Technical evaluation of submerged mussel farms in the Baltic Sea

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Baltic Blue Growth

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KURZEMES PLĀNOŠANAS REĢIONS

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About

Baltic Blue Growth is a three-year project financed by the European Regional Development Fund. The objective of the project is to remove nutrients from the Baltic Sea by farming and harvesting blue mussels. The farmed mussels will be used for the production of mussel meal, to be used in the feed industry. 18 partners from 7 countries are participating, with representatives from regional and national authorities, research institutions and private companies. The project is coordinated by Region Östergötland (Sweden) and has a total budget of 4,7 M€.

Partners

- *Region Östergötland (SE)*
- *County Administrative Board of Kalmar County (SE)*
- *East regional Aquaculture Centre VCO (SE)*
- *Kalmar municipality (SE)*
- *Kurzeme Planning Region (LV)*
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Executive summary

The present document contains two parts, both on the subject of submerged mussel farming in the Baltic Sea. Submerged farming has been presented as a solution to farm damaged caused by high waves and drift ice. As part of the Baltic Blue Growth project, two focus farms (one in Sweden and one in Latvia) were completely submerged. The first part of this document reports on the methods deployed and the outcome of the Swedish farm, the second part concerns the Latvian farm.

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Submerged mussel farm in Sweden - to avoid the drift ice in the Baltic Sea

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1 Introduction

Shelltech Offshore is a new design of mussel farm by the manufacturer Carapax. Baltic Blue Growth is the first project in which this system has been tested. The concept is a submerged net farm with 120 m*3 m Shelltech rope nets of 200 mm mesh size. Each net is anchored with 9 vertical screw anchors and 2 helix side anchors at the sides. Ø30 cm trawl floats are used as flotation. In our trial, there were approximately 400 floats per net. The idea was to over-compensate the weight of growing mussels already from the start, so that no floats would have to be added during the growth cycle due to the increasing weight of growing mussels. The whole farm should stay submerged at 3-6 m depth, no parts in surface. The establishment of the farm encountered several problems. A classic round-bottomed fishing boat was used as a work-vessel, and this was not optimal as it did not function as a stable platform. The anchor-drilling turned out to be extremely weather-dependent due to the bobbing of the workboat, and was delayed. After the farm had unintentionally been floating in the surface for 1.25 years, the team submerged it to 3-6 m depth by pulling ropes attached to the lower net through blocks that were attached to the anchor lines. This required more pull-power than expected, and when submerged, the units kept floating back up again due to problems related to the block´s back-breaks. After almost 2 years at sea, substantial damage of the farm units was documented. One of the nets had been completely ripped off, several anchor lines were torn off and tossed around the nets, lots of floats were missing and at one site it looked like if the net had been thrown over itself by the waves. It was not possible to decide if there had also been some impact from drift ice. Evaluation concluded that both the design of the farm and the vessel and methods used were sub-optimal. There were too many small parts and potential weak spots, and on top of that a lot of handling difficulties. The farm system should have been tested in a smaller scale in a more protected environment first, then gradually adjusted to more rough conditions.

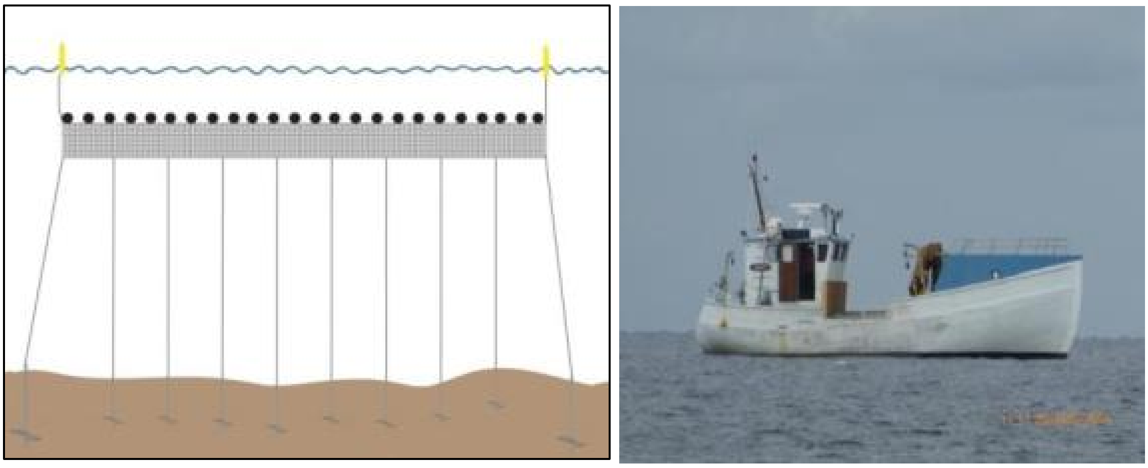

Figure 1. Left: Concept of the Shelltech Offshore farm. Rigth: The work vessel used

1.1 Original plan for the establishment

The farm was made up of 10 net units, each 120 m long. The original plan for establishment was to:

1. Set all the screw-anchors at the farm-site,
2. Tow the nets into position and
3. Submerge them by fastening a line from each vertical anchor to the lower net rope and then pull it down to 6 m depth through a block, using a line-puller on the workboat.

2 Step 1: Setting the anchors

2.1 Positioning of the boat

The work-vessel had been equipped with 4 line-pullers, one in each corner. These line-pullers were used to keep the boat in steady position at drilling. First, 4 bruce-anchors were positioned in the corners of the work space, making it possible to pull the boat into place with the line pullers. Then, the 20 helix anchors for stretching up the main line of the nets were set. Then a line of buoys, the so-called “pearl-string”, was stretched between them to mark the positions for each vertical anchor.

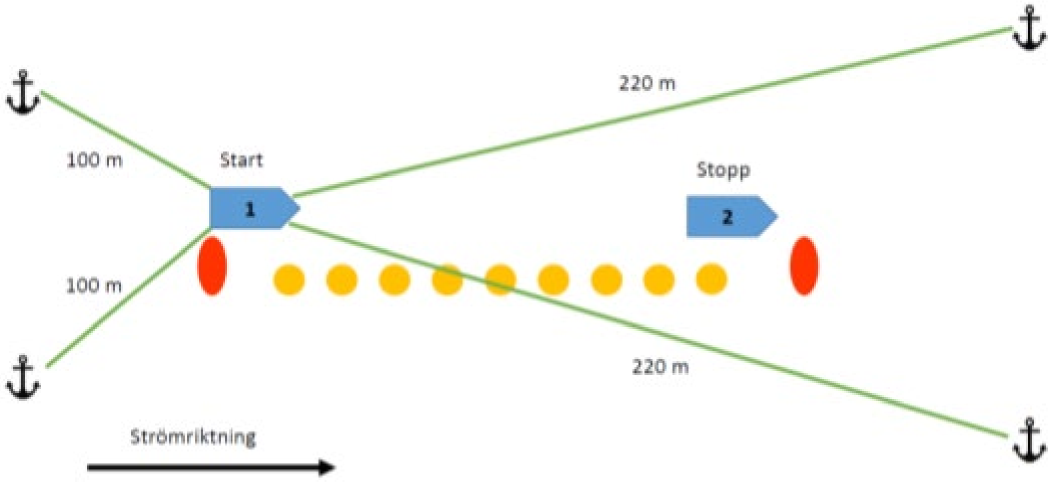

Figure 2. Positioning of the boat at anchor-drilling with help of bruce-anchors, line-pullers and the “pearl-string”.

2.2 Anchor-drilling

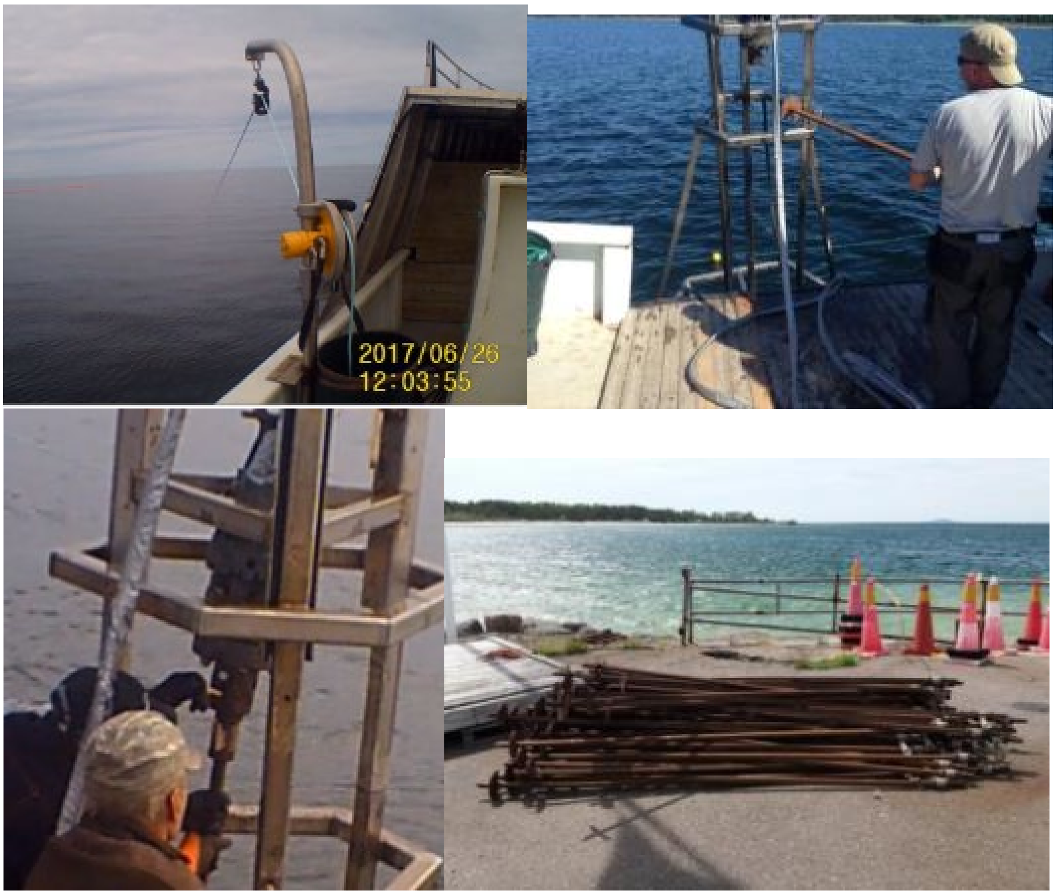

Figure 3: Upper left: Use the line-pullers to position the boat. Upper right: When positioned at a marker on the “pearl string”, load an anchor in the drilling rig. Lower left: Fasten the anchor by popping a wooden stick through the hole in the rotator. Lower left: Screw anchors on quay.

2.2.1 Original method description

1. Load the anchor in the drilling rig and secure by popping a wooden stick through the hole in the rotator and corresponding hole in the anchor (Fig 3).
2. Fasten the anchor rope to the anchor with a shackle at the hold (Fig. 4).
3. Thread the anchor rope under the side of the drilling rig.
4. Lower the drilling rig into the water and put it in position at the sea-floor (Fig 5, Right).
5. While drilling, always watch the anchor ropes-unit, the hydraulic hose to the drilling rig, and the position of the boat. It takes minimum 3 persons to hold and keep check of everything during the drilling.
6. When the anchor is down, winch up the drilling ring so that the wood-stick that secured the anchor to the rotator head breaks and releases the rig. Make sure not to squeeze and damage the hydraulic hose while lifting the rig back on deck.

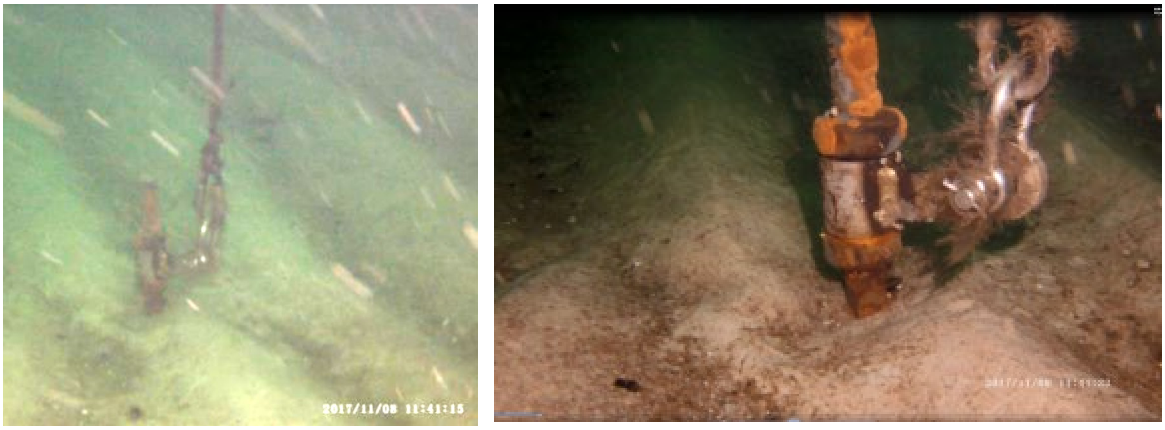

Figure 4: Left: Anchor in position at 16 m depth. Right: Close-up of the (un) spinning anchor hold

2.2.2 Problems and deviations from the plan:

All 20 side anchors plus the 90 vertical anchors were supposed to have been set already in May 2016, before launching the 10 farm units. But delivery of the anchors was delayed, due to a harbour strike in Gothenburg. In June 2016, the 10 net-units of the farm were launched out at the site on temporal anchors. This was done in order not to miss 2016 years´ settling The 20 side anchors that should be used to stretch up the main line of the nets, were then set during the summer in 2016.

It was hard to maneuverer the drilling rig from the classic round-bottomed fishing boat used as a work-vessel, due to the great momentum caused by bobbing also from moderate waves. The safety on board should not be compromised. This problem was partly solved before the next summer in 2017, by removing part of the rail, building a new wooden deck to protect the boat from damage, and apply padding to protect the hydraulic hoses (Fig 5). It was also solved by accepting the fact that no job could be done with this boat in less than perfect weather conditions. Wave height <20 cm and wind-speed below 8 m/s, nevertheless, when these weather-conditions were met, the drilling was done fairly quickly. Approx. 15 minutes to set an anchor and 20 minutes for re-positioning of the boat between anchors.

Figure 5. Left: Setting of the 20 helix side-anchors in 2016. It was hard to maneuverer the swinging drill-rig from a classic round-bottomed fishing boat. The original big plates shown in the picture were soon exchanged to smaller plates that could penetrate the sand-bottom. Right: Setting of 27 vertical anchors in 2017. This job was done with part of the rail removed, a new wooden deck, and perfect weather conditions.

Another problem was that the anchor ropes, when fastened to the hold before the drilling, started to twist from the anchor rotation at drilling. This was not expected to happen as the anchor-hold (Fig 4) was supposed to stay still at rotation. Several different angles to thread out the anchor rope from the drilling rig were tested, but the holder still got stuck, causing the anchor rope to start spinning around the anchor. The manufacturer of the equipment reported having set hundreds of anchors with this method before, so the cause was not easily explained. It was assumed that either rust, or the small momentum cased from stretching of the anchor rope caused this small but crucial friction.
It was decided to drill the anchors without ropes attached to them. Instead, the anchor ropes were put in place later with help of a diver.

In total, 47 of the planned 110 anchors were set in the project. The 20 side anchors were set in 2016 and in 2017 were complemented with 27 vertical anchors. Because of the limited project time, it was decided to “save” the 10 net units of the farm by moving them to a more protected site in a nearby sheltered bay during autumn 2016. When the work was resumed after the winter in 2017, only 3 of the originally planned 10 farm units were towed back to the intended farm site and submerged. The remaining 7 units were left staying in the sheltered bay, floating in the surface.

3 Step 2. Tow the nets into position

The farm arrived in spring 2016 from the manufacturer packed in metal cages that were unloaded on the quay (Fig 5). They were easily dragged out from the cages into the water (Fig 5, Right), and then towed behind the work-boat for 5 km to the open water farm site (Fig 6). A maximum of 6 units could be towed after the workboat at the same time.

3.1 Launching, original method description:

1. Mount the loose quick-link units to the nets either before or after towing. One in each net-end, and one at each 12 m. 11 quick-links per net.
2. At the farm site, secure the net in position with quick-links no. 2 and 10. Don't forget to remove the floats keeping up the anchor lines.
3. Then secure link 3-9.
4. Secure link 1 and 11 last and adjust the farm-unit.

Figure 7. Left: A net with floats towed after the work boat. Right: Quick-links to buckle the nets were prepared on the anchor lines. A float at each quick-link keeps the anchor line afloat while waiting for the nets to be towed in position before fastening.

The quick-links referred to in the manual are buckles (Fig 7, Right), used to quickly connect the preset anchor lines to the nets.

3.1.1 Problems and deviations from the plan:

As explained in the previous section, anchor drilling should have been finished *before* the 10 net units were launched. But the manager decided to do it in the opposite order, to not miss out on the mussel settling of 2016. Because the anchor drilling then took considerably longer time than expected, the farm nets were left floating in the surface on temporal anchors for 1.25 years.

After the summer in 2017, three complete set of anchors were set, for three of the net-units to be properly anchored offshore. So 27-28th of August the three nets were towed back to the offshore position, while the other 7 units remained in the sheltered bay for the rest of the project. Before the move, new anchor-line units (Fig. 2) were fastened by divers at all of the 33 anchors. The 7 anchor rope units (Fig 8) that remained on the 20 anchors that had been set already in 2016 had become completely twisted and needed exchange. It was discovered that also the new rope units that were set out could not be left floating in the surface for more than a few days before they had spun around each other. In order to prevent this from happening, the ropes were left under water in their original bundles, and were released up to the surface by diving just before the fastening of the nets.

The towing (12 km) and anchoring with quick-links took 12h. 5 additional hours on the day after was spent to stretch and adjust the units.

3.1.2 The anchor rope units

Figure 8: Photo of one of the anchor rope units.

Each of the anchor rope units contained the following parts (Fig. 8):

A: Anchor rope that is fastened with a shackle in the screw anchor.

B: Block, used for submerging of the farm

C: Anchor line, to be fastened with a quick link in the lower net-rope.

D: Pull-rope, used for submerging of the farm

E: Release-rope, used to open the block to let the farm float back to the surface

Fig 9: Close-up of an anchor- block (B in Fig. 8)

4 Step 3. Submerging the farm-units

The original plan was that the nets should be pulled down section by section, at each vertical anchor, by pulling the pull-line (Fig. 8D) through the block (B) using a line-puller from the workboat. Then the back-breaks at each block (Fig. 9) should prevent the farm units from floating back up to the surface again. The lower net-rope should be pulled down to 6 m depth and the farm net should then stay between 3-6 m depth for the whole growth period, before released with the release line (E), also from boat, then floating back up to the surface to harvest.

4.1.1 Submerging, methods description

1. Position the boat in the same way as for anchor-drilling.
2. Use a pull-force of 500 kg and measure the length of rope passing through the line-puller (6m) to decide when the lower farm has reached the set depth of 6m. Make sure that the line-puller is properly fastened to the workboat so that it won’t break at the attachment.
3. If problematic to pull the farm down to 6 m at once, start the lowering at one anchor, then continue at the next anchor, then go back to the first anchor, etc.
4. When ready at one anchor, fasten the anchor line and the release line at the top of the net at the next anchor. So that when the farm should be released back to the surface at harvest, the release lines for the next block will automatically reach surface with the previous farm-section.

4.1.2 Problems and deviations from the plan:

The job to submerge the 3 offshore farm-units started in 8 Sept and until 28 Sept, 3 persons worked for 33 hours with different methods. The methods tried were:

1. According to the manual. Pulling with help of a hydralic line-puller.
2. Pulling with divers using 500 kg float-bags
3. Pulling with divers and 750 kg float-bags

Theoretically, the pull force needed to submerge the farm should be approximately 500 kg per anchor point. (12 kg flotation power per float* 400 floats per net)/9 vertical anchors per net. It never became clear to the project manager how much power the line-puller had, as statements from different members of the work-team varied. Anyway, we needed more power to sink the units than what the line-puller could provide. The net was very stretchable, and probably because all flotation strived upwards, the actual power needed at the first sinking-points were not the theoretical 500 kg but more. The strong current at the site (Fig 11) and the waves added more force to overcome when pulling.

Trial 1. With the hydralic power from the line-puller, the first net (net 2) could only be pulled down to 1.5 m depth.

Next discovery was that the back-breaks on the blocks on net 2 weren't strong enough to keep the submerged net down. Upon return the next day, the previously sunken net had floated up to the surface again. Wave action probably added to this problem.

Trial 2. With the pull-power from 2*250 kg lift-sacs, the result was the same. It was not possible to sink the net (net 2) to more than 1,5 m depth with 500 kg pull power.

Trial 3. The two other nets, net 1 and net 3, were submerged by using divers and 3*250 kg lift-sacs providing 750 kg pull-power. The divers succeeded in submerging net 3 to the intended depth at 6-3 m.

But when finishing net 1, a shack to one of the blocks suddenly broke (the sprint fell out). The lift sacs and pulling line then recoiled at a high speed. Luckily the divers did not get hit, but after that incident it was decided to abort mission. So of the 3 nets, only net 3 was fully submerged. Net 2 was left at 1.5 m depth, and net 1 was left nearly fully submerged to 6-3 m depth, but with broken anchor-unit left in the end, and some floats in the surface above it. To prevent the nets from floating up again, at each 33 anchors an extra knot was made by divers to keep the nets down (Fig 10).

Figure 10. Block by-passed by a knot from the anchor rope (Fig. 8A) and anchor line (C) to relieve the slithering breaks.

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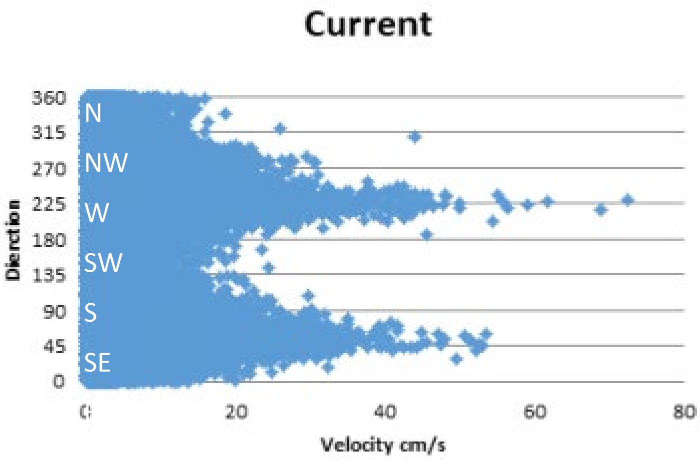

Figure 11: Current velocity and direction measured by an oceanographic instrument at 16 m depth below the farm-site in Byxelkrok, from 2017-11-08 to 2018-08-29. The instrument showed that at some points the current velocities were very high considering incubation depth, up to 1.4 knots. The dominating current direction was NE to SW and opposite, same direction in which the nets were anchored. However, it seemed that the current quite often could come from other directions as well. This caused a lot of extra strain to the construction.

Yet another problem was that because of the lack of direct connection between the anchor line and the line of floats, the mesh in each net was stretched upwards in bows between the anchors. This was partly foreseen, but not that it would stretch so much (approximately 30%). From net 2, that was only submerged to 1.5 m depth, floats could still be seen in the surface in between the anchors (Fig 12).

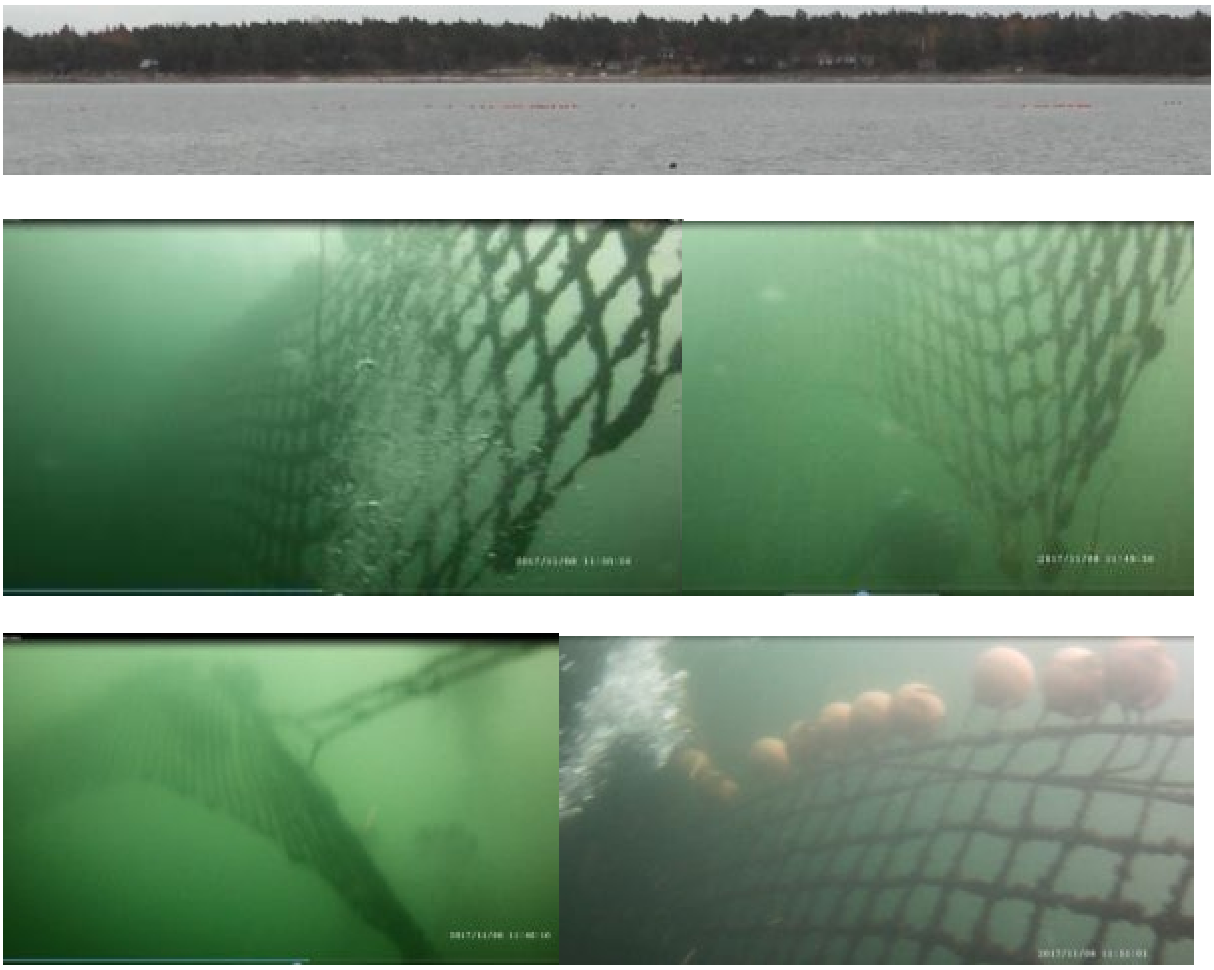

Figure 12: Pictures from the farm site at inspection 2017-11-08. Top: Net 1 and 3 were not visible from the surface, with the exception of 3-5 floats at the site of the broken shack of net 1. Net 2 was still visible as floats coming up between the anchors, due to the stretching of the net. Middle: Note the considerable stretch of the net, partly because of the lack of a direct connection between the attachment of the anchor line and the upper frame of the net. Bottom: Net 3 was fully submerged from 3-6 m depth.

When the farm, now consisting of 3 more or less submerged units was left for the winter in Nov 2017, there was some mussel growth on the nets but not much. The conditions for mussel growth had presumably not been so good in the sheltered bay where the farm had stayed for the last year. Also, a lot of mussels were probably also lost at the towing.

5 Planned harvest of the farm-units

The farm was not harvested within the project because of the lack of mussels. But the original plan was to release it back to the surface after two years and then use a mechanical UW-harvester (Fig. 13). Because those harvesters normally run on a PP-pipe, and this model had trawl floats instead, there would have been a need to do adjustments to the harvester. This part of the project could not be started due to all the delays. But had the UW harvester not worked because of the trawl floats, plan B was to use a catamaran work platform instead (Fig. 14).

Figure 13. Mechanical UW-harvester.

Figure 14. “Plan B” harvester. This method works for net farms that have floats and not PP-pipes for flotation.

6 Results

The general status of the substrate nets, anchor ropes and anchor lines were fine at inspection in 2017-11-08 (Fig 12). We had, however, lost quite a few floats, due to tear from the hard plastic edge of the holes of the floats to the ropes. This fastening was not designed to stand a lot of wave-action as the nets were supposed to be submerged for most of their life-time. But as the units had been exposed to waves constantly during the first 1.5 year of the project, this had led to tearing of the float-ropes.

After the winter 2017-2018, a new inspection was made in 2018-04-20. Now the status of the nets was surprisingly bad. Net no. 1 was not immediately found and therefore not inspected by the divers (it was found at a later dive but not documented by the project manager).

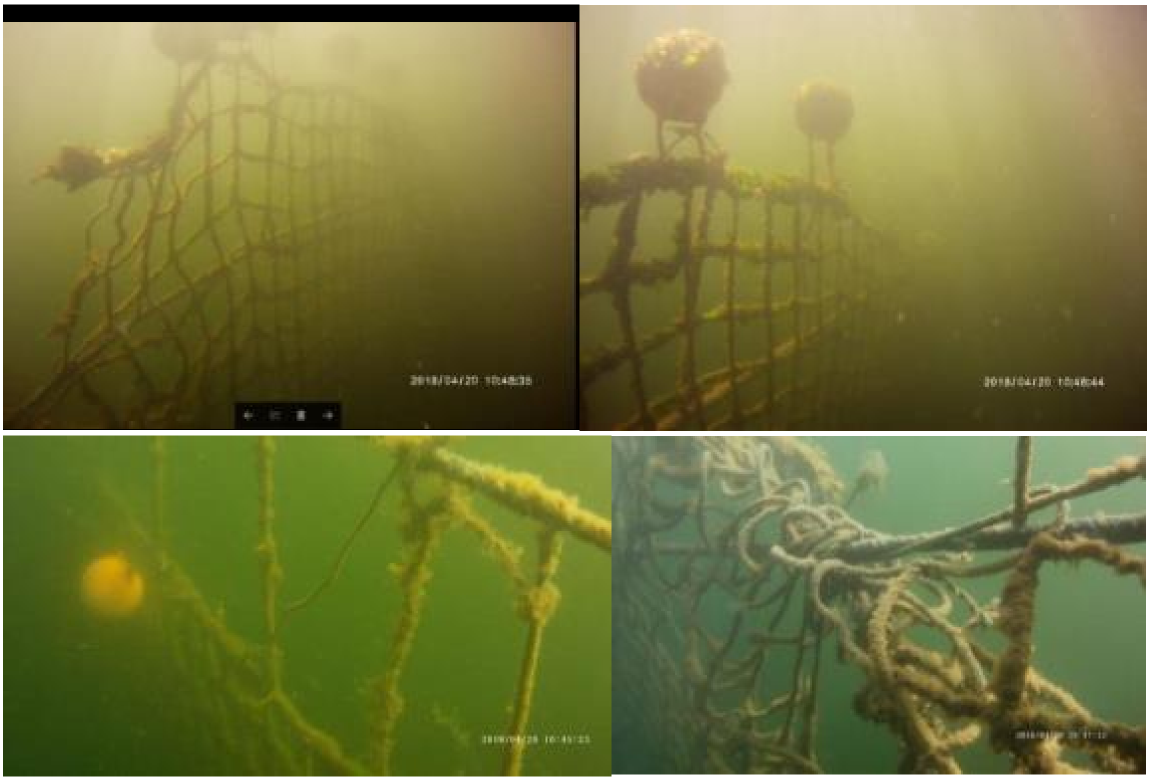

Figure 15: Net 2 after the first winter off-shore.

Net 2, which had been partly in the surface before winter due to the stretching of the nets, could no longer be seen from the surface. It had very few floats left. Some of the floats had cracked and were water-filled (Fig 15 lower left). This had likely happened because they were sitting so close so they had bounced against each other in the waves. The net was ripped off in one of the ends (Fig. 15, upper left). At one site the net was twisted over itself, as if thrown by the waves (Fig. 15, lower right).

Figure 16: Net 3

Net 3, that had been submerged down to the intended depth of 3-6 m was still whole, but had lost the majority of the floats. In addition, at two sites it looked like the anchor ropes had been torn off and wind up around the net (Fig 16 upper right and lower left). Yet another anchor line was hanging loose, floated up towards the surface (lower right).

Figure 17: There were some mussels growing, especially on the lower parts of the nets. But not enough to harvest.

7 Discussion and conclusions

The project encountered several problems, both related to the ability to follow the manual for set-up of the farm, the functionality of the workboat, the construction of the farm itself and the underestimated difficulties with rough weather and conditions at the site.

The setting of drill-anchors was difficult to accomplish with the chosen work-vessel (Fig. 5). When the drilling rig was lifted over the rail it started to swing with the boat heeling, constitute danger to the workers and equipment. This problem was solved by removing part of the rail. However, the round bottom of the boat still made the task of anchor-drilling difficult to accomplish in anything but perfect weather. It would have been better to use a flat, low barge-like platform or stable catamaran vessel.

Much of the roping, especially the ropes making up the anchor units, appeared to be too weak for offshore conditions. On the other hand, similar ropes (PP-lines and polysteel) had proven useful before for mussel farming at the Swedish west-coast. The problems with nets floating back up again after they were submerged, twisted lines, broken shack and torn anchor lines were likely related to the many small parts and 3 different qualities of ropes that made up the anchor rope unit. After the winter in 2017-2018, it was concluded that at least 1 anchor-line and 2 anchor ropes had broken on line 3, which indicate some problems with the roping. However, the roping was also not installed in the way it should, as the divers had by-passed the blocks with an extra knot to keep the net from floating back up to the surface again. The weakest link of the anchor-units was the blocks, and especially the back-breaks on the blocks. They couldn’t match against the floating-power of the units, even when installed correctly. The scary incident of the breaking shack also proved that every additional small detail added potential weakness to the system. Metal parts were not to be recommended at all when it comes to mussel farming, according to one of the experts.

The massive loss of floats due to wearing on the fastening ropes had likely been less severe if the farm had been submerged from start. But anyway, the float attachments should have been designed differently without sharp edges. It was the general opinion from the work-team struggling to submerge the farm that the nets had too much flotation-power. It was designed to compensate a weight of 19 ton mussels per net, but that kind of mussel biomass will never be reached in the Baltic proper anyway. It would have been enough to calculate 5 ton mussel per net. Also, the floats should not have been put immediately next to each other. Several floats cracked and started to leak in water due to collisions with each other. In order to escape the worst wave impact, the farm should have been submerged to at least 5 m sub-surface.

The ripping of net no. 2 (Fig. 15) could hypothetically have been caused by large waves, or by drift ice passing by the farm-site, or collision with a boat. The finding was surprising, as these nets are made of very strong material. The problem was that the net had been partly in the surface during the winter, due to the stretching of the net. A net will always be stretchy, but there should have been a direct connection between the lower and the upper net frame at the anchor points to prevent it from stretching out so much between the anchors towards the surface.

The overall impression from the inspection after winter in April 2018 was that the project-team had underestimated nature’s forces. The cumulative effects of the waves, time and the strong current had not been taken into account when calculating the needed strength of materials. Upon evaluation by external experts, it was stated that all the different steps in the manual, the materials and the dimension of different components, like for example the blocks, should have been tested in smaller scale and a more calm environment, before the project was started.

KURZEMES PLĀNOŠANAS REĢIONS

Mussel farming offshore -Technical evaluation of mussel farm located in Latvia and recommendation on best practice

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1 Introduction

Evaluation of the first Latvian mussel farm was done within the Interreg Baltic Sea Region Programme 2014-2020 project R031 Baltic Blue Growth – Initiation of full scale mussel farming in the Baltic Sea" (hereinafter - Project).

Aim of the Evaluation is to analyse the technological aspects of the mussel farm, situated offshore in Kurzeme Coast of the Baltic Sea opposite to Pavilosta town, established in spring 2017. Farm is situated in extreme open sea conditions therefore it is crucial to evaluate chosen technology in order to ensure durability of the farm. The objective of the document is also to propose secured and optimized submerged longline operations for a viable mussel production.

Evaluation report was produced on site by the external expert John C. Bonardelli, PhD (Shellfish Solutions) and with involvement of the Project partners experts (Zaiga Ozolina, Ligita Kokaine, Juris Aigars, Ingrida Purina) constituting the planning team and working on the Evaluation report from 13-17 August, 2018 in Pavilosta town, Latvia.

Latvian mussel farm evaluation report includes evaluation of the farm activities to date, as well set of proposals and recommendations - safety issues related to offshore environments for shellfish culture; proposal for growing mussels on submerged longlines, and implementation of mussel production.

2 Evaluation of the farm activities to date

2.1 Farm location in open water conditions

Kurzeme coastal zone of the Baltic Sea belongs to high energy shores where wind and waves are the major hydrodynamic forces influencing the coastal habitats. NW and SW wind dominate in the Kurzeme region. The windiest months are November–January in the northern Baltic Sea. Sea ice formation occurs in particularly strong winters near the coastline; however, the open sea is usually free of ice.

It has been calculated the wave closure depth, the average wave height and 1% highest waves along the Kurzeme coastline. Large values of the average closure depth are found along the western coast of the Kurzeme Peninsula (about 5.4 m). According to this the highest hydrodynamic force falls on the area between Užava and Ovīši, decreasing towards the southern part of the Kurzeme coastline. Measured orbital wave velocity at bottom squared has higher impact at 2-5m depth, but it is decreasing by 50% at 10m depth and diminishing further with the depth (Seņņikovs et al, 2007). Both conditions are crucial when planning the mussel farms.

Dominant coastal northward current and wave action ensures the sand flow along the coastline and till the 5m depth covering the underlying hard substrates. Hard substrates dominate only from 5-7m depth till ~40m isobath allowing the growth of Mytilidae molluscs.

Mussel farm is located at ~20m depth, approx. 7.3km from Pavilosta port, where best results were obtained in pilot studies. The orientation of the farm is shown on the Fig.1. Farm was placed and submerged around 5-7 metres deep, with the collector ropes 2,5 m.

2.2 Projected original longline design plan for demo farm

The original farm set up consisted of 5 parallel single longlines, built for scientific demonstration purpose in summer 2017, with no commercial aims (no harvest planned, etc.).

Pre-installation plan of the longline system is shown in Fig.1:

- The **anchor distance** for each longline was 60-70 m apart, using deadweight concrete anchors with a weight of 2,6 tons. The rectangular shape of each concrete anchor was 1x1x0,45 m, and a metal loop cemented on the anchor was available to attach the anchor rope.
- To be noted that the **anchor weight** in water decreased 40% to 1,3 tons under water.
- The **anchor ropes** consisted of 30mm poly ropes, and the mainline used 10 mm rope for the main horizontal line used to attach the 8 mm sisal rope used as mussel collector.
- The **steel corner float** was 270 litres, using shackles and chain, and the float has a steel ring and metal rod through the middle with rings extended at each extremity to attach the float with rope to the longline.
- There were additional 100 litre small floats to lift the anchor line at each extremity.
- There was approximately 50 m distance between corner floats to keep collectors at 5m depth.
- The method used during the limited time of installation was to sink the corner float using a poly-system and inflatable bag or float.

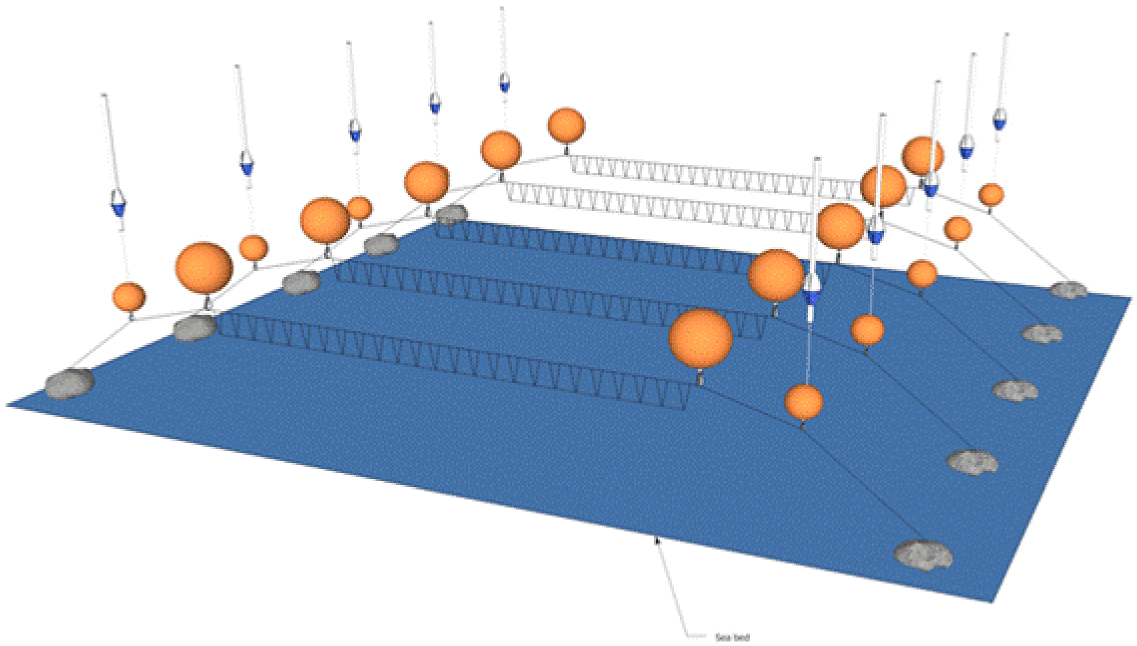


Figure 1 Overall design of the Latvian demonstration farm

When the 2017 season began for the preparation of the material, there were delays in equipment, and the environmental conditions were not favourable to installing the lines as predicted. A larger boat would have been practical but this was also not available at a cost that could be acceptable. Diving expertise with submersible floats were used to install anchors and lines at 5 m from surface.

2.3 Infrastructure design, installation and line tension for demo farm, chronology to date

The submerged mussel farm was successfully installed in May 2017 with longlines and collector ropes at 5m depth. It was visited two times in summer 2017 to estimate technical conditions of farm construction elements. In August 2017 the successful recruitment and growth of juvenile mussels was observed on the collector ropes. Harsh autumn weather prevented the inspection of farm in autumn. The first damage signs on farm site were reported on December 2017. The farm was visited in January 2018 to briefly assess technical condition of construction. The significant damage of submerged longlines and collector ropes was observed after autumn-winter storms.

In May-June 2018 the improved construction of submerged longlines was installed at 10m depth from water surface to avoid further damage. It is believed that 5m depth was not sufficient for the southern Baltic Sea coast.

When the first visit was made, the farm orientation was no longer clear, and the remaining longlines were very difficult to locate, with few mussels available to sample. It appears that the large navigation Buoy Marking was also a beacon for fishermen to fish by. This greater fishing activity around the site may have contributed to the damage incurred on the longlines.

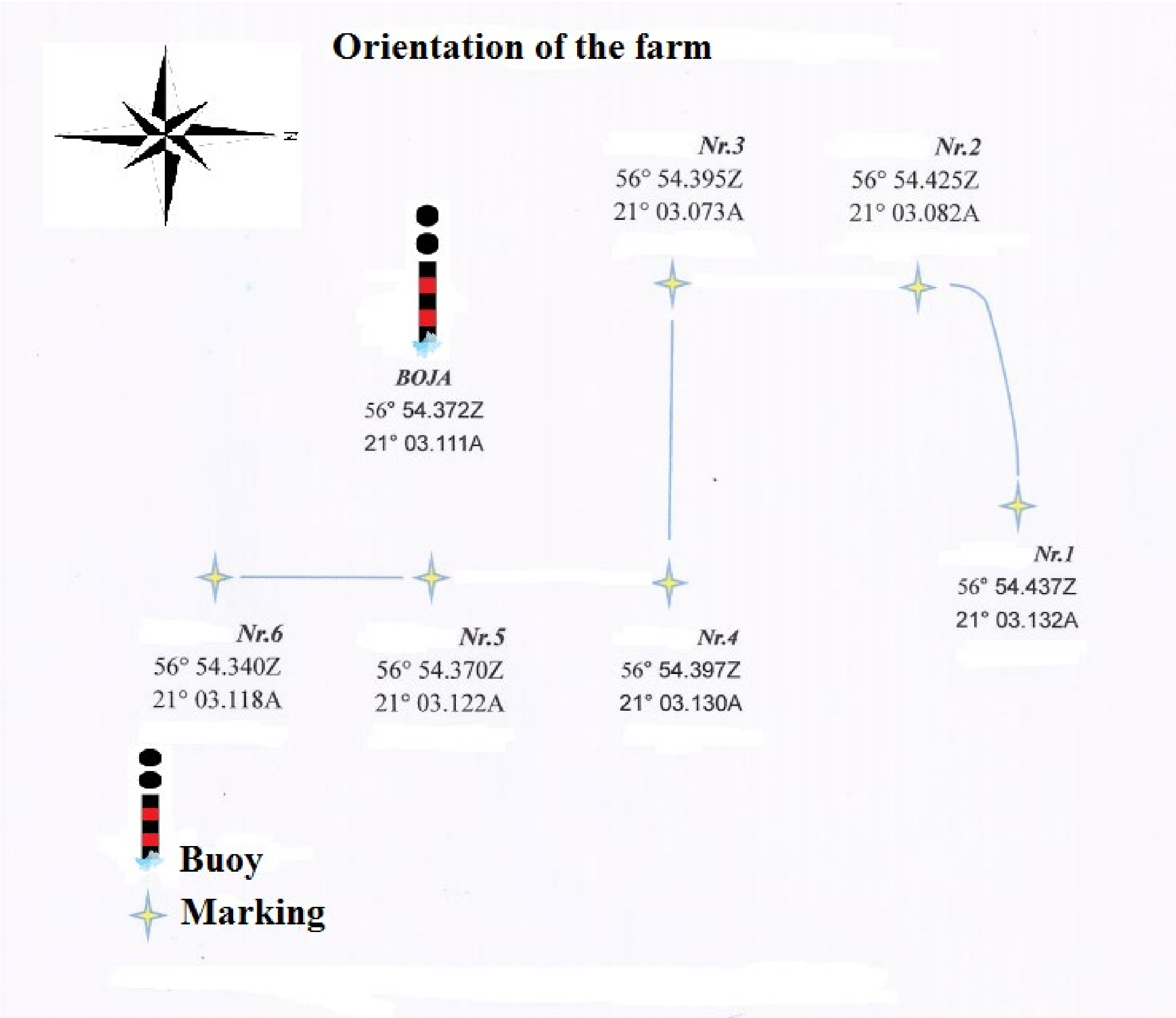


Figure 2 Orientation of the mussel farm in 2018

The lack of tension in submerged longlines is often the beginning of problems in offshore situations. Strong winter waves tend to lift the floats vertically which can cause the anchors to slip when the anchor mass is not sufficient. In addition, it is possible that fishermen approaching the poorly marked site have their gear tangled in the lines which could displace the longlines. It is often the case that a combination of events are initiated when the longline design is not optimized for the location.

2.4 Evaluation & discussion on the 2017 demonstration farm experience

OBSERVATIONS AND CHALLENGES:

Success in offshore shellfish culture is based on adapting the best techniques available for a particular environment. The Baltic Sea conditions are some of the most challenging in the world due to high energy short waves, extreme and constant wind conditions and winter ice. The best chance for building a sustainable industry in this new setting is through careful observation and documentation of mistakes made in the initial phase. This is the prerequisite for developing local solutions and local knowledge. There is NO failure here, unless it is not documented. There is only learning and building on what others have experienced. Then it is possible to adapt and grow.

To be noted that the value of this document will likely have greater impact with those who have and will experienced the difficulties during the BBG project: these are the stakeholders who may benefit most in the value of this technical document, and how to apply the solutions herein.

It takes years to have a complete understanding of all the technical and practical characteristics that make submerged longline culture sustainable in a certain region. There is no magic solution. However, there are certain common practices that will reduce risk and ensure a greater chance of success. Successful operations are based on the right selection of materials and techniques. The purpose of this section is to highlight factors that impact on reducing risk along the Kurzeme coast. Section A will present observations on the Initial longline materials and design. Section B will highlight what is important for future longline materials and design.

A- Initial longline materials and design

1) **Initial planning**: Once on the site to install the longlines in 2017, the team realised that there was little possibility to install the farm exactly as planned when the original design was made. In fact, when it was time to install the farm, there were delays in timing and some difficulty in accessing the proper boats to transport the anchors to the site. The lines were installed within the designated area, however due to weather conditions, waves, winds and currents; the installation process became very challenging and required expert help.
2) **Initial installation plan:** The method used and available at that time was to sink the corner float using a dive team with a pulley-system and inflatable bag or float – this was ok for some lines, but it is time consuming with more than 2-3 lines. Most importantly, it is not feasible or safe when you are planning a commercial production.
3) **Anchors mass:** Anchors (2.6 tons) used in the established 2017 farm were not heavy enough for offshore production of mussels in the Baltic due to the loss of mass due to buoyancy and due to the excessively large steel corner floats.
4) **Rope selection**: When different rope materials are used in a short-term research project, the consequences of poor quality can be less important. However as soon as ropes, floats and small weights are used at sea for extended periods and over winter, the material choice often results in different rope behaviours (abrasion, stretching, chaffing etc.) in water when under tension, because each rope material is chemically and physical different in composition. The unfortunate outcome is variable abrasion, which causes breakage. Rope attached to anchors and floats will each have a different response in open ocean conditions.
5) **Damage to longlines**: There are several possible reasons why the experimental longlines were damaged or shifted after installation:

- ✓ The corner floats of 270 litres were too big for the design of the longline and for the existing anchors – big waves and high winds have a greater impact on vertical displacement of large floats and often cause the snapping or 'yo-yo' effect. This vertical snapping of the float will cause excessive abrasion of the rope and metal fatigue on any steel components.
- ✓ The type of ropes and size were not designed for this type of usage in rough seas. That explains why many of ropes were broken in strange places.
- ✓ Because the longline geometry was more rectangular, the currents had a greater effect on moving a line in all directions. The floats had a greater impact on snapping the line in vertical motion and could not maintain horizontal tension. Once the tension is lost the currents have a greater impact on shifting material or being caught in fishing gear.

- ✓ The use of metal shackles and rings are not recommended for long term use such as in mussel production – they are generally used in fisheries gear or research projects, because they are regularly moved and checked. Metal components will rust. For example, the metal rings in the concrete blocks will rust within several years whereas a rope loop will last for a decade or more under tension.
- ✓ There was limited to no access to proper shellfish type workboats when inspection was necessary. The lack of a proper size workboat to lift the lines has an impact on safety at sea and safety of longlines.

B- Future longline materials and design

1) **Technical considerations**: Generally speaking, parallel single lines are not considered very economical in the open sea conditions as it can cost more to use two anchors per one line, and it is more time consuming to position individual lines, as opposed to a series of lines. This is more challenging because of the wind and currents. From the technical point of view, it is best to install 2 to 5 lines in series with heavier anchors in between that connects 2 lines together. This makes it easier to retrieve lines after the winter period, to maintain and to monitor the longlines on a regular basis with a sounder (sonar) at the end of each work day.
2) **Minimum length of submerged longlines**: When longlines are floating at the surface, the longline can be shorter for experimental purposes, such as 60 m long, as was planned for the original 2017 design. However, when the depth of water is 20 m or more, and the line is submerged more that 3m, it is necessary that the mainline of the submerged longline be at least 120m long and have a special geometry, because of the need to lift the longline to the surface from its submerged position. Furthermore, even a surface line needs a specialized geometry to avoid excessive vertical and horizontal movement that can destroy mussels that are growing on the ropes.
3) **Optimal length for submerged longlines**: it is not economical to have a short longline for growing mussels. One should try to maximize the longline length. However, it is also very risky to have a long longline because it is too difficult to keep it under tension. The best compromise after installing over 1500 lines in open ocean conditions, is a longline that is maximum 200 m between anchors, as this is the most technically practical and cost effective: with regard to the tension, the production efficiency and the cost of anchors and floats.
4) **Distance between longlines**: One must also consider the depth of the water and the depth of the submerged lines from the surface when determining the distance between longlines that are parallel to each other. For a submerged longline at 10m depth from the surface in 20m of water, it is recommended to have at least 30m between lines. The distance between the lines in the plan was 20 m – which is not enough for open sea conditions. The best strategy to adopt when planning the distance between longlines at the start of a shellfish production in open water is to start with 1,5 times the depth of water (if water is 20m depth, then distance between longlines should be 1.5 x 20m = 30m apart) – thus avoiding a situation in windy conditions where the boat carries the line that was lifted to the surface over the other line that is still submerged, e.g. if the current is in one direction and the wind is pushing the boat in the opposite direction over the submerged line.

5) **Compensation floats:** If you have 150 m of submerged longline in open ocean conditions, it is recommended to install intermediate compensation floats with weights – to keep the main line horizontal at the selected depth and geometry. This is discussed further.

6) **Longline geometry**: The geometry of the longline from anchor to anchor is the most important technical consideration in offshore shellfish culture. Most production operations around the world tend to fail when this is not respected or designed right from the start. Unfortunately, there is a definite trade-off when moving offshore: to obtain the best mix between longline tension and enough flexibility in open ocean conditions requires heavier anchors and ropes, and much larger floats, which all require larger boats during installation and operation. The downside to obtaining a sustainable longline system is that it's not possible to adjust the line tension with small boats, or even lift the lines to the surface with boats that are not equipped properly. Going offshore is no longer an artisanal production!

7) **Anchor system**: Anchors have to be preferably selected for a mass of 5 tons (or 2 anchors, each 2,5 tons, 3 meters distance each from other). One of the more common problems with sandy rocky ground is that anchor tends to slip over time, thus reducing the longline tension. If the single anchor cannot be used due to transport issues at installation, another option is placing 2 anchors in a series to minimize the slipping over time. It is also easier to transport and install 2.5 tons anchors, as opposed to 5 tons.

8) **Anchor design:** Remember that the concrete anchor loses 40% of its mass due to buoyancy in water. This is important when the longline is full of mussels (drag in the current). Most important is when the boat is lifting the line to the surface, because the buoyancy of the boat in windy conditions will cause the anchors to lift and slip on the bottom if the anchors are not stable (heavy) enough. Concrete has to have special chemical additive added during mixing so that it resists the saltwater.

9) **Float selection**: All longline floats should be capable of being handled by humans manually, therefore it is better to use plastic floats than metal. Plastic is light, does not rust, and one can select specially pressurized floats for submerged longline culture. It is not wise to use large compensation floats in submerged longline culture because it is more difficult to maintain the line at required depth. Smaller floats are easier to add and remove.

10) **Longline ropes**: It is better to use 30 – 35 mm 'Polysteel'-type rope or NZ mussel line, because these rope products are designed to be more durable and resistant to abrasion. Similar materials will be more resistant as anchor lines, loop rope or for attaching floats. These ropes can be used as a loop in the concrete instead of using metal bars, because you can save the rope on the anchor even when cut, but you have no attachment point when metal rusts away.

11) **Longline Inspection**: On the demonstration farm it was not always possible to go out to sea due to weather conditions and due to other obstacles, which often compromised the maintenance of the lines. It is important to maintain regular visual and underwater evaluation of the condition of line and mussels, especially in the start-up phase.

12) **Longline installation period**: The timing for installing the longlines is critical. The anchors, floats and lines should be installed in summer when there are more calm days and in order to be prepared for next recruitment period.

ADVANTAGES for producing mussels near Pavilosta

- ✓ Access to good port infrastructure to protect boats and good docking facilities with available space for moving material.
- ✓ Proximity of the site in Pavilosta to the port.
- ✓ Access to electricity, freshwater and facilities (fuel for boats, restaurant, toilets, showers, roads) to allow for scaling-up of production.
- ✓ Baltic mussel culture growing community and support system (knowledge, R&D, exchange, government involvement early on).

3 Safety issues related to offshore environments for shellfish culture

Experience over several decades has shown that successful offshore shellfish operations tend to operate with an inherent set of rules based on a philosophy that, when applied, will positively impact safety at sea, production efficiency and risk management.

The respect of these rules ensures a better path toward sustainable production under a safe working environment.

Rule No.1: <u>if you can't lift it, you cannot use it</u>, because it's unsafe in shellfish applications when using 12 – 20 m boats in open waters.

- This applies to lifting submerged longlines that are properly designed with high tension, or to moving and installing big anchors. In both cases you need to plan the logistics for installation, and the logistics for operating the lines on a day to day basis with the right size boat.

Rule No.2: <u>if a 12-year-old can work on the boat at sea, it is safe for everyone</u>. The boat needs to be designed with a crane so that a 12-year-old can handle the equipment (floats, weights, lines) on the boat at all times, otherwise it is totally unsafe in open water conditions.

- This applies to moving, lifting and handling everyday mussel equipment (floats, weights, ropes, and mussel boxes) on the boat at sea. Everyone's body is precious, and it is smarter to install a crane on the boat that can easily move and handle all material on the boat, instead of relying on muscle power. The point is to avoid any potential accidents on the boat. To do so will require a production strategy and investment structure that incorporates mechanized equipment at sea for the offshore operations.

Rule No.3: <u>most anything that can go wrong – and it will</u>. It is just a matter of when. It's is important to define all the production risks and evaluate what to do when it happens, which is a part of the risk management planning.

- There are risks at all levels: biological (predators on mussels, contaminated waters, slow growth, fall-off), technical (hydraulic failure at sea, longline breakage, storm damage, loss of floats), and logistic (inability to check lines at sea, delays in installing anchors or collectors, sick employees). Proper production management is evaluating all potential risks and being prepared for what to do and how.

Rule No.4: <u>avoid SCUBA diving to monitor mussel production</u> as much as possible.

- There are risks also with sending divers to inspect lines on a regular basis: It may be necessary in the beginning of production to visualize what is happening on the lines and anchors. However, the longline design and materials are designed to last. With the use of sonar, there is little need to dive. Diving is not necessary or efficient at larger scales in production. Taking pictures to keep proper inventory of production equipment is a valuable procedure to implement early on.

4 Proposal for growing mussels on submerged longlines

4.1 Material selection for longline infrastructure based on bottom substrate and environmental conditions

The effect of high waves on submerged longlines is more stressful on the materials and especially near the surface, because the waves continually lift and lower the submerged floats in rapid succession, which can cause a snapping effect on the floats, like that of a yo-yo when it hits the bottom of the cycle then jumps back up to the vertical. Thus, the ropes attached to all the floats need to be tight, and strong enough to withstand this vertical snapping effect over time.

The Submerged Longline infrastructure design is based on 6 essential components:

(A) **Anchors:** to keep the longline stable from movement (2 x 2.5 tons corner blocks)

(B) **Corner Buoys:** to maintain vertical tension of the longline (130 L x 2)

(C) **Intermediate Floats & Counter-weights**: to keep mussels from sinking to the bottom. The floats are tied to a counter-weight to compensates for increases in mussel mass over time

(D) **Anchor Line Rope:** to connect the Anchors to the mainline system and corner buoys.

(E) **Unusable Section** of mainline rope: between corner floats and usable mainline

(F) **Mainline Rope**: to support the mussel collector and grow-out ropes

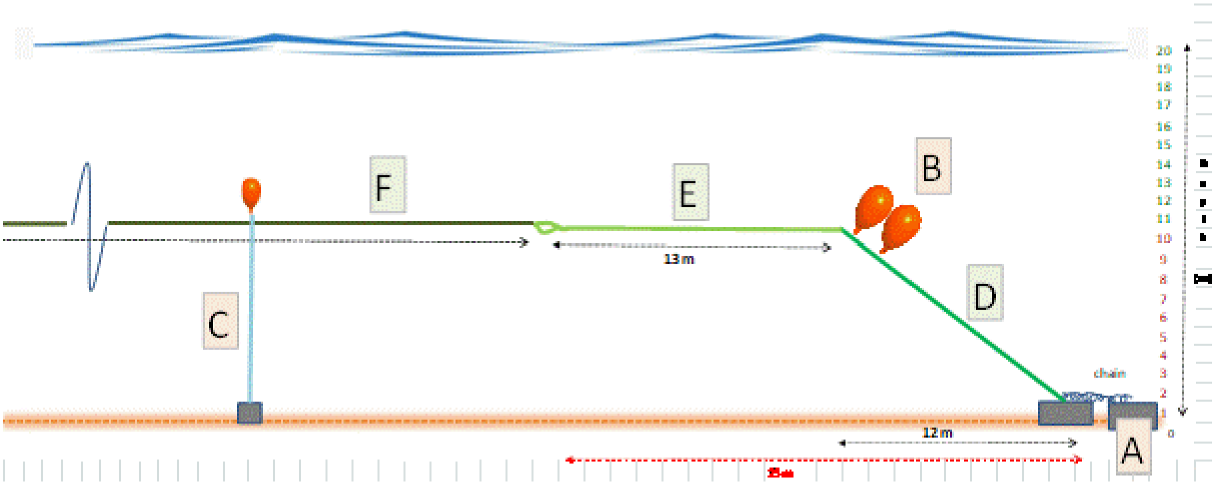


Figure 3 Schematic representation of submerged longline with primary components (A-F)

NOTE: All materials selected for the longline must be designed for periods when the boat is attached to the mainline, so that the anchors will not move and the ropes will not break in strong wind.

Reference Manual to consider:

In order to avoid a lengthy repeat of material and methods, please refer to the technical manual for complete overview of relevant equipment options for offshore production in the Baltic. **Technical and practical requirements for Baltic mussel culture**. John Bonardelli. Reports of Aquabest project 4/2013 ISBN 978-952-303-049-7.

4.2 Assumptions and description of longline material for the Baltic Sea

The Baltic Sea on the Latvian coast represents one of the most extreme offshore environments for shellfish culture. These conditions of short high waves require careful selection of internationally recognized shellfish production materials that can withstand high stress when the boats are working at sea and when boats are lifting submerged longlines to the surface. Because of this everything about the longline infrastructure needs to be oversized for these extreme conditions.

Due to high wind and possible strong currents instead of the 200 meters max distance between anchors it is recommended to shorten the distance between anchors to 180 m to maintain greater tension until more practical field information is available.

The experience from the demonstration farm in Pavilosta shows that a submerged longline survived better at 10 meters depth than 5 meters. We use 10 meters depth to design the longlines until more experience is gained from site to site. Submerging longlines at 10 meters depth is often used in exposed ice-covered wind-driven and hurricane exposed areas with good success.

In consideration of the environmental conditions on the Latvian coast, the submerged longline components best suited for this area are presented, with a short explanation (see Fig 3).

4.2.1 [A] Deadweight anchor blocks:

They must keep the longline stable from movement (2 x 2.5 tons corner anchor blocks) and from slipping over the bottom when the boat is operating at surface

It is suggested to use existing 2.5 tons anchors off Pavilosta to secure the longlines. However, 2.5 tons concrete loses 40% mass under water, so 1 block is not sufficient at the extremities if the longlines. As in the figure above, **2 anchor blocks are recommended**.

- Deadweight mooring anchors are best for this Latvian coast due to transport and workboat limitations to the site. These are preferred over drag anchors because of the bottom rocky-sand substrate.
- Select deadweight anchors heavy enough to prevent a large workboat to shift the longline when the boat is working at the surface in windy conditions.
- Anchors can be wedge-shaped to more easily dig into the substrate or more bulky square or rectangle shape to sink into the mud and sand (this needs to be heavier).

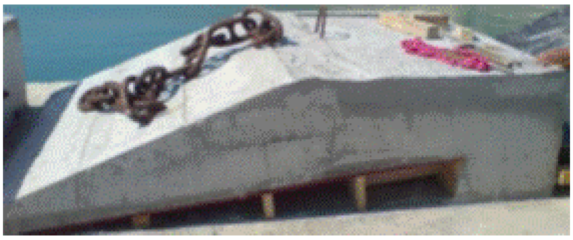


Figure 4 Wedge-shaped concrete block anchor

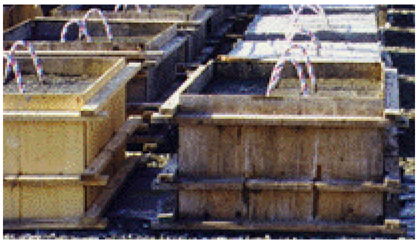


Figure 5 Square concrete block anchor

NOTE: The use of chain is not recommended for the long term unless the chain is over 25mm thick chain link to avoid rust, but then a large steel loop is required to avoid abrasion due to chain on rope. Metal parts are difficult to handle.

Drag Anchor options: In the best of circumstances, if there was a ship able to transport and install 800kg drag anchors with the concrete blocks, this would be better for long term production. The drag anchors would better dig into the sandy-rocky substrate to secure the concrete blocks at the extremity of longlines.

Figure 6 Drag anchor

Note on making concrete blocks for marine anchors:
When you design and build your concrete forms, plan to use reinforcement bars for strength and to attach 32mm 'Polysteel' rope handles to the 'rebar', which will serve as loops to attach the ropes to the surface. Rope does not rust and is amazingly rugged, outlasting the anchor line ropes. Have the cement company put in the proper additive for marine conditions to strengthen the concrete and let it cure for a week before unmoulding: Further hardening of the concrete occurs in the sea.

Anchor distance: Anchors 180 m apart, 2.6 tons each, concrete material with additive against salt water. Notice that the effective mass underwater is around 1.3 tons, which strongly compromises the stability of line in these extreme conditions, especially with large corner floats and the tension by the boat at the surface during windy conditions.

Anchors mass: Due to limited availability of large ships to install heavy anchors over a short period and the greater flexibility of moving 2.6 tons blocks (1.3 tons effective mass) with smaller boats or floatation devices this compromise is acceptable however it is recommended to install 2 anchors in series (3-5 meters apart) at the end of each line. This is especially true when the bottom is rocky or with boulders. Sandy or mud bottoms allow the anchors to dig in and have more friction.

Anchor design: The shape of the anchors really depends on their mass and the ship you have to move them. For simplicity it is still effective to create rectangle blocks 1x1x0.45 m, reinforced with 'steel armature' within the block. It is NOT recommended to attach the long-lines on metal loops in the block due to short term rust. However due to legal regulations it is OK to install a metal ring in the concrete block for transporting and install the anchor in the sea.

Anchor attachment point (loops): It is important to use friction resistant rope such as Polysteel-type with sufficient diameter larger than anchor rope (e.g. 32-34 mm diameter) with 2 loop knots. Each of the loop knots are attached around the armature in the anchors when the concrete is poured (see Figure 5).

Figure 7 Unmoulded concrete blocks after using grease on inside of wooden moulds

4.2.2 [B] Corner buoys:

The most important function of a submerged longline is that it maintains structural integrity and buoyancy when at rest and that it remains under tension while it is brought to the surface. This is accomplished by using large corner floats so it maintains vertical tension of the longline (arrows). While larger corner floats have greater buoyancy, they also have greater vertical pull on the longline anchors (heavy anchors must remain stable).

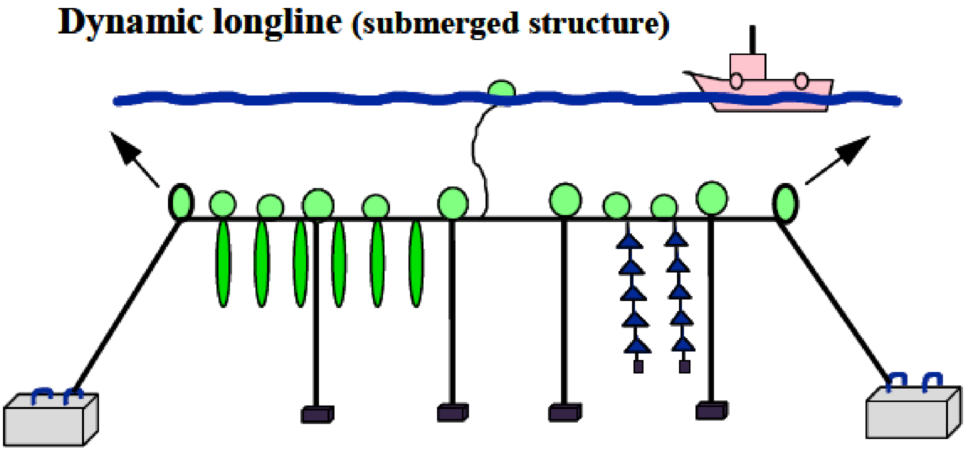


Figure 8 Dynamic longline (submerged structure)

A dynamic longline is one whereby the geometry of the longline returns to its submerged state after being brought to the surface. The corner buoys are important in this process. There are many buoys available on the market, but the only ones that matter here are made of plastic and can withstand the depth down to 10-15m. See ANNEX No.1 (FLOATS) with examples recommended.

Buoy Size: The size of the corner buoy is important in offshore conditions. For all floatation types there is an important set of RULES that apply to everything we install manually.

Rules for longline equipment carried on boats:

1) It must be easy to **install manually**
2) It must be easy to **maintain manually**
3) It must be easy to **harvest or remove manually**

Corner buoy size: The optimal buoyancy volume for corner floats is around 200-250 litres when using anchor blocs of 5 tons or (2 x 2.5 tons), because of the unpredictable environmental conditions. However, 250L floats are very difficult to handle manually (ANNEX No.1).

For the first longline, it is recommended to attach either 1 x 130L submersible buoys (JFC) on the line at the corners, or 3 x 40L floats (JFC or GoDeep) if available. In the simplest case for starters in the Baltic, it may be advisable to test 3 x 40L floats, as these may be easier to handle and attach. The

floats should not be touching so plan the knots distance

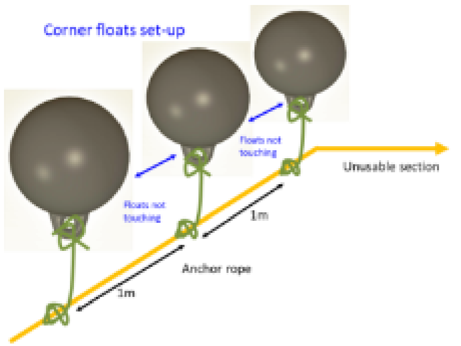


Figure 9 JFC ribbed Float of 130 litres or a JFC 40 L

accordingly.

NOTE: Poor material selection will most certainly compromise the farm site success. The cost is fair!

4.2.2.1 Discussion on corner buoys - practical logic

In this type of submerged longline system, it is preferable to use 200-250 litres flotation (Figure 10), which will provide enormous tension. However, since the boat operating the longline site will not be available in the region, this buoyancy volume is too difficult to sink to 10m depth. There are several options, and all these depend on the type of boat available to install the lines and to operate them.

Thus, it is recommended by deduction to look at several practical options.

Either option A), which is not so practical, is to install 2 smaller corner buoys (100-120 litres, Figure 11), which is preferable to one big corner buoy of 250L (Figure 10), since the rope is likely to break at some time in the project.

Figure 10 JFC submersible buoy of 250 litres

Figure 11 JFC submersible option buoy of 130 litre

However, the problem with larger buoys is that these are very difficult to sink and handle manually when only a small boat is available. The 130L buoy is easier to attach at both ends as a corner buoy.

Option B), which is the preferred option in the Baltic Sea for practical reasons due to easier installation and testing purposes. The team can gain solid experience installing smaller 3 x 40 L corner buoys as described previously.

Figure 12 Corner buoys 40 L

4.2.2.2 Corner buoy rope selection and assembly

You need to attach the corner buoys with 20-24 mm Polysteel rope, such that each float is not touching the other and will be about 30 cm distance from the anchor line (Figure 9). The buoy rope should pass through the braids of the anchor line before the line is tight at sea, then knotted. The position of these corner floats is predefined by geometry and water depth. Usually it should be preinstalled before installing the longline at sea. Due to geometry at 10 metres depth and no tides, the distance of the anchor to the corner float will be about 16 metres. This means it is possible to attach the corner floats on the pre-marked anchor line on a calm day. This way only one of the corner floats could be attached prior to installation depending on local conditions.

NOTE: It is critical to purchase recognised submersible plastic floats that are specifically designed to withstand the pressure down to 10-15 m. These special floats are designed (shape and volume) with a proper attachment points for ropes (ANNEX No.1).

4.2.3 [C] Intermediate floats and counter-weights:

The intermediate floats with counter-weights are an important component of submerged longline production (Figure 13); especially in extreme offshore environments where there are extended periods when the longlines are not accessible over the production cycle (autumn storms & winter drift ice in the Baltic). Although it is well justified to argue that they are more work and maintenance, they do keep mussels from sinking to the bottom. The floats are tied to a counter-weight to compensate for increases in mussel mass over time.

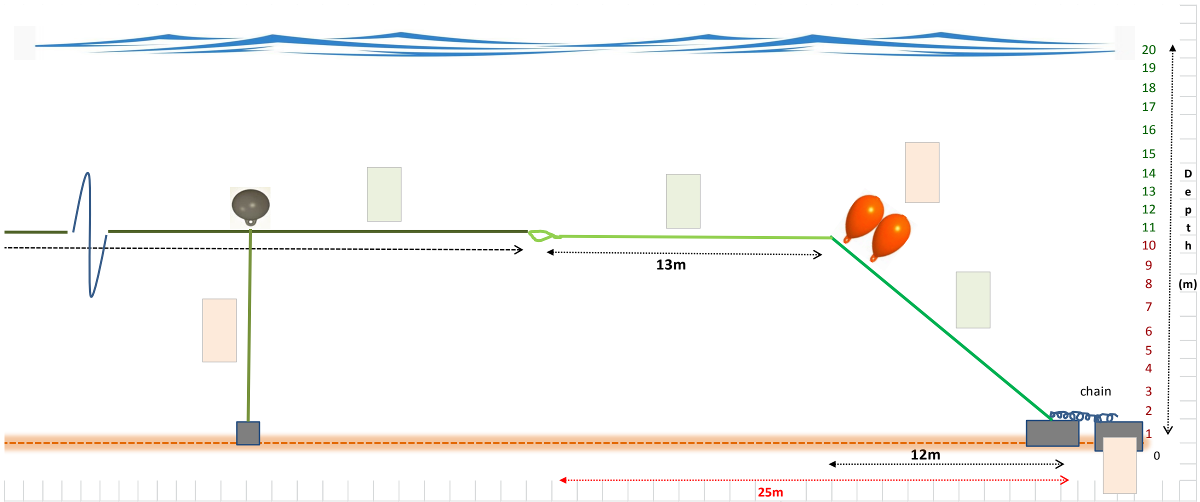


Figure 13 Schematic representation of submerged longline with primary components (A-F), the intermediate Float and weight [C] maintains the mainline at the desired depth of 10m

The Intermediate Float and Counter-weight combination is mostly a strategic risk management approach to saving the mussel production from sinking to the bottom. It is recommended to prepare the 2 parts separately. The concrete block of the Intermediate Float Counter-weight for 10m depth should have the rope tied to the block loop at all times. The Intermediate Float should have its own 1.5m rope (18mm) permanently tied to it so that both are easy to transport and move on the boat.

The counter weight rope (10m) is already attached to the block (bottom). When the distance between the Counter-weight and mainline is 10m, then the rope length for 18mm Polysteel should be at least 10.5m long (10m + 0.5m) to include the knot on the mainline.

Similar for the 1m Intermediate Float rope, one requires 1.5m total rope to add the

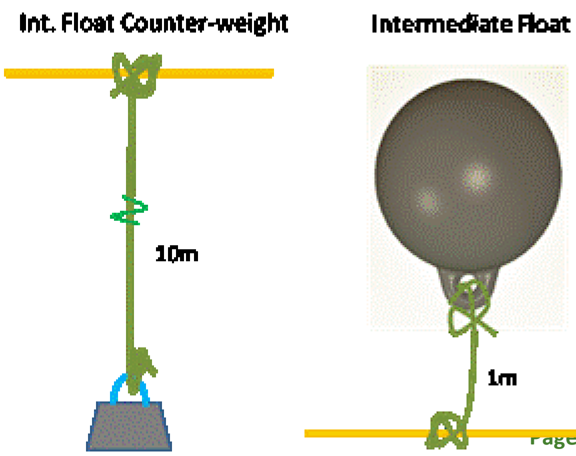


Figure 14 Attachment of rope

knot on the mainline. It is very useful to be able to attach and untie each Intermediate float of the mainline when working on the boat in rough conditions. It is easier to handle on the boat.

4.2.3.1 Impact of intermediate floats and counter-weights on mussel production

Due to the possible strong currents where the mussel collectors will be installed, it is likely that there should be an empty space 2-4 m on each side of intermediate anchor line to avoid rubbing of the collector line (based on experience). <u>If the mussel collector rubs the anchor line, mussels may fall off</u>.

4.2.3.2 Distribution of intermediate floats along the submerged longline

It is better that **Intermediate Floats** be evenly distributed along the longline. There is no point in placing too many intermediate floats along the longline, because it limits the total number of collectors that can be attached. Furthermore, it is especially important to avoid using larger floats than 40 Litres, because they are more difficult to handle and attach to the line. If the floats are larger than 40L, then the counter-weights need to be too heavy to lift over the starwheels and by hand.

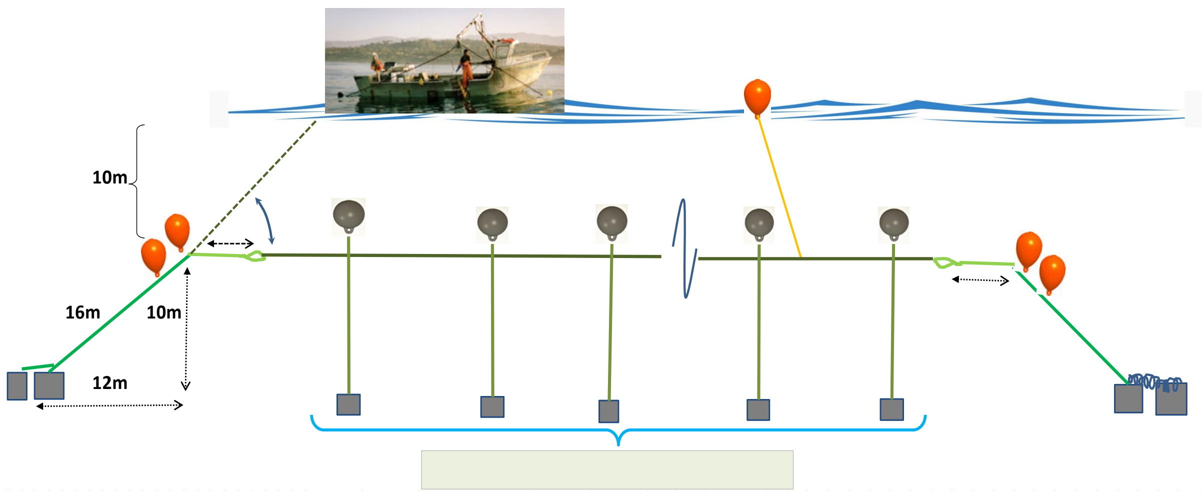


Figure 15 Schematic representation of submerged longline with evenly distributed intermediate floats

4.2.3.3 Calculation of intermediate floatation needs during Baltic mussel production

In a standard Atlantic coast blue mussel production, there would be approx. 5 tons on the longline after the first year of growth, and after several months, it would be necessary to add more compensation floats during the season when they grow fast. There is a careful balance between too much floatation on the line and the mass of mussel growth: it is imperative that the mainline does not float to the surface. However, the Baltic mussels may only reach 1 ton of growth at the end of the season (June settlement to November) before winter arrives and growth stops. One (1) ton of mussels in water lose 75% of their mass with approx. 250 kg remaining. **Only 5 Intermediate floats are required to float 1 ton** (250 kg divided by 40 litres floats = 5 floats). The corner buoys can take up the remaining 50 kg net mussel mass. Thus, it seems correct to use 5 intermediate floats with weights along the mainline to maintain production over winter: <u>time and experience will clarify the needs</u>.

4.2.3.4 Discussion on selecting the right quality floatation

The submersible 40L floats (ANNEX No.1) are specially designed by professional companies with global experience and are selected because they can withstand 10-15m depth to avoid collapse. The best floats are sealed and pressurized for submerged longline conditions. Pricing and quality can vary a little, but the selection must be based on minimum requirements for submerged longline culture, and not for surface lines. Similar quality conditions apply for JFC 85-130-250L floats.

Always ask questions to suppliers and demand proof of concept. Make sure that they sell floats for submerged longline culture. There are many international companies that sell submersible floats, but there is no doubt in the author's experience that Quality Equipment (NZ), JFC Marine (Ireland) and GoDeep (Canada) have reliable product, and they can guarantee it. Verify suppliers with guarantees.

4.2.3.5 Discussion on selecting floatation: no place for cheap floats

Many first time growers try to save money on cheaper floatation. They look at total buoy volume and do not consider the structural integrity when the float is submerged. Consider that the entire farm relies on floats that are floating. If they collapse then they lose the ability to support the longline and keep the mussels from touching the bottom. The value of a float is what it carries when it is submerged, otherwise it is supporting air, as in the photo (Fig. 16).

Figure 16 Inexpensive poor float quality

Professional float manufacturers are those who have tested their floats for submerged longline use, and they can guarantee the float depth (see GoDeep + JFC specifications in ANNEX No.1).

4.2.3.6 Discussion on concrete moulds for intermediate counter-weights

Concrete will lose approx. 40% mass in seawater. For a 40 L float, it is wise to create an 80 kg counter-weight cement block, and use a 20 mm 'Polysteel' type rope, or Duradan, to make the loop in the concrete. Use this loop for attaching the 18mm anchor rope going to the mainline in order to maintain the submerged longline at required 10 m depth.

When producing many weights at the same time, one method is to prepare the 80 kg plastic moulds or use oil buckets that match 80 kg concrete. Prepare all the loop rope (see Figure 17) in a production style process and make a knot at one end. When the concrete truck arrives, hold the loop rope knot in the centre of the mould while pouring. Do not forget to have the additive included in the concrete mix by the cement company.

Figure 17 Production of compensation ballast weights

Because these intermediate float lines are static the currents will cause the collector ropes to drift and rub against the anchor line and mussels will be lost. Depending on local conditions the grower will determine what space (how many meters) is needed to avoid losing the collector ropes.

These intermediate float & counter-weights should be installed after the longline is stabilized at 10 m depth. After this they usually become permanent fixtures to ensure stability of submerged longlines.

4.2.3.7 Discussion on selecting rope material

The type of rope used in offshore shellfish culture is critical to the safety of longlines, of the boat and of the production system. Proper mussel longline ropes are specifically designed to avoid twist and abnormal wear or abrasion. It is critical to select Polysteel-type, NZ mussel line ropes, or other similar quality composite rope materials to ensure long life and durability under these extreme open ocean conditions. Normal fishing ropes of polypropylene and nylon rope are NOT recommended for offshore production.

Oops, wrong material: This first time a producer in the Black Sea used inexpensive import rope made of unknown material and mixed two different rope qualities together (see Figure 18). The end result, although the knots were very tight, was that the small blue twine was more resistant and abraded the larger mainline rope within the first year at sea.

Figure 18 Consequence of using unknown rope material and mixing two rope qualities together

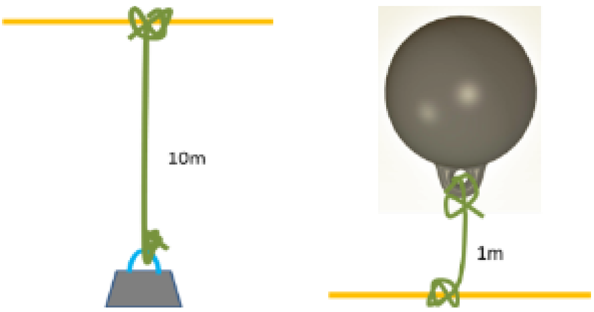
This mainline rope upon which the floats were attached appeared strong enough, but because of the 6-braided design, the wave motion caused the braids to open and close with the constant wave motion and thus undergo greater friction by the tighter blue twine used to attach the float.

4.2.3.8 Discussion on measuring rope

When planning to buy rope it is important to consider the extra length required for making a knot. The extra amount of rope required for attaching to an anchor or a float is about 50 cm for 12-18 mm diameter Polysteel, whereas up to 1.5 m extra length is required for 24-32 mm rope. All measurements presented in this document include the extra rope at each end.

For example, if the distance between the dead-weight anchor and compensation float is 10 m, then the rope length for 18 mm Polysteel should be 11 m long to include a knot at each end.

Similar for 1 m float rope, one requires 2 m total rope to add knot at each extremity.



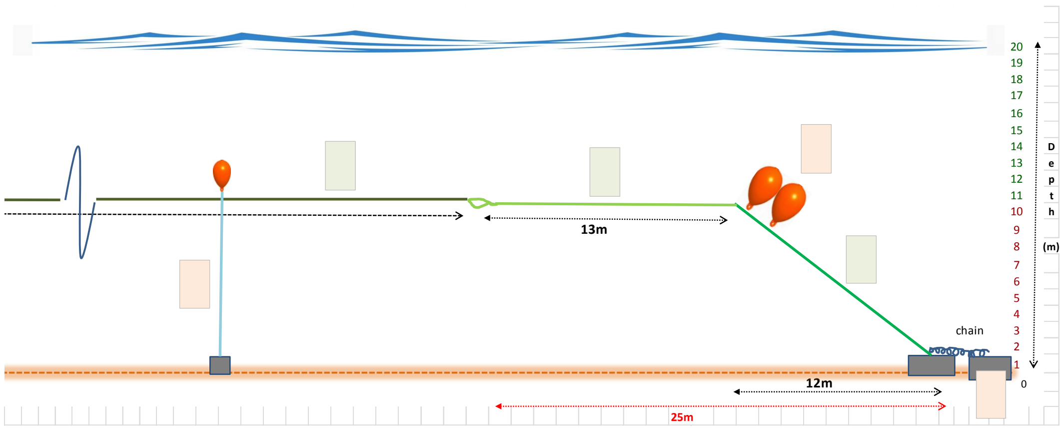


Figure 19 Description of the submerged longline material components (A-F)

Every part of the longline requires careful preparation to assess the proper length of rope materials. It is important to consider rope length (m) required for the knots and total length all components.

4.2.4 [D] Anchor line rope: connecting anchors to mainline and corner buoys

The total <u>**anchor rope**</u> (as the one unit) - 30-32 mm diameter. It is important to use friction resistant rope such as Polysteel-type with sufficient diameter larger than the anchor rope on the anchor block.

The total anchor rope (as the one <u>continuous</u> unit) consists of two parts:

[1] **Anchor Line:**_Anchor rope to the corner buoys

[2] **Unusable section:** From the Corner buoys to the end of the loop, which becomes horizontal when the line is under the tension. The Loop for tying the mainline does NOT need to be spliced because it will be regularly adjusted to compensate for stretching of the line.

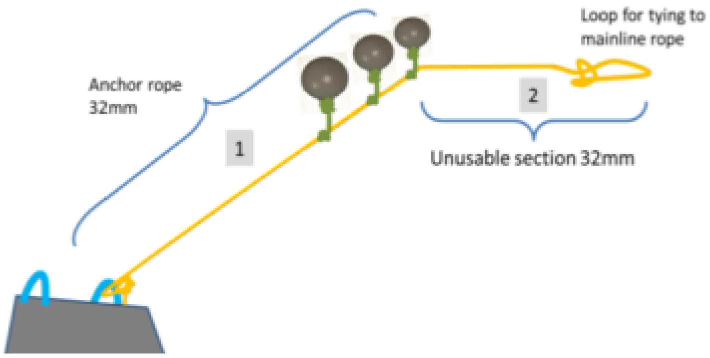


Figure 20 Anchor rope

Diameter of anchor rope: It is strongly recommended to apply a risk management approach for determining diameter of anchor rope tied onto the loop rope, which is securely attached to the metal rebar installed in the concrete before pouring. The anchor rope can be 32 mm, and the loop can be 34 mm, as its best that the weakest rope breaks first. It is best that the mainline rope be 30-32 mm diam.

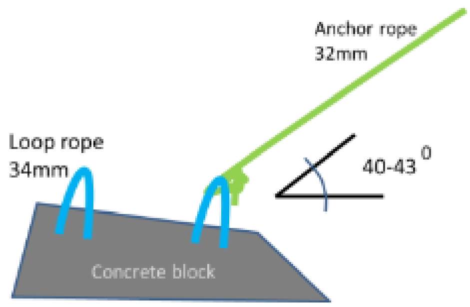


Figure 21 Anchor rope

The **anchor line angle** that works best to maintain both the flexibility and the high-tension of the longline should be around 40-43 degrees. His is established in the original geometric design based on water depth and depth of submerged longline from the surface.

4.2.5 [E] Unusable section of longline: from the corner floats to the mainline

The length of the **Unusable Section** is also established from the original geometric design and is based on the water depth (20 m here) and the depth of the submerged longline to the surface (10 m in this case). We can see (Fig. 22) that there is a difference in the right angle triangle geometry on the anchor line section (10 m) and the submerged line depth (10 m) section. The hypotenuse is 16 m for the **anchor line** length (anchor to corner buoys), and 17 m for the **unusable section** (from corner buoys to the gunnel of the boat where the STARWHEEL is attached (1-2m from the water surface).

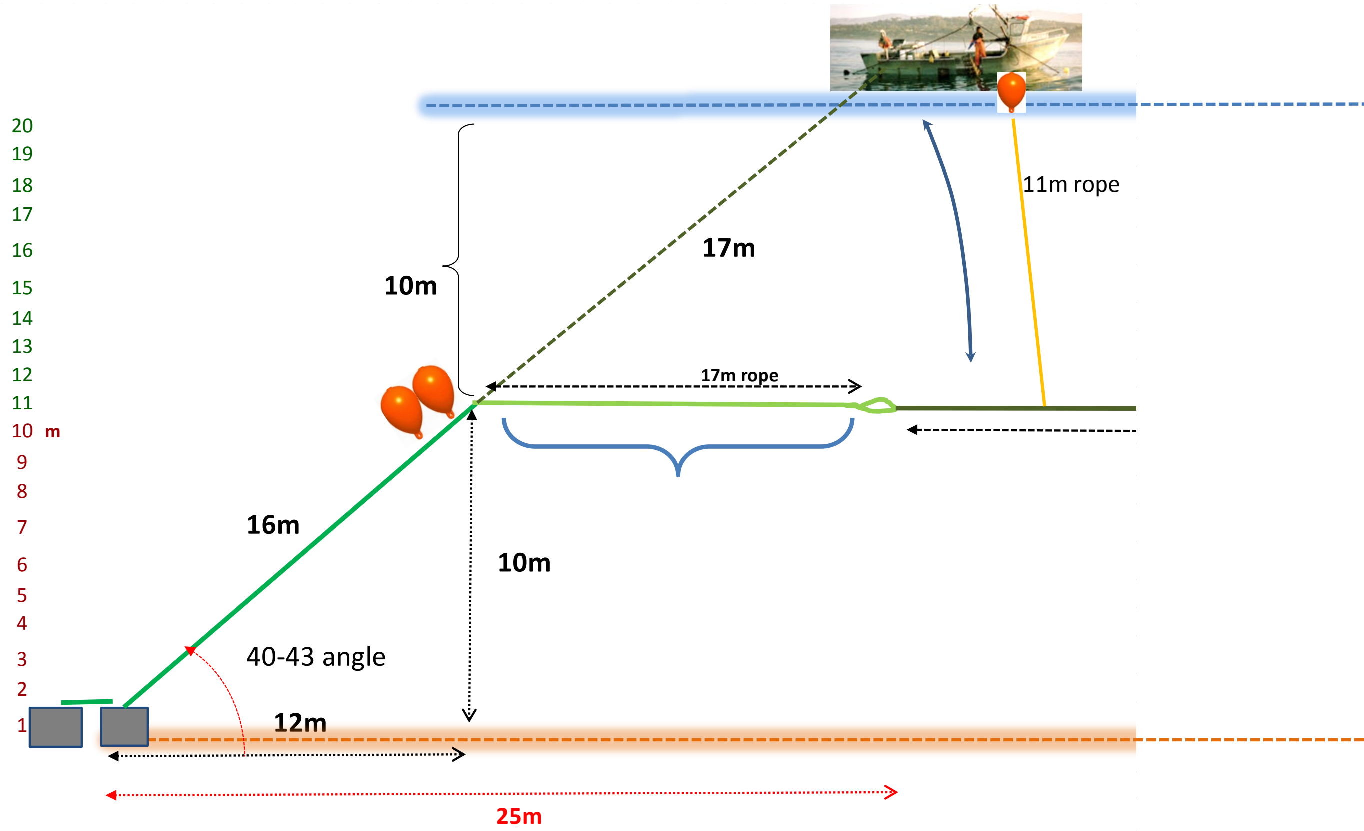


Figure 22 Submerged longline geometry for 20m depth at 10m from surface showing unusable section

NOTE: The exact **length of the Unusable Section** is somewhat theoretical as it needs to be adjusted in the water once the entire longline is installed, because of variable line tension and also because the exact position of anchors cannot be precisely determined. However, this starting point works well, and with experience can be refined.

When designing the submerged longline geometry, the length of the **unusable section** must be long enough at the end of the anchor line so the longline can be secured on the boat when brought to the surface and lifted on the boat over the starwheels. This allows the **loop** to be accessible to adjust the tension after the longline has settled in the water. We see here that the longline requires at least 1-2 m extra vertical height above water, which we must design into the geometry.

Because of the stretch of the rope (5-7%) over time it will be necessary to maintain the tension of the line by tightening one end of the mainline.

4.2.6 [F] Mainline rope: attaching mussel collector ropes and grow-out ropes

The mainline is attached to the loop of the anchor line [A] at each end of the longline (Fig. 23). Ideally the mainline rope diameter (28 – 30 mm diameter) is equal or less than the diameter of the anchor line (30-32 mm). It's better to have breakage on the mainline where it can be fixed, than underwater where diving would be necessary.

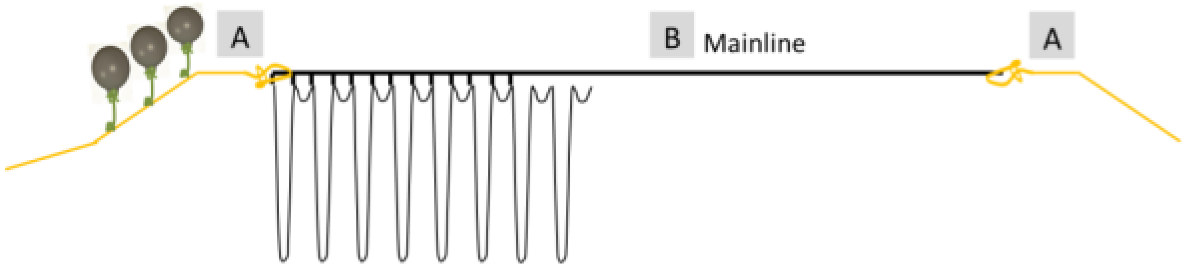


Figure 23 Schematic view of the mainline [B] attached to the loop of each unusable section [A] at each end, the longline is showing collectors attached at equal distance along the mainline

If the mainline is too thick it is very hard to handle manually, and more difficult to operate through the standard starwheels shown below.
While it is important to oversize the ropes from the anchor to the mainline, one must carefully consider the operational aspects. In this case the starwheel groove must be able to squeeze the mainline but not get stuck as the rope threads through it.

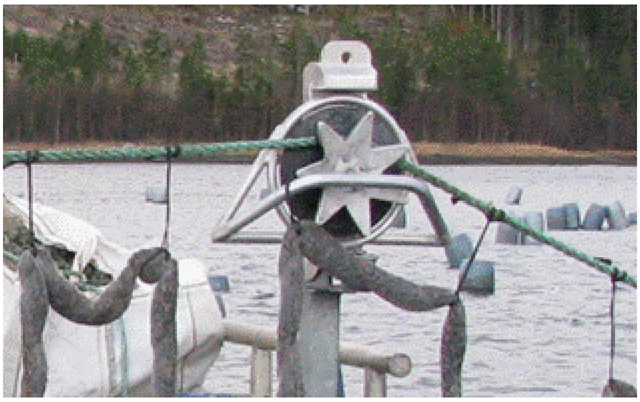


Figure 24 Mainline rolling through the starwheel

4.2.6.1 Selecting collector rope for spat settlement and grow out

There are many types of material that can be used for collecting spat (e.g. Swedish bands, fuzzy rope, old fishing rope, New Zealand mussel ropes etc.), however one must always consider the 4 important rules while selecting the collector material or rope:

Rules for collector material carried on boats:

1) It must be easy to **lift and install manually**!

2) It must be easy to **maintain manually**!

3) **It must be easy to harvest mechanically** without spending time untangling the collectors on the boat!

4) Does the collector material provide the **settlement substrate structure** required for your area to make it easier for the mussel spat to attach and **avoid excessive fall-off** of the mussels during storms and harvesting?

5) The collector material **must NOT tangle** when thrown in the water!

6) Does the **collector need to be weighted** down to avoid twisting in current?

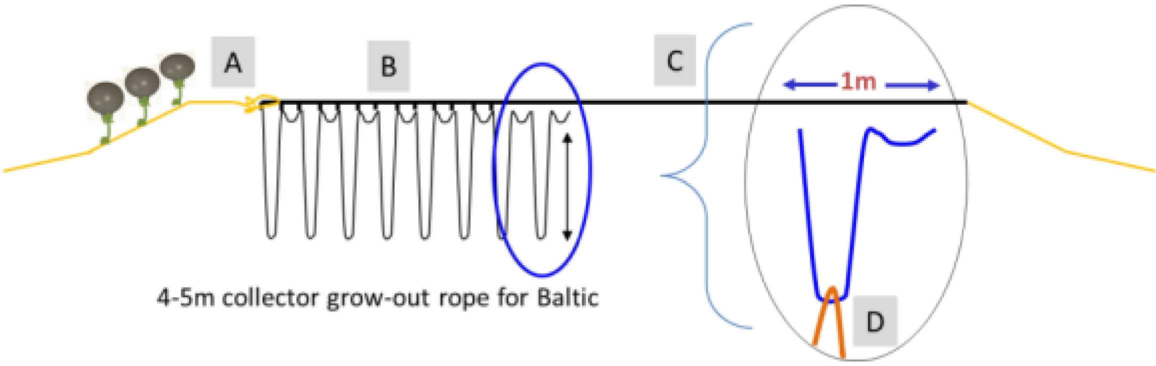


Figure 25 Mainline [B] with continuous collector rope attached at 1m intervals [C] with extra weights hooked at the bottom of collector loop [D] for extra stability in strong currents and waves

4.2.6.2 Attaching collector rope to the mainline with droppers

The collector rope best suited for the Baltic region should be non-twist, multiple strands, and continuous rope resembling the QE mussel rope standards such as produced in New Zealand. The selection of this rope is based on the unique design to collect high volume spat and the ease of installation, maintenance and harvest through mechanized process on the boat. The collector attachment points can be 50 cm for the long loop and 50 cm for the short loop. The collector ropes should have a vertical length of 4-5 m long, to test their behaviour on the site before (Fig. 25).

Due to the currents and mostly the impact of Baltic waves, it may be necessary to add 3-4 kg weights onto each collector long loop. These are made from 25 mm diameter reinforced bars used for concrete structures. Each 50 cm piece can be cut and bent to a V-shape [D], without using an extra attachment rope. They can be dropped on collector ropes from the boat and placed in the sea.

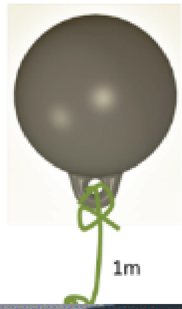
4.2.7 Compensation floats along the mainline

Compensation floats are individual floats that will be added to the mainline as the mussels grow, to compensate their increase in mass and keep the longline buoyancy at the desired 10 m depth. The recommended choice for submerged longline compensation float is about 40 L volume (Fig.26), which follows the rule about handling safely and also allows for gradual addition of buoyancy to the line with slow growing mussels. Rule: floats are easy to manipulate from the boat when adding and removing from the mainline. These floats can be similar size to the intermediate floats, but without the additional counter-weights.

Figure 26 Float of 40 litres

Figure 27 Float by starwheel

Compensation floats description: Between the float and the mainline you will require 18-20 mm Polysteel-type rope to attach and detach the floats as needed. With 2 m length rope this will allow for a knot to tie the rope to the float (permanent) and a knot to tie to the main line, which should leave 80 – 100 cm length that will go through the starwheels.



Note: It is very important to use the sounder image to identify how the longline is sinking, then add just enough compensation floats so the mainline returns to 8-10 depth – The crew must ensure that the mainline is not closer to the surface for this Baltic environment.

Value of starwheels: Collector dropper ropes (Figure 28, yellow arrow) and all buoys ropes should be long enough (50-100 cm) to pass through the starwheels and over the side guard (arrow) of the starwheel when working on the boat.

The boat should always be facing the wind in order to keep the line under tension as the boat is advancing along the mainline. This ensures that the mainline does not sag.

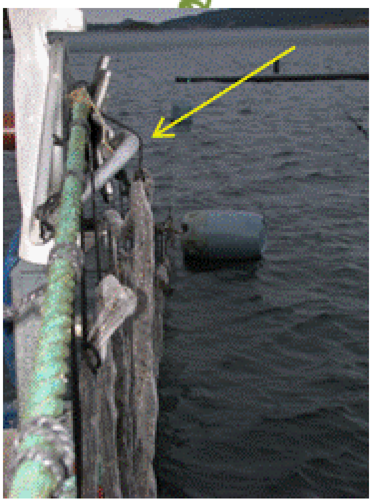


Figure 28 Collector dropper rope

4.3 Optimal design, orientation, preparation and installation of submerged longlines

4.3.1 Submerged longline orientation

Submerged longlines should be installed parallel to the wind direction so the workboat is facing upwind or downwind when attached to the longline as a working platform.

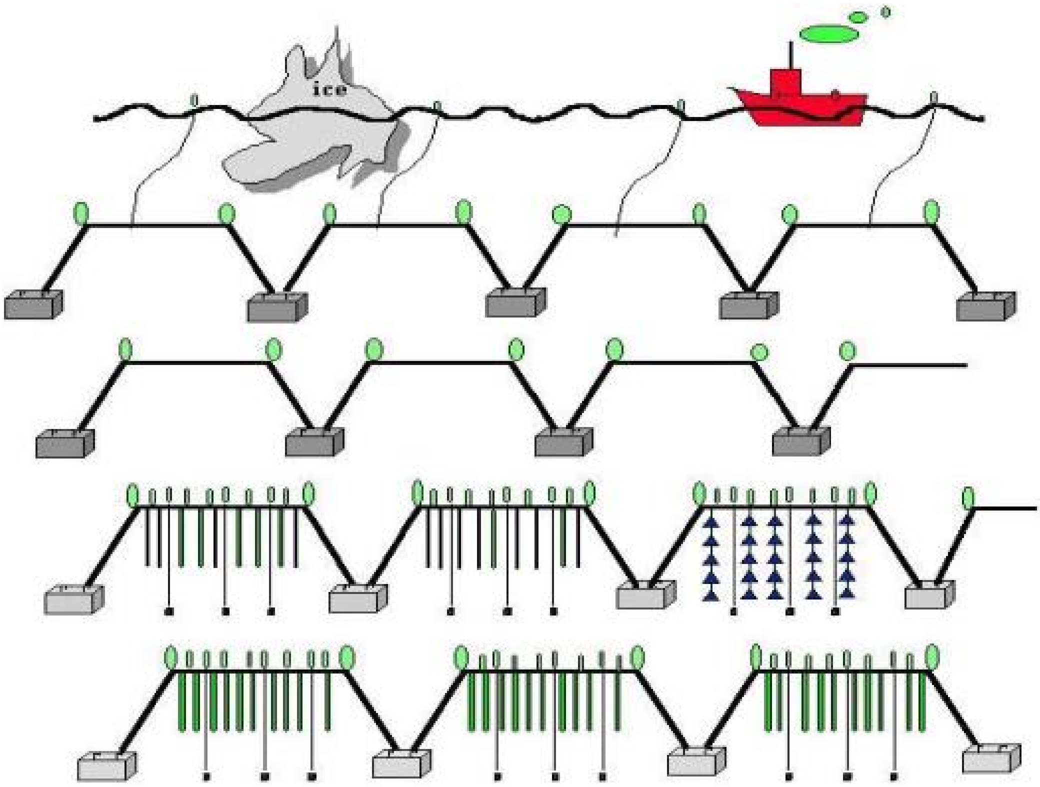


Figure 29 Example - Organisation of a shellfish culture site for submerged longlines (J.Bonardelli)

The orientation of longlines on a site should be parallel to the alongshore flow of currents. Due to the Baltic winds, the most important is for the lines to be in the direction facing the wind. The distance between parallel series should be 30 m apart for 20 m of water (1.5 times the depth).

To be operationally cost efficient when installing longlines, it is ideal to put 4-5 lines in a series, using 5 tons concrete blocks at extremities and single 4 tons block joining 2 lines together. This optimizes the installation time and space in the lease, while facilitating retrieval of longlines with a sounder.

4.3.2 Optimal design assembly for the first longline concept in Southern Baltic

The extreme Baltic environment represents a rather unique challenge for long term scaling of mussel production. In order to address this in a structured way, the proper procedure in every new area is to **establish an optimal longline design** that will remain stable and allow **the pilot production trials** to be carried out as a pre-commercial learning platform. This will allow mussels to attach to the lines so that researchers and pilot growers may gain valuable information about mussels recruitment and settlement.

For this first **pilot production trial** set-up – Plan each of the anchor extremities with the purpose of using 2 existing 2.5 tons anchors (previously installed at Pavilosta demonstration site) and move them (with experienced diver and boat), so that at each end, they are 3 m apart from each other in a series.

1) It is recommended to plan for **180 m distance between the anchors** under the mainline for this exposed Baltic region and to have the submerged mainline at approx. 10 m below the water surface, in 20 m depth. Previous trials at 10 m in Pavilosta gave better results. This may change with experience and more reliable longline design;

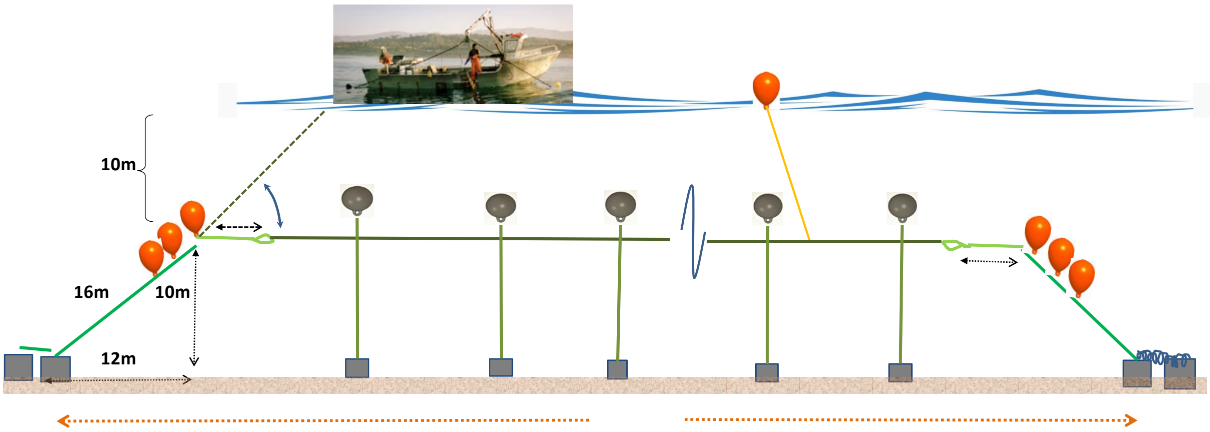


Figure 30 Long line

2) Plan for 6 x 40 L Corner floats (3 at each end), based on the pre-measured geometry;
3) About 5 x 80 kg concrete weights with 40 L floats with 10 m rope to keep mainline at 10 m;
4) When the mussels increase in mass in year 2, it may be necessary to add compensation floats.

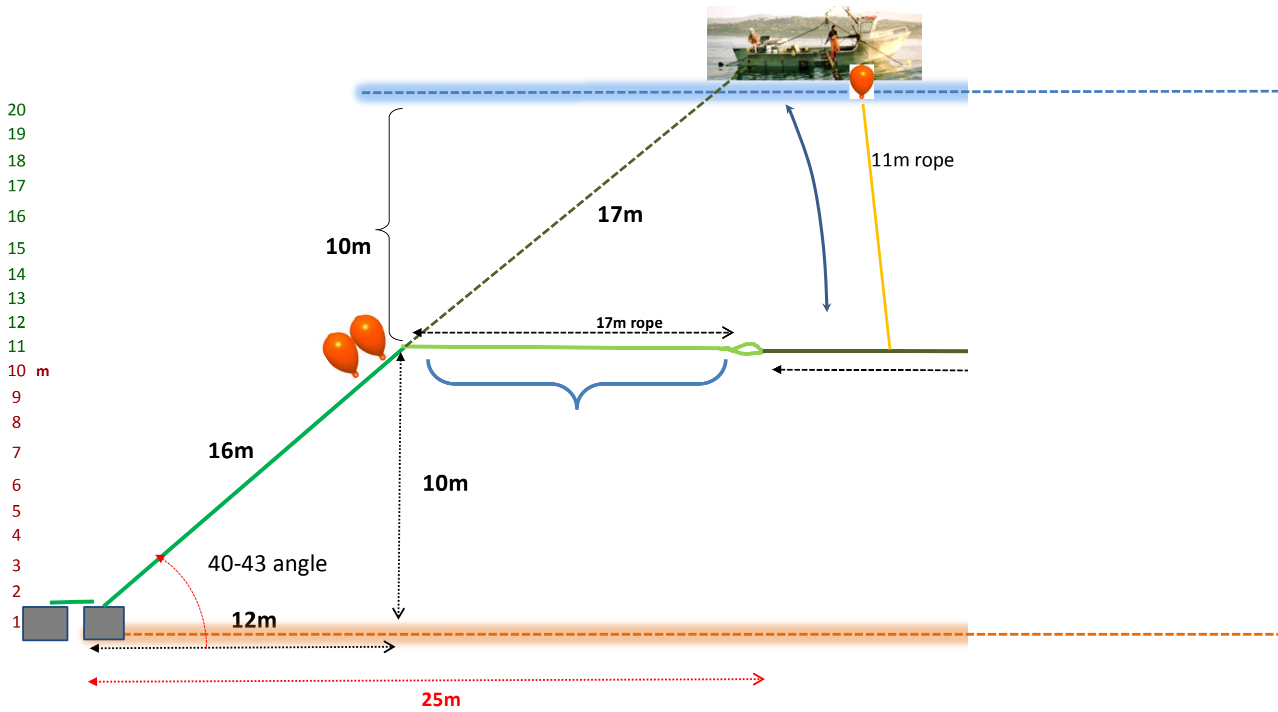


Figure 31 Angle of longline

The angle of the geometric longline should be planned for 40-43° to maintain the best combination of flexibility and tension. All ropes should be pre-measured and then adjusted once the line is at sea.

4.3.3 General description of long line preparation

The previous chapters presented how to assemble anchors, floats and ropes and why certain equipment is superior to others. We should always remember that the discussion revolves around the development and implementation of offshore mussel culture in a rather extreme environment;

the Baltic Sea, where wind waves dominate every process and decision, and that safety of human and material resources is the key driver. This section will cover some of the essential practical preparations you can achieve on land before installing longlines at sea.

4.3.3.1 Land-based preparations

4.3.3.1.1 Managing your people

Always clearly define who the project manager is for the land operations. Clearly explain your plan, what your purpose is for each activity, and demonstrate clearly to every employee what their task is, how to accomplish it, and what result you want. People are able to accomplish what you show them.

The reason for this discussion is to highlight the importance of preparation of material on land, where it is easier to organize people, move equipment safely and store material until required for sea operations. We must remember that time at sea should always be considered limited with any opportunity to work at sea, as a gift of nature.

Previously we prepared the greased anchor moulds, poured the pre-mixed concrete and reinforced the blocks with re-bar (armature), and tied the 34 mm loop rope to the steel reinforcements so the loop is hanging out at least 30 cm from the solid anchor. The corner buoys and intermediate floats were ordered and ropes cut and tied to the proper lengths. So let's discuss some practical logistics to be more efficient in handling large numbers of anchors, kilometres of rope, and hundreds of floats.

4.3.3.1.2 Concrete blocks and longline anchors

Rarely are the 2.5-3.5 tons concrete blocks produced near the loading area where traffic, people and space are in conflict with your activities, so the anchors (steel drag anchors or concrete blocks) need to be transported to where the boat will take them to sea.
Consider these steps:

1) Hire front loader tractor or machinery;
2) Stack blocks neatly near the dock and cover;
3) The front loader with chains can drop anchors in water or onto boat safely;
4) Seriously rehearse all the logistic process with the driver of the tractor or front loader before (!);
5) Seriously rehearse all logistics with the captain of the boat – you are project manager only;
6) Plan your installation at sea so that all pre-measured ropes are prepared and coiled to carry on the boat for deployment at sea- safety first.

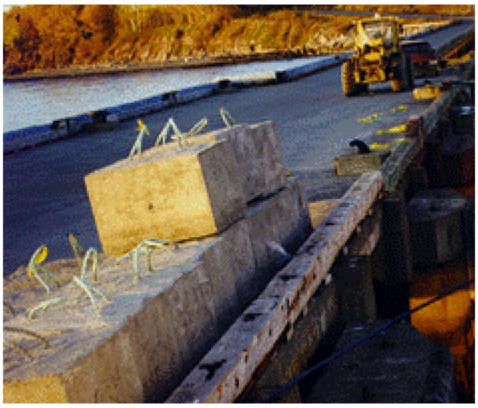


Figure 32 Anchor blocks loaded on dock

Transport and deployment of longlines at sea using a large ship or small boat requires planning. Managers need to establish the cost of the operations, the time it takes to deploy one or more longlines in a series, and who has what responsibility in the team.

4.3.3.1.3 Pre-setting mainline attachment points for collectors and floats on the mainline

It is advisable to predefine the distance of attachment points on the mainline so that the collectors and floats are equi-distant. The reason is simple: there is no time at sea to estimate the exact distance for attaching collectors when the boat is rocking and rolling in extreme conditions.

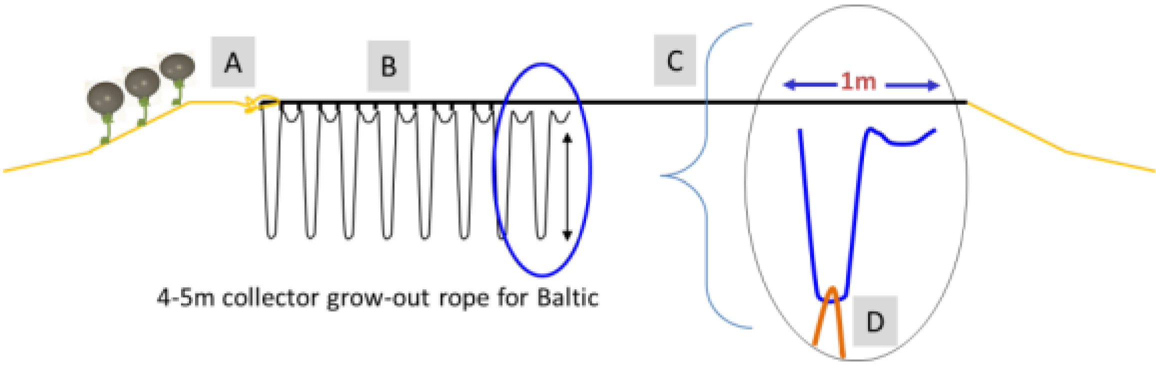


Figure 33 Mainline [B] with continuous collector rope attached at 1m intervals [C] with extra weights hooked at the bottom of collector loop [D] for extra stability in strong currents and waves

The best solution for preventing collectors and compensation floats from shifting on the mainline when lifting them with a grapnel is to use a 7 mm braided twine and threading it into the mainline rope.

Cutting rope or twine in equal lengths: The easiest way to obtain even length of 50 cm pieces is to use a spindle wheel with a defined or an adjustable diameter using wood separators (Figure 34). Then wrap all the twine or rope around it, and cut the 50 cm long pieces or the 18 mm rope, with a hot-knife to melt and seal the rope ends.

SAFETY FIRST: The melted rope and twine ae plastic compounds that are HIGHLY toxic. It is recommended to complete all these tasks outside or in a ventilated area to completely remove the fumes. When exposed for several days, these plastic volatile fumes WILL cause bleeding in the lungs and headaches.

Figure 34 Rolling rope around spindle

Once the 50 cm pieces are all cut and the ends are properly heat-sealed by the hot-knife, each piece of twine is made into a loop by knotting the ends together.
This will allow for rapid utilization and can be

prepared any time of day after the ends have been cut, or while watching TV.

Figure 35 Knotted loop cord is tightened by hand

These loop cords pieces can be packaged together in bundles of 25 for efficient counting. If you have 150 m of mainline, then 6 bundles can be allotted to each person on the assembly table.

Organizing the workflow and storage of materials makes the preparation on land more efficient.

Figure 36 Bundles of cords

4.3.3.1.4 Assembly of loop cords into the mainline

Two teams of two persons are working outside in tandem on the assembly table to insert loop cords into the mainline. There is no problem having the music on and chatting away on a nice day. Most importantly, this land based work can also be completed with women or students on the team.

Each person on the assembly table is opening the braid of the mainline Polysteel 3-braid rope with a splicing tool and inserting the loop cord through it, then passing the loop through itself.

Figure 37 Splicing tool

Figure 38 The Loop cord is easily inserted into the mainline with a splicing tool on the table when the rope is not under tension

The assembly table is pre-marked with 1m equal distances. However, for continuous collectors, it is advisable to mark the mainline every 50 cm and insert the loop cord.

This will provide an option to attach the collectors either 1 m apart between droppers, or at 50 cm intervals once experience is gained on the behaviour of collectors in this rugged environment.

NOTE: Over time the mainline will stretch and the distance between attachment points will increase.

4.3.3.1.5 Coiling the prepared mainline ropes for transport and storage

Once the loop cords have been spliced into the mainline rope, it can be coiled around the spooler and lashed tightly together for transport to the sea where it will be deployed (Figures 39, 40).

Figure 39: The mechanical rope coiler is used to coil the rope for transport and for deploying at sea

Figure 40: Coiled mainline rope ready for storage

Depending on the currents and experience at sea, the first longline should probably be designed to attach the collectors 1 m apart, and the min may be 0.75 m due to the starwheel diameter that is selected for the offshore operations. The ropes (18 mm) of the intermediate floats with counter-weights and of the compensation floats should be threaded through the loop cord, like the collectors, but must only attached directly to the mainline. This method prevents the ropes and floats to slide along the line.

These large dropper ropes are only passed through the loop cord on the mainline and attached to the mainline directly.

The loop cord prevents the dropper or float to shift along the mainline if the current is too strong or when the grapnel is used to lift the mainline to the surface.

Figure 41: Dropper rope is passed through loop cord

Figure 42 Continuous collector with short dropper is threaded through the loop cord and attached directly to the mainline

The lashing (dropper) of the collector ropes will usually have to be threaded through the loop cord on the mainline if the currents are too strong. This will definitely avoid the collectors from slipping along the tight mainline when the grapnel is used to grab the mainline at 10m depth and bring it to the surface. Experience will show how challenging this operation can be, because the collector rope will not be heavy enough to provide enough weight to tighten the knot on the mainline.

4.3.3.2 Deployment of longlines at sea

4.3.3.2.1 Role and responsibility of captain and project manager

There is one important rule to consider when hiring a ship or small boat: there is one captain, and he is responsible for the safety of the boat, his crew and how activities are carried out on the boat. The project manager is responsible for the planning, organization, and execution of the deployment of longlines, anchors and ropes from the time of loading to the final float is thrown overboard.

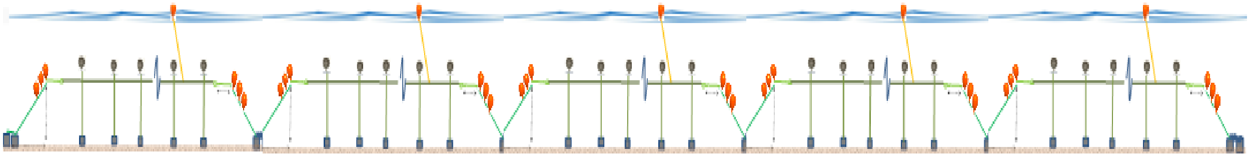
Therefore it is the responsibility of the project manager to ensure that his team is informed of their roles, and that the captain is informed of the objectives and methods of deployment, so that the captain can manage his crew. Even if the team and the crew is the same, it is imperative to maintain this approach so that the chain of command is respectful. It is up to the project manager to discuss issues with the captain and inform the captain of options at sea. Nothing will go as planned all the time. The captain should reasonably have the last decision for the safety of his boat and crew.

4.3.3.2.2 Preparing anchors and longlines using a large ship for offshore deployment

The captain is responsible for how a ship is loaded. This photo shows how a Coast Guard vessel was hired to deploy longlines. This ship is generally used to install and remove navigation buoys in open seas. Below deck it was possible to load 22 concrete blocks, 300 floats and all the rope required for deploying 3 series of 10 longlines. The deck was loaded with 11 blocks (3 tons) for deployment of 10 longlines. The longline design was based on 200 m between anchors, so the deployment from end to end covered 2km.

Figure 43 Coast Guard vessel hired to carry, prepare and deploy longlines at mussel site 4km offshore

This deployment plan occurred after 5 years in production and the lease areas were 300 hectares, which allowed for installation of each longlines series 2000 m long and 1500 m wide. The longline series were separated by a distance of 30 m for a total of 500 longlines on the lease.



It is not difficult to imagine that the Baltic coast could produce mussels and have 5 to 10 longlines in a series as shown below. The important element to consider here is the importance of planning in a structured way, and this is what this section is about. Each producer will develop their own site.

The use of this ship required careful placement of all the blocks on deck so that the longlines could be safely deployed. The captain was responsible for all operations on deck after the project manager discussed the process and planning of the lines. The depth of the 300 hectares site varied between 20 to 25 m, so all the anchor lines and unusable sections had to be cut and adjusted according to the specific geometry profile. The site depth (bathymetry) was verified on site with the local charts. Note that tidal variations had to be taken into account, by designing the geometry for lowest tides. This will not be necessary in the Baltic Sea where tidal variations are minimal.

All the lines were CAREFULLY attached to each block, with all the corner buoys, and marker buoys, in the sequence that the blocks would be dropped at sea. This took 2 hours of careful work.

Figure 44 Transporting and preparing the concrete anchors and longline ropes loaded onto a 60m ship

For each longline, the pre-measured coiled ropes (yellow) of the anchor lines and mainline are spooled onto a bobbin so it is be easily uncoil without tangling. The marker floats (dark blue) and the lines are carefully coiled on top of each block. These serve to indicate the depth of the yellow corner buoys as the longline is stretched between the anchors as the boat is continually moving forward at 2-3 knots.

All the ropes are laid down onto the deck near the crane, on the same side as where the anchors will be deposited in the sea.

The corner buoys (yellow) are attached to each of the pre-determined positions on the longline of the anchor lines and ready to be picked up by hand as the block is lowered on the side of the hull of the ship. Notice that different colour buoys were used for corner buoys and marker floats to increase security and avoid costly mistakes at sea.

Figure 45 Preparation of longlines for deployment with big ship

4.3.3.2.3 Deployment of anchors and longlines using a large ship to tighten lines

The anchors are loaded onto the ship and all the anchor ropes and corner buoys are attached to the mainline on board. The continuous deployment works ONLY because the ship is powerful enough to advance at 2-3 knots, and able to sink the corner buoys as it pulls the longline to maintain tension as it lowers the anchor. A smaller boat could not keep the anchors 200m apart and sink the corner buoys simultaneously. A small boat can tension the longline after the anchor is dropped on bottom.

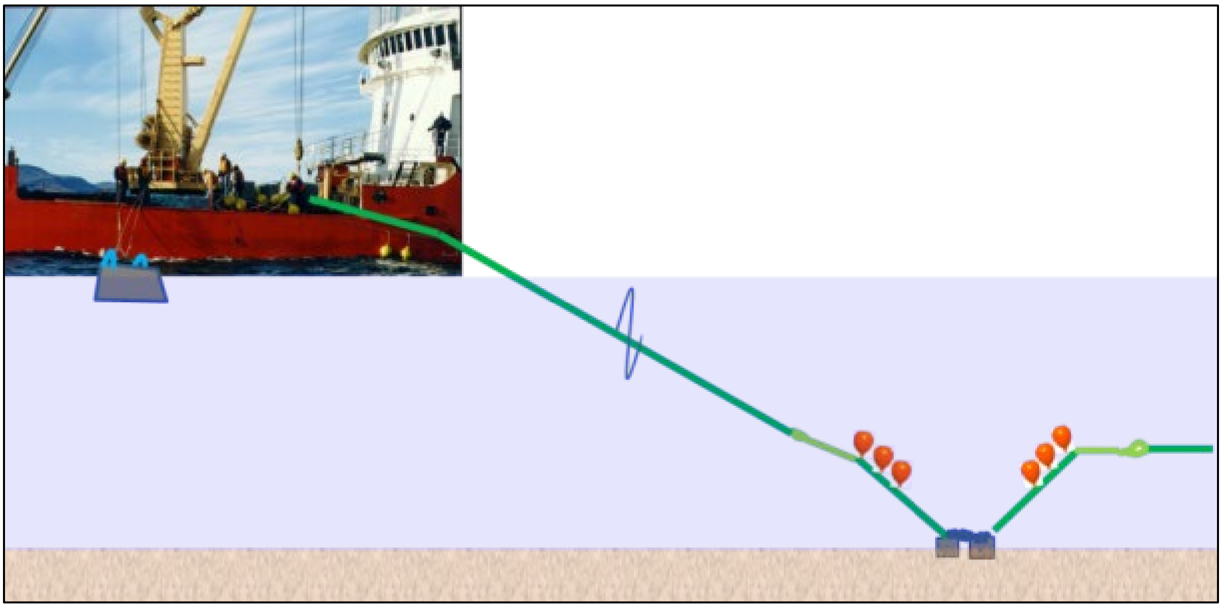


Figure 46 Deployment of the concrete anchors in a longline series from a big ship able to move 3 tons anchor

The longlines are deployed from one end to the other in a continuous process. On this large ship, 11 blocks of 3 tons were used for 10 longlines of 200m between anchors with mainline submerged at 10m (Figure 46). The longlines are installed parallel to the dominant winds, which were alongshore. Longlines are installed in 20m depth and separated in parallel series by 30m distance.

4.3.3.2.4 Quick release system for heavy anchors on board ship

On small boats one can use a sacrificial rope, but on larger ships, it is important to safely release the anchor to retrieve the quick-release system for another anchor deployment in 3 step process:

The crane is permanently attached to the 'shackle' of the quick-release at top. [A] is the pull cord. The cable cord [B] joins the quick-release to the anchor cord [C], which is loose enough to hold both loops.

[A] The crewman snaps the pull cord [B] to release the cable cord [B-2], while [B-1] remains attached to the quick-release. The block is so heavy that [B-2] slips through the anchor cord [C].

The 18mm anchor cord [C] drops to the bottom with the anchor but does not affect the 2 anchor ropes that will rise to the corner buoys. The block sinks.

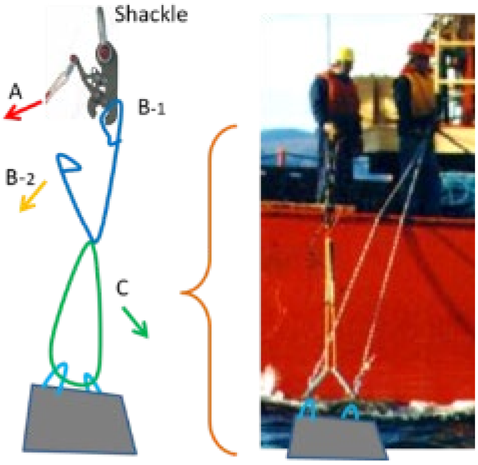


Figure 47 Anchoring

4.3.3.2.5 Crew responsibility while deploying longlines non-stop at sea

To ensure coordinated action on the ship 8 people are involved to safely deploy the longline.

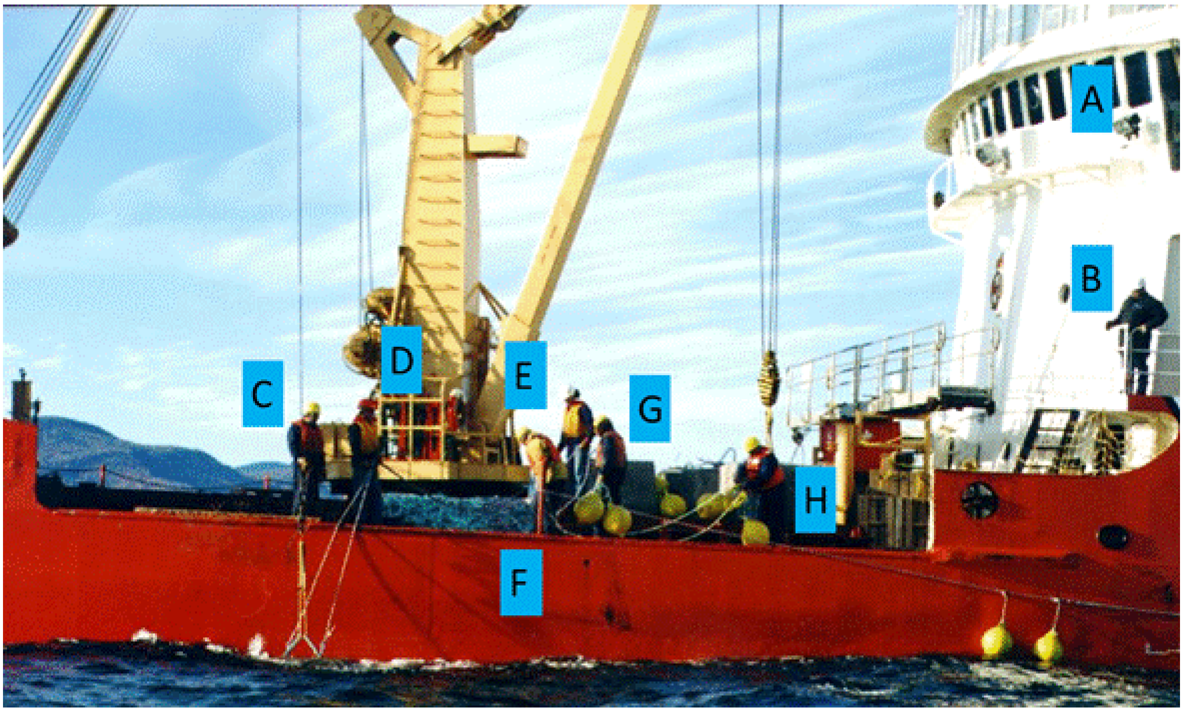


Figure 48 Deployment of the concrete anchors in a longline series from a big ship able to move 3 tons anchor

The captain **(A)** is navigating the ship in the direction facing the predominant wind and receiving information from the 1st mate **(B)**, who is overseeing how the longline is being deployed.

- One crew member **(C)** is holding the quick-release cord near the crane-wire, because the crane is keeping the anchor block leaning against the hull of the ship so it does not bang against the hull in the waves while it is moving forward at 3-4 knots.
- Crewman **(D)** is keeping tension on the two anchor ropes that are attached to the concrete block because behind him they are carefully piled on deck AWAY from everyone's feet.
- Crewman **(E)** is overseeing the feeding of the mainline of the longline to crewman **(F)** who is guiding the mainline around the post as the longline is maintained under tension while the ship is moving forward into the wind. We can see that the block (at left of image) has already hit bottom in 20m depth and that the corner buoys are already been thrown overboard. The remaining 160m of mainline is now being deployed.
- Crewman **(G)** is holding the 2 corner buoys for the other anchor that is presently being held on the side of the hull.
- Crewman **(H)** is holding marker floats with 10m long ropes so everyone can see that the longline is geometrically stable at 10m from the surface from anchor to anchor. Because there is 10m of rope between the mainline and the marker floats, there is enough safety time to throw them overboard as that section of the mainline passes by him.
- When the longline reaches the anchor on the hull, the boat continues forward under tension until all marker floats start sinking, then on command, crewman **(C)** pulls the quick-release to let the anchor sink to the bottom. Then the next longline is prepared without stopping process.

4.3.4 Alternative methods for deploying concrete blocks using small boats

4.3.4.1 Transport for single small craft

The deployment of heavy dead-weight anchors using a smaller inshore boat may look complex at first site, but experienced boat captains are well suited to understand the required safety issues and how to organize the logistics, so the boat remains stable. This method was used extensively in Quebec open waters when the wind and current conditions were safe to operate. The 3 tons blocks were transported under the hull at 3 knots for 1 hour to the mussel site.

Step 1: When ready to install the lines at sea, attach one or two anchors on each side of the boat by lowering them by the dock with a crane or forklift, and attach them to the boat. Since there is no tide it may require more planning to move the blocks from the shore in deep water. Once attached, slowly cast away and drag the anchors to deeper water to the mussel site and drop them into position. It is wise to prepare the location that each anchor should be on the site.

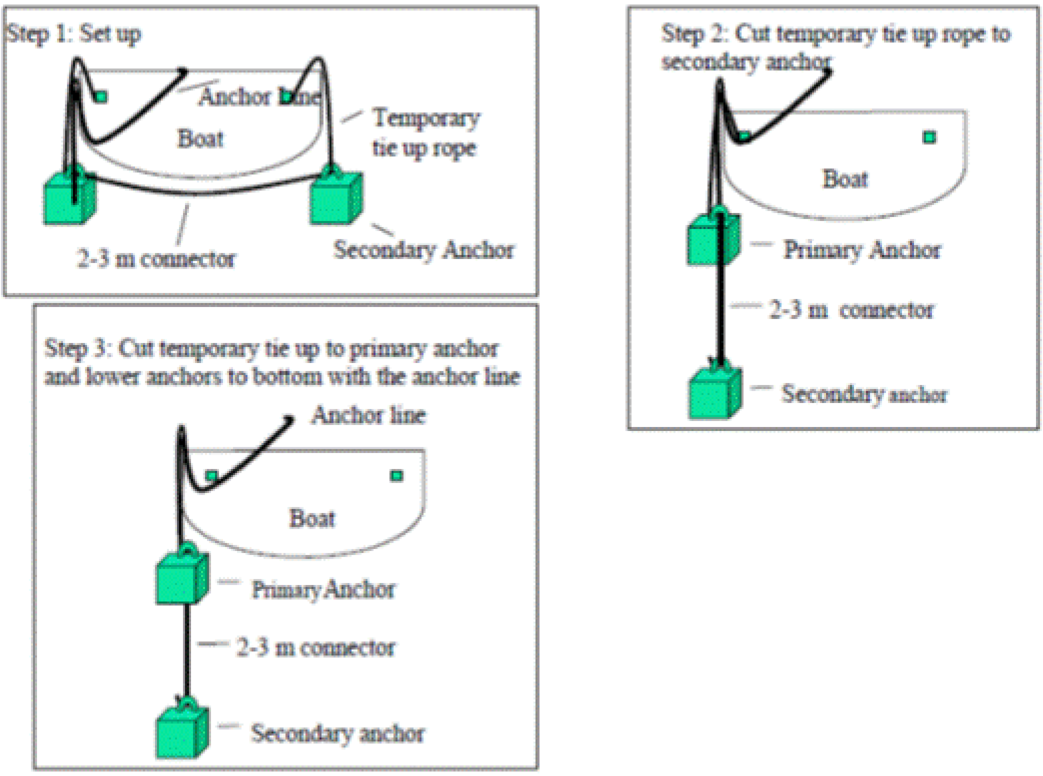


Figure 49 Concrete anchors deployment method for small water craft

This image (Figure 49) was copied from the Aquabest technical manual 2013, authored by Bonardelli.

Step 2: Before transporting the anchor blocks to the site, attach the pre-measured anchor line to the anchor loops. Because the depth of the water at the site will be 20 m, and the corner buoys are designed to be attached at 16 m, it will be necessary to attach them before dropping the anchor. The loop of the unusable section is floating at the surface so it is not necessary to attach the mainline until all the blocks are installed and ready to assemble. Then you will need to tension the line with a boat.

4.3.4.2 Dropping the anchor blocks and anchor line in position on site

The team was careful to mark the position and distance between anchors (180 m) where the anchors should be dropped on the site with a small marker float. Once the anchors and corner buoys have been dropped at the right location, the floating anchor lines can be identified with a small marker float at the end of the unusable section, for boat safety.

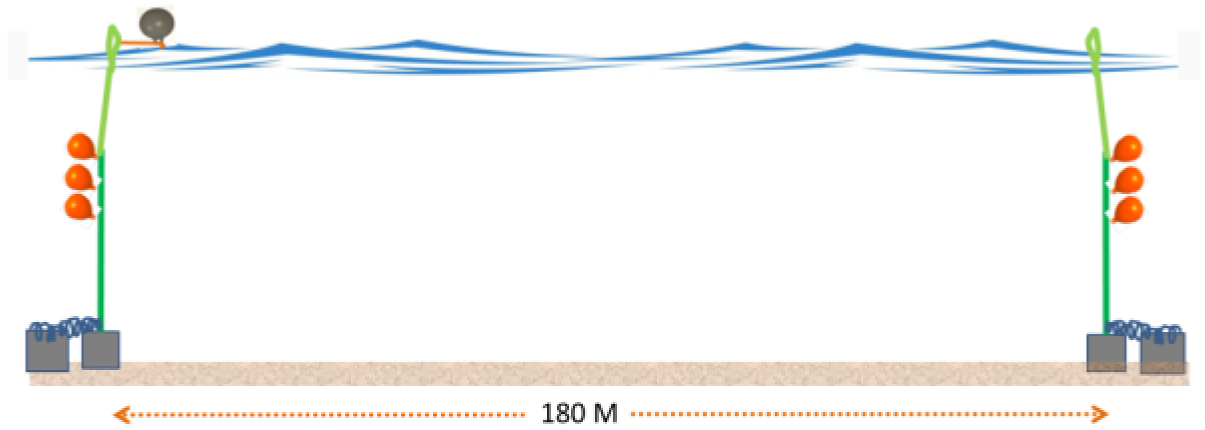


Figure 50 Dropping anchors

4.3.4.3 *Tightening the longline with winch from the small boat*

The crew attaches the mainline at to both ends of the unusable section. It may be necessary to add an extra length of temporary rope to join both ends together. The crew must grab the mainline that is drifting downwind and connect to the upwind side of the longline unusable section (left of image – Figure 51). The wind is pushing the stern of the boat to the downwind side (to the right of image – Figure 51).

The loop of the unusable section should be secure (on the gunnel at the stern of the boat (left side of boat image), and there should be 2 m of lose rope hanging inside the boat to join the tensioned line.

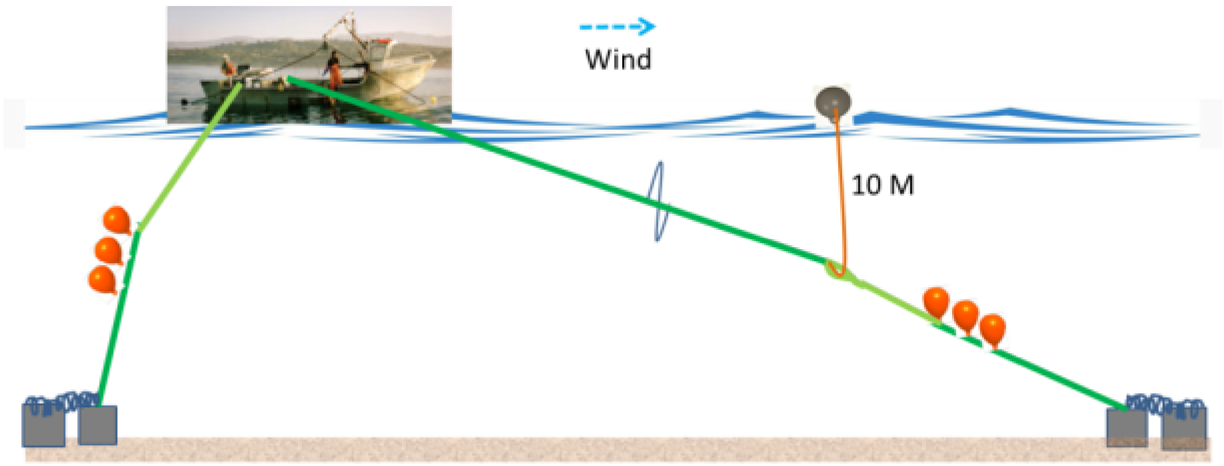


Figure 51 Tightening the longline

Tightening the longline can be an impossible task if the boat does not have a strong winch on deck. The crew starts hauling the loose mainline that is downwind and pull it as tight as possible manually, then start using the winch to pull in the mainline. The mainline is hauled through the winch, which moves the boat forward. You can see the corner buoys sinking at the other extremity. Stop when the 10 m long marker float begins to sink, (tied to unusable loop at the other end of the line). This entire operation can take an hour at best. Secure both ends and have enough rope pulled through the winch so you can attach both loose ends together (mainline right to the loop on left).

4.3.5 Navigation spar buoys - for marking site corners

The marker-buoys should be visible and provide a clear indication about where the lease area is located. This can be especially true when boating activities and fishing is seasonal. However, before winter appears in the Southern Baltic region these marker-buoys and anchors must be removed. The grower must be able to carry out this activity from his boat in the course of operating the farm.

The whole purpose of having navigation marker buoys is to indicate where the hazard is located (the aquaculture site). These conditions can be met with the right equipment. If the farm site is larger, the navigation buoys can be placed after every ~300 m. This navigation strategy should be well advertised to the local fishermen especially, because it is highly likely that they will damage their gear with the heavy 2.5 tons anchors and submerged longlines.

Here is an example for identifying mussel sites with yellow spar navigation floats and also for identifying navigation channels with red and green spar buoys in Canada (see Figure 52).

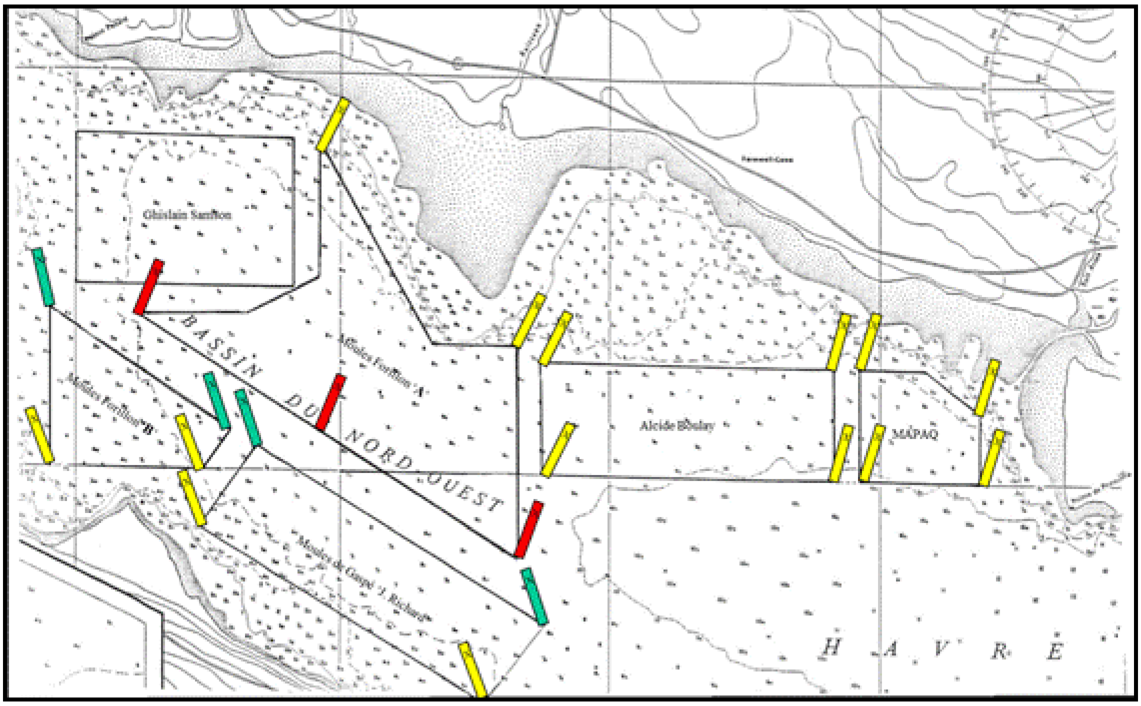


Figure 52 Example of identifying mussel sites with easily handled and anchored spar navigation buoys

The best example of spar and easy-to-handle navigation buoys (Figure 53) that are used in shellfish culture. These can be installed and removed rapidly. They are 2 m tall and designed to be vertically stable 2/3 out of the water. There is a radar reflector inside the tube at the top, and one can purchase and install a solar-powered light on top. Ballast is obtained by heavy chain and the spar buoys are easy to anchor and remove with a winch.

Figure 53 Coloured spar buoys for marking aquaculture sites

4.3.6 Tightening of longline and attaching intermediate floats

Once the longline is submerged, go over the site with the sounder. Use the grapnel with a crane to lift and lower the long line into the water. Let it sink and retrieve the grapnel when the line is stabilised. Readjust the main line if the main line depth is above 9m or below 12 m.

Figure 54 Longline visualisation in echo sounder

An Echo sounder image (Figure 54) showing the 1 m^3 deadweight concrete block (lower right), the two 35L corner floats and the longline geometry in 24.4 m depth set 10 m below surface.

The sounder should be used to regularly verify the submerged longline depth during the season.

If the longline looks ok, in the next few days you should prepare the intermediate floats and counter-weights. When ready, attach them along the main line at even distance around 30 m apart. You will be able to measure exactly the usable mainline length by counting the loops from one end till the other, which are tied 1 m apart. Then you can evenly space the intermediate weights. Work facing the wind.

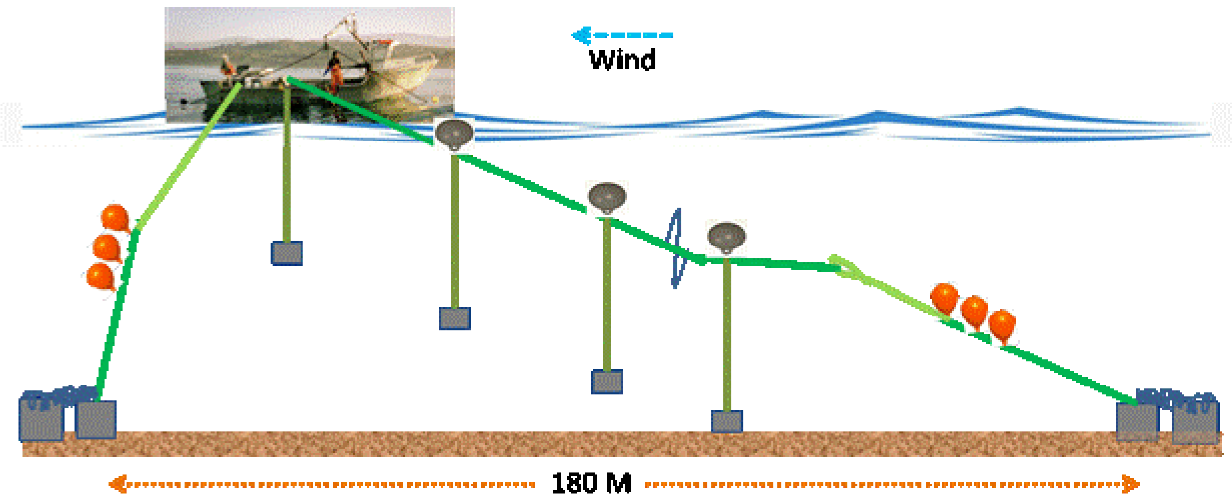


Figure 55 Longline

4.3.7 Discussion on use of surface floats (e.g. 40 litres) to identify mainline

The use of **surface floats** (e.g. 40 litres) to identify mainline in summer or during the fishing season can be recommended if there is no fishermen using them as anchor points. Otherwise it is best not to mark the lines. In fact it is not necessary because you can always locate lines with the sounder.

It's possible to add small surface floats to the mainline to identify or mark it, but they should be removed in winter. E.g. depending on the local current if the line is 10 m deep the surface float would have max 12 – 15 m of 12-18 mm rope. They could preferably be installed at one or both ends of the mainline.

4.3.8 Installation & removal of collector ropes

Once the mainline is submerged and has been adjusted to the right depth at 10m, the longline is ready for attaching collectors.

Decide on the collector material and length (weighted x-mas tree rope). Note that you need to have a method to measure the vertical length of rope loop between each attachment point on the longline. It is simple to build a mechanical wheel and counter (figure 56), or use a manual measurement.

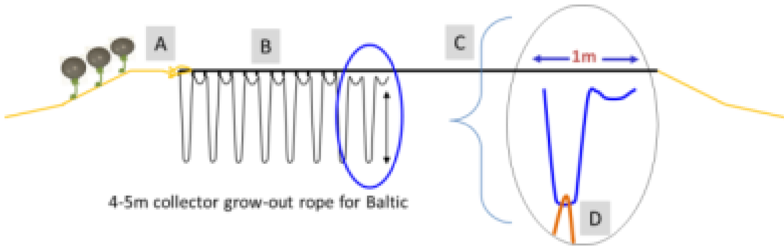
Figure 56 Hand-made mechanical wheel with a counter to measure collector rope length

E.g. if the vertical length is 5 m the total collector section between beeps of the counter will be 2x5 m long loop +1 m bottom half loop+1 m short loop = 12 m.

4.3.8.1 Discussion on installing collectors

- ✓ Prepare the equipment on the boat to be efficient in the deploying the collectors.
- ✓ It is really good practice to wet or immerse the collector rope in the water or in a container to remove air bubbles. Then it will sink rapidly and not tangle at the surface before sinking.
    - In the first year it may take an 8-hour day to attach all the 5 m long collectors on one line with 150 droppers. An experienced crew will complete this in one hour. Therefore, there is learning process to be efficient.
- ✓ When the job is finished, unhook the long line from the star-wheels with the crane, lower the longline SLOWLY using the crane winch and the grapnel until it reaches submerged depth level.
- ✓ It is extremely important to lower the longline slowly so the collectors sink before the longline does, without getting tangled.
- ✓ Collector rope should be stored in the large bag to avoid tangling.

- ✓ In the case where currents are strong it will be important to use weighted Christmas tree rope or add a weight at each loop.



It may be advisable to test the addition of 2-3 kg armature bent into a V-shape on each long-loop of the collector during installation to make them sink if currents are strong to avoid collectors twisting.

4.4 Technological solutions: boats, access to harbour, truck, production volume

4.4.1 The boat requirements and longline flexibility

To lift these submerged lines from 5-10 m below surface requires a boat with a crane, and a strong winch to haul up the line due to the rather high tension. The boat will need to be above 10-12 meters in length and be stable in 1-meter waves. The boat (fiberglass with steel or wood core structure) must act like a platform when stopped to work on the longline. The boat might be in aluminium but a catamaran is recommended in this case, for more stability.

It is important to get to the mussel site rapidly, which a mono-haul fishing boat is designed to do. But the boat must mostly be designed to be a stable platform when attach to the longline. This is why many fishing boats are not always useful for mussel culture. In general, you need work space on the boat on the min area of 9x4 m.

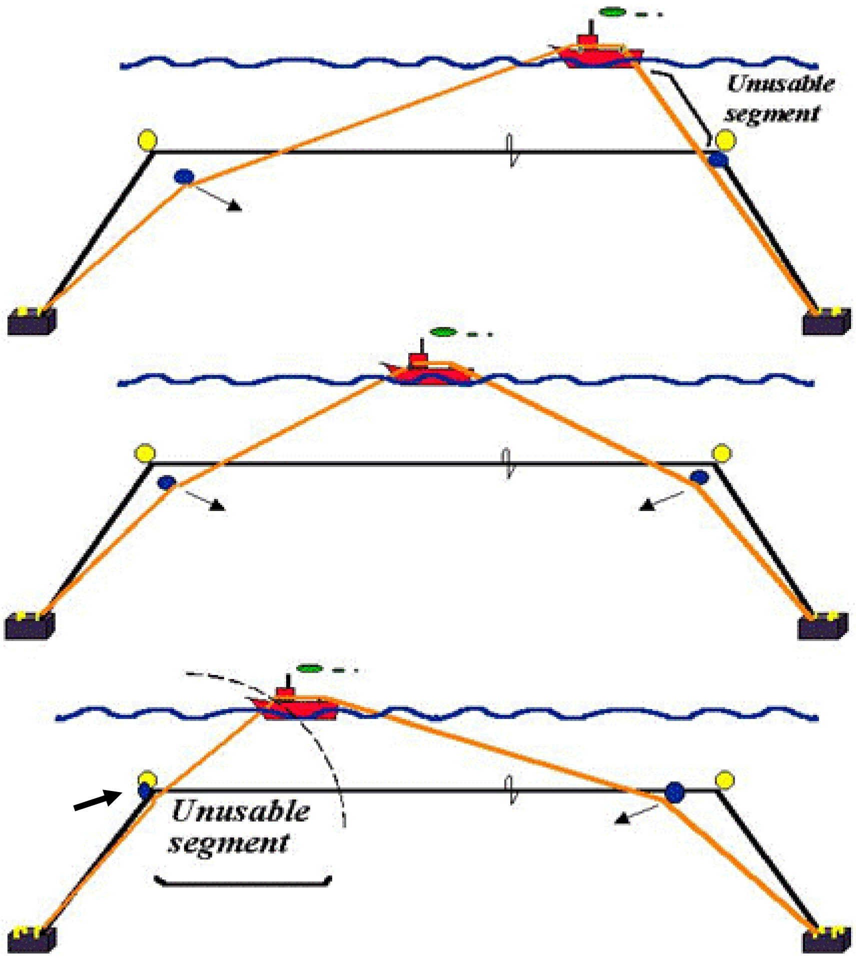


Figure 57 Flexibility of a submerged longline at the surface (J.Bonardelli)

Sequential change in geometry of a submerged longline with good structural tension as it is maneuvered from the surface with the boat. Arrow (Figure 57) indicates displacement of the corner buoys as the geometry of the longline changes. The length of the unusable segment depends on the depth of the mainline from the surface when horizontal. The relation between Flexibility and Tension are inherent in a dynamic longline.

4.4.1.1 Boat essential equipment

The hydraulic crane with the winch on the one side (Figure 58), is an essential component to boat safety, longline manipulation and crew efficiency at sea in difficult weather.

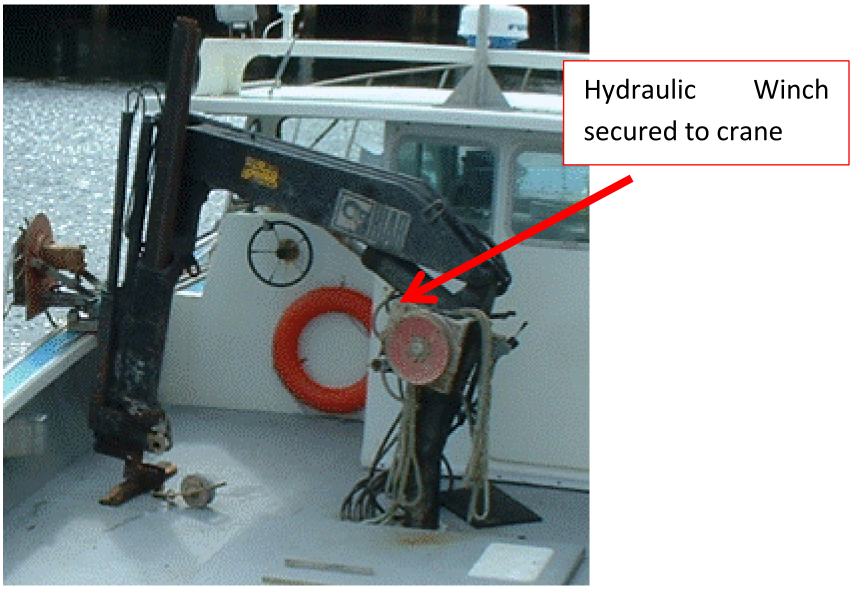


Figure 58 Hydraulic crane with the winch and controls

The best location for the crane is in the centre and up-front behind the cabin so it is not taking up space on deck.

4.4.1.2 A mussel boat with starwheels

Ideally the mussel workboat should have 2 starwheels at each end of the work platform. The forward starwheel should be hydraulic, and not free flowing.

Figure 59: Starwheel set up on a mussel workboat

Figure 60 Hydraulic starwheel set up

4.4.1.3 Hydraulic accessories on the workboat

- ✓ You need a hydraulic outlet for declumping machine, conveyor elevator and washing machine
- ✓ The min size of boat is 10 meters with the flat bottom at the back and the minimal cabin
- ✓ The boat should be able to go at least 9 knots and have enough power to run the hydraulics in continuous mode while anchored to the longline with the motor running full time.

4.4.1.4 Do I need a truck?

It’s recommended to have a pickup truck to carry equipment from the storage house to the harbour. There should be a trailer hitch to move floats and light equipment, as well as the counter-weights and all the rope and tools.

4.4.1.5 Rapid access to harbour

If you don't have a harbour, it is difficult to do mussel farming and ideally the site lies within an hour boat distance from the shore facilities. You need the harbour to store and move material, to transport equipment with a truck and to safely secure the boat.

Wind is always a safety factor to escape from in mussel culture. The safety of the crew is important. The longline is designed so the boat can work safely and if necessary, the line can be released in several minutes. This safety feature is based on the boat having a crane and winch for all heavy lifting. The longline will sink to the proper depth without being at risk of being damaged.

4.4.1.6 Production scenario for producing 20 tons of mussel annually in Latvia

Due to the slow growth of mussel in the Baltic Sea it is estimated that a size of 20-25 mm will be reached after 2 years. If the settlement is in June, this means one production cycle includes approximately 2 summers and 2 winter periods.

4.4.1.6.1 1. Scenario - June settlement

That means if you plan to put 10 lines in the sea, in the year one and in the year two you put 10 lines each year, and in year 3 you need 10 lines again to start production because the 10 lines from the 1st year are not available.

4.4.1.6.2 2. Scenario - September settlement

The settlement in the September you put the lines in the September of 1st year and you can harvest them 2 years later before September. The 2nd year you put another 10 lines, and you harvest 2 years later before settlement September.

4.4.1.6.3 3. Scenario – June and September settlement

You have settlement from June and September, this will impact the growth cycle and density of mussels on collectors. It is important that this information has been researched.

4.4.1.6.4 How the site could look like for harvesting 20 tons of mussel annually

- Lines are 180m long between anchors.
- Producing est. 2 tons of mussels per longline with longlines 30 m apart in 20 m water.
- You need site of the area 200m x 1000 m.
- In the scenario 2 you need 30% less of area.

This size farm justifies 10-15 m mussel work boat, excluding market value of mussel.

Comparison to Denmark or Canada mussel farm, reaching the length of 60 mm commercial size, they would produce 150 tons, at the same space, ropes, the only difference is in volume.

4.5 Methods for winterizing submerged longlines, recovery in spring, maintenance and upkeep

Remove all surface floats and corner markers before ice conditions will appear or when it is no longer possible to access the site due to the autumn and winter storms.

The boat should use an echo sounder or sonar to go over the lines, document the depth and make sure there is enough flotation to compensate the growth for next 5-6 months. It is possible with experience that 4 compensation floats with 80 kg anchors distributed on the mainline for overwintering could be sufficient. This represents 4 floats x 40 kg x 4 (25% mussel mass in water) = 650 kg extra buoyancy for overwintering in the Baltic.

Even it is not possible to lift or handle the long line to the surface it is recommended to make inventory with the sonar when possible through the winter season.

If the submerged longlines are not visible from the surface, because the surface floats have been removed during winter to avoid severe storms or drift ice, the lines can be found using an echo sounder or a side-scan sonar.

Figure 61 An Echo sounder image of 1 cubic meter deadweight concrete block (lower right), 2 35L corner floats and the longline geometry in 24.4 m depth set 10m below surface.

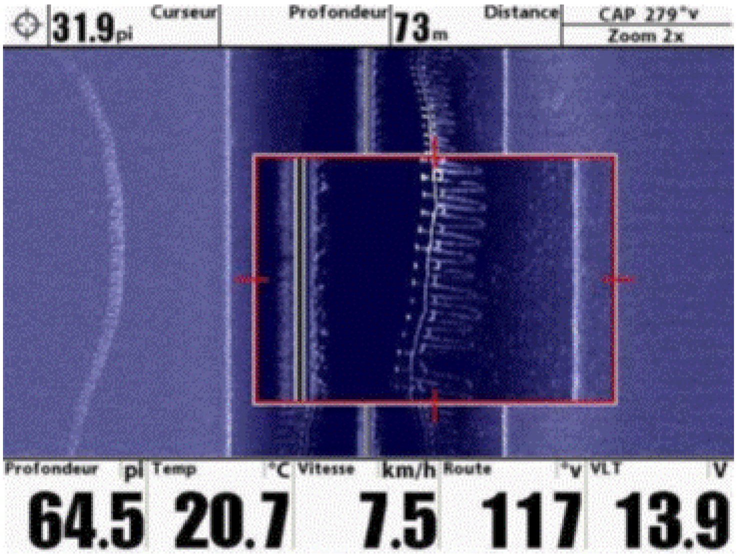


Figure 62 Top image of side-scan sonar of mussel socks on line. This image shows the individual mussel socks as the boat is driving above the submerged longline at 10m below surface. It is possible to see the long and short loops of the continuous mussel ropes ha

Proper inventory control is your best management tool if compensation is required through legal means if the site is destroyed by negligence. Researchers or support teams should document growth, longline stability and fouling on all material on a regular basis through the production cycle.

The object is to produce commercially viable mussels. It is necessary to ensure that the longline is stable and under tension through the growing period.

4.6 Harvesting methods, harvest objectives & mussel quality needs

Harvesting the collector ropes after two years is easier than installing them. This is especially truth when the collector ropes are continuous in one long piece (not vertical individual ropes). Once the boat is attached to the longline with the starwheels and stable the boat should move to one end of the line or to the end of the line facing the wind.

4.6.1 Equipment for harvesting the collector ropes

A sharp Knife to cut rope and the droppers is always essential on a workboat.

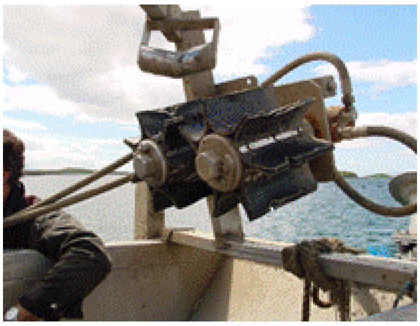
There are so many different models of conveyor ramps, which are useful in offshore sites to slide the collector rope up unto the boat. The ramp prevents the waves from knocking the mussels off the rope as they come on to the boat. The ramp model shown here is for an inshore boat. The top of the ramp shows a hydraulic hauler and stripper to remove the mussels from the collector rope.

Figure 63 Work on farm

The hauling and stripping machine is one unit: the hauler is positioned after the stripper and pulls the collector rope from the sea into the collector bag

Figure 64 Stripper

The stripper (Fig. 64) can be pair of hydraulic brushes or of fixed rubber panels that strip the mussels off the rope. The tension of the collector rope is maintained by the pulling of the hauler and the person controlling the rope to maintain the tension. It is a simple process when the equipment is in front of you.



A large plastic bag or container is useful and should be placed under the stripper (left image Fig. 64) to catch the mussels falling from the rope as they are stripped off on the boat. Bag collecting the empty collector rope is under the hauler winch and kept open by a frame.

4.6.1.1 Harvesting process

Starting at one end of the line that is downstream from the wind, it is easier to allow the boat to harvest when the line is constantly under tension using the hydraulic starwheel at the front of the boat to propel the boat forward. It is rarely necessary to move on the longline using boat propeller.

1. Grab the end of the collector rope and cut the first droppers so you can bring the submerged rope over the conveyor ramp.
2. Thread the collector rope through the stripper and the hauler and start slowly to pull the collector rope.
3. Once the stripping is going on you move the boat forward, cut the droppers (in a stop and go process).
4. It's critical to make sure the collectors are not dragged under the boat with the current. However, since you are moving forward into the wind and up the mainline, there should not be collectors near the propeller because they are being lifted or taken out of the water at the front of the boat.
5. When the mussel container is full, move it with the crane and put the new one.
6. If the harvest takes place during the summertime and hot weather, it is important to plan for carrying enough ice in the insulated fish box on the boat and using this to put layers of ice and mussels in the container to keep the mussels cold and alive until processing will occur.
7. If the line is not empty, cut the collector line and slowly drop the longline in position before leaving the site so you can continue the next day.
8. Last thing to do is to use the sonar and go over the longline to make sure it is stable and at the right depth (quality control).

Note: If compensation buoys where added to the mainline during the second year because the mussels were growing so well, all of those individual floats should be removed while harvesting the collectors. The 40 litre floats with the intermediate weights (80 kg) should remain on the line.

4.6.1.2 When to harvest

The best time to harvest is when there is demand for the product. It is important that mussels are maintained at the right temperature throughout the cold chain.

Normally we expect the Baltic mussel to be harvested when there is a maximum amount of meat for the size of mussel selected. In this case it should be before the spring spawning or the autumn spawning, and this will be determined by monitoring the reproductive cycle and the Gonadal index as well as the cooked meat volume.

Obviously, there should be class A classification before harvesting and both water and mussels must be without toxic algae. The harvest of mussels in the Baltic Sea cannot be done in August due to strong blooms of cyanobacteria.

5 Proposals for implementation of mussel production

5.1 Logistic solutions from land to sea, limiting operational factors

5.1.1 Preparation for going to sea (land to sea)

Rule No.1. Bring fresh water and food on the boat because you never know when you are stuck at sea.

Rule No.2. Be sure you have fuel; your filters are clean and purged.

Rule No.3. Always have extra rope, compensation floats and extra grapnel, and some knives on the boat, also life vests, bandages.

Rule No.4. Always have a logbook with you on the boat.

Plan what you are going to do (installing collectors, maintaining, sampling, harvesting, and preparing the line for the next production, winterizing, spring maintenance).

Installing the collectors – plan for the sufficient bundles of droppers for a day and a half to work; the collector rope in bags, collector weights if necessary in plastic boxes, and the mechanised equipment to do the job.

Maintaining – following the rule No.3 always go over the lines with the sonar and document the condition of each line in the logbook (date, weather conditions, depth etc.). Check that the collector ropes are not tangled and the compensation floats and ropes are in good condition and not missing, also verify the marker-buoys are in place.

Sampling of the mussels on the farm for each longline allows managers to keep a proper inventory of production volume, and to document changes in the reproductive cycle. This is the most important tool for determining when to install collectors on the line. A proper sampling protocol should be conducted monthly if possible by collecting 30 cm of mussels at 1 m down from the collector rope. Once the longline is lifted unto the boat; prepare sample bags and document clearly on the bag: the sampling date, sample size, position on the line and bring insulated container to bring samples from each line to shore.

Harvesting – prepare the machinery and position on the boat, so they are safely secured, check all the equipment required for harvesting, transporting and storing the mussels including enough ice for maintaining quality especially during the hot period;

Preparing the line for the next production – once the collectors have been removed the mainline should be cleaned by removing all the dropper pieces, care should be taken when using a knife to not cut the mainline or loop ropes; make sure you readjust the proper number of intermediate floats and weights for the next production; check the corner-floats and ropes.

Winterizing – basically its going over the lines with sonar, documenting the condition and depth, and adding compensation floats if necessary to the mussel lines; it is likely necessary to remove all marker spar-buoys from the site and storing them on land; check the ropes and anchors for damage; remove the batteries from the lights on the spar-buoys till the next spring.

Spring maintenance – the conditions may not be safe to work directly on the mussel lines, but once the ice is gone the first thing is to reinstall the marker spar-buoys on the site and use a sonar to check all the lines.

5.1.2 Limiting operational factors

The safety of the mussels when working on the line at the surface is really what determines when you install collector or/and harvest at sea. High winds cause big waves and put the boat and crew in danger.

For safety reasons the boat should not operate when the waves make it dangerous to use the crane on the boat.

5.2 Production calendar, human resources

Once we have knowledge about the local production cycle, the change in meat yield over time per each site then it will be important to establish local production calendars. The purpose of the production calendar is to forecast what equipment and human resources are required from season to season. This process also includes planning on how many lines will be installed each year, how many new collector ropes are needed based on the depth and number of new lines, floatation, as well as requirement for new equipment and material purchases (note: delivery time is important in the planning process, especially for international orders).

Note: this is one of the rare businesses where a technical person can include both men and women to work on the boat because it's designed with safety and efficiency in all steps of production.

The installation of collectors is often a period that requires extra labour on the boat especially when the production scales up because of the short settlement window at the sea.

It is recommended to look for availability of second hand machinery overseas.

5.3 Traceability, sampling protocols to optimize production, impact of depth on growth, shell, meat yield

5.3.1 Measurement standards

5.3.1.1 Standards for comparison between sites

- ✓ Determine the amount of Kg /m collector and the density of mussels /m (Figure 66).
- ✓ Calculate the total meters collector/m longline (varies if vertical or continuous), and with the rope type (Swedish band, Xmas tree, fuzzy rope) or nets - all measurement styles should lead to total Kg/m line.
- ✓ The meat yield (Figure 65) is a measure of the available meat for nutritional value, which includes both reproductive and somatic tissue.

Figure 65 Meat content

5.3.1.2 Mussel density

Mussel density on a rope will decrease in number as the mussels grow in size and take up more space. From this graphics (Figure 66) we can see that the estimated density of 40mm mussels at harvest on a standard Xmas tree rope will be about 800-1000 spat per meter rope.

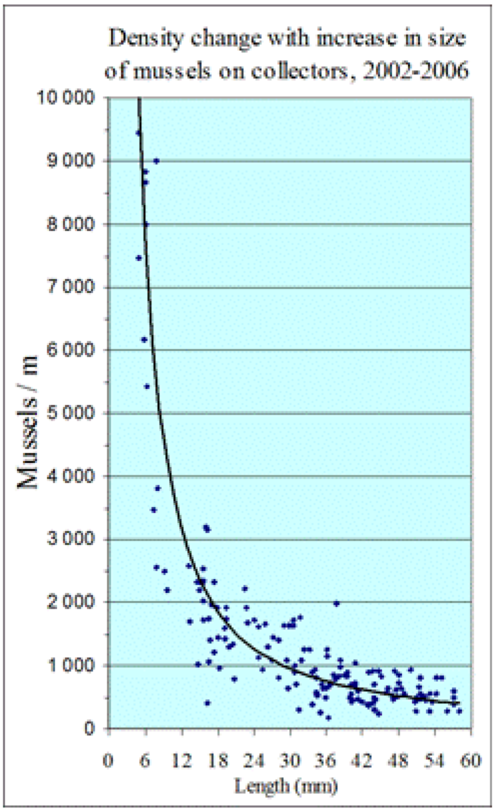


Figure 66: Size range of mussel/m of collector rope shown as a size and density plot.

5.3.2 Traceability of lines

Every longline should be numbered in a standard code that contain this information: site name/ line number/line section/ (e.g. PAV-03-A). Every longline should be divided in 3 sections – A, B, C. This is so that when you start and end harvest this is documented in the production logbook (see Table 1).

Table 1: The example of production logbook

Start Date	Start Time	End time	Line code	m/m	Activity	meters	Comment
12-jun-18	10:00		PAV-03-A	12	install coll	0	x-mas
12-jun-18		14:30	PAV-03-C	12	Install coll	1380	Stop weather
14-jun-18	09:00	10:30	PAV-03-C	12	Install coll	820	complete
30-aug-18	06:00	09:00	PAV-06	12	harvest	2200	complete

5.3.3 Scaling up

In the start-up phase some of the decisions and equipment are based on evaluating what is happening biologically and physically on the site. It is acceptable to spend a little more time doing things manually before buying more expensive equipment. Smart growers will buy second hand equipment so they can gain knowledge about what is needs for their location (the type of boat, harvesting equipment). Local conditions will have a big impact in determining growth, wave conditions, current conditions at 10 m, and how the long line reacts with and within the boat. There is no point of having everything until know what we need for Latvian waters.

A smart approach is to start a small production with methods that are known to work in this exposed environment and over time the grower will be able to define the amount of floats to use over production cycle, distance between collectors and how to manage the site from season to season. Lastly, it includes understanding the biology and production cycle in order to establish a production calendar.

When these pictures are known then you can plan scaling up with more lines, a better boat and more appropriate harvesting equipment and mechanisation. Scaling up to commercial production is not wise when the country is on pioneer stage.

5.4 Solutions to build a production management strategy

Comment: Positioning of anchors in open sea deep water (more than 15 m) it is extremely difficult especially when wind and currents are strong. It is possible that anchors shift or are displaced by fishing boats and will have to be repositioned during the course of production therefore the grower must be capable to operate the farm within the lease area without being hindered by regulations and obstacles irrelevant to the mandate of grower.

Success to the scaling up in any country has been a cooperation between researchers, who accompany the growers in the first stages of production, and this includes government technical support and financing.

While offshore aquaculture occupies a lease area in the public domain the environmental impact and finfish and shellfish are very different. It is as different as intensive agriculture where fertilizers and manure spreading is involved compared to forestry management where trees are planted and left it grown on the land.

Finfish culture is intensive aquaculture, while shellfish aquaculture is extensive with low impact and lower daily investment. For example, a fish farm will occupy 1 ha to produce 20 tons of fish, whereas mussel production will produce 2 tons over 2 years.

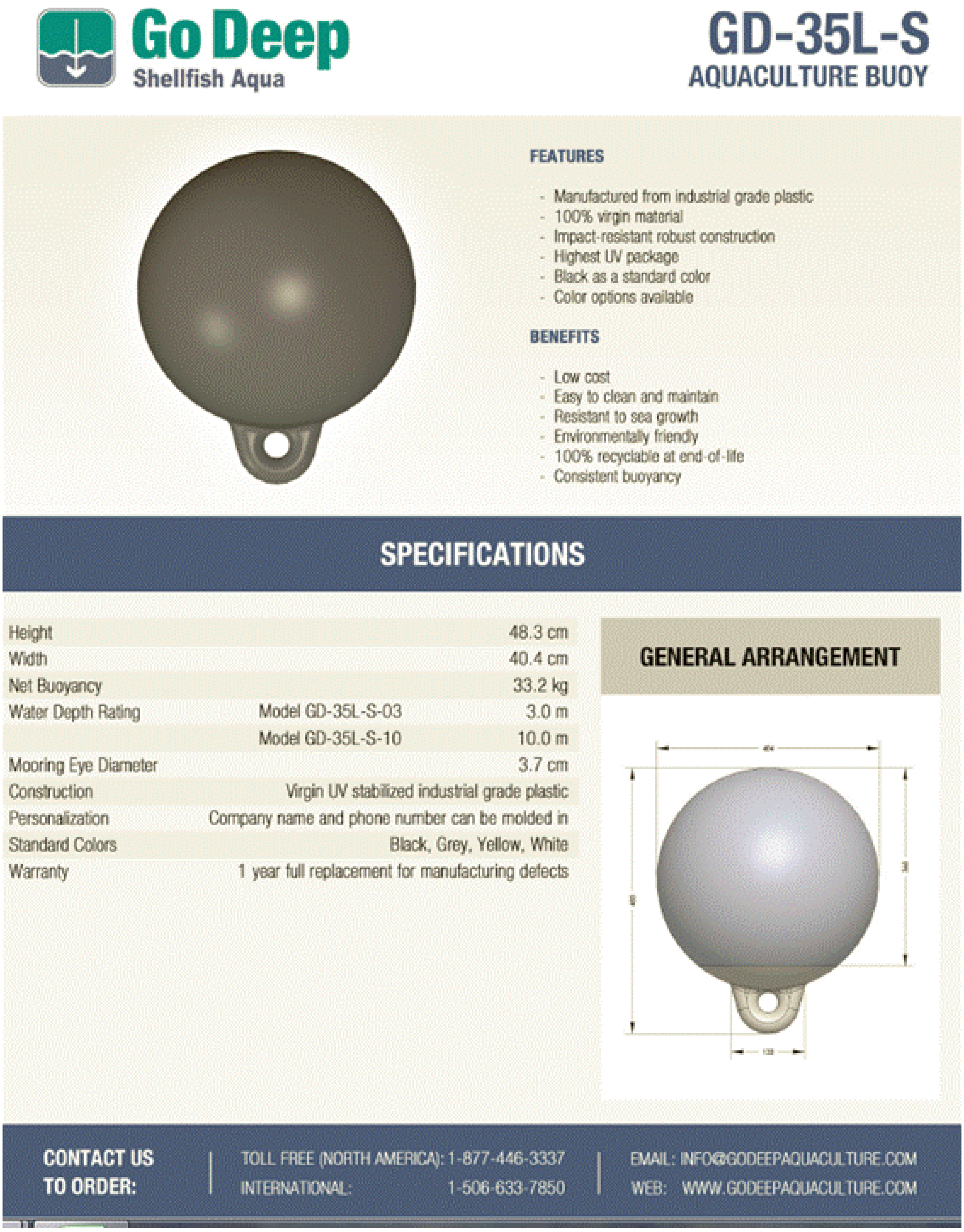
Usually shellfish culture operation and long line infrastructure remain in place on a long-term basis compare to finfish cages which are removed, so fish waste can be washed away to avoid anoxic bottom. This is not necessary for mussel production in offshore environment with currents.

6 Annexes

ANNEX No.1- Floats

Compensation floats 35-40 Litres with Rating for submerged depth to 10 m

1) GODEEP brand Canada 35 Litre float submerged depth 10 m - Net Buoyancy 33 kg



Go Deep Shellfish Aqua

GD-35L-S
AQUACULTURE BUOY

FEATURES

- Manufactured from industrial grade plastic
- 100% virgin material
- Impact-resistant robust construction
- Highest UV package
- Black as a standard color
- Color options available

BENEFITS

- Low cost
- Easy to clean and maintain
- Resistant to sea growth
- Environmentally friendly
- 100% recyclable at end-of-life
- Consistent buoyancy

SPECIFICATIONS

Height		48.3 cm
Width		40.4 cm
Net Buoyancy		33.2 kg
Water Depth Rating	Model GD-35L-S-03	3.0 m
	Model GD-35L-S-10	10.0 m
Mooring Eye Diameter		3.7 cm
Construction		Virgin UV stabilized industrial grade plastic
Personalization		Company name and phone number can be molded in
Standard Colors		Black, Grey, Yellow, White
Warranty		1 year full replacement for manufacturing defects

GENERAL ARRANGEMENT

CONTACT US TO ORDER:
TOLL FREE (NORTH AMERICA): 1-877-446-3337
INTERNATIONAL: 1-506-633-7850
EMAIL: INFO@GODEEPAQUACULTURE.COM
WEB: WWW.GODEEPAQUACULTURE.COM

2) JFC Manufacturing- Aquaculture 40 Litre floats can be submerged – Buoyancy 48 kgs

MARINE
www.jfcmarine.com

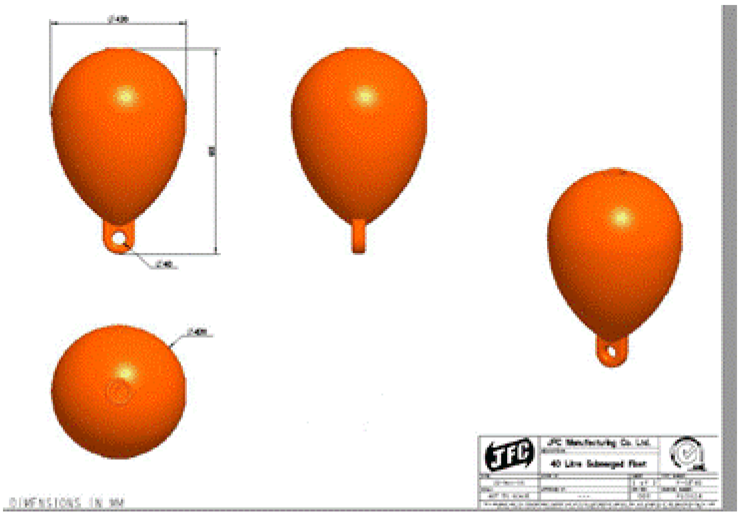
JFC MARINE
JFC Manufacturing Co. Ltd.
Weir Road,
Tuam,
Co. Galway,
Ireland
T. +353 93 24066
E. info@jfcmarine.com

Proposal Reference Number:	180816-1300
Date:	16 August 2018

Contact:	John Bonardelli
Company:	Shell Solutions
Address:	
Contact Number:	0047 98696650
E-Mail:	shell_solutions@hotmail.com

Product / Codes	Description	QTY	Price Per unit	Total
MF250	250 Litre Mussel Float	1	€ 110.00	€ 110.00
MF130	130 Litre Mussel Float	1	€ 63.00	€ 63.00
SF40	40 Litre Mussel Float	1	€ 45.00	€ 45.00
	Optional Extra cost to add Foam to float			
Foam MF250	Closed Cell Foam 250 Litres	1	€ 140.00	€ 140.00
Foam MF130	Closed Cell Foam 130 Litres	1	€ 82.00	€ 82.00
Total Ex- Factory				
Delivery:				
VAT			0%	
Total Price				

Terms & Conditions:	www.jfc.ie/termsAndConditions.html
Vat:	Charged at 23% (Vat Number required outside of Ireland)
Currency:	Euro €
Lead Time:	Please allow up to 6 weeks from receipt of written order, not including transit time
Price Validity:	90 Days from Date of Proposal
	Prices are subject to review thereafter, based on Currency & Polymer price fluctuations
Price:	Price is for the supply of goods only not installation or Assembly unless shown on proposal
	Price does not include moorings unless shown on proposal
Bank Charges:	All Bank Charges / Sender's Charges are not included in proposal need to be paid by client and not the responsibility of JFC
Transit time:	
Delivery Terms:	Ex-Works
Certification:	ISO Certification 9001 : 2008
Origin:	Republic of Ireland
Payment Terms:	A pre-condition of the Terms is "Subject to Credit approval"
1	**Payment In Advance**



JFC Manufacturing- Aquaculture 130 Litre floats can be submerged – when pressurized

JFC Manufacturing- Aquaculture 250 Litre floats can be submerged – when pressurized at