Baltic MUPPETS

# DELIVERABLE 2.1

## REPORT ON THE DEPLOYMENT OF TWO FULL-SCALE MUSSEL FARMS

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# EXECUTIVE SUMMARY

The Baltic MUPPETS project has an overall aim to demonstrate the possibility to create a viable business based on Baltic blue mussels that is both profitable and beneficial to the Baltic Sea environment. The project will enable a new circular economy in the Baltic Sea Region, as well as provide support to mussel farmers across Europe to develop, diversify, and scale their existing businesses.

This report will focus on the deployment of mussel farms by two companies at two different farm sites, Ecopelag EF, located in the north-western Baltic Proper (Sweden), and Wittrup Sea Farm, located in the south-western Baltic Sea (Denmark). Farming of mussels in the Baltic Sea is a fairly new activity. In the north-western Baltic Proper, the salinity is around 6 PSU while in the south-western Baltic Sea, the PSU is around 25. This difference in salinity causes a difference in mussel growth rate, resulting in the choice of two different farming techniques. The reports from the two farm sites describe the different designs of the Swedish and the Danish farm, how they were deployed step by step, and the continuous work on adjusting and developing a methodology suitable for the local conditions. Sea-ice constitutes a problem at both sites, and both companies tackle this problem with innovative, but different, solutions. The most important outlook is that each location for mussel farming differs, and the different environmental conditions must be considered when choosing farming technique.

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## LIST OF CONTENT




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## LIST OF FIGURES



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# 1. INTRODUCTION: MUSSEL FARMING IN THE BALTIC PROPER

Mussels are farmed in different ways around the World, as equipment must be adapted to local conditions. For the low saline part of the Baltic Sea, Baltic Proper, mussels grow slowly compared to more saline areas and reach a size of just 2,5-4 cm after 2-3 years of growth. The small size, in combination with a lack of a food safety regulatory framework for using mussels as food[1] for this area, pose challenges for the Swedish east coast mussel farmers. Nevertheless, a number of previous studies[2] have shown that the high nutrient conditions of the eutrophic Baltic Sea, in combination with high mussel abundance, low biofouling[3] and infrequency of mussel predators, makes some parts of the Baltic Proper interesting for mussel farming. The aim of this report is to describe the deployment of a full-scale mussel farm at the Swedish east coast, which was achieved within the Baltic MUPPETS project (Figure 1).

Link to a movie about Ecopelag's Baltic MUPPETS farm outside of Västervik.

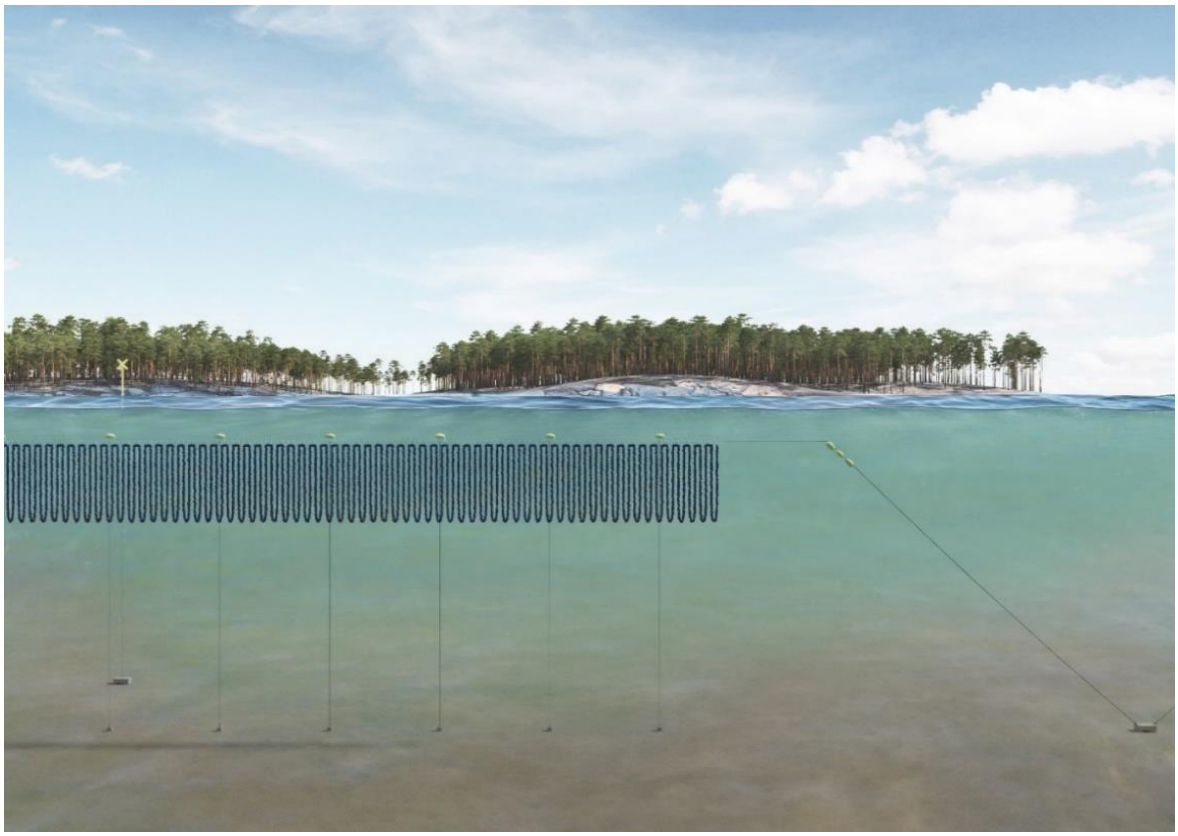

*Figure 1: Illustration of a farm unit used at the Swedish site outside of Västervik. Ice-safe submerged long-line technology is used, where the mussels settle and complete their full life cycle on substrate ropes specially designed for the conditions of the Baltic Proper.*

[1] EG nr 853/2004 section VII Chapter V regarding safe limits for biotoxins in mussels.
[2]LifeIP Rich waters, LIFE15 IPE/SE/000015 on https://webgate.ec.europa.eu/life/publicWebsite/search
Baltic Blue Growht #R031 on https://interreg-baltic.eu/projects
[3] Biofouling; In this context describes organisms that compete with mussels for space, blocking the mussel farm ropes or alternatively grows on top of the mussels.

# 2. THE VÄSTERVIK MUSSELFARM

## 2.1 Mapping and planning

The selected area of 30 hectares is situated in the moderately exposed outer archipelago of Västervik (Figure 2). From 2014 to 2022, a pilot farm owned by Västervik municipality was in operation at the southern part of the site. The depth of the area varies between 18 to 20 meters. The area is marked with 8 yellow navigation marks[4] and holds 37 farm units with space for approximately 56.000 meters substrate. Västervik municipality provided contacts with the private water owners, as well as GIS data to support planning and facilitate the permit application process.

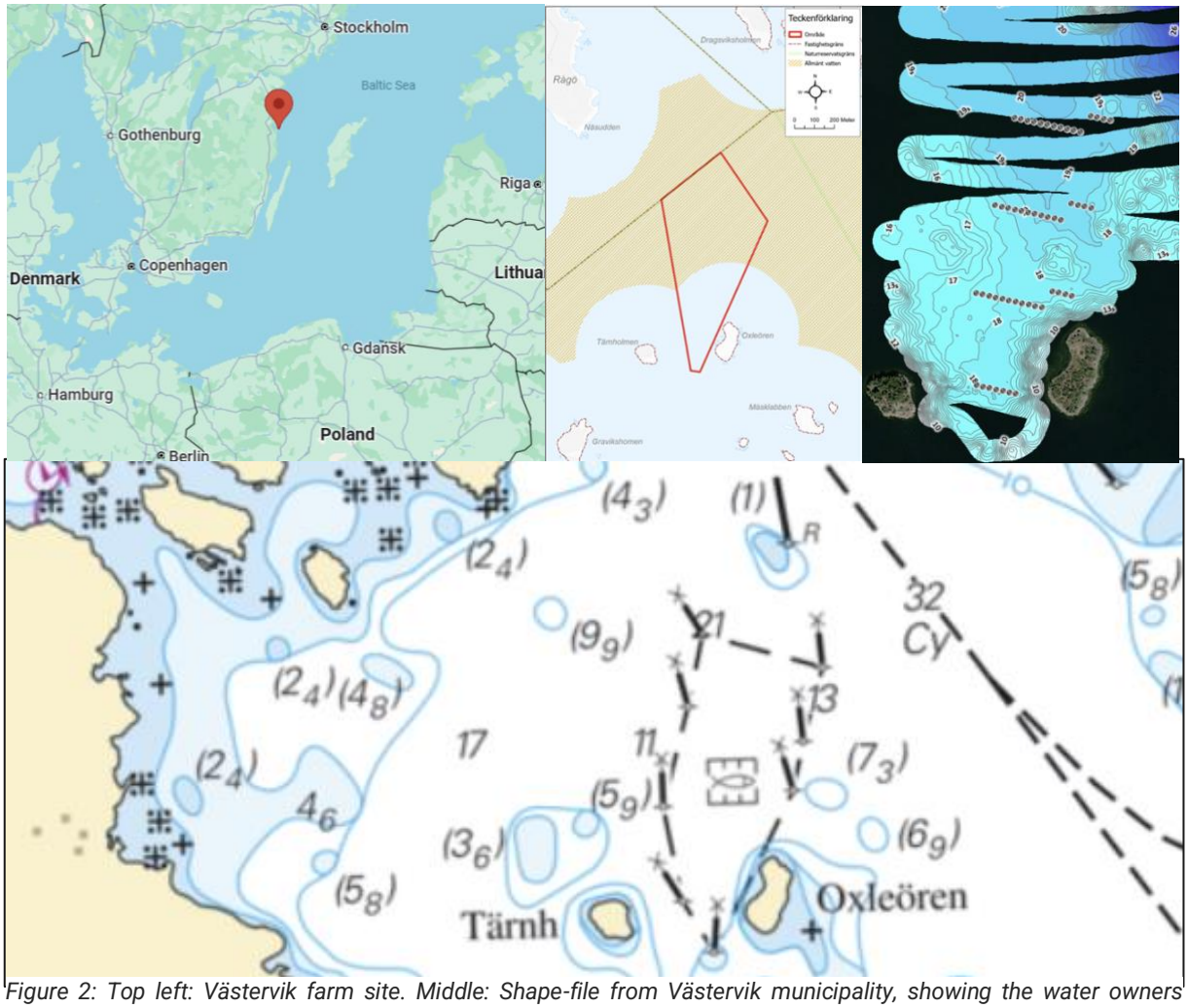


*Figure 2: Top left: Västervik farm site. Middle: Shape-file from Västervik municipality, showing the water owners property boundaries and protected areas Right: Sonar scan over the planned farm area, showing bottom depth and suggested placement of anchor stones. Bottom: Sea chart from the Swedish maritime administration showing the farm site with navigation aids.*

[4] SSA special marks, permit no. TSS 2022-3100, Swedish Transport Agency.

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## 2.2 Permit applications

Ecopelag EF first applied for an overtake of the old pilot farm site, and renewal of the existing production permits in private waters. In the second step, Ecopelag applied for permit to expand the farm area to national waters, which had to be granted by a Swedish State authority[5]. In the third step, new mussel production permits were applied for, a process which involved several different approvals from different authorities.

## 2.3 Contstruction of the farm

### 2.3.1 Farm units and compartments

Each unit of the farm consists of two anchors with buoyed anchor ropes, and in between them a headline of about 100 meters. From each headline hangs weighted substrate ropes to which the mussels attach, 0,5 - 1.0 meters apart in tight loops down to a depth of about 10 meters (Figure 3 and Figure 4). A mussel farm's anchor and support lines can be seen as its structural framework. This framework is made of 32 mm three-ply polypropylene rope (e.g. Aquasteel or PAC steel) and is designed to withstand heavy abrasion and UV light. They are designed specifically for aquaculture and other similar marine applications.

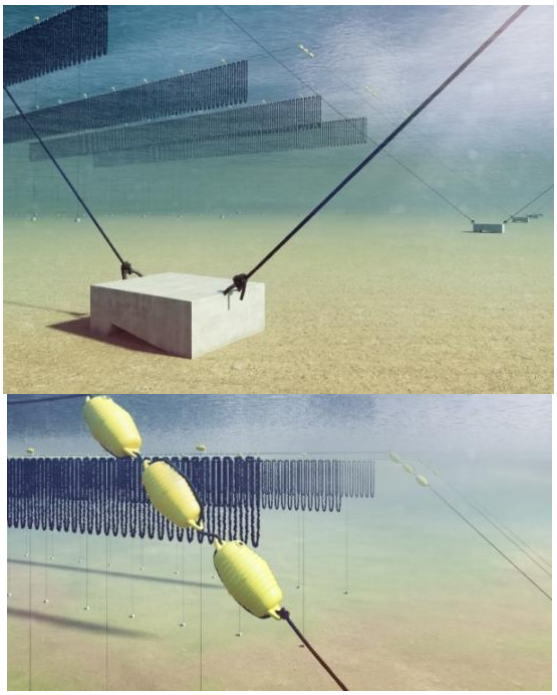

*Figure 3: Left: The farm units are anchored with concrete anchors weighing 3 tons. Two units can share a middle anchor. b) Right: To get the anchor line stretched, each anchor line is provided with three buoys of polyurethane with a total buoyancy of approximately 200 kilo.*

Each headline will carry approximately 1,5 kilometer of substrate rope. Ecopelag's substrate ropes have been designed specifically for the unique farm conditions of the Baltic Sea in terms of design and material selection. To keep the farm unit at a constant depth over the growing period and protected from ice, the headline has been provided with buoyancy (buoys) and weights (concrete plinths) (Figure 5). The headline is placed is approximately 3 meters below the surface. The optimal depth is determined by the degree of exposure at a farm site and can vary between 2 to 8 meters.

The farm compartments were stored, prepared and partly assembled on land at the Baltic Sea Factory in Västervik.

[5] Kammarkollegiet, the Legal, Financial and Administrative Services Agency, is a state authority under the Swedish Ministry of Finance.

*Figure 4: Left: Substrate ropes are being prepared on land with small ropes for use to fasten the substrate loops to the headline later when at sea. Right: UW picture of substrate ropes at the Västervik farm, with growing mussels.*

### *2.3.2 Deployment*

37 farm units were deployed in steps at the Västervik site since project start. In 2023-2024, Ecopelag also repaired 16 farm units at an acquired farm in the St. Anna archipelago[6], and replaced the substrate ropes on 9 more units in the Stockholm region (Jungfrufjärden).

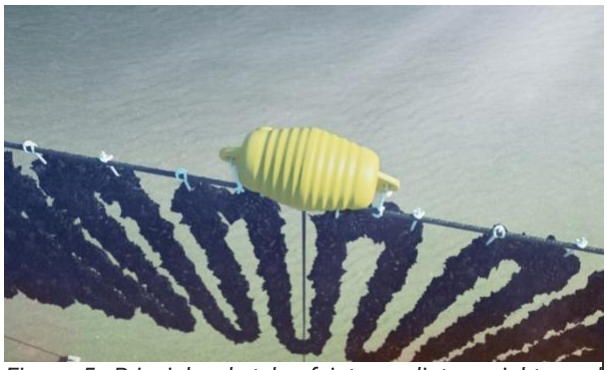

*Figure 5: Principle sketch of intermediate weights and compensatory buoyancy. In Västervik, the farm units are being lowered to prepare for the winter season, mainly to be secured from ice.*

#### 2.3.2.1 Anchors, anchor lines and navigation aids

The first step was to deploy the anchors for the units. Large ship assistance from Smågö Service AB, a marine contracting company, was used for deployment of anchors with attached anchor lines and buoys (Figure 6). Smågö Service and the fishing vessel VK160 Scanö helped with deployment and positioning of the navigation aids.


*Figure 6: Smågö Service from Västervik archipelago was contracted for deployment of the larger farm-parts.*

[6]This farm was first built by Aquaculture Centre east with funds from East Sweden region and the Baltic Blue Growth project (#R031 on https://interreg-baltic.eu/projects)

### 2.3.2.2 Attachment of headlines

When the concrete anchors with anchor lines were in place, the headlines were installed. This was done with Ecopelag's own workboat (Figure 7).

### 2.3.2.3 Mounting of substrate rope

Local fishing boat VK26 Garpen has been equipped with two specially built rope pullers with electrical winches (Figure 8, bottom right). These are used to lift headlines from the mussel farm up to the gunway, for attachment of substrate rope.

*Figure 7 (right): The Ecopelag work boat packed with headlines. This boat is used for assembly of farm parts at sea, substrate setting, precision jobs, general maintenance, monitoring, sampling and smaller repairs.*


*Figure 8: VK26 Garpen. This boat is used for substrate setting, and to mount compensation weights and floats. It can load up to 10 km of substrate rope below deck per journey, and up to 35 buoys on deck in addition to the substrate rope.*

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## 2.4 Special adaptions to local conditions

### 2.4.1 Substrate ropes

Traditionally, “fuzzy” substrate ropes are used only for spat collection. In the Baltic Proper they can be used for the whole growth cycle. In low saline conditions, mussels will attach less firmly to the substrate ropes. Adjusting the harvester to this softer attachment means un-necessary tear of the substrate ropes can be avoided. Mussels in the Baltic Proper have few competitors, so the ropes won’t have to be taken up and stored on land between seasons to avoid biofouling. The plan is to re-use the same ropes for many growth cycles, and leave them out at the farm for their whole lifetime.

### 2.4.2 Submerging the farm to avoid ice

The farm site in Västervik is relatively sheltered but covered with ice for at least some weeks during a year (Figure 9). Ice, and especially drift ice, is a major threat to mussel farming equipment. As shown in Figure 5 (p.10), small weights and corresponding compensation floats are used to settle Ecopelag’s long-line farms at safe depths. These are mounted on fixed distances along with the substrate ropes, with ropes the same length as the bottom depth minus target depth for the headline. When calculating the float power needed, one also has to take into account the growing weight of mussels on the ropes.

*Figure 9: Ice conditions in the Baltic proper. Left: Västervik farm site in January 2023. Right: The St. Anna farm site in March 2018. Photo: Mats Emilsson. Reprinted from Minnhagen et al 2019. Results from Baltic Blue Growth project’s mussel farms*

# 3. THE DANISH MUSSELFARM

In Baltic MUPPETS a mussel production on a submerged system is demonstrated in the Limfjord in Denmark. The Danish business case establishes two business models:

1. Industrial production of mussels on submerged mussel farms with low production costs, and with an export of small mussels from harvest in autumn to feed production, and sale of large mussels from harvest in spring/summer to food.
2. Sale and delivery of mussel production technology and know-how to national and international market. This document reports the deployment of the Danish mussel farms.

In order to reduce the impact of winter ice and visual impact of the mussel farming, a submerged production system is demonstrated as a full scale permanently submerged mussel farm with farming modules with nets on submerged pipes. On a submerged mussel farm, the mussels can winter during a possible ice formation and further grow the following season. The producers can harvest the mussels when they have reached the right marked size for human consumption and when the market is otherwise favorable. Furthermore, a submerged mussel farm will not disturb the local citizens or affect areas of recreation, as neither pipes nor mussel nets can be seen from the surface.

A video describing the deployment of the mussel farms can be seen here.

## 3.1 Description of the mussel farm

The Danish mussel farm consists of 120 submerged mussel production units. The units were deployed in spring 2023 with 60 production units in the southern part of Skive Fjord, and 60 units just south of the Island Rotholmen (Figure 10).

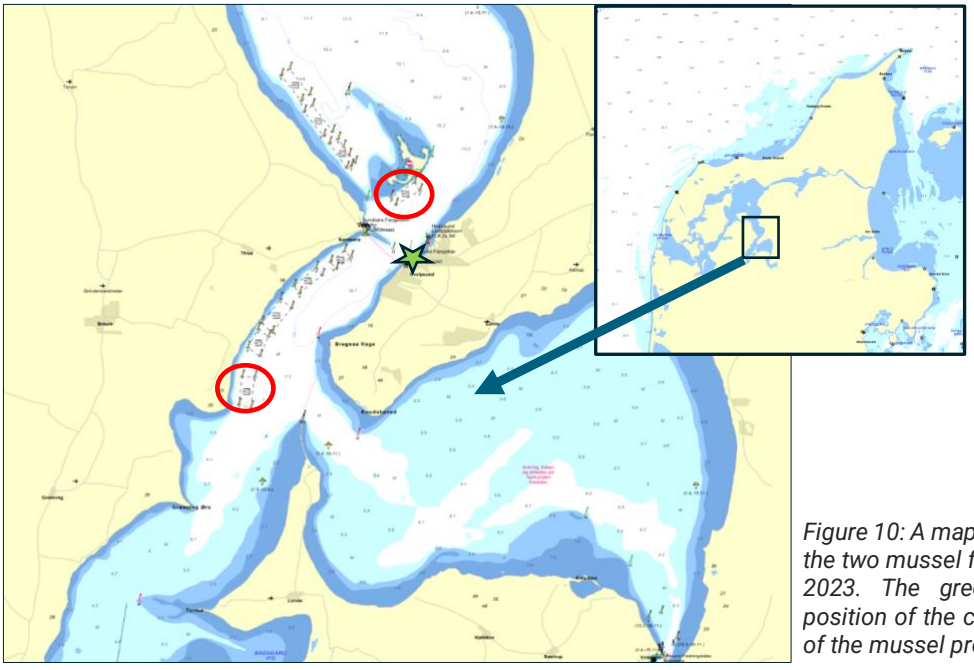

*Figure 10: A map showing the position of the two mussel farms deployed in spring 2023. The green star indicates the position of the construction site on land of the mussel production units.*

## 3.2 Production of farm units

All mussel farm units were constructed at the Harbor in Hvalpsund (Figure 10). The pipes arrived in 18 meter lengths and were welded together to a length of 120 meter. Netting was fitted by hand as it was assembled (Figure 11 and Figure 12).

*Figure 11: The mussel production units were constructed at the harbour of Hvalpsund, where the pipes were welded on land, and the net mounted when the pipes was pushed out in the water from the welding station. All processes were carried on in a container.*

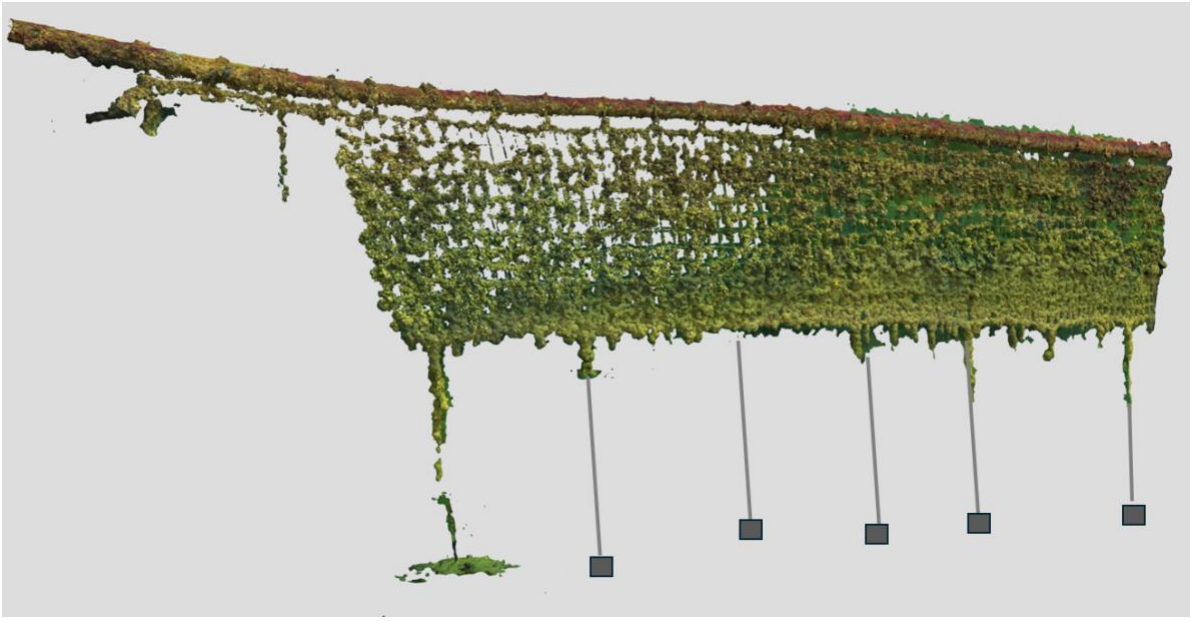

*Figure 12: A picture of the net the mussels attach to, showing the pipe that holds the net in the surface and the concrete blocks holding it to the seafloor. The pipe is about 1 meter below the surface.*

### 3.2.1 Concrete blocks

Each mussel production unit will be kept submerged by 55-60 concrete blocks of 250 kilo. In the development of the production method, different cast models and production methods were tested to bring the price down. The initial plan was to get the concrete blocks produced at a commercial concrete foundry but as all processes at these types of operations are certified, it was not possible to produce the concrete without an expensive certification on a commercial concrete foundry. The solution was to establish a facility at Wittrup Seafood where the concrete blocks were produced (Figure 13).

*Figure 13 (up and right): The concrete blocks were produced at a facility established at Wittrup Seafood to reduce the cost of the production.*

A critical part of the production of concrete blocks was to develop a robust attachment system to connect the blocks to the line attached to the net. Different types of attachment systems were tested. The first ones were cast with an iron-ring for attachment, but after testing for two months we could see that they started to wear out in the transition between concrete and the iron-ring. A new type of attachment system was made of stainless steel, which was cast in. After three months, the system was tested again, and it was found that the rope was worn where it is mounted in the stainless steel-ring. A new and stronger attachment system had to be designed. Therefore, a model was made where a 28 mm rope was cast down and protected by a piece of water hose. This solution was again tested after three months and was deemed to work and chosen as the final solution.

### 3.2.2 Deployment of the mussel farm units

On the site at Rotholm, all the mussel farm units were mounted with screw anchors at both ends. At the southern mussel farm, experiments were carried out where two farm units moored together and a screw anchor was placed at each end of the two units (Figure 14).

*Figure 14: Drone photo of the plant on site south of Rotholmen. The depth from surface to bottom is 7-8 m.*

### 3.2.3 Development of technology for mounting concrete blocks on the farm unit

The process to develop a system that could be used to attach the concrete blocks to the net and efficiently but gentle to bring the blocks down to the seabed at a depth at 7-8 meter without having to induce too much power to the net and the pipe was challenging. A free drop solution was not an option as it would be harmful to the net and pipe. Several systems were built and tested throughout almost a year before it worked. The result of the final design was a hydraulic grab system at each end of the boat (Figure 15). The hydraulic grab system catches the net underwater and lift it to the surface. When the net is up, it is possible to mount anchor blocks to the lower part of the net. Without straining the pipe, the fork can lead the net with the block down. The front end is lifted higher than the stern end, which gives the pipe an angle, that does not damage the pipe when it is loaded with concrete blocks but still not placed on the bottom.

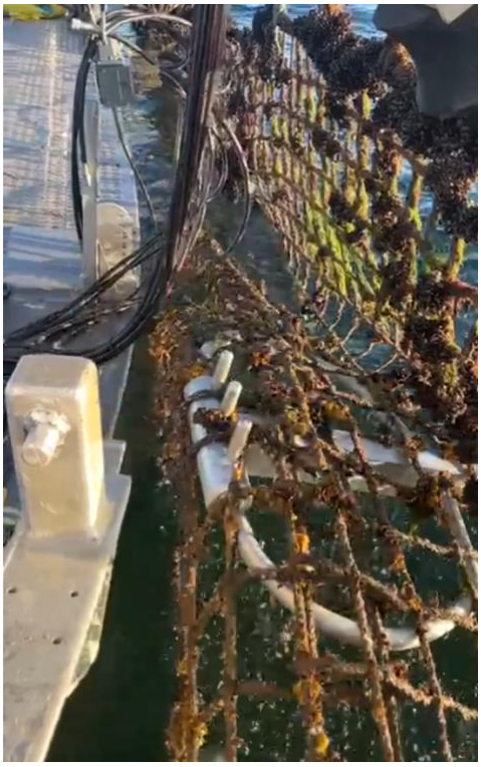

*Figure 15: With the development of a hydraulic grab system, the nets are lifted to the boat, and the concrete blocks can be mounted and afterwards gently lowered to the seabed.*

## 3.3 The mussel production

The mussel spat that settled in the spring 2024 grew well and fast (Figure 16). When harvested they were used for pet food, bottom cultures or for grow-out on longline mussel farm units. Mussels harvested in the fall were transported to Sweden for further processing for pet-food.

*Figure 16: In the Limfjord the mussels grow fast due to eutrophication and high salinity. From June to September the mussels grow to 3,5 cm.*

## 3.4 Lessons learned

We have learned from the results that mooring the mussel production units together to save money on the cost of anchorage is not a good solution at the site. At the southern mussel farm, the mussel production units were moored together two and two and was attached to the seabed by two screw-anchors. The experience with this solution caused some problems as the units could drift in a transverse direction. The large distance between the two anchors attaching the unit of two pipes caused the pipes to drift. This situation complicated operations in the surface on the system and increased the risk for loss of mussels when two systems collided, and the mussels were scraped off the systems. When submerging the system with concrete blocks the solution will result in a curved position of the system which will complicate the maintenance and harvest operation.

During the winter 2023/2024 there was ice cover on both mussel farms (Figure 17). The mussel production units were not submerged by concrete blocks, and to avoid damage, all pipes were filled with water and lowered to the bottom. In spring the pipes were lifted again, and the pipes were emptied using compressed air. The process was time-consuming and delayed the project significantly. It was estimated that the process by sinking and lifting the mussel production units were 4–5 person-hours per unit.

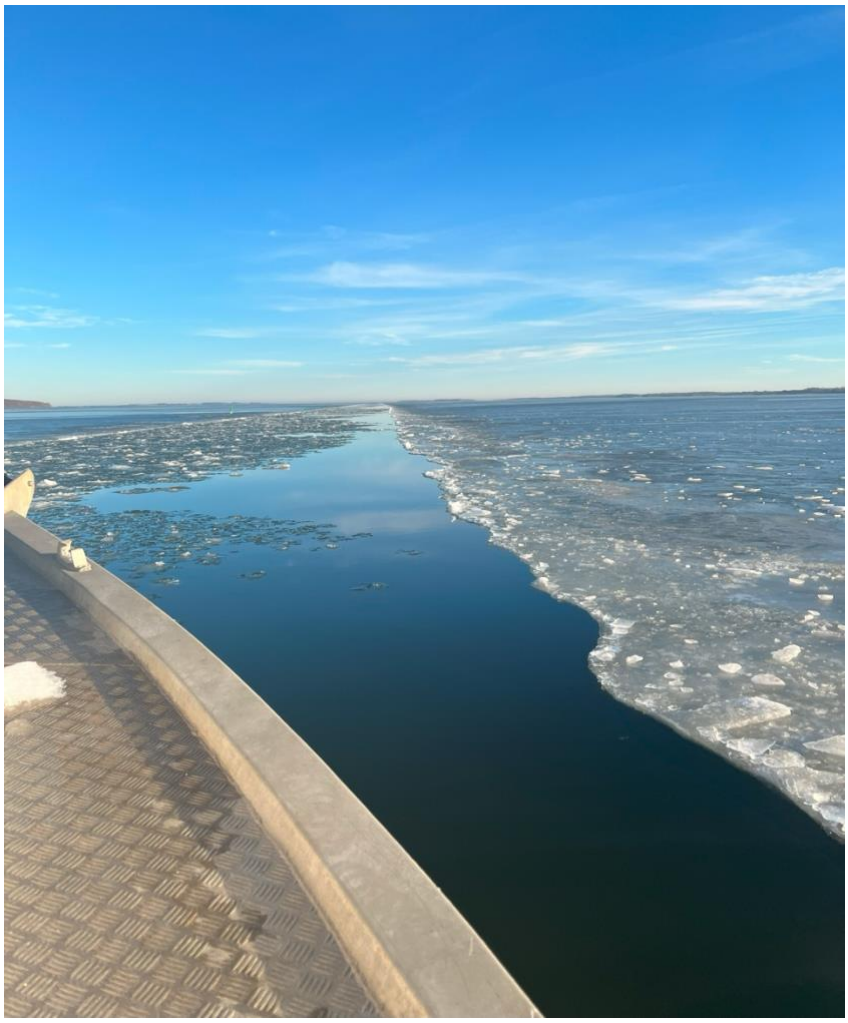

*Figure 17: During the winter 2023-24 winter ice caused problems for mussel production. Unsubmerged parts were filled with water to submerge the units and avoid destruction from the ice.*

# 4. CONCLUSIONS

The most important outlook is that each location for mussel farming differs, and the different environmental conditions must be considered when choosing farming technique. Since farming mussels in the Baltic Sea is a fairly new activity, the process of adjusting and develop the farming technique to Baltic conditions will continue.

When it comes to permits and legislation, authorities has shown interest in developing this new area where there are gaps, especially in the permits and legislation concerning the development of mussels into feed.

Continuous work on adjusting and developing all aspects of mussel farming is an important part of the Baltic MUPPETS project to be able to produce mussels and develop a product ready for the market within the timeline of the project.