Possibilities to change harmful algae community to less harmful with mussel (*Mytilus edulis*) farms.

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Abstract

Harmful algae like Dinophysis spp. producing diarrheic shellfish toxin (DST), is a great problem for the mussel farmers in Sweden. Mainly during autumn these algae propagate from the open sea into the fjords, and cause stop of mussel harvest for long periods. Investigations are made to look at possibilities to protect mussel farming areas against the harmful algae with filter barriers made of mussel farms. In order to look at the changes of a phytoplankton community that is influenced by mussel filtration, we have studied the outflow from the Baltic Sea through Öresund, which is passing large mussel banks. This study shows a shift from large algae to smaller, and there were almost no dinoflagellates in the increased primary production initiated by improved light conditions and released nutrients, after the mussel bank. In the farming area, the Si concentrations are relatively high and sufficient to support a production of diatoms inside a future barrier of protecting mussel farms. The effect of the biomanipulation with a mussel barrier should be that one could create a farming area dominated by fast growing diatoms that hopefully is toxin free.

Keywords:
Biomanipulation, mussel farming, harmful algae.

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Introduction

The development of the mussel industry in Sweden and many other countries, has been hampered by toxic algae. Mussel farming started the year 1971 in Sweden, but it was not until 1983, diarrheic shellfish poisoning (DSP) was observed among people consuming mussels. The DSP toxin found in Swedish mussels, is the phycotoxin okadaic acid (OA) produced by Dinophysis spp. So far OA is the only shellfish toxin that has been found in harmful concentrations in Swedish Waters.

The harmful algae seems to come from the open sea, and the DSP toxin concentrations in mussels from the outer archipelago, at most occasions, are higher than the concentrations in mussels from the inner parts, according to several years (1987 to 1999) of observations. Mussels in fjords like the Gullmars Fjord, with a deep sill and large water exchange with sea, are more often toxic than mussels in the Koljö Fjord nearby, where the sill is shallow and water exchange with the open sea is small. It is also possible to follow the propagation of the toxins into the fjords from the sea, by frequent sampling of mussels (Haamer 1995).

The seasonal variations of toxin concentrations often shows a maximum of DSP toxins in the autumn and some years the mussels prevail toxic during the whole winter. In the spring, the phytoplankton community is dominated by diatoms, that are not often toxic. After the mussels have been feeding on diatoms for a couple of weeks, the toxins disappear from the mussels.

For the mussel industry in Sweden these long periods, when it is impossible to harvest mussels, are very distressing. In order to mitigate the problems with the harmful algae for the farmers, there has been a search for areas with less presence of Dinophysis ssp., and in the inner parts of the Orust- Tjörn fjord system (Fig. 1), such an area was found. Many farms were established in there, but the growth of the mussels was much less than in the outer archipelago, and the farmers have now abandoned these inner parts. One farmer still pulls his farms from the farming sites in the outer archipelago, to this area, in order to get rid of the toxins in the mussels.

This investigation has the aim to look at the possibilities to manipulate phytoplankton community by mussel farming, in order to create farming sites with good growth, where toxin free mussels can be produced.

Conceptions

Natural mussel banks and mussel farms can have a dominant influence on the flux of nutrients in coastal waters. Meeuwig et al (1998) demonstrated the role of mussels in 15 estuaries in Prince Edward Island where areas with mussel farming have much lower chlorophyll / nutrient ratios than areas with no farms. Also Cloern (1982) show how natural mussel populations in South San Francisco control phytoplankton biomass, and decrease the negative effects of eutrophication.
These examples verify the effectiveness of mussels in estuaries, and the plans now are to establish mussel farms in the entrance of the Orust–Tjörn fjord system, in order to filter most of the water coming in from the open sea. In that way one could create a barrier against harmful algae. Inside the barrier we hope that the new phytoplankton production will consist of fast growing diatoms, in stead of toxic dinoflagellates that grow slower. In that way toxin free mussels could be farmed inside the barrier all the year round, and the “barrier mussels” could be harvested during periods with no toxins. This is the plan.

Investigations

The experimental area the Orust–Tjörn fjord system

Nutrient chlorophyll a carbon and oxygen concentrations together with salinity and temperature are measured every month at 5 stations in the Orust- Tjörn fjord system (Vattenvårdsförbundet i Västra Götaland). At one station at the innermost part, also phytoplankton community composition is documented. These investigations at the previous extent started in 1990. Also several investigations of the circulation in the fjord system, have been made by Björk (1983) and Björk et al. (1998). Mussel growth and larvae settling in different parts of the fjords where there are no farms, has been investigated, during the last three years, in order to find suitable areas for the “barrier” and the new farms.

The large mussel banks in Öresund

In Öresund (Fig. 2), one of the two outlets from the Baltic Sea, an investigation has been made with the aim to investigate what kind of impact the large mussel banks there have on the passing water. For that purpose we have followed a watermass in the southern part of the Öresund and measured the decrease of chlorophyll a and the remineralisation of nutrients in the turbulent well mixed water, during the passage of the large mussel banks at the sill. We also studied what is happening in the phytoplankton community afterwards, in the nutrient enriched water (Haamer & Rodhe 1998, Norén et al. 1999).

Results

Experimental area

Lokal suplies of nutrients from point and non point sources to the Orust-Tjörn fjord system increase the nutrient concentrations in the fjords compared to the open sea outside. Average concentrations of nutrients in surface water before spring bloom in Koljefjord compared to the open sea (Skagerrak) is for DIN 12 µM L⁻¹ compared to 8 µM L⁻¹, for DIP 0.7 µM L⁻¹ compared to 0.7 µM L⁻¹, for SI 15 µM L⁻¹ compared to 5 µM L⁻¹, for TN 30 µM L⁻¹ compared to 28 µM L⁻¹ and for TP 1µM L⁻¹ compared to 0.9 µM L⁻¹.

The measured supply of nutrients from local sources to the whole fjord system (230 km²) is c. 420 tonnes N yr⁻¹ and 10 tonnes P yr⁻¹. There is also a large unverified supply of nutrients from the large Göta River that flows into the sea just south of the
entrance of the fjord system. This extra nutrient supply has lead to an increased primary production and also higher chlorophyll a concentrations in the fjords compared to the open sea. When the rich primary production reach the deep basin water, the biological oxygen demand (BOD) increase. In the inner parts of the fjords, where the deep-water exchange is very limited oxygen concentrations are very low in autumn (Fig. 3).

The circulation is directed from the south through the fjords and the net average transport is c. 160 m$^3$ sec$^{-1}$ through the system. The water exchange in Havstensfjord is c. 200m$^3$ sec$^{-1}$. Due to a low tidal range at the Swedish West Coast (c.0.3m) the tidal water exchange is small.

**Öresund**

In Öresund the large mussel bank (1 million ton wet weight) at the sill removed c. 75% of the phytoplankton biomass measured as chlorophyll a, when the water transport through the Sound was about 36000m$^3$ sec$^{-1}$ (Fig. 4). At the same time, the release of NH$_4$ from the bank was 0.7ton h$^{-1}$. After the passage of the bank phytoplankton biomass increased rapidly but there was a shift in phytoplankton community to smaller phytoplankton cells (Fig. 5).

**Discussion**

*Dinophysis* ssp. are mixotrophic and can therefor be favoured compared to autotrophic diatoms during low light conditions. As we could see from the investigation in Öresund, light penetration in the watermass increase, due to less turbidity after the passage of the mussel banks. Together with a selective filtration by the mussels, where a greater amount of large than small phytoplankton were ingested, improved light conditions can also play a part in the change of the phytoplankton community. The phytoplankton community that remain and start to grow rapidly after the passage of the mussel banks, consists mainly of small cells (2 – 12 µm), ciliates and almost no dinoflagellates were left (Noren et al 1999). Due to supply of nutrients from mussels metabolism, a kind of plankton bloom was initiated, and the species that were growing were the small ones not dinoflagellates.

Dinoflagellates are favoured compared to diatoms, by the increased N/Si ratio that normally comes with eutrophication. In the Orust- Tjörn Fjord system however, the N/Si ratio is surprisingly low compared to other eutrophied areas, and the Si concentrations during summer and autumn are high enough to support a diatom production. The dominance of diatoms is the main reason, we think, for the relatively rear occurrence of toxins in mussels from this area.

The special nutrient conditions and the net transport in one direction make the Orust – Tjörn Fjord system suitable for a “mussel barrier” experiment. Based on mussels filtering capacity, the amount of mussels in the barrier should bee about 6000 tons, in order to get a good protection against harmful algae in the inner parts of the fjords.
References


Vattenvårdsförbundet i Västra Götaland Addr. c/o Bosam, Box 305, S- 45118 Uddevalla.
Fig 1. Map of the fjord system around the islands Orust and Tjörn, that is our experimental area at the Swedish West Coast. The sampling stations for hydrography and chemistry are indicated on the map. At station 19 also phytoplankton samples are taken.
Fig 2. Map of the Öresund area between Denmark and Sweden. The sampling stations and the mussel banks are indicated on the map.
Fig 3. Yearly variations of the oxygen concentrations at 15m dept in Koljöfjord station 11 north of the island Orust.
Fig 4. Chlorophyll a concentrations in a steady waterflow from south to north at stations T0 - T6 in Öresund.

Fig 5. The observed phytoplankton community change in the watermass at the passage and after the passage of the mussel banks in Öresund.