Sustainable Uses of Baltic Marine Resources

in collaborartion with AQUABEST

Perspectives from the Åland Aquaculture Week
Mariehamn, Åland | 9–12 October 2012

Mussel Farming in the Baltic Sea Region: Prerequisites and Possibilities

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The Åland Aquaculture Week was hosted by the Baltic Sea Region Programme projects Aquabest and SUBMARINER in Mariehamn, Åland from 9 to 12 October 2012.

This magazine presents the perspectives on possibilities and prerequisites of mussel farming in the Baltic Sea that were shared during the event.

About the Åland Aquaculture Week

The Åland Aquaculture Week took place in Mariehamn, Åland from 9 to 12 October 2012 and hosted over 60 participants from all over the Baltic Sea Region. The event was organized in cooperation between the two Baltic Sea Region projects Aquabest and SUBMARINER. It offered a platform for cooperation and networking among different stakeholders in the Baltic Sea Region's aquaculture sector, such as policy makers, feed manufacturers, fish and mussel farmers.

Closing the nutrient loop

The first two days were dedicated to the challenges and opportunities for "closing the nutrient loop" of aquaculture in the Baltic Sea. Multiple perspectives were contrasted during presentations and roundtable discussions. Mussel farming was discussed as one of the possible contributions to developing a more suatainable fish feed from Baltic Sea resources.

Focus on mussel farming

The last two days focused explicitly on the conditions for mussel farming in the Baltic Sea. Different methods and practices for farming as well as the possibilities for mussel meal production were presented and compared. Experiences and important lessons from different trials were shared among the participants. The Åland Government has a pilot mussel farm in the archipelago municipality of Kumlinge (cf. contributions on pp. 12–13 and p. 16). The participants made a field trip to the farm and were also given the opportunity to taste freshly cooked mussels from the farm.

About this magazine

This publication provides an overview on the perspectives on mussel farming in the Baltic Sea Region that were shared during the Åland Aquaculture Week. The contributors discuss the use of mussel farming as an environmental measure for improving the water quality of the highly eutrophied Baltic Sea, other applications such as human consumption and feed production, technological solutions to be applied in Baltic Sea conditions, but also possible challenges to a wide-spread introduction of mussel farming in the Baltic Sea.

SUBMARINER Perspectives from Cooperation Events

This magazine is part of the series "SUBMARINER Perspectives from Cooperation Events". The articles published in this series form an important input to the SUBMARINER Roadmap to be published in summer 2013, indicating the concrete steps to be taken in the coming years within the Baltic Sea Region so as to promote beneficial uses of Baltic marine resources and mitigate against negative impacts.

Earlier issues in this series have been published as a follow-up of the SUBMARINER Cooperation Events on Algae (Trelleborg, Sweden, September 2011) and Blue Biotechnology (Kiel, Germany, May 2012). All issues are available for free download at publications.submariner-project.eu.

Mussel Farming: Human Consumption and/or Nutrient Extraction? A Danish perspective.

Jens Kjerulf Petersen | Danish Shellfish Centre, Denmark

Unlike in most parts of the Baltic Sea, the conditions for commercial seafood mussel farming are good in parts of the Kattegat and the connected Danish fjords. In the Limfjorden, which connects the Kattegat with the North Sea in the northern part of Jutland, the nutrient richness and the high salinity result in production cycles of appox. 1 year or less for full-scale mussels, for instance.

Still, because of a small domestic market for seafood mussels, the biggest share of mussels produced for human consumption in Denmark is being exported. Additionally, challenges in fulfilling the national action plans for achieving good environmental status in the Danish waters, have made mussel farming interesting as a mitigation tool. As abatement measures on land are expensive, alternative tools are required. Especially in estuaries and coastal areas, huge pools of nutrients are stored in the sediment and in some estuaries internal loading is bigger than runoff contributions. Assuming that mussels contain roughly 1 % nitrogen (N) of the total mussels weight (see table 1 for details), mitigation cultures seem possible in such areas.

The MuMiHus project

Within the framework of the MuMiHus project ("Mussels – Mitigation and feed for Husbandry", 2009–2013), the conditions of mussel farming as an environmental mitigation tool are investigated in more detail. A full-scale mussel farm in the Danish Skive Fjord with 90 long-lines on an area of 18 ha is used for measuring the biomass and nutrient content and for investigating the environmental impacts of mussel cultivation, especially sedimentation and fluxes of nutrients and oxygen. What is more, the project calculates the costs of abatement and develops management models and tools.

Detailed results of the economic calculations will expectedly be published in 2013. First results indicate that the costs for abatement are relatively low and compatible with land based abatement measures, with labour costs for maintaining the culture unit including adding buoys being the largest cost factor in long-line production systems.

Table 1: Content of organic carbon, nitrogen and phosphor (in kg) in 1 tonne fresh mussels

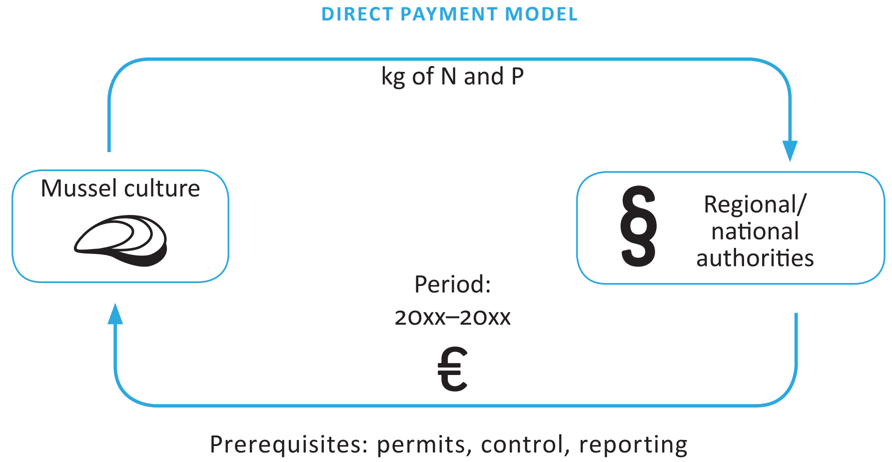
Mussels from long-lines							Mussels from fishery						
	Mussel meat			Mussel shell				Mussel meat			Mussel shell		
	C	B	P	C	B	P		C	B	P	C	B	P
Mean	39	8.2	0.5	5.7	1.7	0.1	**Mean**	22	4.7	0.3	5.7	1.7	0.1
Min	19	4.5	0.4	5.1	1.5	0.1	**Min**	11	2.5	0.2	5.1	1.5	0.1
Max	65	16.2	0.9	6.3	1.9	0.1	**Max**	35	7.7	0.4	6.3	1.9	0.1

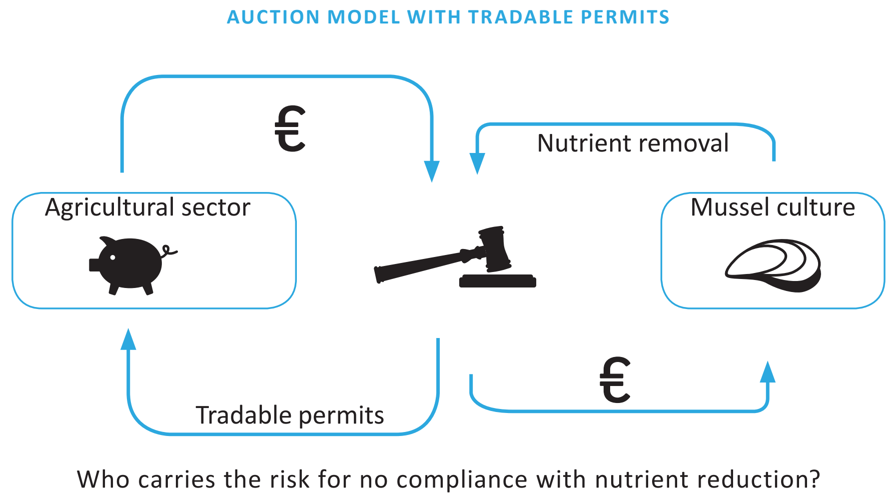
Possible management models

Two possible management models have been considered within MuMiHus (see figures in the right hand column):

- direct payments by regional or national authorities or
- an auction model with tradable permits and payments from the agricultural sector

Guarantees for nutrient removal are required in order to make mussels as mitigation tool successful. Experience from an earlier attempt to use mussels for nutrient removal in Lysekil (Sweden) shows that relying only on market economy is risky. The key for a successful operation will be to find solutions for multiple uses of mitigation mussels, e.g. for human consumption, as animal feed, fertiliser or renewable energy source.





Mussels are first of all an excellent seafood product…

…but also an effective mitigation tool for improving water quality.

Challenges for mussel cultivation in the Baltic Sea

Nardine Stybel | EUCC – The Coastal Union Germany /
Leibniz-Institute for Baltic Sea Research Warnemünde, Germany

Mussel cultivation in the Baltic Sea is not very widespread, just the southwestern part is known as traditional area. The local focus is on using mussels for human consumption, whereas within the last years in other areas of the Baltic Sea first small-scale pilot plants for eutrophication abatement have been implemented. The knowledge about impacts of mussel farming in the Baltic Sea on the ecosystem and the influences on socio-economy is limited; experiences from other mussel farming areas in northern Europe can be used initially. To get a holistic overview about pros and cons of mussel farming as an eutrophication abatement measure a SWOT analysis can help. The following aspects can be affected by mussel farming and should be taken in consideration if bioremediation by using mussels is planned.

Biotic factors

Competition for food: Extensive bivalve aquaculture can lead to intra- and interspecific competition for food between natural and aquacultured bivalves or other suspension feeders.

Changes in benthic communities: Cultures can alter infaunal or benthic communities through provision of complex habitats and artificial reefs, e.g. mussels falling to sediment. This can provide new substratum for settlement and growth of beneficial and unwanted biota. Opportunistic enrichment tolerant species (e.g. starfish) can become predominant. Changes in benthic communities are also possible by the input of organically rich material rejected by farmed mussels. A decrease in abundance and biodiversity of benthic communities may follow (e.g. Peterson et al. 2011).

Changes in pelagic communities: Mussels can filter selectively and may promote unwanted changes in phytoplankton composition.

Physico-chemical factors

Influence of hydrodynamic regimes: Cultivation structures can modify the current velocity and the direction of water movements. That alters natural patterns of erosion and sedimentation (Lasiak et al. 2006). This impact is important for sediment oxygen uptake that increases with lower current velocities.

Concentration and accumulating of organic matter: Faeces, pseudofaeces & dead mussels on the bottom decompose under oxygen consumption and may affect biogeochemical cycles. Oxygen depletion events can follow. It happened in the western Baltic Sea area, when average water currents were less than 0.82 cm per second below a mussel farm (Carlsson et al. 2009). Moreover, decreased rates of denitrification and an increase of ammonium production are possible underneath intensive farms.

Socio-economic factors

Costs and benefits of mussel cultivation: The use of harvested mussels as seafood is highly profitable, but their use in the Baltic Sea area is limited due to size, meat content, concentrations of heavy metals, toxins and pathogenic microbes. Even the use of mussels as feedstuff and fertilizer depends on good quality of harvested mussels. Considering the costs for the direct removal of nutrients by harvesting cultivated mussels, marginal costs per kg nitrogen vary between 0 and 10 Euro and for phosphorous between 0 and 100 Euro (Gren et al. 2009). To calculate the overall marginal costs of nutrient removal by mussel cultivation in the Baltic Sea enhanced release rates of nitrogen and phosphorous from sediments as well as the potential loss of denitrification due to the accumulation of organic matter on the bottom must be considered as well (Stadmark & Conley 2011).

Potential farmers may tend to have a narrow short-term view focused on immediate profits. Aquaculture operations do not often recognise economic value of bioremediation. A missing polluter-pay principle enhances this problem.

Spatial use conflicts: The improvement of coastal water quality by mussel cultivation is of high ecological value. But mussel cultivation plants may compete for space with various economic interests, such as e.g. fishery, maritime transport, and tourism.

Acceptance of local population: The acceptance of mussel cultivation plants in coastal areas can be low due to aesthetic problems by visual intrusion (buoyage on surface). The risk of drifting of torned off cultivating structures linked to storm events or ice-drift may also decrease local acceptance. This would create marine litter and endanger large vertebrates (mammals, birds) by possible entanglement.

Legal aspects: At the European level as well as in some riparian states of the Baltic Sea area an aquaculture law is missing. In addition, limited experiences with mussel cultivation can make an implementation difficult.

Conclusion

To improve the implementation of bivalve mussel cultivation for eutrophication abatement, incentives for potential farmers and help of responsible authorities are necessary. Furthermore, a polluter-pay principle can make bioremediation more attractive, if implemented costs of biofiltration can be added to production costs and could constitute additional income to farmers.

For future sustainable mussel cultivation in the Baltic Sea selecting appropriate sites are of high importance. Densities and biomass of cultivated mussels must remain in accordance with assimilative and dispersive capacity of the surrounding environment.

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Visual disturbance by the first pilot station of mussel cultivation in Usedomer See, linked to the Szczecin Lagoon (Picture: Sven Dahlke)

Case study Szczecin Lagoon

The German-Polish Szczecin Lagoon in the southern Baltic Sea is highly eutrophic coastal water. Mussel cultivation seems to be a supporting internal measure to improve the ecosystem function of the shallow lagoon. Zebra mussels (Dreissena polymorpha), a species currently inhabiting the whole lagoon, may help to clarify the water by high filtration rates. But presumably a lack of appropriate substrate has led to a decrease of zebra mussel population during the last decades. The cultivation of zebra mussels on lines or nets in combination with periodical harvest could reduce the turbidity and the nutrient content in the Szczecin Lagoon.

Since 2012 University of Greifswald (Germany) has installed a pilot plant for zebra mussel cultivation in Usedomer See, linked to the lagoon. Based on that, in co-operation EUCC-Germany will conduct analyses of ecological and socio-economic impacts (projects ARTWEI and AQUAFIMA).

SWOT analysis of zebra mussel cultivation in the German-Polish Szczecin Lagoon. (Source: Stybel et al. 2009)

Strengths	Weaknesses	Opportunities	Threats
· **Environmentally friendly**, "native" species · **Removal of nutrients** by periodic harvest · **Improvement of ecosystem quality** by increased biodiversity · **Low limitation by spatfall** in comparison with bottom cultures	· **Uncertain commercial use** because of slow growth and small harvest size · **Increased concentration of heavy metals** affects mussel use for animal husbandry · **Reduction of mussel biomass** by predators (fish, waterfowl) or lack of food · **No tradition and experiences** in mussel cultivation · **Uncertain legal and planning situation**	· **Resettlement of macrophytes** by improved water transparency · **Altered food web interactions**, more benthic feeding fish and expanded fishery · **New regional jobs** in harvesting and processing of mussels · **Higher number of tourists and overnight stays in summer season** by improved water transparency	· **Local anoxic surface sediment** by deposited organic material · **Bothered tourists** by mussel shells washed ashore · **Material damage** by fouling of boats, gillnets etc. · **Damage of net structure** by ice cover in winter

Perspectives for mussel farming in the Baltic Sea Region – with focus on feed mussels

Odd Lindahl | The Royal Swedish Academy of Sciences, Sweden

Mussel farming as an environmental measure

It is well known that mussels improve coastal water quality as they "harvest" nutrients through their food intake of phytoplankton. The potential of mussel farming to improve coastal water quality in marine waters has been scientifically described in numerous studies. The most obvious results have been that the establishment of mussel farms has dramatic effects on water clarity through the removal of particles in the water (mainly phytoplankton), doubling light penetration and leading to a significant decline in chlorophyll-*a*.

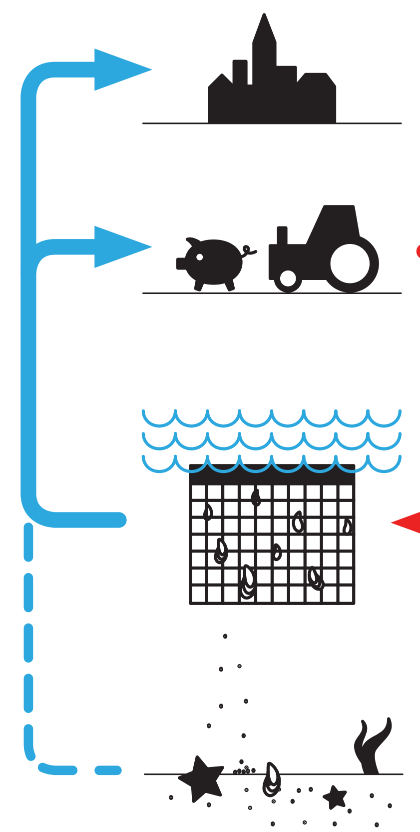
The mussels, both wild and farmed, feed on naturally occurring phytoplankton. The phytoplankton can in some way be compared to catch crops in agricultural operations on land and the mussels as the grazers. The phytoplankton uses nitrogen and phosphorous for their growth. The nutrients are transformed into mussel meat and will be returned to land when the mussels are harvested. Thus, mussel farming can therefore be compared to open landscape feeding on land, but in the sea. A large part of the nutrient discharge to coastal waters has its origin in agriculture operations and the return has been called the Agro-Aqua recycling of nutrients by mussel farming.

Mussels catch and reuse nutrients and transform these into mussel meat, which in turn can be used as seafood, feed and fertilizer. Mussel use is generally determined by its size and meat content. Most of the global mussel farming is intended to produce mussels for human consumption. The annual world production of mussels today exceeds 1.5 million tonnes, of which half is produced and consumed in Europe. Both wild mussels as well as cultured mussels are available for seafood from the southwestern part of the Baltic Sea (with a mussel farm in operation in the Kiel Bay). With decreasing salinity levels towards the eastern and northern parts of the Baltic Sea, blue mussels become too small to be used for traditional seafood purposes. Thus, this application will not become of major importance within the Baltic Sea Region.

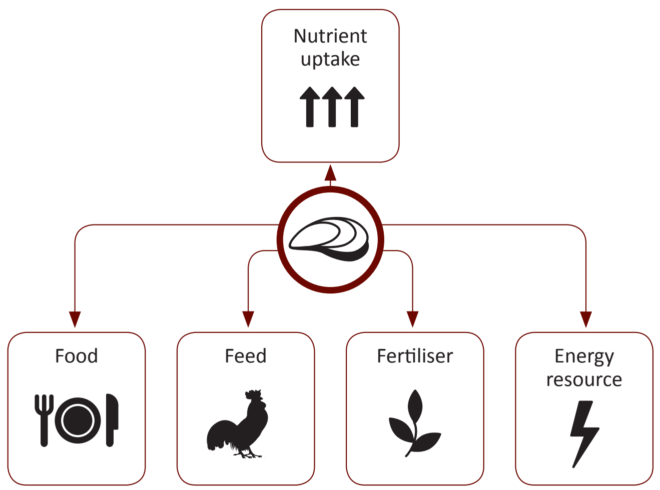
Mussels for production of feedstuffs

Since mussels are at the second step of the marine food chain, the use of mussels instead of fish for feed production also is of large ecological importance at a time when many fish stocks are over-exploited on local, regional and global scales. The blue mussel has a high content of the essential sulphur-rich amino acids methionine, cysteine and lysine, which match the content in fishmeal. They can, when shells are included in the feed, also provide calcium carbonate. Mussels are an excellent high protein feed for poultry as well as fish feed and have a fat content of about 2 % (40 % of which are Ω3 long-chain fatty acid molecules).

A pilot plant for the production of mussel meal has been set up during 2011 and first half of 2012 in Ellös situated on the Swedish West Coast (see pictures on p. 11). The pilot plant project has a capacity of processing 1 tonne of fresh mussels per day, which results in about 40 –50 kg of mussel meal and 400–500 kg of shell with some dried mussel meat attached thereon. Besides locally produced (fresh) mussels, steamed and frozen mussel meat with origin from south-western Baltic has been processed. In September 2012, a first trial was carried out processing barely a ton of small and fragile Baltic mussels with origin from Åland.



The Agro-Aqua recycling of nutrients by mussel farming



Possible applications of mussel farming

The use of mussels instead of fish for feed production is of large ecological importance.

One of the greatest challenges producing mussel feed is to get rid of all or a certain part of the shells, especially the very thin and fragile shells of Baltic mussels. The shells may also constitute a part of the feed mainly as a source of calcium (Ca). Depending on the amount of shells, or more correctly shell pieces, mixed up with the mussel meal, there are different possible uses for feed products with a varying content of shells. If all shells are included, the ratio between mussel meal and shells will be about 1:10 and the protein content of this mixture is below 10 % (dry weight). When no shells are included the protein content of the mussel meal will be about 65 %.

Feed trials using mussels

Feed trials using mussel meal processed from fresh mussels or steamed mussel meat have so far been carried out or are presently carried out. First of all, mussels as a high protein source in the feed were carried out on poultry, both layers and chicken breed. These trials have demonstrated that feed based on dried mussel meat do not transfer any fish taste to eggs or the meat and also that the yolk will become nicely colored through the content of astaxanthin in the mussels. Further that a part of the shells can be included as a calcium source.

Feed trials on fish were started during autumn 2012. The species used ware Rainbow Trout, Arctic Char and Atlantic salmon, but no results were available at the Åland Aquaculture Week. Feed trials on Norwegian lobster and pig were also started up.

It could be mentioned that the process of producing mussel meal will most likely be approved according to EU feed regulation in the near future. Further that the mussel meal will approve as an organic feedstuff.

Mussel meal economics

At present mussel meal cannot economically compete with e.g. fish meal on the feed market due to a too high price. The main reason is that it is not possible to produce the mussels at a low enough price. However, there is one option to overcome the gap between what the feed industry can pay for feed mussels and what the mussel farmer needs to run the mussel farming enterprise. This option is that the mussel farmer is paid for the environmental service the mussel farm provides to society through the recycling of nutrients from sea to land.

Actually, if the mussel farmer is given compensation according to the same scale as given to agricultural farmer for their measures to reduce nutrient leakage from far land, the price of mussel meal is estimated to come close to that of fish meal of good quality. Swedish governmental authorities are working on such a proposal which, if approved, may come in service in 2014.

Summary

Mussel farming as an environmental measure and feedstuff source can be summarized as follows:

- Recirculates nutrients from sea to land.
- Is suitable in nutrient trading schemes.
- Mussels are a valuable raw material for producing feedstuff.
- Mussel meal can be used in feed for a number of monogastric animals.
- Mussel shells (Ca), astaxanthin and micro-nutrients are added values.
- Mussel farming is a win-win measure for the environment, society and industry.

A mussel farm in the Baltic proper

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Eutrophication in the Baltic Sea

Eutrophication is one of the most critical problems to be resolved in the Baltic Sea Region. It has been calculated that 20 million tonnes of nitrogen (N) and 2 million tonnes of phosphorus (P) have been released into the Baltic Sea during the last 50 years. This has caused the destruction of approximately 60000 km^2 of bottom area due to hypoxia and anoxia, although this area is constantly changing from year to year. Although drastic changes in our way of living, with heavily reduced nutrient discharges into the sea, will be needed to save the Baltic Sea, a number of different "engineering" methods have also been suggested to combat eutrophication. Many of these measures are extremely expensive and their effects in the long term are unknown: e.g. the continuous pumping of air down to the sea bottom or the release of polyaluminiumchloride compounds that could bind P and make it sink to the bottom. A far cheaper and more ecological mitigation tool could be the implementation of mussel farms, where we could provide settlement substrates for the billions and billions of mussel larvae present in the sea and take advantage of their ecological engineering capacities while filtering plankton and binding the nutrients into their body meat, 24/7.

Mussel aquaculture

A broad-scale development of mussel aquaculture could contribute to the improvement of the water quality to the Baltic Sea and at the same time generate well-being of Baltic Sea countries. Considering the growing number of humans on Earth and the increase in global fishery (average increase of fishery efforts is 7.4 % per year), the captured volume of wild fish is expected to go down by 2.6 % per year, but the volume of aquaculture is expected to increase by 8.7 % per year. Blue mussel fishery is estimated to increase by 1.3 %, per year. In the Baltic Sea, especially in its more saline parts, mussel farming has been partially successful, but high uncertainty and scepticism still predominates in the Baltic Sea region, especially regarding how to attain a sufficiently efficient mussel growth (reasonable size for harvest and end-use). Predominating concern is also present regarding potential negative environmental effects from mussel farming activities, such as accumulation of organic matter (a product of the excretion of pseudo-faeces), which potentially could induce more hypoxia and anoxia in the Baltic Sea and a release of additional P from oxygen-free sediments. These concerns are based on the process of decomposition of organic matter which utilizes oxygen (oxidation by bacteria) diluted in the sediment and in the water. When the oxygen is depleted other types of bacteria take over which releases ammonium and phosphate increasing eutrophication.[1] Other experts suggest that this can be avoided by carefully choosing the locations for mussel farms in terms of good water circulation, which can avoid the accumulation of sediments at a specific site and by regulating the size of mussel farms. Petersen et al.[2] also listed several economic-environmental advantages of mussel farming highlighting its function as a eutrophication mitigation tool and its capability of recycling nutrients of diffuse origin back from sea to land. The removal of nutrients should further bring an additional improvement in the form of increased water transparency which could have positive ecosystem effects such as the stimulation of photosynthetic capacity in macroalgae and in macrophytes promoting their photosynthesis and oxygen release.

A broad-scale development of mussel aquaculture could contribute to the improvement of the water quality of the Baltic Sea and at the same time generate well-being to the Baltic Sea countries.

Environmental effects of a small farm in the Baltic Sea

Taking into consideration these views, we assessed the environmental effects of a small mussel farm located in the Baltic proper (in Kumlinge, Åland Islands). The conditions of this mussel farm differ in many ways from those debated by scientist above, which mainly refers to mussel farms located at the west coast of Sweden and in Limfjorden in Denmark, where salinities range between 15–20 psu, the farms are bigger and the ecological conditions are different. Due to these differences, it is absolutely necessary to examine the effects of mussel farms also in the Baltic proper at salinities around 6 psu.

We thus evaluated environmental effects induced by a small mussel farm (ca. 30 tonnes of mussels after 2.5 years of operation, 2010–2012), at a previous fish farming site (fish farming ended 2008) and expected damaged bottoms beneath the farm in terms of reduced biodiversity, high organic matter, lower abundance of organisms, hypoxia, etc. In addition, we feared that the waters around the farm could exhibit high concentrations of N and P, and perhaps also Chlorophyll-a in case the farm merely released nutrients than took them up.These expectations were not fulfilled, because we did not find any other harmful effects than an increased organic content beneath the farm, which also could be a left-over from the previous fish farming period). On the contrary, we found many positive effects that possibly were induced by the mussel farm compared to the controls (water areas chosen at 500 and 1000 m distance from the farm into three directions). For example, total abundance of organisms and total number of animal species were higher at the mussel farm, with no sign of anoxia or hypoxia, although diversity did not differ. Additionally, the water around the farm contained less P than the controls and the water was clearer due to lower concentration of chlorophyll-a thanks to an effective filter-feeding of plankton by the mussels.

The mussel farm facility in Kumlinge, Åland Islands. Each line represents a mussel farm unit.

Economic perspectives

The economic-environmental benefits can further increase when mussels are harvested removing their nutrient content. It has been calculated that 1 tonne of mussels removes 8.8 kg N, and 0.7 kg of P, a nutrient removal which could be traded between the users who release fertilizers into the sea and persons in charge of mussel farms by some sort of "discharging rights". In that way mussels will recycle nutrients present in the Baltic Sea basin by closing the biogeochemical loop.

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This article is based on results of the Baltic EcoMussel project.

Socking mussels: Success factors and mishaps to watch for

John C. Bonardelli | Shellfish Solutions, Norway

For many growers, socking your mussels is an obvious next step this fall after placing collectors in the sea, and probably an ongoing activity in your production planning. Yet how many can boast that they are successful at it, or rather that they attain the yields that socking is supposed to bring? In most cases, good results after socking are related to smart preparation, timely handling at sea, and proper materials. In my evaluation of socking mishaps, which may appear as fall-off, poor spat attachment or mortality in the months following socking, most failures seem to be related to a variety of logistic errors committed during socking itself.

Why sock in the first place? There are several reasons, the most common being better control over density and over the range of sizes at socking, which in turn: optimizes the potential growth rate, shortens the time to market, reduces the risk of fouling, limits fall-off and provides higher yields in commercial biomass, with less waste at harvest.

The ultimate goal in socking mussels is thus to obtain the highest commercial yields in the shortest possible time with minimal waste.

This paper presents some of the more obvious 'dos' and 'donts', which should help your production planning evolve. For the more persistent cases when socking doesn't seem to work just right, some on-site evaluation may be required to refine the logistics with individual producers.

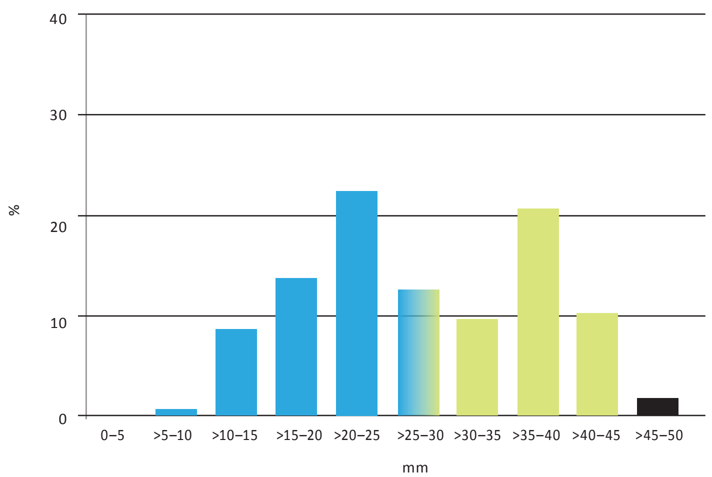
There are basically 3 stages to obtain successful results in socking: Planning, execution and follow-up.

Planning

In the previous Grower "2-Spat recovery options", I exposed 3 different settlement strategies, ranging from 'single set', 'double or multiple sets', and 'second set'. So before we start socking, it's important to sample some collector lines to establish the size distribution of your spat, and what's out there. You want to know the spat density (number spat per meter), from which you calculate the total available spat for socking, from all spat lines. You may have 1800 spat/meter, but realize that after grading only 78 % (1400/mm) is within the size range you want to sock. If you have 5000 meters collectors, you will likely sock 10,000 m at 700/meter, if you use large diameter material like NZ rope.

Further, you may have 2 separate size groups, which you want to sock as small (10–25 mm) and medium (30–40 mm) spat. In the example shown, it so happens that if you grade properly, each group provides about 700 spat/m to sock, so that 1m collector yields 2 m socked spat. Next, identify which lines are free to install your small and medium spat.

Decide what core rope will best hold your spat. Is it old salmon netting, NZ core rope, old fishing rope, or some plastic material? Personally, due to its longevity, level of socking efficiency and



Size frequency of spat on collector

Rucking cotton onto sock tube

harvest speed, I prefer the NZ ropes, which hold higher spat densities due to their diameter and available settlement surface. Your production volume and location defines your methods, based on your ability to invest, the length of your production cycle, your husbandry and the depth at which mussels can grow.

Execution

There are few elements in shellfish culture that we can really control, so when we can we should make every effort to master our task. Socking is actually the only production stage where a grower decides the fate of his mussels; where machine technology, environmental conditions and mussel biology interact in a short time frame. How you handle the spat will determine what you have to harvest later.

Check your machinery beforehand: Make sure that your stripper, declumper-grader and conveyor do not crush or dislocate your spat. Provide lots of water during the process and test that your grader bars actually fit the spat size structure you want to group together. Does the waste include too many big mussels? I have rarely seen perfect grading bar distances, mostly because of poor welding or distortion over time, yet this is the most important tool in the industry for selecting size of spat, as well as for grading out valuable market size mussels. Saving 10 % on 100 Tm will easily pay for adjustments.

Measuring the grading bar distances for uniformity

Handle spat with care: Spat should be hauled out, declumped and graded without damaging or crushing them. They should be held on deck for as short a time as possible.

With cotton socking, you can install (ruck) up to 1 km onto a 2 m tube (bottom), whereas only 500 m if it is not rucked at all. This ensures that less time is wasted at sea when a 3-man crew has to stop for 10 minutes to change a tube.

The socks should sink immediately. Avoid that the freshly socked mussels float on the surface for the minutes it takes the rope to sink, which can cause clumping of spat and eventually greater losses. Higher post-socking yields are obtained when the seed and the core rope are pre-soaked: meaning that the spat do not fill with air while they are held in the socking bin too long, and the rope is immersed in sea water prior to socking.

Socking perfection. It's not complicated but it takes experience. A good socking team will test the density of the socks during the day, to make sure they're getting the 700/m. This is especially important when you change seed size. The fresh sock is placed across a known distance and the two ends tied before cutting the cotton to let the spat fall out and be counted. From this you can adjust the socking machine.

Why be satisfied with 5 kg/meter that requires more longlines to produce commercial yields when you can obtain 7 kg/m and be more efficient?

Follow-up

Socking operations usually take several months, and may even be spread over fall and spring, which is a big bonus for staggering production. Don't take anything for granted once socking is underway. After 3–4 weeks, it's wise to go back on the socked lines, and do a recount of the live spat in the sock. Check the density, and observe if they are well byssed. If they are clumped or densities are too low, you should check your methods and refine them. Lastly, if you use the wrong floatation, or put too many floats at once, the lines will jolt the spat during storms and greater losses will occur. Keep an eye out for predatory ducks and new fouling during the final stretch.

Mussel farming perspectives of the Åland Islands: aquaculture updated

Petra Granholm | Åland Government, Åland

On Åland, "aquaculture" has traditionally only meant fish farming. Fish farming has since the late 70's been important particularly in the sparsely populated archipelago with its vast water areas for cage farming. However, intensive fish farming has an environmental impact in form of eutrophication, and in pace with a more serious state of the Baltic Sea, the pressure on fish farmers to find environmentally sound solutions have increased.

The idea to start mussel farming came from fish farming, as the former fish farmer Torbjörn Engman had heard of the attempts with mussel farming as a nutrient compensation measure on the Swedish west coast. The local fish farming association,with support from the EU Fisheries Fund and the Åland Government, started two pilot projects in 2006 with long line farms in the municipality of Kumlinge, and in the west of Åland, at the fish farm Storfjärdens Fisk in Eckerö. As the experiences from this first pilot project proved that cultivating mussels is possible in Ålandic waters,[1] the Åland Government proceeded to attempt a pilot farm on a larger scale in 2010. This is a project in three parts: The physical part is four 120-metre units of the type "Smart Farm" , which were put out in the same place as the first pilot farm in Kumlinge around midsummer 2010. The harvest will take place in December of 2012. In 2011, a survey of the whole of the Ålandic archipelago was made to map suitable locations for mussel farming. The most important criterion for such sites is the balance between a good water flow for oxygen and mussel food in form of plankton coupled with enough shelter to avoid exposure to storms and pack ice. In order to have the most accurate data, consultations with locals were held all over Åland and the result showed that Åland indeed has many good areas for mussel farming.[2]

It was, however, soon realised that mussel farming would not be profitable as an environmental measure only. There is a definite need to find a use for the small Baltic Sea mussels, dwarfed by their struggle to survive in the low salinity of the brackish waters. Therefore, the economical prerequisites need to be given much attention, and a report on economic aspects and possible uses for the Åland mussels will be published in the first half of 2013. In connection to this work, the possibilities of making mussel meal out of the Åland mussels will be reported as part of a trial attempt at the mussel meal pilot line in Ellös at the west coast of Sweden. In the best of worlds, this mussel meal could then be used as feed for the Åland farmed fish and the nutrient loop of the Baltic Sea could be closed. Even though this might come true only sometime in the future, it is still possible to use mussel farming as a compensation measure to fish farming in an integrated multi-trophic aquaculture system, where the meaning of the word "aquaculture" has more than one dimension. As the Åland Government now is partner to the EU Baltic Sea Region Programme project "Aquabest", the pilot projects have received a natural continuation in cooperation with Baltic Sea Region partners.

Excursion to the pilot farm at Kumlinge during the Åland Aquaculture Week

References

1 Cf. Engman, Torbjörn, "Musselodling i miljöns tjänst: ett pilotprojekt I åländska vatten", slutrapport, Ålands landskapsregering, 2008.

2 Cf. Granholm, Petra, "Utredning av de fysiska förutsättningarna för storskalig musselodling på Åland", Ålands landskapsregering, 2012.

Åland is looking into possibilities of using mussel farming as a compensation measure to fish farming.

The purpose of mussel farming: Finding answers to the "W Questions"

John Tyrstrup | Kingfisher offshore AB, Sweden

To be successful, mussel farming has to rely on the answers to the following questions: What is our purpose of farming? Where will the farm be located? What is the proper timing for launching the project? How and when do we harvest? Who are the end customers? Are we a commercial or non-profit mission? Is there any governmental financial support involved in the project?

The strategies of mussel farming are always depending on the answers to these questions. If, for example, the purpose is to grow mussels to eat in fancy restaurants, the project is very different from those farming mussel to feed fish with. And also the harvesting method differs depending on who the end customers are and what requirements they have. The locations of mussel farms are very heterogeneous, differing in terms of whether one is located at sea or in the archipelago. The kind of seabed at the location is of huge importance, especially for what mooring technique can be applied. And the mooring system has huge financial implications due to the fact that it is a large part of the overall investment. Methods of harvesting are also important, especially for the operational costs. Thus, harvesting is an important part of the efficiency formula but has to be balanced versus the purpose of farming. Again, we have to ask the question: Who are the end customers and what are their demands for the delivery? The choice of harvesting techniques is also subject to considerations concerning local conditions such as depth, constitution of the seabed etcetera. Adding to the complexity is that harvesting can be carried out at sea but often it is more convenient to harvest in a harbor with immediate access to containers as well as transportations.

For centuries, policy makers in Europe have spent huge amounts of money to support as well as regulate the agricultural sector. However, concerns about global climate should encourage them to rather, or at least, invest money in project such as mussel farming. That would give them an efficient tool to deal with the emission into seas and oceans of substances such as nitrogen and phosphorus. Today, the phosphorus is reduced dramatically at land but not at sea. And since mussel farming, is a great method not only for reducing problems caused by nutrient and phosphorus which cause the eutrophication of the sea, it should provide a good argument for governmental subsides. One model would be to apply reverted taxes linked to the reduction of substances that are of major concern from a sustainable climate point of view. It would unfold very much as a similar problem to controlling fishing quotas. And the model for a reverted tax system could be applied to mussel farming according to very similar principles as those used in quota control, including for example checking of volumes during mussel framing harvesting seasons.

There are many arguments pointing at mussel farming not only to be here to stay but also being a business with tremendous growth potential. Financial and environmental arguments should of course encourage investors and others to launch mussel farming endeavors. But the current development of wind turbines located at sea provides a great opportunity for mussel farmers to find locations for their farms. In fact, there are also many other environments at sea – manmade as well as natural ones – that offer excellent conditions for successful mussel farming. And this is very encouraging when the world – finally and seriously – is taking on the pollution problems in our seas and oceans.

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The development of offshore wind parks provides great opportunities to find new sites for mussel cultivation.

Large-scale mussel farming: reducing cost and labour

Mads van Deurs | Smart Farm, Norway & Nordshell, Denmark

The Nordic countries and countries surrounding the Baltic Sea have had a positive experience with mussel farming. And all together a great experience is accumulated. These areas experience intensive agriculture and wash of to the marine environment. The nutrients in the wash off causes mass growth of plankton and periods with lack of oxygen. This is, however, an opportunity to introduce massive aquaculture production and would lead to a mutually beneficial situation. The aquaculture projects would act to facilitate the environmental needs from run off and at the same time produce a high quality and protein rich product from the lowest parts of the food chain.

Making mussel farming comercially viable

The challenge is to run these mussel farms as a commercial and financially feasible business. Experience has shown that certain businesses, which have been running for a few years while receiving subsidies, have failed in their efforts to make their business a commercially viable enterprise. The challenge dictates that there is a need to reduce production costs in order to meet market prices and to work on labour costs as this is generally high in this part of the world. This includes direct employment and external services on all levels.

The Smart Farm system

To date the longline system for producing rope grown mussels has been preferred because of its initial start up costs. An alternative to this is the Smart Farm system which is based on the same principles of rope material for on growing and air for buoyancy. The SmartUnit consists basically of a pipe carrying a net. The pipe is typically 135 meters long and has enough carrying capacity to hold the biomass growing on the net underneath. The SmartUnits are designed to suit the individual customer concerning water depth, exposure of the site and wanted biomass. The harvesting and husbandry is done easily with the Multi Machine. This machine is operated from the boat and can carry out tasks like removal of predators and fouling (star fish, tunicates or barnacles), for density control, for cleaning the net and also harvesting of the mussels. All operations are done under water – the nets are not lifted out of the water but mussels are transported in water onto the boat where they are loaded into big bags or into the hold as bulk.

The Smart Farm system is designed for large-scale farming. In Germany a farm operates 255 SmartUnits and harvest 4,000 tonnes every year with a daily landing of 150–200 tonnes. This operation is carried out during three months of the year. This farm is situated in waters with 3–4 knots current.

The Smart Farm system consists of pipes carrying nets. It is designed for large-scale farming.

Socioeconomic valuations

In cooperation Smart Farm, Norway and Nordshell, Denmark have carried out some financial analysis of an optimized mussel farm. Detailed calculations of food access, growth and environmental conditions has also been studied. The basic assumptions in the financial analysis is that the boat and the harvesting machine should be in use as much as possible. This gives 200 days of harvesting at sea each year. With a conservative calculation this would give a yearly capacity of 20,000 tonnes. In order to produce this biomass it is chosen in the example to equip the farm with 800 SmartUnits. The units will in this case be divided into six sites. With the best use of the equipment and a rational workday the production cost will be € 0.05 per kilo. On top of that there will be deprecations and financial expenses adding up to € 0.11 per kilo. The overall cost will then be € 0.16 per kilo and represents good opportunity to have a healthy and feasible business.

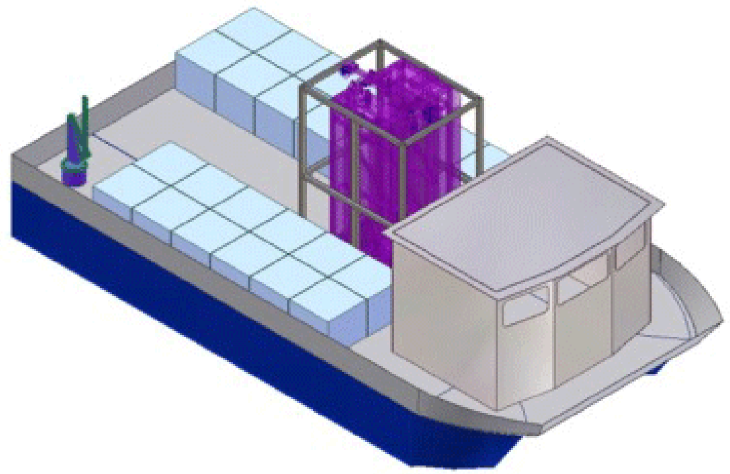
Smart Farm AS is providing solutions that allow customers to be competitive in a global market. The Solutions and technologies are growing some of the most environmentally friendly products that are at the bottom of the food chain. The technology provides a low production cost and at the same time focus on safety and a good work environment. The high quality technology is made to last for a long time in the water. The SmartUnits works well even in strong winds and large waves and is now in use in many different places in the world.

Smart Farm AS wishes all customers to succeed and is usually cooperating with the projects from the very start thru planning and establishing of the farm to future adjustments and training of employees.

Apart from the patented SmartUnits the Smart Farm company also have solutions for:

- Seaweed production
- Production of oyster, clams and cockles
- Eider duck fence
- Mooring equipment
- Work barges

Smart Farm AS is continuously developing their products and technologies. One of the newest developments is to integrate the harvesting machine into the hull of the boat operating the farm (see below figure). During the winter 2012 / 2013 the first prototype is being constructed and will represent a new step and further optimising of the operation and logistic around the farming activities.



Sampling: A reliable tool to know your site

John C. Bonardelli | Shellfish Solutions, Norway

If you have to sample many sites to identify spatial trends in meat yield, locate the best (heaviest) mussels for packaging, or estimate the biomass for each site to help a large company improve its harvesting strategy, then you need an efficient and reliable sampling protocol. When should we go about sampling sites? There is absolutely no reason to sample, if you don't have a clear objective in mind. But if you know what result you want, use a reliable sampling protocol to effectively compare mussels between locations. Proper methodology should be scientifically valid and provide a means for tracing the results to their source, especially when multiple sites and lines are concerned. This means that when you return to the line section you sampled, you should obtain similar results, and by collecting samples over time, you can make valid comparisons, establish growth curves, follow meat yield changes, and compare mussel quality and density on collectors or sock ropes.

Admittedly, most growers are not very interested in sampling, as they feel it's a waste of time.

Even poor methods are good, because they oblige growers to visit their farms and maintain a running status of their sites, before something goes wrong. Professional growers seeking to get the most out of their production know that sampling is a means to improve their decision-making ability. I know many growers who put the effort into monitoring their production, and do it well. How much sampling is enough, depends on how seriously you take the business.

Each longline a production unit

The purpose of internal control management is to properly evaluate production volume to determine the time to market, and where to harvest selected longlines. The longline is the production unit upon which mussel stocks rotate. The turnover and associated costs of each longline depends on the time one stock in production remains on that line until harvest.

Mussel longlines, floating and submerged, vary in style and length, from single to double longlines, to rigs of 3 to 10+ lines.

Most longlines have at least 150m of productive space. Each longline unit (single or double) may support thousands of meters of collectors or socked mussels, thus it is not feasible or necessary to sample the entire line to obtain good estimates of mussels size, density, or total biomass.

Section it to sample

I prefer to sample mussels within defined sections of a longline. A good recommendation is to select few information-rich sections, such that section-lengths at the site represent differences in environmental conditions (wave exposure, food availability, settlement or fouling), which will influence mussel mass and shell thickness. Experience shows that line centers are often different from the ends, so I code at least 3 sections for lines over 180 m, with maximum section length at 120 m.

Sampling strategies should reflect the information required by the grower and be based on experience and oceanography. Sampling intensity (number of samples per line), depends on the settlement variability or production event defining that particular stock.

Lines with mussels growing on collectors until time to harvest are more variable in size and density between depths and between lines, than mussels that have been well sorted and socked in a short period.

Standardized sample depth

In many regions, spat settlement occurs within 1-4 m below the surface, above the stratified layer where food concentration is high. Early spring or autumn settlements may completely cover collectors, even below 10m depths. Valid comparisons are about consistency, and removing variability you can control. Because of safety and accessibility, my standard sample is always at 1m below the mainline, which may be at 1, 3 or even 10m below the surface. This standard sampling depth within the same section is the prerequisite to following trends. Since I can expect lower meat yields on inside lines, I consistently sample at the exterior of a site.

How much sampling is enough, before you sell?

To evaluate the biomass of a line, a grower should take samples representative of the mussel density, their size distribution, and the mass of mussels for 5mm size class, both at the top of a collector or sock, and at the bottom.

These may differ greatly, due to faster growth or second-set near the top, or to heavy fouling by sea squirts near the bottom. I disagree with hauling out a sock or collector to calculate a mean mass, because it's not a reliable indicator of the optimal production volume or size, and it's a waste of mussels. It's wiser to evaluate the time to harvest a line when the bottom portion is commercial; what's the point of investing in socking and labour if the bottom remains unproductive or mussels get discarded. To calculate total biomass with accuracy and estimate harvest volume, try sampling 2 to 3 sections of each line.

Sampling frequency

This is the big question, which depends on the sampling purpose and the type of report required. It's simpler if you combine your important sampling activities on a calendar to minimize the cost of outings at sea.

Recommended sampling frequency for mussel growers before harvest

Reports	Data to measure	Frequency	Spring	Summer	Autumn	Winter
Meat yield %	Standard size mussel 50–55 mm	3–4 weeks	Every 3 weeks	Every 3 weeks	Every 3 weeks	Every 4 weeks
Growth curves	Length for each stock in production	2–3/year	April–May	only if required	Aug–Sept	Dec–Jan
Pre-harvest biomass	Length & mass for 5 mm size classes No. shells/kg	2–3/year 1–2 week before	before spawn	after spawn	prior to major harvest	prior to major harvest
Harvest for sorting	Length & thickness for selected lines	1–3 week before	Once before terminating a stock			

1) Meat yield is one of the most important variables in mussel farming. Seasonal changes are a relative indication of food content and show short term variations related to spawning, which indicate when to place collectors or when to harvest. It is not uncommon to uncover long term trends, which would otherwise not be seen from sporadic or random sampling in a site, from mixing sizes or using mussels with different shell thicknesses (mass).

2) Growth helps define your harvesting strategy. When collecting mussels to measure growth, length is required. This should be done 2-3 times in the year for each stock in production, ideally in between critical seasons: before spring growth, after summer, or before winter. Higher frequency for longer production time improves risk management and will indicate when it flattens out. In combination with density and size distributions, this is a powerful tool.

3) Pre-harvest biomass reports are necessary for growers to show what is ready to sell to processors, for acceptance of the shells/kg, shell appearance and meat yield. Processors and growers improve negotiations when they both know what harvest volume and quality they can expect to pack. Total mass,

spawning condition and water loss greatly influence minimum acceptable market size. Thus, size distribution at harvest is more relevant for selecting one site over another to ensure a match between volumes harvested and those packed for market.

4) Length-thickness relations for commercial mussels vary between concessions, specially after changes in production method. Growers should inform potential clients about their mussels, since processors may have different sorting and grading settings adjusted to different stocks

Clean samples on boat

Density affects growth, and you can calculate it by stripping your mussels from the sock across a known diameter bucket. Separate the shells by vigorously massaging clumps between your hands until individually separated, rinse and transfer to a marked bag.

Cleaning mussels on the boat is fantastic and saves time later with little mess to clean when measuring at home. Identify dry sample bags with site name, sample date, longline and section code, and sample length (cm). Special comments inscribed with a felt pen designed for plastic bags are useful later.

From what I have witnessed, the best sampling is frequent sampling. To reduce your work load, collect and measure a line each week. Top growers consistently monitor their sites, and integrate frequent sampling protocols into their production.

Mussel production potential in an urban environment in the Western Baltic Sea. The revival of an almost forgotten tradition

Yvonne Roessner & Peter Krost | CRM – Coastal Research & Management, Germany
Carsten Schulz | Gesellschaft für Marine Aquakultur (GMA), Germany

Increasing demand for high value seafood products in a situation of stagnating traditional fishery resulted in high growth rates for the aquaculture sector. But the regional potential is individually depending on various factors. In the Kiel Fjord, mussel aquaculture has been performed in history, but has decreased with industrialization and the associated habitat degradation. Nowadays, as aquatic habits has recovered, the production of high value food products like mussels seem again to be feasible with regard to nutritional, ecological, legal and also economical aspects.

Until 1906 Ellerbek, a small village of fisher- and ferrymen, existed at the east coast of the Kiel Fjord. Their most valuable income in summer was the famous smoked sprat „Kieler Sprotten“. Additionally, farmed mussels, known as „Kieler Pfahlmuschel“, served as another income during winter months, when fishing was almost impossible. Mussels were cultivated on five meter long oak, alder or beech trees. The stems were manually pushed into the sediment in a water depth of approx. 4–5 m. Up to 2000–4000 trees were installed this way per mussel field, from which five existed in the Fjord. After mussel spat settled in early summer, mussels grew on the „musseltrees“ for 3–4 years until final harvest. They were sold on regional markets and also transported to markets in Hamburg, Prague and Budapest. In the end of the 18th century Kiel became an important naval port. Due to the increasing traffic on the water and the associated incremental water pollution the mussel cultivation was shut down.

Today, more than 100 years later, Kiel has grown to a state capital city with approximately 200,000 inhabitants. The Fjord is still an important cruise harbour and forms the Baltic entry of the Kiel channel. However, the water quality has recovered and blue mussels (*Mytilus edulis*) are abundant in the Kiel Fjord. The salinity of ~1,5 % and a constant current speed of 1–3 cm/s provide good hydrographical conditions for mussel aquaculture and therefore led to the decision to revive the tradition of mussel farming. In 2010 the Deutsche Bundesstiftung Umwelt (DBU) funded a three years joint project between Coastal Research & Management (CRM) and the Gesellschaft für Marine Aquakultur in Büsum (GMA) to develop a longline musselfarm in the Kiel Fjord.

The musselfarm was rather designed as an upgrade of an already existing algae farm (*Saccharina latissima*) of CRM. Mussels and algae are grown combined in an integrated system (see figure 1). The production field is located in a military restricted area close to the Kiel Channel. It has an average water depth of 10 m and size ranges over 100 x 60 m. According to the main current direction, that passes parallel to the long side of the area, the used longlines extend to a length of 100 m. Both ends of the longlines are permanently fixed by screw-in-anchors. The length of the production substrates of approx. 3 m provide sufficient space between seafloor and cultured organisms.

In late spring, when water temperatures exceed 12° C, the natural mussel population provides a regular spatfall with yearly constant high mussel larvae abundances. Since 2009 the amount of mussel larvae ranged between 16,000 (2011) and 90,000 (2009) larvae / m³ at peak. The young mussels (shell length ~0.5 mm) settle initially on mussel spat collectors. After three months at the latest, the mussel spat is transferred into mussel socks (polypropylene and cotton, different mesh sizes). Mussels remain in these substrates until they are harvested in the following winter. Substantial shell growth occurs at water temperatures above 13° C. Mussels reach market size of minimum 55 mm within 18 months.

The high production potential of mussels is reflected by comparatively high shell growth rates (see figure 2) as well as by high meat contents and short recovery time from poor condition.

Mussels and algae are grown in an integrated longline system in the Kiel Fjord in Germany.

Meat content of mussels were high in November 2010, December 2010, May 2011 (> 50 %), and low in March 2011 and April 2011 (39 and 44 %). Similar pattern is reflected by the mussel condition index.

The clear drop in the mussel quality parameters in March and April 2011 is probably caused by low food availability during the long and cold winter 2010. On the other hand it could also be explained by the inappropriate sampling material of the mussels in this time. Due to an invasion of Eider Ducks in January 2010, almost all mussels that grew outside the socks and had a good condition, were eaten up by the birds. Unfortunately, the risk of predation by birds was underestimated at that time. But until now the invasion was a singular event and mainly due to the harsh winter conditions. Nevertheless there will be arrangements (flutter tape, noises) to prevent future invasions.

In addition to biological parameters which show a great potential for food mussel aquaculture, food safety measurements have to be taken into account. According to the EU regulations 852, 853 and 854 /2004, specific rules are defined to organise official controls on products of animal origin intended for human consumption. Therefore the status of algaetoxins, microbiological quality and chemical contaminants are essential parameters for food mussel production in the EU.

During the monitoring from 2010–2012 in Kiel, no algaetoxins occurred in analysed mussels (monthly measurements in 2010 and during mussel season in 2011 and 2012). The bacterial load (E.coli) was analysed at the same time and appeared to be closely related to water temperature. The microbiological quality of the shellfish water "Kiel Fjord" was proved „A“ (< 230 cfu / $g_{mussel\ meat}$) except during summer months where it was proved „B“ (230 – 4600 cfu / $g_{mussel\ meat}$). According to these findings, mussels can be sold fresh during winter harvest. All further analyses of chemical contaminants like heavy metals, organic pollutants or other harmful residues were uncritical.

Compared to mussel fishery by dredging, mussel farming on longlines has a low environmental impact. Therefore the mussels of the Kiel Fjord are certified organic according to the EU regulation 834/2007 since 2011.

Moderate hydrographic conditions, high growth rates and clean waters suggest that mussel aquaculture in the Kiel Fjord is profitable from the biological, legal and also economical point of view. The mussels represent high value products of both: quality and price.

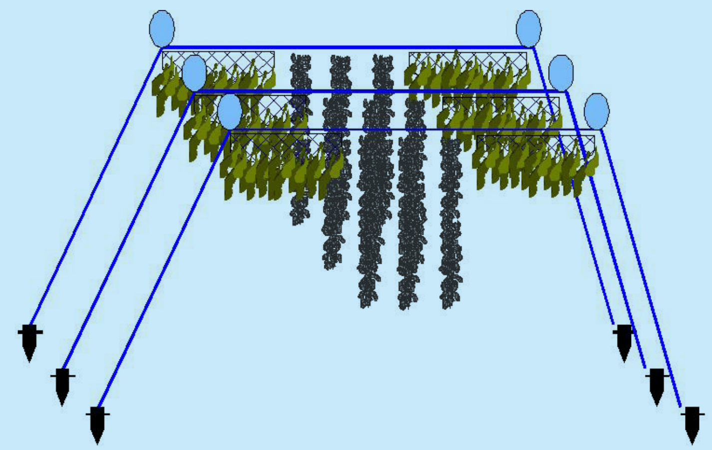


Figure 1: *Sketch of the integrated longline system for algae and mussel cultivation.*

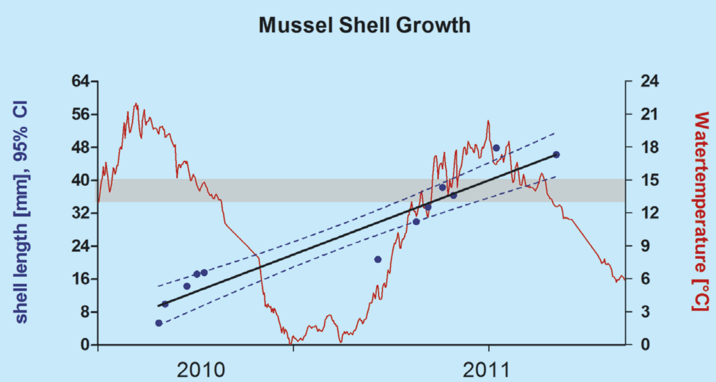


Figure 2: *Mussel shell growth in the Kiel Fjord pilot farm.*

Feasibility of coastal mussel *Mytilus trossulus* cultivation in the Gulf of Gdańsk with the aim of eco-remediation

Izabela Zgud & Maciej Wołowicz | Department of Marine Ecosystems Functioning, Institute of Oceanography, Poland

Mussel aquaculture in the Gulf of Gdansk is a novel and challenging scientific venture.

Over the recent decades, the spatial distribution and standing stock of *Mytilus edulis trossulus* have extended in the coastal waters of the southern Baltic. Abundance and biomass of the mussels in the Gulf of Gdańsk increased substantially in the deep zone (40–50 m). The mussels play an important role in the transfer of organic and non-organic suspended particles from the water column to sediments. They serve as an efficient biological filter, purifying water masses from suspended matter and a number of chemicals and component they contain. The bivalve accumulate both in meat and shell a large amounts of nitrogen and phosphorus, as well as contaminants e.g. heavy metals.

The grow-up rope floating in the water column

Although *Mytilus* is a most commonly farmed mussel species in Europe, until today there has been no information on mussel cultivation in the Polish coastal zone. In April 2009 a small-scale experimental study on mussel farm started at three sites in the Polish territorial waters. Mussel aquaculture in the ecosystem of the Gulf of Gdańsk is a novel and challenging scientific venture, and requires thorough understanding of local environmental conditions, bivalve biology and physiology. Focus of the study is put on the technical requirements to withstand environmental conditions at the coastal location and on mussel biomass production potential under local conditions.

The experimental study was carried out using 7-m polypropylene ropes (32 mm diameter each) as both a spat collectors and grow-out ropes. The ropes were submerged vertically in the water column with buoys to provide flotation. The system operated in a submerged mode at a depth of about 2 m horizontally below the surface to avoid the destructive effects of maritime traffic.

Preliminary studies have shown apparent differences in density of individuals among three study sites and at different depths. Observations on mussels larvae settlement indicate a great number of spat living in the water with peak in abundance after spawning (July/August). Number of individuals after one year from settling reached even 20,546 ind. m^{-1}. The percentage cover of mussel decreased markedly with depth.

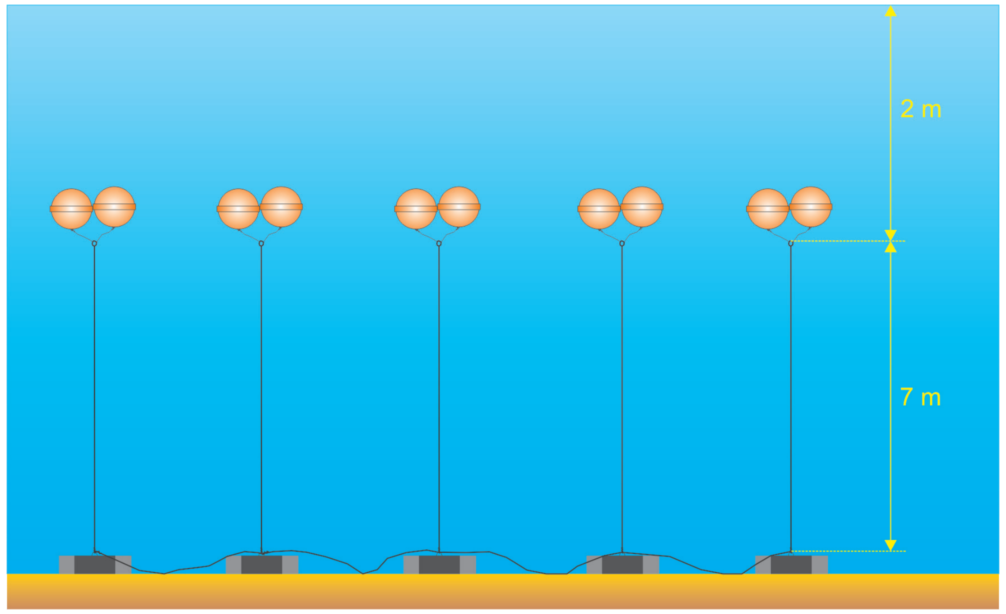
The wet weight of mussel tissue and shell at three study sites reached from 1.0 to 2.0 kg m^{-1} rope after two years from settling. There has been observed a typical pattern with mussels in upper part of the water column being heavier than those in the lower parts.

The shell length of individuals can reach the maximum of 36.0 mm after two-year farming. Observations of mussel growth rate indicate both geographical and seasonal variation with a clear increase in growth rate during phytoplankton bloom indicating that depth of cultivation is the major micro-scale factor affecting the growth of the rope-cultured mussels in the Gulf of Gdansk. It seems that in our experiment, the food abundance was an important factor explaining differences in mussel growth with depth.

According to the available literature, a mussel filtration rate depends on density, physiological condition, population structure, water temperature, salinity and food supply. Laboratory studies have shown that the process of particle removal is most effective in the spring season by largest individuals (30.01-40.00 mm). The highest condition index of mussel occurs in the spring-summer season. Therefore, the highest clearance rate can be expected during the phytoplankton bloom, resulting in increase in chlorophyll concentration. Based on the data on the mussel soft tissue dry weight the maximal filtration rate after two years equals more than 10,776 l d^{-1} $rope^{-1}$. This calculation implies that mussel *Mytilus edulis trossulus* cultivated on ropes could potentially improve water quality, especially water transparency which is crucial factor for development of benthic algae.

Mussels are a valuable and healthy marine food product, rich in protein and of low fat content. Due to restricted tradition in consumption of living marine resources in Poland, the mussels are not an obvious candidate for direct consumption. Utilization of cultured mussels harvested from ropes in consumptive and non-consumptive sectors should be decided based upon toxicological results. In case of high contaminant concentrations accumulated in soft tissue concentrations the harvest can be utilized as an addition to fertilizers for urban green areas or combusted in a similar way as dry sludge from wastewater treatment plants. When not in excess of contaminant levels, soft tissue of mussels can offer an excellent prospects for production of active biological substances e.g. collagen, which has many advantages as biomaterial used in medicine.

The first results of the study suggest that mussel restoration project and establishment of even small-scale mussel aquaculture operations may mitigate the negative effects of eutrophication. However it is important to know whether these pilot project can be extrapolated to large-scale production and to other regions as commercialization of mariculture in Polish coastal location can have tremendous future economic potential.



The scheme of construction unit

The SUBMARINER Project

The Baltic Sea Region faces enormous challenges including new installations, fishery declines, excessive nutrient input, the effects of climate change as well as demographic change. But novel technologies and growing knowledge also provide opportunities for new uses of marine ecosystems, which can be both commercially appealing and environmentally friendly. Through increased understanding and promotion of innovative and sustainable new uses of the Baltic Sea, SUBMARINER provides the necessary basis for the region to take a proactive approach towards improving the future condition of its marine resources and the economies that depend on them.

Compendium: Describing current and potential future marine uses

- Comprehensive inventory of current and new uses
- Strengths, weaknesses, opportunities and threats to the BSR
- Environmental and socioeconomic impacts
- State and availability of technologies
- Market potential
- Gaps and obstacles in the legal framework

Regional Strategies: Testing new uses in real conditions

- Feasibility studies for new uses
- Technological and financial needs
- Impacts on environmental and socioeconomic conditions within the area
- Specific legal constraints

BSR Roadmap: Recommending necessary steps across all disciplines to promote beneficial uses and mitigate against negative impacts

- Research topics
- Institutional and network initiatives
- Legal changes (e.g. spatial plans)
- Environmental regulations
- Economic incentives

BSR Network: Bringing relevant players together

- Business cooperation events for algae and mussel cultivation, blue biotechnology industries, wave energy, and reed utilization
- Network structure (incl. membership, mission, independent finances, business plan, etc.)
- Virtual information and exchange platform
- Regional, national and BSR-wide roundtables and seminars on new marine uses

Project Duration

October 2010 – December 2013

Project Budget

- ERDF Co-Finance: €2.8 million
- Partners' contributions: €0.8 million
- Total Project Budget: €3.6 million

SUBMARINER Partners

Poland:

- Lead Partner: The Maritime Institute in Gdańsk
- Gdańsk Science and Technology Park

Germany:

- Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
- Norgenta North German Life Science Agency
- Kieler Wirkstoff-Zentrum am GEOMAR | Helmholtz Centre for Ocean Research Kiel
- University of Rostock
- BioCon Valley Mecklenburg-Vorpommern e.V.

Denmark:

- ScanBalt
- Lolland Energy Holding

Sweden:

- Royal Institute of Technology (KTH)
- The Royal Swedish Academy of Sciences
- Trelleborg Municipality

Estonia:

- Tallinn University of Technology
- Entrepreneurship Development Centre for Biotechnology & Medicine

Lithuania:

- Klaipeda University Coastal Research and Planning Institute
- Klaipeda Science and Technology Park

Latvia:

- Ministry of Environmental Protection and Regional Development of the Republic of Latvia
- Environmental Development Association

Finland:

- Finnish Environment Institute – SYKE

SUBMARINER
Sustainable Uses of Baltic Marine Resources

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