DELIVERABLE 3.4

REPORT ON THE MUSSEL TRANSPORTATION SYSTEM

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CONTENT

LIST OF FIGURES

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1. INTRODUCTION TO THE LOGISTIC CHALLENGES

Because mussel farming is a relatively new industry in the Baltic Proper, a major barrier to economically viable expansion is the lack of appropriate infrastructure. Very few vessels in the region are suitable or specifically designed for mussel farming operations. Only a limited number of landing sites with cold storage remain from the former coastal fishing industry, and there are few marine entrepreneurs with experience in aquaculture. Despite the long and sparsely populated coastline and archipelago of eastern Sweden, it can be difficult to secure access to quays and storage areas for loading and unloading of equipment near the farming sites. And at present, there is only one mussel processing facility available: the Baltic Sea Factory in Västervik, Sweden.

Ecopelag EF currently operates six mussel farms, along a coastal stretch with a distance to the BSF of up to three hundred kilometres by land (two hundred kilometres by sea) (Figure 1). A significant challenge is long-distance transport of fresh mussels from the farms to the processing facility. After harvesting, the mussels must be stored and transported alive. Only mussels of high quality will pass the first processing step, meaning that the success of subsequent processing depends strongly on logistics such as transport time, temperature, and handling conditions.

To enable the sector to expand, more efficient systems for harvesting, transport, and intermediate storage are needed. These challenges have been partly addressed within the Baltic MUPPETS project. Given the present lack of infrastructure for aquaculture in the Baltic Proper, one approach is to adapt and reuse existing but underutilized infrastructure originally developed for the fishing industry.

Figure 1: Map of the Baltic Proper, showing the location of Ecopelag EFs six mussel farm sites along the Swedish east coast (red), and the Baltic Sea Factory (blue). Ecopelag EF operates farms both in sheltered waters and offshore, distributed from Stockholm to Västervik.

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Figure 2: Picture showing harvest of mussels in the St. Anna archipelago. The mussels are scraped off the ropes, washed, separated in two different size fractions, and then collected in big bags for further storage and transport to the Baltic Sea Factory.

2. THE PROCESSING FACILITY

The Baltic Sea Factory in Västervik is a retrofitted fish-processing facility located in a central position within the Baltic Proper. The site is still used as a landing port for herring and sprat, and offers well-developed infrastructure for the handling of marine resources. This includes a large quay for unloading and loading of transports from sea and from land, industrial halls suitable for large-scale operations, and possibility to store biological materials both before and after processing.

The BSF also benefits from experienced personnel with expertise in seafood processing procedures. The in- and outdoors facility is shared between Ecopelag AB, Sweden Pelagic AB and Cresponix AB, all three companies active within the aquaculture and fisheries sector. Within the Baltic MUPPETS project, Ecopelag AB (ECO) installed a mussel cooking and processing line in the existing facility (see D3.1).

Figure 3: The Baltic Sea Factory in Västervik. Mussels from several different farm sites are transported here, and then processed by Ecopelag AB. Within the Baltic MUPPETS project, the mussels have been used to manufacture pet food products and fertilizer (see 4.1 and 4.1 on DELIVERABLES | Baltic MUPPETS, under WP4 Product development and marketing).

3. USE OF EXISTING INFRASTRUCTURE AND LOCAL ENTRPRENEURS FOR LOGISTICS

The logistics system developed within the Baltic MUPPETS project builds on existing infrastructure near the farm sites, including quays, boat berths, and local marine contractors. Several transport alternatives have been evaluated, including the use of Ecopelag's harvest barge, transport vessels, trucks, and fishing vessels. The most appropriate transport solution depends on the volumes to be handled as well as on geographical conditions and transport distances.

3.1 Transport of equipment

Longline mussel farms consists of several different kinds of ropes, buoys, weights, heavy anchors and navigation aids. The pictures below show some examples of local solutions for intermediate storage, assembly and transport of materials out to the mussel farm sites

Figure 4 Left: Assembled anchor lines with attached buoys are waiting to be picked up from the quay by a transport barge. To the right: The transport barge is loading the 3-ton concrete anchors for transport to the mussel farm. At the farmsite, the lines are secured to the anchors and deployed.

Figure 5: Left: A fishing boat is used for transport of buoys and ropes to the mussel farm. This boat can store and transport several tons of substrate rope below deck, ready for deployment. The boat has been equipped with two custom built line-haulers, mounted at the appropriate angle to facilitate the work. Right: Close-up of one of the line-haulers. It is custom-built to fit the hull shape of the fishing vessel. Here it is used to catch the mussel farm´s underwater headline with a grapnel.

Figure 6: Deployment of the substrate ropes on which mussels will grow. The picture shows how the boat is pulled along the farm headline, while substrate rope is attached to it in continuous loops that go 10-14 m deep. This mussel farm now consists of a total of 55 km substrate rope.

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3.2 Transport of harvested mussels

Harvested mussels are collected in big bags, which then have to be quickly transported to the processing facility to maintain quality. During harvesting operations in Norstensfjärden, located approximately 10 nautical miles offshore, the mussels were transported by a chartered vessel to Ornö. From there, they were transported by road to the processing facility in Västervik.

Figure 7: Left: A chartered transport ferry is used to transport mussels from the archipelago to the major roads. Right: Mussels arriving to the BSF by road.

An alternative to the above example—provided that the processing facility is located at or near a quay—is to transport the entire distance by vessel. Ecopelag's farm in Västervik is located only seven nautical miles from the BSF, making sea transport to the processing site feasible.

Figure 8: Left: Re-loading of mussel-bags from Ecopelag's own harvest barge. Right: Mussels arriving to the BSF by sea with a transport barge.

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4. LOGISTIC SOLUTIONS FOR THE FUTURE

4.1 The BALANCE project: Innovation for In-Situ Storage of Blue Mussels in the Swedish Baltic Sea

Significant reductions in production costs can be achieved when harvesting volumes, logistics (such as transport), and processing capacity are well coordinated in both timing and scale. At present, the harvesting vessel has a capacity of approximately five tonnes per day, while the processing line can handle about six tonnes per eight hour workday and a truck can transport up to fifteen tonnes per delivery.

Within Baltic MUPPETS, A call for innovation was issued for to propose a solution to this logistic mismatch. The project selected for implementation was called **Baltic aquaculture: low-impact alterations for next-gen cultivation efficiency** (BALANCE), implemented by the Saga Aqua group (Landbaserad Fiskodling i RAS | Saga Aqua). The objective of this solution is to maintain mussel quality so that harvested mussels can be stored in situ at the farm site for 3 days until a full truckload is ready for transport. After arrival at the processing facility, the mussels should be able to remain in good condition for an additionally two to three days before processing is completed.

According to the report, literature research and expert consultation indicated that the best way to keep mussels alive is to keep them “cool and wet”, a mantra repeated in nearly all of the available literature. If these conditions could be maintained, then survival would be increased. A mutual decision was made between Ecopelag and Saga Group: Blue mussels would be harvested directly into 1m^3 units and left floating in the water. The practice mimicks land-based traditional farming practice where bales of silage are left in the field during harvest and collected later.

The initiative explored the use of floating holding systems that allow mussels to be temporarily stored alive in the water at the farm site. Such systems would enable harvested mussels to remain submerged and viable until enough volume has been accumulated for efficient transport. Each cubic metre bag/crate of mussels is approximately five hundred kilogramms and so a system where thirty such bags are allowed to float at the farm-site awaiting pickup would allow for a transport of fifteen tonnes in total.

By implementing this approach, harvesting operations can continue uninterrupted while the transport process becomes decoupled from harvesting activities. Larger transport vessels or trucks can then collect the mussels once a full load has been assembled.

Following an iterative design process involving several prototypes, a floating structure based on pontoons carrying three big bags was developed and tested. The system is designed to allow harvested mussels to remain submerged while buoyed by the water, ensuring continuous water flow through the bags. The floating frame can be lifted using built-in lifting points and a crane, allowing the bags to be easily retrieved and transferred to transport

vessels. Multiple units can also be anchored together near the farm site until sufficient volumes are available for collection.

Figure 9: Left: The holding pen at constrution by SagaAqua AB. Right: Net bags used for temporary storage of harvested mussels in the sea.

Due to algal blooms in the Baltic Sea archipelago, harvesting operations were restricted in July and August, and full-scale testing of the system could not be conducted during the project period. Comprehensive in situ trials are therefore planned for the spring of 2026. However, preliminary tests of the mechanical stability and handling of the system were carried out both at the factory and in the water using weighted bags. These tests demonstrated that the structure remains stable and that bag retrieval can be performed efficiently using a crane and hook.

In parallel with the development of the floating storage system, Ecopelag also conducted smaller-scale trials to investigate the possibility of short-term in situ storage at the farm site. Harvested bags of mussels were submerged and secured to the harvest barge for periods of one to three days before processing. The mussels were subsequently processed without any detectable decline in quality, likely due to the stable temperature and continuous supply of oxygen-rich seawater. Overall, it seems like the development of floating in situ storage systems has potential to improve logistics efficiency.

Figure 10: Pilot test of in-sity storage of mussels. The picture shows a string of yellow buoys floating after the harvest pram. Net bags with mussels were left in the sea overnight, kept afloat by the buoys and staying alive until transport to the factory on day 3 of the harvest.

Figure 11: AI-generated picture showing the holding pen from BALANCE in its intended work environment. Net bags filled with mussels should be attached to the raft and hang down from the frames, suspended in water. The frames' special design makes it easy to retrieve the filled mussel bags using a crane.

4.2 Test of transporting mussels using a fishing trawler

In a significantly larger cultivation scenario, the objective is to harvest and keep alive sufficient volumes of mussels to fill an entire vessel (approximately one hundred cubic metres). Harvested mussels could then be pumped from stationary, adapted cages (with pre-installed connections for trawl pumps) at the farming site. Transporting volumes of this magnitude would significantly improve cost efficiency, but it is important to emphasize that all stages of the production chain must be able to handle such volumes—including the final processing. Today Ecopelag's capacity is limited, but nevertheless, a pilot-test utilizing existing technology in fishing vessels was made in the former EU-project Life Rich Water (www.richwaters.se), in preparation for future scaling.

The tests were conducted in collaboration with the crew of the herring trawler *Scanö* at the end of May 2022. The main objective was to evaluate whether the vessel's trawl could function as a temporary storage cage for mussels and whether the mussels could be transported in the vessel's fish tank using the onboard pumping system.

The type of trawl used on *Scanö* is designed to remain in the water during normal fishing operations. Instead of being lifted onto the vessel, the catch is pumped directly from the trawl through a nozzle located at its bottom. The fish are transported through a pumping system and separated from excess water before being deposited into the vessel's fish tank. During the trial, the trawl was filled with previously harvested mussels. The mussels were then pumped through the vessel's water separator and into the fish tank, using the same pumping system normally used for fish. After transport, the mussels were pumped from the fish tank onto the fish landing tower at BSF.

Figure 12: Left: Pumping mussels from the fish-tank to the water separator. Right: The separated mussels were lifted by elevator to the landing tower, then loaded in big boxes.

Although this was a small-scale trial, it demonstrated that the technology functions for pumping mussels. The only significant adjustment required to transport mussels through this system was to increase the water flow, as mussels have a higher density than fish.

In addition to testing the pumping technology, a simple experiment was conducted to investigate the effect of pressure between mussels during storage or transport. When large volumes of mussels are stored together, they inevitably exert weight on one another, which could potentially lead to shell breakage and increased mortality. To simulate this effect, a six-meter-long pipe was completely filled with mussels. The mussels at the bottom of the pipe were then examined to determine whether the weight of the overlying mussels caused any damage. No visible effects or shell damage were observed, indicating that mussel shells can withstand relatively high loads without breaking.

Naturally, other challenges are associated with transporting large volumes of mussels—such as temperature control and oxygen supply—but these aspects were not possible to examine within the scope of this project.

5. LOGISTICS AT THE PRODUCTION SITE

5.1 Present infrastructure and workflow

An important component of the Baltic MUPPETS project has been the adaptation of part of the Baltic Sea factory building to accommodate Ecopelag's new mussel processing operations. New interior walls have been constructed to divide the processing halls into zones with different permit requirements, cleaning procedures, and temperature conditions.

Internal transport of mussels and processed products is primarily carried out using pallet jacks, forklifts, and conveyor belts. Mussels are delivered in big bags to the quay by truck or boat and are then transported into the factory by forklift.

After passing through the initial processing step—the steam cooker—the fresh mussels are hygienised. From this stage onward, they must be handled, stored, and transported within a designated "clean zone," where they are kept strictly separate from untreated mussels. This separation is maintained throughout all subsequent processing steps until the final product has been packaged.

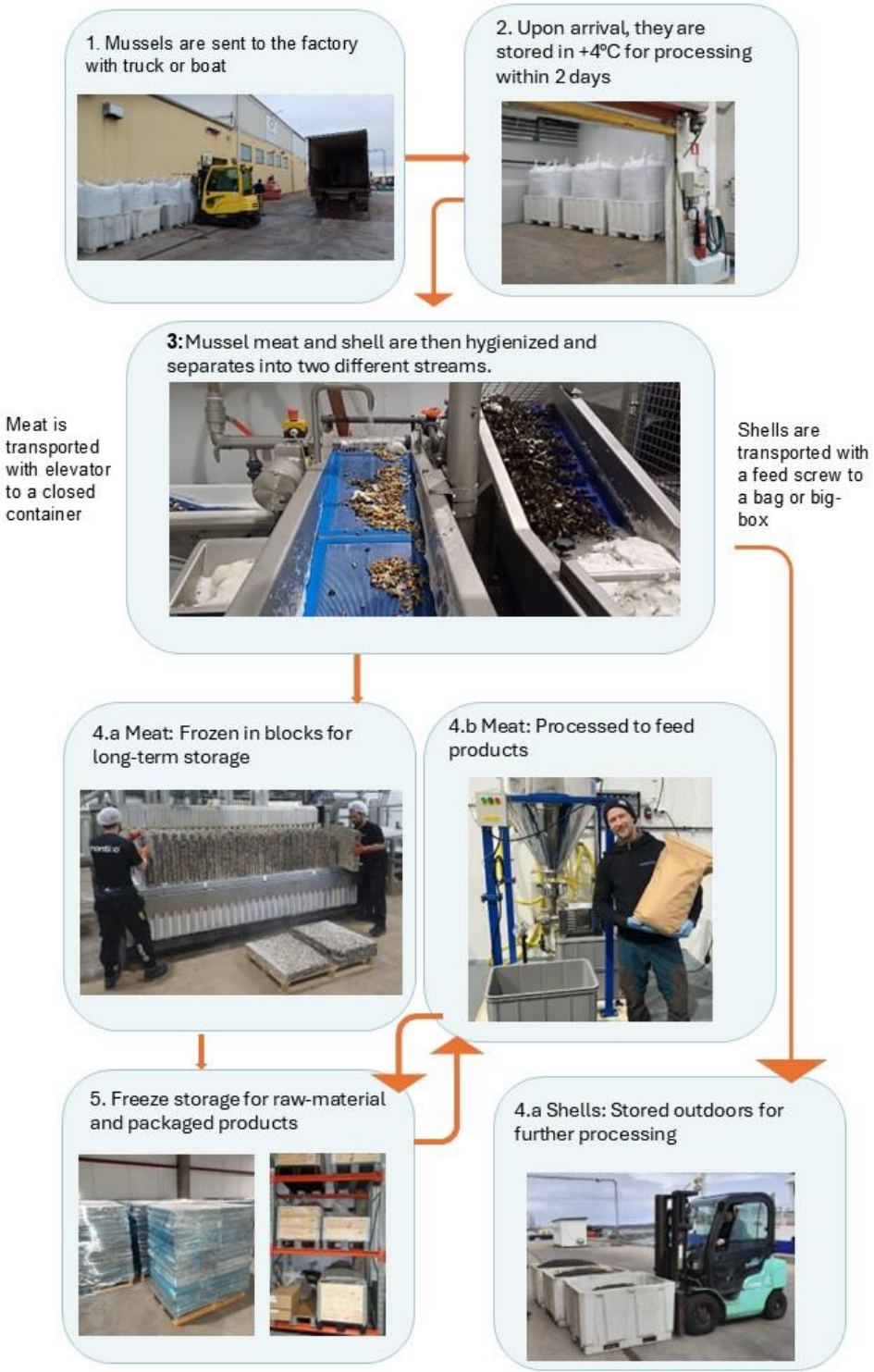

Figure 13: Overview of process flows in Ecopelag AB's production line at the Baltic Sea Factory.

5.2. Future vision

The Baltic Sea Factory was previously used as a sorting and freezing facility for herring and sprat, with a processing capacity of two hundred tonnes per day. Fish were pumped directly from trawlers and stored in tanks while awaiting processing. The storage tanks, pumps, and seawater supply pipelines are still in place.

Looking ahead, parts of this existing infrastructure could potentially be repurposed to handle significantly larger volumes of mussels at the Baltic Sea Factory. This would also make it possible to store mussels for extended periods, helping to stabilize workflow and improve operational efficiency.

Figure 14: Underutilised infrastructure at the Baltic Sea factory, originally developed for the fishing industry.

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