Mussel farming in Baltic coastal waters
Application of a System Approach Framework

Case study - Oder/Szczecin lagoon

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A SYSTEM APPROACH FRAMEWORK FOR COASTAL RESEARCH & MANAGEMENT

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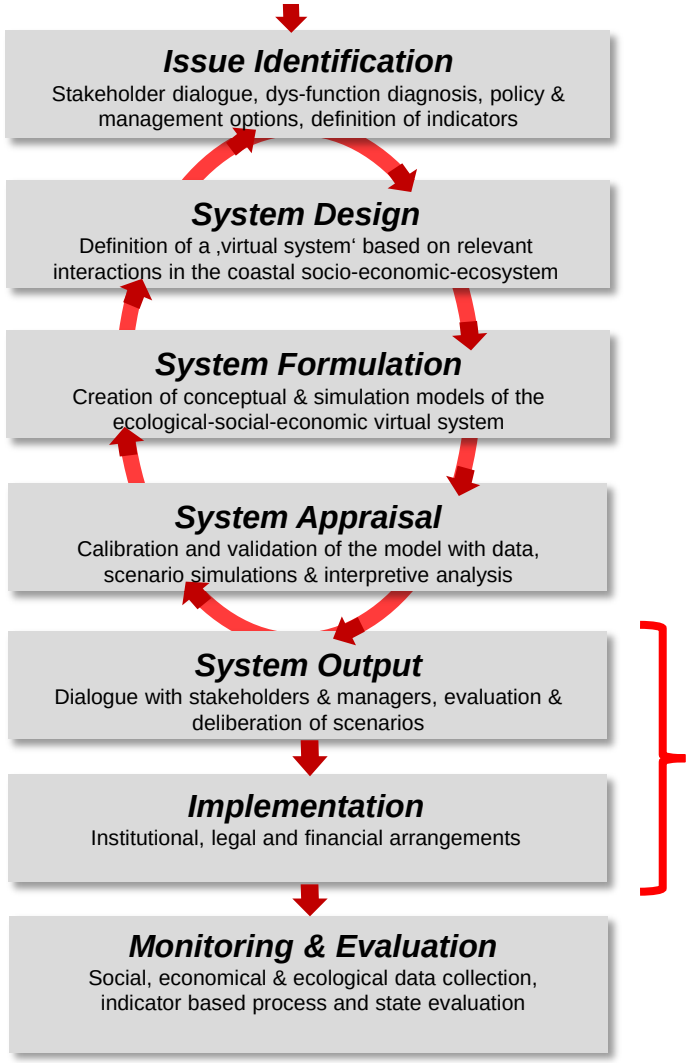
Systems Approach Framework

Ecological-Social-Economic-Assessment (ESE)

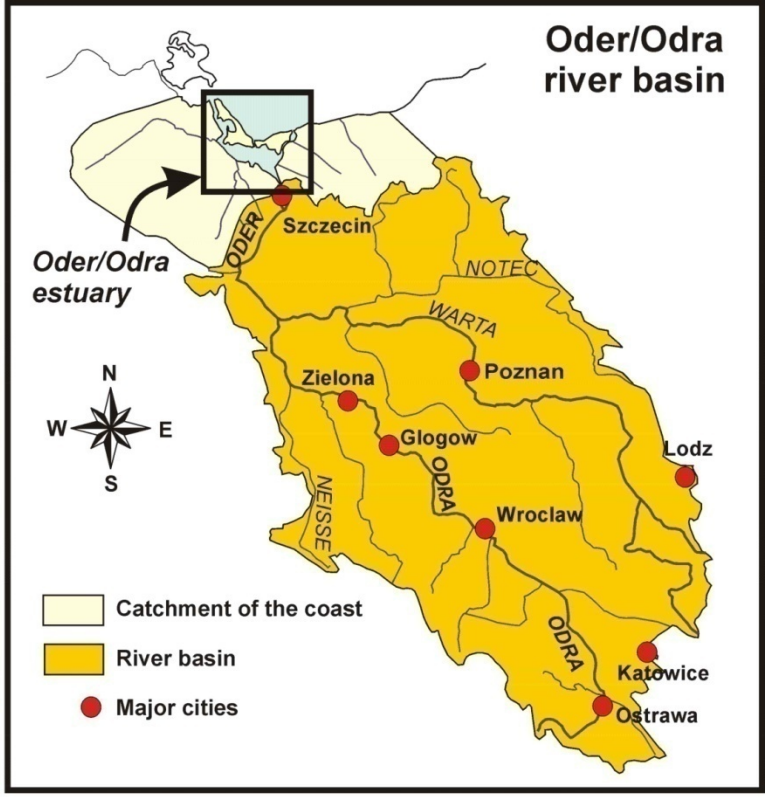


- How do the steps from output towards implementation look like?
- How does the iterative cycle looks like in practice?

- The issue: Eutrophication
- Aquaculture and mussel farming a solution?
- Mussel farming in Szczecin lagoon: A feasibility study

HELCOM Baltic Sea Action Plan

- The **HELCOM Baltic Sea Action Plan (2007)** is a programme to restore the good ecological status of the Baltic marine environment by 2021.
- **Eutrophication** is a major problem in the Baltic Sea. Since the 1900s, the Baltic Sea has changed from an oligotrophic clear-water sea into a eutrophic marine environment.
- **Excessive nitrogen and phosphorus loads** coming from land-based sources are the main cause. About 75% of the nitrogen load and at least 95% of the phosphorus load enter the Baltic Sea via rivers or as direct waterborne discharges. About 25% of the nitrogen load comes as atmospheric deposition.
- The BSAP agrees on **maximum allowable nutrient inputs** and resulting reduction requirements of 135,000 t N (15,250 t P)
- The **country-wise nutrient reduction** requirement for Poland are 62,400 t N (8,760 t P) and for Germany 5620 t N (240 t P).



Oder/Odra river basin

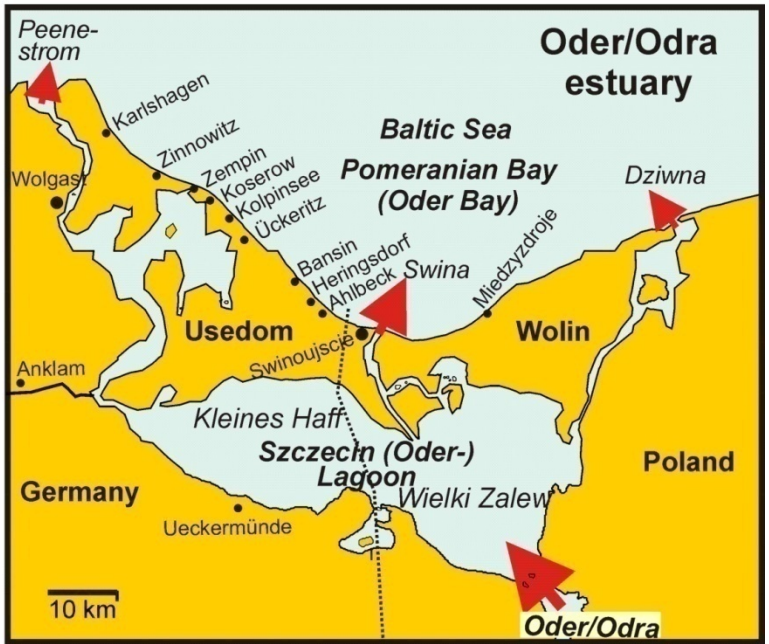
Length (km):	854
Catchment (km²):	118,000
Discharge (m³/s):	530 (average)
Population (Mio):	15.4

Oder/Odra estuary

Catchment (km²):	8000
Lagoon area (km²):	687
Lagoon depth (m):	3.7 (average)

Coastal climate:

Temperature (°C):	8.7 (average)
Precipiation (mm):	550



The Oder/Odra river–coast –sea system

Tourism
at the Oder Lagoon

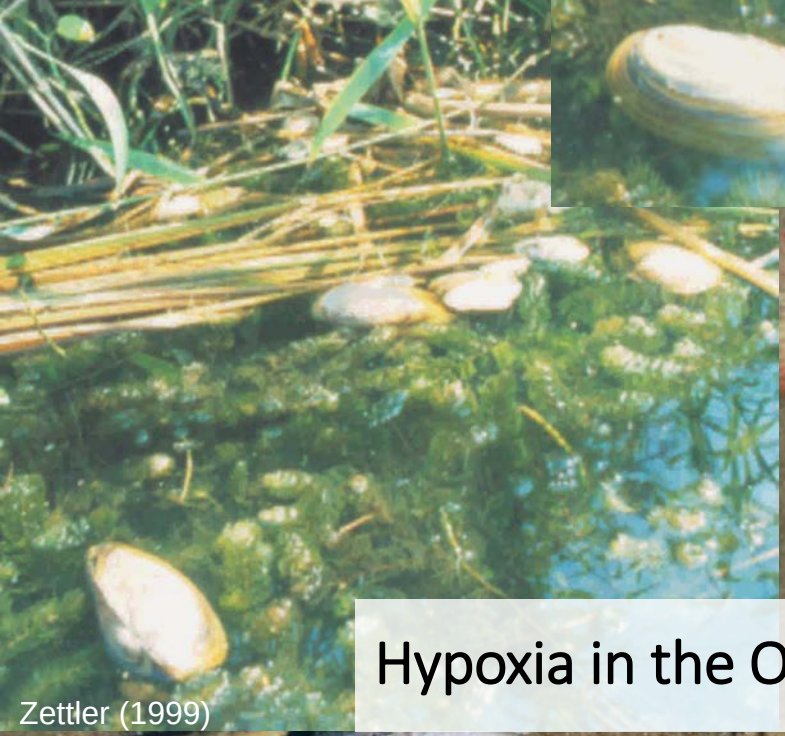
Oder/Szczecin Lagoon

Schernewski
(2008)

Eutrophication and algal blooms in the Oder Lagoon

Schernewski
(2000, 2001)

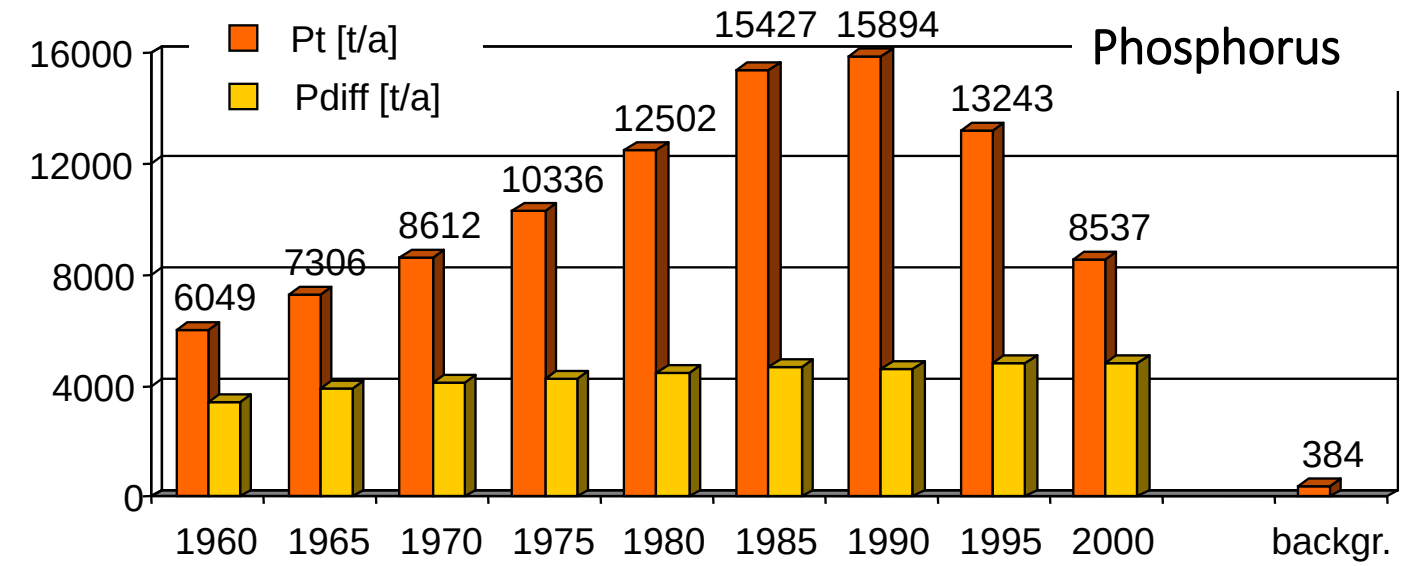
Hypoxia in the Oder Lagoon

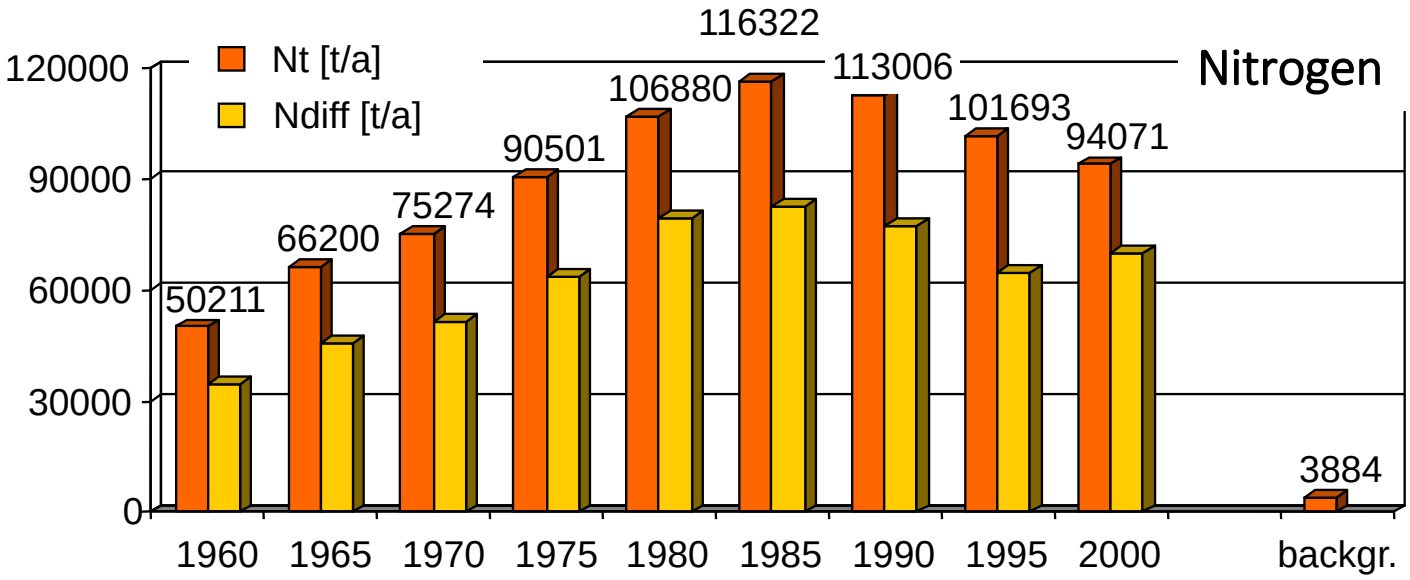


Zettler (1999)

Oder Lagoon in May 2000 (Schernewski 2000)

Oder/Odra river nutrient loads





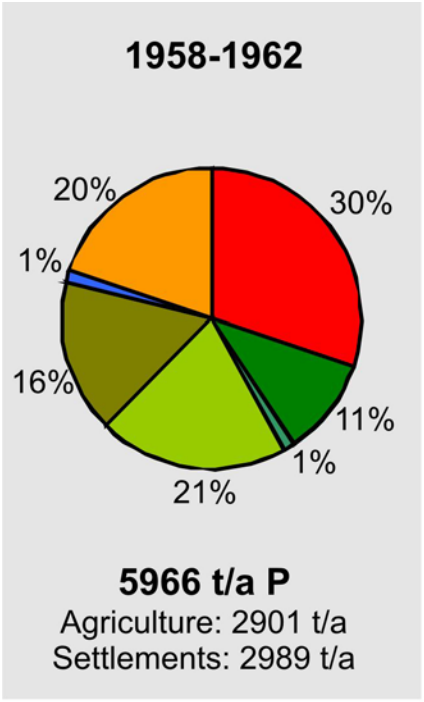
Behrendt et al. (2005)

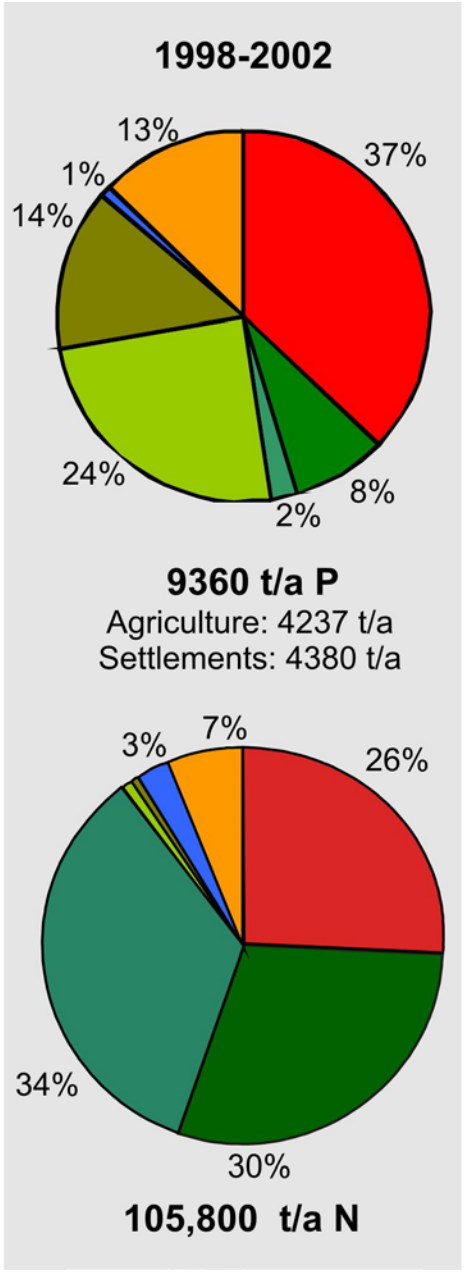
Possible nutrient load reductions in the river basin

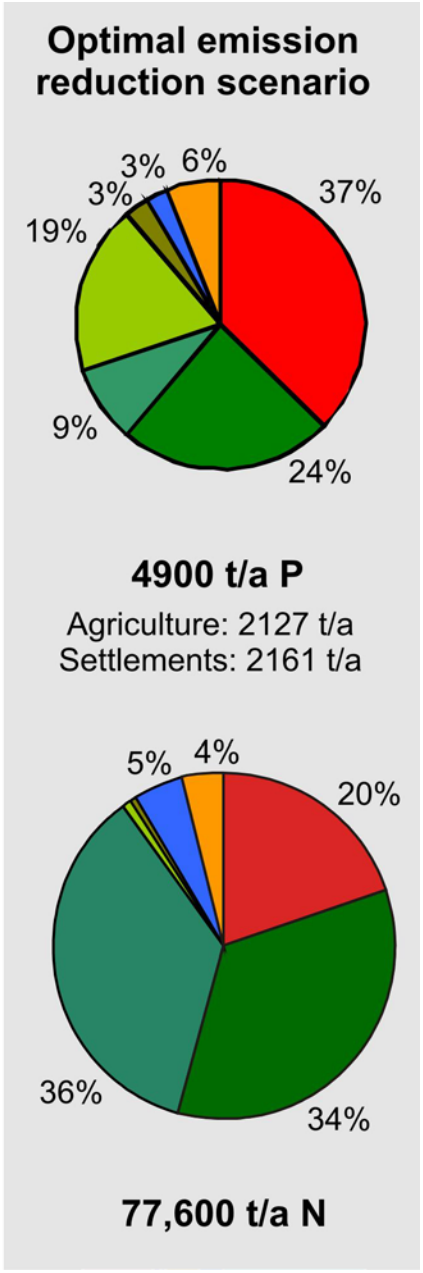
Questions:

Can we reach the load reduction required in the BSAP? (Poland 62,400 t N and 8,760 t P)

Would this reduction ensure a good water quality in the river and in coastal waters?







Nutrient loads at the Oder/Odra river mouth for phosphorus and nitrogen

Results:

The load reduction according to the BSAP can be fulfilled in the Oder river basin!

In the river, this reduction would not entirely ensure a “good” water quality according to the Water Framework Directive (WFD)!

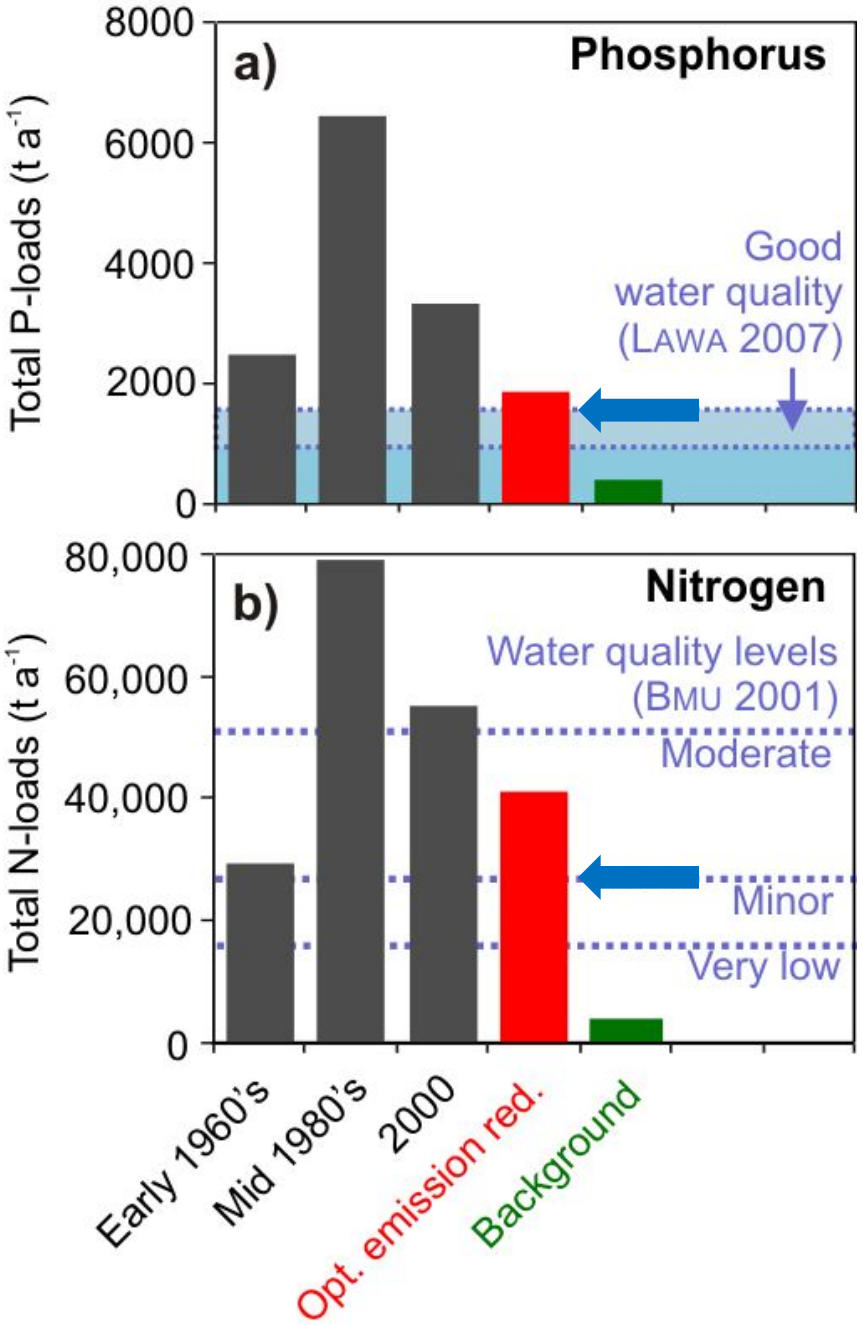
The lagoon would by far not reach a “good” water quality (WFD) and remain in a highly eutrophied state.

Consequences:

Nutrient load reductions into the river beyond the requirements of the BSAP are necessary.

Higher load reductions will be expensive, with the existing set of measures in the river basin.

Suitable additional cost-effective measures have to be considered.



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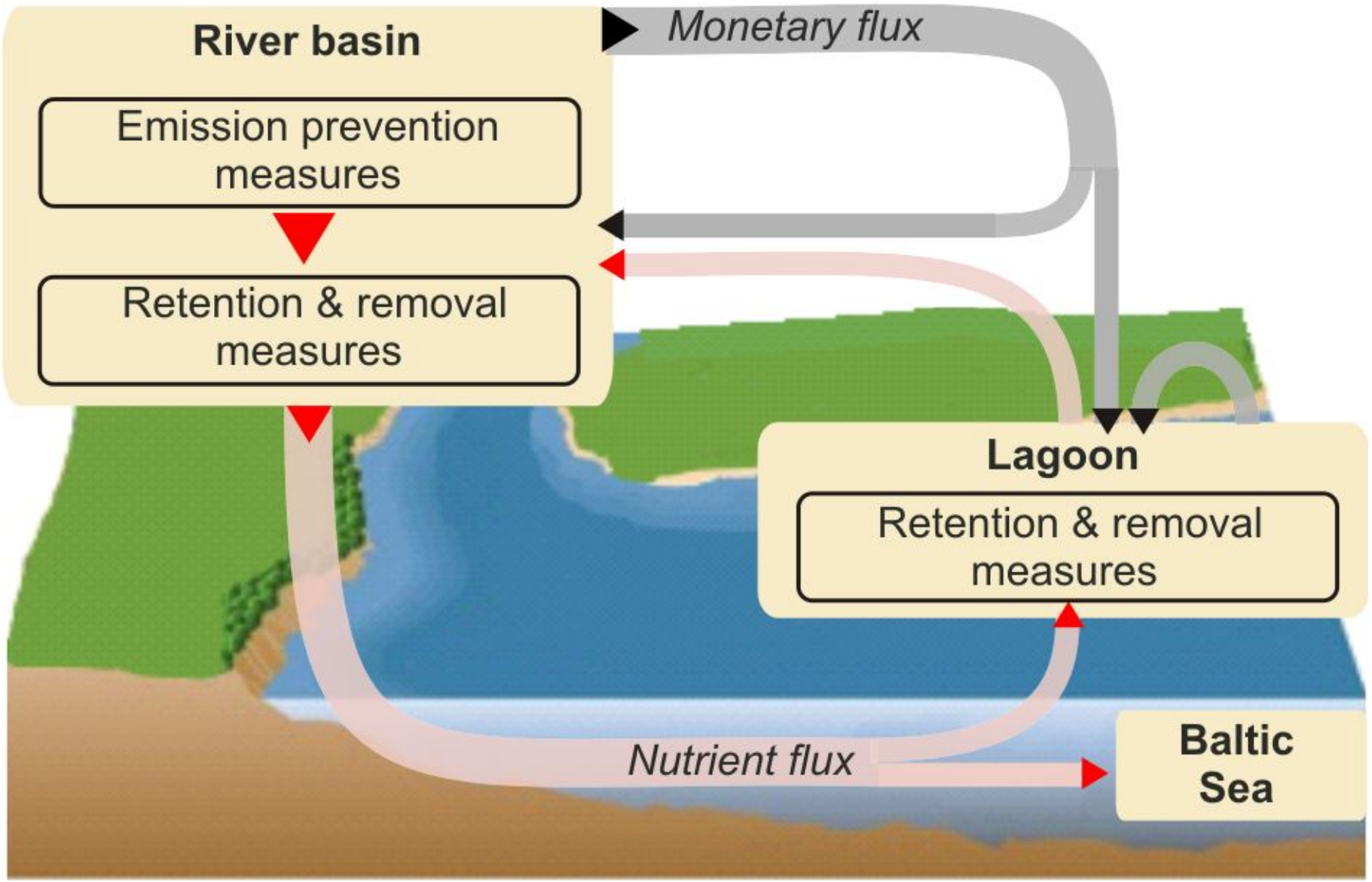
Integrated approach to eutropication management



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If water quality in the lagoon cannot be managed via riverine loads what are the alternatives?

Can measures in coastal waters reduce eutrophication?

Is mussel-farming an option?

Internal measures to improve water quality

Biological:

- Mussel cultivation
- Enlargement of natural mussel beds
- Bio-manipulation (selective fisheries)
- Macro algae cultivation
- Enlargement and management of macrophyte areas

Mechanical:

- Groin rows to support sedimentation
- Dredging of sediment and dumping on land
- Sediment capping to prohibit nutrient release from sediments

Chemical:

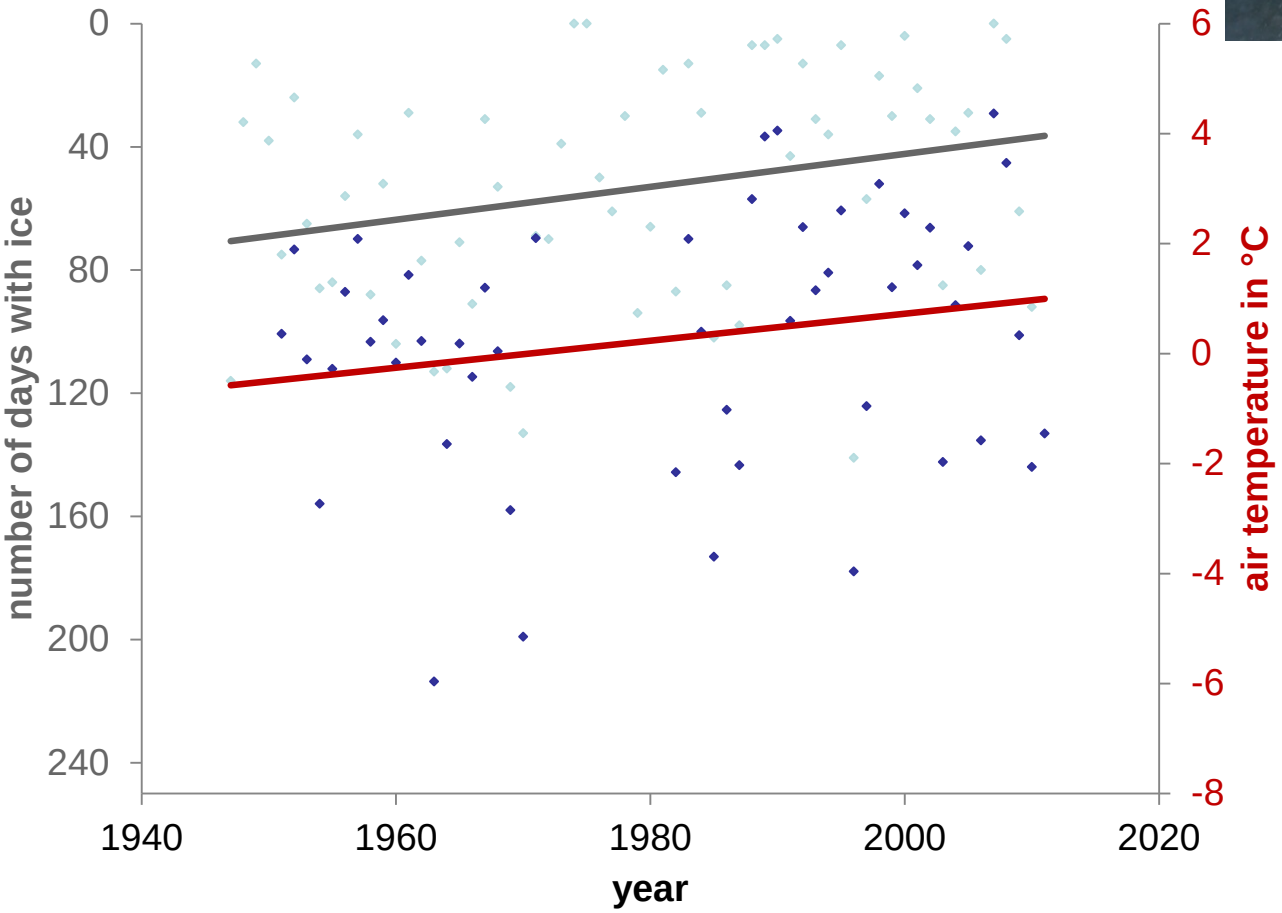
- Precipitation of nutrients

- **The issue: Eutrophication**
- **Aquaculture and mussel farming a solution?**
- **Mussel farming in Szczecin lagoon: A feasibility study**

Why does aquaculture and mussel farming practically not exist in the Baltic Sea?

Mussel farming near Kiel

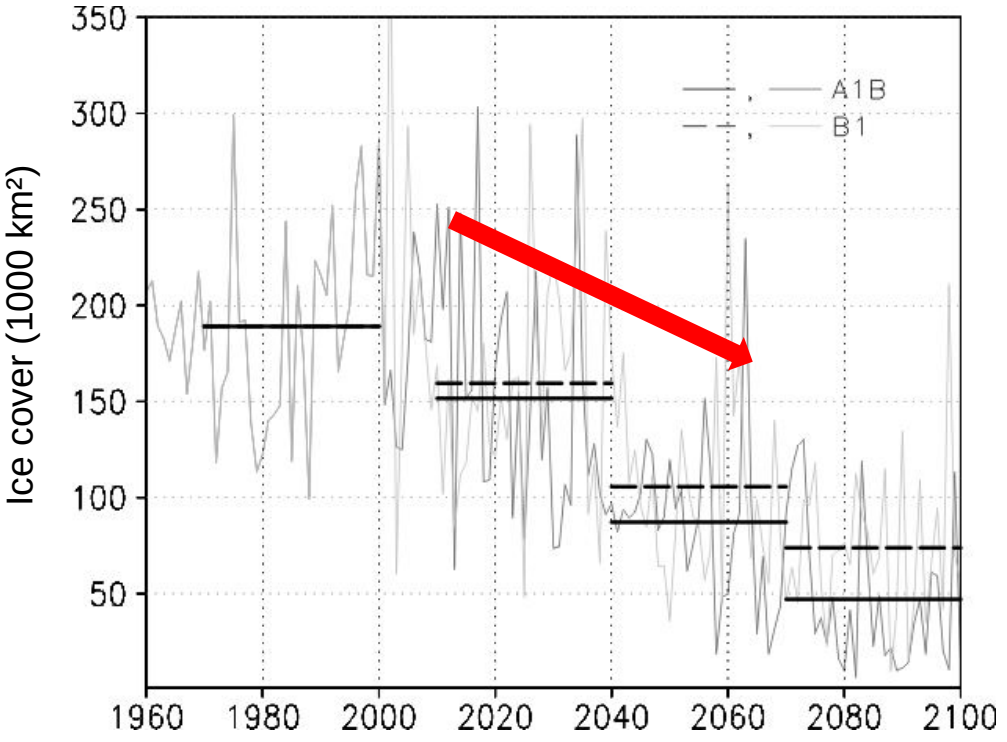
Ice cover and drifting



Impact of Climate Change on the Baltic Sea: Reduction of ice-cover

At the end of this century winterly ice cover will be

- restricted to northern Scandinavia and
- ice along the German Baltic coast will become the exception.



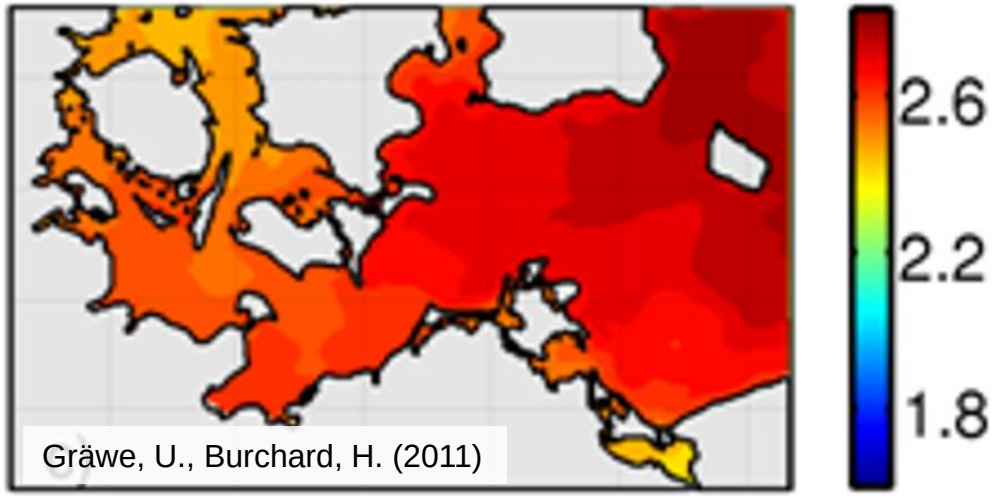
Neumann (2010): Climate-change effects on the Baltic Sea ecosystem: A model study, Journal of Marine Systems, 81 (3): 213-224

Climate Change :
Increasing wasser temperature & decreasing salinity

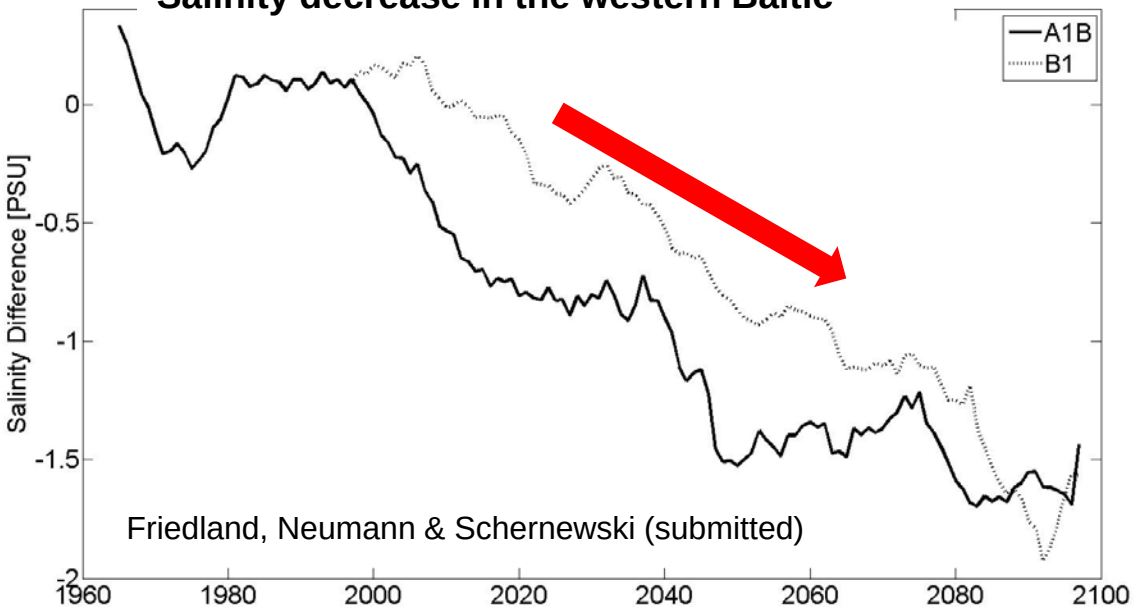
According to szenario A1B, the Baltic Sea **surface temperatur** will in increase by about 0,9°C (2,5°C) in the period 2020-2050 (2070-2100) similiar to the air temperature.

Salinity will decrease by 1,5 PSU (g/kg) in the western Baltic until 2100!

Water temperature change 2070-2100 (A1B)



Salinity decrease in the western Baltic



What are the consequences of Climate Change on mussel farming in the Baltic Sea?

Is Blue mussel (*Mytilus*) cultivation an option?

Mussel farming and new mussel beds:
Zebra mussel (*Dreissena polymorpha*)

2-3 cm

Zebra mussel (Wikipedia)

Mussel bed (Wikipedia)

Zebra mussel shells (R.Scheibe 2008)

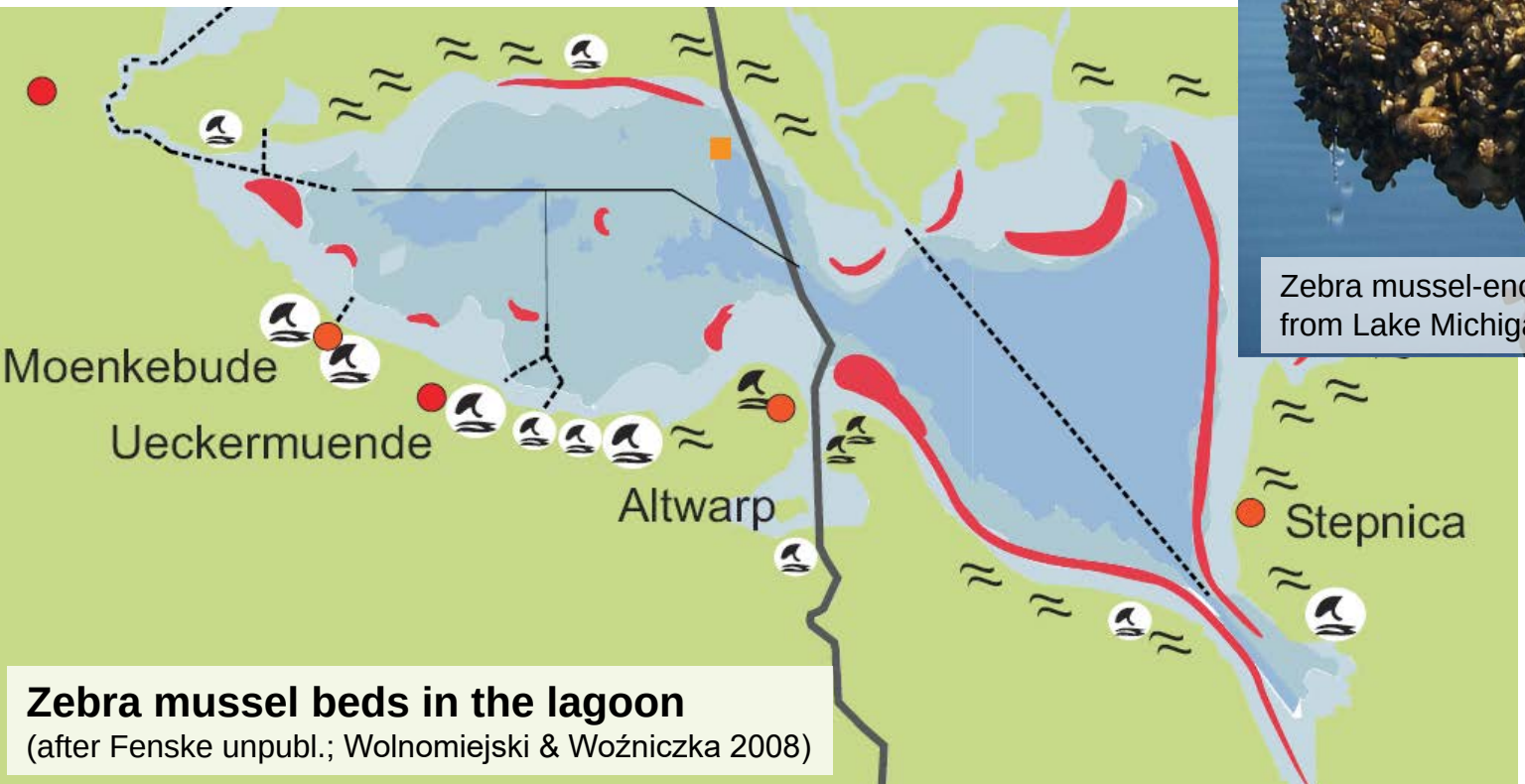
Questions:

- To what extent can we adapt and transfer approaches and experiences with Blue mussels in the Baltic to Dreissena in the lagoon?
- Are mussel farming and beds environmental friendly and what is the carrying capacity of the Oder Lagoon?
- To what extent can mussel farming contribute to nutrient retention and water transparency improvement in the lagoon?
- Are mussel farming and beds a cost-effective measure compared to measures in the river and the catchment?
- Can mussel farming be a profitable business and support local economy?

Zebra mussels in the Oder/Szczecin Lagoon

- Total biomass: ca. 68.000 t (about 8.000 t in the German part)
- Mussel beds in the German part: 6,56 km² or 2,4%
- Limitations for natural settling and spreading: missing hard substrate and anoxia

(Data after Radziejewska et al. (2009); Wolnomiejski & Woźniczka 2008)



Zebra mussel beds in the lagoon
(after Fenske unpubl.; Wolnomiejski & Woźniczka 2008)

Zebra mussel-encrusted current meter from Lake Michigan (Wikipedia)

Legal situation

General:
No German aquaculture law!

Permission depends on:
- Structure, size and place of construction
- Method of cultivation (e.g. nutrient input, risk of anoxia)

Szczecin Lagoon:
- Definition as fisheries method or water protection measure determines if a permission is required.
- Uncertainty about Environmental impact assessment (EIA) (e.g. depending on cultivation yield)??
- Permissions according to water law, environmental law, building law required?
- Licence for fishing necessary.
- Permission under police requirements relating to river and shipping

Zebra mussel beds in the lagoon

- Average abundance on beds: 4000 mussels per m^2, filtration rate: 1083 l/m^2*d
- Reproduction at water temperatures of 12-18 °C; larvae settle after 5-6 weeks (June)
- After 2 years a size of 12-14 mm (max. 30 mm) and a weight of 500-1000 mg (max. 2500 mg)

(Data after Fenske, unpubl.; Wolnomiejski & Woźniczka 2008)

(Stybel 2008)

Zebra mussel cultivation in Szczecin Lagoon: Experiments by Sven Dahlke

(Fotos: Klamt 2011)

Zebra mussels for human consumption

(Klamt 2011)

Is it possible to sell Zebra mussels (*Dreissena*) for human consumption?

Are mussel farms or mussel beds the better solution?

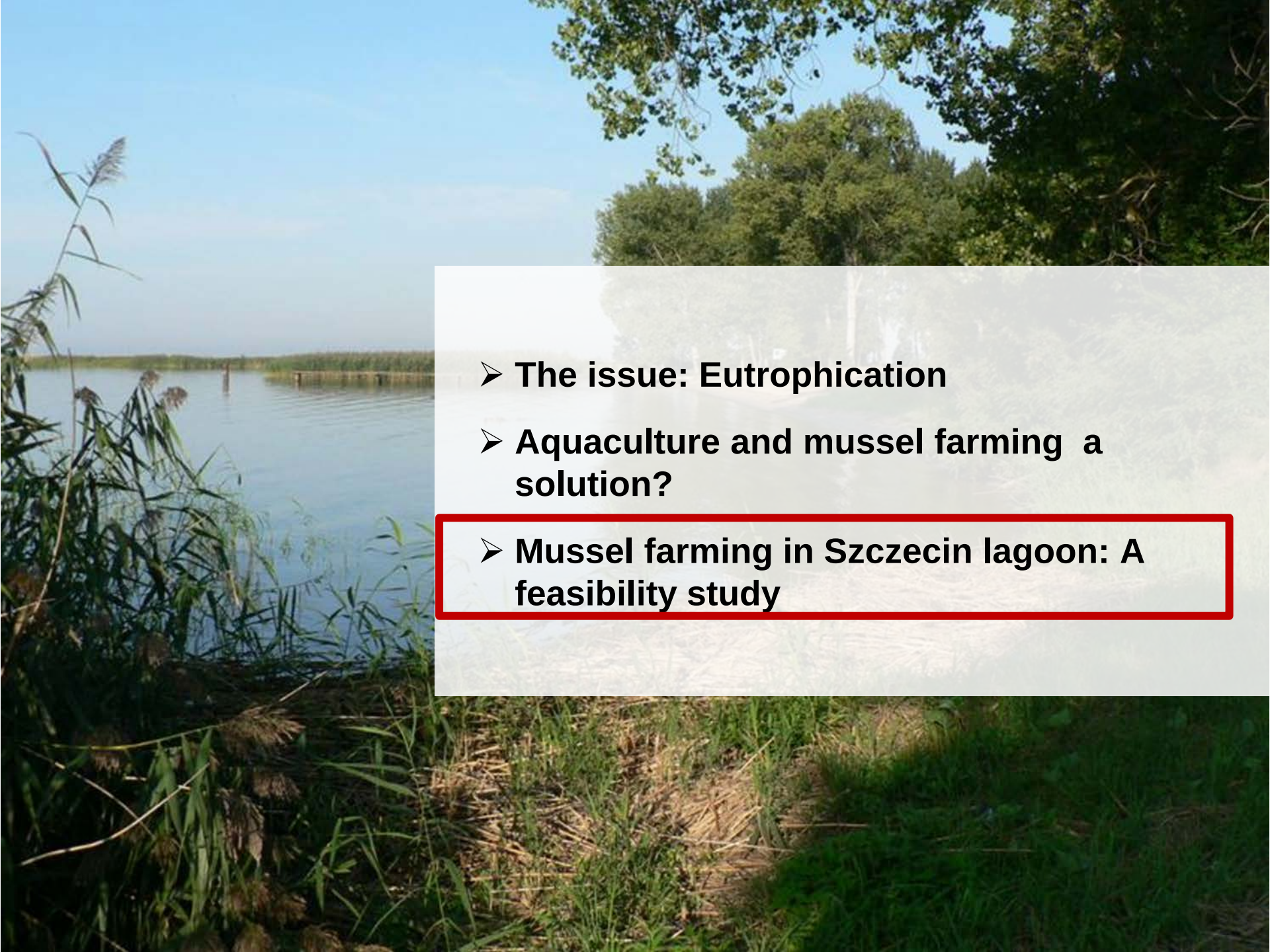
Mussels for human consumption – a matter of size?

Striped Venus Clam (*Chamelea gallina*)
Vongole at the Italian Adriatic coast:
Production 2005: 21,000 t/a
Production 1994: 108,000 t/a
Consumer-price: 10-13 €/kg

(Source: Romanelli et al. 2009, Acta Adriat.)

Mussels for human consumption: Vongole

Full maturity after two years at a size of 20-25 mm (commercial size > 25 mm)



- **The issue: Eutrophication**
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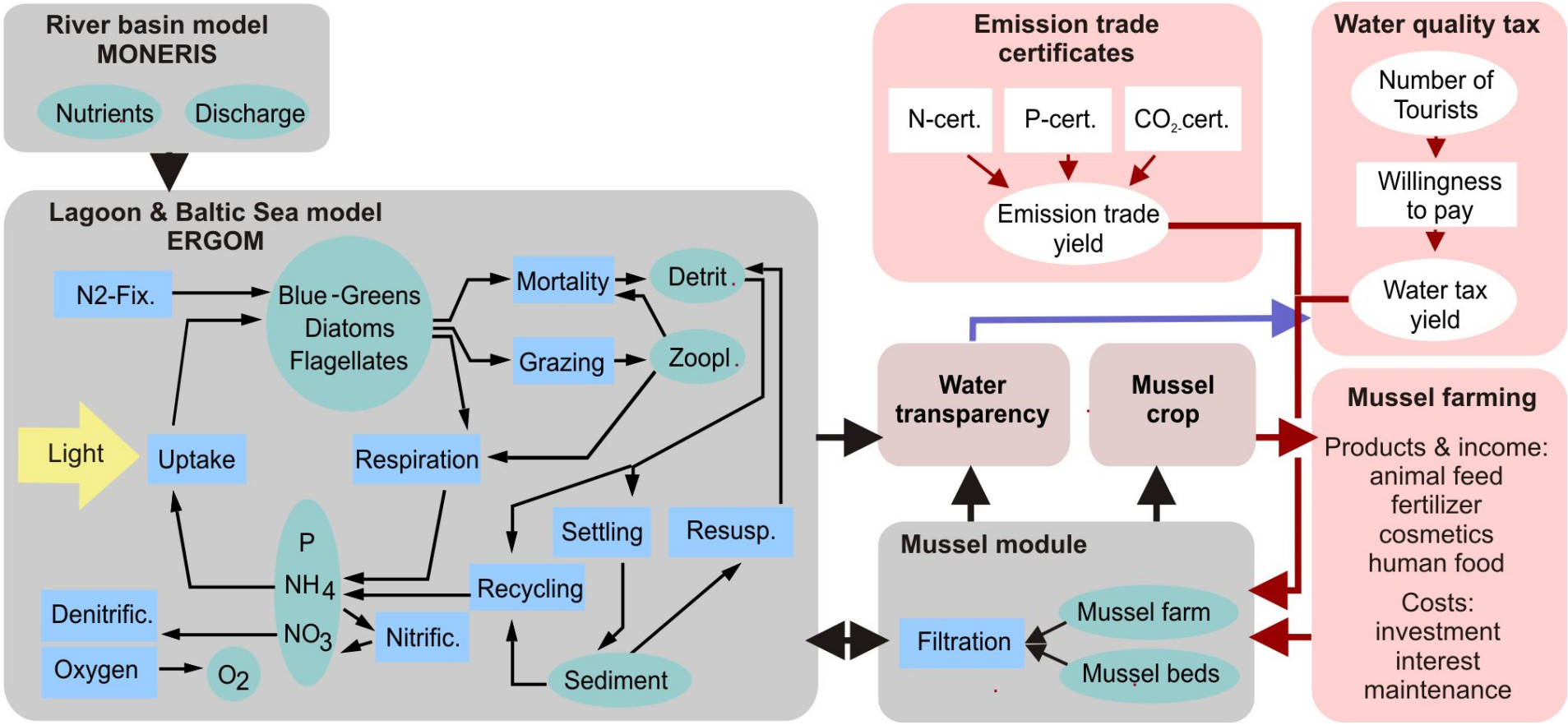
Our approach:

- Extension of an ecological model by a mussel module
- Development of an economic model
- Linking both models via water transparency and mussel yield
- Scenario simulations with the model system



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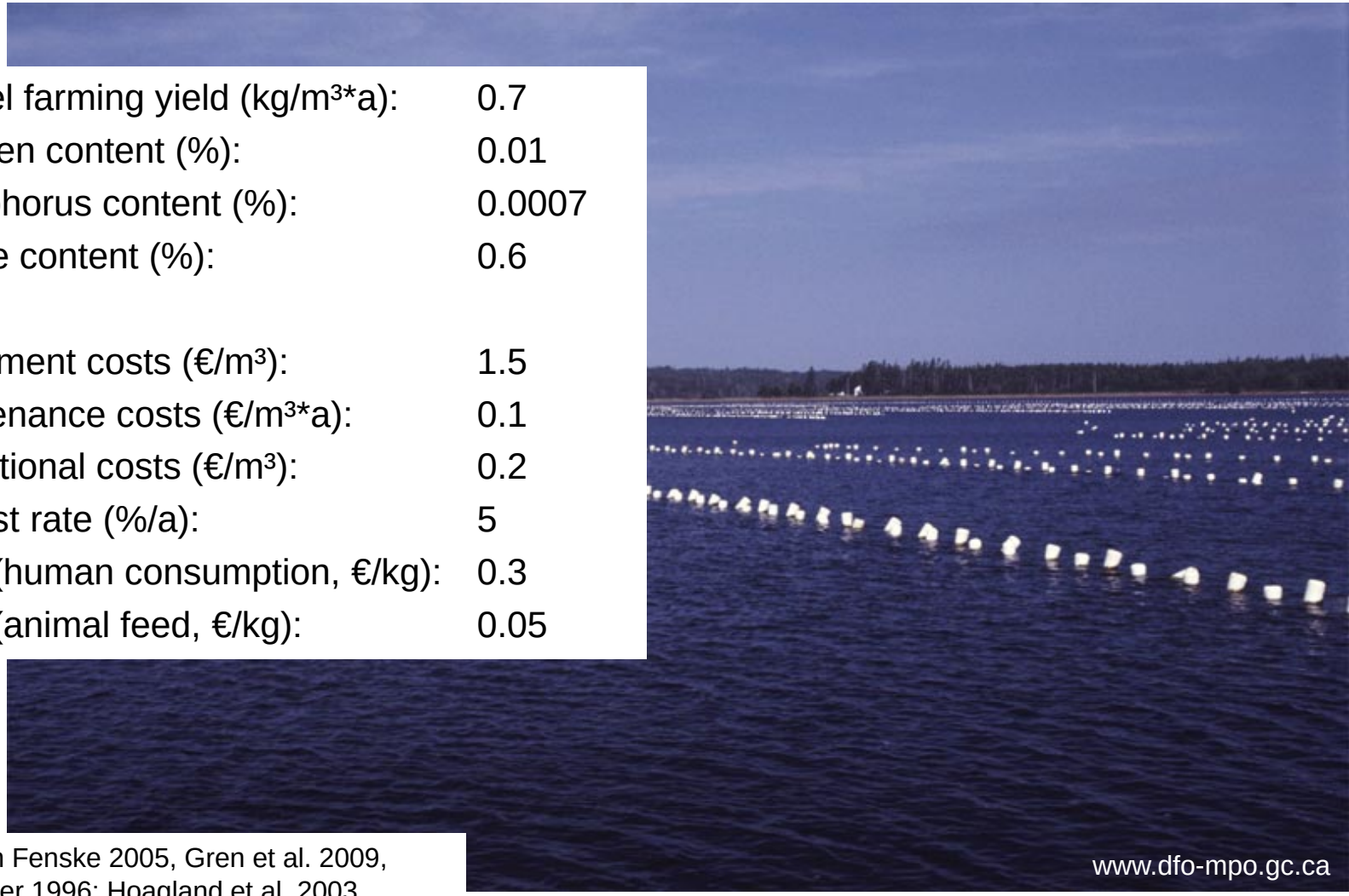
Zebra mussel farming:
Some basic assumptions in the economic model

- Mussel farming yield (kg/m³*a): 0.7
- Nitrogen content (%): 0.01
- Phosphorus content (%): 0.0007
- Calcite content (%): 0.6

- Investment costs (€/m³): 1.5
- Maintenance costs (€/m³*a): 0.1
- Operational costs (€/m³): 0.2
- Interest rate (%/a): 5
- Price (human consumption, €/kg): 0.3
- Price (animal feed, €/kg): 0.05

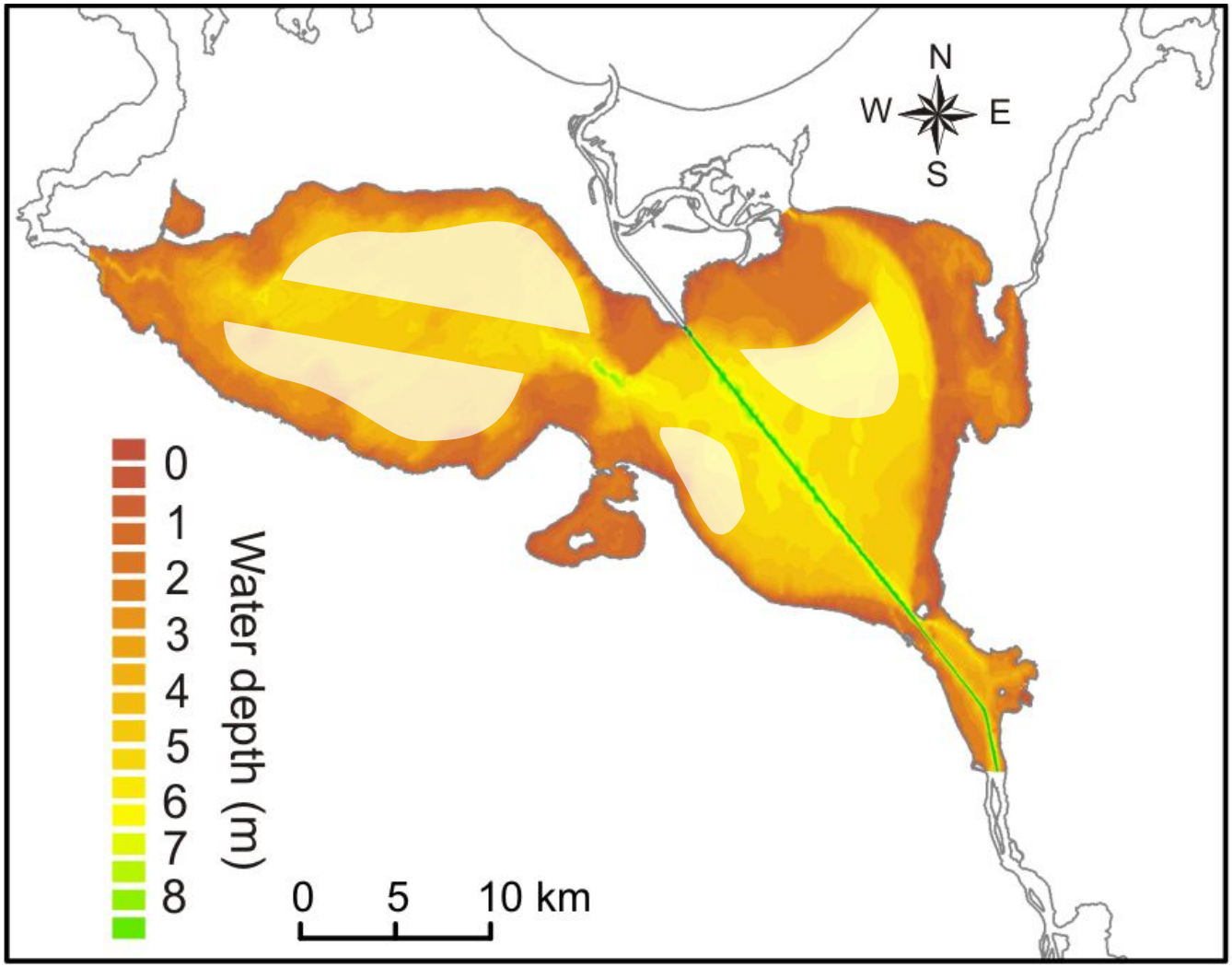


(after data in Fenske 2005, Gren et al. 2009, 2010; Haamer 1996; Hoagland et al. 2003, Jönsson et al. 2010; Lindahl et al. 2005, Smartfarm AS)

Zebra mussel farming: Carrying capacity

- Theoretical farming area (2 and 5 m water depth): 335 km²
- Max. realistic farming area: 134 km² (20% of the lagoon surface)

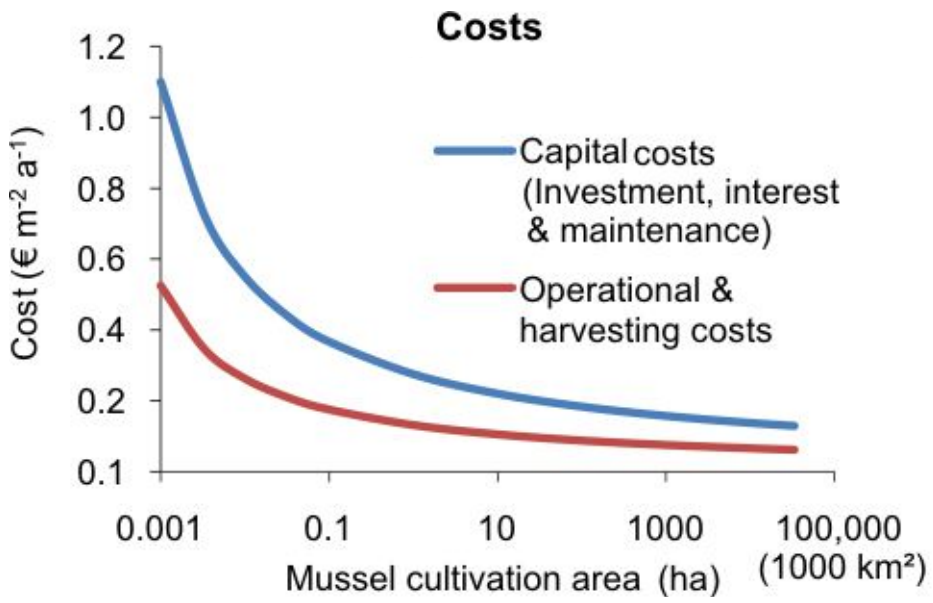
Derived from Thau Lagoon data; Dupuy et al. 2000; Gangnery et al. 2001

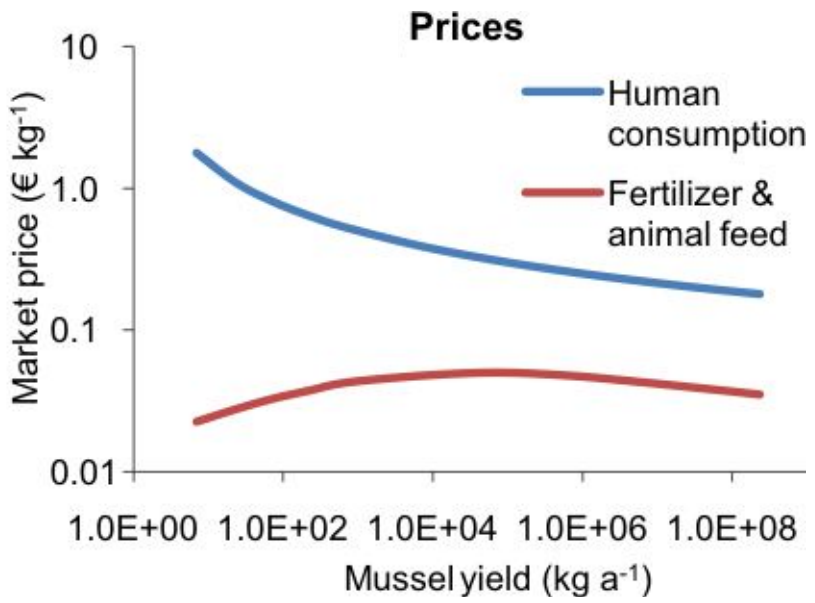


Zebra mussel farming:
Products, cost and price functions

Zebra mussel products:

- Human consumption (fresh, frozen, preservatives)
- Mussel meal as organic animal feed (chicken farming, aquaculture, pet food)
- Lime fertilizer





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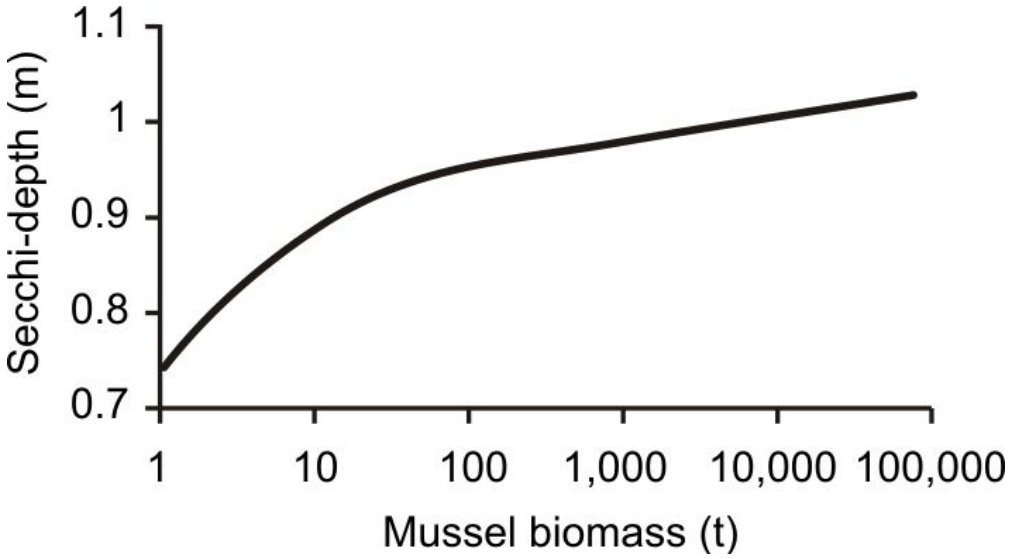
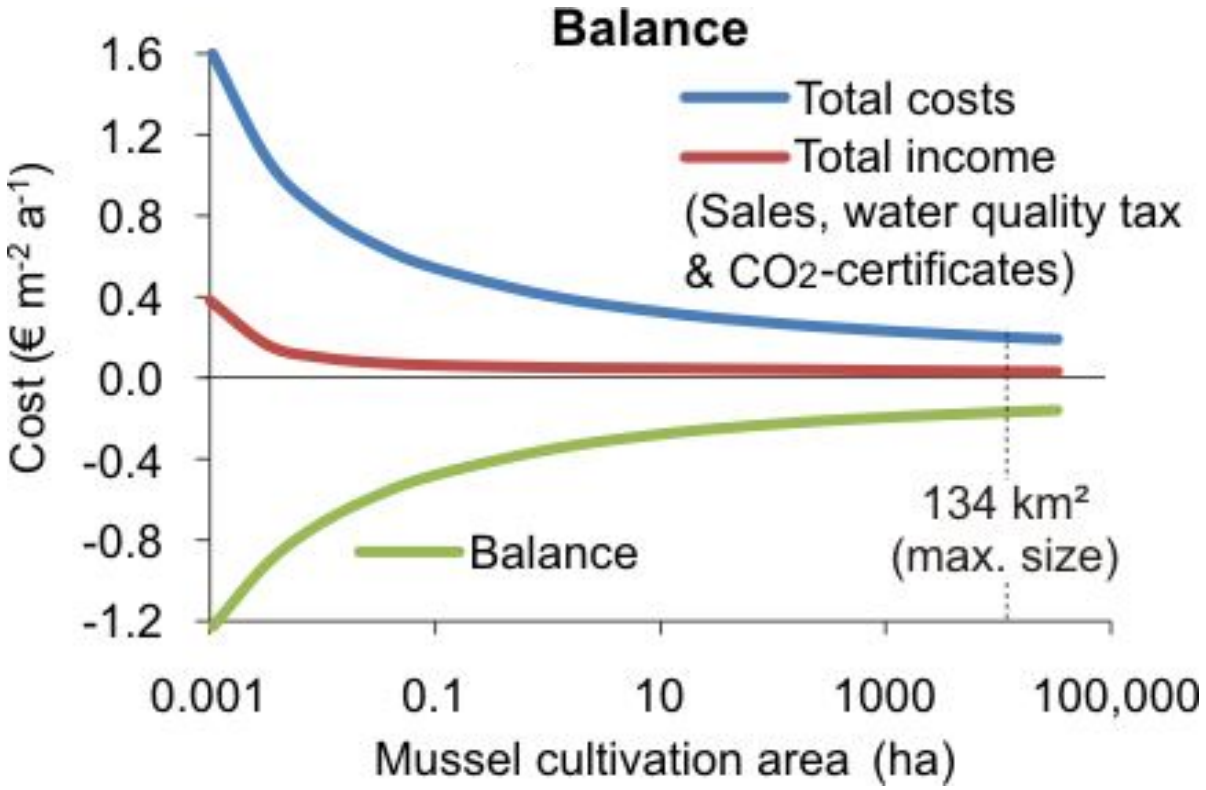
Zebra mussel farming:

Additional sources of income – water transparency and emission certificates



- **Water quality tax:** Tourists are willing to pay 1 €/day for one meter improved water transparency. The calculation is based on 200,000 over-night stays and 340,000 day tourists (Hirschfeld, unpubl. survey)
- **Tourism:** An 1.0 m improvement of water transparency would pursuade 25 % of the summer visitors to come 0.25 times more often. As a consequence, the number of summer overnight stays would increase by 6,850 (+6.75% of summer stays or +3.4% of annual overnight stays) (Hirschfeld, unpubl. survey)

Zebra mussel farming:
Balance between total costs and total income



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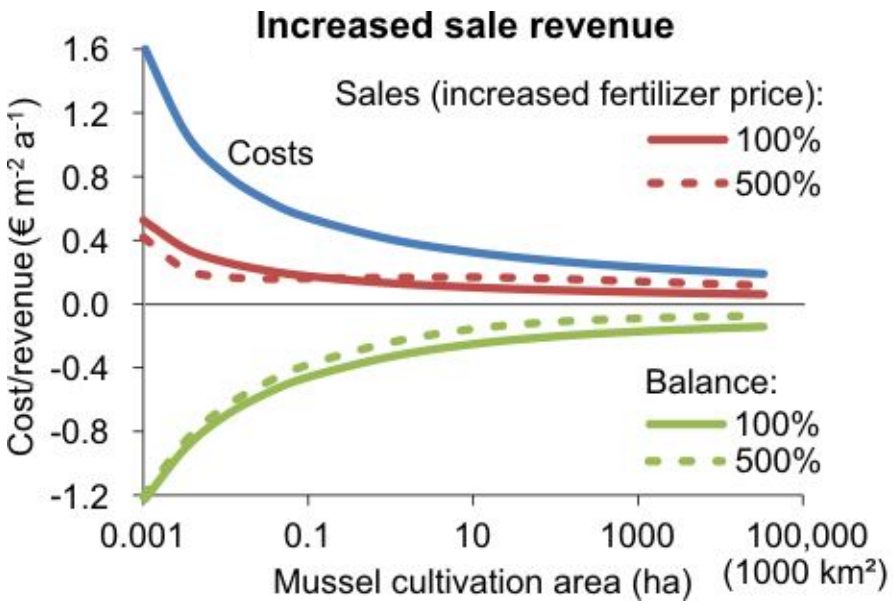
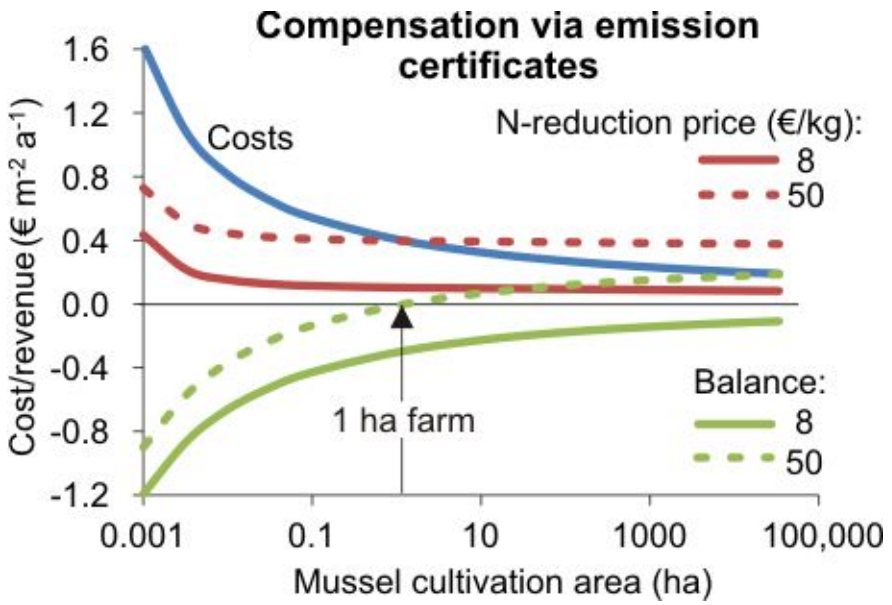
Zebra mussel farming:
Future scenarios

- impact of increased fertilizer/animal feed market prices on the profitability of mussel cultivation in the lagoon
- effect of additional income from nitrogen emission certificates (financial compensation/subsidy for removing nitrogen from surface waters) on profitability





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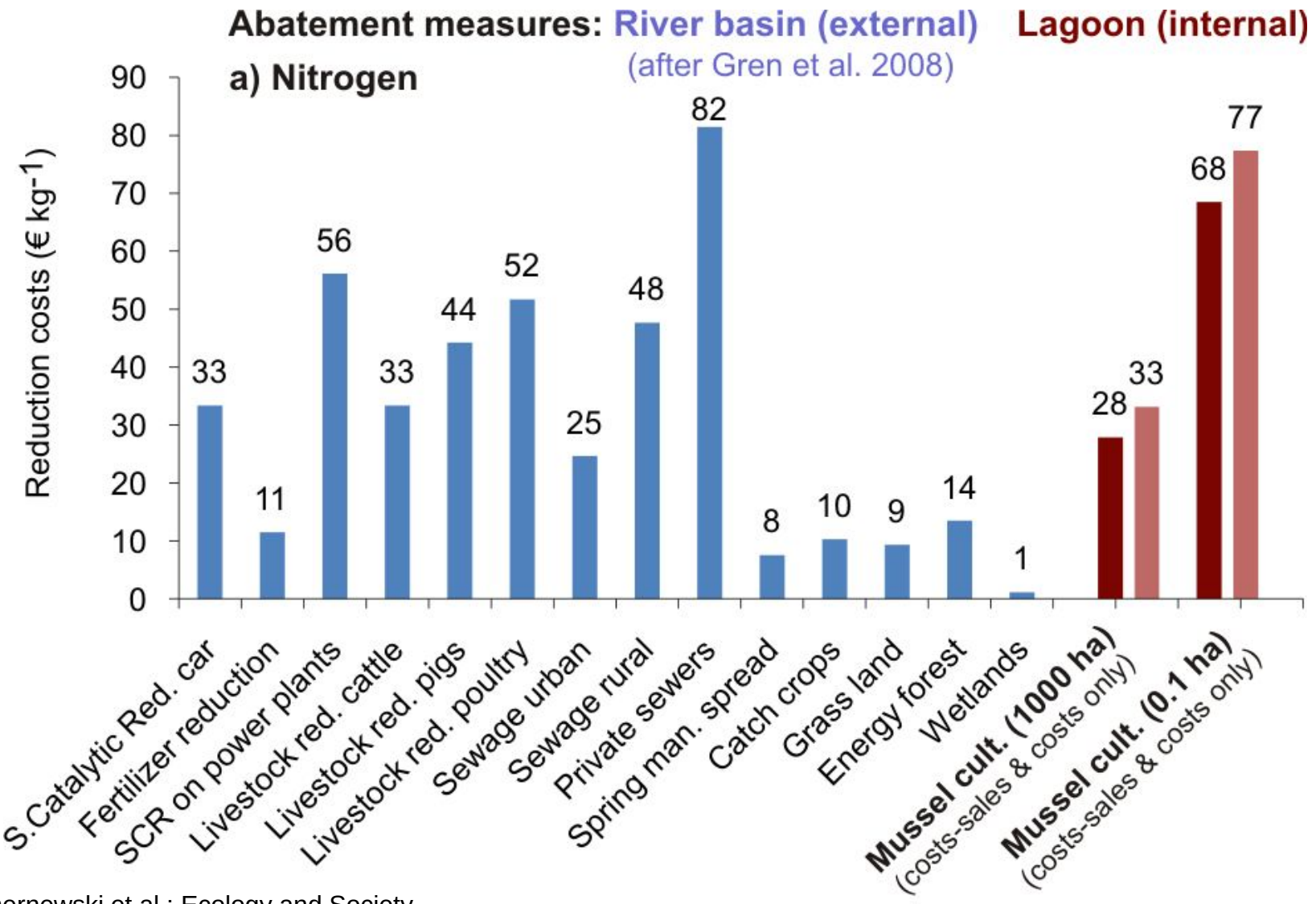
Zebra mussel farming:

Costs of measures in the Oder/Odra river basin to reduce 1 kg of nitrogen



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Is Zebra mussel (*Dreissena*) farming a realistic option?

Strengths and weaknesses

SWOT-Analysis
Zebra mussel cultivation in Baltic coastal waters

Strengths & opportunities

Removal of nutrients via harvest and **increased water transparency**

Efficent WFD measure if water quality is indicated by transparency

High-quality protein and fat acid source with increasing prices for products

Mussel meal as subsitute for fish meal reduces pressure on wild fish stocks

Re-settlement of macrophytes due to improved water transparency (possibly regime shift)

„Native“ species used and **knowledge transfer** from Blue mussel cultivation

Synergy effects with local fisheries and alternative jobs for fishermen

Increased number of tourists because of improved water transparency and a new local attraction (dishes, excursions)

Reduction of summerly algal blooms

Weaknesses & threats

Lack of experience in Zebra mussel cultivation and processing methods

End-of-pipe solution for nutrients

Not profitable without subsidies and requires large scale investments

Uncertain legal situation

Uncertain effects on the ecosystem (denitrification, shifts in species composition, increased risk of hypoxia)

Accumulation of pollutants

Damage of farms by drifting ice

Losses due to predation

Spreading and settling of mussels on constructions and boats

Lack of tradition, poor acceptance of Zebra mussels and products and uncertain commercial use

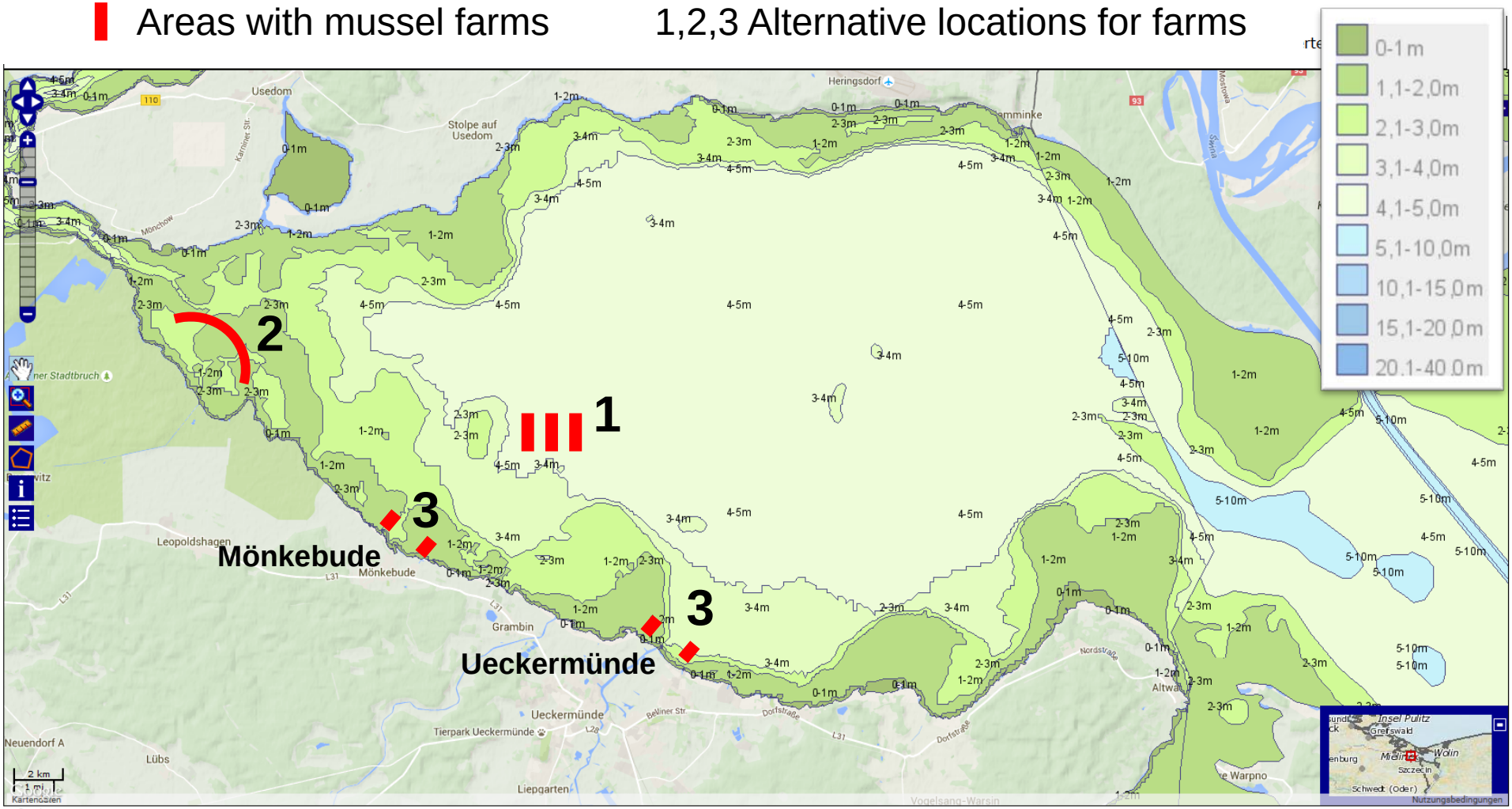
Conlusion and the way ahead

- Zebra mussel farming is a **suitable supportive measure to remove nutrients** and to protect the Baltic Sea. In the Oder/Odra mussel farming potentially could remove nearly 1000 t N per year or 2 % of the annual Oder N-loads. Its potential is limited in the Oder Lagoon, but this is different for other systems.
- Zebra mussel farming is **not a cost-effective measure** to remove nutrients today. At a N-load reduction target of 50% and more, mussel farming would become cost-efficient and has the additional benefit of improving water transparency.
- Zebra mussel farms in the lagoon are **not profitable** and would require additional subsidies.
- Zebra mussel farming can be regarded as **environmental friendly** as long as the carrying capacity and specific max. density are not exceeded. Mussel meal as the major product of Zebra mussel farming can substitute fish meal and help to implement a sustainable fisheries.
- In the Oder Lagoon mussel farming will very likely not allow a **regime shift** from a phytoplankton dominated into a clear water, macrophyte dominated system.
- Extended **mussel beds** seem to be no suitable nutrient retention measure but the increasing water transparency would have positive effects on the ecosystem.
- Mussel farming may be a suitable measure to tackle defined and spatially limited problems. This needs to be further explored…..

Scenarios for mussel farms in the Oder lagoon

Areas with mussel farms

1,2,3 Alternative locations for farms



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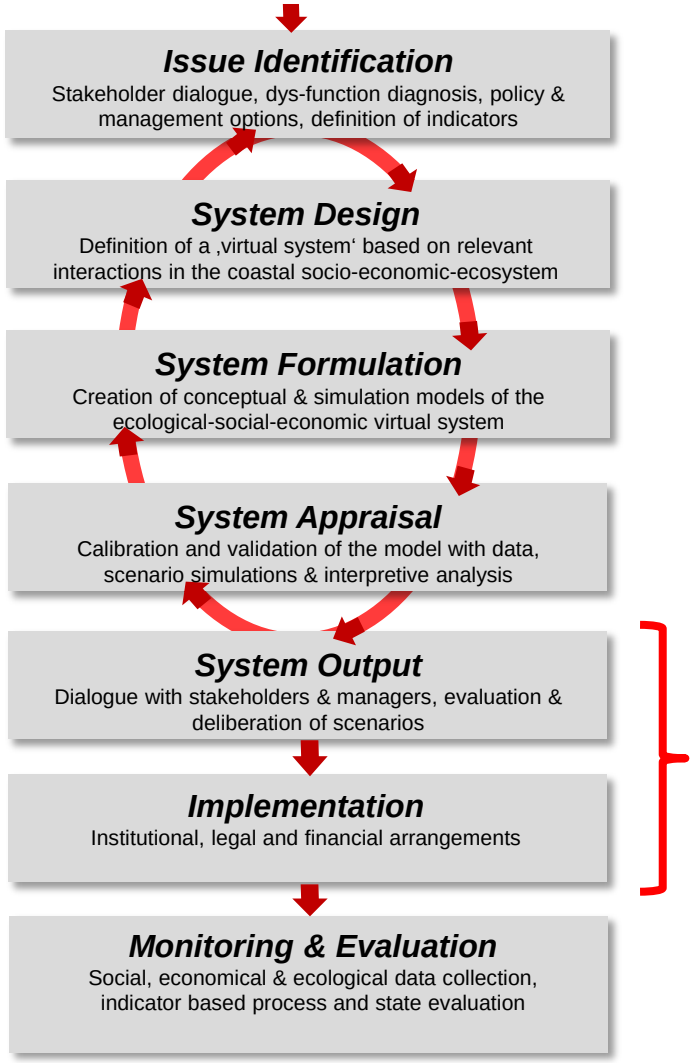
http://gis.eucc-d.de/ikzm/

Systems Approach Framework

Ecological-Social-Economic-Assessment (ESE)



Mussel-farming in the Oder lagoon was subject to two System Approach Framework cycles!

Where is the implementation?

The problem: The Quagga mussel, (*Dreissena bugensis*)


Source: Wikipedia

- is indigenous to the Dnieper River drainage of Ukraine.
- is of major concern in the Great Lakes of North America as an invasive species brought by overseas shippers that use the St. Lawrence Seaway.
- **is currently invading the Oder lagoon**

The alternative:
Active management and extension of macrophytes belts (requires a 3rd SAF cycle)

or:
to tackle a different system like the Greifswalder Bodden

Thank you for your attention!

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BONUS BaltCoast

RA:dOst Regionale Anpassungsstrategien für die deutsche Ostseeküste

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