



Workshop “Mussel farming in the Baltic: experiences and perspectives”  
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## **Managing Eutrophication: Cost-effectiveness of Zebra mussel farming in the Oder (Szczecin) Lagoon**

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# 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).

# The Oder/Odra river-coast-sea system



**Oder/Odra river basin**

Length (km):	854
Catchment (km <sup>2</sup> ):	118,000
Discharge (m <sup>3</sup> /s):	530 (average)
Population (Mio):	15.4

**Oder/Odra estuary**

Catchment (km <sup>2</sup> ):	8000
Lagoon area (km <sup>2</sup> ):	687
Lagoon depth (m):	3.7 (average)

**Coastal climate:**

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



# Tourism at the Oder Lagoon









**Oder/Szczecin  
Lagoon**



Schernewski  
(2008)





**Eutrophication and algal blooms  
in the Oder Lagoon**



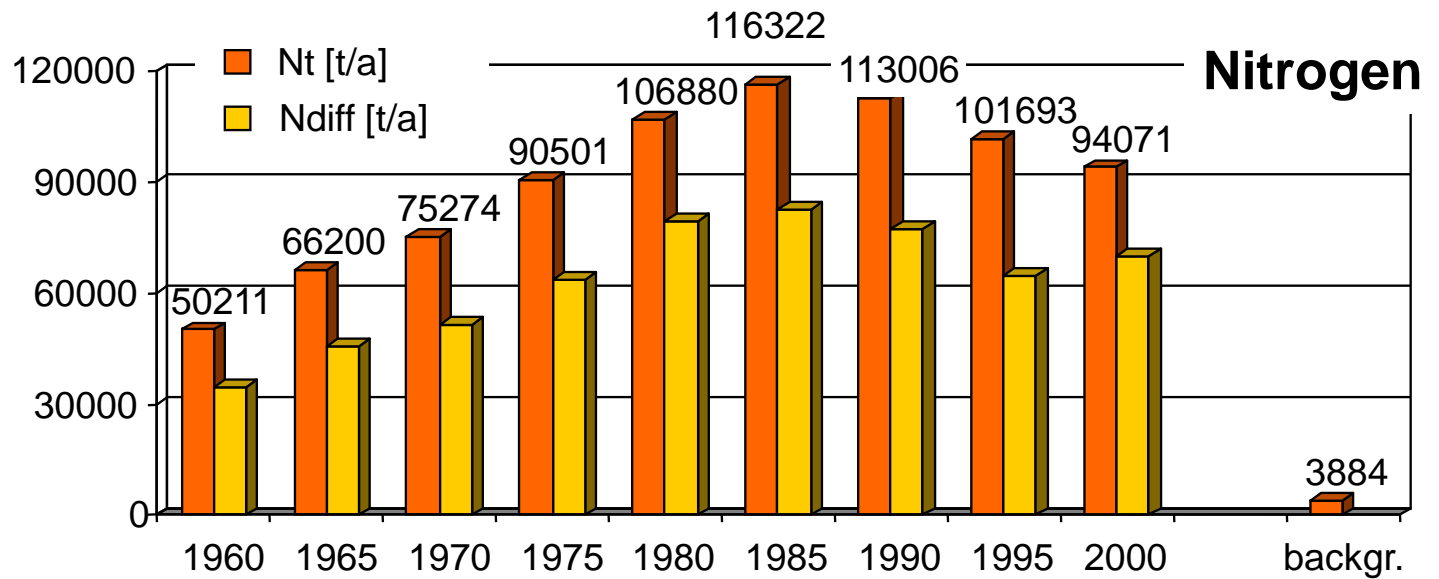
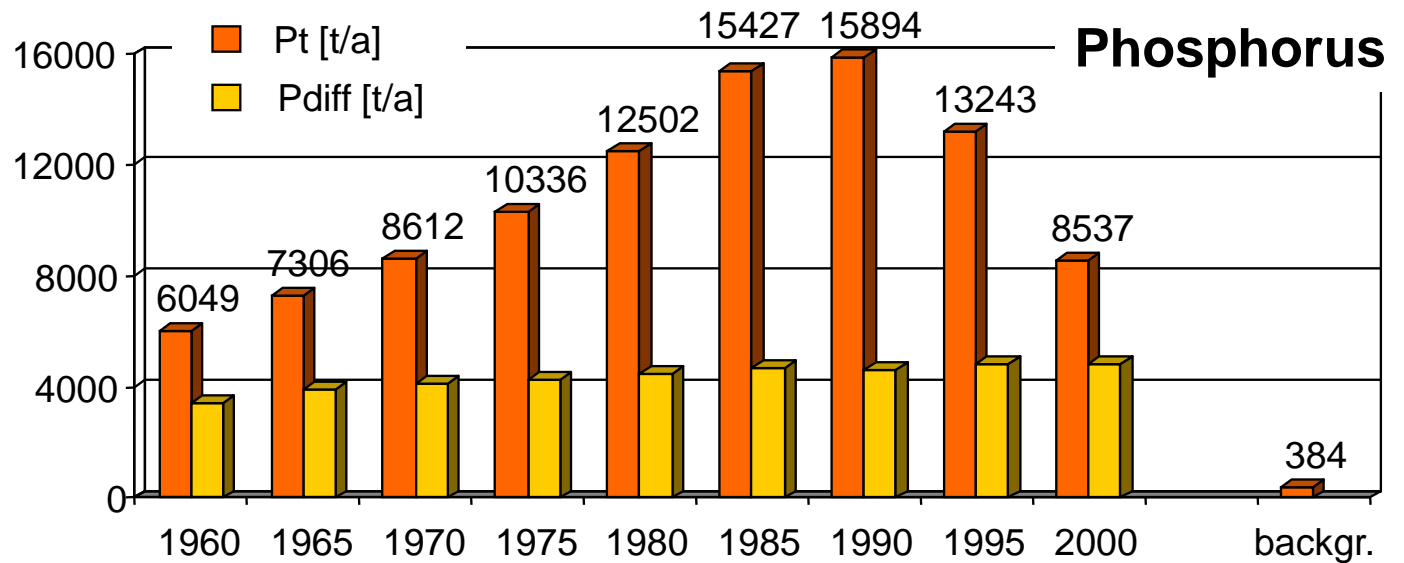
## Hypoxia in the Oder Lagoon

Lotter (1999)



Oder Lagoon in May 2000 (Schernewski 2000)

# Oder/Odra river nutrient loads



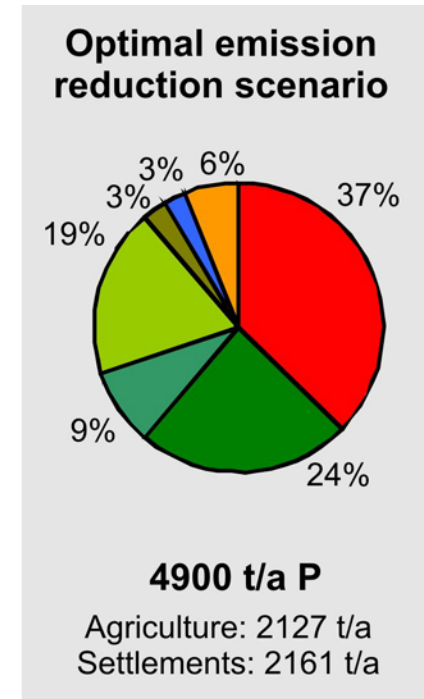
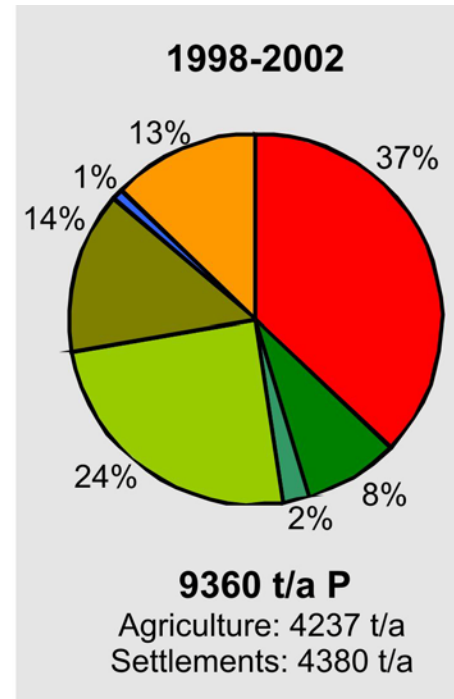
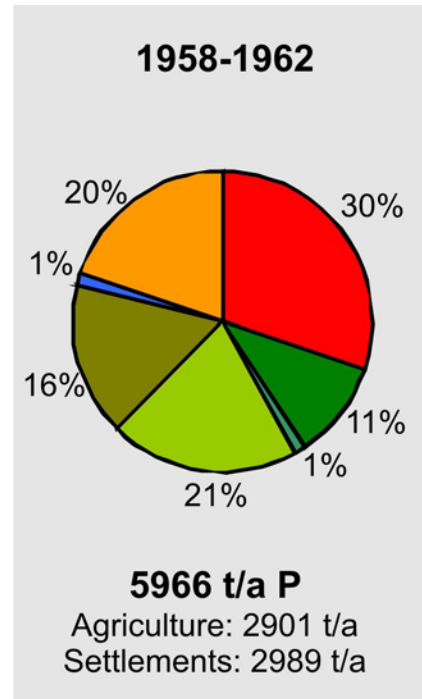


# Possible nutrient load reductions in the river basin

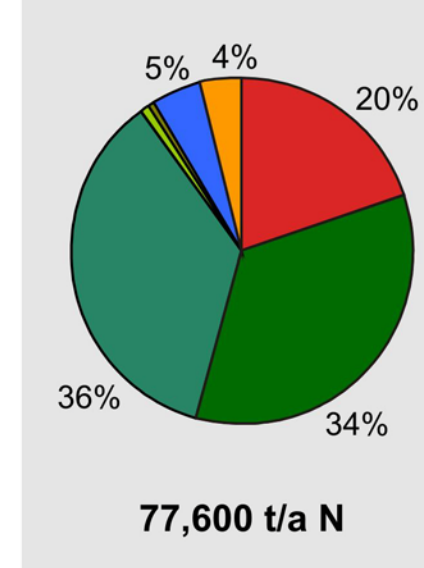
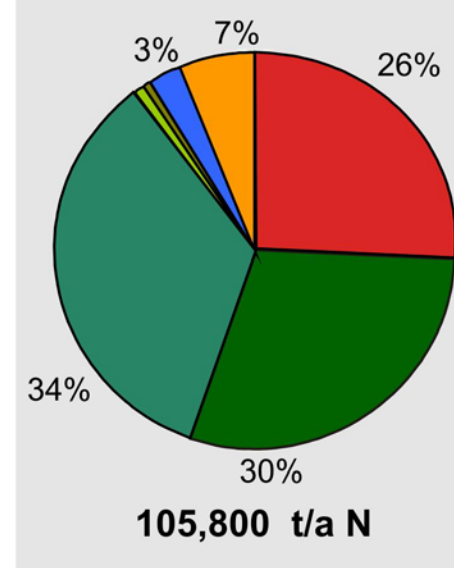
## Questions:

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?



- Urban areas
- Point sources
- Groundwater
- Tile drainage
- Erosion
- Surface runoff
- Atm. deposition



# 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)!

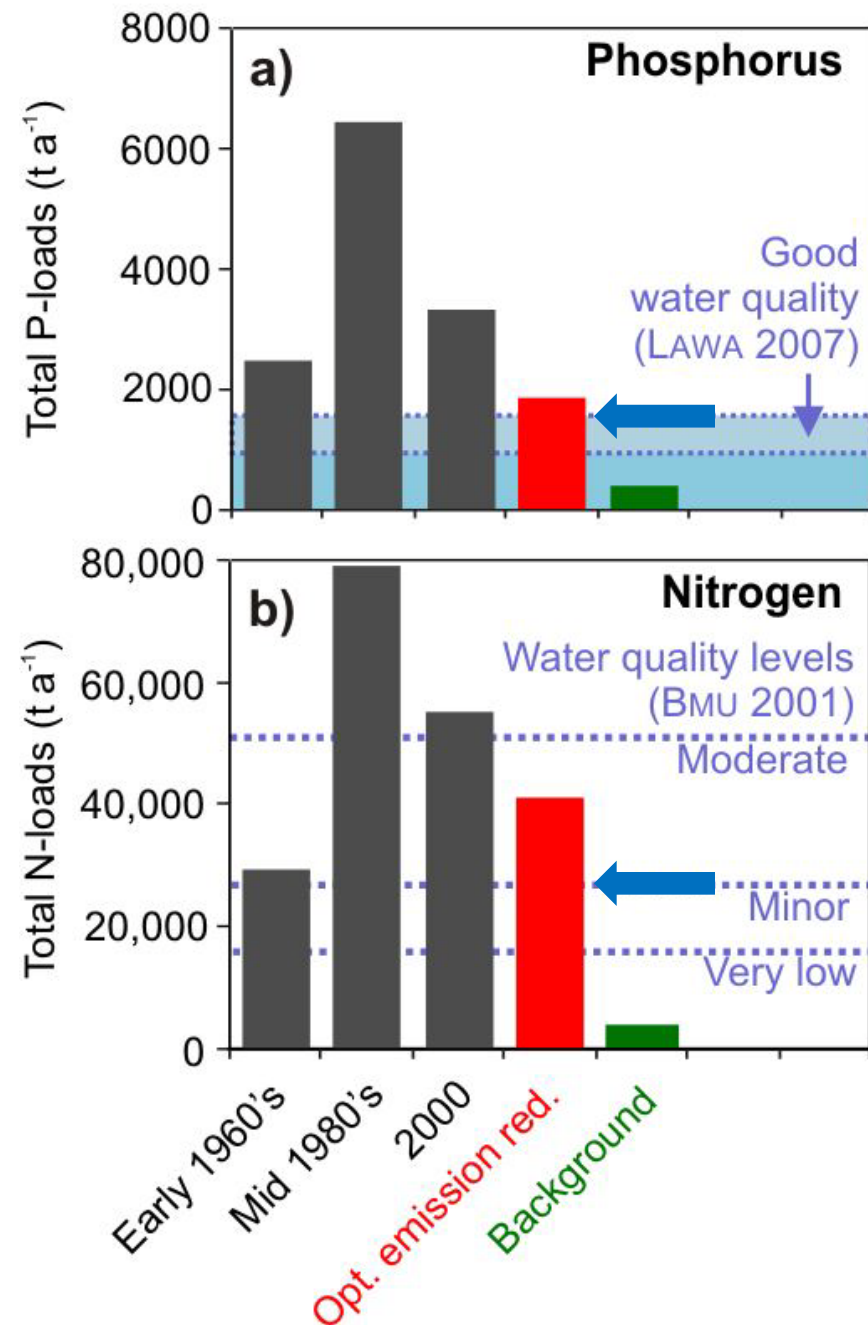
The lagoon would by far not reach a “good” water quality (WFD) and remain in a highly eutrophied state.

## Consequences:

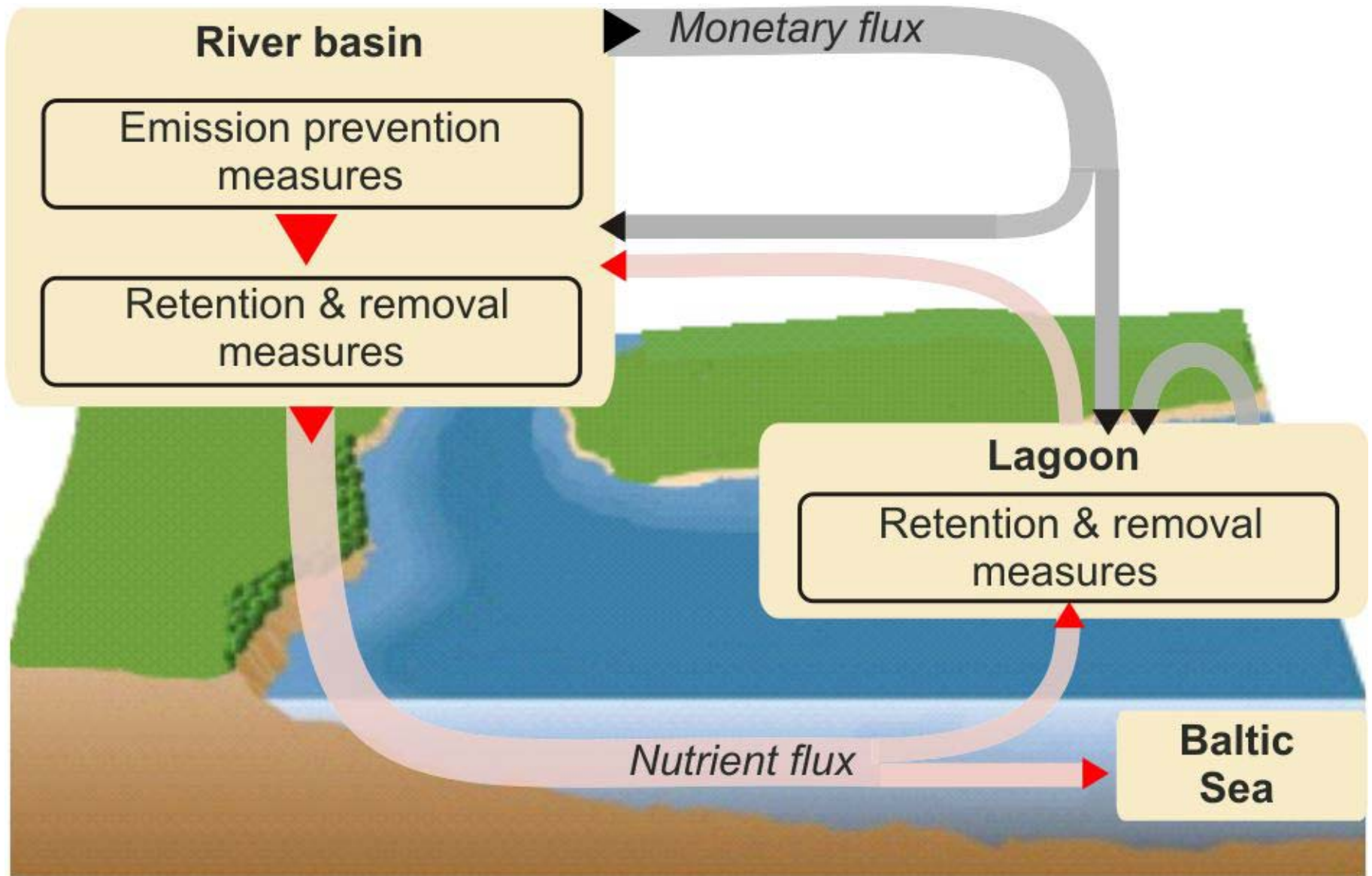
Nutrient load reductions into the river beyond the requirements of the BSAP are necessary.

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.



# Integrated approach to eutropication management



# 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

# 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?

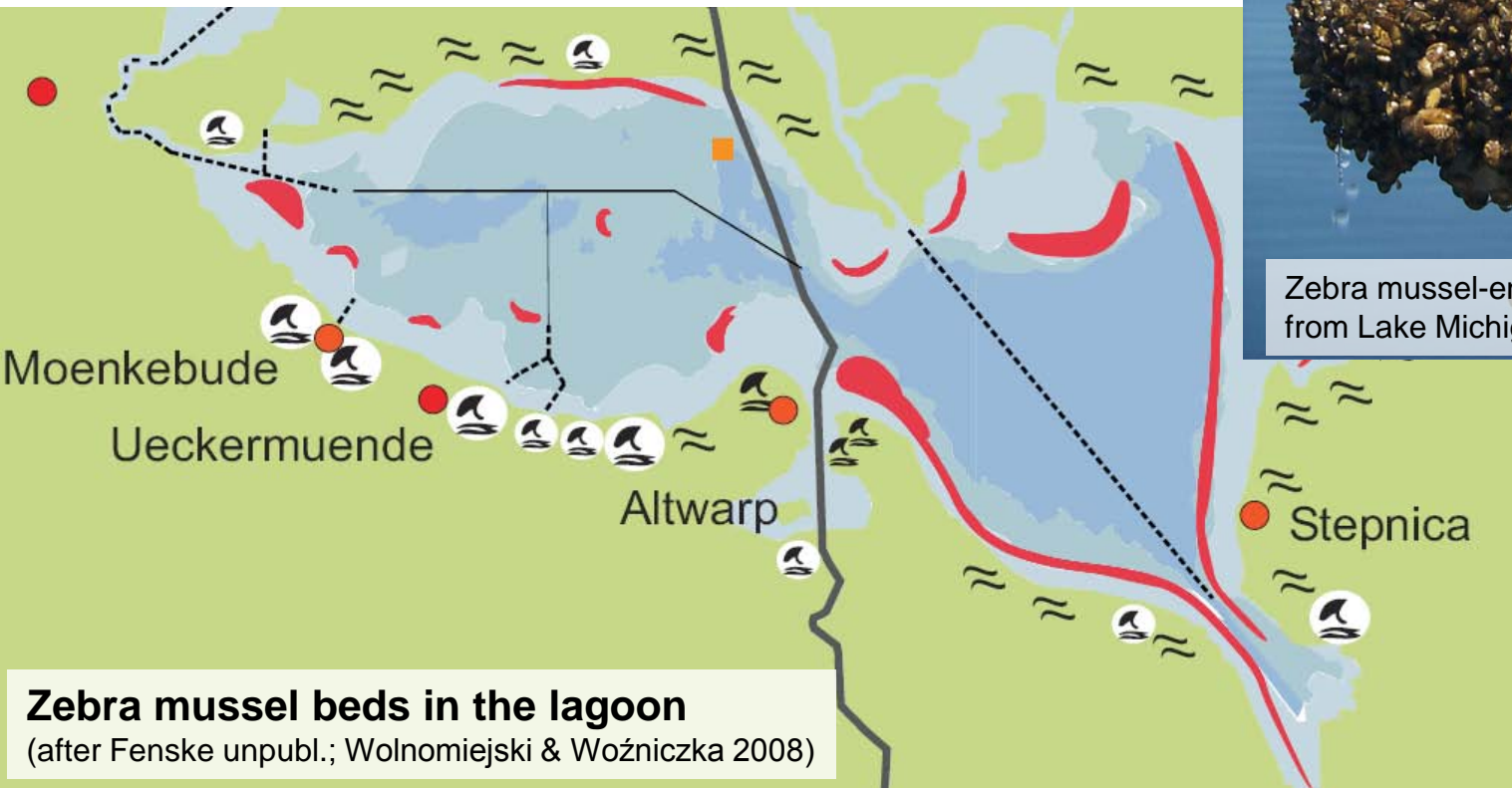
# Zebra mussels in the Oder/Szczecin Lagoon

- Total biomass: ca. 68.000 t (about 8.000 t in the German part)
- Mussel beds in the German part: 6,56 km<sup>2</sup> 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-encrusted current meter from Lake Michigan (Wikipedia)

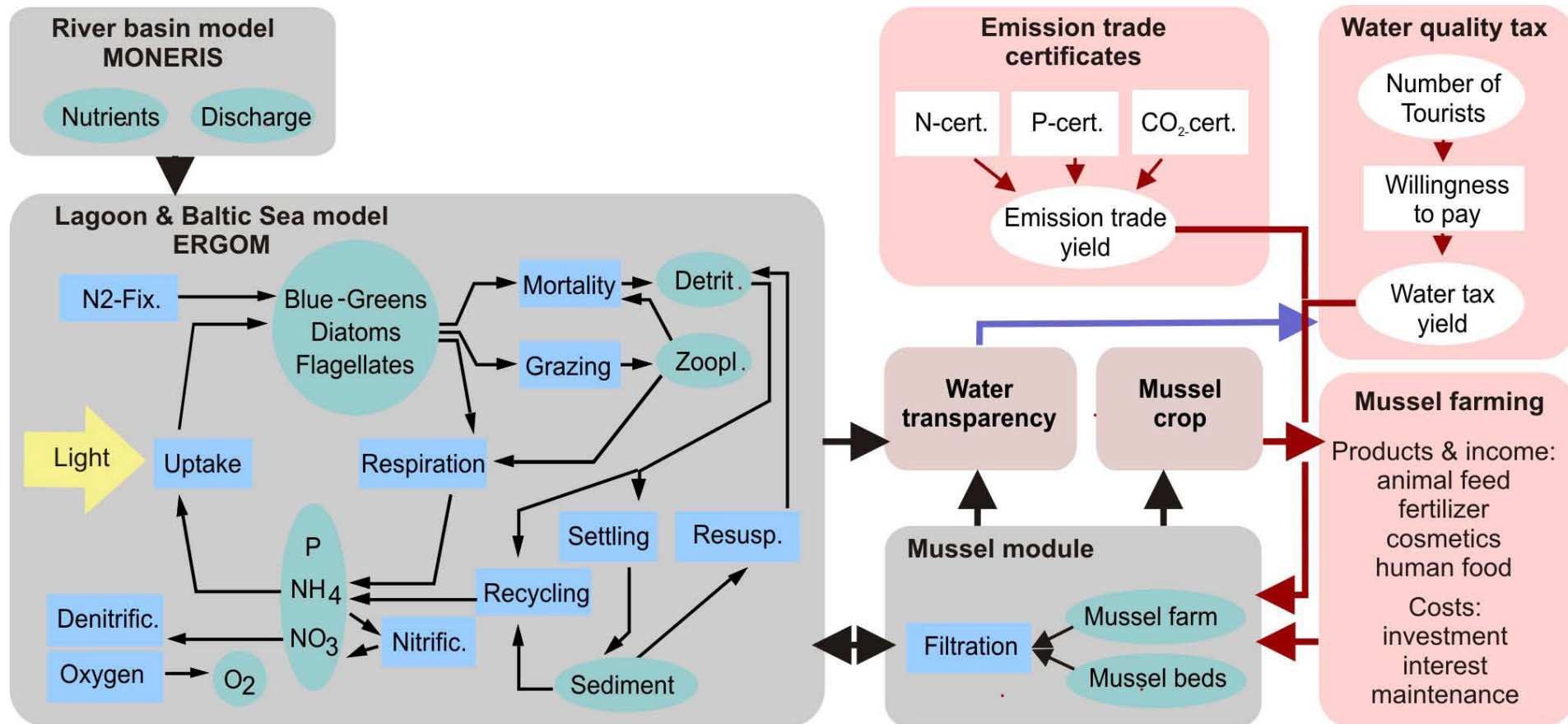


## Zebra mussel beds in the lagoon

(after Fenske unpubl.; Wolnomiejski & Woźniczka 2008)

## Our approach:

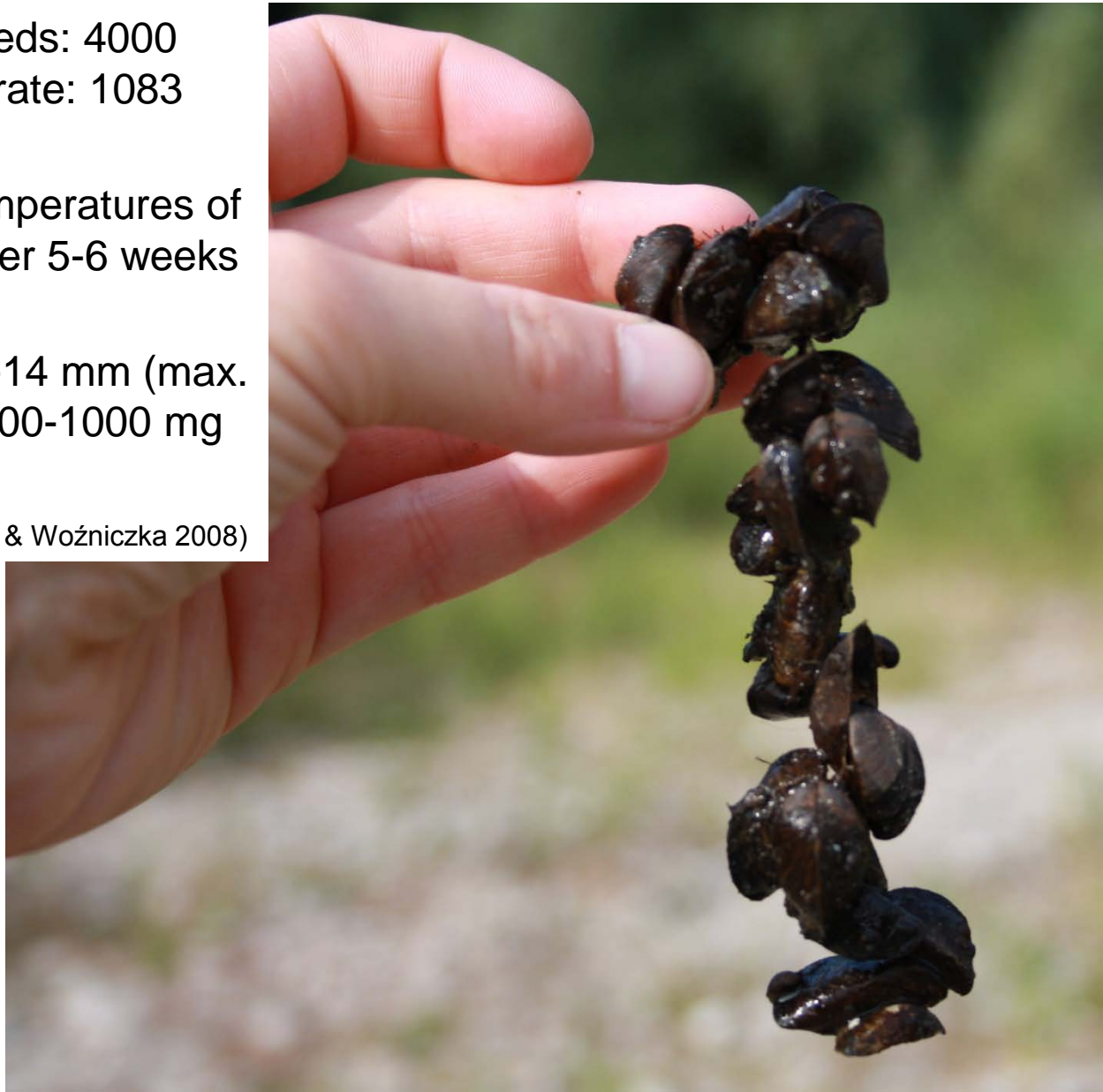
- Extension of an ecological model by a mussel module
- Development of an economic model
- Linking both models via water transparency and mussel yield
- Scenario simulations with the model system



## Zebra mussel beds in the lagoon

- Average abundance on beds: 4000 mussels per m<sup>2</sup>, filtration rate: 1083 l/m<sup>2</sup>\*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)





# Zebra mussel farming:

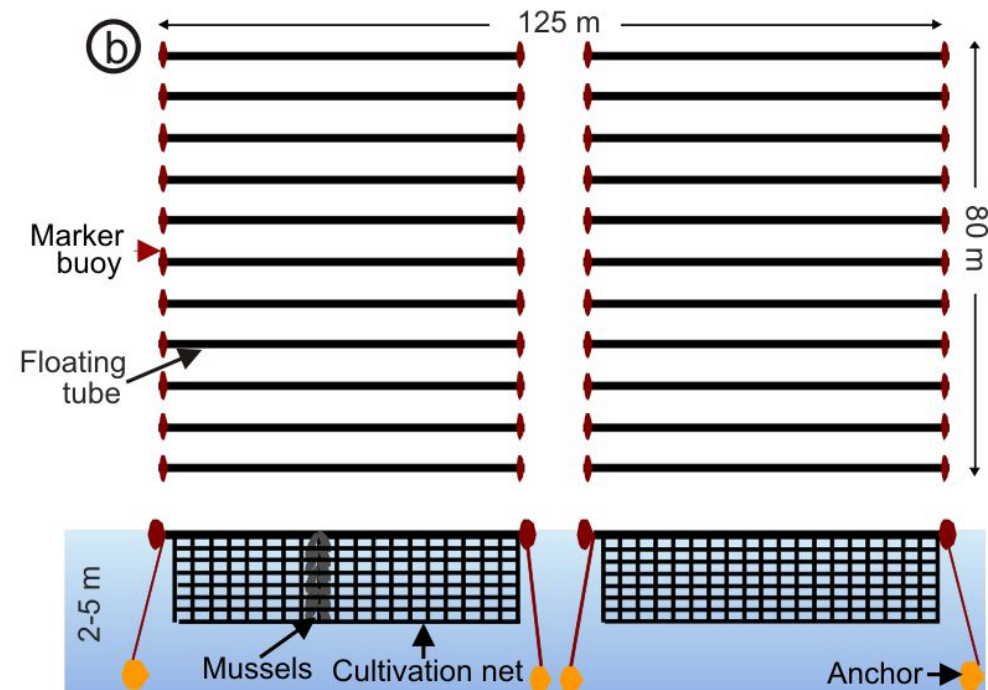
## Some basic assumptions in the economic model

- Mussel farming yield ( $\text{kg}/\text{m}^3 \cdot \text{a}$ ): 0.7
- Nitrogen content (%): 0.01
- Phosphorus content (%): 0.0007
- Calcite content (%): 0.6
  
- Investment costs ( $\text{€}/\text{m}^3$ ): 1.5
- Maintenance costs ( $\text{€}/\text{m}^3 \cdot \text{a}$ ): 0.1
- Operational costs ( $\text{€}/\text{m}^3$ ): 0.2
- Interest rate (%/a): 5
- Price (human consumption,  $\text{€}/\text{kg}$ ): 0.3
- Price (animal feed,  $\text{€}/\text{kg}$ ): 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)



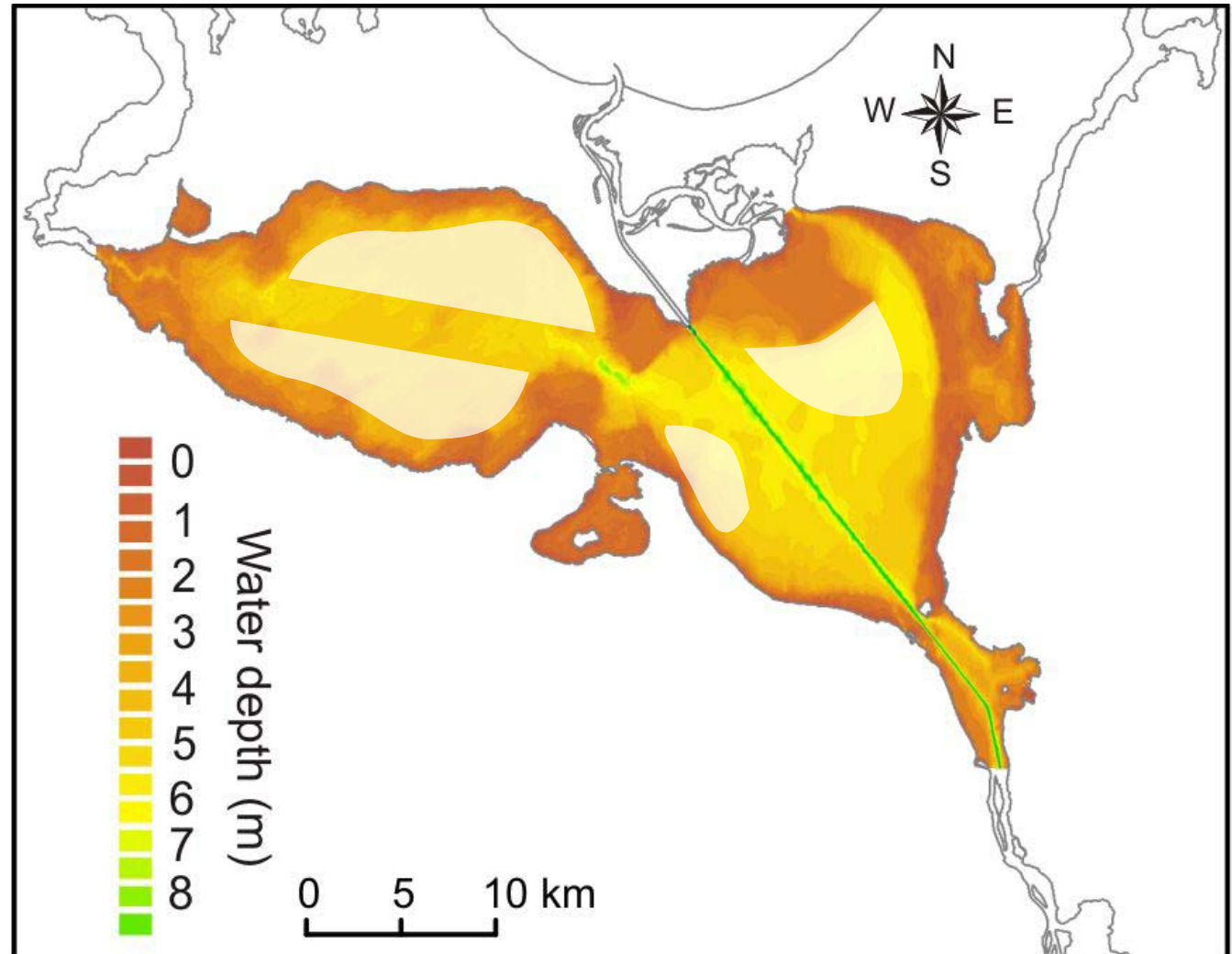
Smartfarm AS



## Zebra mussel farming: Carrying capacity

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

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

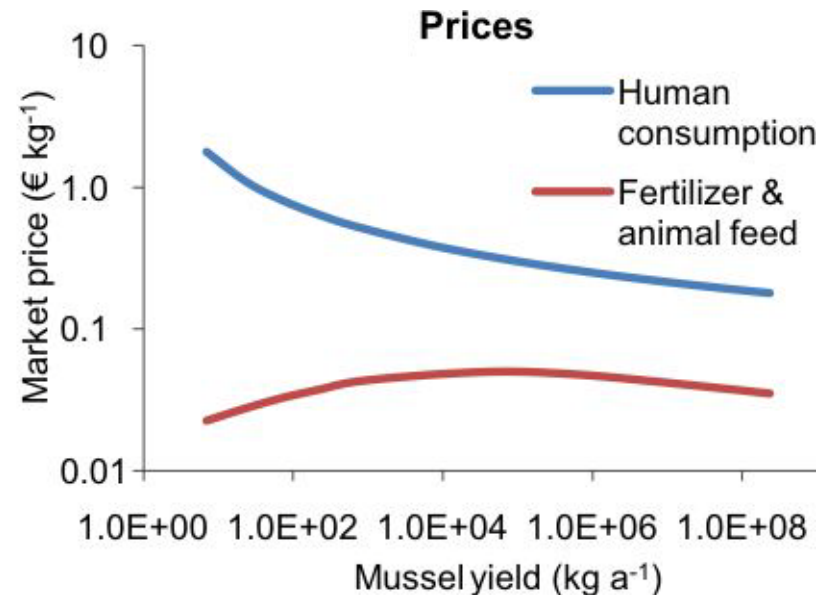
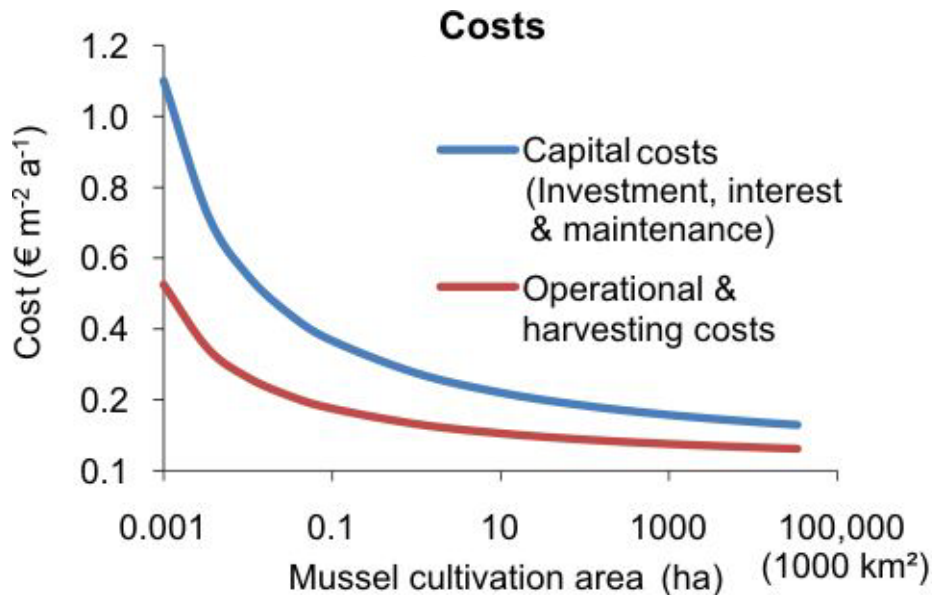


# Zebra mussel farming: Products, cost and price functions



## Zebra mussel products:

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



# Long-line mussel farming



[www.dfo-mpo.gc.ca](http://www.dfo-mpo.gc.ca)



[www.dfo-mpo.gc.ca](http://www.dfo-mpo.gc.ca)

## 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.)

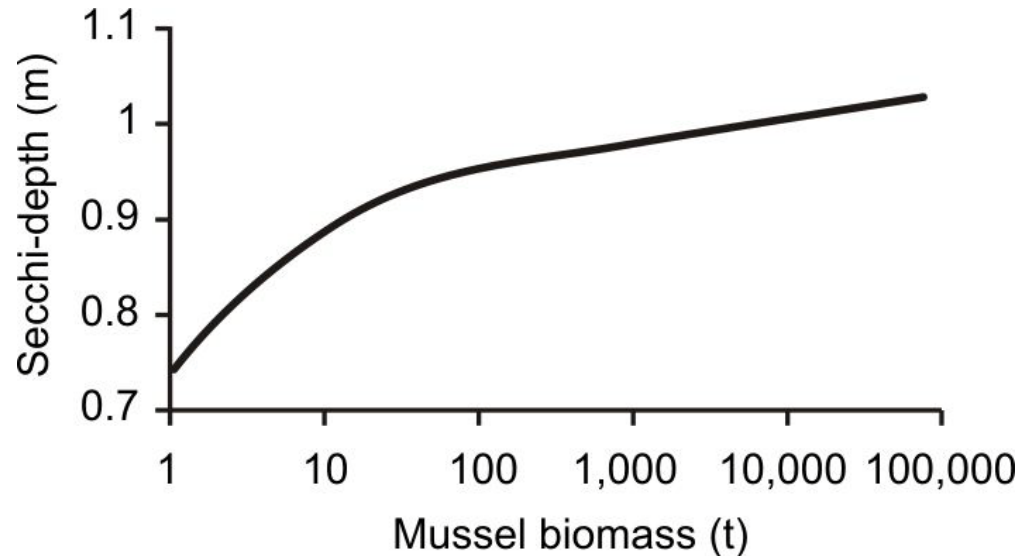
## Mussels for human consumption: Vongole



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

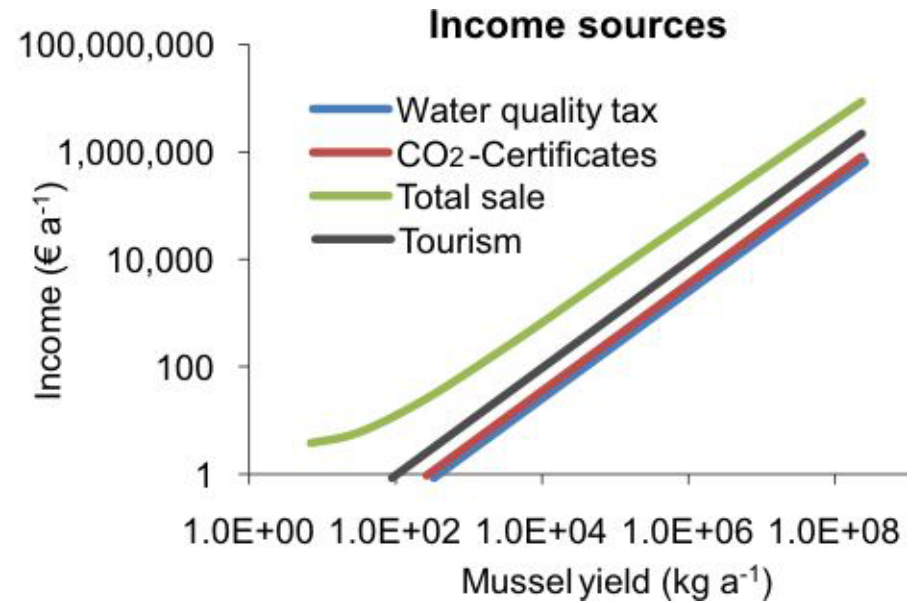
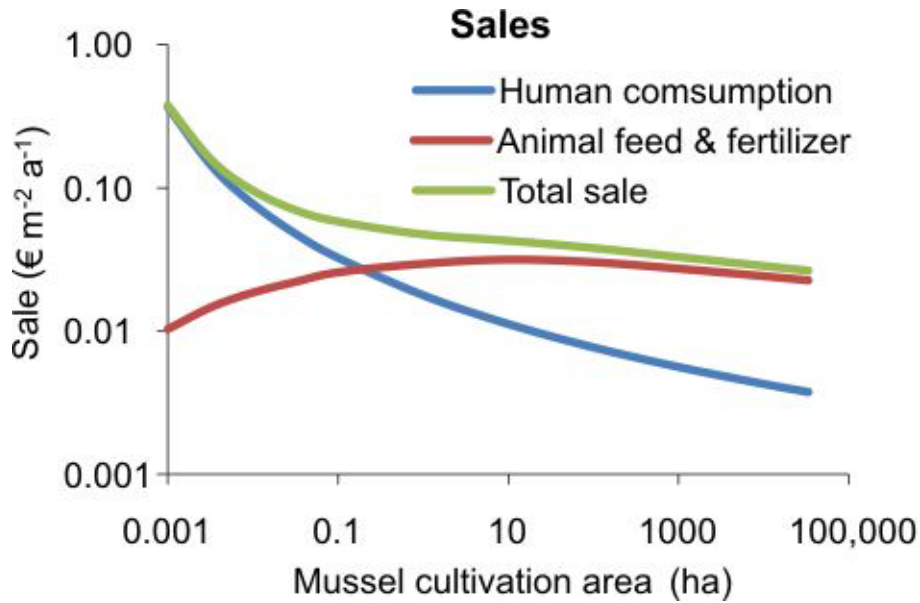
## Zebra mussel farming:

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 persuade 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)
- **CO<sub>2</sub>-emission certificates:** Verified Emission Reduction futures (Carbonfix standard) which are sold on the voluntarily market at a price of 12 €/t (adapted from BaumInvest project). 26.4% CO<sub>2</sub> in fresh mussels (shells) are assumed.

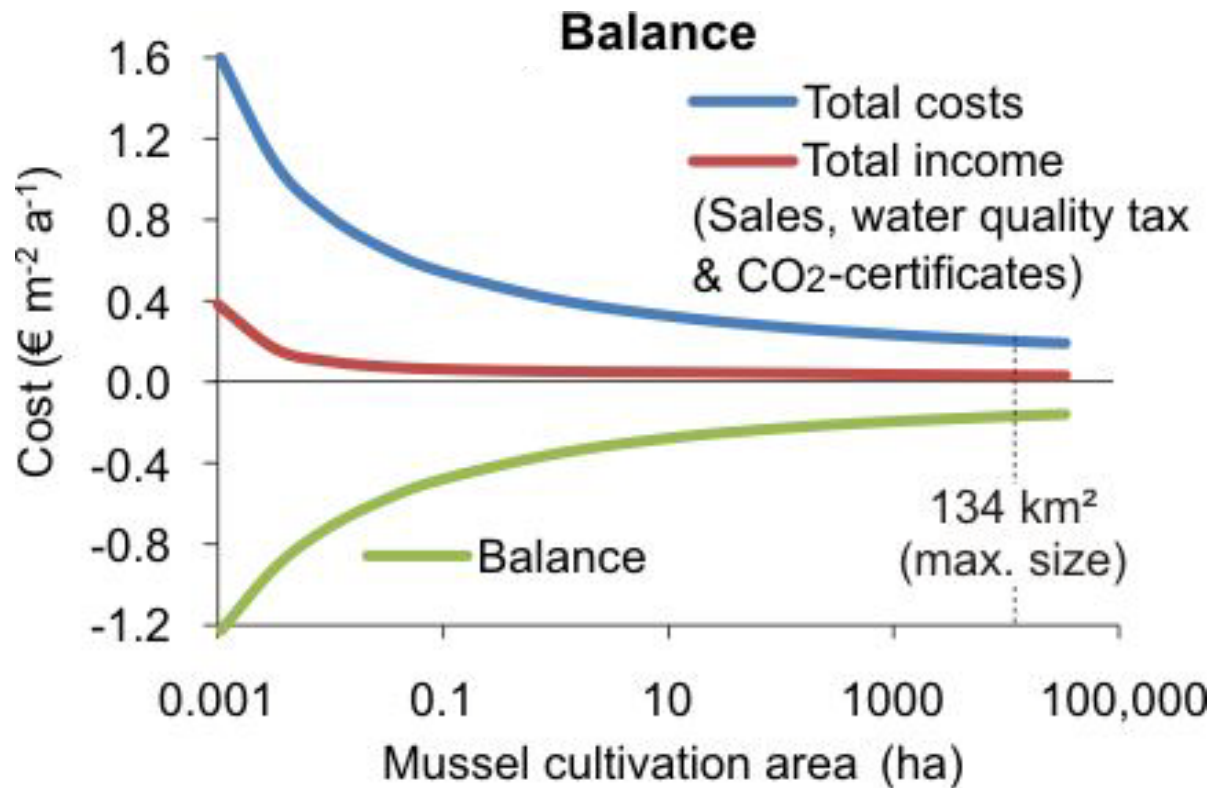
# Zebra mussel farming: Sales and additional sources of income





# Zebra mussel farming:

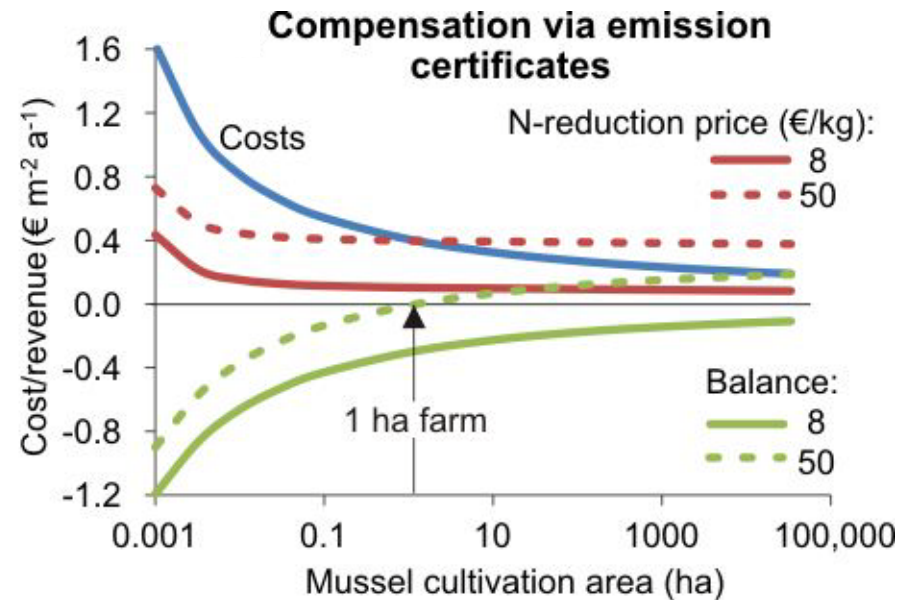
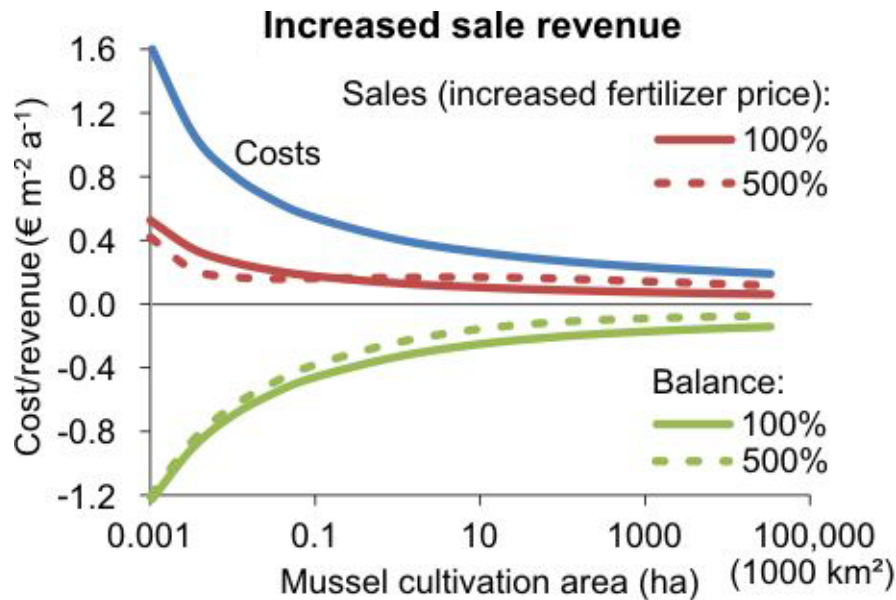
Balance between total costs and total income



# Zebra mussel farming:

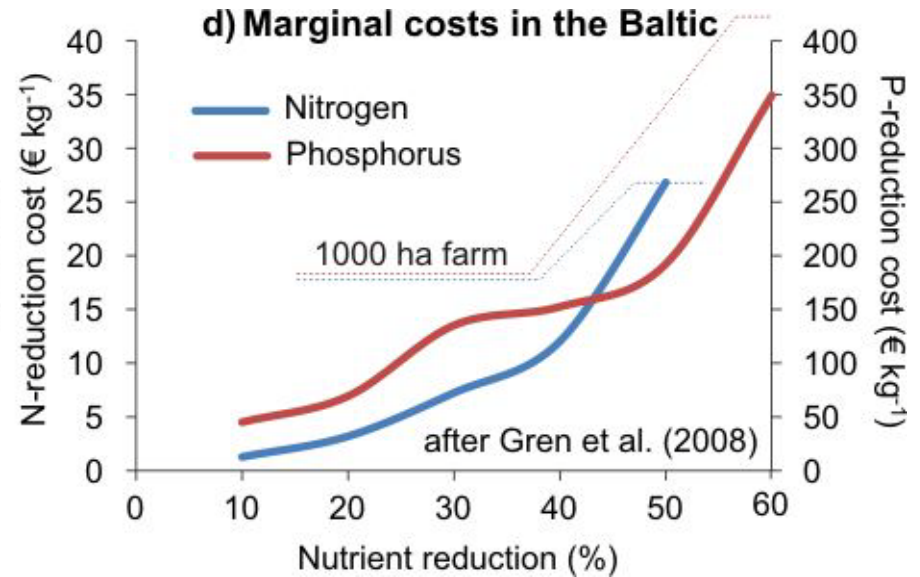
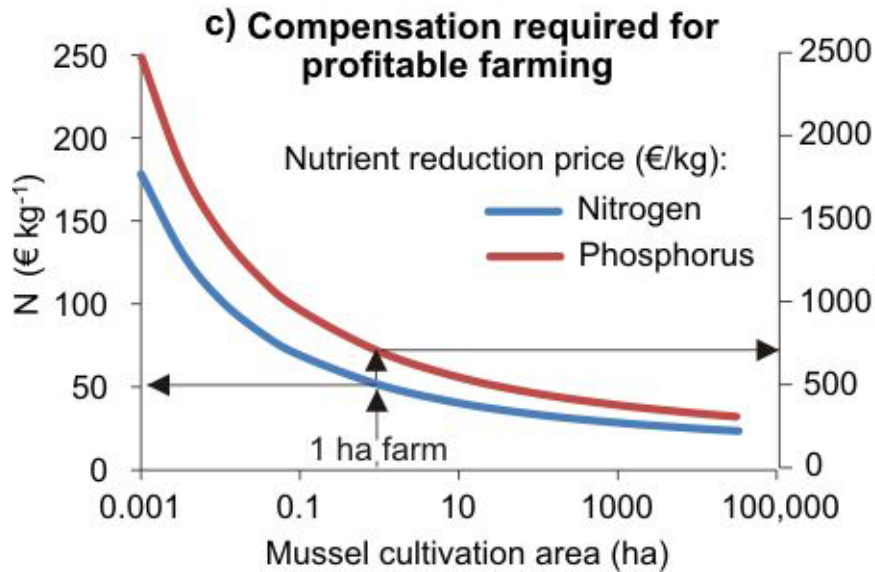
## Future scenarios

- 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



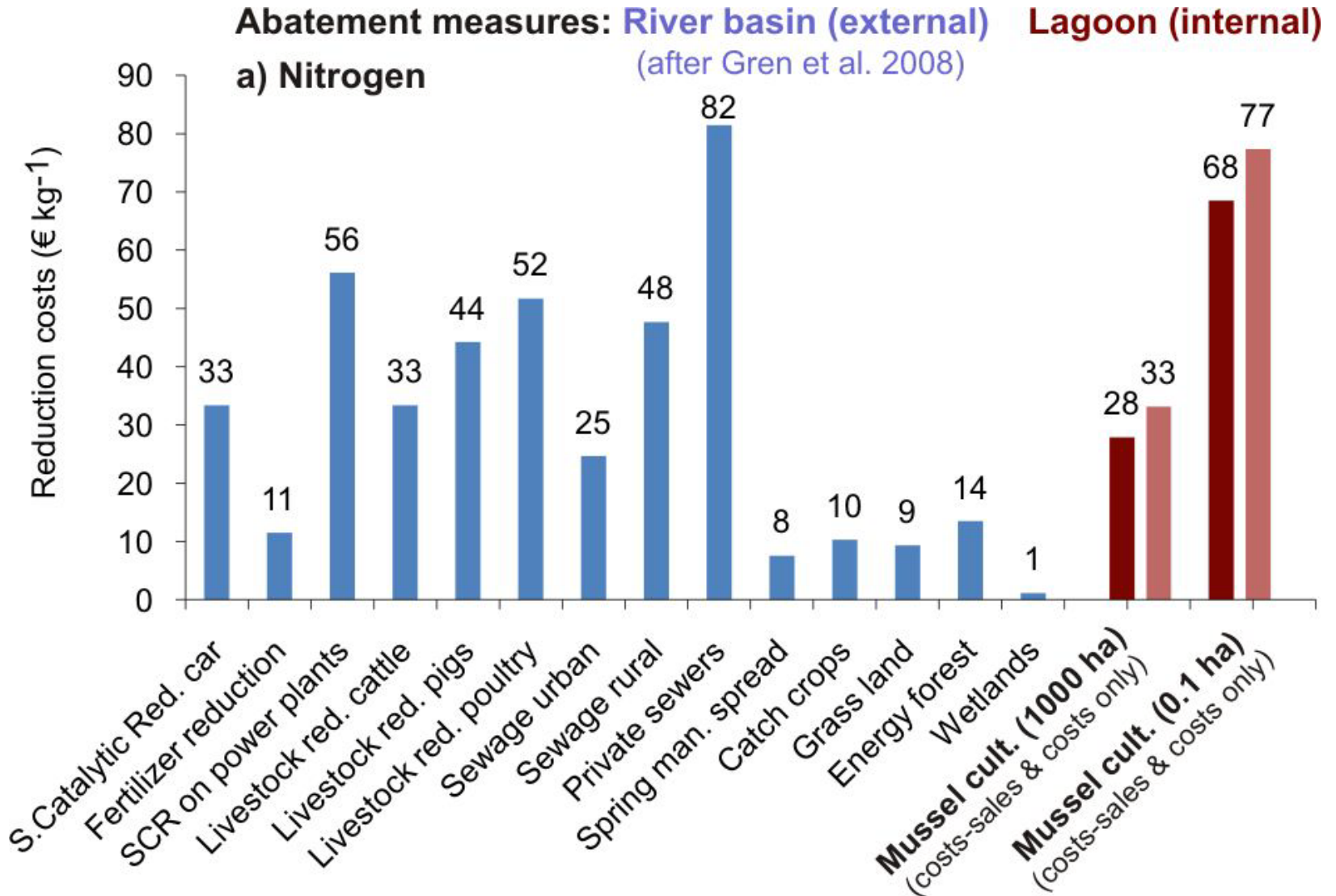
# Zebra mussel farming:

## Required economic compensation and marginal costs



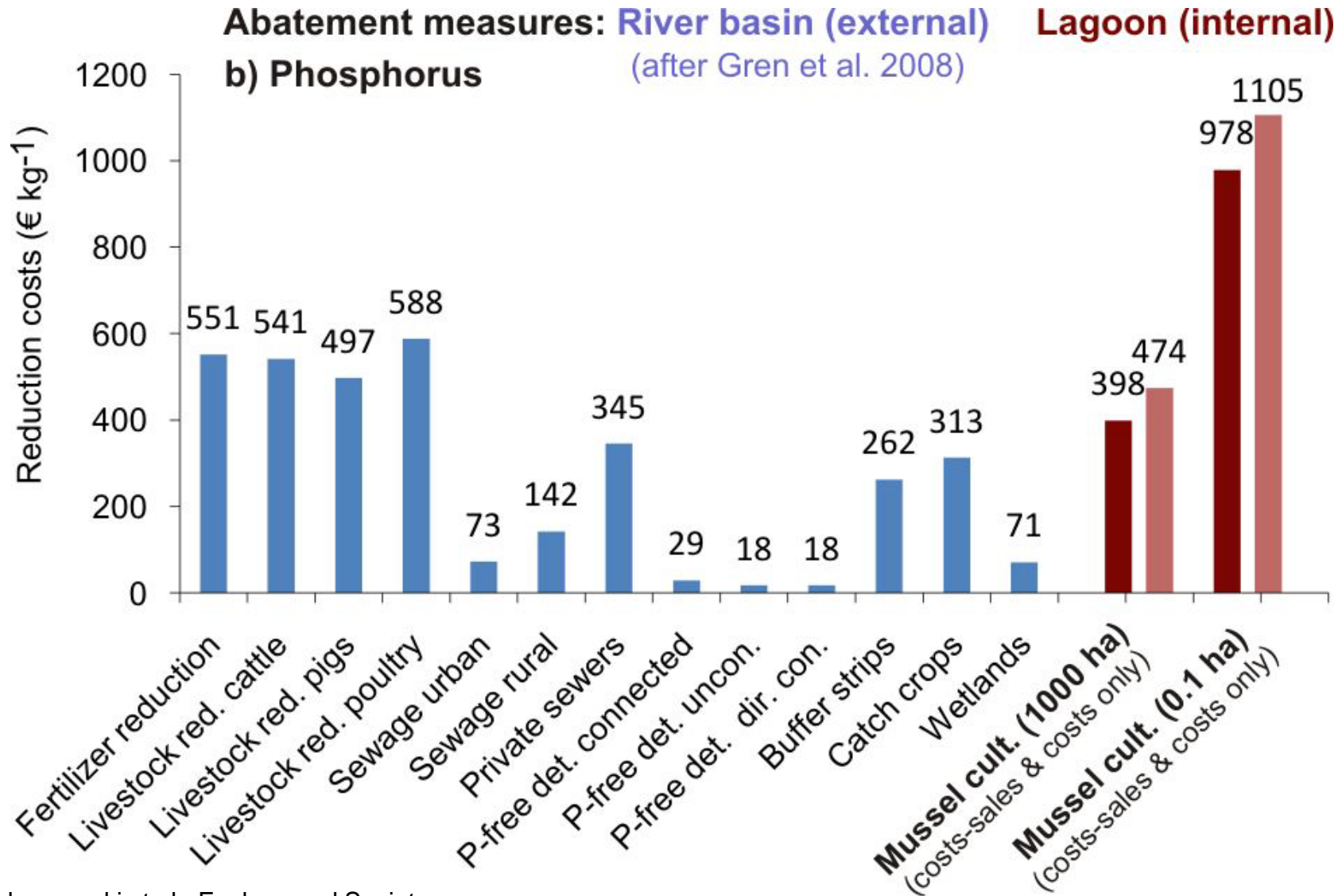
# Zebra mussel farming:

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



# Zebra mussel farming:

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

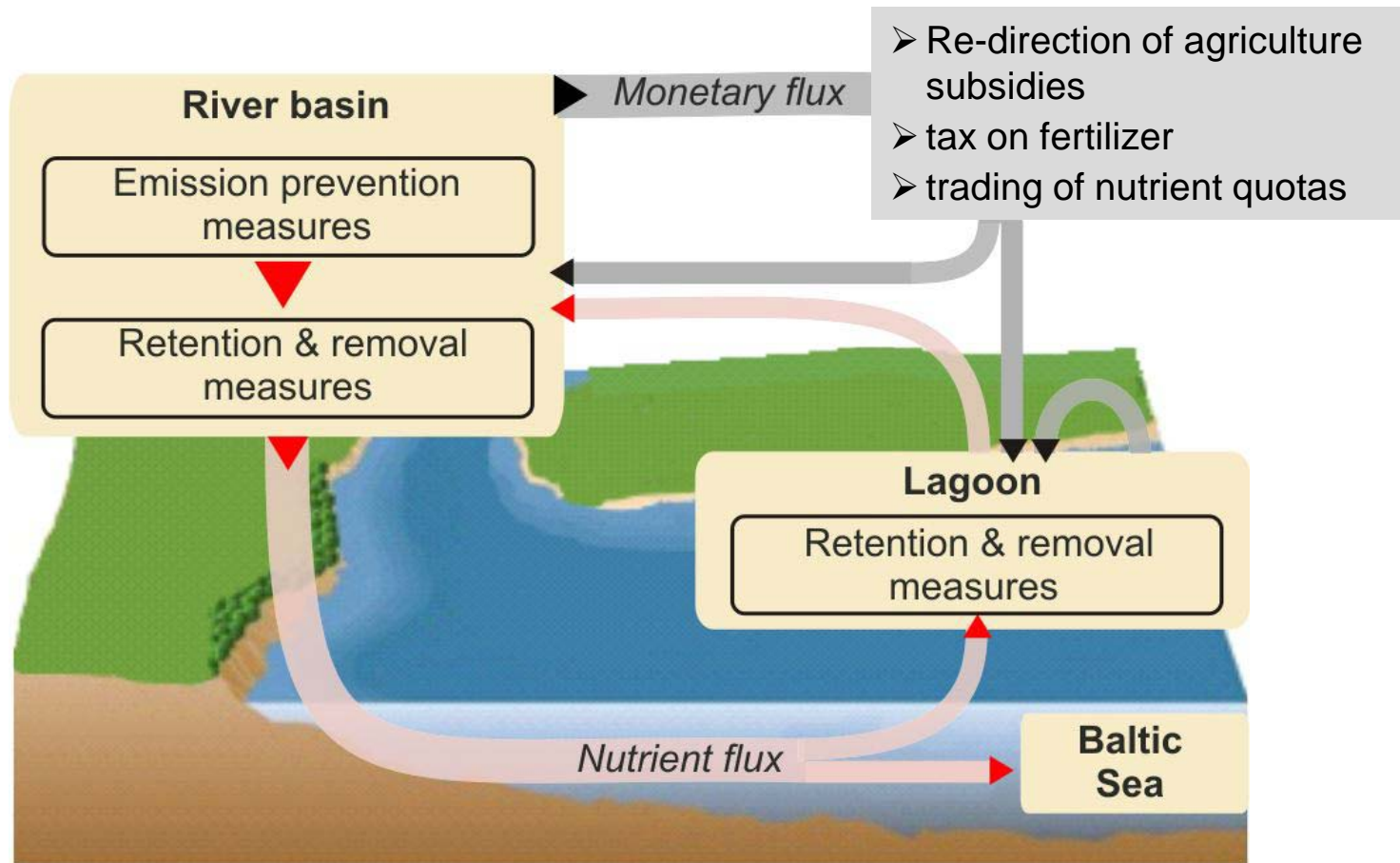


# Summary

- 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.

# Perspectives

Zebra mussel farming will require additional funding (subsidies). The development of strategies to provide funding for the mussel farming as a nutrient removal measure is one of the most important tasks in Germany at the moment.





# Thank you for your attention!

This work has been supported by projects:

