Eutrophication management in a Baltic estuarine system

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Destruction of the natural heritage: 
*Eutrophication*
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
Managing eutrophication: Approaches

a) External river basin management to reduce nutrient loads

b) Internal lagoon management in a socio-economic framework
Managing eutrophication

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?

Tasks

- To explain the long-term eutrophication history in the river and in the estuary and their causes;
- 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.
Managing eutrophication: Models

MONERIS - a river basin model for nitrogen and phosphorus
(after Behrendt & Dannowski 2005)

- Erosion
  - Slope
  - Arable land
  - Soil loss
  - Sediment input
    - N, P in top soil
    - P, N input
  - N, P in suspended solids

- Surface runoff
  - Runoff surface area (km²)
  - N, P concentration
  - P, N input

- Tile drainage
  - N-surplus
  - Field capacity
  - Leakage
  - Tile drained area
    - P, N concentration
    - Precipitation drain flow

- Ground water
  - N-surplus
  - N in seepage
  - N-retention
  - N in groundwater
    - Seepage water level
    - Water balance
    - Base- & inter-flow
  - P, N input

- Atmospheric deposition

- Urban areas
  - Paved urban areas
  - Combined sewer system
  - Separate sewer system
  - Sewers without WWTP
  - No sewage
  - Loss per inhabitant
    - P, N input
  - Discharges

- Point sources
  - Municipal sewage
  - Industrial discharge
  - Fish farms
  - P, N input

- Retention in river
  - Water discharge
    - N & P load

Schernewski (2007)

*Behrendt, H. [Hrsg.]; Dannowski, R. [Hrsg.]: Nutrients and Heavy Metals in the Odra River System: Emissions from Point and Diffuse Sources, their Loads, and Scenario Calculations on Possible Changes; Weissensee Verlag Berlin*
Managing eutrophication: Models

MONERIS - Examples of geographical input data

(from Behrendt & Dannowski 2005)

Behrendt, H. [Hrsg.] ; Dannowski, R. [Hrsg.]: Nutrients and Heavy Metals in the Odra River System: Emissions from Point and Diffuse Sources, their Loads, and Scenario Calculations on Possible Changes
The optimal load reduction scenario shows loads like in the late 1960’s.
Eutrophication history: Long-term model simulations


Behrendt et al. (2005)
Managing eutrophication: Models

ERGOM - a 3D flow & ecosystem model

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

Solar radiation

Water discharge N & P load

Denitrification

Atmosph. O2 Input

Detrit.

N2-Fixation

Blue-Greens

Diatoms

Flagellates

Grazing

Zoopl.

Mortality

Respiration

Recycling

Sediment

Nitrification

Settling

Resuspension

Uptake

P

NH4

NO3

O2

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
Eutrophication history: Long-term model simulations

a) Summer - Dissolved Inorganic Nitrogen (mmol m$^{-3}$)

1961-1964

1999-2002

b) Winter - Dissolved Inorganic Nitrogen (mmol m$^{-3}$)

1961-1964

1999-2002

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

### Suggestions for water quality objectives for the EU-Water Framework Directive

<table>
<thead>
<tr>
<th>Oder/Odra river</th>
<th>Total-P (average) (mg l$^{-1}$)</th>
<th>PO$_4$-P (average) (mg l$^{-1}$)</th>
<th>Total-N (average) (mg l$^{-1}$)</th>
<th>NH$_4$-N (average) (mg l$^{-1}$)</th>
<th>Total-P load (t a$^{-1}$)</th>
<th>Total-N load (t a$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing</td>
<td>0,1</td>
<td>0,07</td>
<td></td>
<td>0,3</td>
<td></td>
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<tr>
<td>Suggestion</td>
<td>0,1</td>
<td>0,07</td>
<td>1,5</td>
<td>0,3</td>
<td>1700</td>
<td>25000</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Oder Lagoon</th>
<th>Total-P (average) (mg l$^{-1}$)</th>
<th>PO$_4$-P (winter) (mg l$^{-1}$)</th>
<th>Total-N (average) (mg l$^{-1}$)</th>
<th>DIN (winter) (mg l$^{-1}$)</th>
<th>NO$_3$-N (winter) (mg l$^{-1}$)</th>
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</thead>
<tbody>
<tr>
<td>Existing</td>
<td>0,016</td>
<td>0,006</td>
<td>0,21</td>
<td>0,15</td>
<td>0,11</td>
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<td>Suggestion</td>
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<td>0,05</td>
<td>1,2</td>
<td>0,85</td>
<td>0,7</td>
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</tbody>
</table>

Managing eutrophication: Approaches

a) External river basin management to reduce nutrient loads

b) Internal lagoon management in a socio-economic 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

4. Mussel farming – a solution?

The MONERIS- ERGOM system with extensions: Mussel module and economic model

4. Mussel farming – a solution?

The cost-efficiency of nitrogen retention measures in the Oder river - coastal - sea system

Abatement measures: River basin (external) Lagoon (internal)
(a) Nitrogen

2. Water quality objectives & nutrient loads

Some conclusions (based on model simulations)

- The lagoon is a natural eutrophic system and a good water quality status cannot be reached with external load reductions alone.
- N-load reductions reduce phytoplankton concentrations. Therefore, N reduction measures make sense.
- N-Fixation does and did not play an important role in the lagoon and will not compensate riverine N-load reductions.
- Between 1960 and 2000 a temporal shift and changes in the availability of N and P took place. A real, lasting nutrient limitation is and was unlikely.
- Denitrifikation in the lagoon declined from 26 % (1960er) to 15 % (1999-2002) of the riverine loads. An increase in denitrifikation in the coastal Baltic Sea is observed.

Next steps

- Increased spatial resolution of ERGOM
- Extension of the approach to the entire German catchment/Baltic Sea
Thank you for your attention
2. Water quality objectives & nutrient loads

Nitrogen fixation and denitrification in the Oder lagoon (1960-2002)

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.