An Attempt at the Economic Valuation of Waste Bioremediation Service in Brackish Estuaries (Gulf of Gdańsk - the Southern Baltic Sea)

Ilona Kamińska, Tomasz Zarzycki and Anna Szaniawska

Department of Experimental Ecology of Marine Organisms Institute of Oceanography, University of Gdansk, Poland
Structure of the presentation

- aims, problem description
- concept of full research
- regulation service - bioremediation
- benthic and shore habitats
- assessment of the monetary value of ecosystem service
- discussion and conclusions – lessons learned
Aims

An attempt at the economic valuation of bioremediation service as one part of the total economic value.

Point out habitats' effectiveness in removing nutrients.
Sea bed is characterized by high biodiversity and provides crucial ecosystem services.

Marine eutrophication has emerged as one of the major environmental issues of our time. Enclosed seas with high river runoff like the Baltic Sea are especially affected by the increasing riverine nutrient loads.

Nitrogen and phosphorus discharged from anthropogenic sources are the driving force behind eutrophication, especially in coastal areas.

Despite of various negative anthropogenic pressures habitats of Gulf of Gdańsk significantly contribute in provision of ecosystem services such as bioremediation of waste.

No concrete valuations of bioremediation service in Gulf of Gdansk.
The best way to estimate the economic value of bioremediation is through measurement of replacement costs. The human engineered system provides functions that are equivalent in quality and magnitude to the ecosystem service of the cheapest alternative. The economic value of the bioremediation service is calculated by replacing costs of artificial processes (technical substitutes) with contingent valuation method (CVM).
The best way to estimate the economic value of bioremediation is the replacement cost method.

Under certain conditions it can be used for evaluating the indirect use values. 

**three conditions**

1. the human engineered system provide functions that are equivalent in quality and magnitude to the ecosystem service;

2. the human engineered system is the least cost alternative way of replacing the ecosystem service;

3. individuals in aggregate would be willing to incur the replacement costs if the ecosystem service was no longer available (Sundberg, 2004).
What is the bioremediation of nitrogen and phosphorus?

**BIOREMEDIATION**

Removal of different types of chemicals through storage, burial and recycling and other processes like dilution, chemical decomposition and redistribution (detoxification and purification processes) (Beaumont et al. 2007).

through activity of living organisms (Beaumont et al. 2007).
Why nitrogen and phosphorus ??

The Gulf of Gdańsk is a highly **eutrophicated** water body and loading of excess nutrients (**nitrogen and phosphorus**) have **negative effects** on the whole ecosystem.

### Nutrient sources in the Gulf of Gdansk in 1993 - 1998

<table>
<thead>
<tr>
<th>Source</th>
<th>DIP</th>
<th>DIN</th>
<th>P total</th>
<th>N total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vistula River</td>
<td>4,720</td>
<td>77,870</td>
<td>79 %</td>
<td>89 %</td>
</tr>
<tr>
<td>Vistula Lagun</td>
<td>600</td>
<td>3,860</td>
<td>1,380</td>
<td>6,730</td>
</tr>
<tr>
<td>WWTPs</td>
<td>220</td>
<td>2,660</td>
<td>278</td>
<td>3,330</td>
</tr>
<tr>
<td>Industry</td>
<td>67</td>
<td>310</td>
<td>84</td>
<td>386</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>&lt; 71</td>
<td>3,018</td>
<td>71</td>
<td>3,800</td>
</tr>
<tr>
<td><strong>total</strong></td>
<td>5,678</td>
<td>87,718</td>
<td>8,817</td>
<td>132,421</td>
</tr>
</tbody>
</table>

Source: Witek et al. 2003
Four main steps

The assessment of the monetary value of ecosystem service bioremediation of nitrogen and phosphorus using the replacement cost approach

**four steps:**

1. **identification and quantification of the nitrogen and phosphorus reduction effects** through denitrification, retention in living tissue and permanent burial (ecosystem function)

2. definition of **substitute and costs**

3. **economic valuation of the ecosystem service**

4. **verification** the estimated value
Several words about the main "ACTORS" in bioremediation of nitrogen and phosphorus

**Habitats of Gulf of Gdansk**

<table>
<thead>
<tr>
<th>benthic</th>
<th>coastal</th>
<th>pelagic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mussels beds</td>
<td>Sandy beach</td>
<td>Suspension feeders</td>
</tr>
<tr>
<td>Seagrass beds</td>
<td>Reed beds</td>
<td></td>
</tr>
<tr>
<td>Microalgae</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Blue mussels beds (Mytilus trossulus) -bioremediation service-

- **BURIAL AND DENITRIFICATION** - “bottom-up” control through biodeposition and promotion of nutrient removal

- **STORAGE** of nutrients in the form of proteins in tissues and shells (e.g., Rice 1999);

- **NUTRIENT RECYCLING** - mussels link water column productivity to the benthos by removing pelagic organisms, increasing rates of particle deposition (Cloern 1982; Kotta & Møhlenberg 2002; Lauringson et al. 2007); increased nutrient availability in the benthic system through the excretion and/or biodeposition.
nutrient removal via BURIAL or long term loss of nutrients in coastal ecosystems (Middelburg et al. 2004).

ability to SEQUESTER and immobilize large quantities of N during the growth season.

reduce resuspension and erosion – increased in sediment ACCUMULATION (Scoffin, 1970; Redfield, 1972) - higher nutrient concentration in sediments (Kenworthy et al., 1982; Benoy and Kalff, 1999).

N-CYCLING - an important effect of eelgrass beds on estuarine
to influence the rate and vertical zonation of **DENITRIFICATION** (Risgaard-Petersen et al. 1994, Currin et al. 1996, Lorenzen et al. 1998).

**ASSIMILATE** nutrients from both the overlying water and the sediment pore water (Nilsson & Sundback 1991, Sigmon & Cahoon 1997).

- Microphytobenthic **ASSIMILATION** and **DENITRIFICATION** are both processes that remove dissolved bioavailable N from the system
breakdown of organic materials and pollutants

water filtration and purification (McLachlan, Brown, 2006)

RECYCLING nutrient mineralisation (Defeo et al. 2009; McLachlan et al., 1985; McLachlan, 1989; Kotwicki et al., 2005). Wastes materials are and, by digestion, fermentation and metabolism, are converted into useful basic building materials, both nutrients and biomass, to start the ascent of the ecological ladder once again, via protozoa, meiofauna, grazers and consumers (Pugh, 1983).
The total surface area - 4940 km²
(1.2% of the entire Baltic Sea surface area)

Volume - 291 km³

The maximum depth - 118 m

Surface water salinity - 8.28 PSU

Sandy bottom biotopes dominated by macrophyte vegetation mainly occur in the sheltered Puck Bay.

There are also areas of stony (near the coastline) and muddy (deeper part) bottom covered with macrophytes and algae.

Source: Witek et al. 2003
Four main steps

ASSESSMENT
of economic value of ecosystem service

bioremediation of nitrogen and phosphorus

by using replacement cost approach

Case study area - Gulf of Gdańsk
1. **STEP**

**Identification and quantification of N and P reduction effects**

through denitrification, retention in living tissue and permanent burial

<table>
<thead>
<tr>
<th>Bioremediation of waste</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Denitrification</td>
<td></td>
</tr>
<tr>
<td>Permanent burial of nitrogen</td>
<td></td>
</tr>
<tr>
<td>Permanent burial of phosphorous</td>
<td></td>
</tr>
<tr>
<td>Retention of N in living tissue</td>
<td></td>
</tr>
<tr>
<td>Retention of P in living tissue</td>
<td></td>
</tr>
</tbody>
</table>
1. STEP
identification and quantification of N and P reduction effects through denitrification, retention in living tissue and permanent burial
2. STEP
definition of substitute and costs

price of the alternative
(human engineered system similar to ecosystem service)

municipal sewage
Inflow: 28mln m³/yr
N – 2,500.4 t/yr
P - 308 t/yr

Outflow

<table>
<thead>
<tr>
<th></th>
<th>Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>t/yr</td>
<td>%</td>
</tr>
<tr>
<td>N – 369.6</td>
<td>85.3 %</td>
</tr>
<tr>
<td>P – 17.64</td>
<td>94.3%</td>
</tr>
</tbody>
</table>

Wastewater treatment plant (WWTP)

3.38 PLN (1.17 USD)
Cost of treatment 1 m³ municipal sewage

Data from Saur Neptun Gdańsk - a water and sewerage company

2500.4 - 2 130.8 = 369.6
308 - 290.36 = 17.64

3.38 zł/ m³ * 28mln m³ = 94.64 mln zł
3. STEP
the economic valuation of the ecosystem service

<table>
<thead>
<tr>
<th>biological sewage treatment</th>
<th>Natural remediation of nitrogen and phosphorus</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>reduction in t/yr</strong></td>
<td></td>
</tr>
<tr>
<td>N – 2,130.8</td>
<td>N – 45,440</td>
</tr>
<tr>
<td>P – 290.36</td>
<td>P – 1,035</td>
</tr>
</tbody>
</table>

Total cost: 94.64 mln PLN

For N: 84,26 mln PLN
For P: 10,38 mln PLN

84,26 * 21.3 = 1,794,738 mln PLN
10,38 * 3.5 = 36,33 mln PLN

1,831,063 mln PLN

Efficiency of removing P is about **3.5** times greater

Efficiency of removing N is about **21.3** times greater

1.83 bn PLN (0.63 bn USD)
4. STEP (future plans)  
Verification

Contingent valuation method  
individuals in aggregate would be willing to incur the  
replacement costs if the ecosystem service was no longer  
available.

Aim of the last step –  
verification the estimated value using cost based method –  
AVOIDANCE of overestimation risk
Conclusions – lessons learned

Bioremediation is a very complex process, thus it is extremely difficult based on available data to indicate real participation of particular habitats in this service.

Nevertheless, habitats' effectiveness in removing nitrogen and phosphorus is significant.

Replacement cost method is supposed to be rather easy to understand and therefore might be suitable to enhance social perception of indirect use values.

Bioremediation of excess loads of nutrients. Bioremediation of all wastes has much border range in terms of involved processes. Thus, this value might be regarded as the lower bound of the socio-economic value of this service.

Economic value is about 1.83 bn PLN (0.63 bn USD)

Argument for allocation of funds into marine bioremediation conservation. Support of the habitats conservation objectives by their economic justification.
Thank you for your attention!

Acknowledgements:

This research was found by grant nr G 220-5-0511-0

University of Gdansk
Poland