Environmental impacts of mussel farming

Introduction

Worldwide, aquaculture, including mussel production, has been fastest growing sector of the food industry since 1970s. The increase in production has also generated increased concerns related to impacts of the activities on local environments. Although initially concerns were directed at fish farming, the localized increase of biodeposition generated by farmed bivalves has been an issue of interest for several decades as well. There have been only a few studies on the actual impact of mussel farming on the environment. As part of the Baltic Blue Growth project, six mussel farms in different locations were investigated regarding their ecological impacts. In order to provide a good knowledge base on mussel farming impacts on the Baltic Sea environment, we will concentrate on one of these farms and examine the environmental impact results from the Sankt Anna mussel farm in Sweden.

Environmental impacts of mussel farming

Moreover, the pan-Baltic model from the Operational Decision Support System (ODSS) tool (http://www.sea.ee/bbg-odss/Map/MapMain) can provide information regarding the biomass yield as well as nutrient removal service (e.g. the amount of nutrients that are removed through harvesting) for specific locations in the Baltic Sea.

What are the environmental impacts of mussel farming in the Baltic Sea?

Mussel farming can be very effective as a mitigation tool on a local scale since the effect from mussel filtration is immediate. Contrast this with land-based measures where effects often have large time lags. Moreover, legacy nutrient accumulation in the Baltic Sea does not make it possible to remove those nutrients through land-based measures. Thus, mussel farming and similar sea-based solutions are needed to effectively remove legacy nutrients from the water and reduce the eutrophication issues directly in the Baltic Sea.

On the other hand, there has been expressed concern that sedimentation of organic material in a form of mussel biodeposits can lead to enhanced oxygen consumption in sediments underneath mussel farms resulting in hypoxic or even anoxic conditions that will increase nutrient release from sediments, hence arguing that nutrient removal by this method is substantially offset by altered environmental conditions and which could impact nutrient cycling in proximity of the mussel farms. However, it should be stressed that the effect of enhanced biodeposition under mussel farms is local and highly site specific. There have been studies showing negative (as well as positive) impacts from mussel farms on benthic communities (references maybe?). However, this impact has not previously been studied in the Baltic Sea. Aquaculture based on bivalve (or other filter-feeding invertebrates) has a relatively low environmental impact and a net negative nutrient impact compared to e.g. nutrient release from open fish farms.

Sankt Anna mussel farm

Sankt Anna mussel farm is the first full-scale mussel farm with a long-line system on the Swedish East coast. It is located in the very sheltered archipelago of Östergötland (Figure 1).

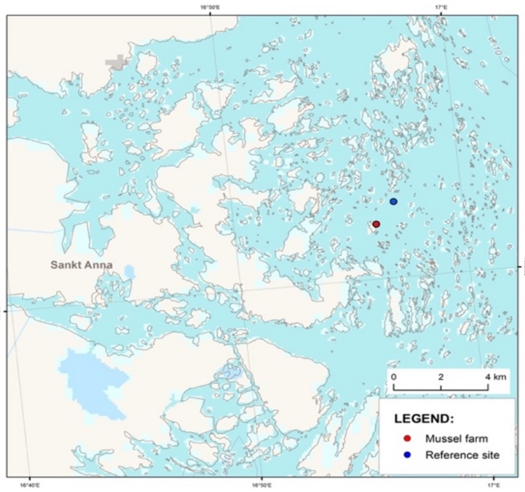

Figure 1: Location of Sankt Anna mussel farm and reference site.

The area of the farm is part of protected natural area. The water depth at the farmsite is approximately 20 m and water salinity varies between 6 and 7 g kg-1. During summer, temporal vertical stratification can be observed in the area. The farm area is 4 ha and mussel growth depth is 2-12 m. The soft sediments under the farm, as well as at the reference area, is characterized by relatively high carbon, nitrogen and phosphorus concentrations. No distinct differences in nutrient concentrations in sediments between mussel farm and reference areas could be identified. The observed differences most likely are due to natural local spatial variability.

Methodology

All water quality parameters were studied in 2017 and 2018 at a reference site and at the mussel farm. The visits to monitoring stations were timed so that the period from June to October, when the mussel farms are most likely to have an impact on water quality or sediments, would be covered by monitoring observations. The oxygen concentration was measured as continuous profile by CTD except in Sankt Anna where oxygen was measured in the same water samples as nutrients by use of standard analytical methodology.

Monitoring results from Sankt Anna mussel farm

Salinity

In June 2017, salinity was homogenous throughout the whole water column at the mussel farm (6.8 g/kg) and reference location (6.9 g/kg).

Oxygen

The summer 2018 was extraordinarily warm in Europe, which resulted in a pronounced and severe water stratification at the Sankt Anna mussel farm in August. The oxygen in the near-bottom layer was completely depleted both underneath the mussel farm and at the reference site. This phenomenon was due to large-scale variability in oxygen conditions and was not related to the mussel farms (i.e. depletion even at the control site). In August 2017, oxygen concentration at the benthic (near-bottom) layer was higher (by about 3.0 ml/l) in the Sankt Anna mussel farm compared to the reference area. Overall,the mussel farm had no negative impact on dissolved oxygen conditions, not only during our monitoring visits but for the extent of the whole study.

Nutrient concentrations

The concentrations of inorganic fractions of nitrogen, especially nitrate and nitrite, were on the most part very low (see Table 1) comprising, on average, only around 2 % of the total nitrogen and indicating rapid uptake of inorganic nitrogen by phytoplankton even late in the year (October). The exception was August 2018 when an obvious water vertical stratification event created a situation favorable for nutrient accumulation in the benthic layer. As a result, increased concentrations of ammonia were observed in the near-bottom layer reaching around 17 % of total nitrogen. Note however, that the concentration increase was observed at both the mussel farm and reference sites, indicating that the observed concentration increase is attributable to natural factors rather than an influence of the mussel farm.

Similarly to nitrogen, the concentrations of inorganic phosphorus were also relatively low (see Table 1) in June 2018 comprising from on average of 10 % in the surface layer to 40 % in the near-bottom layer. The inorganic phosphorus fraction was lowest in the surface layer and highest in deeper water layers. Similarly to nitrogen, substantial increases in inorganic and total phosphorus concentrations in the benthic layer could be observed in August 2018. In 2017, inorganic phosphorus accumulation was less pronounced and varied on average from 10 % in August 2017 to 42 % in June 2017. However, there was no detectable difference between mussel farm stations and reference area stations.

Table 1: Average concentrations of nutrients (µmol L^{-1}) in Sankt Anna (both mussel farm and reference area) in 2017 and 2018

Parameter	2017			2018		
	June	August	October	June	August	October
NH4	0	0.59	0.66	0.56	5.4	0.4
NO2, NO3	0.12	0.04	0.38	0	0.69	0.12
TN	19.29	19.64	20.71	22.5	24.4	17.11
PO4	0.31	0.12	0.28	0.29	1.44	0.71
TP	0.73	1.1	0.93	0.94	1.84	0.96

Phytoplankton

The total phytoplankton biomass in the mussel farm in June, August and October 2018 was similar and varied between 407 and 430 mg m^{-3} (Figure 2). Phytoplankton succession in June was characterized by a mix of all functional groups. Total phytoplankton biomass in the reference site was lower (30% in average) comparing with the mussel farm and did not exceed 262 mg m^{-3} in June and October, and 356 mg m^{-3} in August. The taxonomical composition in the reference area was similar to that at the mussel farm in June and August while a mixture of four groups (20-25%) was more pronounced in October. The average chlorophyll *a* concentrations in farm and reference sites in all sampled months were low with highest values in June and lowest in August. At the same time, the water transparency was lowest in August (4.2-4.9 m) and highest in October (8.9-9.8 m) with slightly lower values in mussel farm stations.

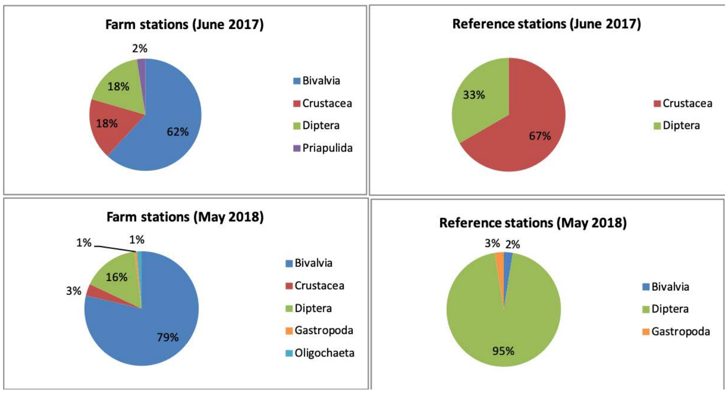

Figure 2: The phytoplankton biomass by taxonomical groups in the Sankt Anna mussel farm and at the reference site.

Benthic habitats

Samples of benthic organisms from Sankt Anna Archipelago were collected twice over the two-year period - June 2017 and May 2018. Overall, in both mussel farm and reference stations, a small number of taxa and organisms were detected in the benthos. In mussel farm stations (June 2017) only 4 taxa groups were found represented by only seven species. At the same time, only two taxa groups - *Crustacea* (67%) and *Diptera* (33%) were identified at the reference stations perhaps suggesting higher biological diversity in the benthos at mussel farm sites (see figure 2).

Results from samples collected in May 2018 presented slightly greater variety of taxa in mussel farm stations but the overall percentage was small and the dominant taxon again was *Bivalvia.* However, identified taxons were represented by just 6 species.

Conclusion

Mussel farming is suggested as a tool for mitigating Baltic eutrophication. Concerns over potentially detrimental impacts of bio-deposits and reduction in benthic oxygen levels,, appears to be inherently related to site-selection and hence very localised hydrological and nutrient conditions. Certainly two-year results from the Sankt Anna location do not appear to support the claim for excess bio-deposition and decreased benthic biodiversity, or the increased likelihood of hypoxic or anoxic conditions under the farm site. However, excess deposition has been observed at other locations and is likely related to sub-optimal water current conditions and/or excess production densities. This could theoretically lead to the above-mentioned problems and highlights the importance of proper localisation and production density of the farm. Consideration over, for example, water currents, bottom substrate type, bathymetry and level of production density should be considered when choosing a farming location. In addition, regular monitoring of the level of deposition will aid in the evaluation of the effects (if any) on the benthic environment allowing for proper mitigation.

Additional information on the environmental impacts of mussel farms in the Baltic Sea can be found on the following link: https://www.submariner-network.eu/projects/balticbluegrowth/deliverables

Interreg Baltic Sea Region
Baltic Blue Growth

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

THE PROJECT

This factsheet has been elaborated by the Baltic Blue Growth project. The aim of Baltic Blue Growth is to advance mussel farming in the Baltic Sea from experimental to full scale to improve the water quality and to create blue growth in the feed industry. 18 partners from 7 countries are participating, with representatives from regional and national authorities, research institutions, private companies. The project is coordinated by Region Östergötland (Sweden) and has a total budget of € 4.7 million. It is a flagship project under the Policy Area "Nutri" of the European Union Strategy for the Baltic Sea Region (EUSBSR).

Region Östergötland

Lead Partner:
Region Östergötland
Contact: Lena Tasse
Lena.Tasse@regionostergotland.se

SUBMARINER NETWORK

Project communication:
SUBMARINER Network for Blue Growth EEIG
Contact: Lisa Simone de Grunt
lsdg@submariner-network.eu

www.balticbluegrowth.eu
#BalticBlueGrowth

Interreg Baltic Sea Region
Baltic Blue Growth

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

EU STRATEGY FOR THE BALTIC SEA REGION FLAGSHIP

April 2019