Mussel farming in the Baltic Sea as an environmental measure

- new positive data from three ongoing EU projects[1]

Authors[2]
Anders Kiessling[5.1], Martyn Futter[5.2], Katarina Elofsson[5.4] och Aleksandar Vidakovic[5.3]

Ingress: New results show that mussel farms in the Baltic Sea can make a significant contribution to reducing eutrophication while supporting the circular economy and circular food production. In order to take mussel farming to the next level, further improvements of farm technology are required, but most of all more farms and also larger farms in conjugation with monitoring of their environmental impact, together with further work developing effective and profitable routes to reintroduce harvested mussels back into the food system.

Mussel farm at S:T Anna. Photo Lena Tasse, Region Östergötland

Background: Over the past hundred years, the Baltic Sea region has built up a large surplus of nutrients, both phosphorus (P) and nitrogen (N), mainly through the import of artificial fertilizer, animal feed and food. Sooner or later, this excess of nutrients ends up in the Baltic Sea via watercourses and sewage treatment plants where it contributes to eutrophication with overgrown coves, algal blooms and dead bottom waters as a result. More than 40 years of land-based measures have failed to solve this problem and even if we were to completely stop the supply of nutrients from land, it would still take many years before we regain acceptable water quality in the Baltic because the legacy of nutrients from previous emissions stored in the sediment - so-called internal load – continue to leak out. Therefore, in order for a recovery of the Baltic Sea to be possible within a foreseeable future, we also need to make efforts that remove nutrients from the system. Several measures have been proposed, such as large-scale dredging, increased fishing and locking P in the bottom sediments with, for example, aluminum. However, none of these alternatives can be described as sustainable or realistic and a realization has therefore emerged, that in addition to reducing the losses of nutrients from land to water, we must create a functioning, long-term cycle where nutrients are returned from the Baltic Sea back to food production on land. This is absolutely crucial in order to

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[1] **Information from the following projects has been used in the compilation of this brief:**

- Baltic Blue Growth, Interreg Baltic Sea Region Project 2016-2019. https://projects.interreg-baltic.eu/projects/baltic-blue-growth-11.html
- NutriTrade, Interreg Central Baltic project 2015 – 2018. https://nutritradebaltic.eu/
- Rich Water, EU Life project 2016 – 2024. http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=6104

[2] **Authors affiliation**
[1] Professor in Aquaculture, Dept of Animal Nutrition and Husbandry (HUV), Swedish University of Agricultural Sciences (SLU). Member of KSLA.
[2] Docent, Dept. of Aquatic Science and Assessment, SLU. Member of KSLA.
[3] Researcher and WP responsible Baltic Blue Growth, HUV, SLU.
[4] Professor in National Economy, Södertörns högskola. Docent Dept. of Economics, SLU). Project responsible, NutriTrade.

create a sustainable, circular system linking sea and land, but also in order to reduce our reliance on imports and to create a more climate friendly balance between exports and imports of nutrients in food, feed and fertilizers.

In March 2018, the Baltic Sea Center at Stockholm University (SU) published a recommendation not to support mussel farming in the Baltic Sea as an environmental measure, due in part to a lack of knowledge[3]. What they did not mention was that, on the initiative of both Sweden and the EU, several projects were also ongoing to build the evidence base for better decision making on the value of mussel farming as an environmental measure in the Baltic Sea. These new investigations were needed as available data were weakly substantiated based on old technology. Now the new projects are starting to bear fruit. They show that mussel farming with the right technology can constitute an important and cost-effective complement to land-based measures for controlling eutrophication in the Baltic Sea. We believe that SU recommendations regarding mussel farming in the Baltic Sea should be replaced with new recommendations based on up to date knowledge.

New technology provides new data: The EU InterReg Baltic Blue Growth (BBG) project has produced the first set of comparable data for nutrients in mussels grown in brackish and salt water, respectively, and has utilized new cultivation techniques developed especially for small mussels like those in the Baltic Sea. Earlier recommendations were based on technology for large mussels, typical of the West Coast. Although this new technology is still in the testing stage, we already see a production of 3-4 kg mussel per running meter of cultivation rope, which is almost 400% higher than what was previously achieved in the Baltic Sea with technology adapted for farming large mussels.

Harvest of small mussel at S:T Anna. Note the design of the attachment of the farming substrate allowing harvest without detaching the line. Hereby the harvest can be performed at sections and at intervals of the farmers choice, making use of the mussel for feed, or other purpose, possible as a continues delivery. Design and construction, Mats Emilsson, VCO. Photo Jason Baily, VCO

Examples of cultivation with the new technology adapted for Baltic Sea mussels include the BBG project (St Anna archipelago) and the Life-IP "Rich Waters" project (Stockholm archipelago)[4]. In St Anna's archipelago, Östergötland, 4 hectare mussel farm was established in 2016 for environment-/ feed- mussel production using the new and adapted Baltic Sea mussel technology. An expected harvest of 25 tons was calculated based on earlier results with old technology adapted for large mussels. When the 2-year cultivation cycle ended, 80 tons had been harvested, that is, more than 3X more than was thought possible. A similar result of 4X higher than expected production was obtained in the Life-IP project which evaluates mussel farming in the Stockholm archipelago using the new technology adapted to the small Baltic Sea mussels. The production was so high in this project the buoyancy of the test rigs had to be increased continuously so that the large amount of mussels would not sink them, which actually also happened. Fortunately, it was always possible to salvage these mussel laden rigs and increase their buoyancy so that they could continue to be used throughout the project.

Nutritional content in brackish and salt water: In addition to the fact that the mass of mussels harvested per production unit is much higher than expected, we can also note that the difference in nutritional content between mussels from the low salinity Baltic Proper and the high salinity western Baltic (Denmark / Kiel) is less than what has been presented previously. In particular, P content in whole mussels harvested during autumn and winter (when harvesting usually occurs) is similar from high and low salinity (brackish water) sites on both Swedish coasts. Figure 1 shows this as mean values for the different salinities. Figure 2 starts from the same data, but here

[3] Hedberg N, Kautsky N, Kumblad. L and Wikström S. 2018. Limitations of using blue mussel farms as a nutrient reduction measure in the Baltic Sea. Report 2, 2018. Baltic Sea Center, Stockholm University

[4] Video of mussel farm and harvest in St. Anna, Sweden: http://www.vattenbrukscentrumost.se/sv/2018/06/11/ny-film-om-musselodlingen-i-sankt-anna/ and http://novaator.err.ee/634918/24-kilomeetril-koitel-elab-soodav-merepuhastusjaam (in Estonian)

the individual measurement points per sample are shown (each sample consists of a batch of 50-150 mussels). What we see is that most of the samples from the western Baltic Sea have higher P content between March and June, but that there are only a few samples from the low salinity eastern Baltic (the Swedish East Coast from Kalmar to St Anna and Baltic States coast) during the same time (Fig. 2).

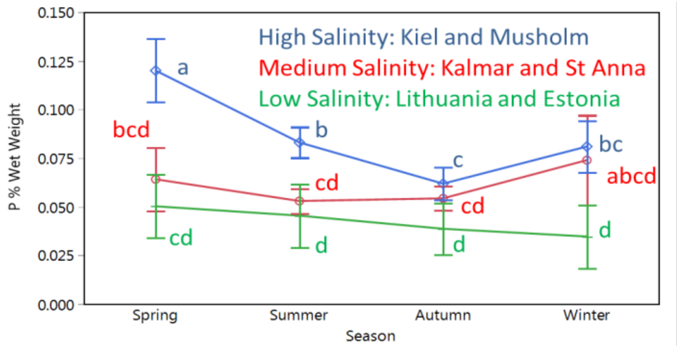

Figure 1: Seasonal changes in phosphorus (P) concentrations in whole mussels (shell, soft tissue and water) at harvest for different levels of salinity across the Baltic. Data are from the Interreg Baltic Blue Growth project (BBG)

However, we see that the few samples taken from low salinity sites during this period have a high P content (Fig. 2). Because the levels of P per whole mussel are so similar between the western and eastern Baltic in summer, autumn and early winter, we suspect that samples taken during spring and early summer represent more mature bivalve molluscs, which because of large amounts of gonads (gametes) have higher nutrient content. It is therefore likely that if mussels gathered from the eastern Baltic including also mature mussels, they would have had the same level of P regardless of whether the mussel had grown in the western or eastern Baltic. In order to clarify this, sampling specifically targeting mature and non-mature mussels is needed. Results from analyses on pure mussel meat (mussels but shell, see table 1) also indicate that there is no real difference in nutritional content between mussels from high and low salinity sites. There is also no difference in the total amount of mussel meat (dry matter) between mussels from low and high salinity sites (Table 1). This is extra interesting as it is in the mussel meat we find N and P and not in the shell. So far we have only analyzed the N and water content of the mussel meat, but we see from analyses in whole mussel (with shell) that the P content is strongly related to the N content, (R2> 0.82, see figure 3), that is, more than 80 percent of the variation in N follows exactly that of P. This is common in living tissue because these elements must be in a physiological balance. We therefore assume that the relationship we see in whole mussel between N and P (see figure 3) can be used to calculate P from N measured in mussel meat (see Table 1).

The harvest weight of mussel is a simple measure to use for both growers and authorities. We also use this measure when we evaluate how much nutrients we manage to recover. The harvest weight can be divided into three parts: shells, mussel meat and free water. The free water is found both outside the shell and some inside the shell. The mussel meat, in turn, contains protein, fat and some carbohydrate and minerals as well as bound water inside the tissue. This is where we find N and P in the mussel. If we analyze the content of bound water and nutrients in the mussel meat itself, we see no difference between mussels grown at low or high salinity farms (Table 1). What we see, on the other hand, is a clear difference in percent soft tissue, that is, how large a proportion of mussel meat constitutes the total harvest weight. This is of interest when one will understand why different mussels can contain different amounts of nutrients expressed per harvest weight. Since we do not find any difference in the actual mussel meat between low and high salinity, and we know that shell of larger mussels (which we find in high salinity) are heavier than those for small mussels, we believe that the difference we see is due to the fact that small mussels from Sweden's east coast contain a greater proportion of free water in and around the shell. This is quite logical as many small mussels have a much larger area

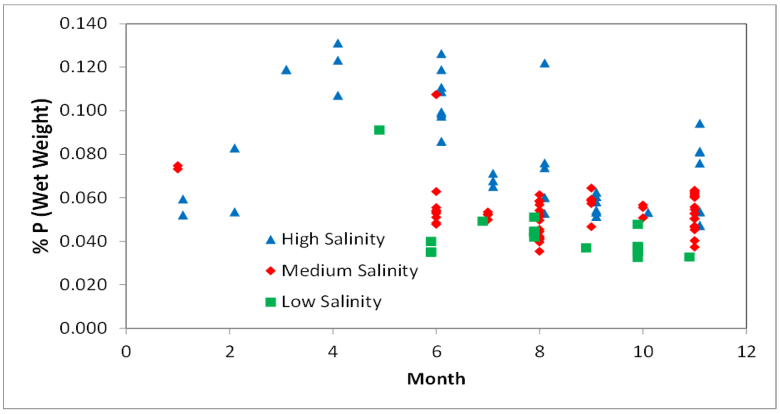

Figure 2: Monthly variation phosphorus (P) concentrations in whole mussels (shell, soft tissue and water) at harvest for different levels of salinity across the Baltic. Data are from the Interreg Baltic Blue Growth project (BBG) project (BBG)

than few large mussels, where water can be trapped during harvest. In practice, it has no significance, since we always count on the amount of N and P per kg harvested mussel based on the seasonal average and area of harvest, including shell, water and meat. We therefore believe that the slightly lower nutrient content of mussels from the Eastern Baltic, when we calculate N and P per harvest weight of whole mussel (Fig. 1 and 2), is due to the fact that more free water is trapped in the mussel when harvested. The fat content of the meat is, on the other hand, somewhat higher in mussels from the eastern Baltic, with an intermediate level in mussels from the Swedish East Coast and lowest in mussels from the high salinity western Baltic (Table 1). If this means that mussels from the Baltic Sea contain more, for us, healthy fats than mussels from higher salinity waters remains to be investigated. If so, it could have significance for the use of the mussels in different processes on land after harvest. Some of these possibilities are shown in a short film published by BBG[5].

Table 1: In this table, data from analyses of mussel flesh from the western Baltic (high salinity), the Swedish east coast (medium salinity) and the Baltic coast and Åland (low salinity) is presented. Parameter values that are followed by the same letter show no statistically significant difference between regions.

Area	Salinity	Meat Dry Matter %	Percent Soft Tissue	Soft Tissue Fat %	N (% soft tissue dry weight)	P (% soft tissue dry weight)
Western Baltic	High	15.1 a	58 a	9.5 a	9.5 a	1.41 a
Central Baltic	Moderate	14.2 a	52 b	10.3 a	10.3 a	1.48 a
Eastern Baltic	Low	13.7 a	41 c	9.7 a	9.7 a	1.33 a

Production costs: Overall, these new results show that the production cost, and thus the cost of recycled P and N, approaches the costs seen in salt water harvest, with the potential for further cost reduction by adopting work-saving technologies, such as video surveillance. Furthermore, costs may be further reduced by collaboration between farmers purchasing larger volumes, or sharing harvesting equipment, transport, processing technology and much more. The Life-IP project also shows something else important, namely that we can reach significant production levels right up to Norrtälje as well as in Swedish inner coastal areas. Thus, both the inner and outer archipelago may be able to gain from the well-known water quality benefits of mussel farming, where the mussels filter out particles, which in turn provides clearer water and greater visibility at depth, thus improving breeding grounds for fish by promoting the growth of macro algae and bottom-living plants (see this effect demonstrated in film from BBG[3]).

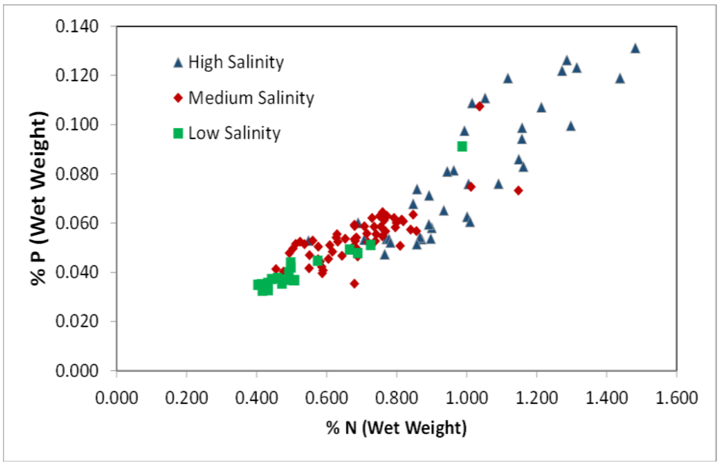

Figure 3: Covariation between dry weight (shell and soft tissue) concentrations of nitrogen (N) and phosphorus in mussels harvested at different levels of salinity across the Baltic. Data are from the Interreg Baltic Blue Growth project (BBG)

Under the farm: Furthermore, we have seen that sedimenting shells / mussels and faeces benefit bottom fauna living under the farm. This effect has previously been investigated in detail at the Åland mussel farm[6]. The same effect seems to occur in the BBG project farms in St. Anna[7] and in Kiel Bay[8], i.e.. increased biodiversity as a result of farming, at least at the intensity investigated. In other words, new evidence from the BBG project deomonstrates the exact opposite of what has been feared about the effects of mussel farms on benthic fauna. We fully agree with previous reports that there are gaps in knowledge about how the environment may be affected by large-scale cultivation in, for example, larger fjords and / or offshore (which is a possible strategy together with ofshore wind

[5] https://www.youtube.com/watch?v=oDSEfeetDQY

[6] Kraufvelin & Diaz. 2015. Sediment Macrofauna communities at a small mussel farm in northern Baltic proper. Boreal Envir. Res. 20: 378-390.

[7] Fact sheet, " Environmental impacts of mussel farming" by BBG, https://www.submariner-network.eu/projects/balticbluegrowth/deliverables

[8] Philipp Süßle, Particulate Organic Matter Sedimentation and Ecological Consequences at a Blue Mussel Farm in the Kieler Förde, Bachelor Thesis, Fach Hochschule Lübeck, Univ. Applied Sciences and Coastal Research & Management.

power parks). Today's knowledge, however, indicates that growing mussels in smaller farms in much of the Swedish archipelago is an effective way of removing nutrients, and these new results indicate that there may be ten if not hundreds more suitable cultivation areas than was previously thought, so perhaps this is where we should invest in the near future?

Harvest of small mussel at S:T Anna. Note the simple equipment, being a significant factor in reducing production cost. Design and construction, Mats Emilsson, VCO. Photo Lena Tasse, Region Östergötland

Within the NutriTrade project, data on planned mussel production and production costs have been collected from projects in the Baltic Proper and in Denmark. Analysis of these data shows that if farm equipment is used throughout its lifetime, the cultivation cost amounts to just under SEK 5 per kg of whole mussels harvested. In this calculation, no future cost efficiency improvements have been taken into account, nor have possible scale effects on production cost been considered. This means that the cost of using farmed mussels in suitable locations to remove P from the Baltic Proper, even with the current evidence base, to be lower than the cost of some measures, which today receive support via the rural development program for this purpose, such as protection zones and wetlands. As the target for reduced P-levels in the Baltic Proper is not reached at present, further measures are necessary. In this context, mussel farming can be cost-effective even in brackish water. Although mussels grow better on the west coast, it is in the Baltic Proper that cultivation must be carried out to benefit the Baltic Proper.

To conclude: These new data show that mussel farming throughout the Baltic Sea, including the Baltic Proper is economically justifiable and can be a measure to recover nitrogen and phosphorus.

Recommendations

1. Supplement reduced nutritional input from land with a resumption of nutrition

Despite decades of land-based measures, the total amount of phosphorus in the Baltic Sea is still increasing, which shows that the rate of action is too slow and that the effects of internal fertilization are extensive. If we are to achieve our national and international Baltic Sea environmental goals, measures such as mussel farming, which also reduce the nutrients that have already leaked from land to sea, are therefore required. The Baltic countries and their organisations as HELCOM should therefore consider mussel farming as a tool in the national water management plans and in the Baltic Sea Action Plan.

2. Invest in more and larger crops to increase knowledge of the environmental effects

To date, no significant negative environmental impacts have been observed from mussel farms in the Baltic Sea. On the other hand positive effects such as improved visibility, reduced nutrient levels and increased biodiversity have been observed repeatedly. However, today's mussel farms are small and in order to ensure environmental benefits, the effects need to be measured on more and larger crops according to standardized methods.

3. Work on technology development and optimization

A number of small-scale projects have tested and developed methods for the special conditions of the Baltic Proper and in less than 10 years, among other things, the harvest has been increased by several hundred percent. These new data indicate that we in fact are approaching the predicted potential for mussel production. It is likely that upscaling and continued technology development can further contribute to even higher production and lower costs.