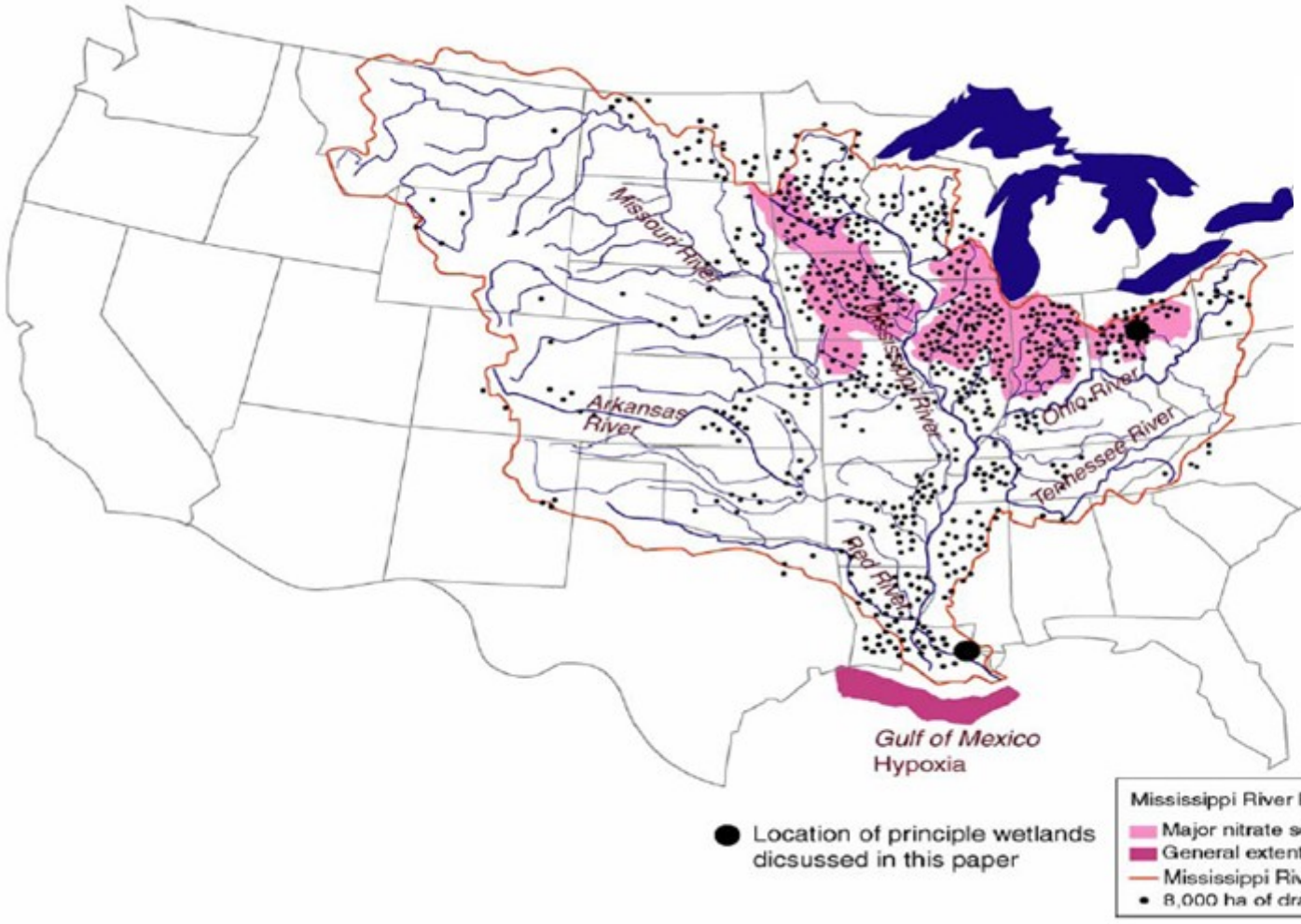

$$\text{Area required}\,(\text{km}^2) = \frac{\text{load}}{\text{removal}} = \frac{1.57 \times 10^{12}(\text{g-N year}^{-1}) \times 0.40}{29(\text{g-N m}^{-2}\,\text{year}^{-1}) \times 10^{6}(\text{m}^2\,\text{km}^{-2})} = 22,000\,\text{km}^2$$

Retention rate

After Mitch et al. 2005

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Conclusions

- It is possible to define conservation objectives in a quantitative way
- Functions can be combined

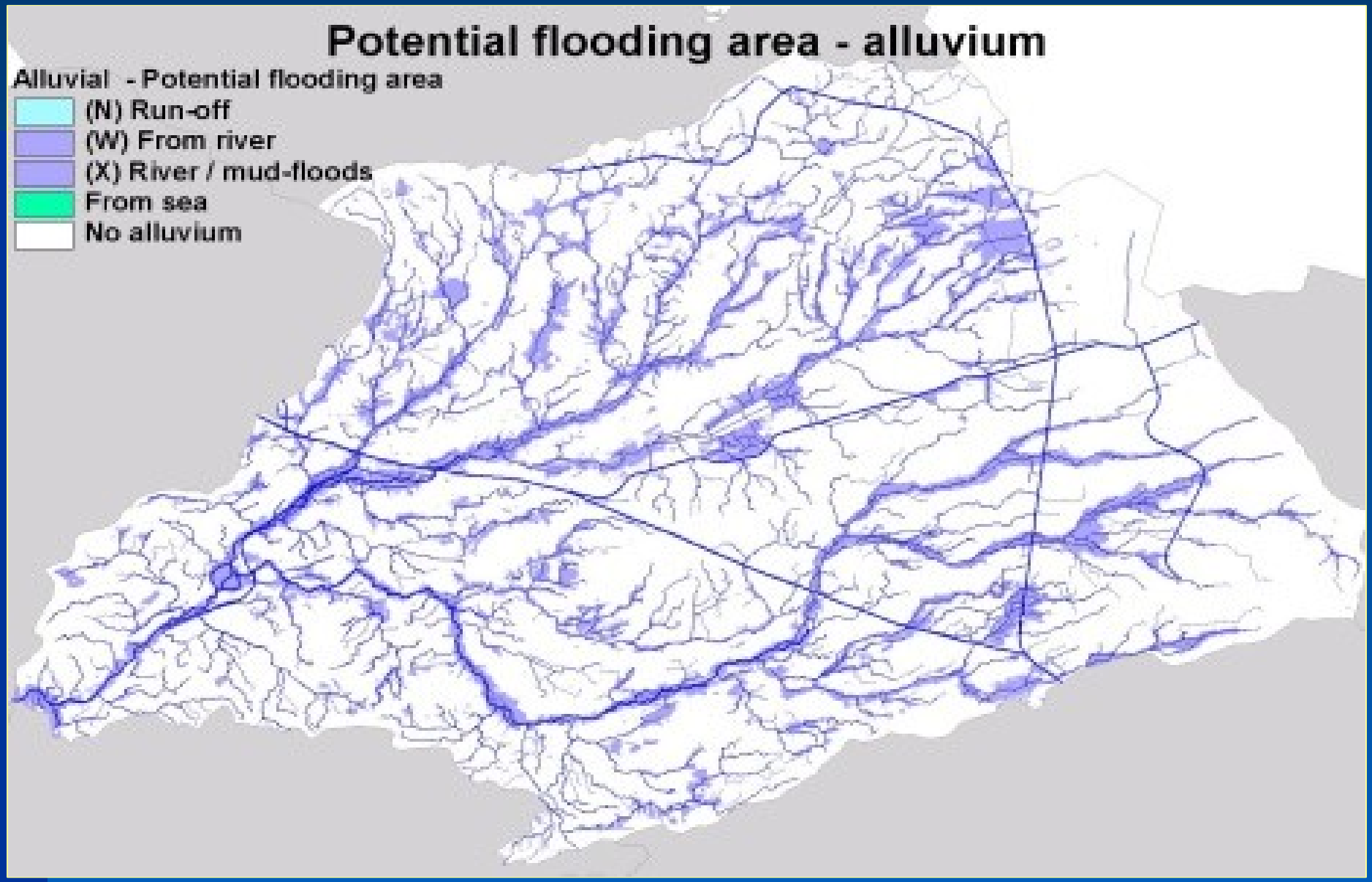
- This was done for the Schelde estuary leading to an overall claim of 4000 ha of wetlands needed
- Both the approach and the results were approved by the Flemish government and a time table for realisation was set up

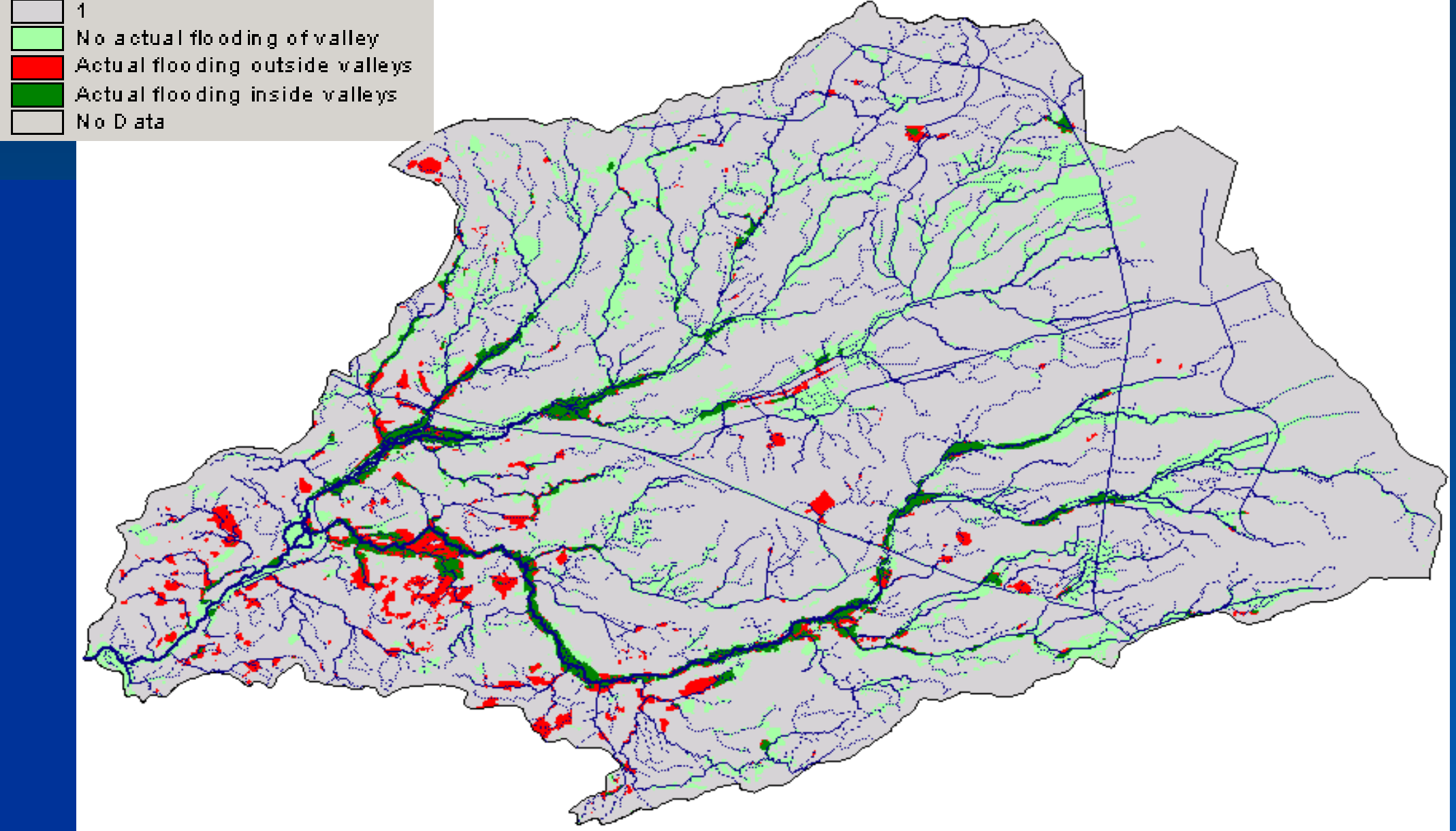
- However: how to integrate this in a river basin mangement plan?

Inundations

Grote Nete 17 september 1998

Photo: AMINAL


Potential flooding area - alluvium
Alluvial - Potential flooding area
(N) Run-off
(W) From river
(X) River / mud-floods
From sea
No alluvium

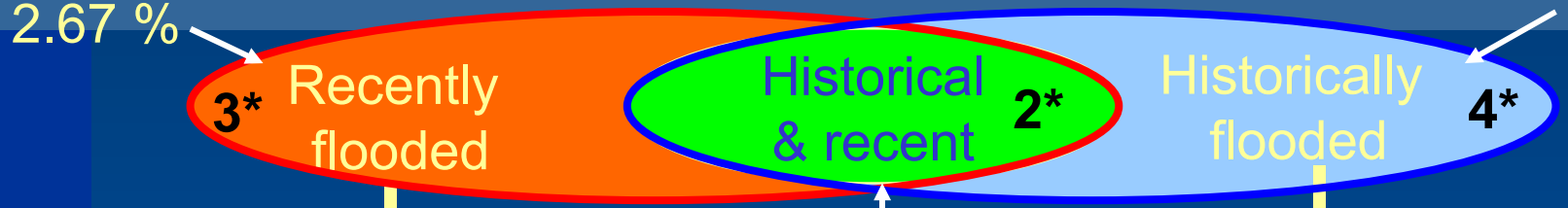


2.67 % of basin area is recently flooded outside its natural valley (alluvium)

13.3 % of the basin is natural alluvium that has no recent flooding

3 % of the basin is natural alluvium that has recent flooding

Map actual - Historical situation



3 %

Downstream increase of non-desirable flooding 3*

- non-desirable
- high costs / damage
- not-natural (soil-type)

Upstream Loss of wetlands and floodplains

- Canalisation of streams
- Drainage
- Embankments
  - agriculture
  - recreation
  - urbanisation

4*

Loss of functional inundations areas

- Area decrease
- % managed

1* **Managed Floodplains**

- Short residence tim
- High quantity/m²
- Low biodiversity

4* **Natural floodplains**

Development of maps for vision building

Physical suitability for sectoral claim

- Physical suitability to satisfy sectoral needs and demands in a sustainable way
- Does not take the actual situation or possible technical solutions into consideration.

Visualisation of the sectoral claim.

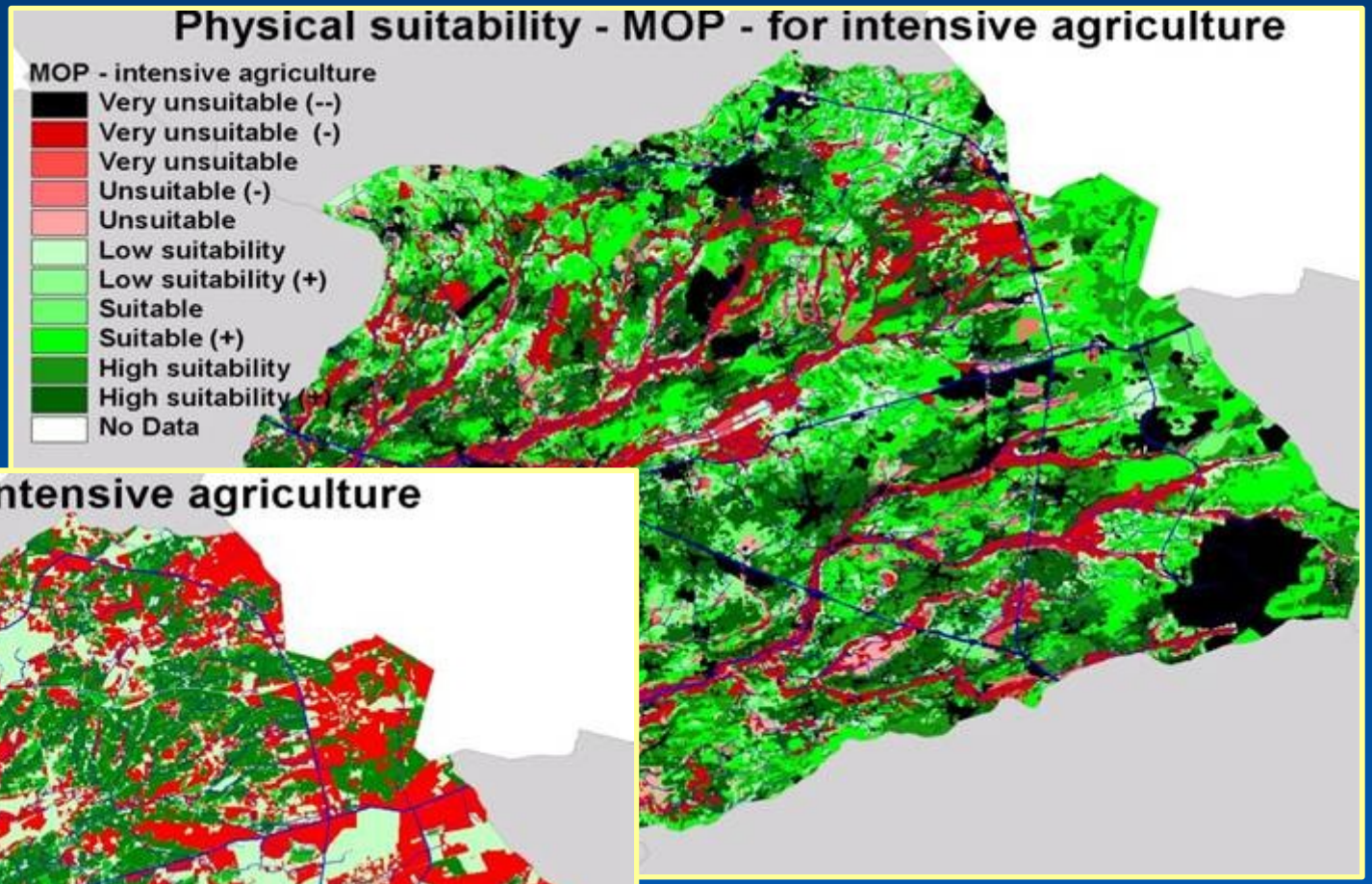
- Map created by stakeholder representatives
- Selection of Existing – new maps.
- Valuing combinations of maps through the use of combination-tables

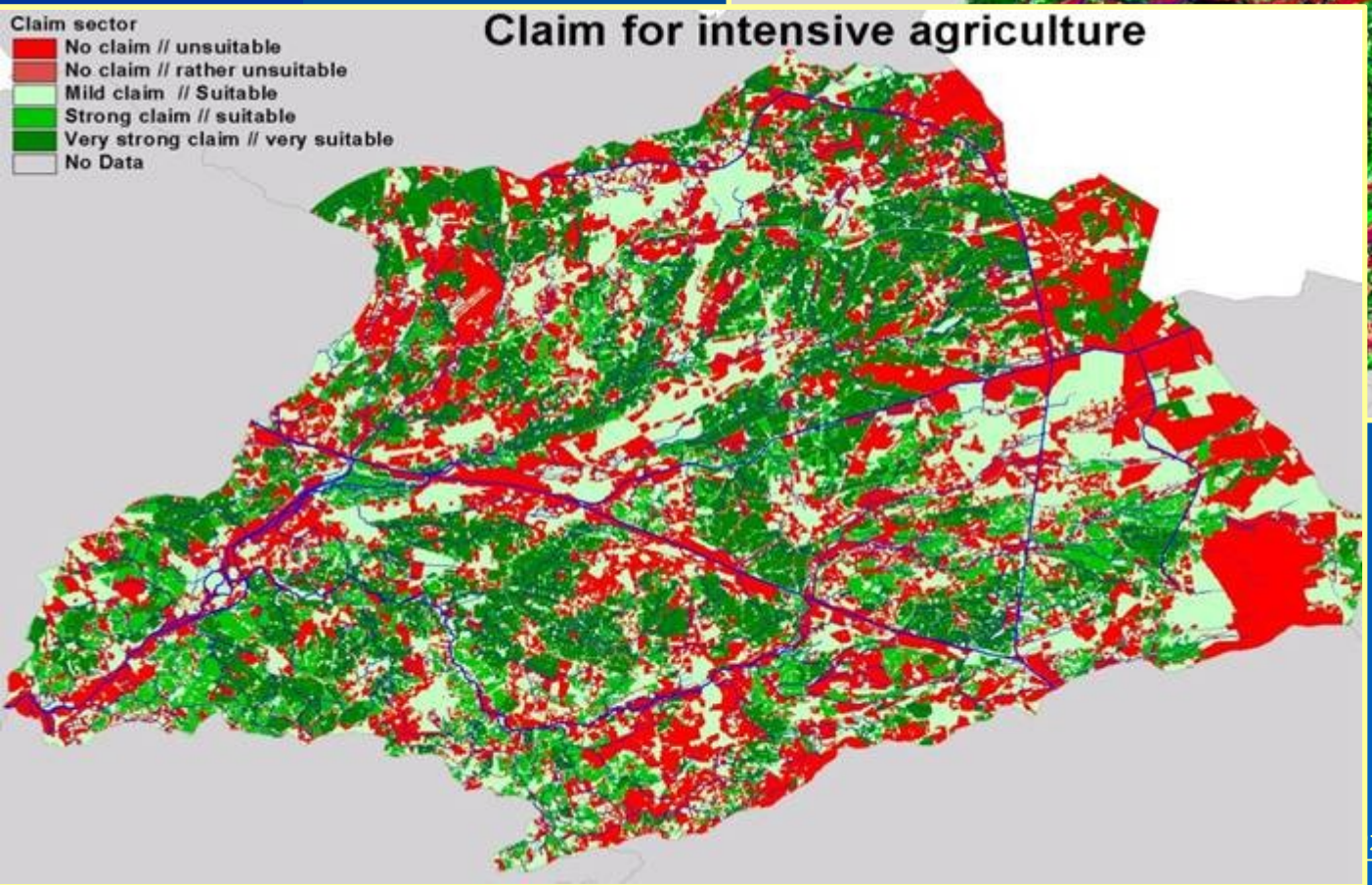
Suitability maps showing:

- Conflicts on claims
- Opportunities for future claims
- Consensus on claimed areas
- Consensus on not-claimed areas

Subcategorised in function of matrix position.

Examples: Physical suitability & sectorclaim





zba

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Suitability Maps

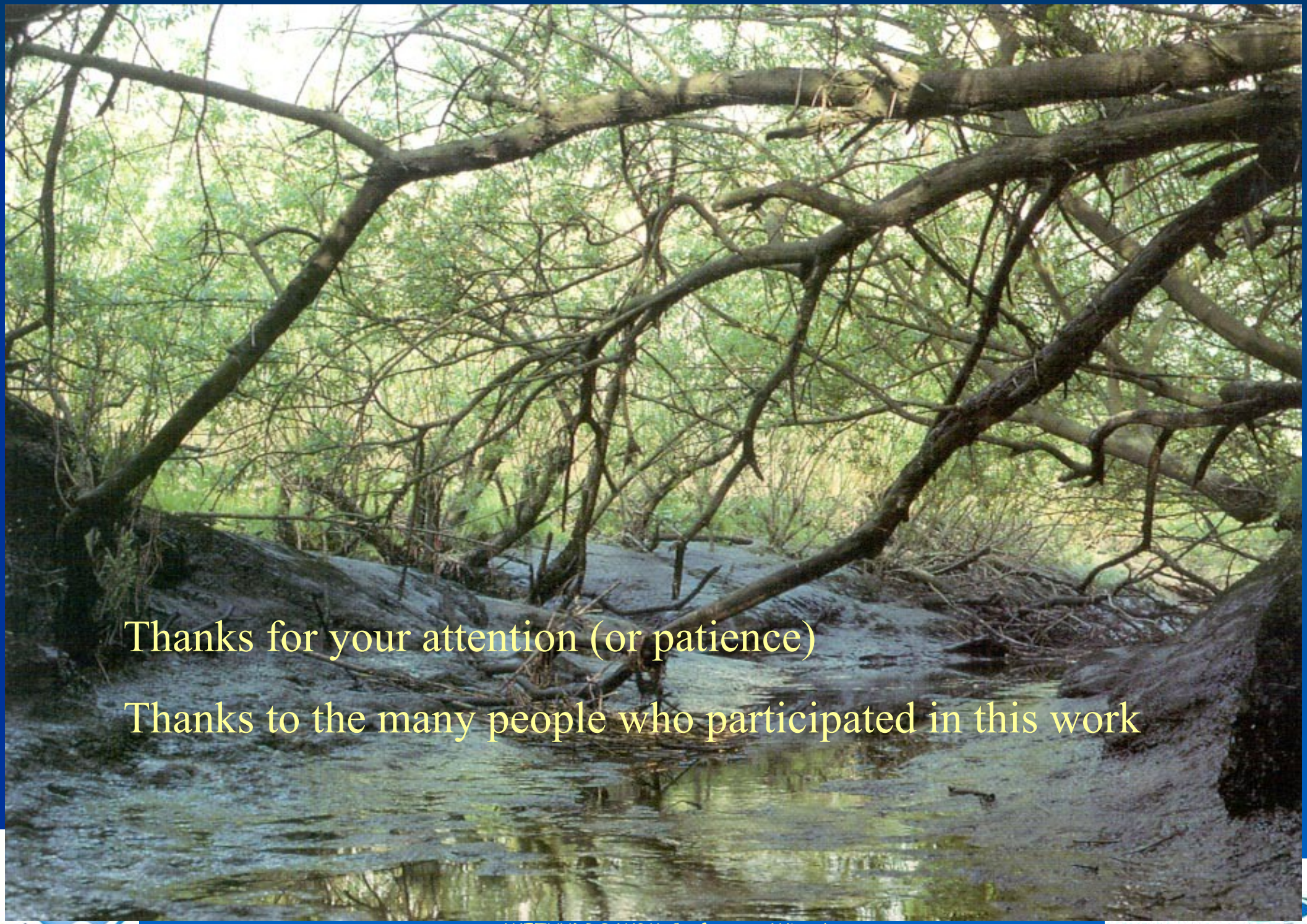
	Map of opportunities - Suitability from natural system				
Claim - Suitability according to sector)	Unsuitable (0-2)	Low suitability (3-4)	Medium suitability (5-6)	Suitable (7-8)	Very Suitable (9-10)
No claim (0-2)	No claim, no opportunity	No claim, no opportunity	Opportunity	Opportunity	Opportunity
Low suitability // No claim (3-4)	No claim, no opportunity	No claim, no opportunity	Opportunity	Opportunity	Opportunity
Medium suitability // Weak claim (5-6)	Evaluation	Evaluation	Consensus	Consensus	Consensus
Suitable // strong claim (7-8)	Evaluation	Evaluation	Consensus	Consensus	Consensus
Very Suitable // Very strong claim (9-10)	Evaluation	Evaluation	Consensus	Consensus	Consensus

- River basin management plans become to a large extend land use plans taking into account the physical conditions and the necessary spatial relations of both the socio economic environment as the natural environment (up versus downstream etc.)

Overall conclusions

- Functionality in the landscapes is to a large extend lost due to long term human activities
- Restoring ecosystem functioning is a crucial element of sustainable development
- Determining conservation objectives is a possibility to quantify different goods and services per habitat
- This should be taken into account in a river basin management plan. We should in fact start gradually to redesign the landscape based on functionality

- Crucial is to try to quantify what is needed for a good functioning ecosystem
- Keep in mind the balance between function and structure, eg. the best solution to remove N is anoxic rivers!!


Thanks for your attention (or patience)
Thanks to the many people who participated in this work