COASTAL & MARINE

Blue mussel farming for improving water quality in the Baltic Sea

EUCC Coastal & Marine

EUCC-D

Volume 28 • No. 1 2019

Editorial

Dear Reader,
BONUS call 2015: Blue Baltic included among others a theme of elaborating scientifically justified criteria which allow the development of environmentally balanced and socially accepted aquaculture production. A consortium led by National Institute of Aquatic Resources, Technical University of Denmark and involving apart of Danish also German, Polish and Swedish researchers and innovators won the competition and in April 2017 BONUS OPTIMUS 'Optimization of mussel mitigation cultures for fish feed in the Baltic Sea' was started.
This issue of Coastal & Marine presents in a brief and popular form a synthesis of what has been already learned. And there is a lot! How to quantify the possible positive and adverse effects of mussel farming on ecosystem? What kind of potential conflicts with other components of ecosystem and uses of its services could occur and how better to avoid them? What kind of legislative measures promoting mitigation mussel farming are already in place in some countries and how this can be improved? How best to integrate mussel farming into coastal maritime spatial planning? These are just few of the questions that the authors of the papers delve into.
Wishing you an interesting and useful reading,

Andris Andrusaitis

Andris Andrusaitis
Acting Executive Director, BONUS
The joint Baltic Sea research and development programme

Content

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Colophon

EUCC's magazine 'Coastal & Marine' Special 'Blue mussel farming for improving water quality in the Baltic Sea' (volume 2019-1),
ISSN 1877-7953

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Design & Layout: *Tom Will, Germany*

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Thanks for support are expressed to:
Jane Hofmann, all contributing authors and photographers.

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BONUS OPTIMUS project has received funding from BONUS (Art 185), funded jointly by the EU and Baltic Sea national funding institutions.

Introductory

The Baltic coastal zone faces many challenges. One major challenge is the effects of many decades of excess nutrient load from land causing many well-known undesired phenomena such as oxygen depletion, algal blooms and degeneration of the coastal environment. Despite many efforts from the Baltic countries and not least the implementation of the EU Water Framework Directive, environmental status of Baltic coastal waters have generally not yet reached good ecological status.

There are other challenges in the Baltic coastal zone that in general is heavily exploited. On one side is recreational activities either in relation to tourism including holiday houses or to leisure activities like yachting, kayaking, angling etc. These activities rely on high environmental quality of the coastal waters and undisturbed seascapes. On the other side, the increased demand for sustainable food, feed and other biological resources require that we utilize the sea and thereby stimulate job creation in rural areas. Blue growth strategies are promoted by the EU as well as Baltic countries but in the heavily exploited Baltic Sea, it is of key importance for the long-term sustainability of the blue growth that it does not add to the pressure on the coastal environment.

Aquaculture of blue mussels is an example of a blue growth potential that will not add to the pressure on the Baltic ecosystem but in contrast has the potential to mitigate some of the effects of excess load of nutrients. Nutrients lost from land and incorporated into microalgae are ingested by the mussels through filtration of the water. When the mussels are harvested, nutrients are brought back to land. In addition, the mussel filtration has increased water transparency. This is the basic mechanism behind the use of mussel farming for mitigation of nutrient loading to the coastal environment.

Blue mussel farming is, however, not very well developed in the Baltic. Low salinity and harsh weather conditions with ice cover during winter have together with low regional interest in mussel products prevented a development of mussel farming seen in other European regions. As goals for environmental quality in the Baltic coastal zone have still not been met, the ecosystem services provided by mussel farming become a potential important tool for mitigation of the effects of nutrient enrichment. Combined with an increasing demand for the valuable protein source that blue mussels are both for human consumption and as a feed ingredient, mussel farming has potential also in the Baltic area.

To unlock this potential, the ecosystem services of mussel mitigation farming has to be documented and efficient farming practices has to be developed for Baltic conditions. Equally important, tools for spatial planning taking all interests in the coastal zone into account are needed. The tools shall include predictions of optimal sites for both mussel production and need for nutrient removal as well as indicators of where mussel farming can be integrated in the coastal zone with local acceptance. BONUS OPTIMUS aims at contributing to solutions in order for mussel farming to become an important activity in the Baltic.

Locations of mussel farms used in BONUS OPTIMUS , © EUCC-D

Project Coordinator BONUS OPTIMUS
Professor Jens Kjerulf Petersen
Danish Shellfish Centre

Optimal production modes and a tool to compensate for finfish aquaculture production in Denmark

The principle of mitigation mussel cultures is based on a mass balance perspective through nutrient removal from the marine environment when shellfish are harvested; e.g. one metric ton of excess nitrogen in the marine environment will be compensated when one metric ton of nitrogen stored in the harvested mussels are brought back to land.

The mass balance principle was adopted in 2017 into Danish legislation as a mechanism to compensate for new sources of nutrients. In particular, the new law demands that any further expansion of fish farming in coastal and offshore waters must compensate for nutrients emissions removed from the environment by marine measures, i.e. mitigation mussel cultivation. Thus, mitigation mussel culture is not considered a physical filter, removing precisely the nutrient molecules released from the fish farm, but as a means to 'balance the nutrient budget'.

Longline mussel farm

However, the legislation does not enforce compensation for other effects associated with an increased fish production e.g. increased use of antibiotics and anti-biofouling substances or enriched organic content and changes in nutrient fluxes in the sediment.

During implementation of the legislation, several aspects of the potential of using mussels as a compensation measure for expansion of fish production was debated in the Danish Parliament.

The four main points of discussion were:

1) if mitigation mussel cultivation in offshore areas are effective enough to compensate for the excess nutrients without covering large areas,
2) if there are enough natural mussels beds in the offshore areas to provide sufficient recruitment of mussel larvae for the mitigation mussel cultures
3) risk of loss of mussels due to predation by e.g. eider ducks and
4) the effects caused by the increased sedimentation (mussel faeces) on the seabed underneath the mitigation mussel culture.

Two study areas

In Denmark, research activities are focused in two areas: the Limfjorden, and near the mouth of Horsens fjord in the southern Kattegat. Optimizing production methods of mitigation mussels is ongoing in the Limfjorden in connection with a national project on mitigation mussel cultivation (MuMiPro, see page 22/ 23), aiming at a national production of 100K tons of mitigation mussels per annum. In the southern Kattegat, we are documenting the potential of mitigation mussel cultures in offshore areas in terms of recruitment, biomass volumes, and how to prevent predation from eiders.

Furthermore, we are also investigating the benthic impacts caused by mitigation mussel cultivation; hence the outcome of BONUS OPTIMUS will provide empirical results addressing the four main points discussed in connection with implementation of compensation mechanisms for further expansion of fish production in Denmark.

Example Limfjorden

The Limfjorden is a eutrophic estuary system in northern Denmark which hosts the bulk of the Danish mussel aquaculture industry and the heart of the mussel fishery. The algae-rich waters provide excellent growing conditions for mussels and proving grounds for intense mitigation mussel production due to the combination of persistent eutrophication and existing expertise in cultivating mussels.

In connection with the associated national project, MuMiPro, full-scale production modes are being tested to assess yield potentials (i.e. nutrient extraction) and associated operational costs, in order to optimise unit-area production of mitigation mussels.

In BONUS OPTIMUS, a number of different technologies and methods of mitigation production are also being tested in the Limfjorden to assess

1) optimal materials and configurations for cultivating mitigation mussels,
2) production processes and practices to minimise costs,
3) methods to reduce the impacts of ice cover on farms, and
4) adaptability of current knowledge to different cultivation practices.

While mitigation farming has been documented in the Limfjorden as a feasible mode of nutrient abatement, current farming practices for human consumption may not be directly transferrable. As such, field studies of different farming practices and technologies are an integral part of BONUS OPTIMUS. Preliminary production results demonstrate considerable differences in yields based on practices and technologies. For example, optimization of longline configurations yielded ~1300t of mussels per model farm, while nets demonstrated yields exceeding 3000t per model farm. Accordingly, consolidated experiences and production data in these testing conditions will provide guidance for the proliferation of mitigation mussel cultivation in other coastal waters in the Baltic region.

Example southern Danish Kattegat

The cultivation of mussels in association with fish farms is not a novel concept; it has persisted as a recurring theme in so-called 'multi-trophic' or 'integrated multi-trophic' aquaculture in many regions. In Denmark, trials have been carried out within the past 10 years

Harvested blue mussels

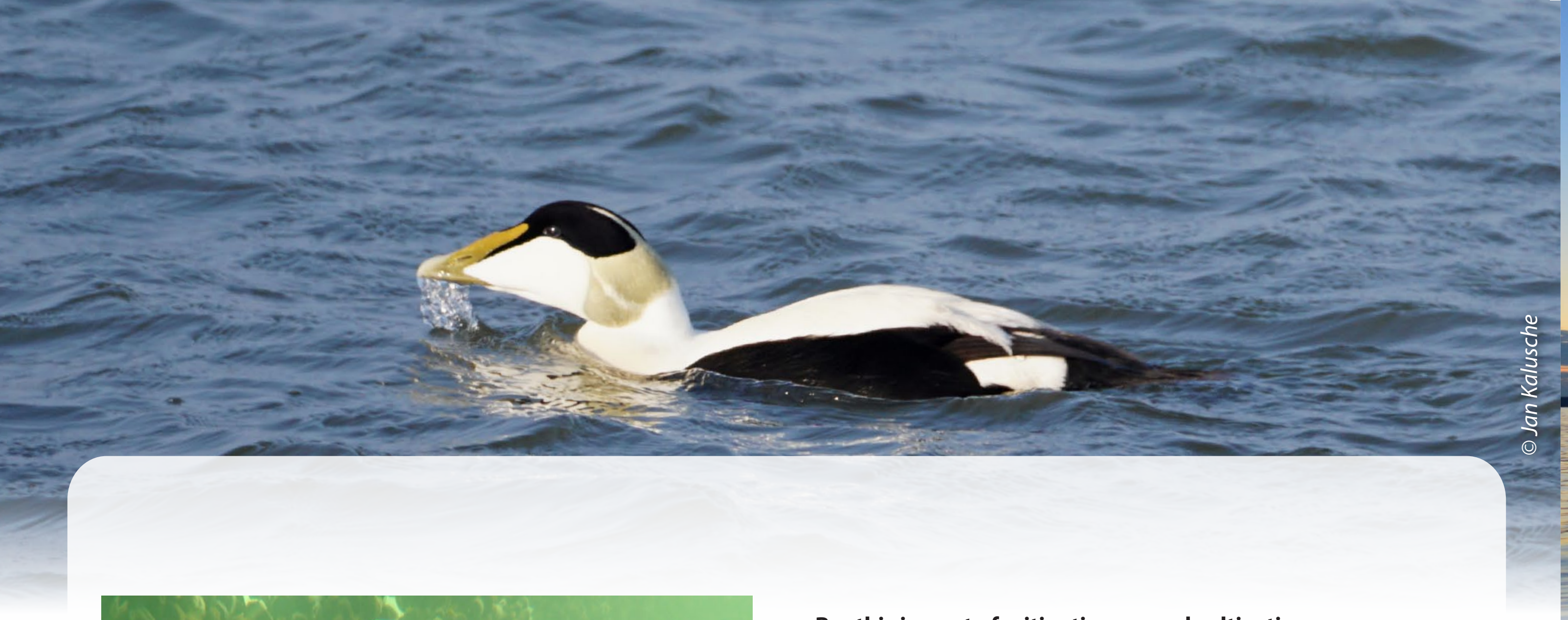
at different fish operations. However, not all have been successful, and general documentation of the potential of mitigation mussel farming has not been provided. Since the incentive for compensation of nutrient emissions from fish production has just now become part of legislation, further expansion of fish production must be accompanied by compensation measures.

In BONUS OPTIMUS, an existing mitigation mussel farm near Horsens Fjord is used as a test-farm for documentation of the mussel recruitment and biomass yield potential in the area.

Preliminary results from the test-farm have shown some interesting findings already:

1) the most successful recruitment occurs in the autumn, which compared to other areas in Denmark e.g. the Limfjorden normally occurs in spring,
2) biomass yields in one year are comparable to similar configurations in the Limfjorden,
3) harvest timing is critical to avoid heavy predation by eider ducks.

The settlement of larvae in the autumn increases the risk of loss of mussel biomass due to ice cover in sheltered waters, and predation from eiders. Harvesting the mitigation mussels before the first post-settlement winter is not possible due to low total mussel biomass and hence, also a low nutrient removal potential. Thus, in areas with



Mussel farm with nets

autumn spat fall (settlement), mitigation mussels will be harvested at earliest in the following spring to ensure sufficient nutrient removal, but at the same time increase the risk of loss of mussels.

In Denmark, eiders are mainly a migratory bird appearing during autumn and remain over the winter. One eider duck is capable of consuming 1-3 kg of mussels per day; a flock of eiders can therefore empty an entire mussel farm within a few days. Thus, the eiders are chased away from the mitigation farm near Horsens Fjord by boat several times a day to secure the mussel biomass, whereas the Swedish BONUS OPTIMUS partners are looking into other initiatives e.g. physical exclusion using nets in combination with boat chasing to prevent predation from eiders.
Preliminary results have shown that optimized mussel production methods and cost-efficient solutions to reduce predation from eiders need to be sufficiently addressed to succeed with mitigation mussel cultivation, especially in areas where successful recruitment of mussels occurs in the autumn.

Benthic impact of mitigation mussel cultivation
One of the major objections against mitigation mussel cultures is the effect of increased sedimentation of mussel faeces under the culture units. Other studies have found that mussel culture may stimulate nutrient regeneration and sediment oxygen consumption, but at the ecosystem-scale, this impact is expected to be much less than the nutrient removal capacities through harvest of the mussels.

In the BONUS OPTIMUS project, researchers from the Technical University of Denmark, and the University of Gothenburg, Sweden have been investigating the complex nutrient dynamics in the sediment underneath a BONUS OPTIMUS mitigation mussel test-farm. Four campaigns have been planned to document the effects of increased sedimentation caused by the mitigation mussel farm, covering the initial period without mussels, during the mussel growth season and post-harvest.
Sophisticated benthic incubation units provided by University of Gothenburg were deployed to characterise different processes e.g. denitrification, fluxes of nitrogen and phosphorous, dissolved oxygen, and carbon in the sediment underneath the mussel test-farm and at a reference site outside the farm. Furthermore, sedimentation traps, sediment core samples, and further environmental sampling were also deployed during each campaign. The data are still being analysed and no final conclusion can be drawn on the impact on the sediment cause by the mitigation mussel test-farm before the final (post-harvest) campaign has been finalized in 2019.

Harvest of mussels farmed on longlines

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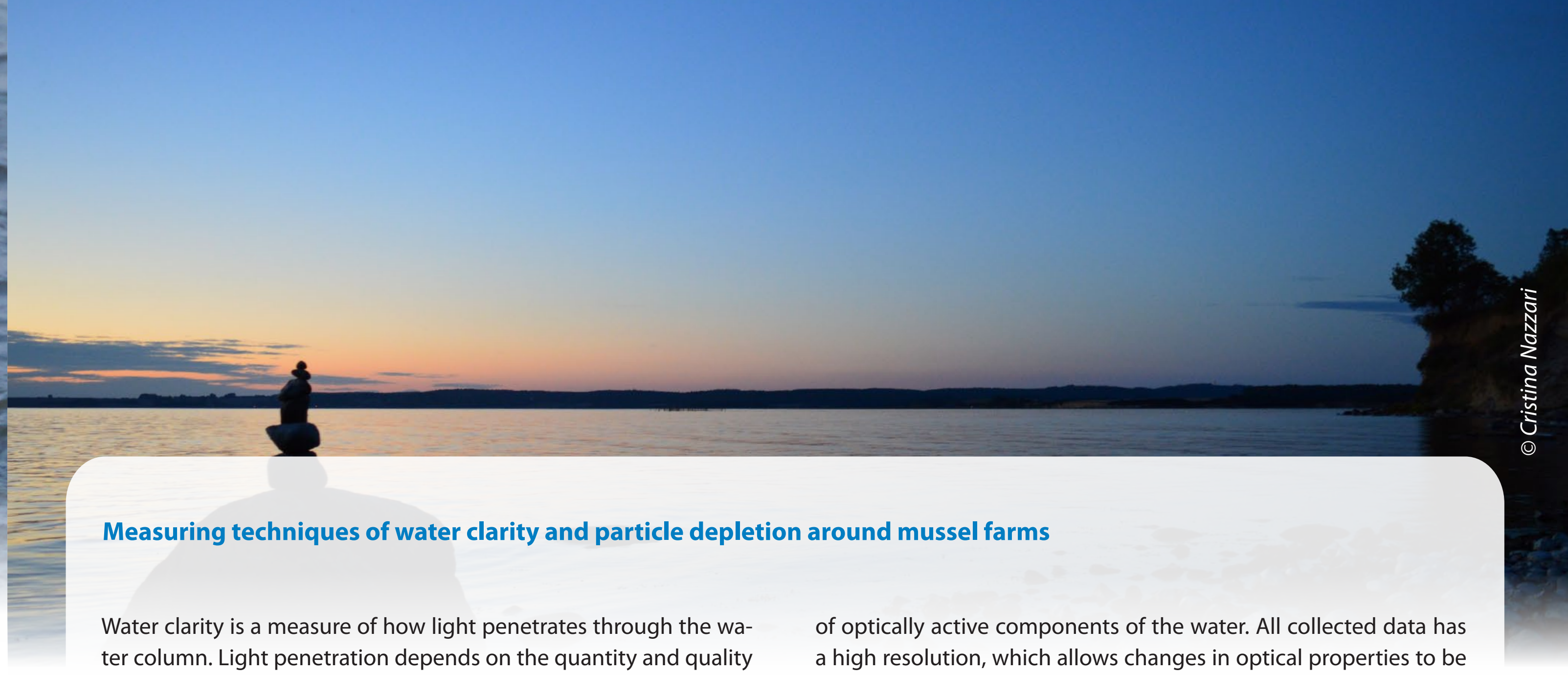


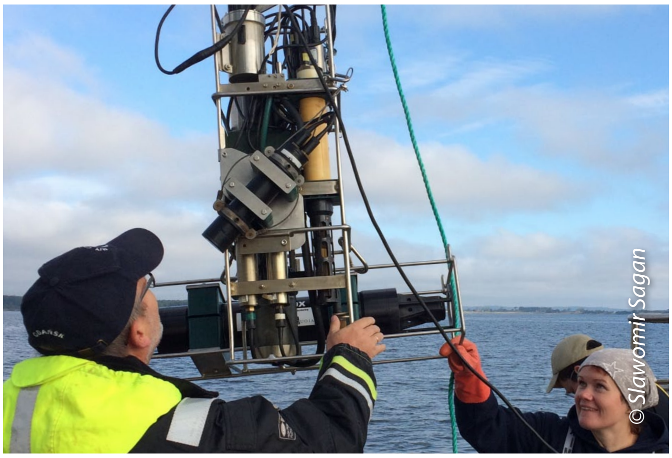
Measuring techniques of water clarity and particle depletion around mussel farms

Water clarity is a measure of how light penetrates through the water column. Light penetration depends on the quantity and quality of substances dissolved and particles suspended in the water. Both, dissolved and suspended matter, interact with sunlight in processes of absorption and scattering and are called optically active components. Amount, shape and origin (organic – e.g. phytoplankton or inorganic - e.g. sediments from erosion) of the particles determine the water clarity. Clear, blue in colour waters have a low amount of optically active components, whereas high concentrations causes high turbidity and changes water to a greenish or brown colour.
In BONUS OPTIMUS the Institute of Oceanology of the Polish Academy of Sciences (IOPAS) team is investigating water clarity and particle depletion around blue mussel farms by using optical and remote sensing methods. The main goal of the study is to estimate the transformation of the water clarity due to mussel filtration.

Water sampling campaign

Sampling campaigns

Two research campaigns have been performed in September 2017 and 2018 on mussel farms located in Horsens fjords and Limfjord in Denmark. In all cases, several locations were investigated inside the farms and, as a reference, in the areas outside the farms. At each station Secchi depth was measured as a basic optical indicator for the water transparency. Then, continuous measurements were performed directly in the water column, from the surface to the bottom. The measurements included temperature, salinity, suspended particles size, amount and volume, in-water light radiance and irradiance (apparent optical properties) and light absorption and scattering (inherent optical properties) by particles. Additionally, water samples were collected from selected depths for further laboratory analysis. The analysis included assessment of quantity and content of optically active components of the water. All collected data has a high resolution, which allows changes in optical properties to be observed on a scale of the mussel farms.



Research campaign in Denmark

Preliminary results

Despite the different hydrological (salinity and temperature) conditions observed in Limfjord and Horsens fjord and different absolute values of optical parameters in sampled waters, a similar pattern of differences have been noticed between inside and outside areas of the mussel farms. In particular, water was more transparent inside the farms, with observed Secchi depths values up to 25 % lower outside the farms. In-situ data showed a considerably lower amount and a shift towards smaller sized suspended particles inside the farms, which can be documented as particle depletion related to mussel filtration.
Results of the in situ and laboratory measurements will be matched with high-resolution satellite images previously corrected for the effects of atmospheric conditions. This will allow for the development of new algorithms for spatial variability of particles sizes and concentration, apparent optical properties and water clarity over the area. It will allow for the tracking of water transparency and particle loads, changed by the presence of mussels (influence on the environment), beyond the study timeframe.

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Mussel farming in Sweden

The first mussel farm in Sweden was established by researchers on the southwest coast in 1971. Farming still occurs and is concentrated in this region were growth is higher compared to along the Baltic coasts due to higher salinity levels. One of these researchers, Joel Haamer, developed a technique suitable for the Swedish conditions. The original Swedish model, the so-called Longline technique (Figure 1), is a simplification to better handle stress in rough environmental conditions.

Figure 1. Longline farm on the Swedish west coast

Here a farming unit consists of approximately ten longlines, each around 200 m long, that are firmly held in position at both ends by weights and floated to the surface by barrels. From each of these lines a cluster of evenly spaced cultivation bands hang down to 5-6 m depth resulting in approximately 25 km of cultivation bands per unit giving, under normal conditions, ~150 tons of harvestable mass.

After peaking (2556 tons; 1987) in the mid-80s, the mussel production in Sweden has stabilized at just below 2000 tons. The decline was mainly a result of an increased spread of toxic algae which resulted in the collapse of many small companies. With the development of sampling and control programs for toxins, this is no longer a limiting factor for the mussel farming industry in Sweden. Instead, other (new) factors have come into force. With the current production, Sweden contributes to 0.01% of the global production of farmed bivalves but the interest has increased over the last couple of years with new commercial companies investing. At the same time, there has been an increased interest to investigate the potential use of mussel farming in mitigation practices within eutrophied areas which has led to the establishment of several test farms along the Swedish Baltic Sea coast.

Research objectives and activities

Project farming area

The farms used in the BONUS OPTIMUS project are situated in the most densely farmed area on the Swedish west coast and the production is certified according to strict criteria for organic farming by the KRAV label (www.krav.se/in-english). During the early farming days there were a lot of negative comments from the residents about the farms, mainly related to various out-door activities. Such concerns have decreased over the years and today mussel-farming largely receives social acceptance by local residents and tourists. A main problem for the industry is conflicts with eider ducks, which despite a declining population have become an increasingly important predator of farmed mussels. With an adult eider duck being able to consume ~2kg of fresh mussels per day, whilst also ripping mussels from the line in the feeding process, a few birds can quickly destroy large parts of a farm.

Our Work – earlier work

The project area represents the most intensively farmed area in Sweden and consequently a lot of research has been performed there over the last ten years. The basis for successful farming practices is the recruitment of mussel larvae and to minimise the impact of fouling organisms. Therefore, a method to monitor the recruitment potential was investigated and provided a way for farmers to identify the optimal time to deploy the farm lines. Also, fundamental for farms' economic success is the growth of the recruitment therefore we performed growth measurements of blue mussel at a large number of sites along the Swedish coast. The data were then used to evaluate the potential of predictive modelling to provide spatial data on an important ecosystem function for the use in site selection of mussel farms. Based on the developed model implemented in GIS and predicted growth, a map of the most suitable sites for farming was produced. On a more general note, this study exemplified a feasible method, based on measuring, modelling and mapping, to obtain scientifically based spatial information on ecosystem functions and services affected by a complex set of factors. This information is fundamental for maritime spatial planning and ecosystem based management.

To mitigate potential negative impacts that mussel farms have on the benthic environment, we investigated the potential use of bioturbation. In these studies, we showed that polychaete species can survive and grow well on the organic material generated by mussel farms and that their bioturbation can help by oxidizing the sediment and generally enhancing the decomposition of organic matter thus increasing the assimilative effect of the sediment.

Our Work – Current work

Since the eider duck has become increasingly problematic for the farmers in the area, current research has partly been devoted to investigate the interplay between the eider ducks, the farms and the farmers. To further complicate the matter, the eider population itself is in decline and considered a threatened species (it is on the Swedish Redlist). Farmed mussels constitute an increasingly important food source for the bird as the natural mussel beds are reportedly in decline. Therefore, any preventive actions around the farms are made more complicated as they have to both protect the farms and limit any negative impact on the bird population. In ongoing studies, we analyse the dynamics of eider populations and their interaction with existing mussel farms during the last 10-20 years. This includes testing new methods (i.e. nets, Figure 2) to reduce the economic losses due to predation by eider duck in an ethical sustainable way. Among other aspects, we study how covering the entire farm in fine meshed nets affects the predation and the growth performance of the mussel inside the farm compared to non-covered farms.

Figure 2. Mussel farm covered with fine meshed nets to prevent predation by Eider ducks.

We also continue our investigation on the environmental impacts of the benthic environment by studying the sediment biogeochemistry and fluxes between sediment and the overlying water using high technological research equipment. These experiments include studies on how the farming practices affect important processes such as denitrification during a farming cycle.

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Blue Mussel Farming in Germany

In Germany, mussel farming and mussel fishing (fishing of wild mussels, usually via dredging) take place mainly in the North Sea. As blue mussels (*Mytilus spp.*) grow faster in the North Sea with salinities up to 35 psu they are more attractive economically. But also in the Baltic Sea blue mussels are spread down to a salinity of 5 psu high up north of the Baltic. In the German Baltic Sea shellfish farming trials have been conducted since the 19th century. Mussel farming was practised, e.g. by fishermen near Kiel, using trees or piles of wood fixed in sediments along the coast. Increasing ship traffic, pollution and other coastal uses put a temporary end to the small mussel farming industry. Further investigations on mussel and oyster farming took place once again in the 20th century in the Flensburg Fjord and at the Mecklenburg coast. Nonetheless, commercial mussel farming has not succeeded in establishing itself in the Baltic Sea until 2010, when the longline farming system (Figure 1) was set up in the Kiel Fjord within the research project EBAMA.

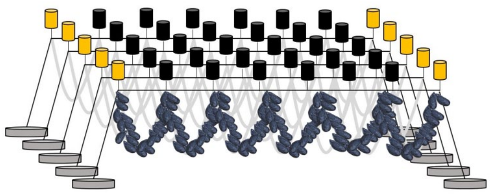

Figure 1. Schematic principle of a longline musselfarm

The project provided valuable insights into extractive aquaculture of mussels and seaweed within the Baltic Sea and from then on the Kiel farm operates on a commercial basis by producing mussels for human consumption and macroalgae (*Saccharina latissima*) for cosmetic products. Up to 5 tons per year of organic certified blue mussels are harvested for the regional food market.

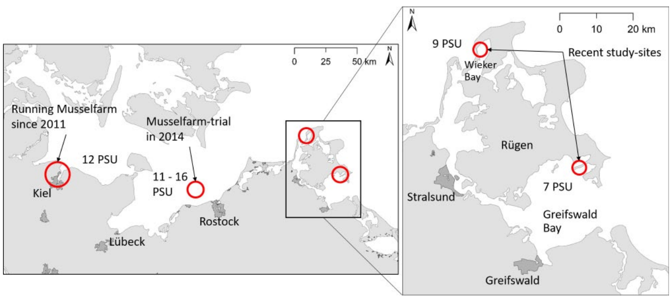

Figure 2. Study sites of trials cultivating blue mussels (Mytilus spp.) along the German Baltic Coast

Within the project BONUS OPTIMUS the Leibniz-Institute for Baltic Sea Research (IOW), supported by the University of Greifswald, set up two small scale test farms in Greifswald Bay (GWB) and Wieker Bay (WB) in 2017 (Figure 2). The aim is to investigate the recent potential of establishing mussel farming in the low saline environment of the Baltic Sea. The two selected bays very well reflect the eutrophic status of Baltic coastal waters, influenced by agriculture and with events of algae blooms, low water transparency and decreasing macrophyte vegetation. Furthermore, these areas with 9 (WB) to 7 (GWB) psu are along the salinity edge of mussel growth and very valuable to gain new knowledge about chances and limitations of mussel farming in low salinities.

Small scale test farms

Both German test farms use the longline system, where longlines are anchored and buoyed at the water surface while collector material hangs off these lines (Figure 1). The farm in GWB includes 5 longlines, each 50 m long, covering a quadric area of 0.25 ha (see header photo page 10), while in WB an area of 10 x 10 m was used forming a U-shaped set up (header photo page 11). Bands of 5 cm width and a length of up to 250 m serve as collectors (Figure 3), where free-swimming (planktonic) mussel larvae can attach and grow.

Mussel life cycle

Mussels spawn in spring when water temperatures rise above 10 °C. After a few weeks, mussel larvae settle on the provided collector material or hard substrate by using their byssus thread. When mussel shall be produced for human consumption, mussels with a length of 2 cm are removed from the collectors, sorted and filled in so called "mussel socks". In these socks they can grow to the marked size, because this thinning step ensures minimal food competition between the mussels. If produced for other uses, where size is of no importance, this intense working step is skipped and mussels stay on the collectors until harvesting.

Measurements

During the study period, larvae occurrence, settling densities, mussel growth and environmental parameters such as salinity, temperature and chlorophyll concentration are measured at least monthly.
Larvae settled in densities of up to 4 per cm^2 but decreased within the second season (summer 2018). Growth was high during the first month but stagnated around 1.5 cm in winter 2017.

Additionally, sediment samples are taken to measure impacts of the mussel accumulation on total organic content (TOC) and life

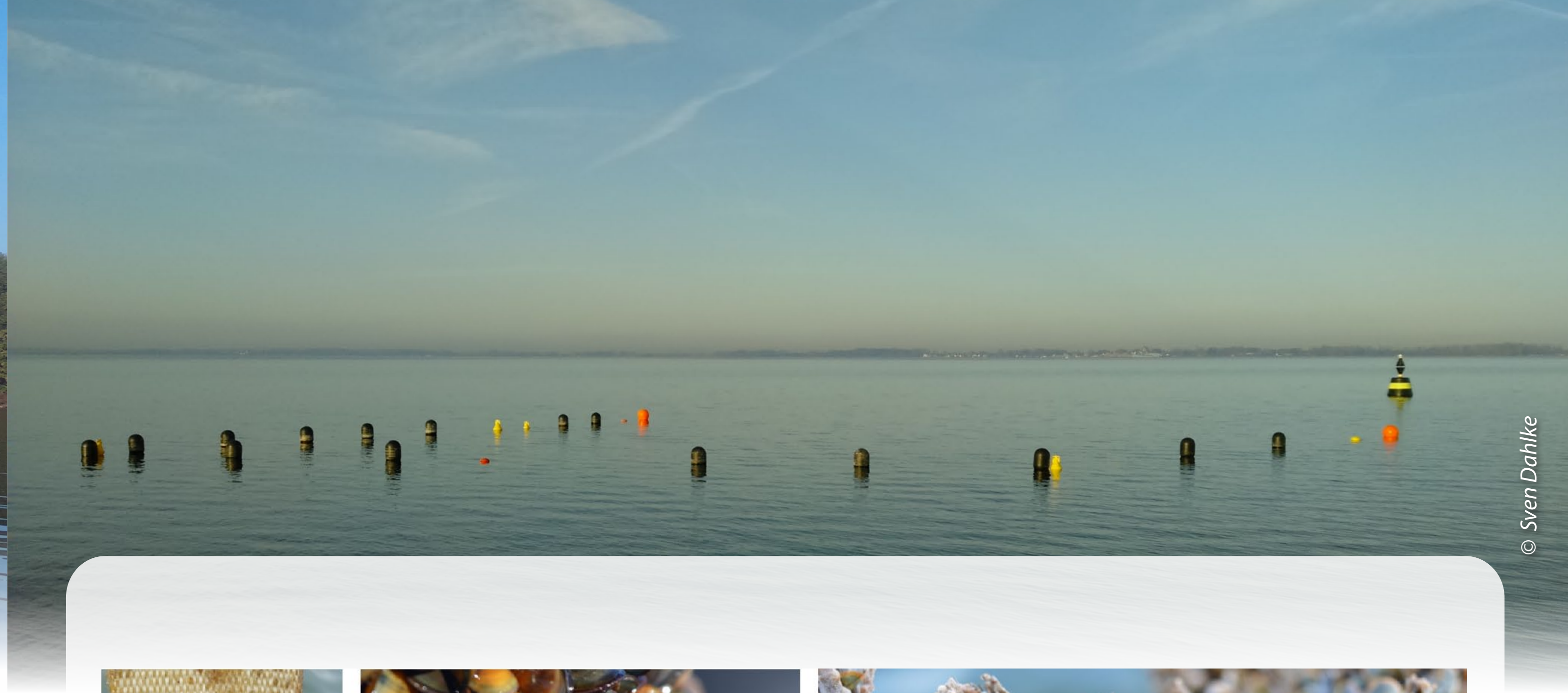

Figure 3. Mussel settlement in Greifswald Bay and Wieker Bay: a) black dots are small mussel spat attached to band; b) mussels in May 2018 on band and c) mussels attached to Christmastree rope in Wieker Bay in October 2017

(macrozoobenthos) underneath the farm. At this farm size, no significant increase in total organic content has been detected so far compared to a reference site at approximately 100 m distance to the farm. Results for potential changes in the community of macrozoobenthos are still to come.

To evaluate the mitigation potential, mussel samples have been analysed for carbon, nitrogen and phosphorus (CNP) as these nutrients cause eutrophication and algae blooms. Results are not yet completed. Furthermore, clearance efficiency is investigated in the field and in laboratory experiments, to estimate the potential clearance effect and improvement of water clarity. Experiments show a significant reduction in chlorophyll *a* (used as phytoplankton indicator) when mussels are present compared to a reference sample without mussels. Figure 4 shows how filtration of 6 mussels of the Wieker Bay with a total dry weight of 7.3 g can reduce chlorophyll from 15 to 8 g/l within less than an hour while no decrease in chlorophyll takes place without mussels.
Therefore, mussel farming has the potential to reduce phytoplankton in the water column. Even small mussels in low saline areas show high filtration capacities. Nonetheless, changes of the water clarity at the test farms in the GWB or WB are not yet visible. At farms of larger size and combined with a suitable harvest management, mussels will improve water transparency and extract nutrients of the waterbody.

Further, long time data are needed and will partly be provided within BONUS OPTIMUS to ensure that no negative effects of mussel farming will occur in future. Additionally, trials with mussel larvae

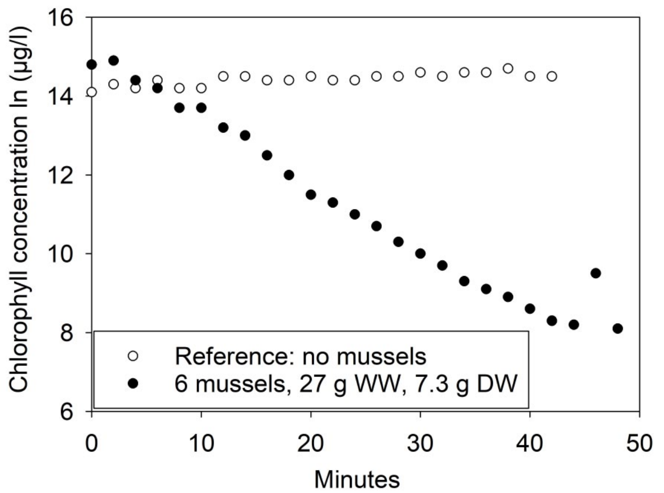

Figure 4. Filtration rate experiment using chlorophyll concentrations over time with and without mussels

and their survival under low saline conditions are ongoing as well as the identification of the best harvesting time in regards to nutrient removal and further processing, e.g. of fish feed, will be investigated. Results will help to optimize mussel aquaculture under low salinities and its use as mitigation tool towards cleaner oceans and nutrient thresholds recommended for the Baltic Sea.

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Ecosystem modelling of environmental effects from mussel farms

Before mussel farming can be accepted as a mitigation tool, there is a need for a robust demonstration of the ecological feasibility of using the tool in different types of environments in the Baltic Sea. Mussel farms not only remove nutrients by harvesting, but in addition have positive effects on the environment by reducing algae and particle concentrations and thereby improve water clarity. There may on the other hand be negative effects through increased sedimentation of biodeposits below the farms increasing the oxygen consumption and changing the sediment chemistry and ecology.

This impact is known to depend on mussel density and environmental conditions such as hydrography, water exchange, sediment type, and eutrophication status. 3D ecosystem modelling will be applied to estimate the mussel farm's impact on water quality indicators on fine spatial and temporal scales in local set-ups of Horsens Fjord in Denmark and Greifswald Bay in Germany. The models will incorporate collected data on sediment chemistry, as well as field- and satellite data from the respective water bodies. This will result in maps of impact magnitudes on different spatial scales and will be used to demonstrate the feasibility of using mussel mitigation cultures in different environments and to optimize farm layout to fulfil water quality targets.

Description of the applied ecosystem model

The ecosystem model DANECO applied to Horsens Fjord describes biogeochemical cycles of carbon (C), nitrogen (N) and phosphorus (P) between sediments and water column through plankton (microplankton and zooplankton), detritus and mussels with the associated changes in dissolved concentrations of nutrients, oxygen and adsorbed phosphate to mineral particles (Figure 1A). The water column model is coupled to a sediment biogeochemical model through sinking of detritus and diffusive fluxes of nutrients and oxygen. A fraction of the mineralised nitrogen is lost from the system as N_2 gas by microbial processes. Phosphate is retained in the sediment by adsorption to metals under oxidized conditions and released during oxygen depletion.

Modelling blue mussel growth

The blue mussels in DANECO are described by a dynamic energy budget (DEB) model of individuals (Figure 1B). The DEB model describes the energy flow through an organism and the resultant growth in response to changes in temperature, salinity and food. Mussels are filtering the water for food. The ingested food is assimilated by constant assimilation efficiency and the non-assimilated food is egested as faeces. The assimilated food

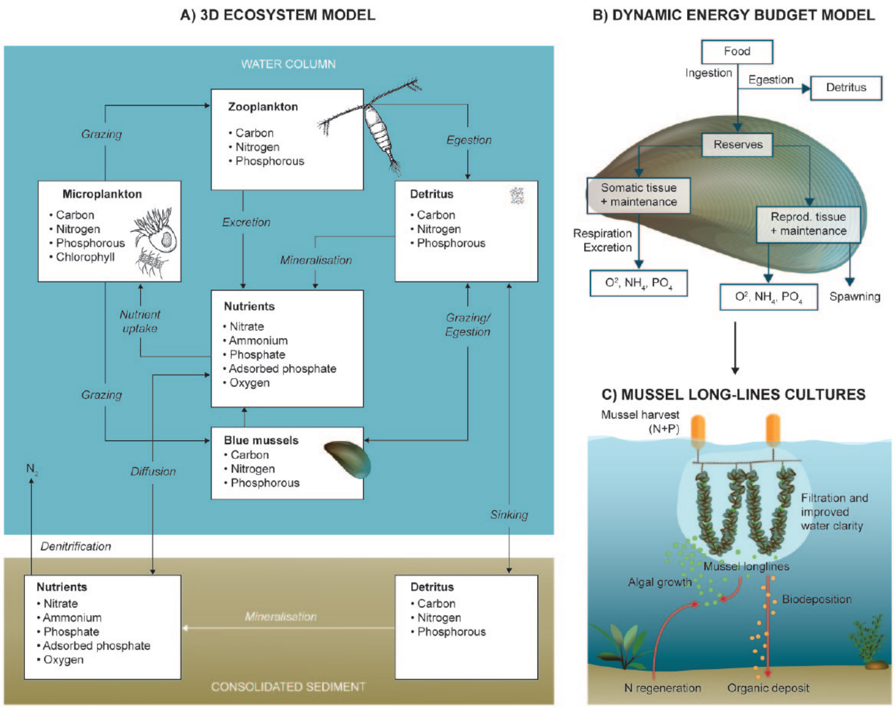


Figure 1.
A) Diagram of the DANECO model shows interactions and B) the growth of blue mussels C) combined with mussels on longlines.

goes to the energy reserves of the mussel, from where it can be allocated to growth of somatic tissue, reproductive tissue (gonads) and maintenance respiration. Energy is allocated from the reserves with a fixed fraction to somatic growth and reproduction and the related maintenance costs. During severe starvation, the somatic and reproductive tissue can pay for somatic maintenance. Water temperature is modifying all physiological processes with an optimum temperature of 19°C from where it decreases. Mussel filtration and ingestion is increasing with food concentrations until a saturation level. The stress response to low salinities is described as an extra maintenance cost at salinities below 16.2. Spawning takes place above a temperature threshold and at a fixed amount of reproductive tissue.

Mussel densities from observations are used in the model to determine population size (ind m^{-3}) over time in the farm, which are affected by recruitment, detachment from the lines, predation from birds and natural mortality. The DEB model is two-way coupled to DANECO through ingested and egested food, excretion of nutrients and respiration of mussels.

Farm scale model

On farm scale, the DEB model for individual mussels is combined with a population model describing the abundance of mussels on the longlines in the farm (Figure 1C). The initial number of mussels per m^{-3} in the farm and the loss of mussels over time due detachment from the longlines or predation is based on observed abundances in the farm. The mussel farm interacts with the environment in the model, where i) mussel filtration decreases the Chl *a* concentration and increases water clarity, ii) direct excretion of nutrients from mussels stimulates algal growth and iii) biodeposition increases organic matter below the farm and sediment nutrient regeneration, which also affects algal growth.

Model results showing food depletion around a mussel farm

A farm-scale 3D model was set-up for a mussel farm 250 m long and 200 m wide extending 3 m below the surface located in a water column of 9 m depth (Figure 2). The model resolution was 10-50 m and forced by temporal data of water current speeds and directions from the Limfjorden in Denmark. The incoming water Chl *a* concentration to the mussel farm was 10 mg m^{-3} (red colour). The DEB model was used to describe mussel growth and filtration of microplankton within the farm. When water is passing the farm, mussel filtration depletes the Chl *a* concentrations to lower values (blue-green colours). The modelled depletion of Chl *a* (proxy for microplankton food) is shown for two days. Highest depletion (dark blue colour) was found in the north-eastern direction on the first day (Figure 2A) and in the south-western direction on the second day (Figure 2B). Hence, the depletion varies over time due to changes in current directions and speeds, where highest depletion is observed in the downstream current direction away from the farm. Mussels located in the food depleted area will grow slower than mussel located upstream with better food conditions. The depleted area extended 400 to 600 m from the farm. Mussel filtration and the resultant depletion of Chl *a* will lead to higher water clarity, which is an important water quality indicator.

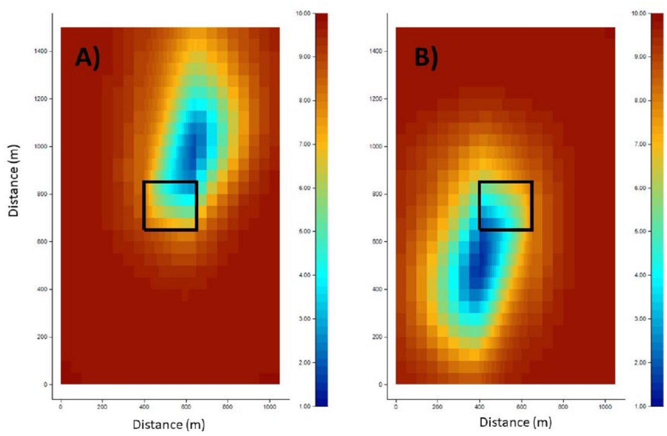


Figure 2. Model results show depletion of microplankton (blue-green colours) around the mussel farm (black square in the middle).

In BONUS OPTIMUS, the food depletion and other environmental impacts will be compared among study sites to demonstrate the feasibility of using mussel mitigation cultures in different environments. The models will be applied to Horsens fjord in Denmark with lower Chl *a* values and intermediate salinity (~22) and to the Greifswald Bay in Germany with very high Chl *a* concentrations and low salinity (~7). The results will help managers to evaluate both possible and negative effects of mussel farming on the environment in high and low salinity areas with different eutrophication levels.

Marie Maar
Aarhus University, Denmark

Friendly neighbours?
On local acceptance of mussel cultivation in the Baltic area

It is a recurring problem in land use management, including also coastal management, that the location of all kinds of infrastructural installations and production plants can cause conflicts. Such siting conflicts arise even when new facilities provide general societal benefits such as reduction of greenhouse gas emissions or of nutrient loads in fjords and seas. Discrepancies between greater societal concerns and local resistance sometimes lead to accusations of so-called NIMBYism – i.e. 'Not in my back yard'-ism – implying that local interests are egoistic when they acknowledge the greater good of a facility but just want it located elsewhere. The term is, however, more useful as abuse than as analysis, because it completely blocks any consideration of the legitimacy of local concerns and also blocks the integration and negotiation of such concerns in land use planning.
The accumulated experience regarding facility siting has revealed a pattern of recurring issues that are at the root of potential conflicts. Thus, residents, permanent as well as seasonal, can feel a strong attachment to the place in which they reside. This is not least true of seasonal residents, i.e. summerhouse owners and other recurring visitors in an area who may have a longer connection to the area than they have to their permanent residence, and who are particularly concerned about the landscape of their leisure time not being ruined by any changes.

On the other hand, local residents may also embrace the location of a new facility, if and when they feel involved in the planning process, if they believe a facility is in accordance with local values and if they think the facility in other ways will benefit themselves and their community. Following the EU strategy to increase the Blue growth of the marine and maritime sector, e.g. new aquaculture facilities, it is therefore important to consider and adapt to local reactions to the siting of a new facility in their area.

Investigation of local acceptance in case areas
As part of the OPTIMUS project, we have investigated the issue of local acceptance in three case areas, where mussel farms have been established: one in Hagensche Wiek as part of the Greifswald Bay in Germany and two in Denmark - in As Vig, which is part of Horsens Fjord and in Skive Fjord, which is part of Limjorden. Here we have conducted interviews and questionnaire surveys as well as stakeholder workshops.

It appears from the preliminary studies that mussel cultivation has a chance of being met with local acceptance, although locations of the facilities have to consider various concerns and interests.

It should be mentioned that mussel cultivation has a longer history in Denmark than in Germany. This means that in Denmark there are already local experience with mussel farms, but also with other forms of aquaculture in or close to the case areas in Denmark, especially fish farms but also seaweed cultivation and so-called marine gardens (see page 22/ 23).

When reviewing the questionnaire surveys in As Vig and Hagensche Wiek, we can see some considerable differences between the Danish and the German case, but also some recurring patterns. First of all, there is a level of ignorance about mussel cultivation in both case areas. Respondents are to some extent unaware that there is a mussel farm in their vicinity. 83% of the German respondents had not noticed the facility in Hagensche Wiek. Half the respondents in As Vig had noticed that there was a facility, but did not know what it was or thought incorrectly that there was only fish farms in the bay. Furthermore, a good 40 % in both case areas do not know what impact mussel cultivation can have on water quality.

Another recurring pattern is the importance attributed by respondents to the quality of water and beach. They were asked how important water clarity is for them on a scale from 1 (unimportant) to 5 (very important). 80 and 96% respectively answered 4 or 5. Especially for the Danes, water clarity was very important. And half of the Danish respondents also found that water quality had deteriorated over the years they had visited the area.

It was obvious that the Danish respondents in particular blamed fish farms (and not mussel farms) in the bay for the reduction in water quality. 82 % indicated that fish farming reduces water quality, 67 % indicated that mussel farms to some or to a high extent spoil their experience of the landscape, 57 % find that aquaculture facilities spoil their view a little or a lot, and in their open replies they blamed fish farms for cloudy water, for a muddy, slimy seabed and for the disappearance of flatfish in the bay.

Some of this frustration with fish farms may have rubbed off on their somewhat more sceptical attitude towards mussel cultivation. While 74 % of the German respondents agreed partly or fully with the statement "I don't mind that there is mussel farming in this area", only 30 % of Danes agreed and 41 % disagreed fully or partly. From our media study, we also learned that there is a concern in the local public that mussel farms – due to their water cleansing capacity – will be used as a lever to introduce even more fish farms in Horsens Fjord including As Vig. While fish farms are the main frustration for

the Danish respondents, the German respondents are much more concerned with other problems such as litter on the beach, too much car traffic and density of summerhouses (figure).

From stakeholder workshops in both countries, we furthermore learned about a number of concerns expressed by local businesses, property owner associations, leisure and sports associations, NGOs and local government. Thus, mussel and other fishers have an interest in not getting their fishing grounds disturbed or ruined by mussel farms. Channels for ships can of course not be blocked in any way. There is a wide range of on-water leisure activities such as kayaking, wind and kite surfing, fishing and sailing, which potentially can be disturbed by a mussel farm. And they wanted an effective system for cleaning up litter – such as loose buoys – from mussel cultivation facilities. On the other hand, the need to take action against excess nutrients in the water and the significant benefits of protecting and improving water quality was widely acknowledged.

In conclusion, we would suggest that a strong emphasis on water quality would be useful, if developers of mussel cultivation want the acceptance of local stakeholders as well as local seasonal and permanent residents and want to include them in processes of planning, establishing and managing mussel farms.

Lars Kjerulf Petersen, Aarhus University
Nardine Stybel, EUCC – The Coastal Union Germany

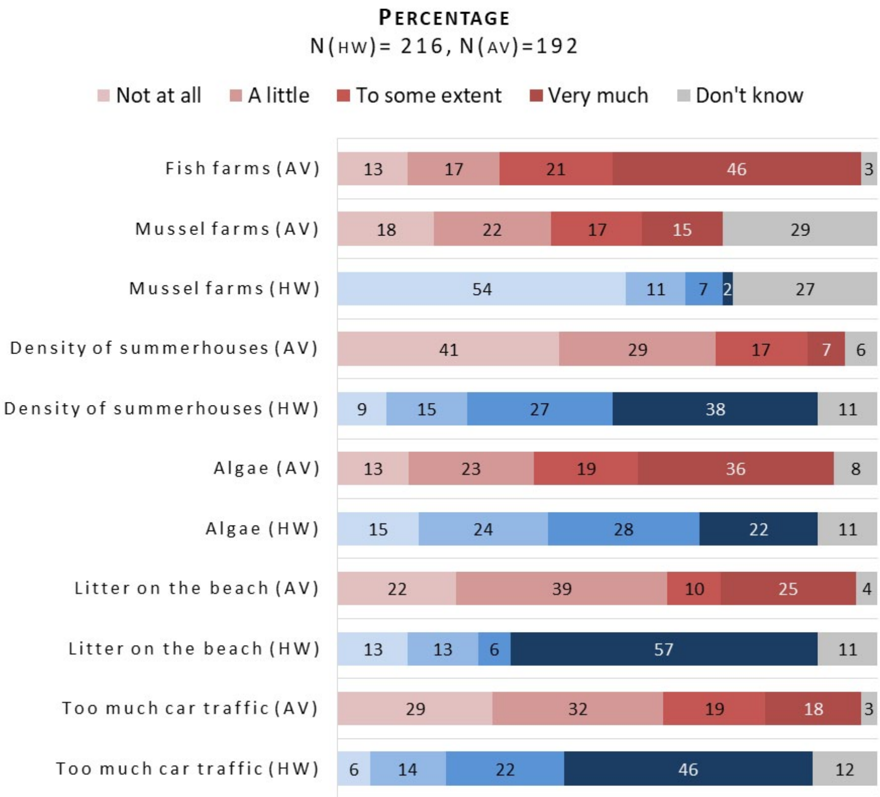
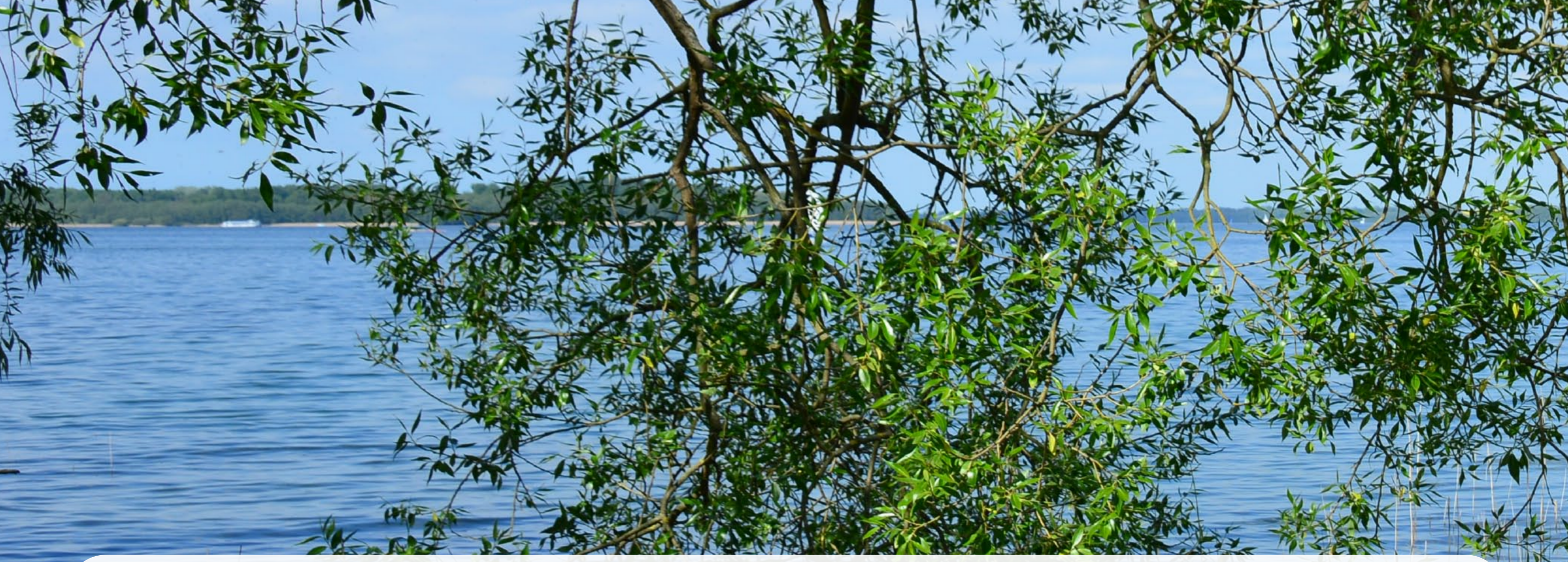


Figure. Do you think that any of the things, to a lesser or higher degree, spoil your experience of the landscape, the beach and the water?



Floating wetlands in combination with mussel cultivation to boost nutrient removal

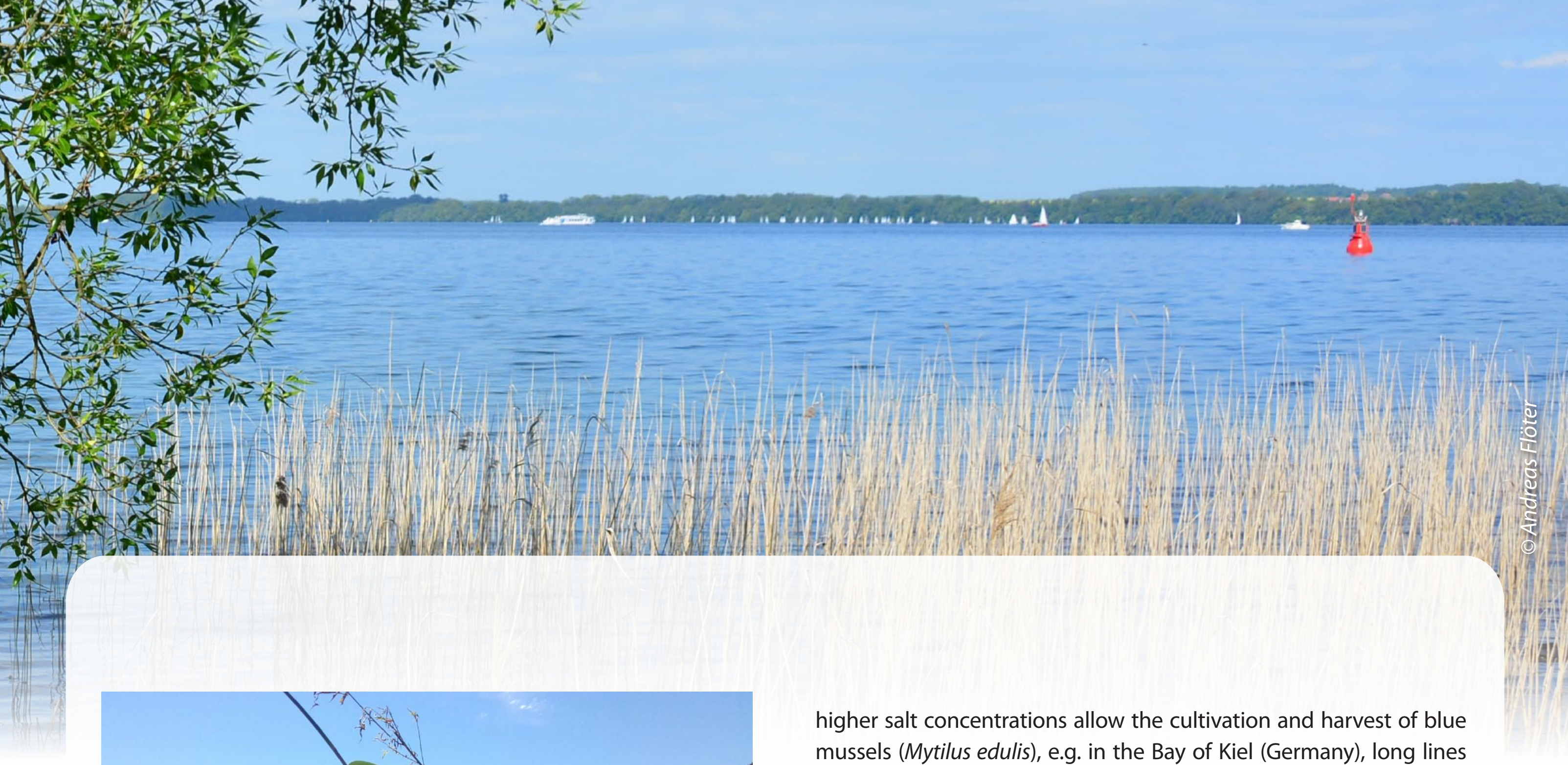
One option to tackle internally accumulated nutrients in eutrophicated coastal waters is phytoremediation and the harvest of emergent macrophytes. Besides the harvest of natural wetlands which has been carried out for centuries along the Baltic coast, a new potential has arisen: Floating wetlands! Floating structures are planted with native emergent macrophytes such as yellow flag (*Iris pseudacorus*), sedges (*Carex acutiformis*) or common rush (*Juncus effesus*). The plant roots in the water column directly absorb nutrients (e.g. phosphorus and nitrogen) and incorporate them into their tissues through biosynthesis. Additionally, floating wetlands enhance particle settling and nutrient burial by attenuating wave and water flow.

Scheme of a floating wetland

Commercial applications of these so called 'living barriers' that aim at both habitat restoration and local enhancement of water quality exist already in freshwater environments, but no installation of floating wetlands existed so far in coastal waters. Within the Interreg South Baltic project LiveLagoons existing floating technologies were adapted to local environmental conditions at the South Baltic Sea and islands with native emergent macrophytes have been installed in three different lagoons: Curonian lagoon (Lithuania), Szczecin lagoon (Poland) and Darss-Zingst Bodden Chain (Germany). The target is to improve the water quality by reducing the nutrient concentrations and thus eutrophication with the help of floating wetlands. Therefore, the project partners and coastal municipalities worked together to find the best installation sites for the floating wetlands in order to maximize nutrient removal, gain additional aesthetic benefits to boost tourism and prevent spatial conflicts of use. A variety of aspects needed to be considered before the installations could start, e.g. regional laws and regulations impacting the permit procedure or such physical constraints as water depth, water level fluctuations, waves and currents which influence anchoring. Also precise environmental data of the regional flora and fauna is necessary as only native and non-invasive emergent macrophytes, preferably perennial and with aerenchyma ("air channels"), can be used on floating wetlands. Depending on the choice of plants, the islands can also become biodiversity hotspots as they offer diverse habitats for fish, birds, insects and microbes.

Results from Curonian lagoon

In the Curonian lagoon, the floating installation became additionally a habitat for mussels. Large amounts of zebra mussels (*Dreissena polymorpha*) were attached to plant roots and net structures. This adds to the total nutrient removal capacity of the floating installation: Nutrient concentrations in the mussels are approximately 1 % nitrogen (N) and 0.1 % phosphorus (P). The 'net', a custom-made floating rig of 200 m length and 1 m height, placed at 1 m depth has its structure disposed at whole cross-section of the water column. Zebra mussels attach both the rig itself and the plants fixed to the net at 40 cm below water surface, presumably avoiding excessive wave shear stress and ultraviolet radiation. It is estimated that below this depth, 60 cm of the willow stem could be fully covered with zebra mussels. Those mussels attached to a single stem by the end of the first growth season produce ~8 g of dry weight equivalent to ~8 mg of P and 79 mg of N. In total approx. 5 g of P and 47 g of N could be harvested altogether with willows.



"Net" installation at Curonian lagoon

Settled zebra mussel on the "net" installation at the Curonian lagoon

There were even more zebra mussels attached to the rig itself, though harvesting is difficult and inefficient. Therefore, longlines or hanging ropes similar to ones used in the BONUS OPTIMUS project could be attached and tested as an additional substrate. All in all the possibility to intentionally combine mussel cultivation with floating wetlands from the beginning on would boost the nutrient removal efficiency. In the Curonian lagoon, addition of longlines for settling of zebra mussels larvae to the floating islands could enhance the removal of nutrients by a substantial amount (additionally 13 % of nitrogen and 17 % of phosphorus were removed when harvesting zebra mussels from the artificial net structure). Further west in the Baltic Sea, where higher salt concentrations allow the cultivation and harvest of blue mussels (*Mytilus edulis*), e.g. in the Bay of Kiel (Germany), long lines could be attached between different floating wetlands.

Maximization of nutrient removal

To maximize nutrient removal efficiency of floating wetlands also the timing of plant harvest is crucial. Perennial macrophytes move their nutrients into the roots when senescence starts in autumn. To be most effective, harvest should be in (late) summer but still in agreement with local nature protection regulations. Not only nutrient concentrations in different plant species are important, but also biomass development and thus total nutrient stocks. For example biomass growth of broadleaf cattail (*Typha latifolia*) is larger than of flowering rush (*Butomus umbellatus*). Particle settling and nutrient burial is especially enhanced by macrophytes with a dense rhizome network such as reed (*Phragmites australis*). However, site-specific conditions need to be considered: If oxygen shortages are a problem at the installation sites, plants with shorter roots should be chosen to allow free water flow.

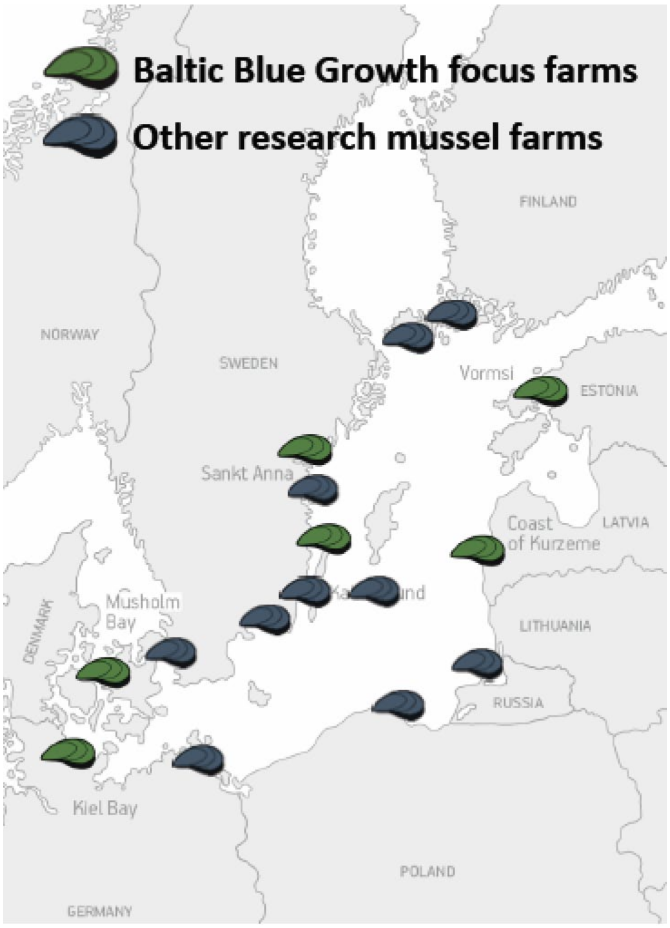
Combinations of floating wetlands with mussel and also potentially with macro algae cultivation could be linked to nutrient quota trading mechanism or to voluntary financing schemes (see page 22/ 23). Such funding opportunities would make floating wetlands also more attractive for small coastal municipalities in economically weak regions. A participatory mapping study showed that people appreciate floating wetlands and their ecosystem services, especially their esthetically benefits. Hence floating plant islands with mussels offer not only the chance to combine water quality improvements with blue economic growth by commercialization of harvested plants and mussels, but are also a chance for the recreation and tourism sector.

Svenja Karstens, EUCC - The Coastal Union Germany
Artūras Razinkovas-Baziukas, Klaipeda University
www.balticlagoons.net/livelagoons

LiveLagoons
Interreg South Baltic
EUROPEAN UNION
European Regional Development Fund

Full-scale mussel farming to counteract eutrophication and create new Blue Growth opportunities: the Baltic Blue Growth project

Farming blue mussels in the Baltic can combat eutrophication and can contribute to Blue Growth opportunities through providing new business models for the feed industry. The Baltic Blue Growth (BBG) project has worked to advance mussel farming in the Baltic Sea from experimental to full-scale through implementing several pilot mussels farms and exploring under which biological and financial conditions mussel farming in the Baltic Sea Proper is possible. As a result of BBG, several new technologies were explored and results have shown that mussel farming in the Baltic can actually realize



Baltic Blue Growth focus farms and other research mussel farms

a significant amount of biomass: over 100 tons of mussels were harvested in 2018. BBG farms included Sankt-Anna (Sweden) (see header picture), Vormsi (Estonia), Kalmarsund (Sweden), Kurzeme (Latvia), Musholm (Denmark) as well as a farm in Kiel (Germany).

Environmental impacts

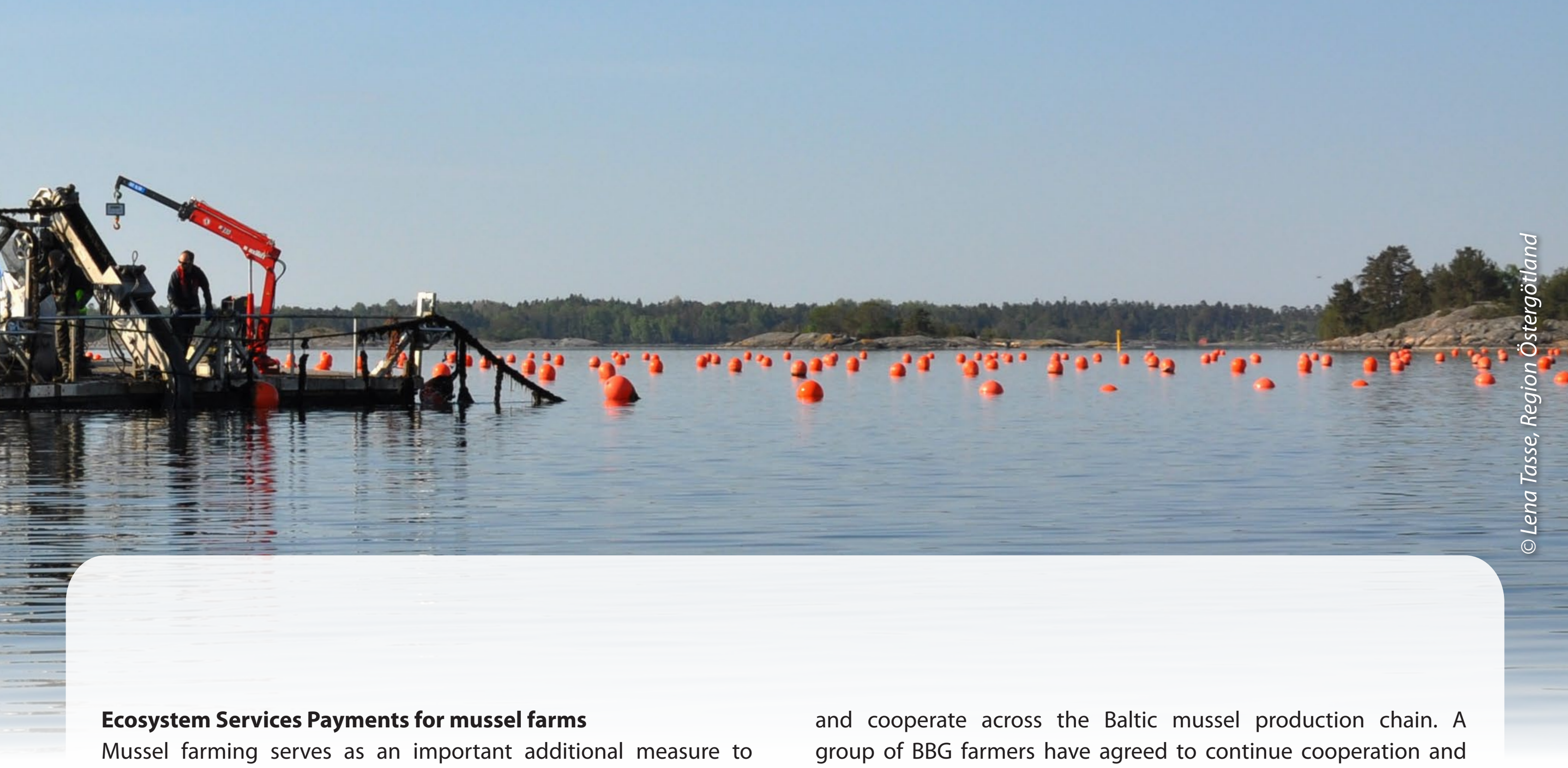
It is known that in areas with higher salinity levels, mussels tend to grow to bigger sizes. However, BBG pilot farms have shown that farms in areas with lower salinity levels (e.g. the Baltic Proper) remove only 36% less nutrients per hectare than farms situated in higher salinity areas. This shows that farms situated in areas where nutrient removal is most important, are much more effective than previously expected. Farming blue mussels with the right technology and in the right place can furthermore substantially improve the water quality and transparency as mussels filter water and take up hazardous substances and nutrients. Mussel farming can thus complement source-related measures and make important local contributions to counteracting eutrophication. Mussel farms are the only mitigation measure that actively removes legacy nutrients from the water and BBG has shown that farmed mussels in the Baltic Proper take up nitrogen and phosphor. BBG results have also shown that species diversity and abundance are higher near the mussel farms and oxygen levels remained stable. The overall environmental impact of mussel farms may differ between sites and change over time during the production cycle, so more monitoring and research will be needed to complement the BBG results.

Feed market potential

The project explored various legal, regulatory and environmental challenges, including low salinity levels, climate, and predators. BBG also investigated potential uses for the harvested mussels and their role in closing the nutrient loop. Blue mussels can be processed into high quality protein meal; a good substitute to soybean or fishmeal traditionally used for feed, thus alleviating pressures on both the climate and fish stocks. Blue mussels also contain high quality marine fatty acids, including Omega-3. More research and cooperation will be needed to provide sufficient mussel biomass for feed plants.

The 'Operational Decision-Support System'

BBG developed a user-friendly web application: the ODSS portal. The portal is unique as it builds on harmonized methodologies and big data with high scientific quality. All existing on-site evidence of the effects of mussel farming in the Baltic Sea area is integrated and it features a new spatial modelling framework to show where mussel production potential and nutrient removal is highest. To avoid conflicts with other uses, the portal also shows the spatial allocation of other human activities. The portal is available online for all to use.



Ecosystem Services Payments for mussel farms

Mussel farming serves as an important additional measure to prevent increased eutrophication in the Baltic Sea and achieve Good Environmental Status. BBG has undertaken a study to provide concrete guidance on how an appropriate ecosystem payment scheme for Baltic mussel farms may be developed. Payments for ecosystem services provided by mussel farming can come from a mix of public as well as private funding schemes. Various EU funds such as the EMFF are readily available to be used for financing mussel farm projects, but it is up to national authorities to make use of them accordingly. Even though at first sight a 'polluter-pays principle' may seem logic, evidence suggests that the 'beneficiary-pays principle' is more in line with promotion of further measures to reduce nutrient production. The study also discusses different forms of awareness raising and motivation for the development of compensation mechanisms such as eco-labelling and certificates, nutrient calculators and voluntary emission trading systems.

The future of Baltic Sea Mussel Farming

The BBG project has produced a summary report and a short policy brief as well as dedicated reports, factsheets and online FAQs on topics including licensing, mussels for feed, socio-economic impacts, MSP and many more. The SUBMARINER Network has launched a Mussels Working Group to further research, promote and cooperate across the Baltic mussel production chain. A group of BBG farmers have agreed to continue cooperation and monitoring and to share and publish their data. The Working Group will also continue working on legal issues and potential certification of mussels. If you want to learn more about mussel farming in the Baltic, visit submariner-network.eu/projects/balticbluegrowth to see the project outputs and learn more about (how you can join) the Mussels Working Group.

Baltic Blue Growth (2016-2019) is led by Region Östergötland and is co- financed by Interreg Baltic Sea. It is a Flagship project under PA Nutri of the EUSBSR.

Lisa Simone de Grunt,
SUBMARINER Network for Blue Growth EEIG

Interreg
Baltic Sea Region
Baltic Blue Growth

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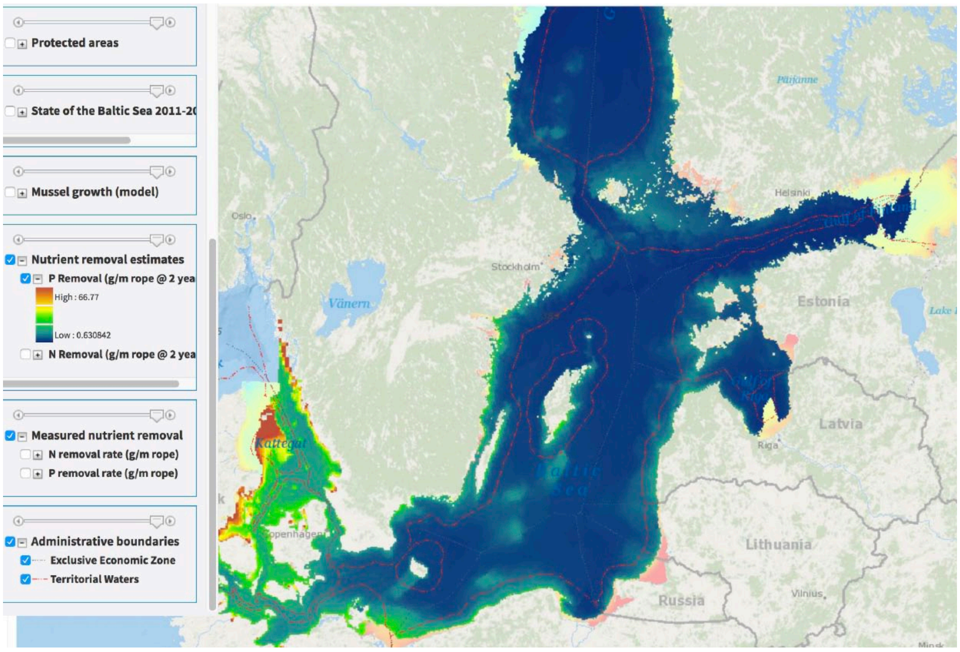

Interface of the BBG ODSS

Potential use of mussel mitigation cultures in the Baltic Sea for fish feed

Within the OPTIMUS project investigations are conducted how undersized blue mussels can be used in fish feeds for salmonids. These mussels serve as ingredients to replace fishmeal or other animal protein sources in feeds for various animal live stocks such as fish, poultry or pigs.

Mussel meal has nutritional properties of protein, amino acids and essential fatty acids, that are similar to those of fish meal and has proved a good substitute for fish meal in feeds for several species of fish. In addition, mussel meal may provide additional properties in terms of valuable pigments and attractants.

Several challenges, however exist before blue mussel can be a competitive and sustainable resource for fish feed. Production cost, for instance, is an important factor determining the potential of mitigation mussel as a future nutrient resource. While production of under-sized mitigation mussels is cheaper than production of uniform larger sized mussels targeted for human consumption, due to less labour (grading, socking), production costs still comprises investment, growing, harvest, transport and processing. In future scenarios significant reduction of costs for farming mitigation mussels could imply subsidies for the contribution of environmental benefits or tradable auction models; i.e. €/ ton N, P^{-1} removal. Although costs related to production, harvest and transport have been estimated, methods and costs for processing have not yet been described.

Mussels produced for mitigation are of varying size, and more fragile than mussels for human consumption, due to thinner shell thickness. Thus, certain parts of the mussel may easily be crushed during harvest and transport, which can reduce the (safe) storage time until qualitative deterioration takes place. Likewise, mitigation mussels are often bio-fouled with other growing organisms i.e. sponges and barnacles, which may possibly influence on the nutritional composition and quality of the final product, which could limit its ability as a fish feed ingredient.

In the BONUS OPTIMUS project, the partners investigate new cost effective methods of processing whole mitigation mussels into meals. As fish opposite to poultry cannot utilize the calcium carbonate rich shell fraction, the methods so far applied include juicing, centrifugation, enzymatic treatment and drying techniques at various temperatures and duration to ensure nutrient quality. The first fish experiments with blue mussel meals will be finished in spring 2019. The first setup tests nutrient digestibility and growth performance in rainbow trout given 5 diets for which fish meal has been gradually substituted by mussel meal, obtained by crushing whole mussels incl. byssus threads and biofouling organisms. The resulting mass has been filtered and the juice, collected from a press filter, has been subsequently spray dried at two different temperatures into two meals and formulated and extruded into pellets. The aim of the first experiment is to obtain knowledge of the usability of whole mussel meals in fish feeds when processed in a simple and cost efficient way at two drying temperatures.

Conventional mussels meal (browndark) and meal and pellets from mitigation mussels, where everything has been crushed juiced and spray dried (greenish)

Fish experiments with mussel meal

Ivar Lund, DTU Aqua, Institute of Aquatic Resources, Denmark
Nina Gringer, DTU Food, National Food Institute, Denmark

Where to place mussel mitigation farms in the Western Baltic Sea?

Large-scale implementation of mussel mitigation farms in the Western Baltic Sea requires political decision makers first to outline possible farming areas. Therefore, evidence-based estimates of mussel harvest potentials, cost-efficiency, and environmental impact of farms across the area of interest need to be determined. These figures require evaluation with respect to the policy framework including both (inter-)national regulations and local conflicting interests. In BONUS OPTIMUS, we intend to develop an integrative spatial multi-criteria site selection tool as guidance for political decision makers throughout this complex process. Currently, we include data from marine areas between Denmark, Germany, and Sweden across the W. Baltic Sea. The illustration shows schematically how this tool will perform. A stepwise integration of several layers in a geographical information system (GIS) is required before the final area selection (left). Therefore, complex interaction models between the four following categories of external drivers for potential mitigation effects of mussel farms are included (right):

Environmental conditions

A 'dynamic energy budget' (DEB) model is calibrated based on spatially resolved mussel growth potentials determined from test-farm experiments. Growth rates of individual mussels can then be predicted under different environmental conditions. Using spatially and temporally resolved data on environmental conditions, we can model mussel growth potential across the W. Baltic Sea by applying suitable statistical models. Mussels can also be lost from a farm due to temporarily unsuitable conditions (e.g. hypoxia, predators such as eider ducks) and this risk of biomass loss requires spatial quantification.

Infrastructure

Mitigation farms can have different size, type and density of growth substrate, and protection measures against physical exposure and predators. Specific farm constructions can optimize local harvest and nutrient reduction potentials, and they define respective costs for installation and maintenance. Together with aspects of local infrastructure (e.g. distance to harbours), cost-efficiencies of potential farms are determined.

Conflicting interests

Local utilization of marine areas (e.g. shipping routes, protected areas, economic and recreational uses) can interfere with the implementation of farms. Numbers and magnitudes of such possible conflicting interests are qualitatively and spatially assessed based on available datasets.

Policy framework

Cost-efficiencies of farms require balancing against local eutrophication mitigation needs to cope with e.g. EU regulations on water quality. Policy makers from the countries involved have to be able to weigh benefits of farms against conflicting interests. They have to decide about available production areas and respective mitigation effects.

All evaluations in this integrative approach for site selection are based on a range of available and modelled spatial data layers, being processed through a GIS. The developed GIS-tool, made available for all relevant authorities and stakeholders, should contribute to an integrative and sustainable marine spatial planning for the W. Baltic Sea.

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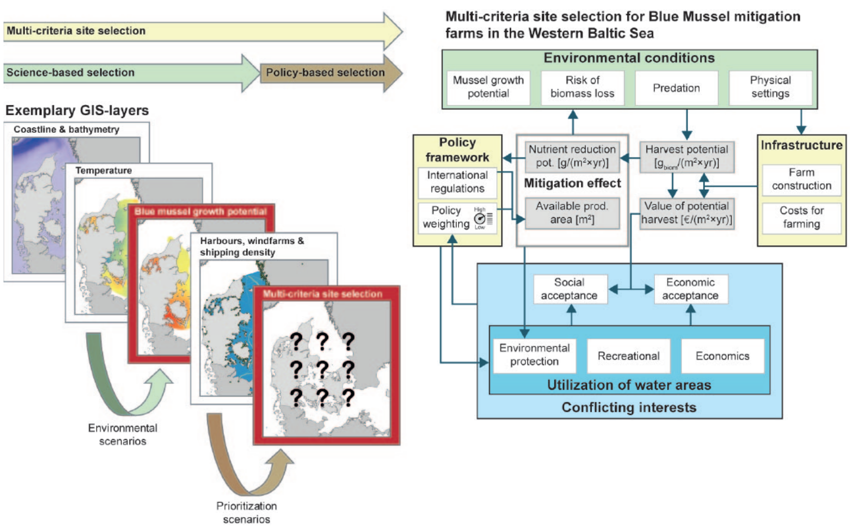
Aarhus University, Denmark



Schematic illustration of the integrative multi-criteria site selection tool for Blue Mussel mitigation farms in the W. Baltic Sea. Left: Illustration of the stepwise integration of exemplary GIS-layers to the final area selection. Modelling results are marked in red. Right: Simplified model of the complex interactions between four categories of external drivers that determine potential mitigation effects of mussel farms.

Projects & initiatives

Marine Gardens

The cultivation of bivalves, including mussels, is not limited to the commercial farmer. Bivalve gardening has become a popular activity in several countries as both a form of 'crowd-sourced' restoration activity and as a hobby-scale food source. In Denmark, community-scale seafood gardens have been assembled near a number of cities, including the capital, Copenhagen. Imitating a small-scale commercial farm, these gardens provide the local community a means to engage with the marine environment and cultivate their own seafood – be it mussels, oysters, seaweeds, or other marine food products. This has been recognized as a useful method to diversify diets and enhance the nutritional value of meals. Gardening for these communities promotes healthy lifestyles through physical activity, time spent outdoors, and cooperative work. The opportunity for exploring marine ecology is also an important feature for these seafood gardens. The expansion of seafood gardening is generally perceived as a positive development for Danish society.
For more information on bivalve gardening, see "Bivalve Gardening" in Goods and Services of Marine Bivalves, Springer Publications 2019.

More information on Danish seafood gardens:
https://www.fjordhaver.dk/

Daniel Taylor
Danish Shellfish Center, DTU Aqua

Mussel harvesting event at seafood gardens

Join us in saving the Baltic Sea!

The Nutribute crowdfunding platform is the first platform in Europe for fundraising for water protection. Besides the promotion of nutrient reduction measures, policy recommendations are published for the introduction of new methods and nutrient offsets. Among the new measures, particularly gypsum amendment of agricultural fields and fishing of cyprinids proved to be cost-effective ways to reduce nutrient loading. These methods will soon be tested and applied in other countries in the Baltic Sea region. The project also initiated successful mussel farming and gained experience in nutrient exchange. All in all, Nutribute reduced phosphorus loading to the Baltic Sea by around 30 tonnes in 2018.
Nutribute was developed within the Interreg Central Baltic project NutriTrade (2015-2019).

More information: www.nutribute.org

Anna Saarentaus,
John Nurminen Foundation

Nutribute
Nutrient Offsetting for the Baltic Sea
Interreg
Central Baltic
EUROPEAN UNION
European Regional Development Fund

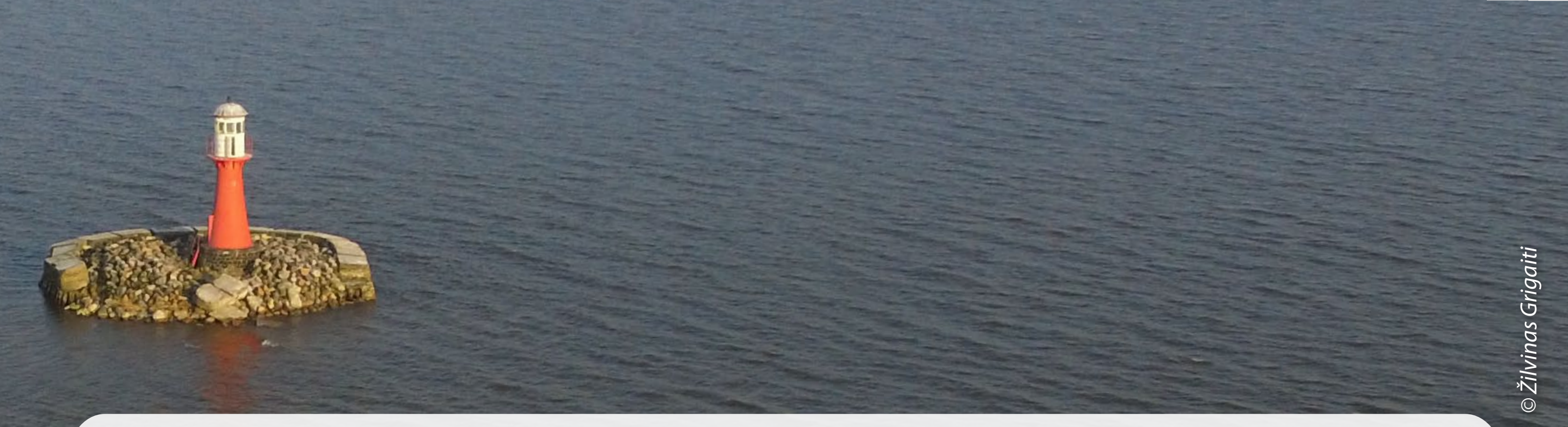
Advancing Baltic Blue Bioeconomy Capacities

Blue Platform (Interreg BSR 2018-2021) will synthesize, promote and encourage the uptake of Blue Bioeconomy project results by developing a dynamic website and organising interactive stakeholder workshops. Blue Platform is the key information and service point for all actors interested in the Baltic Blue Bioeconomy. It disseminates and generates knowledge for new initiatives, and stimulates increased transnational and cross-sectoral cooperation. Blue Platform is raising both awareness as well as the capacities of actors in the Baltic Blue Bioeconomy.
Blue Platform will help to define the next generation of support actions, by taking an active role in the update of the EU Blue Bioeconomy Strategy; EMFF & ERDF operational programmes; EUSBSR Action Plan; and many others.

More information:
www.submariner-network.eu/projects/blue-platform

Lisa Simone de Grunt
Submariner Network

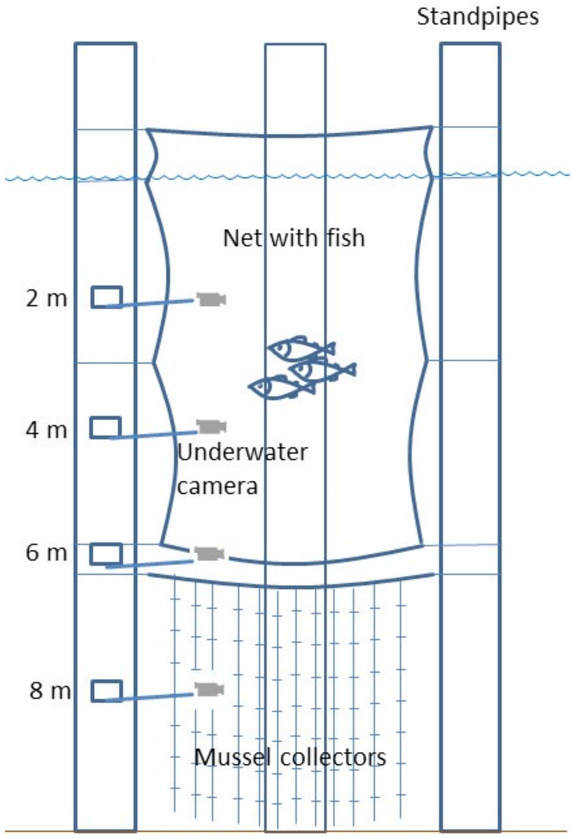
Interreg
Baltic Sea Region
EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND
Blue Platform



Combined marine aquaculture

The project "Testing of a blue mussel production method in combination with a fish farm for a decentralised aquaculture" aims to enhance the self-sufficiency with aquaculture products in the federal state Mecklenburg Western Pomerania (Germany). Mainly whitefish (*Coregonus maraena*) and salmonides will be cultivated in a cage of 3 m diameter between the standpipes of the working platform of the artificial reef Nienhagen near Rostock-Warnemuende. To compensate the nutrient input of the farmed fish in the production unit blue mussels will be cultivated below the cage. Different collector materials, corresponding growth rates and harmful substances in the mussels will be analysed to be able to develop opportunities for regional processing and use of farmed mussels. The project will generate transferable results for the establishment of further sites of a decentralised aquaculture in coastal waters. It is financed from federal state resources and EU funds (EMFF) until 2022.

Thomas Mohr
State Research Institute for Agriculture and Fisheries MV



Combined aquaculture at the working platform of the artificial reef Nienhagen

Mussel Farming for Mitigation and Protein Source for Organic Husbandry (MuMiPro)

MuMiPro aims to provide guidance for the development of an industry in Denmark for the production of mitigation mussels directed to organic husbandry. The development of novel industrial feeds production presents challenges in relation to production efficacy, processing innovation to transform mussels to feedstock, and business models. Based on the high demand for organic and marine protein sources, strong mussel recruitment and eutrophic conditions in Danish coastal waters, the opportunity for the development of mitigation mussel culture in Denmark is promising. MuMiPro intends to investigate aspects related to production optimization, processing of mussels into meal, assessment of the potential for mitigation production at the national level, nutritional trials on piglets and chickens, and economic analyses to determine payment schemes and business models. These aims will provide the springboard for the production of 100,000 t of mussels; equivalent to 15,000 t of meal, and 1,000-2,000 t of nitrogen extracted annually.

MuMiPro is funded by Innovation Fund Denmark. For more information, visit: www.mumipro.dk

Daniel Taylor & Jens Kjerulf Petersen
Danish Shellfish Center, DTU Aqua

Blue mussels on longlines

BONUS OPTIMUS Summer school 2019

Topics:

Mussel mitigation cultures, mussel growth, environmental quality and site selections

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