Eutrophication management in a Baltic estuarine system

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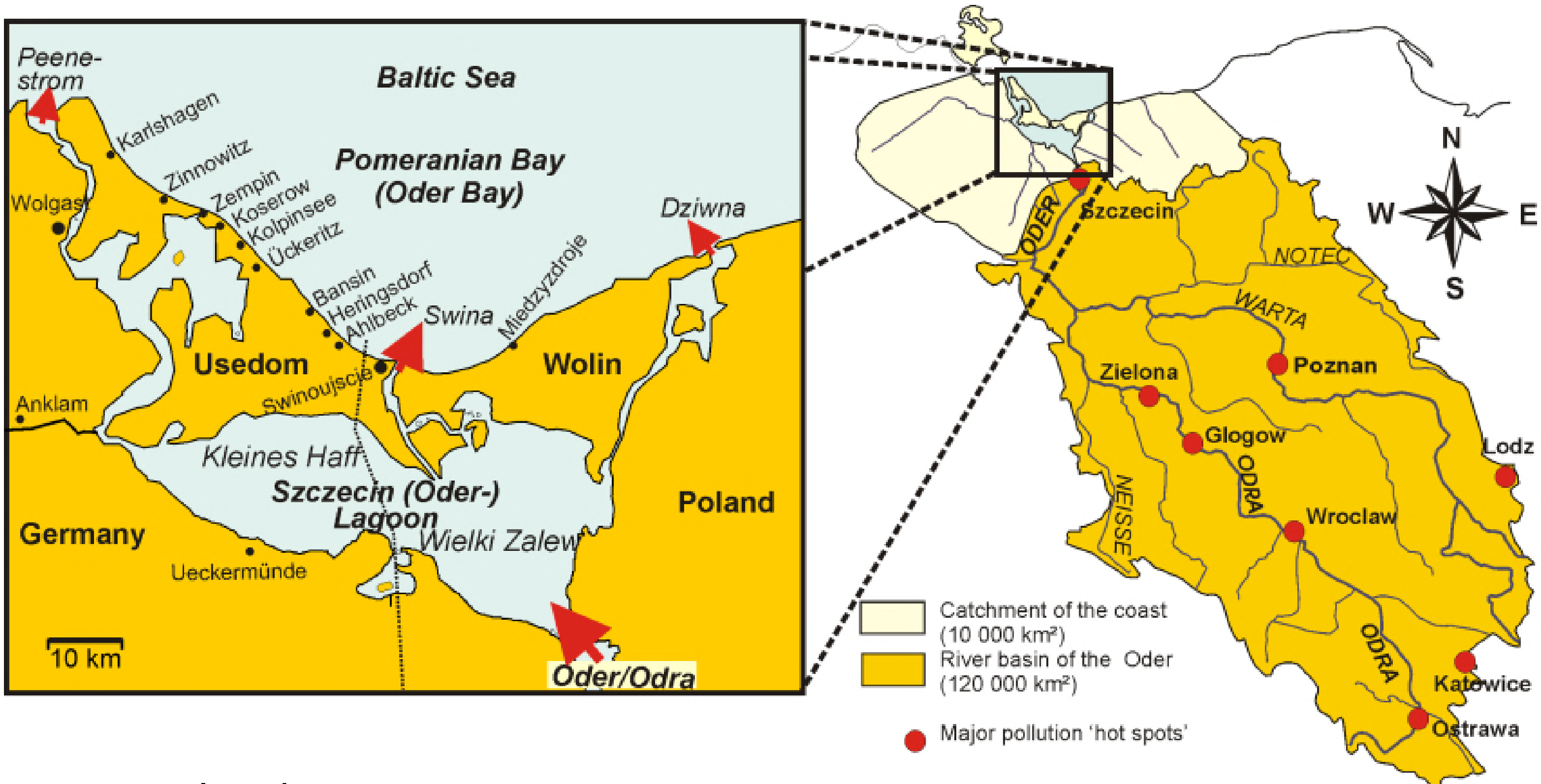
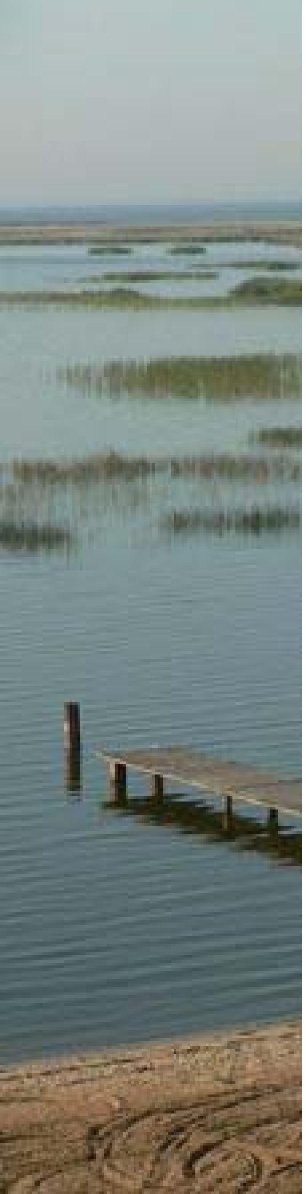
The Oder/Odra estuary case study



A coastal region

- characterized by a complex pattern of land, lagoons and sea
- divided between Germany and Poland and
- dominated by the Oder/Odra river basin



A story of success:
Tourism

Pictures: Schernewski 2000

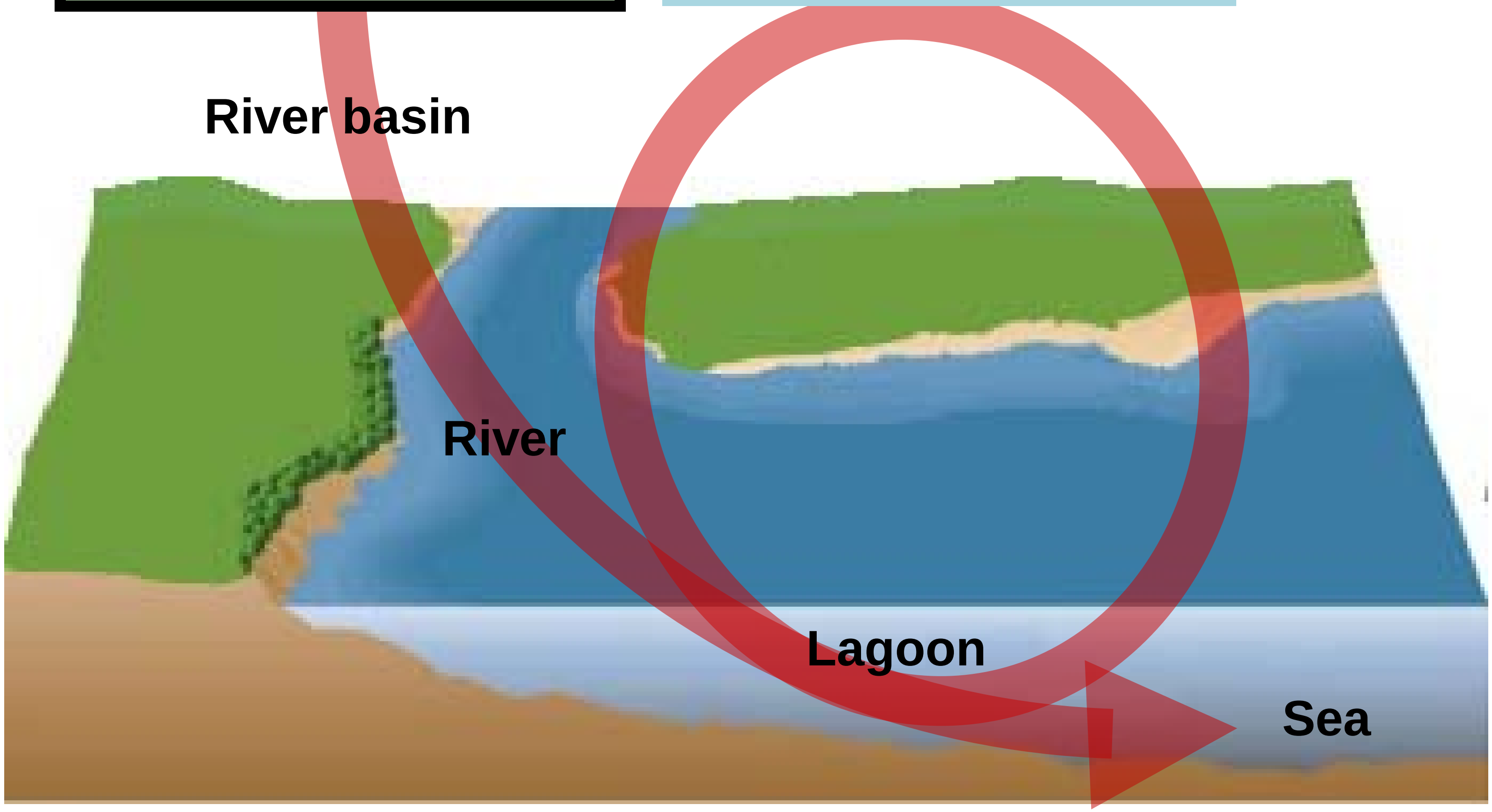
Destruction of the natural heritage:
Eutrophication

Pictures: Schernewski 2000

Managing eutrophication: Approaches

a) External river basin management to reduce nutrient loads

b) Internal lagoon management in a socio-economic framework



Managing eutrophication

Tasks

- To explain the long-term eutrophication history in the river and in the estuary and their causes;
- to analyse the functional changes in the estuary during the last 40 years and their consequences for the Baltic Sea;
- to assess the relationship between external loads and the water quality status, nutrient availability, limitation and algal biomass and
- to improve our understanding about sources, pathways and spatial origin of nutrient loads.

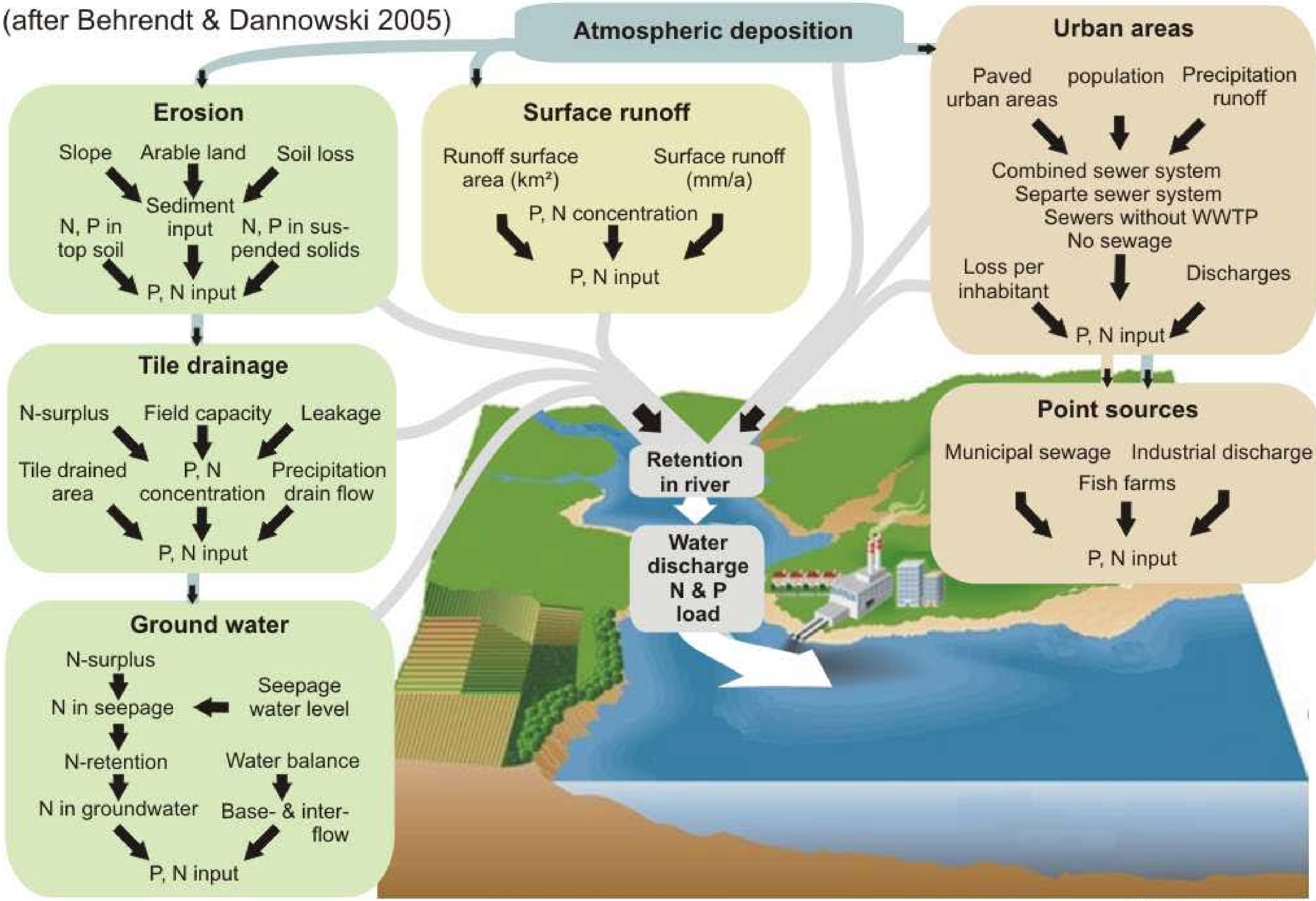
Questions

- To what extent can the nutrient load in the Oder River be reduced?
- Can we reach a good water quality status according to the Water Framework Directive via a river basin management? If not, what are realistic objectives?
- Should a nutrient load reduction and management efforts focus on nitrogen or on phosphorus?

Managing eutrophication: Models

MONERIS - a river basin model for nitrogen and phosphorus

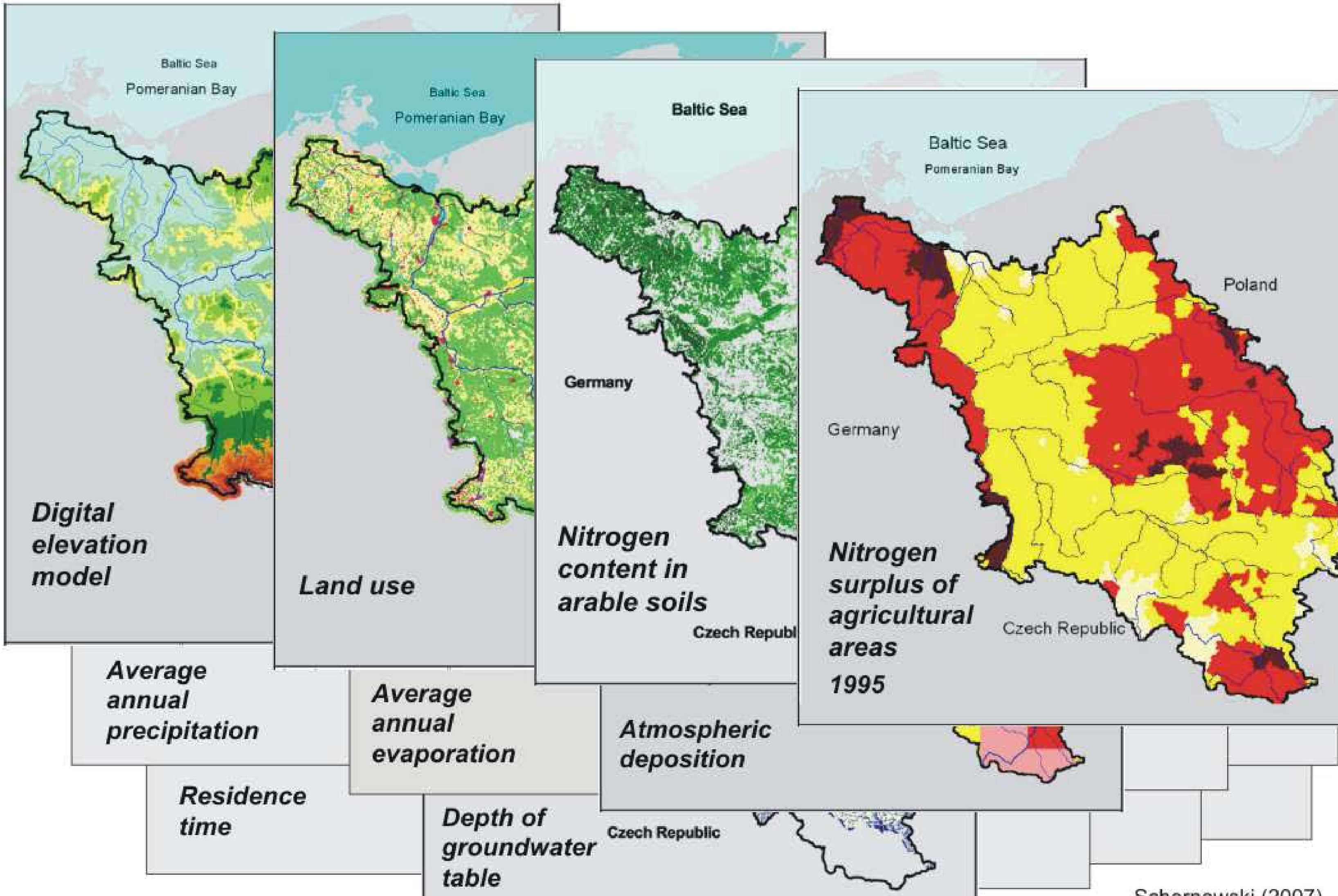
(after Behrendt & Dannowski 2005)



Schernewski (2007)

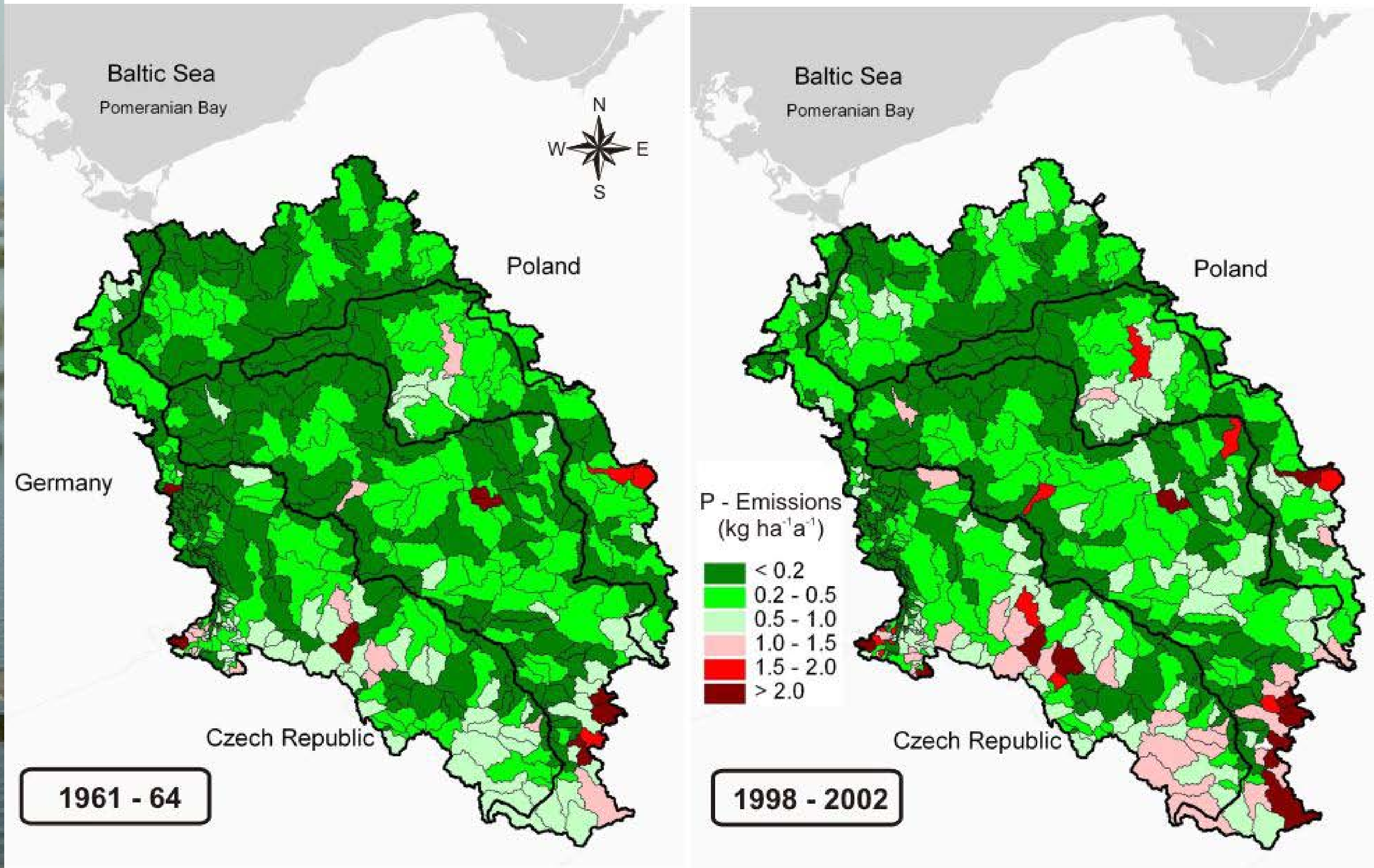
Managing eutrophication: Models

MONERIS - Examples of geographical input data (from Behrendt & Dannowski 2005)



Schernewski (2007)

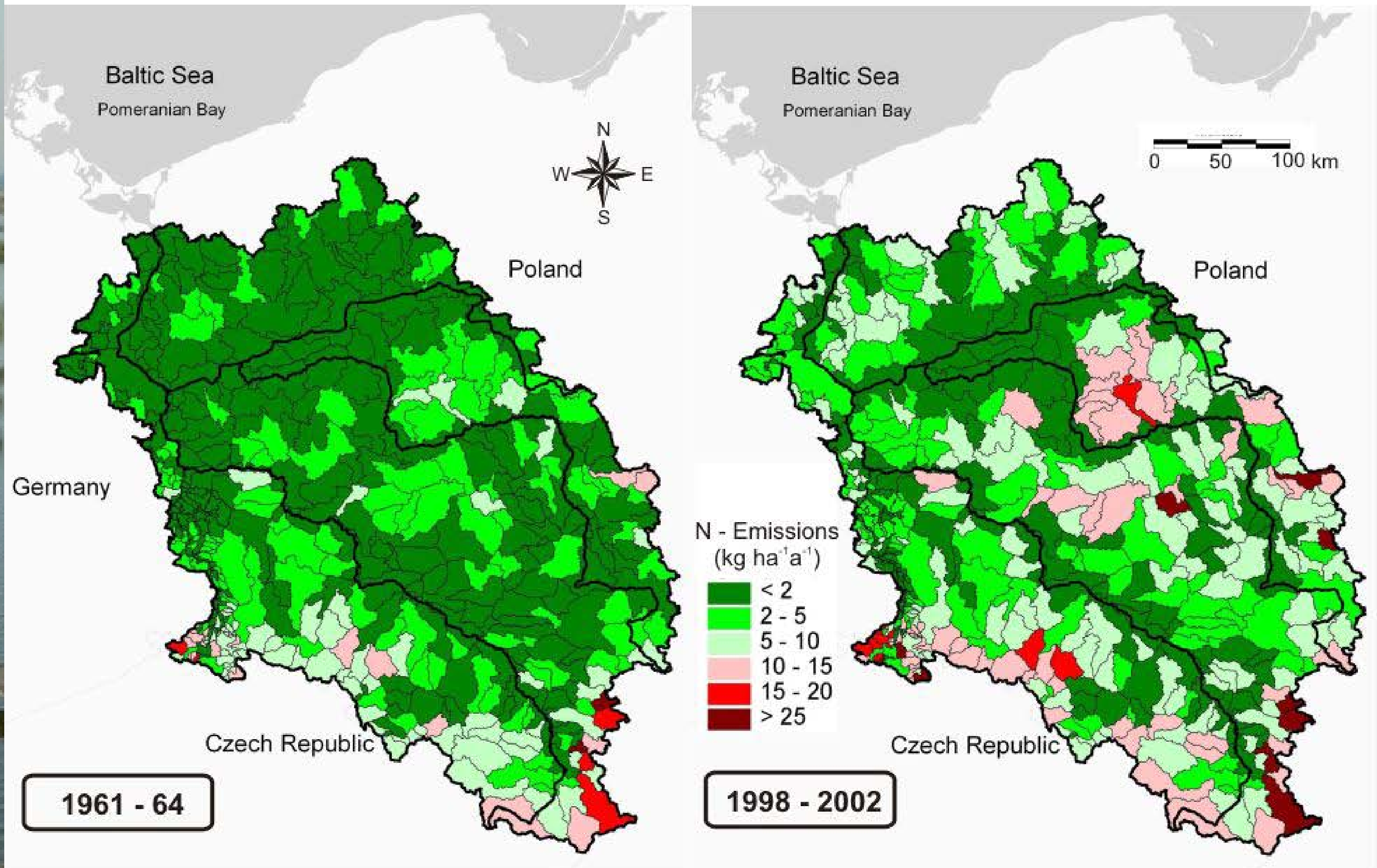
Eutrophication history: Long-term model simulations



Schernewski, Neumann, Opitz & Venohr (submitted): Long-term eutrophication history and functional changes in a large Baltic river basin - estuarine system. Estuaries and Coasts

SPICOSA

Eutrophication history: Long-term model simulations



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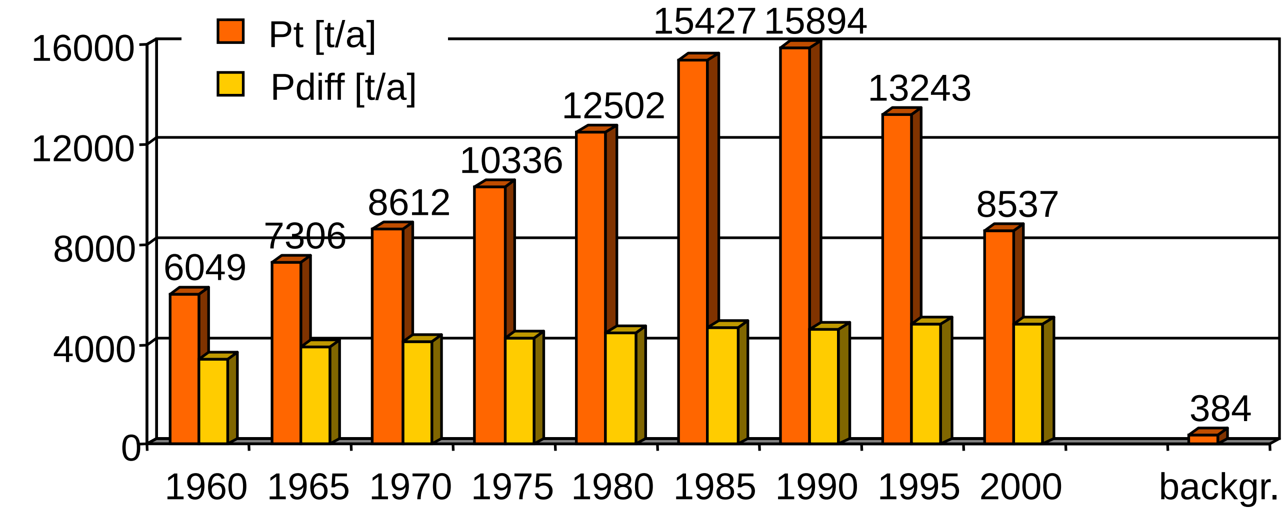
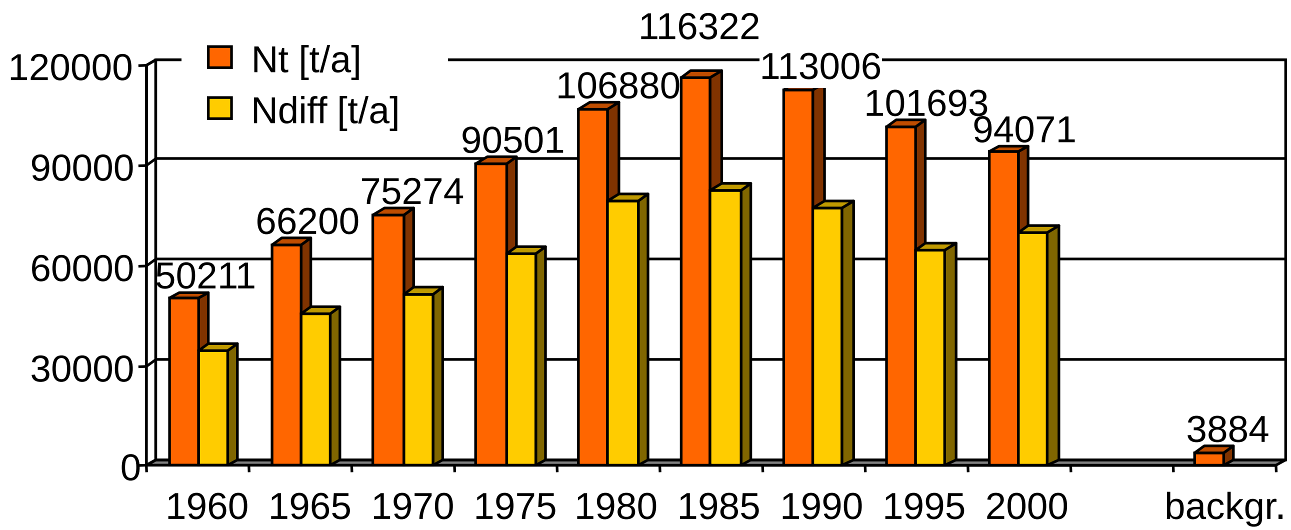




Behrendt et al. (2005)

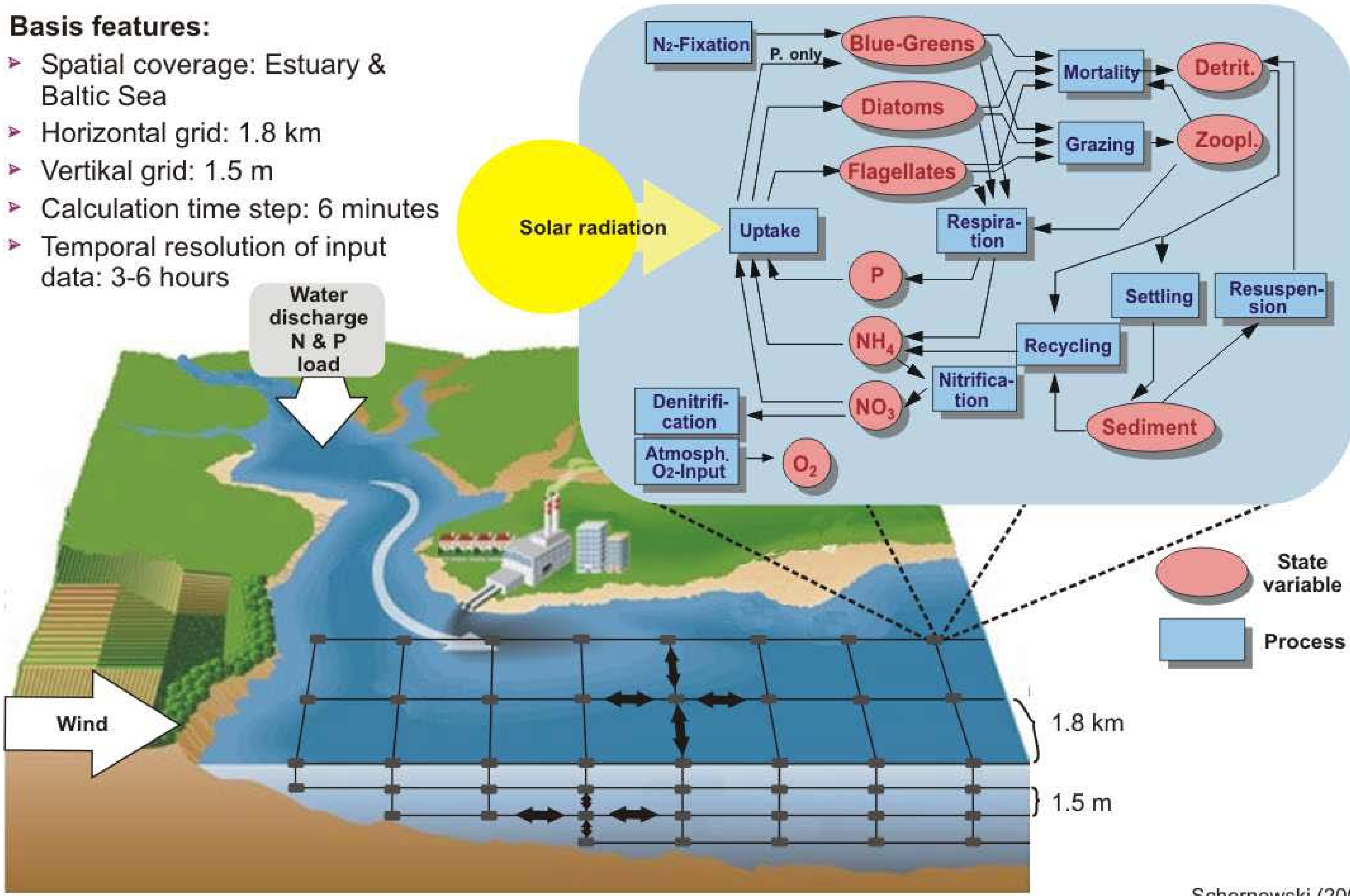
Managing eutrophication: Models

ERGOM - a 3D flow & ecosystem model

(after Neumann et al. 2002)

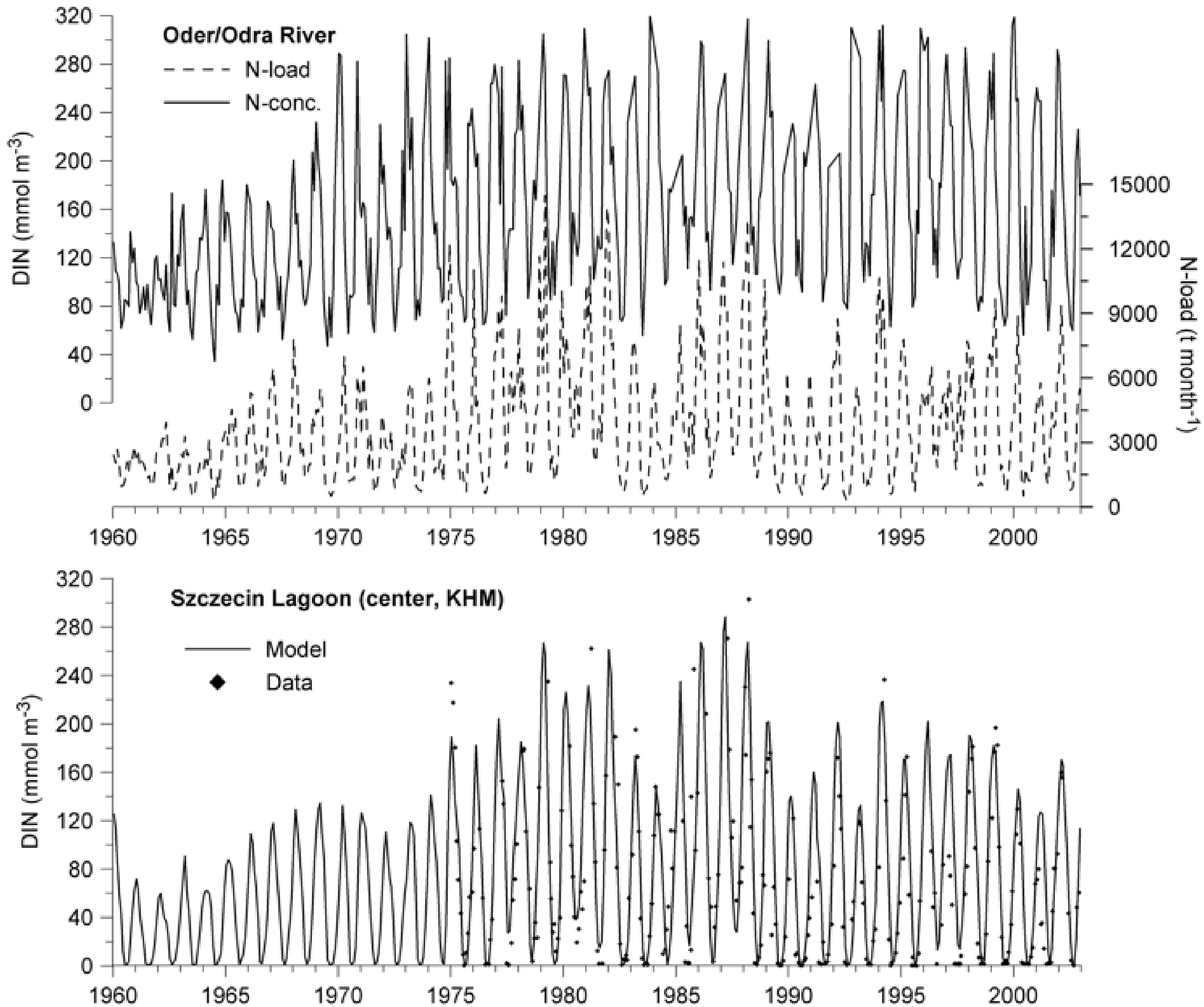
Basis features:

- Spatial coverage: Estuary & Baltic Sea
- Horizontal grid: 1.8 km
- Vertikal grid: 1.5 m
- Calculation time step: 6 minutes
- Temporal resolution of input data: 3-6 hours



Schernewski (2007)

Eutrophication history: Long-term model simulations



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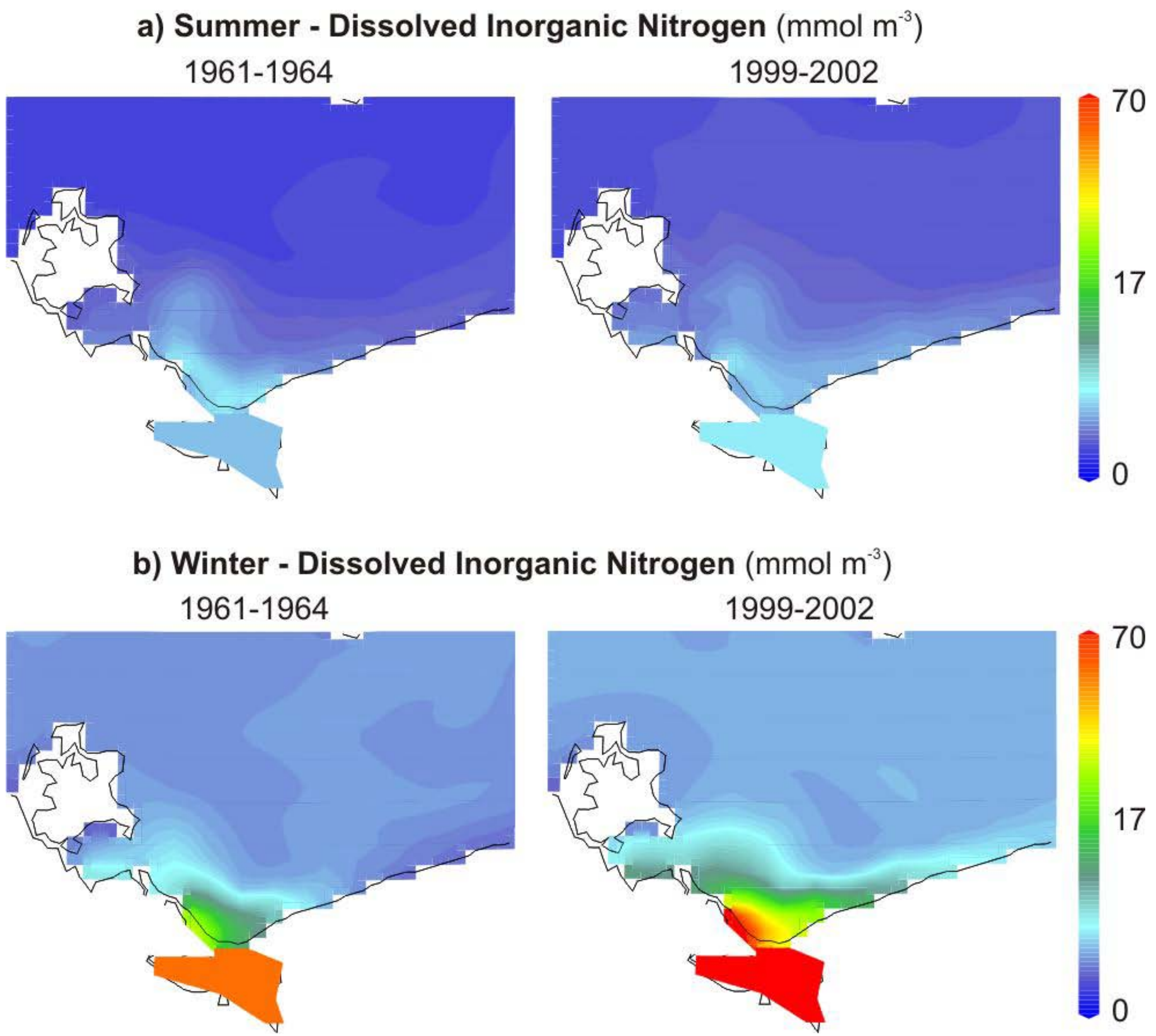
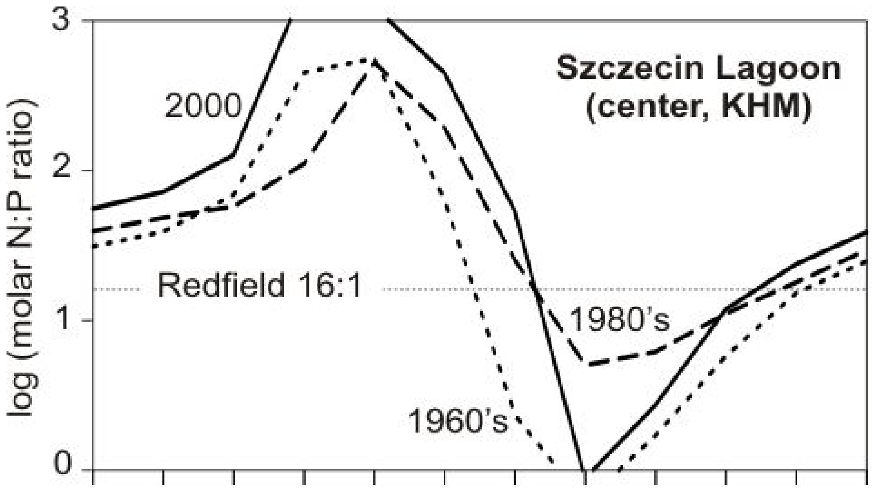
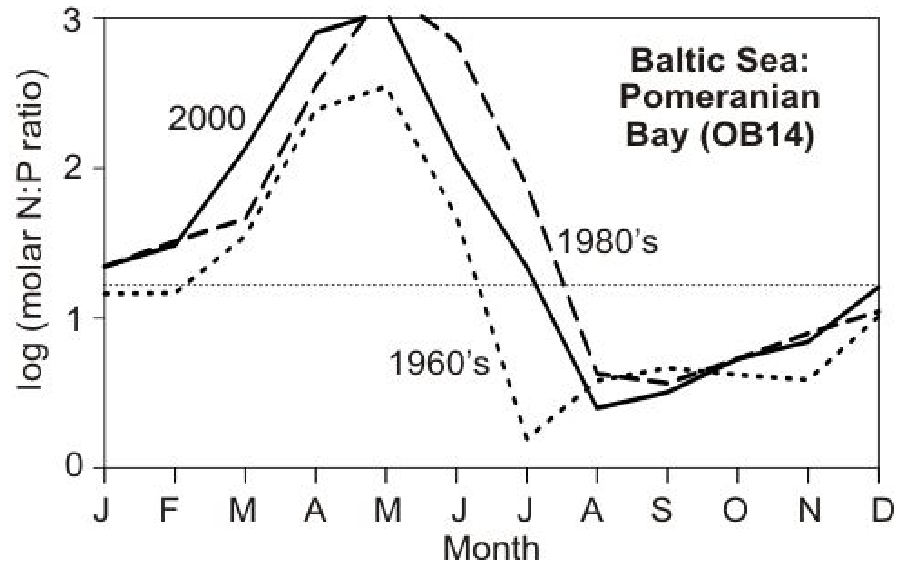


Schernewski, Neumann, Opitz & Venohr (submitted): Long-term eutrophication history and functional changes in a large Baltic river basin - estuarine system. Estuaries and Coasts

Eutrophication history: Functional changes



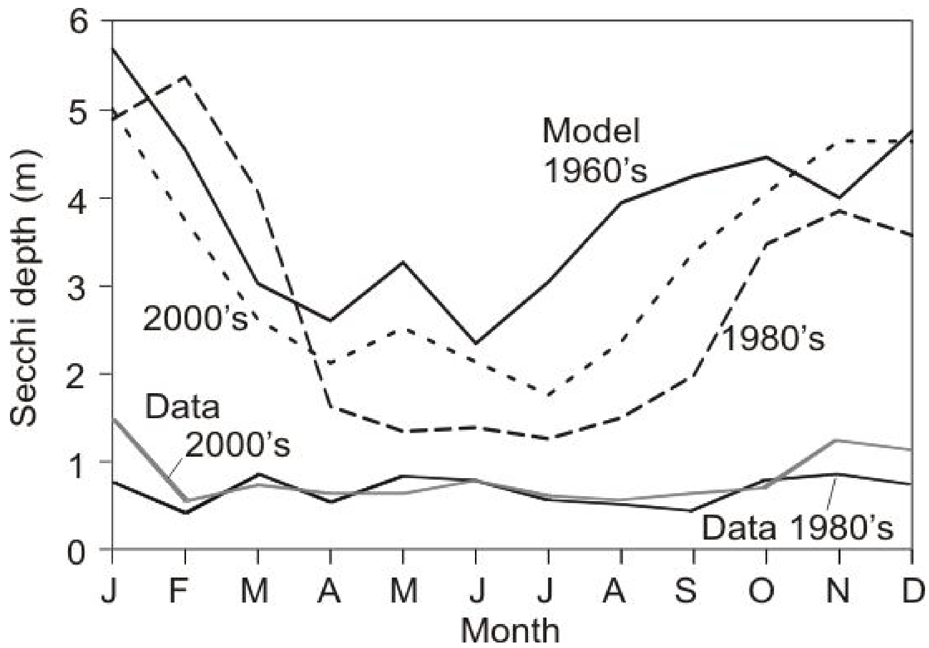


Some results

- Nutrient removal in the lagoon via **denitrifikation** is reduced from 26 % (1960's) to 15 % (1999-2002). An increase of denitrification in the coastal Baltic Sea took place.
- **N-Fixation** does not play an important role in the lagoon. It was higher in the 1960's. Heavy blue-green blooms can contribute up to 30% of the monthly river load.
- **Limitation**: A temporal shift and changes in nutrient availability took place. However, a lasting nutrient limitation can not be assumes.

Schernewski, Neumann, Opitz & Venohr (submitted): Long-term eutrophication history and functional changes in a large Baltic river basin - estuarine system. Estuaries and Coasts

Eutrophication history: Functional changes

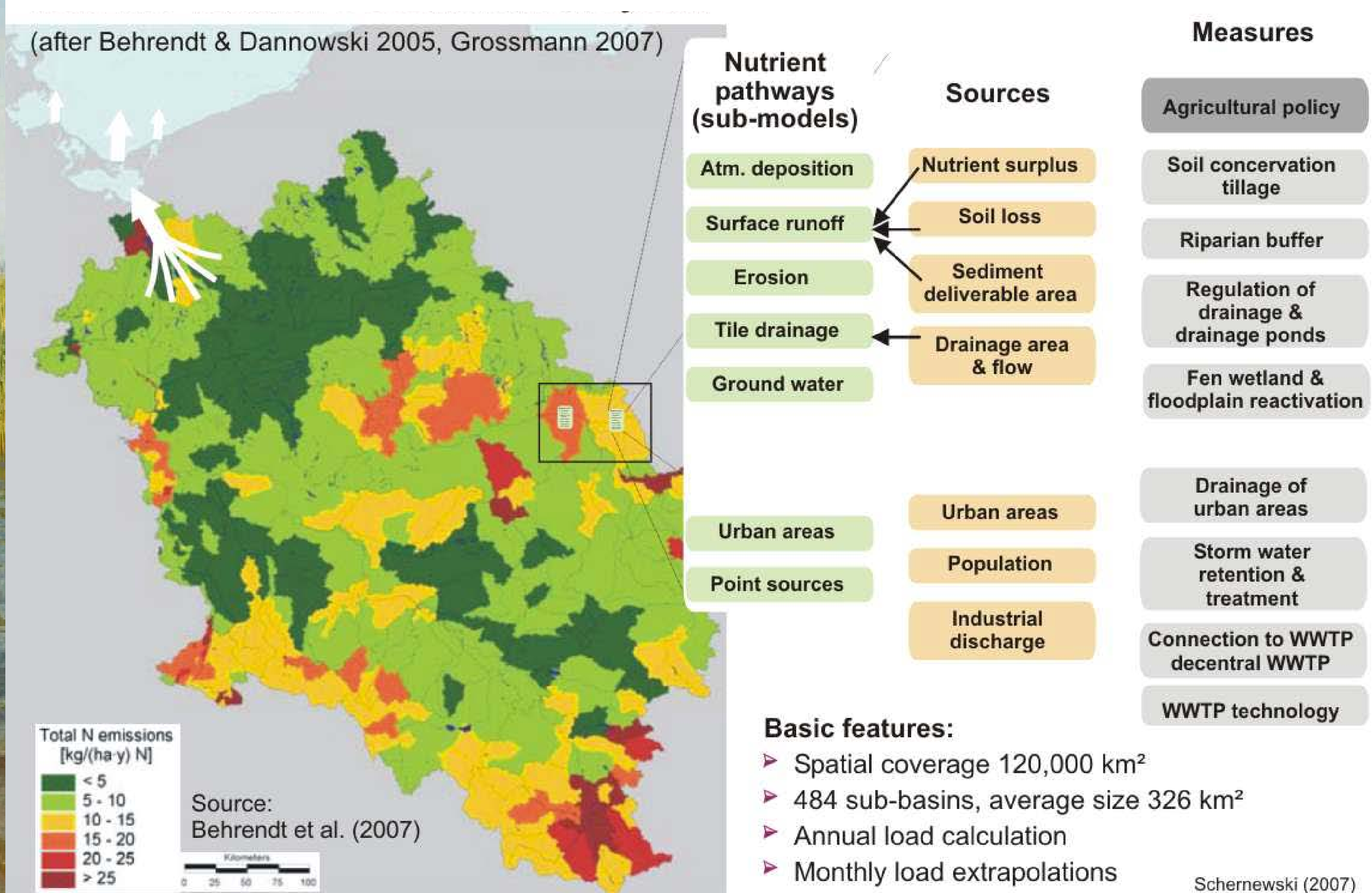


Some results

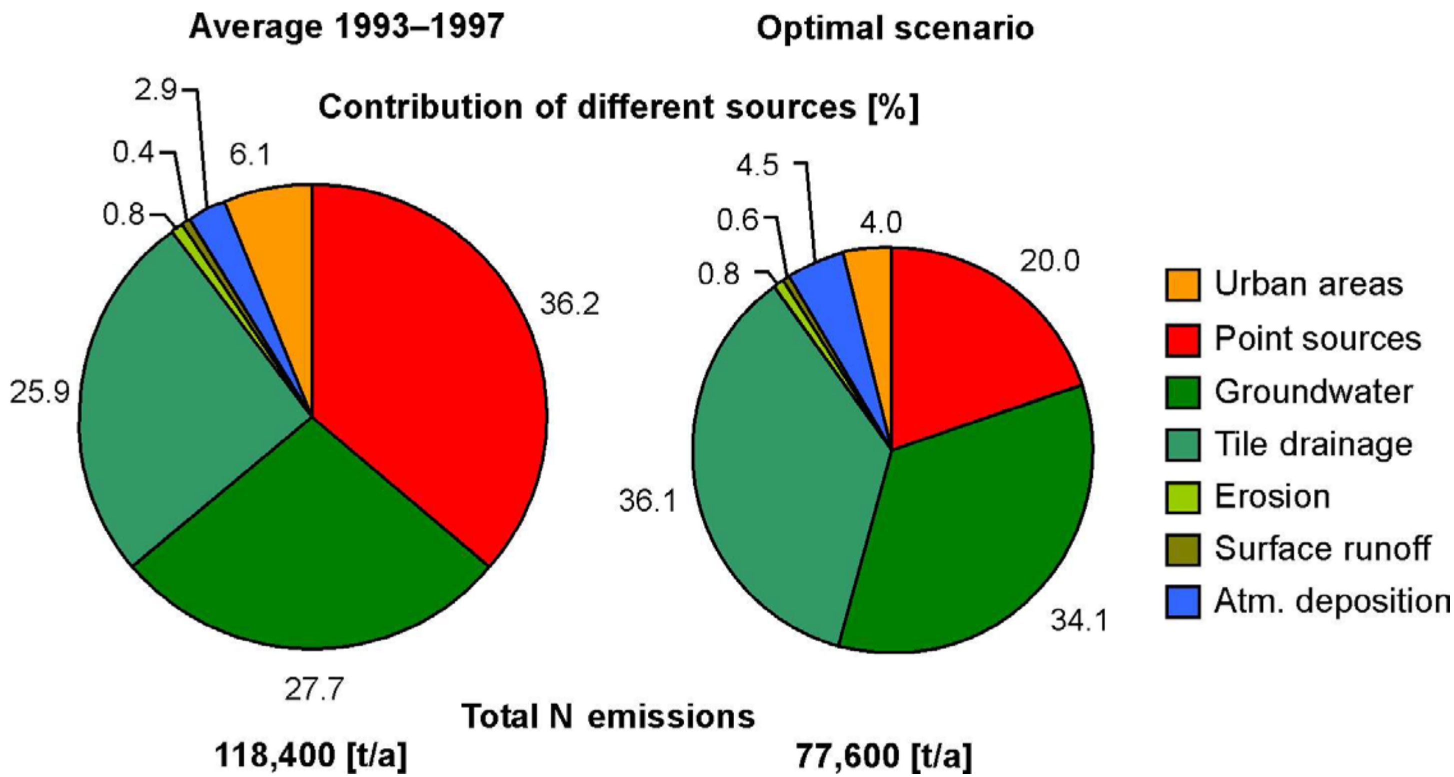
- The aquatic flora and fauna has undergone changes during the last decades. A clear relationship to eutrophication is not obvious.
- Reduced water transparency might be responsible for the decrese of submersed macrophytes

River basin management:

The backbone of a successfull eutrophication management



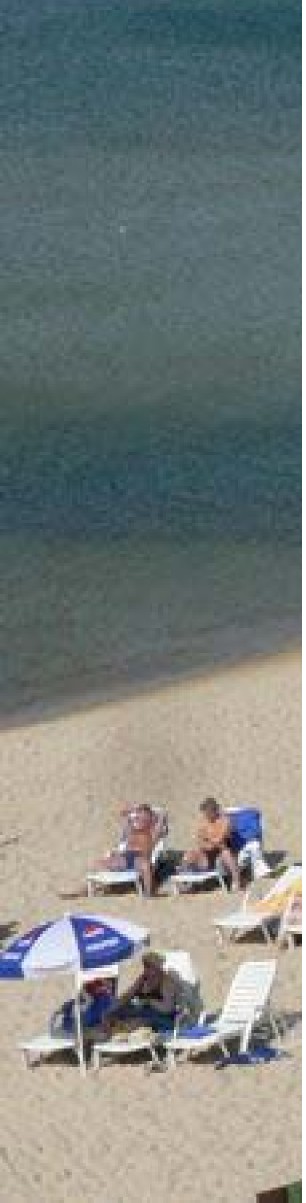
River basin management: N-Scenario



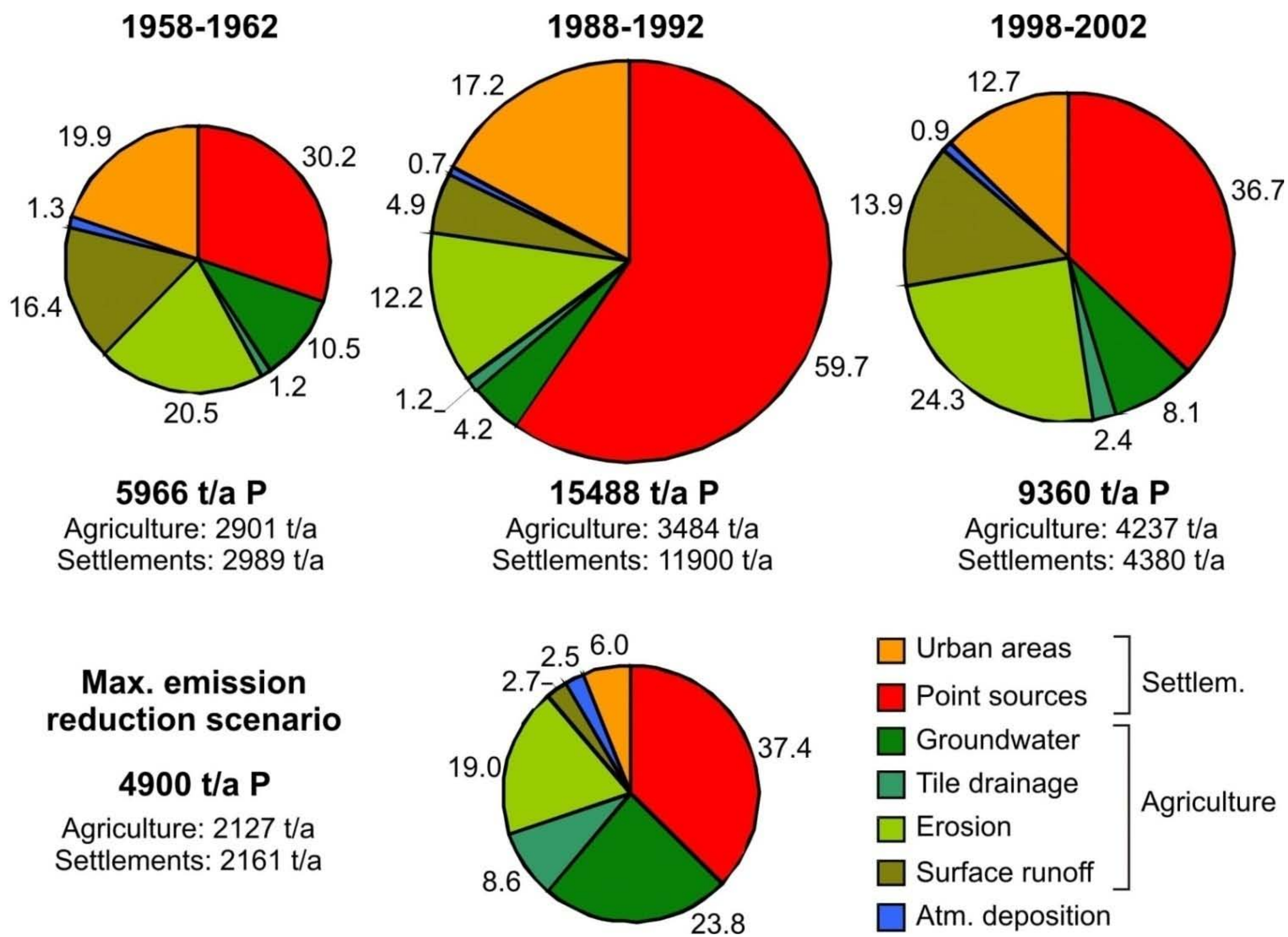
- The optimal load reduction szenario shows loads like in the late 1960‘s

Schernewski G. & H. Behrendt & T. Neumann (2008): An integrated river basin-coast-sea modelling scenario for nitrogen management in coastal waters. J Coastal Conservation

![SPICOSA]



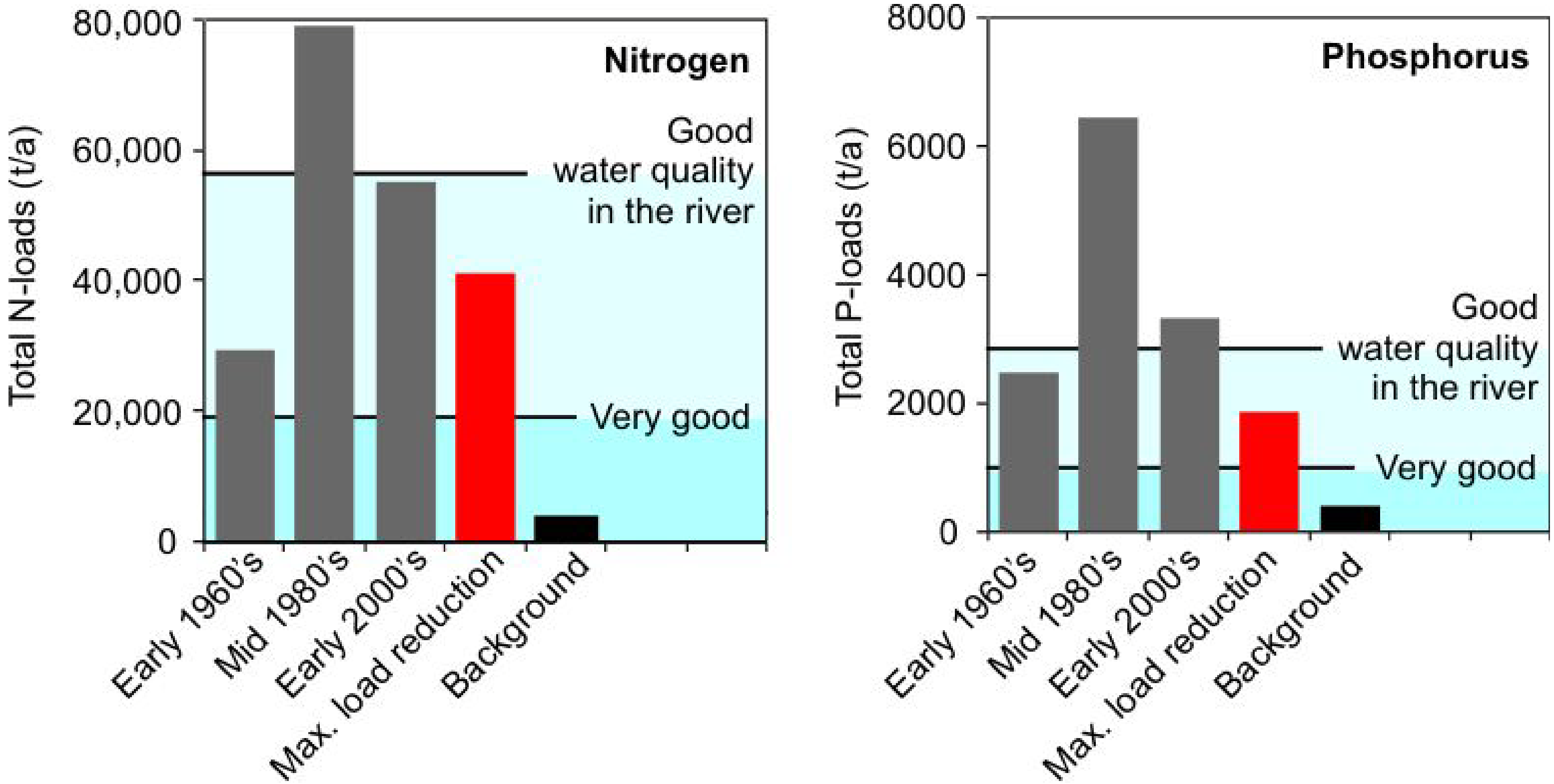
River basin management: P-Scenario



- The optimal load reduction szenario shows loads like in the early 1960‘s

Schernewski, Neumann & Behrendt (submitted): Sources, dynamics and management of phosphorus in a southern Baltic estuary. Springer

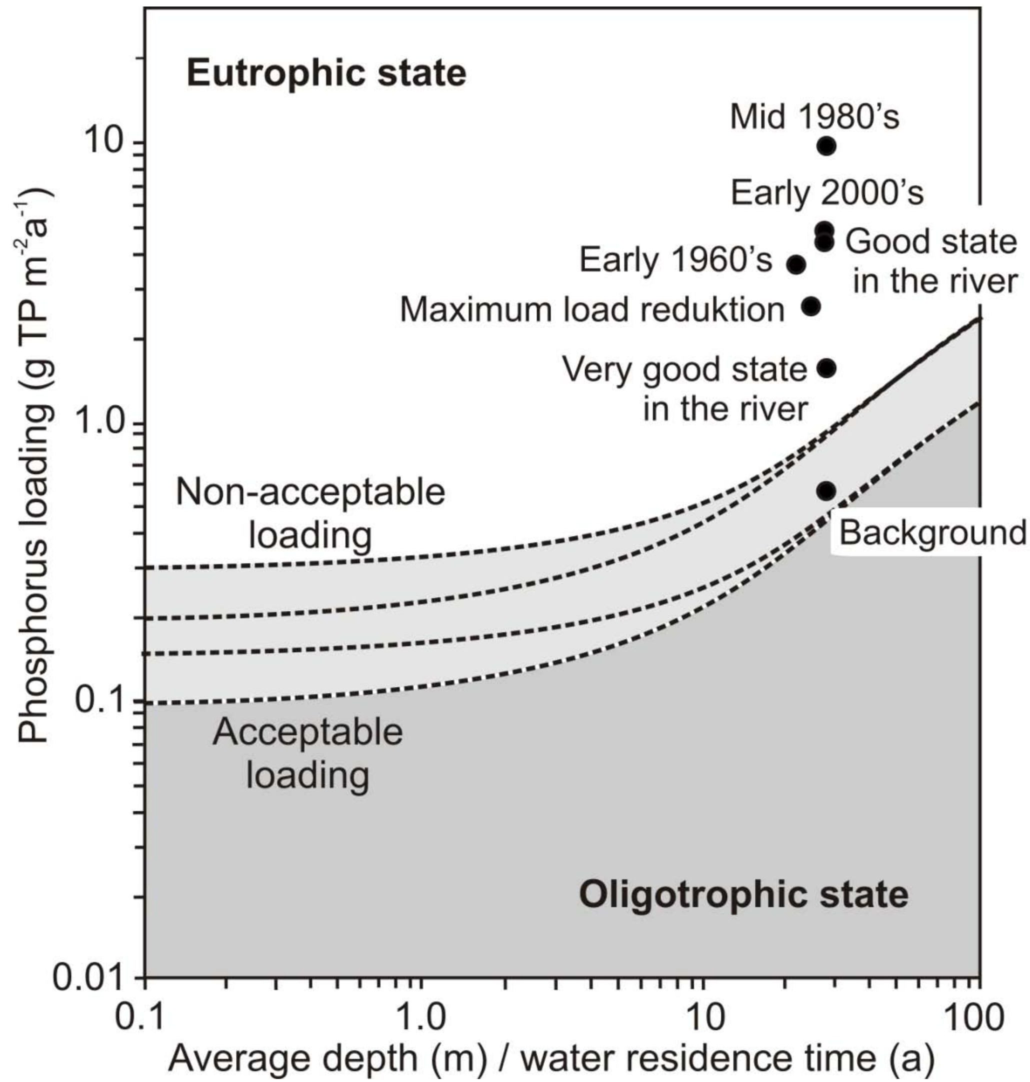
Water quality objectives in the river



- A „good water quality“ in the river is a realistic objective, but this will not cause a good status of coastal waters

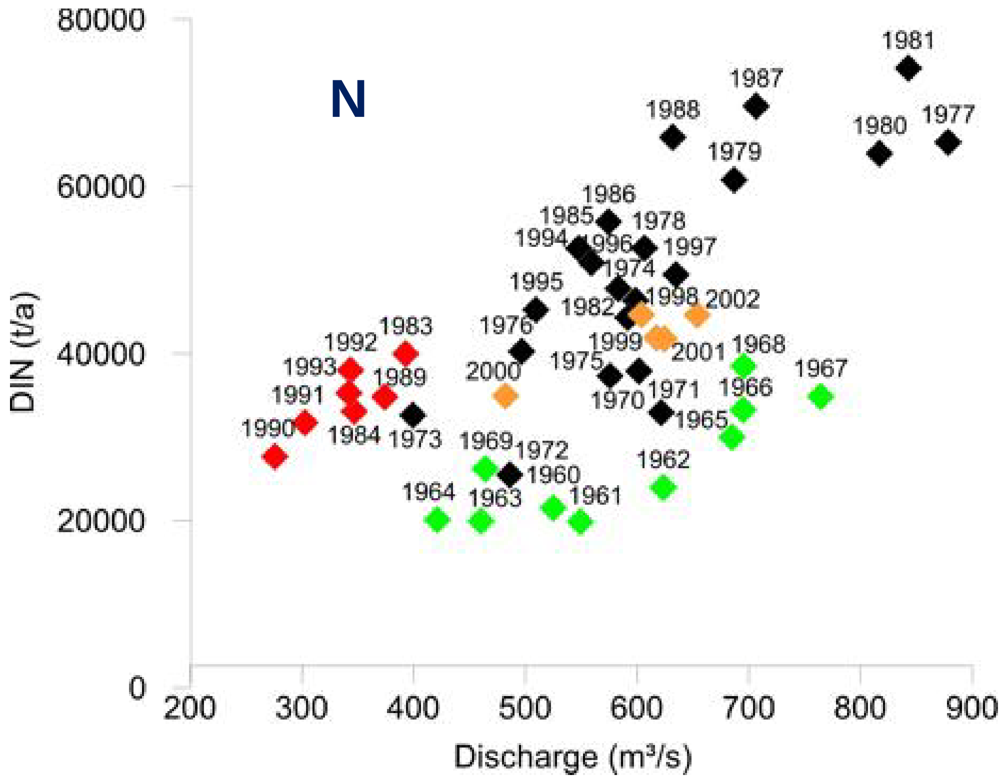
Voss, Dippner, Korth, Neumann, Opitz, Schernewski, Venohr (in prep.) : History and future development of Baltic Sea eutrophication. Estuarine, Coastal and Shelf Science

River basin management: Possibilites & limits



Voss, Dippner, Korth, Neumann, Opitz, Schernewski (in prep.) Venohr: History and future development of Baltic Sea eutrophication. Estuarine, Coastal and Shelf Science

Future scenarios: Climate Change

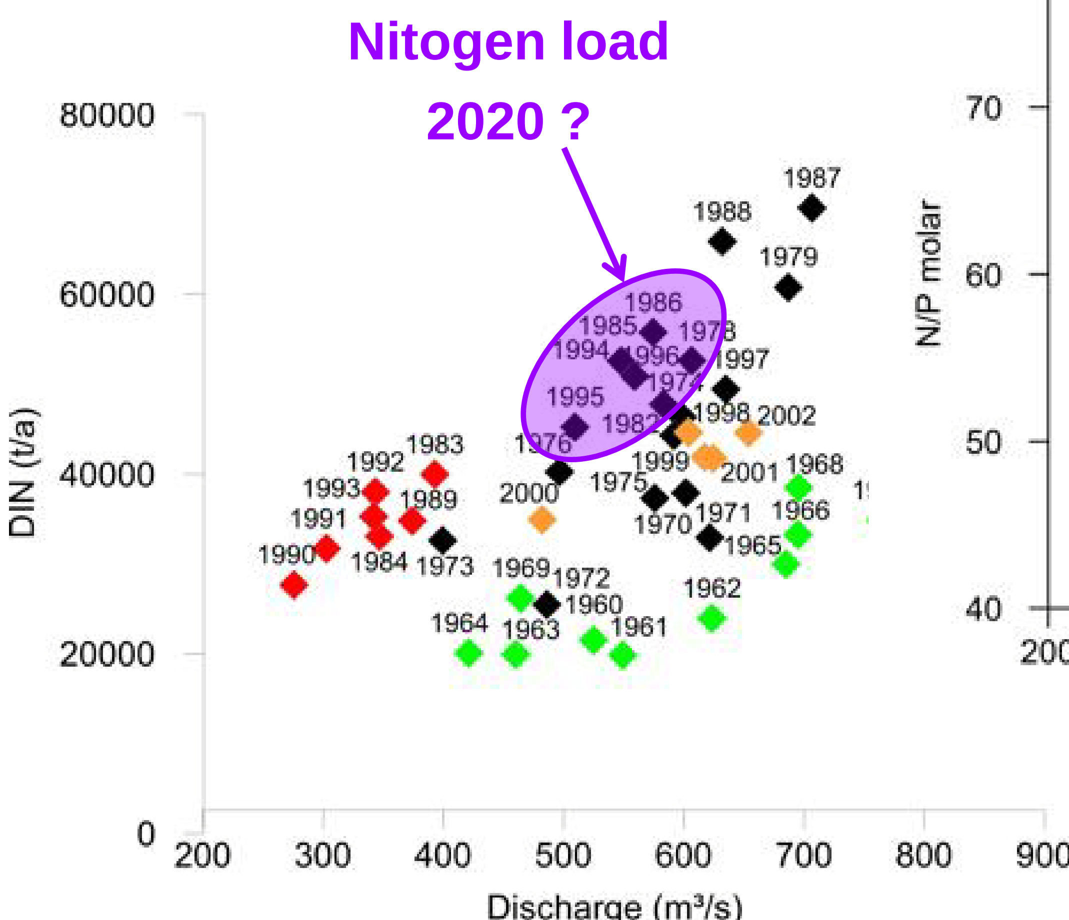


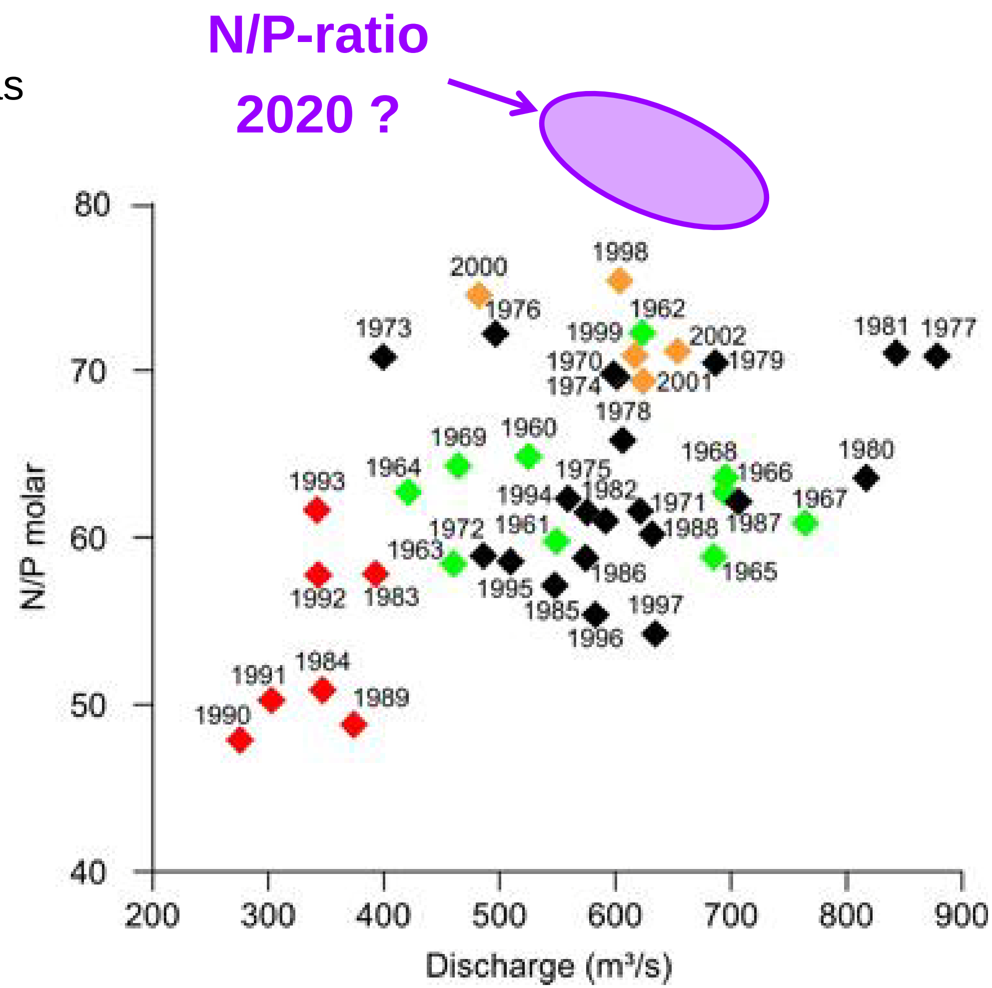
- Annual temperature shall increase by about 2 K and precipitation shall remain stable. Shifts between winter and summer are very likely.
- Weather plays an important role for nutrients loads and coastal water ecology.
- Climate Change will have an effect on eutrophication of coastal waters, but is less important than transpformation processes

Schernewski, Neumann, Opitz & Venohr (submitted): Long-term eutrophication history and functional changes in a large Baltic river basin - estuarine system. Estuaries and Coasts

Future scenarios: Land-use changes

Perspectives based on scenarios „business as usual“ and „subsidized agriculture“.





Managing eutrophication: Approaches

a) External river basin management to reduce nutrient loads

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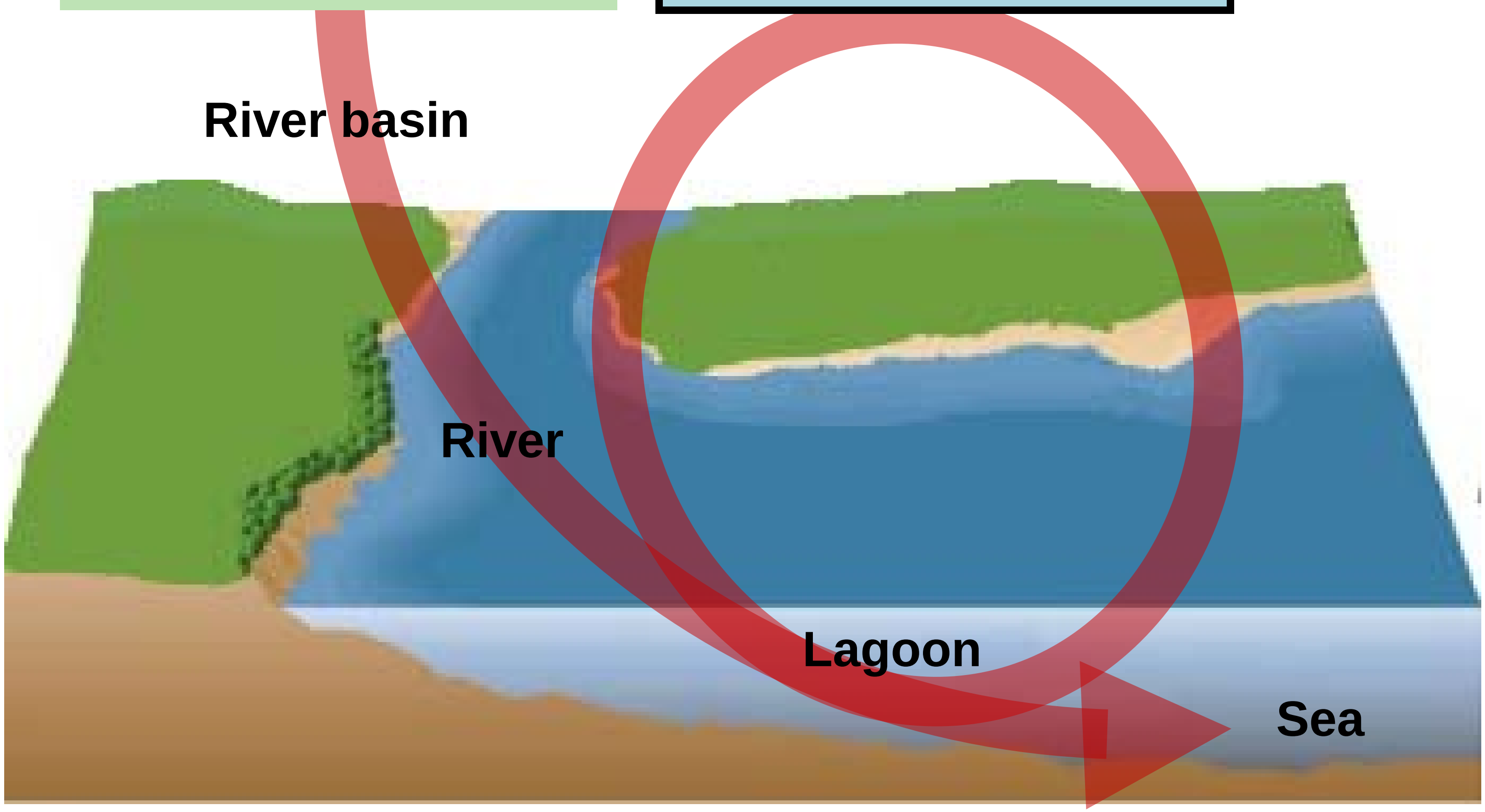
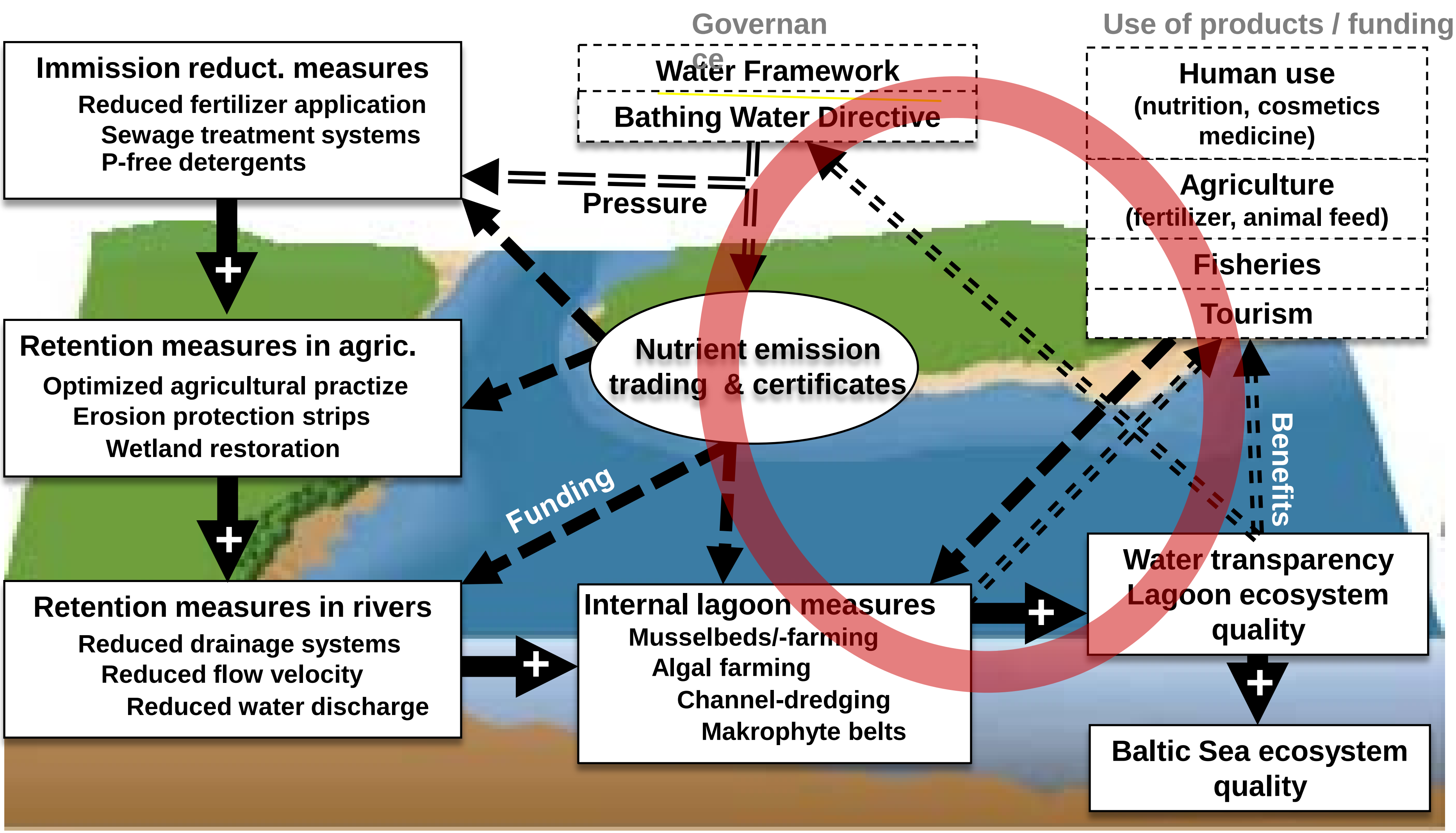


Managing eutrophication in the lagoon

Questions

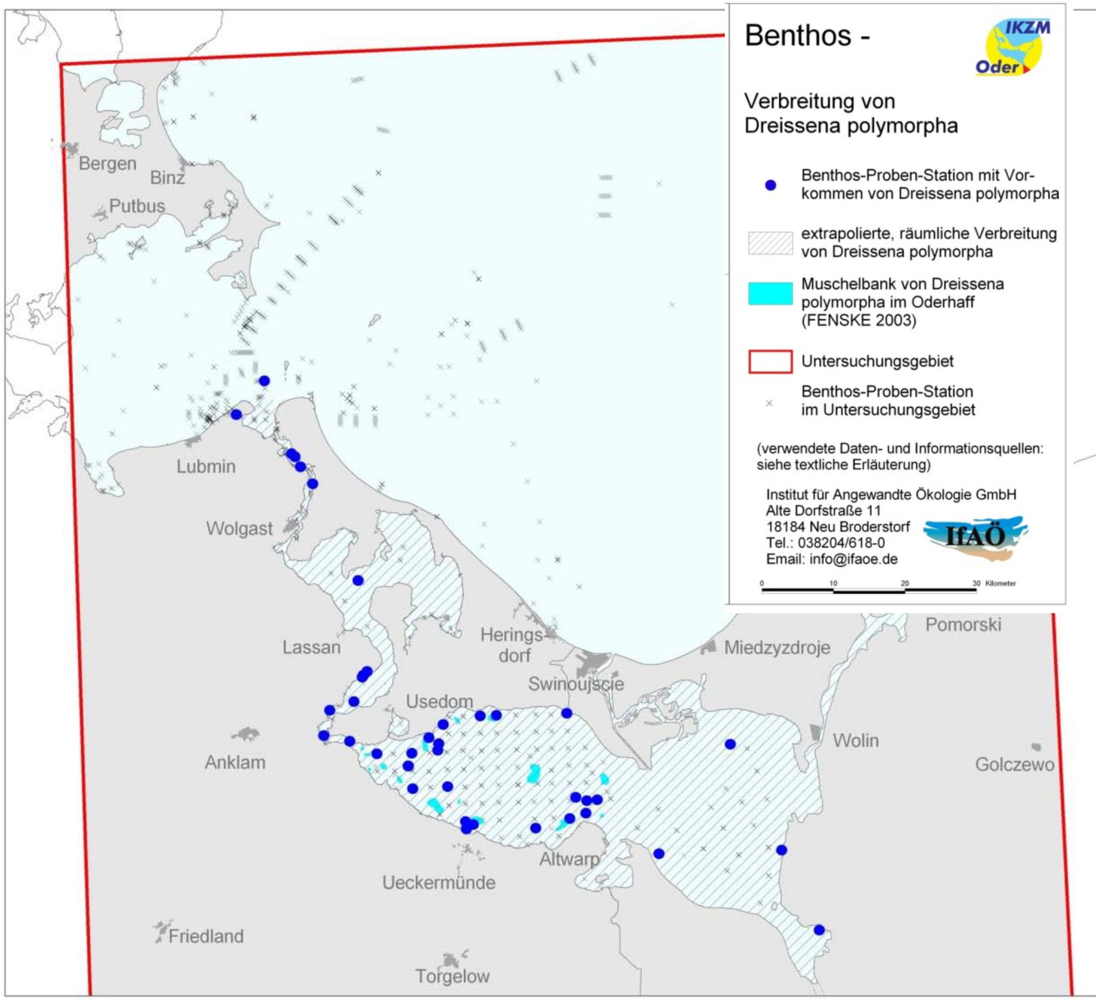
- To what extent can internal management measures in the lagoon increase nutrient retention and improve water quality?
- How efficient are mussel farming and mussel beds compared to other measures?
- How can we fund internal management measures in the lagoon in a sustainable manner?
- What will be the social and economic benefits of improved water quality?
- How can an optimized integrated river basin - coastal water management system look like?

The Management-Framework



Zebra mussels in the Szczecin Lagoon

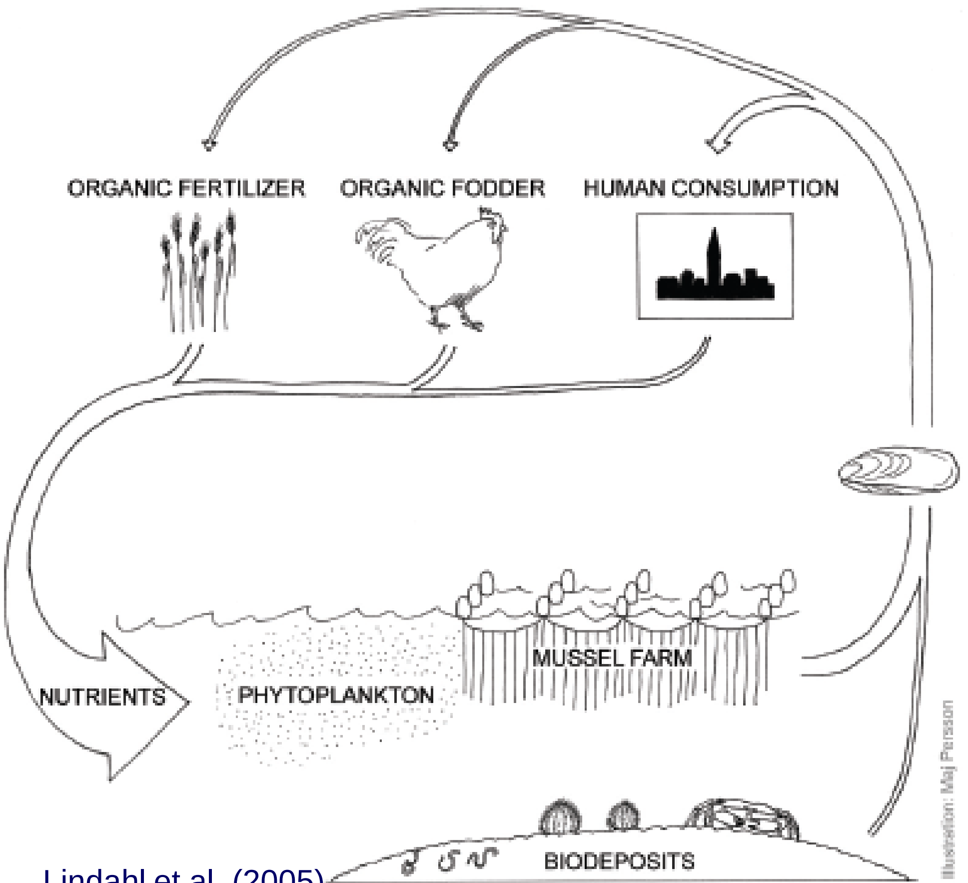
- **Biomass: 68,000 t**
- **Coverage in the German part: 2.4 %**
- **Average abundance on beds: 4000 mussels per m²**
- **Filtration rate: 1083 l m-2 d-1**
- **After 2 years**
  - size: 12-14 mm (max. 30)
  - weight: 500-1000 mg (max. 2500 mg)



(Data after Fenske, unpubl.; Woźniczka & Wolnomiejski unpubl.)

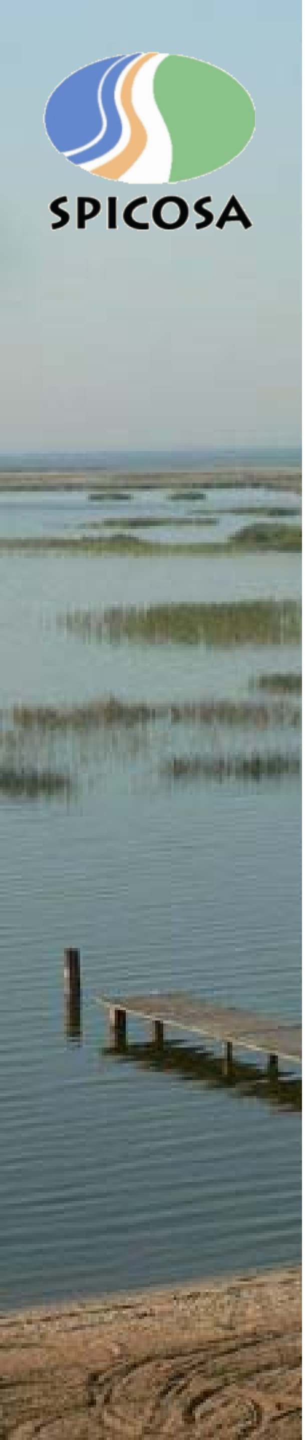
Water quality improvement by mussel cultivation

- **Enhancement of filtration capacity** by cultivating on long lines or nets (increase of mussels from 4000 - 6400 per m²)
- **Improved water transparency** by higher filtration capacity
- **Harvesting** of 6.4 kg mussels per m² every 2 years
- **Removing** of 1% N per mussel (64 g N per m²)
- Mussels / mussel shells could be used for: **human food, animal feed and fertilizer**



Lindahl et al. (2005)

Methods of farming



Costs and benefits of mussel cultivation

30 % of the whole lagoon are necessary to remove 10 % of the annual river load (=>6,500 t N)

Costs

- **Investment costs range from 600 to 700 million Euro**

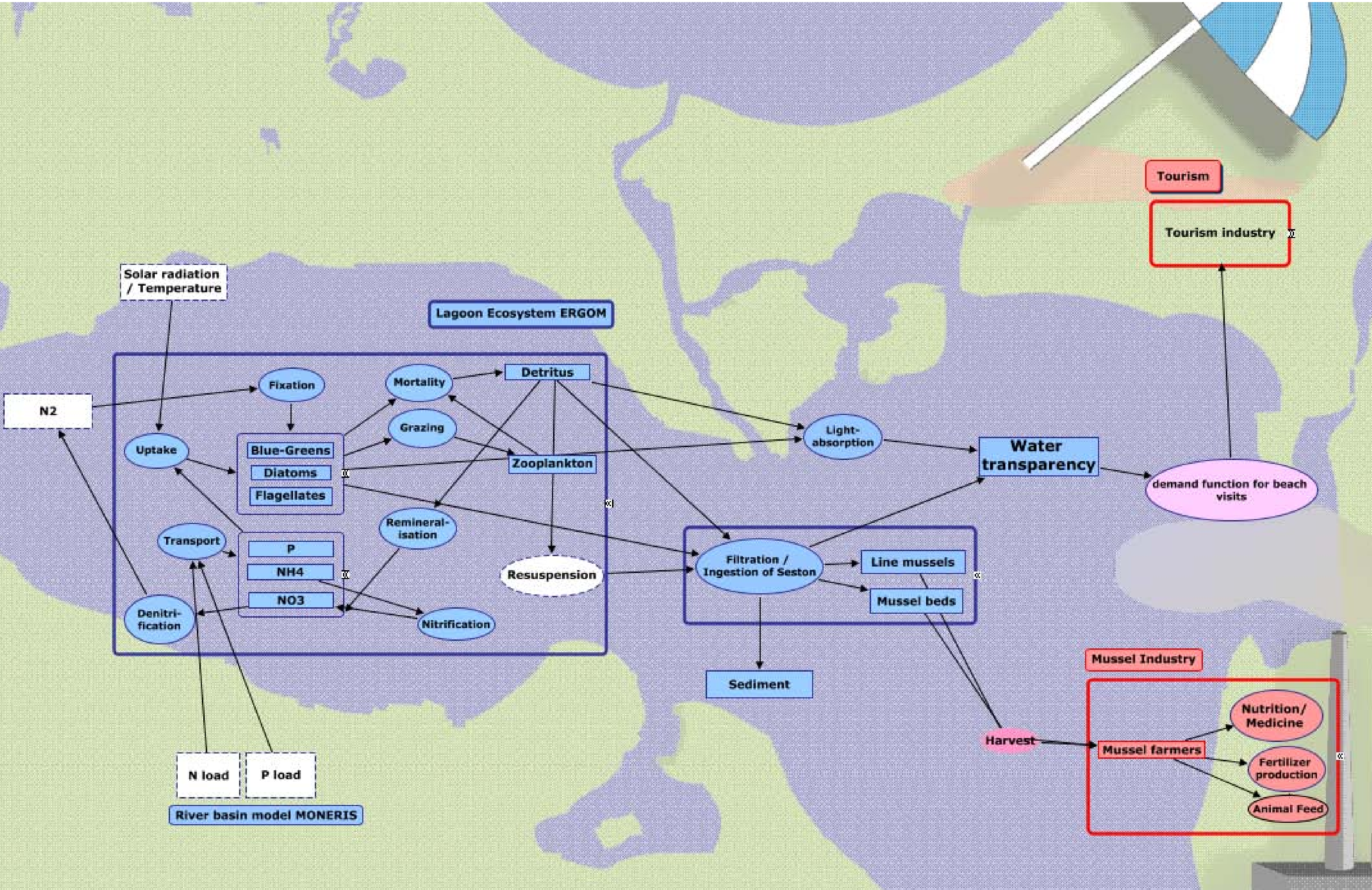
Benefits

- **A sale of 650,000 t mussels per year could result in an income of 4.2 million Euro**
  when 0.1 % for human consumption (1.43 Euro per kg), remainder for other products (5 Euro per t)
- **Total financing only when 100 % are produced for human food (unrealistic assumption!)**

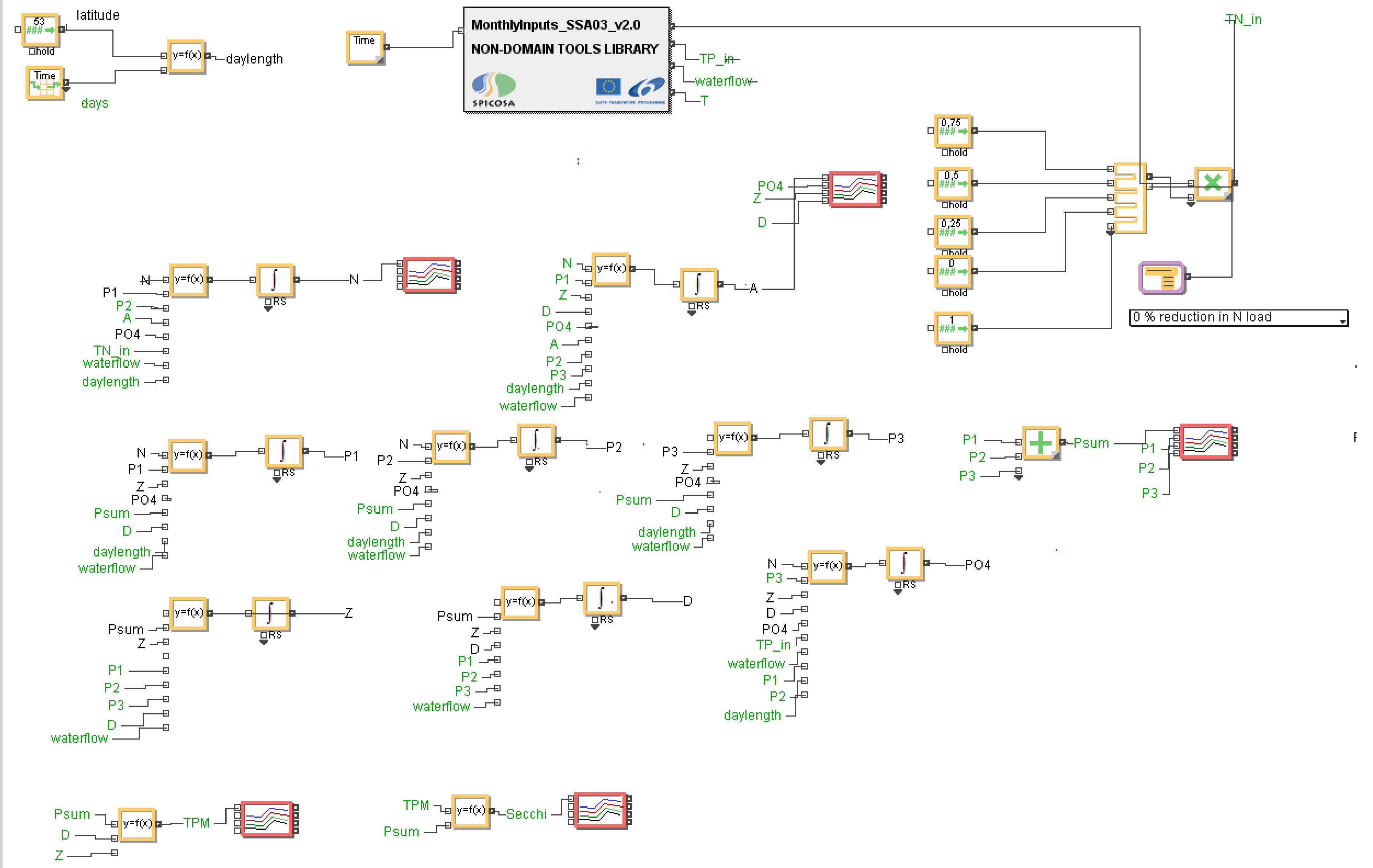
SWOT-Analysis: mussel cultivation in the Szczecin Lagoon

Strenghts	Weaknesses	Opportunities	Threats
• **Environmentally friendly**, native species • **Removal of nutrients** by periodic harvest • **Improvement of ecosystem quality** by increased biodiversity • **Low limitation by spatfall** in comparison with bottom cultures • **In line with environmental law and water law analysis** (German site)	• **Uncertain commercial use** because of small harvest size • **Increased concentration of heavy metals** affects mussel use for animal husbandry • **Reduction of mussel biomass** by predators (waterfowl, fish, crustaceans) • **Region without experiences in mussel cultivation**	• **Resettlement of macrophytes** by improved water transparency • **Altered food web interactions,** more benthic feeding fish and expanded fishery • **Higher number of tourists and overnight stays in summer season** by improved water transparency • **New regional jobs** in harvesting and processing of mussels • **Best practice project**	• **Local anoxic surface sediment** by deposited organic material • **Bothered tourists** by mussel shells washed ashore • **Economic damage** (waterworks) by settlement

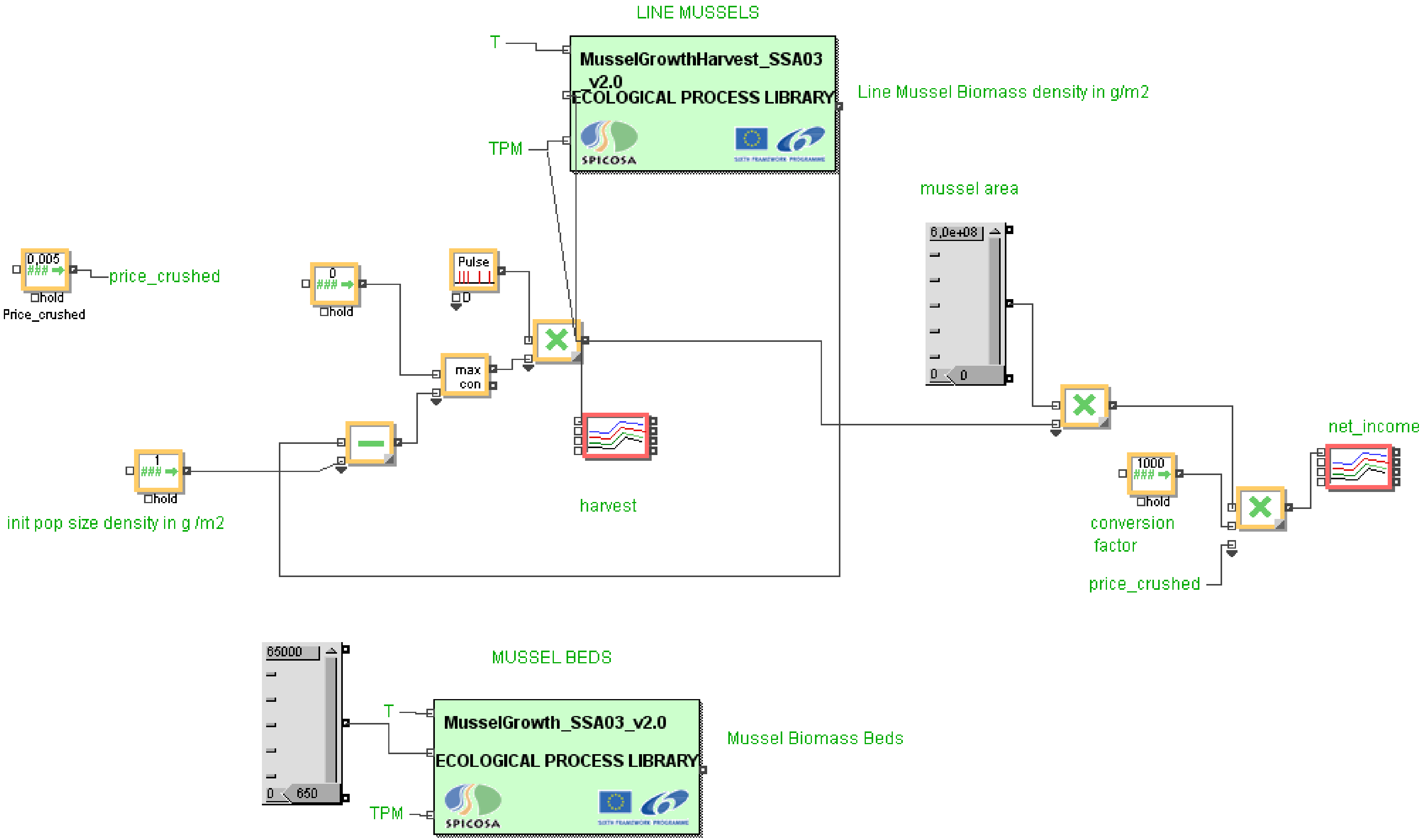
Conceptual map SSA03



EXTEND model SSA03 – NPZD submodel



EXTEND model SSA03 – mussel submodel



EXTEND model SSA03

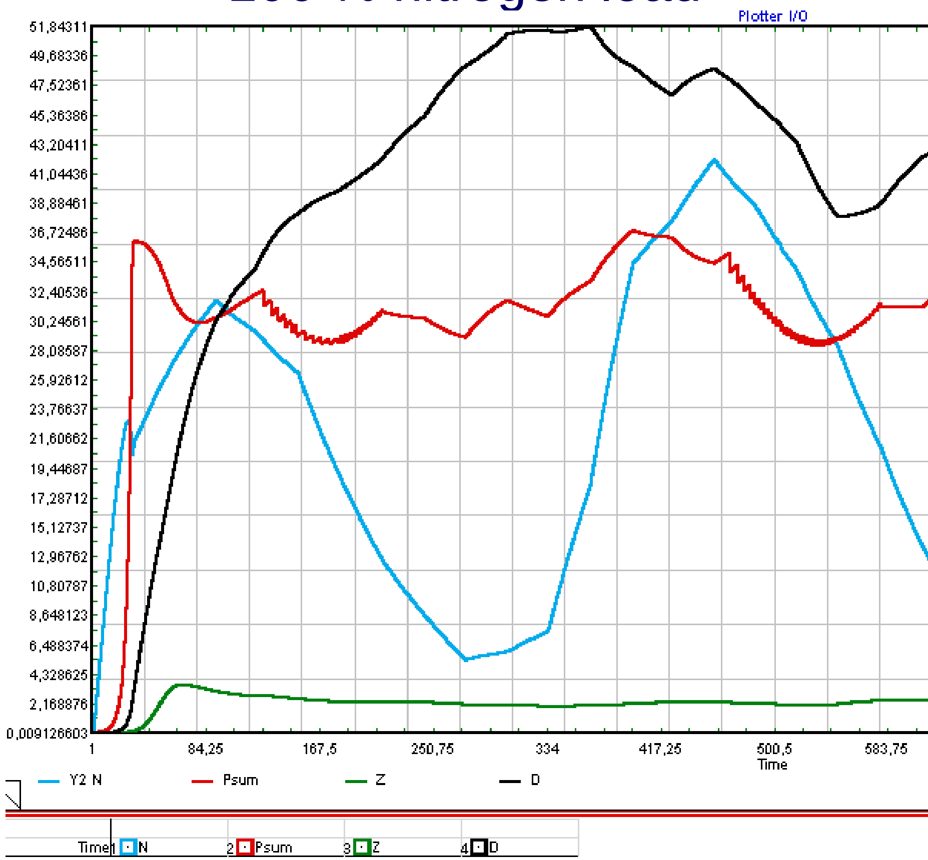
Scenarios

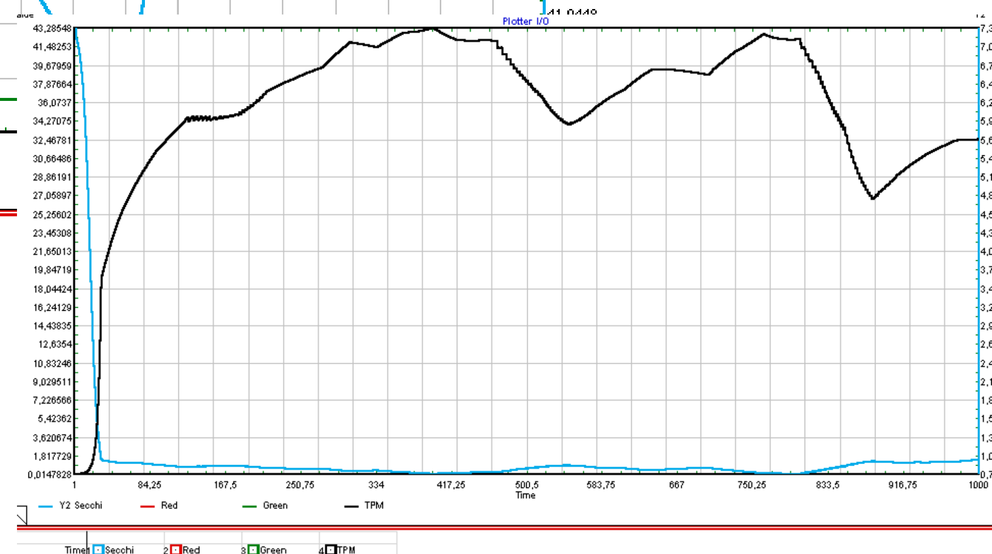
External: Reduction of nitrogen load in the river basin against the background of WFD

Internal: Available area for mussel settlement / area for aquaculture (lines or nets)

EXTEND model SSA03 - results

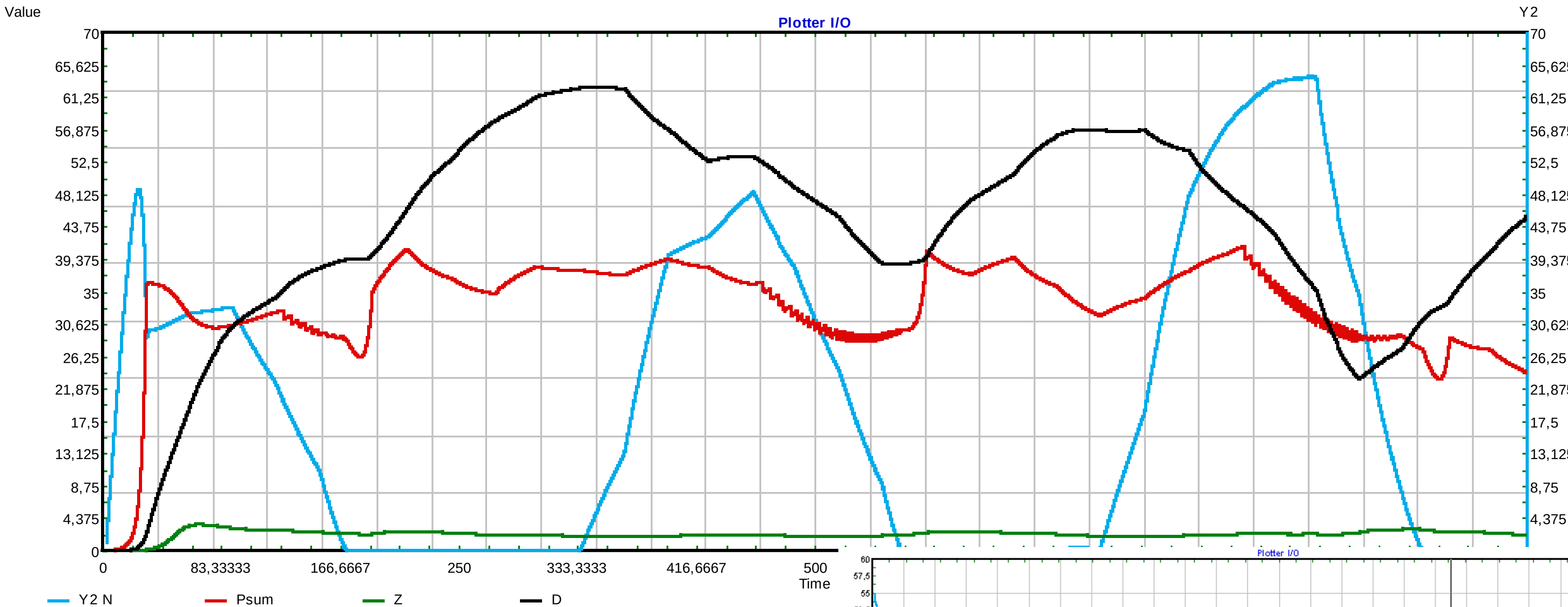
100 % nitrogen load

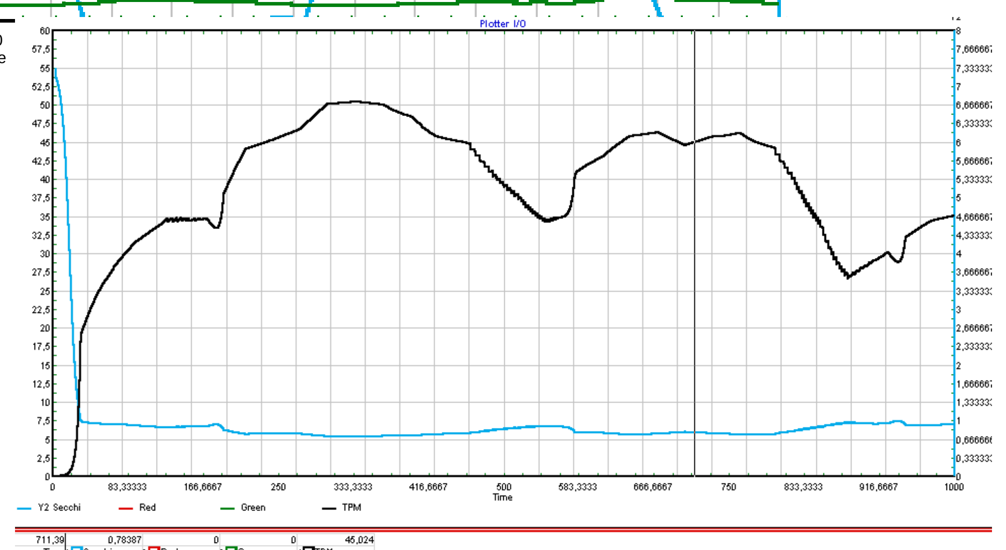




EXTEND model – SSA03

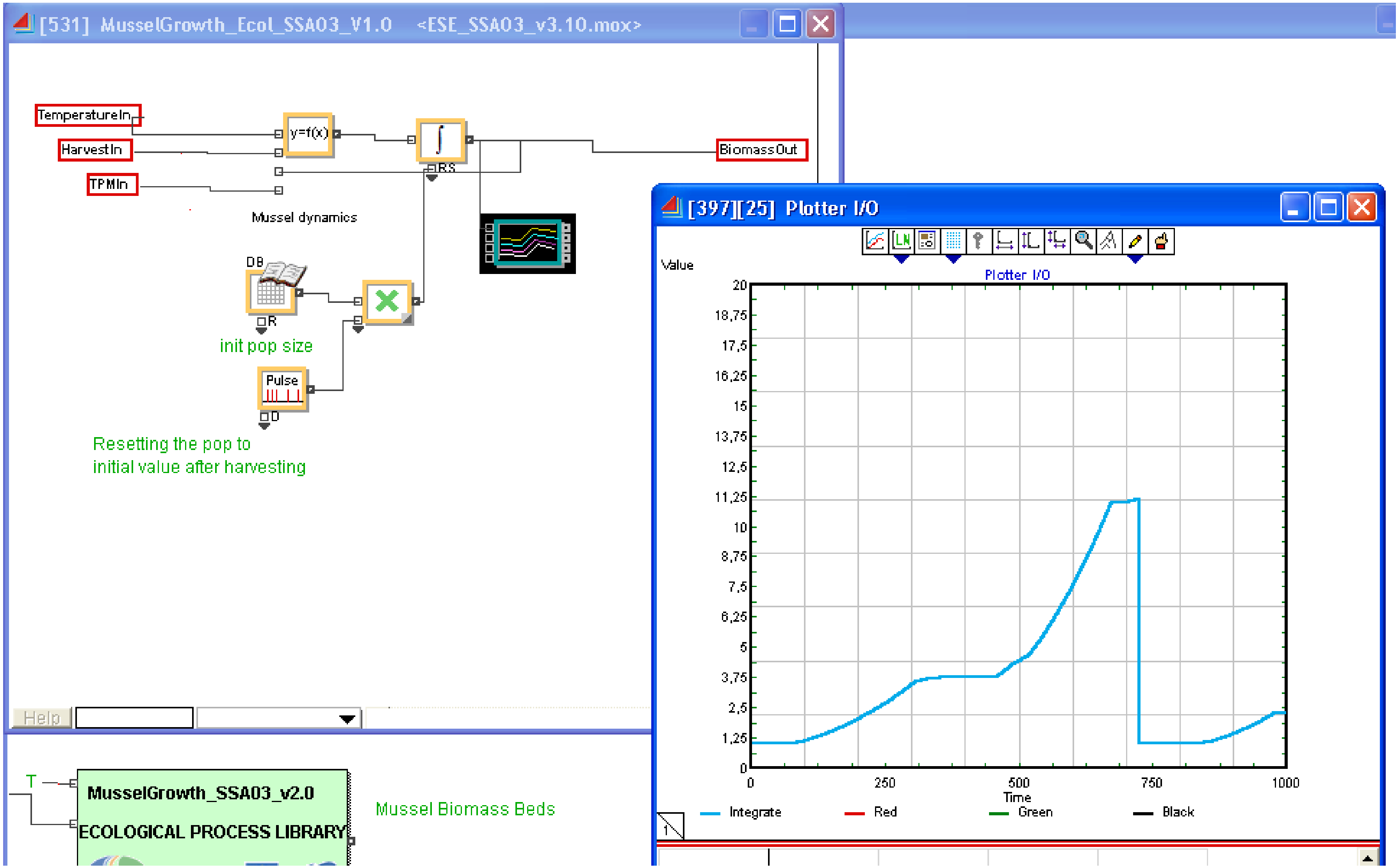
50% nitrogen load





EXTEND model – SSA03

Growth and harvest of line mussels



EXTEND model SSA03

Current state:

- Model development is still under progress
- Problem: Secchi depth based on changes in seston

Technical results:

- Hierarchical blocks: Monthly Input – Daily Input, Mussel Growth

Next steps:

- Hblock - Phytoplankton growth
- Sensitivity analysis and calibration
- Finalisation of the documentation report until end of October

Thank you for your attention !!

Recent publications of SSA Oder/Odra estuary

2008

Janßen, H., Schernewski, G (2008): ICZM and Climate Change - The Oder/Odra Estuary region. Research Publishing, Singapore and Chennai

Kessler, V. (2008): Touristeninformation über die Ostsee in Mecklenburg-Vorpommern - Touristenbefragung und Medienanalysen, IKZM-Oder Berichte 40

Neumann, T. & G. Schernewski (2008): Eutrophication in the Baltic Sea and shifts in nitrogen fixation analyzed with a 3D ecosystem model. Journal of Marine Systems 74, 592–602

Radziejewska, T. & G. Schernewski (2008): The Szczecin (Oder-) Lagoon. In: Schiewer, U. (Ed.): Ecology of Baltic Coastal Waters Series. Ecological Studies , Vol. 197, Springer, Berlin, 115-129.

Schernewski, G. (2008): First steps towards an implementation of coastal management: From theory to regional practise. Rostock. Meeresbiol. Beitr., 19: 131-148

Schernewski, G. (2008): Inter-linking Coastal and River Management in the Oder Delta, Germany. Coastline " European Coastal & Marine Policies" Vol. 17, No. 2-3, 7.

Schernewski, G., Behrendt, H., Neumann, T. (2008): An integrated river basin-coast-sea modelling scenario for nitrogen management in coastal waters. J Coast Conserv, DOI: 10.1007/s11852-008-0035-6, 12: 53-66.

2009

Hirschfeld, J., Behrendt, H., Edler, J., Janßen, H., Knippschild, R. & Czarnecka-Zawada, S. (2009): Transformationsprozesse im Einzugsgebiet der Oder - Szenarien 2020. IKZM-Oder_Berichte 56

Preißler, S. (2009): Evaluation of the quality of European coastal waters by German tourists. Coastline Reports 12

Schernewski, G., Janßen, H. & Schumacher, S. (eds.). Coastal Change in the southern Baltic Sea Region, Coastline Reports 12

Schernewski, G., Neumann, T., Stybel, N., Behrendt, H., Fenske, C.. Coastal eutrophication management: Lessons learnt from long-term data and model simulations. Coastline Reports 12

Schernewski G., T. Neumann, S. Maack & M. Venohr (submitted): Gewässereutrophierung. Fränzle, Müller & Schröder (Hrsg.) Handbuch der Umweltwissenschaften,Wiley –VCH Verlag.

Schernewski G., T. Neumann & H. Behrendt (submitted): Sources, dynamics and management of phosphorus in a southern Baltic estuary. In: J. Harff, S. Björck & P. Hoth : The Baltic Sea Basin as a natural Laboratory. Springer

Schernewski, G., T. Neumann, Dieter Opitz & Markus Venohr (submitted): Long-term eutrophication history and functional changes in a large Baltic river basin - estuarine system. Estuaries and Coasts

Stybel, N., Fenske, C., Schernewski, G.. Mussel cultivation to improve water quality in the Szczecin Lagoon. Journal of Coastal Research, SI 56

Voss, M., Dippner, Korth, Neumann, Opitz, Schernewski, Venohr (in prep.): History and future development of Baltic Sea eutrophication. Estuarine, Coastal and Shelf Science