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Dynamics of mussel beds in the Szczecin Lagoon

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Abstract

Mussel beds play an important role as secondary hard substrate both in the North Sea and in the Baltic Sea. Many species live on them, stabilise the sediment and foster bentho-pelagic coupling. In the very eutrophic Szczecin Lagoon at the German-Polish border, zebra mussels (*Dreissena polymorpha*) might help to restore more natural conditions by filtering and thus cleaning the water. In preparation for a pilot project for biological restoration methods using zebra mussels we wanted to evaluate the mussels' status quo. We therefore mapped the current distribution of zebra mussels in the Szczecin Lagoon in summer 2007, using underwater video imaging, a scientific SCUBA-diving team and benthos samples taken with Van Veen grabs and box corers.

Apparently the mussel beds have strongly decreased in size over the last 14 years. This could be due to the high trophic state in combination with global warming, causing temporal oxygen deficiencies. Other reasons may be strong predatory pressure or methodical differences in preceding studies. We plan to continue investigating the dynamics of mussel beds in a German-Polish interdisciplinary project.

1 Background

Mussels such as blue mussels (*Mytilus edulis*) or zebra mussels (*Dreissena polymorpha*) are known as "habitat engineers" (Jones et al. 1994) because they live in clumps or bigger aggregations ("beds") that offer many niches and hard substrate for a wide variety of other species dwelling on the mussels. Mussel beds are therefore often islands of high biodiversity, especially in areas with muddy sediments where only few species can live. By enhancing interspecific facilitation, a high biodiversity can thus lead to more effective resource consumption and better ecosystem functioning (Cardinale et al. 2002).

Recently many mussel beds in Germany and North America have decreased in size and biomass (Smith et al. 2006, Büttger et al. 2008), raising the question of the causes.

In the Wadden Sea, the *Mytilus* decrease is attributed to 1) mild winters causing low recruitment and 2) the invasion of the Pacific oyster *Crassostrea gigas,* a neozoon which is a competitor for food and space. In North America, a strong winter (1979/80) caused a massive reduction in density and biomass of mussels (*Mytilus spp*.), caused by ice scour (Cousson& Bourget 2005). The recent decline of mussel bed community diversity (about 60 % from 1960/70 to 2002) is attributed to climate warming (Smith et al. 2006).

Besides providing hard substrate for many other species, mussels have another important function: they filter the water. This capacity can be used for bioremediation (restoration of a less eutrophic state of a water body) (Reeders & Bij de Vaate 1990). In order to calculate the necessary amount of mussels to allow for a better water quality, it is essential to know the status quo of the existing mussel population.

2 Objective

The aim of the present study was to map the existing mussel beds of *Dreissena polymorpha* in the German part of the Szczecin Lagoon (Kleines Haff). The distribution and population composition are prerequisites to estimate their active filtration potential. The results are a basis for calculating the number and biomass of mussels necessary to ameliorate the water quality. We plan an interdisciplinary German-Polish project to test biological restoration methods, especially aiding the existing *Dreissena* mussels to increase water clarity and enable remesotrophication.

3 Location and Methods

The study was carried out in June and July 2007 (4.6.-5.7.2007) in the German part of the Szczecin Lagoon, called Kleines Haff, which is situated at the German-Polish border. June was chosen because it has the highest visibility in summer according to long-term monitoring data (LUNG MV unpubl. data) and water temperatures that enable long diving periods. We used the research vessel "Bornhöft" of Greifswald University and a rubber boat. Sediment samples were taken with Van-Veen grabs (0.1 m²) and Günther box corers (0.06 m² surface, penetration depth: about 20 cm).

A total of 701 stations were checked for *Dreissena* mussels. Investigations took place along a grid with sampling points every 0.5 nautical miles. The very deep and muddy areas were only sampled randomly because they do not offer suitable substrate for mussel attachment. At sites with mussels, divers measured the exact sizes of the mussel beds, using GPS, a compass and van Veen grab samples. As the visibility was very low, they often had to rely on haptic instead of optic evidence.

On board and in the laboratory, the lengths of the shells were measured with digital callipers. The samples were sieved (0.5 mm mesh size) and preserved with 10 % formalin. Species were determined with a stereomicroscope in the lab after watering the samples overnight and thoroughly rinsing with tap water. Additionally, the Secchi depth and oxygen saturation was measured. Water samples were taken for the analysis of nutrients, seston, BOD5, and chlorophyll content (methods and results in Fenske et al. (in prep.)).

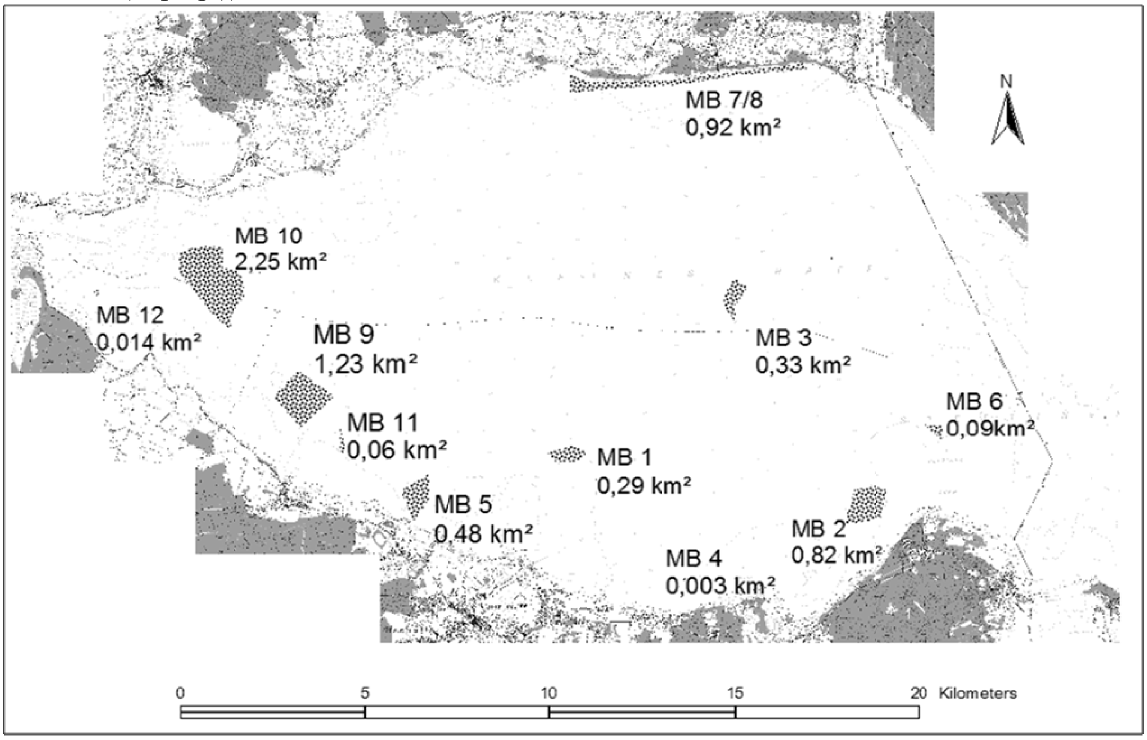

Figure 1: Mussel beds in the Kleines Haff, summer 2007. The total area covered by zebra mussels is 6.56 km² (=2.4%).

4 Results

Twelve mussel beds were found in the “Kleines Haff”, covering a total area of 6.56 km² (656 ha) which corresponds to 2.4 % of the area. Most of the mussel beds were found in sandy areas in 2.0-3.5 m water-depth, surrounding the lagoon like a belt (figure 1). One exception is the central mussel bed (MB 3), which lies on a prelitorine elevation.

The macrozoobenthos comprised 40 taxa. The average abundances of the most dominant taxa are shown in table 1. The zebra mussels (3,951 inds/m²) had a calculated total biomass of 8812.65 t (for calculation see Fenske 2003). The total average abundance of macrozoobenthic species on 7 mussel beds (26 samples) was 14,554 individuals/m².

Table 1: Average abundances of the most dominant taxa on mussel beds in the Kleines Haff

Taxon	Average abundance (individuals/m²)
Dreissena polymorpha (Mollusca, Bivalvia)	3951
Oligochaeta (Tubificidae)	4543
Chironomidae (Diptera)	2647
Helobdella stagnalis (Annelida, Hirudinea)	486
Bithynia tentaculata (Mollusca, Gastropoda)	237

5 Discussion

Mussel beds can persist over years or even decades, but they depend on many factors:

1. offspring and recruitment success (how many larvae develop successfully into adult mussels?)
2. underground (in general, hard substrate is necessary for attachment)
3. currents (too strong currents hinder settlement; low to medium current velocity secures food supply and higher chances of sufficient oxygen conditions compared to a stagnant water body)
4. temperature (if too high, mussels die)
5. oxygen supply
6. predators
7. parasites, pathogens
8. pollutants
9. intraspecific competition (within the same species)
10. interspecific competition (between different species)

No reports exist from the beginning of the 20th century about the mussel bed cover or total biomass of mussels in Szczecin Lagoon. Brandt (1894) investigated the eastern part of the lagoon and found *Dreissena polymorpha* in typical places (about 2 m depth, in areas not too exposed). However, there are no quantitative results.

In the North Sea (Wadden Sea area near Sylt), mussel beds clearly increased in size during the 20th century (Reise & Lackschewitz 1998). This may be due to positive effects of eutrophication providing more food (phytoplankton) for suspension feeders. Recently, eutrophication has been considered as a negative factor, one reason being the potential oxygen deficiency which it can entail.

Blue mussels (especially *Mytilus edulis* living in the eulitoral) can suffer from ice scour and strong winds. These reasons accounted for a strong decrease in the St. Lawrence River during the winter 1979/80 and for high mortalities in the Sylt Wadden Sea area (Nehls et al. 1998).

However, *Dreissena polymorpha* only lives in areas which are permanently submerged and most of them in depths of at least 2 m, so that in general, even strong winters should not cause them to die off completely.

On the other hand, very mild winters may also affect the mussels: It has been reported that recruitment success after mild winters is particularly low (Büttger et al. 2008). However, for several bivalve species in the North Sea, post-settlement processes decide reproductive success (Straßer et al. 2001).

While we found a total area of 6.56 km² of *Dreissena* mussel beds (= 2.4 % of the area of the Kleines Haff), a former mapping describes 19.2 km² (= 6.9. %) (figure 2, Andres 1993). The methods used were similar (scientific divers, underwater video camera recording, van Veen grab samples), but the former study was carried out over 2 weeks in August 1993 while our investigation took place for a 5 weeks period in June/July. At this time of the year, far fewer juveniles can be expected. However, this does not affect the area of the existing mussel beds. Estimates based on sediment samples taken on grid points of 1 nautical mile across the Kleines Haff in 1993 and 1994 gave a total area of *Dreissena* beds of 57.0 km² (20.6 % of the area) (Günther 1998). In these last investigations, the size may have been overestimated, as the rim of the mussel beds were not confirmed by divers.

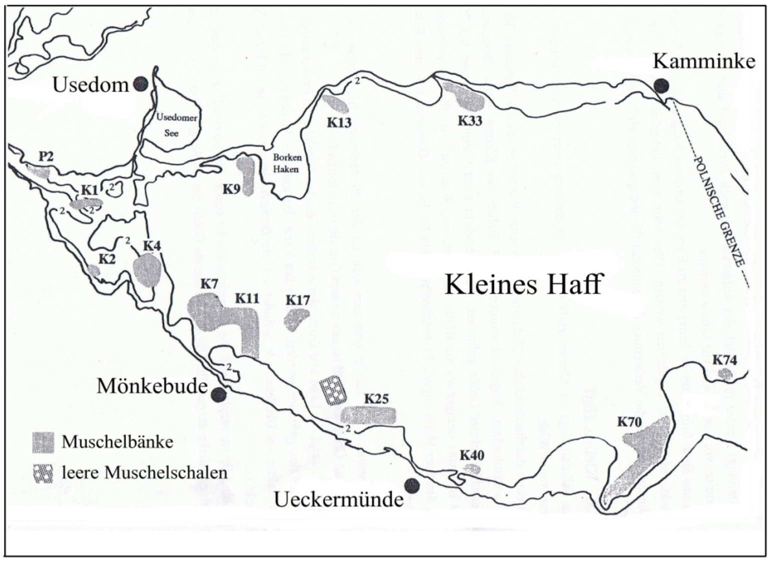

Figure 2: Mussel beds mapped by Andres (1993). The total area in 1993 was 19.2 km², about 3 times the size of mussel beds in 2007.

The "rise and fall" of mussel beds

At least one living mussel bed had vanished between 1998 and 2009. It was the one in the middle of the German-Polish border which was present (and repeatedly sampled) in 1998 (Fenske 2003), while in 2007, only dead shells but no living mussels could be found (this study). At the recorded GPS positions divers searched intensively, but there was no living mussel bed anymore. A similar fate may have occurred to the field of empty mussel shells off the south shore between Ueckermünde and Mönkebude (near K25, figure 2).

Some mussel beds discovered by Andres (1993) had vanished as well, e.g. K9 and K13 at the north-western end. K70 on the south-east side had clearly decreased in size.

On the other hand, at least two mussel beds found in our study (MB1 and MB3) are not mentioned by Andres (1993). They may not have searched intensively enough in the central part (which is mostly muddy and therefore an unlikely settling ground for *Dreissena* mussels). Still, the differences in size of the total mussel beds recorded are so large that we can assume a strong decrease in mussel beds over the last decade.

Some *Dreissena* mussel populations have been reported to vary strongly. In Lake Mikolajskie (Mazurian Lakes, Poland) abundances ranged from 100 mussels/m² to 2200 mussels/m² over the time span of 31 years (1959-1989) with abrupt changes in density (Stańczykowska & Lewandowski 1993).

A strong decrease was also observed by Wolnomiejski and Woźniczka (2008) for the Skoszewska Cove, a sheltered bay in the east of Szczecin Lagoon. Comparing the years 2001/2002 and 2005, the mussel bed area in Skoszewska Cove remained the same (10.70 km² = 51.6 % of the bay), but the average abundance (2172 mussels/m²) went down to half the number before (4691 mussels/m²). Biomass was reduced to little more than 10 % of the previous value (192 g freshweight/m², compared to 1760 g/m²). Even the high values of 2001/2002 are one order of magnitude below those from the 1950s: Wiktor (1969) describes maximum densities of 114000 mussels/m² and a maximum biomass of 20 kg/m²!

Does this imply an internal cycle of rising and falling of mussel beds? Do they reproduce and recruit so successfully that after some years they start to cause their own (intraspecific) competition? Phytoplankton production in the Szczecin Lagoon is still very high (polytrophic conditions) and competitors such as *Anodonta anatina* or *Unio pictorum* occur in comparably low numbers (about 2/ m² in our investigation). Despite their larger filtration capacity, their total impact is much lower than that of zebra mussels. In a semi-enclosed bay like Skoszewska Cove, it is possible that the stagnant water is filtered several times by the mussels so that in the end not enough food is left. However high densities of one single species (monoculture!) also favour parasites and illnesses. These factors have not been checked in Skoszewska Cove.

In Lake Zürich, internal cycles of *Dreissena polymorpha* abundances were positively correlated to predator densities (birds). From 1976 to 1988 no total gain or loss of *Dreissena* was observed (Burla & Ribi 1998).

One reason for a decrease or break-down of mussel populations could be oxygen deficiency caused by eutrophication in combination with warmer water temperatures. Compared to the long-term average (1975-2000), average water temperatures between 2002 and 2006 were 0.8°C higher (LUNG Gewässergütebericht 2006). Once a mussel bed has disappeared, it may take several years to re-establish, as pelagic larvae might not be drawn to that particular place. Even though larvae might be ingested by adult mussels, as suggested by Mörtl & Rothhaupt (2003), the normal settling size (200-300 µm) is above the preferred size of food particles of adult mussels (15-40 µm, Ten Winkel & Davids 1982). This suggests that the filtering activity of adult mussels should attract larvae and help them settle in suitable places.

For Lake Zürich, Burla & Ribi (1998) found a positive correlation between the number of adult mussels and the number of larvae. With a small current mussel population in the Szczecin Lagoon, it might therefore take several years before the total population and size of mussel bed regains its potential size and filtering capacity.

6 Conclusion

Mussel beds in the Szczecin Lagoon decreased in size, average abundance and biomass between 1993 and 2007. Whether this was caused by single factors (e.g. food shortage, oxygen deficiency, mild winters and little recruitment) or whether this represents a long-term cycle remains an open question. We intend to investigate some of the influential parameters, such as predation impact and population dynamics in a joint German-Polish project on biological restoration methods.

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