Offshore fish farm investment and competitiveness in the Baltic Sea

Markus Kankainen, Rune Mikalsen

Baltic Sea Region
Programme 2007–2013

Part-financed by the European Union (European Regional Development Fund and European Neighbourhood and Partnership Instrument)

AQUABEST

AQUABEST

Finnish Game and Fisheries Research Institute, Helsinki
2014

ISBN 978-952-303-077-0

Reports of Aquabest projects 2 / 2014

Offshore fish farm investment and competitive-ness in the Baltic Sea

Markus Kankainen,
Finnish Game and Fisheries Research Institute,
Rune Mikalsen,
Akvagroup

Description

Authors Markus kankainen and Rune Mikalsen		
Title Offshore fish farm investment and competitiveness in the Baltic Sea		
Year 2014	**Pages** 40	**ISBN** 978-952-303-077-0
Abstract In this report we introduce a subjective (made by Akvagroup) example of the investment in fish farming offshore units in the Baltic Sea. We evaluate the investment items needed, investment costs and finally compare the competitiveness of offshore farming to the present production system. Investment decisions are made according to existing knowledge of the production environment. Baltic production conditions provide an extra challenge in planning offshore farming operations. The production volume of offshore units should be large so that the investment cost per fish does not become too large for profitable business. However, if larger production units are allowed offshore, it is possible to improve the efficiency of production operations; that may be to the benefit of offshore units compared to the present dispersed production system. We evaluated the investment costs and competitiveness for 300 tonne, 600 tonne and 1,000 tonne offshore production units.		
Keywords Offshore, Fish farming, Investment, Profitability, Baltic Sea		
Publications internet address http://www.aquabestproject.eu/reports.aspx		
Contact markus.kankainen@rktl.fi		
Additional information		

AQUABEST

Contents

1. Introduction

1.1. Offshore fish farming

Typical of offshore farms are rough production conditions in exposed locations at sea and long maintenance distances to shore. Generally speaking, offshore farms are understood not only to include production completely in the open sea, but also to cover production sites far from shore but in such areas where there is some shelter against the heaviest wind and waves. For example, Ryan (2004) has classified sites separately in totally open waters and sites in exposed areas with some shelter. The feeding and maintenance of the farming units is more practical and safer at sites where there is some shelter against the heaviest weather. Because of the heavy production conditions in areas of exposed water, farm and maintenance equipment should be constructed to withstand rough winds, waves and currents. Fish farm equipment manufacturers have categorized stamina levels for production equipment according to classifications or maximum weather conditions such us wave heights.

1.2. Why go offshore?

The demand for fish products is increasing continuously. Aquaculture production has increased rapidly in past decades to meet this increased demand for fish products. It is the fastest growing food industry sector, with an increase of 17 million tonnes (from 43 to 60 million tonnes) in five years (2006-2011, FAO 2012). Fish farming is the only method to meet the demand for fish products, as fishing cannot be increased on a large scale, because of the decreased and limited wild fish populations. In addition, FAO has stated that fish farming is the one of the solutions to meet the increased demand of an increasing population, because fish is an efficient production method for producing protein.

Worldwide, the major reason for the development of offshore farming is the lack of sheltered sites for fish farming and the awareness that there is plenty of open ocean in the world. Even though there still appears to be plenty of potentially sheltered sites inshore, and other production methods such as recirculation farming (RAS) have also increased, because of the high forecasts of production increases; the majority of the production is likely to be committed to open waters. In addition, not only aquaculture but also other water area users wish to use coastal areas. Other industries, recreational use and conservation are only some examples of the players interested in the same inshore locations that are suitable for aquaculture production. Environmental preconditions are in some locations the reason why aquaculture is directed offshore; for example exposed areas can tolerate more nutrient loading, outer farms do not harm wild fish populations to the same extent with possible diseases, and sensitive ecosystems on coastlines, and in rivers or lakes are not threatened if intensive farming were to appear in open and deep waters. For this reason, on the contrary, larger units are possible in exposed areas. Economies of scale make offshore farms efficient even though the distances and harsh conditions increase production costs (Asche 2008); for example, in Norway the largest offshore farms produce around 4,000 tonnes of fish annually at one production site.

1.3. A spatial plan for Finnish fish farming: grow-out sites for edible fish offshore

In Finland new production has not been established in coastal areas since the 1980s. While writing this report, a new licence has been given to produce 300 tonnes offshore. On the contrary, in Finland fish production volumes have decreased or production licences have expired in the licensing procedure by the authorities. Even though fish farmers would like to increase their production, as the demand for fish is good. Nutrient load and the opposition from other water area users are the main reasons for cutting production. To maintain and increase fish production in Finland, a project for a spatial plan for fish farming was launched by the Ministry of Agriculture and Forestry and the Ministry of Environment.

According to a so-far unconfirmed plan, the most potential areas for future farming are to be found in exposed areas offshore (MMM 2014). One of the major aims of the project was to minimize the negative effects of the nutrient load (Setälä et al. 2012). Therefore, only edible fish farming, the stage of the production cycle involving environmental loading, were directed offshore where dispersion of the nutrients is good. The spatial plan concerns only edible I stage of the farming, because it was understood that in addition to offshore farms, farmers should have enough separate, sheltered sites for smaller fish, and warehousing the edible sized fish or cages throughout the winter. At these sites the volumes and loading would be smaller.

1.4. Present farming and common global offshore production system and logistics

In the present sea cage production system in Finland many companies have their own maintenance harbour, including feed warehouses and offices near to the sea cage sites. The feed is loaded onto boats in the harbour and delivered to the cages; the common way is to use cage-specific feeders, because there are generally many small units owned by the same company dispersed throughout the area. Even though the companies have invested in larger working boats, because of the concentration of the business, boats are not specially designed for working in heavy offshore conditions and handling very large cages (e.g. with double efficient lifters in a vessel). The largest fish farm work vessels used nowadays in Finland can take around 20 tonnes of feed cargo and their length exceeds 10 meters.

Likewise, in Finland the most common method used in offshore finfish farms has been to produce fish in robust and flexible plastic rings and net cages. However, there are many innovative methods such us submergible solutions that are already in use in very harsh conditions in some numbers in the industry worldwide (Ryan 2004, Vielma & Kankainen 2013).In global offshore farming when units become larger and the maintenance distance increases, two commonly used solutions for feeding are either to use feed barges or to blow the feed to the fish from the boat. Both systems have their advantages and disadvantages.

The capacity of feed barges for feed varies from cage specific one tonne barges to 1,000 tonne barges, where workers have fully equipped facilities for working/living for longer periods. Large barges are practical at sites where feed consumption is many thousands of tonnes daily. Feed is generally delivered to these barges with large bulk/feed cargo vessels from time to time. When the farming unit and feed consumption increases significantly, it is no longer efficient to transfer the feed using "small" working boats. Feed can be transferred directly from the feed companies via some logistic harbour centres to the farming site, and fish farmers therefore do not necessarily need feed warehouses of their own.

Feeding from a boat is quite a simple method for organizing the feeding. A disadvantage as against the feed barge solution is that one cannot monitor the fish and feeding as well. The timing of the feeding is also more challenging, especially if the distances to units are long. In addition, if feeding is carried out from semi-sized boats, there can be periods of storm when feed cannot be delivered to the fish, which can have a further effect on, for example, growth rates. Further if the fish volumes and the need for feed is large, it is quite time-consuming to blow the huge amount of feed into each production unit/cages separately. In very rough or deep conditions if feed barges cannot be installed, boat feeding may be the only practical method for delivering the feed to the fish (Vielma & Kankainen 2013).

1.5. Need for offshore investment analysis in the Baltic Sea

There has not been a great deal of experience of large offshore fish farms in the Baltic so far. Fish farms have mostly been located in the intermediate archipelago in the shelter of some islands near the coast, and the product units even in the outer parts of the archipelago have been quite small. In the north of Sweden there are some 600 tonne production units at sea; in Denmark the largest sea sites near Atlantic produce even 2500 tonnes, In the Åland Islands some produce 150 tonnes, and in along the main Finnish coastline the largest have been about 80 tonnes.

The offshore farms should be robust enough to take the heaviest conditions so that the expensive investment in equipment and the fish inside the units are lost because of bad weather. In the 1980s and 1990s in Finland, when fish farming was a rather new production method, during heavy storms some production units installed in semi-exposed sites broke and drifted away with fish escaping. Offshore farms should be efficient and suitable for special production environment with special characteristics and logistics in the Baltic.

To have the experience of offshore farming with large production units, the major fish farm manufacturers were asked to assist with the investment analysis. These companies were chosen according to their experience in installing open sea fin fish farms in exposed locations. Competitive bidding for this investment consultancy was awarded to the largest manufacturers operating in Northern Europe, and Akvagroup (http://www.akvagroup.com/home) was chosen to assist in the investment analysis.

The analysis given in this report includes investment descriptions by item needed for offshore fish farming. Within the each investment item, a brief introduction is given as to why this equipment is chosen for the specified Baltic conditions and production. The investment and logistics costs are analysed in order to evaluate the competitiveness of offshore farming. In a profitability analysis, we compare how the product volume (300 tonnes, 600 tonnes or 1,000 tonnes) and feeding method (between feed barges and boat feeding) affect the value and efficiency of the investment.

Because investments are always site-specific, we chose two specific investment locations where investment analysis was conducted so as to illustrate the requirements in Baltic offshore conditions. The exact sites were chosen according to their exposed nature, the fish farmers' willingness to expand into these areas and the Finnish aquaculture spatial plan under process. The sites are located in the Northern Archipelago Sea and in the Bay of Bothnia. The aim was to make a bid involving a real investment (Appendix 1) with the best available solutions for those areas according to data on current production conditions.

2. Production and conditions in the northern Baltic Sea

2.1. General and special production conditions in the northern Baltic Sea

Even though the Baltic Sea is not the largest of seas, it can be quite challenging for fish farming in exposed areas. Average waves after periods of the highest winds can be more than seven metres high, and some waves have reached a height of 14 metres. Currents are not as strong as in some coastal areas in other oceans, yet in some special locations currents are so strong that robust mooring is needed to keep the production units at the site and the cages in shape, especially for large fish farms (Itämeriportaali 2013, Kankainen et al. 2013).

A special characteristic of the Baltic Sea is the length or density of the waves and ice in winter. The Baltic Sea is quite shallow and the fetch lengths, that are the distance to the (opposite) shore, may not be as long as in major oceans. The shallowness and the fetch length reduce the length of the waves (Dalrymple 1998). The density of the waves may have an effect on choice of production equipment; in the major oceans the waves may be higher, however, the length of the wave is so long that the cages may float between the waves. When the density of the waves increases, the sharp waves impacts the equipment differently. The average density or length of the waves in the Baltic Sea is stated to be 25 metres (Itämeriportaali 2013); however, this is dependent on many variables such us wave height, shallowness of the sea bottom and salinity. The waves in the Baltic can be many times sharper when compared to deep water waves in the open ocean (modelled in Kankainen et al 2013). The density of the waves becomes especially high in shallow areas or on the coastline before the waves break. (Dean & Dalrymple 1984).

It appears that the fish farming equipment should be removed from the offshore sites before the winter and the ice. Moving ice fields, pack ice, as well as drift ice, impact the equipment to such an extent that it is likely that none of the cage materials used could take this pressure. Pack ice has torn heavy fish farm anchorages with chains from the bottom from more than ten metres in depth; pack ice is greatest in exposed areas near the coastline. Even in existing production systems, fish farmers take the net cages and plastic rings to winter sites in to the shelter of archipelago where the ice will not move as much. It has been suggested that submergible farming techniques would be a solution to avoid this transfer of the equipment to sites where the ice cover would not reach the bottom. If this is realistic, meanwhile there would be no longer a need for winter sites. However, for large cages, this would mean quite deep waters and an extra risk of leaving the equipment and perhaps fish for long periods without supervision and the possibility of maintenance. Also many other unclear effects exist in submerged solutions in the Baltic such as changes in water temperature at different depths and other fish welfare-related issues (Kankainen et al. 2013). During frost heave and the winter period, fish farmers would need special equipment to observe the production sites such as ice-resistant boats, hydrocopters and snowmobiles. The ice melt usually occurs in the northern Baltic in March-April, and the water freezes in October-December.

2.2. Area-specific conditions in selected case study investment locations

Investment in a fish farm is always planned based on environmental and site-specific production conditions. For this reason, we chose two potential sites to evaluate the investment necessary. Data on site-specific production conditions relevant to fish farm installation and investment analysis were received from weather observations stations near to the case study sites. Some of the weather data has been gathered since the 1970s. It is rather important that there is long-term data for the site's worst weather, because the production system should be planned to withstand the worst conditions there might be. These data on weather and other production conditions used in the investment analysis were confirmed from entrepreneurs who had operated near these selected sites at Kustavi (North Archipelago Sea) and Vatunki (Bay of Bothnia).

These maximum (and minimum) weather conditions are also used in this report on investment planning in defining equipment robust enough to withstand the strongest storms that may exist (Table 1). Maximum significant wave heights may in both places be higher than given in the table; however, we included the maximum wave heights observed during the assumed grow-out period at the site. More details about the sites and Baltic weather conditions, for example water temperatures, sea charts and weather data, are introduced in more detail in the Aquabest report: "Fish farming production conditions on the Finnish coast" by Kankainen et al. 2013.

Table 1. Site specific weather conditions hypothesis used in investment decisions (Kankainen et al. 2013)

Production factor	Site 1 (Kustavi)	Site 2 (Vatunki)	Unit
Wave	4m	4m	Maximum significant height during growout period
Wave	10m	14m	Maximum single wave height during growout period at area
Wave	>5%	>4%	Steepnes (modelled with 23m/s Kustavi and 25 m/s Vatunki wind; not accurate in shallow waters)
Wave	50	41	Lenght (at 10 m/s wind; meanwhile wave heights 2m Kustavi, 1,5 m Vatunki)
Current	1 m/s	0,5 m/s	Maximum during growout period
Wind	25m/s	23m/s	Maximum during growout period (average at 10 minutes)
Wind	19	17	Heavy wind days (>15 ms) at average year during growout period
Seabed	rocky, semihard sediment	rocky, semihard sediment	Quality at top of seabed (no seabed radar committed)
Depth	10	9	Minimum at farming site
Depth variation	10-30m	9-15m	At mooring area
Volume	300/600	300/600	tonne (additional growth)
Ice mass	No	Yes	May reach the seabottom at winter

Overall, production conditions were considered to be quite similar at the two production sites. In the Bay of Bothnia (Vatunki), winter comes a little earlier and that affects the grow-out period. In Vatunki, because the water is shallower nets may be needed, which may further influence the need for the number of cages, but this decision needs even more detailed site selection than committed in this investment plan. In addition, in shallow areas near the coastline, the pack ice may reach the bottom, and that should be considered as regards the mooring or anchorage system. Also, differences in current speed affect investment items, especially mooring, but this would also require a more detailed site-specific analysis.

Especially current and seabed analysis, as well as wave length/density analysis should be carried out in more detail before considering whether the place is suitable for fish farming or what equipment would be suitable. Current speed and the seabed quality in particular affect the mooring system and selection of the anchorage method. Wave lengths and heights are evaluated using available hydrodynamic models (Dalrymple 1998) with applied data by Kankainen et al. (2013), however, models rarely accurately reflect the real environment at sea, as so many variables influence wave lengths. If the wave length is short, the waves may impact the surface farming equipment heavily. Also, the fish may escape if the sharper waves “flush” the cages.

2.3. Offshore farming concept in the Baltic: take equipment in to shelter before the ice appears

The offshore concept in the northern Baltic would probably be to take any offshore farming equipment in to shelter each year. Therefore the installation and uninstallation of the mooring and cages should be flexible. In practice this concept would mean that only the anchorages are left on the sea bottom for the winter in those places where packed ice may reach the bottom. In spring, the main mooring lines are attached with heavy shackles to the anchorage with the assistance of divers.

When the mooring is installed, the fingerlings are transported from fingerling sites to offshore units immediately in the spring when the water is open and warm enough for the fish. When the grow-out period is over, the offshore equipment and fish are towed to shelter of coast. Fish are delivered to the harvest site where it is possible to land the fish and cut them throughout the winter period and spring to guarantee a stable supply. Another method is to use wellboats to transport the fish and only tow in the cages. Empty production equipment is taken to sheltered winter sites to wait for the next spring installation offshore; meanwhile, the empty nets can be cleaned. Likewise, if the site is very vulnerable to the ice, the feed barge should also be towed to shelter for the winter, if the barge feeding method is selected.

3. Description of the investment

3.1. Cages

Flexible plastic cages that are made from raw materials especially suited for the dynamic loads of the sea are considered a well-proven concept for extreme conditions. AKVAgroup invented the plastic (Polarcirkel) cage in 1974, and has since supplied more than 42,000 cages for fish farming. Plastic cages started out as small single pipe circles, but now Akvagroup's largest models approach a 200 metre circumference with floating pipes of 500 mm diameter (Figure 1).

Extensive use of strong and high quality PE (Polyethylene) in PIM (Pressure Injection Moulded) brackets eliminates corrosion, minimizes expensive and difficult maintenance, and substantially increases cage lifespan compared to steel brackets. This is especially important in areas with high salinity, warm water temperatures, in high-energy offshore farm sites and areas with high UV radiation from the sun. For areas prone to icing, such as Norway and Canada, another critical advantage of the HDPE brackets is that they will not ice up as steel brackets do. Icing is a dangerous safety problem for all floating structures, including cages. Heavy ice overloads the cage, reduces stability and jeopardizes overall cage integrity.

In order to increase crew safety on fish farms, another Polarcirkel innovation was launched in 1999 – the integrated Walkways. The anti-skid walkway panels fit securely between the two floating pipes, forming a stable and safe working surface. The PE pressure-moulded panels are held in place with strong and flexible continuous PE tubing inter-locking the panels to the PIM brackets.

Figure 1 Heavy but flexible plastic (PE) cages for offshore conditions

In some locations where the currents are strong or the nets are larger, it is possible to use the sinker tube concept. The idea of the tube sunk below the net is to keep the shape and capacity of the net in heavy conditions. The Sinker Tube consists of a 200-280mm heavy-walled PE pipe filled with steel wires (typically 20-70 kg/m). It is supported by strong ropes fastened through the stainless steel sleeve in the PIM brackets. However, we did not calculate the sinker tubes into the offer because there are other more flexible ways to keep/weight the nets in shape and sinker tubes would be hard to uninstall before winter.

Akvagroup also provides submergible solutions. According to present knowledge about the conditions, submergible cages were not considered necessary at these sites, because surface cages are used and these worked in heavier conditions. Even though waves are sharper in shallow Baltic conditions, PE pipes have worked in present farming in such difficult conditions In Finland, Åland, Denmark and Sweden, and some of the sites are already located in quite open areas of sea.

According to preliminary estimations about the maximum production conditions at sites (see Table 1 and Appendix 1), pipes with 400 mm and a wall thickness of 24 mm were selected. A circumference of 90 metres was chosen so that the cages and nets would still be practical to handle with the working boats chosen. With selected nets and the maximum capacity, these cages may each produce 100 - 150 tonnes of fish.

3.2. Nets

Nylon nets were chosen for the investment analysis because these are practical to handle (Figure 2). The major reason for choosing traditional nets was that cages and nets should be easy to take along to the shore and clean and maintain in winter periods. The duration of nylon nets is around 4-7 years. Econets are a new brand at Akvagroupp and have several good qualities in offshore conditions, such us keeping their form and durability; however, because of their heavier weight and rigid character these were not chosen for Baltic investment.

Figure 2 Nylon nets are lighter to handle with lifters

The nylon nets can be cleaned with special cleaning systems at site or washed/dried and coloured with antifouling each year when the equipment is taken to shore, as present fish farmers do in Finland. If the nets are of a reasonable size, it is more practical to handle and wash them without technical devices. Cleaning is important even during the growout periods if the mesh clogged up so as to ensure the wellbeing of the fish.

The net investment offer in this report also includes bird nets and necessary ropes to install the net to the cage (see Appendix 1). The number of nets (and cages) depends on the production volume, maximum density of fish in the grow-out period and water depth. In investment analysis 15+1.3 m deep (+one spare) nets are suggested. At a northern site, because the depth is only a little above 10 metres in the shallowest locations; lower nets and cages may be needed for the same production volume.

3.3. Feeding

3.3.1. Alternative 1. Feed barge

Feed barges are the growing method for arranging feeding in large offshore farms. The present state-of-the art feed barges includes not only feed silos but high technology feeding systems with fish and water quality monitoring. In the largest barges employees have facilities for longer working periods. Electricity is provided with power generators. The largest barges have the capacity of 1,000 tonnes of feed and general practice where extensive production exists is that large bulk/feed vessels deliver the feed directly from feed manufacturers to the barges. At small production sites feed barges are not common because of the rather high investment costs (see Chapter 5 Offshore investment costs.).

The special advantage of the feed barges is that you are able to monitor the fish and production conditions constantly and design your feeding exactly according to these parameters. In many cases, this will improve the bio-economic productivity factors such us feed efficiency, mortality and fish growth (Kankainen et al 2012).

As an option to Baltic offshore fish farming, we calculated the price for a150 tonne feed capacity wavemaster for a 1,000 tonne production unit and 94 tonne (AJ94 classic) feed capacity for 300 and 600 tonne units. The barges are “certified” to take 7 metre waves.

Figure 3 State of the art feed barges include feed silos, feeding system, monitoring centre, employee facilities and power devices

3.3.2. Alternative 2. Feeding from a boat

When conditions are very rough, feeding is often organized directly from a boat. If the cage is at the surface, the feed is blown to the fish using air pressure. The advantage of boat feeding is that rather expensive investments are not needed for the feeding. The disadvantage is that the feeding is possible only when the feeding boat is at the site. Also, the monitoring and other aids such us lights, feed counters or underwater cameras cannot be used as from a power-equipped and sheltered feed barge. If the feeding boat is not rough weather-resistant, feeding is only possible when weather conditions are decent. If there is the possibility to feed only one farming cage at a time, delivering sufficient volume to large production units takes a lot of time. However, feeding systems in boats have also developed and these can be adapted with intelligent production planning software programs and feeding control systems.

3.4. Mooring

3.4.1. Anchorage method depends on seabed quality

Anchorage investment and related costs are only an estimation, because detailed seabed analysis has not been carried out. Detailed seabed analysis is needed for determining what kind of anchorage method would be suitable at the site; for example, traditional anchorage is suitable at sites where there is enough deep sediment layer. If the sea bottom is rocky, perhaps drilling would be a better method to keep the mooring system and cages at the site. Echo sounding and sea bottom samples are methods used to evaluate anchorage. The largest anchorage might weigh more than ten tonnes each in huge offshore location farms where lots of tension occurs in the mooring system.

3.4.2. Mooring system according to tension and weight

The mooring system is designed according to local conditions and the heaviest anchorage is set to the side where wind, waves and currents impact the cages and nets the most. Flexibility against waves is controlled with a buoy system. A common method is to attach the single cages to the main mooting lines in groups. In Figure 1 left a mooring system for cages and rig mooring for the barge.

A huge amount of chains, buoys and ropes is needed so that the cages are robustly installed. The challenge for Baltic production is to release and install the mooring system each year. As single cages can be attached with shackles to the main mooring line, the shackles could also be used before the grow-out period in spring to installing the mooring system and cages to the anchorage. This operation would need further consideration. .

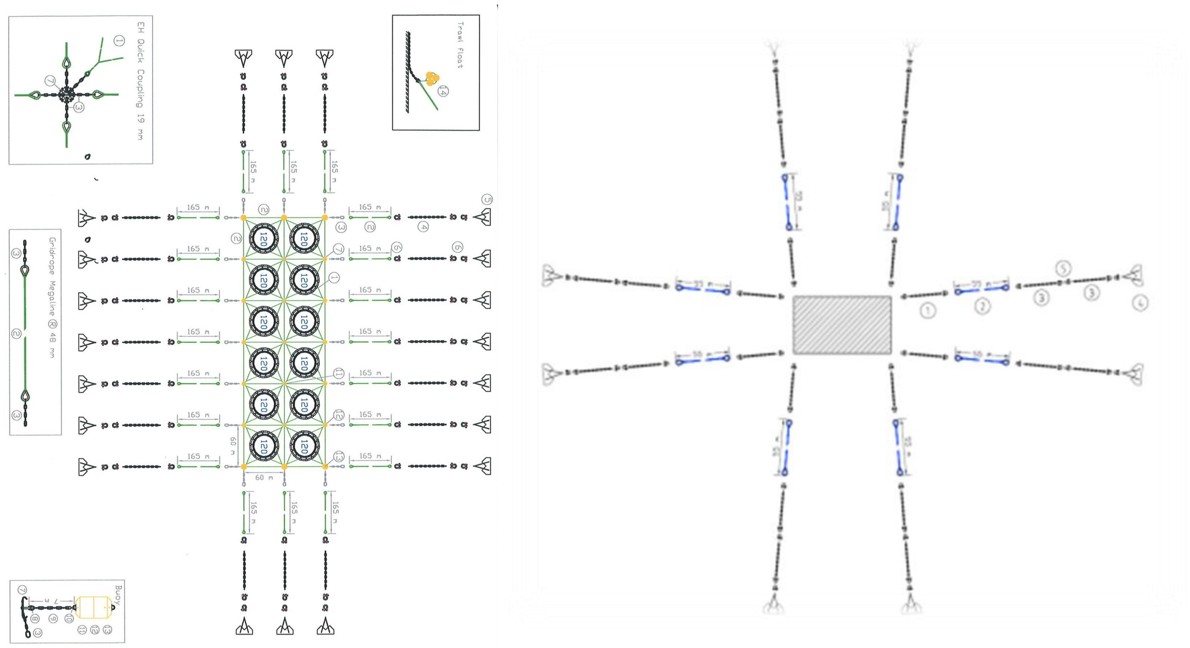


Figure 4 Left: mooring system for cages, Right: mooring for feed barge

3.5. Working boats

In Finland larger fish farmers at sea nowadays use work vessels of more than 10 metres with above 20 tonne cargo capacity and lifts. Likewise, in Norway the common work vessels have been less than 14 metres in length, catamaran-type fast vessels where the cabin is in the front and the aft deck open for cargo (Figure 5). The vessels are equipped with the necessary work devices, and the price of this size of vessel can vary from 0.5 to 2 million euros, depending on the accessories.

However, when Norwegian farms have also moved offshore, there have been discussions whether this size of boat is robust and safe enough in bad conditions (Vielma & Kankainen 2013). One of the most important features of the vessel is to maintain the exact location and stability with the steering so that the vessel will not swing or drift and cause damage to the personnel or the fish farm cages. It is quite common that companies also have several boats for different purposes, for example, smaller boats for personnel transport or fast maintenance. Also, when units are larger two work vessels are often needed to manage the lifting operations. In the Baltic concept, if large cages are towed or pushed to shelter, it could be also safer and more efficient to have two work vessels, but we calculated the investment cost with one 14-metre work vessel and one offshore transport boat.

Figure 5 Common work boat in Norway, bigger boats are needed to work in rough conditions

3.6. Other operational devices

3.6.1. Net cleaning and maintenance

In the net cleaning system, filtered sea water under high pressure is used to remove growth on the nets. The cleaning process is carried out while moving the cleaning rig up and down on the inside of the net. Effective net cleaning ensures optimum oxygen levels and faster growing biomass in places where growth in the net mesh prevents the fluent flow through of seawater. The large net cleaners can be operated in semi-automatic mode by two persons via a crane, winch, cap stand or as a mounted option on an ROV (Remotely Operated Vehicle). The smallest net cleaners can easily be operated from the cage by a single person. The larger rigs include video systems that provide a full overview, and the possibility of inspecting the nets.

3.6.2. Sensor systems

Sensor systems ensure optimum operations and a healthy environment for both people and fish. Fish behaviour and water quality can be monitored actively, and therefore farming can be managed dynamically, which increases the efficiency and prevent risks in production. Flexible camera solutions, like monochrome feeding cameras or winch-controlled 360° cameras provide pictures and video to a monitoring centre. Feed calculators give input to feeding devices to optimize feed efficiency. Environmental sensors can be used to monitor the environmental status and water quality so that fish wellbeing can be ensured. Biomass estimators are useful for estimating feeding regimes and sales biomass. Underwater lights can be used e.g. to control the timing of the maturity or activity of the fish. Power availability is needed in the surface of the cages for the wireless transmission of underwater video images, feeding and environmental data if the control unit is located on shore. The challenge in off-shore sites has been to ensure the availability of electricity in heavy conditions far from shore.

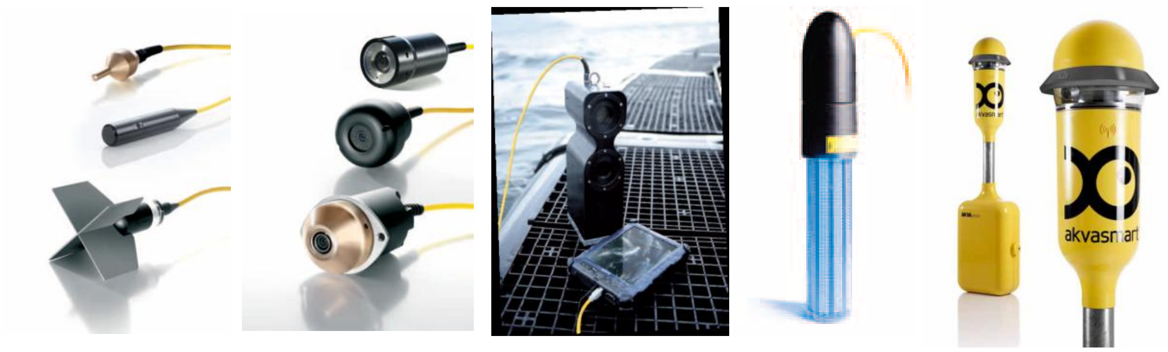


Figure 6 From left: Environmental sensors, cameras, biomass calculator, Underwater light and wireless transmitter

3.6.3. Feed system concept and production planning software

The feeding systems in the barge are able to feed a number of cages at a production site simultaneously. The feeding system consists of a PC with man-machine interface, an electrical control cabinet, a control computer and various mechanical parts for transporting the feed from the silos to the cages (Figure 7).

In the cage, feed can be delivered widely with special spreaders to ensure that all the fish get the feed. A twin delivery system consists of two air blowers, two air coolers and two selector valves, and each silo is equipped with a doser. A twin feeding system line can feed two cages at the same time. Each silo is connected to one of the feeding lines. The AkvaControl Software is the special designed process control software for the Akvasmart feeding system in Akvagroup (See more in Appendix 1).

Figure 7 State-of-the-art feeding systems are controlled by production planning software programs

4. Investment and installation costs

4.1. Offshore farm investment costs

We calculated the investment costs for different production volumes to analyse the relation of economies of scale and investment value. In the Finnish national fish farming spatial plan and related environmental analysis it is estimated that in offshore areas near to shore some 300-600 tonne production volumes per site would be sustainable (MMM 2014 a ja b). In outer parts larger scale production is also possible. Because the feeding method chosen significantly affects to the investment value and total operational cost of fish farming, we have separated out the barge feeding investments in Table 1. The approach and investment alternatives were that the offshore investment include, in addition to cages, either a feed barge and a normal offshore robust work vessel or a work vessel with a feeding system, which has a higher price. Both options include a smaller transport boat.

The investment value of the offshore production unit and vessels required varied between 3.0 million euros and 1.7 million euros, depending on the feed system and production volume chosen. In a 1,000 tonne unit, each separate cost item – cages, feeding barge and work vessels – takes about a one third share of the investment costs. The investment cost per fish produced changes significantly between the volumes. When the volume is lower, the fixed prices of vessels and feeding barge increases the production cost and reduces the competitive advantage of farming significantly. The cage investment has a more production volume-dependant and variable character. Thus, barge investment in feeding seems not to be economically viable in small units. However, which feeding method is more profitable also depends on operational costs.

The investment cost share of production cost is lower in the present sheltered production system compared to calculated offshore unit. It appears that in 300 tonne units the present farm investment costs are below 0.30 €/kg produced. Kankainen 2007 calculated around a 0.20 €/kg cost share for the same investment items for a 300 tonne producing company from project data from the fish profitability analysis model. Even when inflation and some new investments are added to this value, the costs are far from the offshore investments calculated here. The profit margin of fish farming nowadays is lower than the gap between these investment costs. Thus, the offshore investment would significantly reduce the competitive advantage if the volumes are low. To maintain the competitiveness and profitability of business, larger volumes per site, many sites close together (that can be managed with the same boat) or significant subsidies to investment are needed for competitive offshore fish farming.

Table 2. Table 1 Offshore investment costs by items

Investment items	Description	1000tonnes	600tonnes	300tonnes
Cages				
Plastic cage rings (PE)	12/ 6/ 3 pieces, 400mm/90m ring	444 000	244 800	122 400
Mooring system for cages		114 000	120 000	72 000
Anchorage*	20/ 18/ 12 pieces*42000nok/p	100 800	90 720	60 480
Nets	15 meter deep, polynets	228 000	114 000	57 000
Net cleaning system		114 000	114 000	114 000
Installation and supervising		68 400	40 800	32 400
Freight*		36 000	18 000	9 000
Total		**1 105 200**	**742 320**	**467 280**
Feeding, maintenance				
Barge, feed system and spreaders	Feed barge AJ 150/ AJ 96/AJ 96	756 000	664 800	540 000
Mooring system for barge		72 000	72 000	72 000
Anchorage*	8 pieces*42000nok/piece	40 320	40 320	40 320
Feeding pipes	3000m/1500m/1000m*32nok/m	11 520	5 760	3 840
Sensor, monitoring system		96 000	96 000	96 000
Production planning, software		23 700	23 700	23 700
Installlation, supervising, training		28 200	28 200	28 200
Freight*		24 000	18 000	12 000
Total		**1 051 740**	**948 780**	**816 060**
Boats				
Work vessel*	14 meter catamaran with lifts	720 000	720 000	720 000
Work vessel with feeding system*	Same, including feeding system	1 080 000	1 080 000	1 080 000
Offshore transport boat*		120 000	120 000	120 000
EUR Total feeding from barge		**2 996 940**	**2 531 100**	**2 123 340**
€/kg Total feeding from barge		**0,48**	**0,68**	**1,13**
EUR Total feeding from boat		**2 305 200**	**1 942 320**	**1 667 280**
€/kg Total feeding from boat		**0,37**	**0,52**	**0,89**
*Accurate price depends on item quality, accessories and investment place				

4.2. How conditions affect the investment costs

The investment was calculated first for a 315mm diameter /60m circumference cages which withstand significant wave heights up to 3m, and currents up to 1m/s with a net depth of 15m and after that for 400mm/90m cages that withstand significant wave height sup to 4m, and currents up to 1m/s with a net depth of 20m (that is with a 15 metre current can be much stronger). For 300 tonne production capacity calculated 6*315mm/60m diameter cages cost 540 000 NOK and for 2*400mm/90 diameter 680 000 NOK. Thereby, a one metre bigger wave-resistant unit costs 25% more when considering only cages. In offshore conditions stronger mooring, larger anchorage and bigger vessels are also needed.

4.3. Offshore farm operational costs

4.3.1. Logistics and economies of scale

Many other productivity factors change if fish farm location or production volume is changed. The explicit impacts are caused by the changes in the logistics costs (Rubino *et al*. 2008). These costs include not only the investment costs that are needed to produce fish at a certain site but also variable costs dependent on distance.

The major variable costs, which depend on the distance to and/or between the fish farm units, are fuel cost and working time. It is common for fish farmers to visit their production sites almost every day during the grow-out period to feed and monitor the fish. Live fish, dead fish, cage and net transfers also take time. The greater the distance between the maintenance infrastructure and the production site, the larger the costs are to the producer.

By increasing the site-specific production volume, it is possible to improve the production efficiency of these logistic costs. With almost the same working effort and investment costs for feeding, feed storing, working boats, it is possible to produce more fish. In areas where overall production is limited, concentrating small units into a larger unit substantially improves production efficiency.

4.3.2. Production conditions and feeding methods influence growth survival and feed efficiency

Site-specific production conditions and feeding methods affect bio-economic productivity parameters such as fish growth, mortality or feed efficiency. For example, water temperature influences fish growth rate. Also, the production cycle may be shorter at offshore sites, because the equipment has to be removed earlier because of the weather/ice risk. Water quality and harsh conditions may affect fish welfare and thereby mortality. These bio-economic parameters may have a substantial effect on profitability (Kankainen *et al*. 2012); however, Baltic offshore production conditions effects on bioeconomic parameters have not been evaluated in more detail.

Investment analysis shows that the feeding barge would be the more expensive option than feeding the fish from a boat. However, feeding barges are considered to be a robust method for organizing feeding offshore. These state-of-the-art barges include automatic feeding and fish observation techniques that may lead to better feed efficiency and overall risk management. Automatic feeding barges can also ensure sufficient delivery of the feed. For example, growth may decrease if feed cannot be delivered efficiently due to rough weather conditions or feed delivery cannot be controlled well. Feed efficiency may also decrease if the fish or waste feed cannot be monitored. If the feeding is only carried out from a boat from time to time, this can also lead easily to “overfeeding” of the fish, If it is intended to counteract some growth loss with additional feed.

4.3.3. The effects on competitiveness of offshore farming volumes, distances and feeding strategies

Figure 7 illustrates some business strategies with different site selection, production volumes, and feeding methods. Option A describes the present system in Finland, and options B, C, D and E describe new potential options if larger units are established offshore. Nowadays, Finnish fish farmers commonly have several small units in the intermediate or outer archipelago. The maintenance route is long because the units are widespread (Option A). In this option for calculating the variable logistic costs, we have set the maintenance route at 40 km and assumed that the feed is delivered to cage-specific pendulum feeders with a 20 tonne capacity working boat.

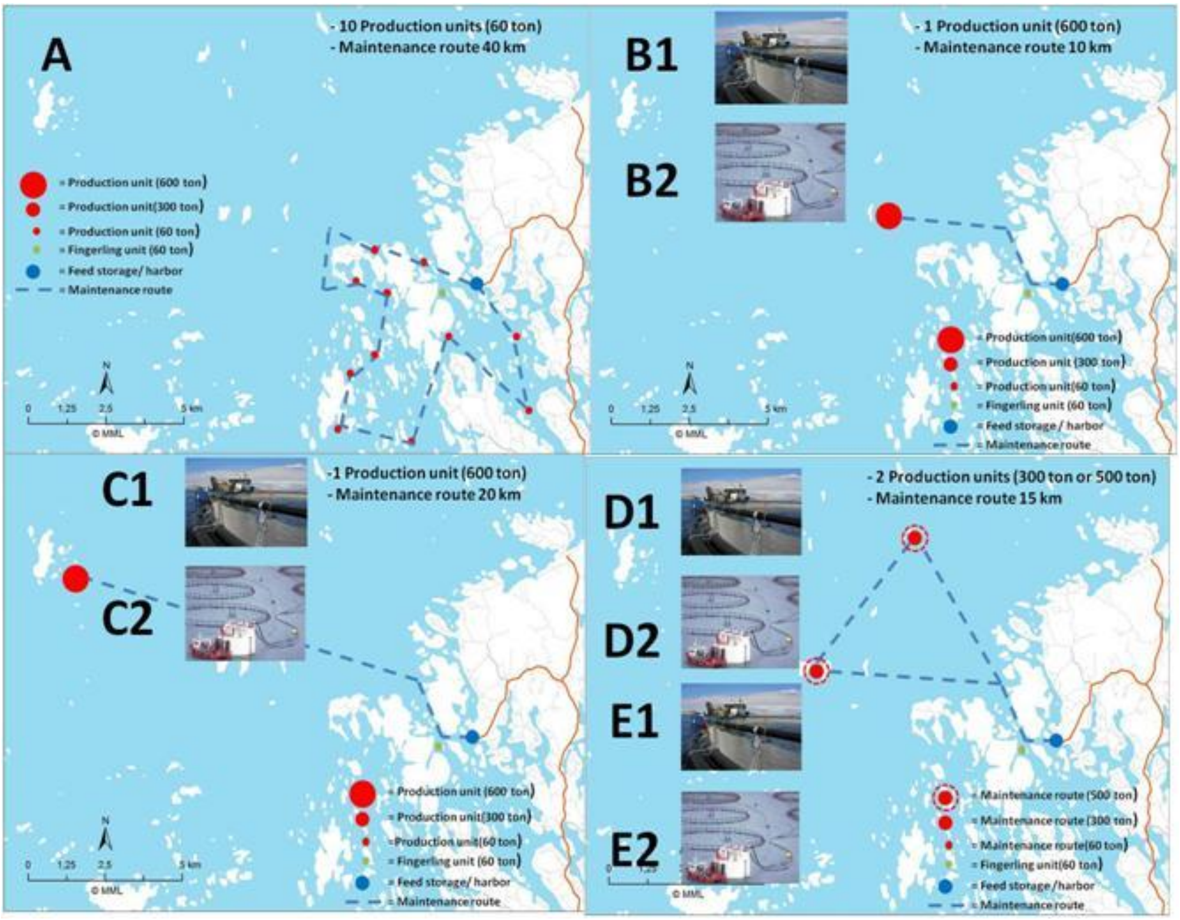


Figure 7 The feeding method (1 or 2), distance (B or C), the number of production units (B or D), and the production volume (D or E) have an effect on production costs.

With options B, C or D, we compared how the distance and the number of production units affect production costs (Table 2). We also calculated the costs of feeding from a boat (Option 1) and feeding from barges (Option 2) at each site. We assumed that robust offshore farming techniques and equipment introduced in this paper are used. Fuel cost was determined as €1.5/l and the operational personnel work costs as €20/hour. Logistics personnel and fuel costs are calculated based on distance and time consumption in each operation. Thus, only efficiency affecting travel and work costs are included. Other cost factors such as fuel consumption and feed capacities assumptions of each business operations are introduced in Appendix 2.

Compared to the present dispersed production system, the calculated logistics costs were lower in Option 1 were feeding is committed from boat, because of the high feed barge cost and low production volumes. However, we did not expect or include any growth, survival or feed efficiency benefits into calculations that may be achieved with automatic feeding from a barge. Major savings were achieved in Option E, in which the production volume was increased from 600 to 1,000 tonnes.

We have also calculated an option where 600 tonnes production is divided into two units. In this option, the benefit of concentration was totally lost if the company used expensive barges (Option D2). Doubling the maintenance route (from harbour to unit and back) from 20 kms to 40 kms did not have a major effect on costs (compare for example B1 and C1). However, it should be noted that the simulation does not cover all the practical changes in productivity. The real profitability calculation for the concentration operation made with entrepreneurs showed that work expenses and investment values may decrease even to one third of the original (€0.14-0.47 /kg; Setälä & Kankainen 2009). In real life, the companies could have released operational staff, boats and even feed harbours if concentration into larger units had been possible.

Table 3. The logistics costs: The present system where the maintenance route distance is: 40 km (A), 10 km route (B), 20 km route (C), 15 km route (D); The number of production units: 10 (A), 1 (B,C), 2 (D,E); The volume: 600 tonne (A, B, C, D), 1,000 tonne (E); the feeding from boat (1) or from feed barge (2)

Production option	A	B1	B2	C1	C2	D1	D2	E1	E2
	€/kg	€/kg	€/kg	€/kg	€/kg	€/kg	€/kg	€/kg	€/kg
Personnel costs	***0,07***	***0,03***	***0,02***	***0,04***	***0,02***	***0,04***	***0,02***	***0,03***	***0,02***
Cage and fish transfer	*0,01*	*0,00*	*0,00*	*0,01*	*0,01*	*0,00*	*0,00*	*0,00*	*0,00*
Feeding/ observation	*0,05*	*0,03*	*0,01*	*0,03*	*0,02*	*0,03*	*0,02*	*0,03*	*0,01*
Fuel costs	***0,04***	***0,01***	***0,01***	***0,02***	***0,02***	***0,02***	***0,01***	***0,01***	***0,01***
Cage and fish transfer	*0,01*	*0,00*	*0,00*	*0,01*	*0,01*	*0,00*	*0,00*	*0,00*	*0,00*
Feeding/ observation	*0,03*	*0,01*	*0,01*	*0,02*	*0,01*	*0,01*	*0,01*	*0,01*	*0,01*
Investments	***0,53***	***0,55***	***0,67***	***0,55***	***0,67***	***0,55***	***0,92***	***0,23***	***0,46***
Boats	*0,14*	*0,32*	*0,22*	*0,32*	*0,22*	*0,32*	*0,22*	*0,19*	*0,13*
Feeding equipment	*0,06*	*0,03*	*0,25*	*0,03*	*0,25*	*0,03*	*0,50*	*0,02*	*0,30*
Cages and equipment	*0,33*	*0,20*	*0,20*	*0,20*	*0,20*	*0,20*	*0,20*	*0,02*	*0,02*
Logistics cost total	***0,63***	***0,59***	***0,70***	***0,61***	***0,71***	***0,61***	***0,96***	***0,28***	***0,49***
Change in production cost	***0,00***	***-0,04***	***0,07***	***-0,02***	***0,08***	***-0,03***	***0,33***	***-0,35***	***-0,14***

5. Risk assessment

5.1. Production risks

5.1.1. Seals and birds, escapees

Seals and birds may effect significant damage on production. Bird nets prevent birds from harming the fish and also seals "surfing" with waves into the nets becomes difficult when the surface is covered. Only single polynets are suggested, the 90 metre circumference nets are so heavy when they are weighted in form that seals have difficulty in pushing the nets and eating the fish through the net. Control systems such as cameras help to monitor if seal manage to break the nets. Nets should be changed from time to time before they weaken according to site-specific duration. Escapees are not a significant environmental problem in the Baltic; however, business operations such us good monitoring and decent assembly prevent the escape risks.

5.1.2. Heavy storms, wind and waves

Heavy storms, wind and waves may impact and damage the fish farming equipment from time to time. This can be avoided by good installation, prior risk assessment, production condition analysis and thereafter choosing sufficiently robust production equipment according to the site in question. Still, some environmental risks can arise, and these losses should be noticed in pricing the production. One way is to pay for the insurances to cover the unexpected risks.

5.1.3. Ice

A huge moving ice mass can tear and damage the fish farming units beyond repair. It is important to take the equipment to shelter before the ice appears, or choose a production unit location where the ice will not move in the area. Submergible solutions below the ice shelter are possible, but may complicate maintenance of the unit. Also, in this option it should be ensured that the production site is not in the area where pack ice occurs.

5.1.4. Mooring and seabed

Seabed analyses are important in order to discover what kind of anchorage method would be robust to keep the fish farms in place. Whole mooring systems as well as nets should be chosen according to waves and currents at the site. If some of the mooring system is left uninstalled for the winter, it should be ensured that the ice will not grab and tear the mooring system and anchorage within.

5.2. Insurance policy, quality standards and guarantee policy

Fish, farming units and related operations and devices can be insured (Table 3). Insurance costs depend on the risk, insurance cover and own liability share of the risk. Generally case-specific risk analysis is required before insurance is determined.

Table 4. Table 3 Factors that can be insured in aquaculture industry

Aquaculture insurances can be agreed to cover risk such us: Pollution, Predation or physical damage by predators or other aquatic organisms, Storm Damage, Freezing, Supercooling, Ice damage, Deoxygenation / Changes in the chemical constituents of the water, Disease, Flood, Mechanical or electrical breakdown, Subsidence / Landslip, Drought, Fire, Lightning, Explosion, Earthquake, Theft and malicious acts, Product recall, ;Marine equipment and vessels, Marine liabilities, Live transport of aquatic animals, Cargo and a wide range of other associated risks (http://www.fp-marine.com/aquaculture)

Fish farming equipment introduced in this report meets the requirements of global ISO 9001 and Norwegian NS9415 certificates. The warranty is one year of implementation if the installation and use are carried out according to terms of use and assembly.

6. Conclusion and need for research

In this paper we have introduced a subjective example of the investment in an offshore unit in the Baltic Sea. There are also many other methods and suppliers for offshore farming (Vielma & Kankainen 2013). Investment decisions were made according to existing knowledge of the production environment and possible need for items can be determined after detailed analysis. The production system and existing equipment and infrastructure chosen also affects the investment.

The production volume of offshore units should be large so that the investment cost per fish does not become too great for profitable business. If the offshore unit is not large, it appears that a feed barge are too expensive if the feed efficiency or other productivity factors do not improve significantly while investing in this state-of-the-art method. If comparing only investment costs, the industry will lose competitive advantage by moving offshore; only 1000 tonne production units were quite close to the present investment cost share out of production cost. However, by making larger production units it is possible to improve the efficacy of production operations, which may be to the benefit of offshore units compared to the present dispersed production system.

Baltic production conditions provide an extra challenge to offshore farming. In this paper, the approach was that all offshore equipment should be taken into shelter from ice each autumn and back to the offshore site each spring. This kind of "dynamic production" operation is not very common in global aquaculture and may need some technical innovation in mooring systems and logistics. Other open questions for entrepreneurs and researchers, that influence the profitability of offshore farming, are:

- How to organize the whole production chain from fingerling to harvest?
- As the Finnish spatial plan concerned only the edible stage: how to organize space for winter sites, fingerling production and harvest if the production increases offshore?
- What kind of work vessels are needed in Baltic offshore conditions?
- Is the water quality, e.g. temperature, suitable for farming in exposed areas?
- Is the growth period adequate for profitable farming offshore?
- How large a production volume per site is allowed and what bases the licence are given ?
- How to evaluate production conditions at site before the investment decision?
- Do production environment risks, e.g. seals and sharp waves, need any special innovation?
- Are there other cost effective methods of organizing farming offshore?
- Is barge feeding suitable in Baltic offshore conditions, and how it would affect the bio-economic productivity parameters ?

References

Asche, F., 2008, Farming the sea, Marine Resource Economics, Volume 23, pp. 527–547, USA

Dalrymple R. A., 1998, Sharing Pedagogy with Java, Linux Journal, December http://www.coastal.udel.edu/faculty/rad/wavemaker.html and http://woodshole.er.usgs.gov/staffpages/csherwood/sedx_equations/RunSPMWave.html.

Dean R. G., Dalrymple R.A., 1984, Water Wave Mechanics for Engineers and Scientists, Englewood Cliffs: Prentice-Hall, Inc., Reprinted: World Scientific Publishing Co., Singapore

MMM, 2014a, Fish farming spatial plan Finland (Suomen kansallinen vesiviljelyn sijaiininohjaus-suunnitelma), Maa- ja metsätalousministeriö. http://www.mmm.fi/attachments/kalariistajaporot/lausuntopyynnot/6E3Tm6zDH/Vesiviljelyn_kansallinen_sijainninohjaussuunnitelma_110113.pdf

FAO 2012, The state of world fisheries and aquaculture 2012, Rome

Itämeriportaali 2013, http://www.itameriportaali.fi/en_GB/, WWW pages published by: Ilmatieteenlaitos (FMI), Suomen Ympäristökeskus (SYKE), Ministry of environment (YM)

Kankainen, M., Niukko J., Tarkki, V. 2013, Fish farming production conditions in Finnish coastline of the Baltic Sea, Aquabest project reports, EU XXX, Hesinki

Kankainen M., Setälä J., Berrill I. K., Ruohonen K., Nobel C., Schneider O., 2012, The economic effects of improving productivity in fish farming with the specific focus on growth, feed efficiency and survival,

Rubino M (Editor) 2008, Offshore aquaculture in the United States: Economic Considerations, Implications & Opportunities. U.S Department of Commerce; Silver Spring, MD; USA. NOAA Technical Memorandum NMFS F/SPO-103. 263 pages.

Ryan, J. 2004. Farming the Deep Blue. Irish Sea Fisheries Board and Irish Marine Institute.

Setälä J., Kankainen M., Suomela J., Vielma J., Tarkki V., 2012, Environmental analysis of fish farming spatial plan Finland, In Finnish: Vesiviljelyn sijainninohjaussuunnitelman ympäristöselostus (Luonnos 11.10.2012), (SOVA), RKTL:n työraportteja, Riista ja kalatalouden tutkimuslaitos, Helsinki.

Setälä, J; Kankainen, M; Norrdahl, O. 2009. Varsinais-Suomen kalankasvattajien näkemyksiä vesiviljelyn uusista ympäristöohjauksen vaihtoehdoista. Riista- ja kalatalous. Selvityksiä 16/2009:1-15.

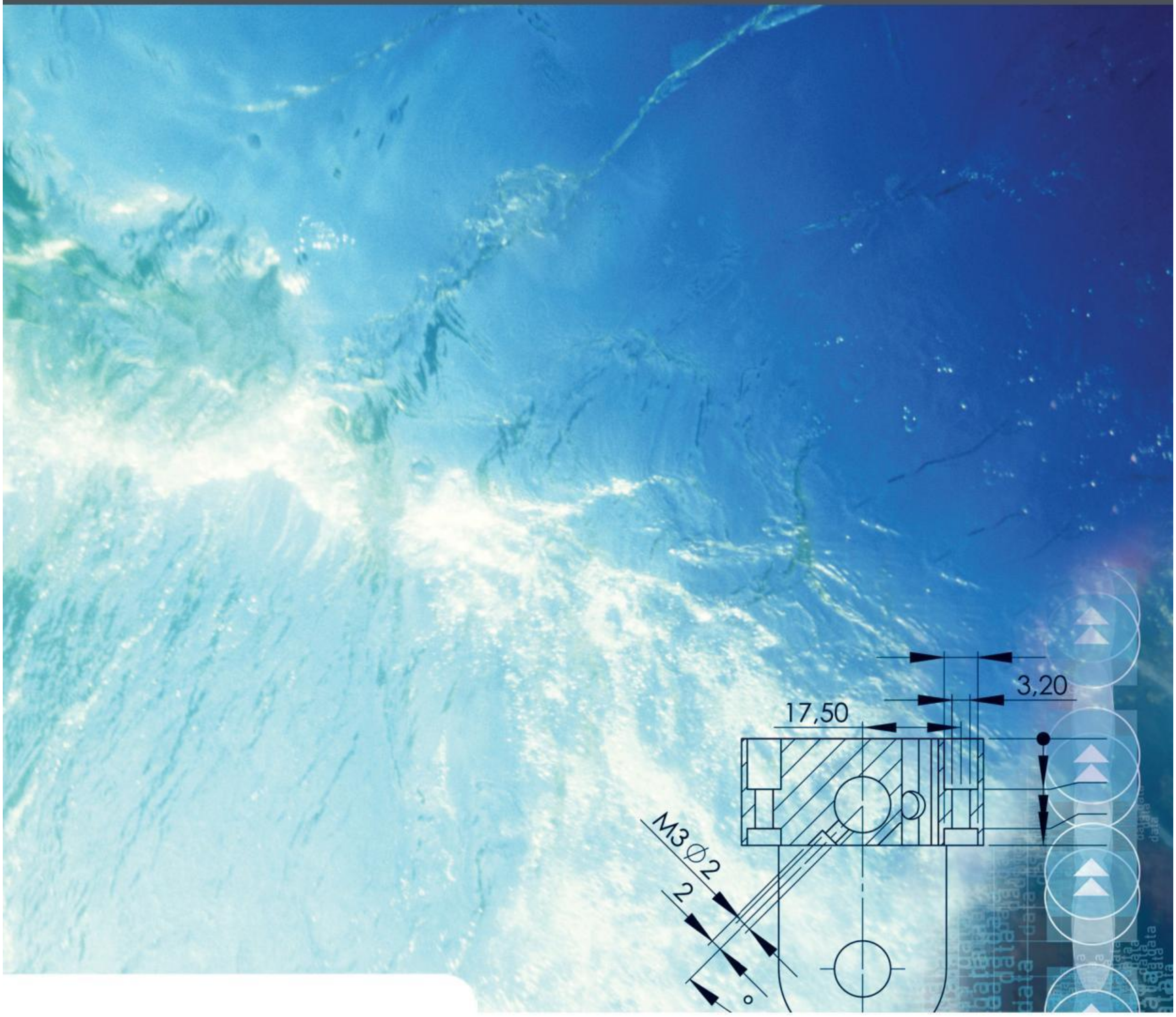
Setälä J, Mäkinen T., Kankainen M, Salmi P., Tarkki V., Halonen Timo 2013 Spatial planning of aquaculture, Finnish Archipelago Sea as a case. Paper presented at ICES Annual Science Conference, Joint ICES/PICES Session Q – Sustainability of aquaculture 18.9.2012 in Bergen, Norway. 14 p.

Vielma J., Kankainen M., 2013, Offshore fish farming technology in Baltic Sea production conditions, Aquabest project reports, EU XXX, Hesinki

Appendix

Appendix 1: Investment plan/offer for 1000 ton offshore unit (11 pages)

AKVA GROUP



Finland

Budget Quote

Preliminary Budget Quote
1000 tons/year
24.04.2013.

wavemaster™ polarcirkel™ fishtalk™ akvasmart™

Site data:

- 1000 tons/year. Species?

Content of this PRELIMINARY budget quote:

1. Polarcirkel cages
2. Mooring system for cages & barges (approx. 30 m depth)
3. Nets
4. Wavemaster Feed barges incl.
   Akvasmart Feed Systems
5. Feeding pipes
6. Idema Net Cleaning System
7. Sensor Systems (Camera and oxygen)
8. Fishtalk production software
9. Supervising, training & start-up
10. Freight

1. Polarcirkel Plastic cages, 1000 tons production

Numbers of cages:	**12 (100 tons biomass calc. per cage)**
Material	HighDensityPolyethyleneHDPE 100
Floating Pipe diameter:	400mm
Wall thickness of floating pipe:	24mm
Circumference:	90m
Brackets :	45 units (2.5 m distance)
Diameter:	28m
Diameter handrail upright	160mm
Diameter handrail pipe	140mm
Nethook	12 mm stainless steel
Expanded Polyester	Included in inner pipe
Walkways:	45 sections each cage

NB: The above cost is using Ø400 as floating pipes, using Ø315 will reduce the cost substancially. Size will be according to conditions at site!

2. Mooring system: Polarcirkel cages & barges

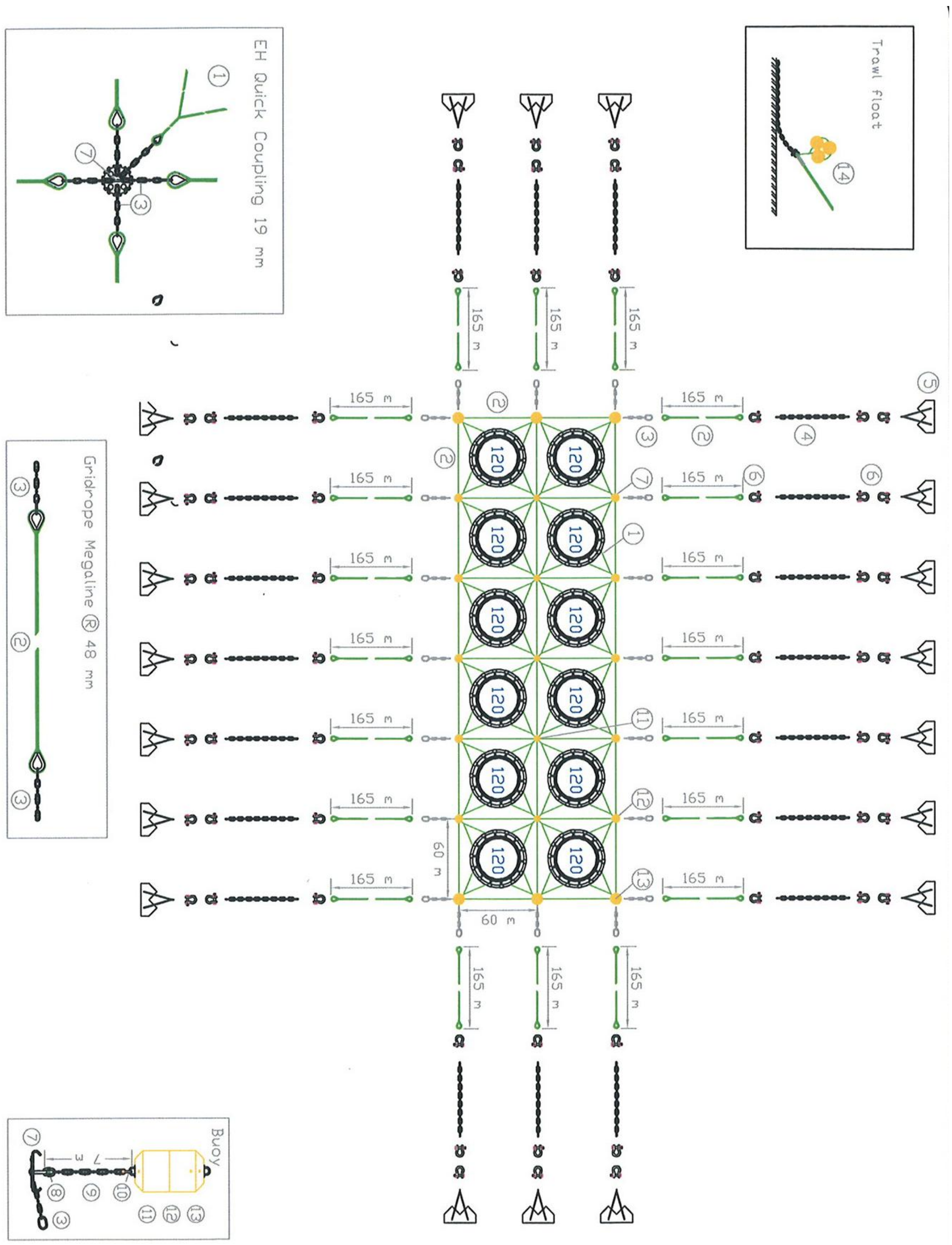
Mooring system is calculated and dimensioned according to the Norwegian standard NS 9415.
Complete Mooring system for:

- 1 group of 2 x 6 / 90m circumference
- 1 Barge

Mooring systems 2 x 6 for 1000 tons site

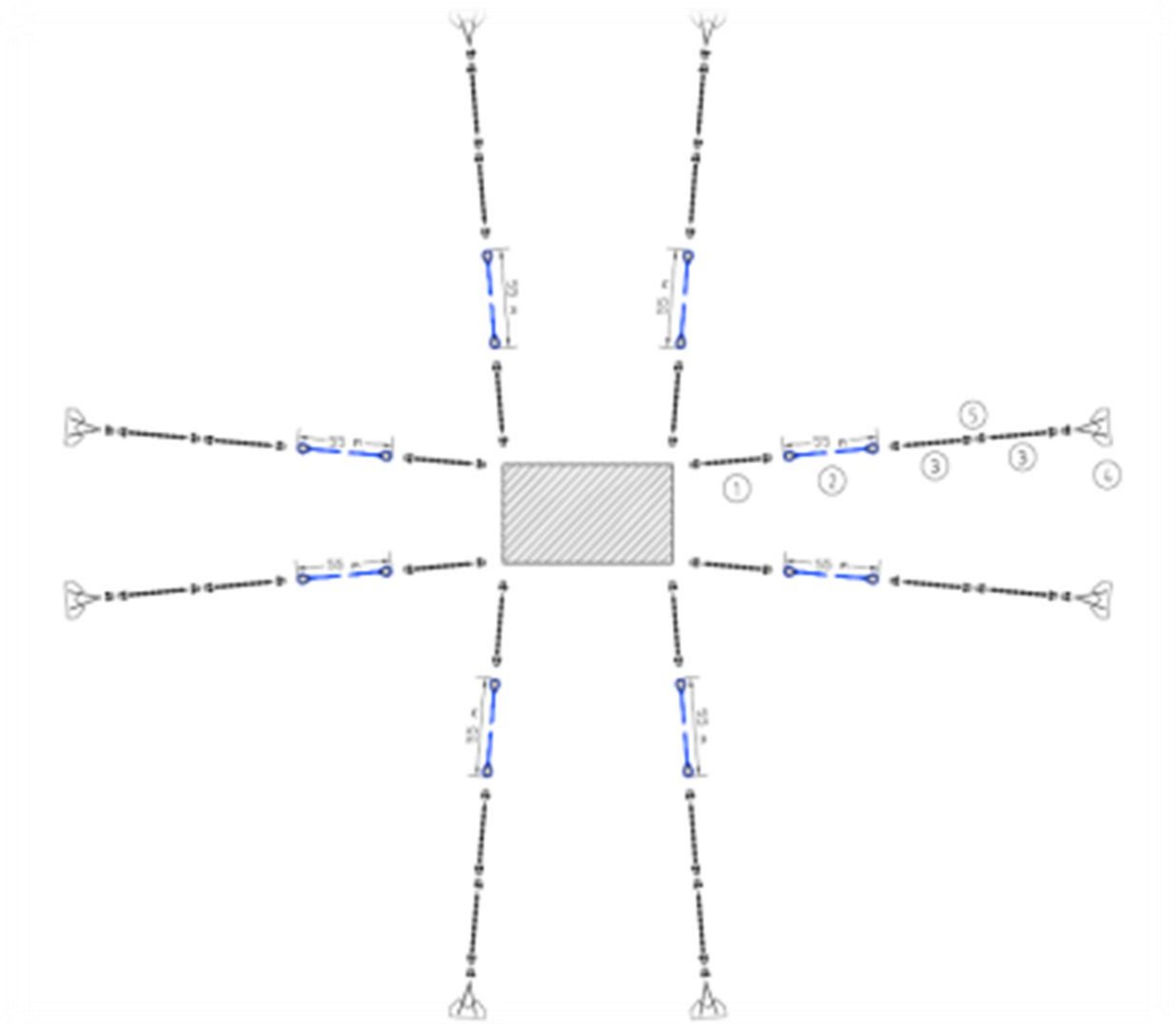
Details of mooring system 2x6 / 120m cages 60x60 :

No. on drawing	Quantity 2 x 6 cages	Description	Minimum Breaking Load (MBL) in ton
1		Megaline 32mm (rope)	**16.8**
2		Megaline 40mm (rope)	**25.7**
3		Chain sling 19mm	**34.0**
4		27.5m stud link chain 28mm	**47.6**
5	20	Concrete blocks, locally produced in ????? could be anchor system	
6		Mooring shackle	**60.0**
7		EH Quick coupling 19mm	**34.0**
8		Connection link galva-nized 16mm	**23.0**
9		7m chain galvanized alloy 13mm	
10		Mooring shackle	**28.0**
11		Buoy 440 liter	
12		Buoy 680 liter	
13		Buoy 1100 liter	
14		Trawl float	



The drawing of the mooring system is a preliminary set up, need to be discussed further for a final set up.

Mooring system for Wavemaster Classic Feed Barge :



Details of mooring system barge:

No. on drawing	Quantity	Description
1		27.5m Stud link chain 28mm
2		56mm mega steel
3		27.5m Stud link chain 36mm
4		EH Megahold 35 (anchor)
5		Mooring shackle MBL 60 ton

3. Nets 1000 tons

The Nets are calculated and dimensioned according to the Norwegian standard NS 9415.

Scope of delivery:

Nets Circumference	90m
Numbers of nets:	12 pcs
Depth	15m + 1,3m
Full Mesh size:	28 mm
Numbers of the filament:	24
Thread no:	210/60
Weight kg/m2	0,370
Bottom type:	Coned bottom design
Mortality collector included	yes
Antigrowth coating	yes
Certification	NS9415 and ISO 9001

Net details:

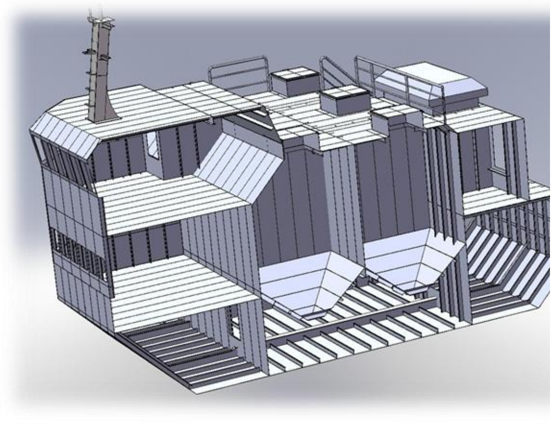
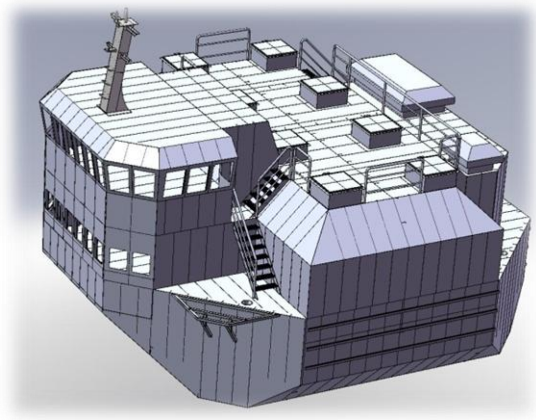
Size	The nets are produced with circumference of 93 m
Marking	All nets are marked with production no, size of net, mesh size, name of producer and customers name
Top rope	18 mm 4 strand hard Danline with 16 loops
Waterline rope	18m hard Danline with 16 loops (plastic covered)
Down rope	18 mm hard Danline 16 pcs
Lifting rope	18 mm Danline 8 pcs
Base rope	1 kg leadline with leg in 18 mm hard Danline with 16 loops
Shape off base	Standard flat bottom and cone shape
Cross rope	18 mm hard Danline 4 pcs
Dead fish system	Double ring in centre of base for mortality collector. The rope for mortality collector installed
Reinforce-ment	Double net in centre of 5 x 5 m
Antifouling	EN Coat Classic
Certificate	NS9415 og ISO 9001

Bird nets 90 m circumference, 360 mm full mesh, tread no. 40, 12 pcs, Included in above net investments.

4. Wavemaster Feed Barge

Product specification AJ 150-MED (or AJ96)
Product specification Akvasmart CCS feeding system
Total Investment

Appendix A: GENERAL ARRANGEMENT WaveMaster AJ 150-MED

1. Product specification AJ 150-MED

General

This Product Specification from AKVA group ASA, describes the standard fishfarming feed barge, type AJ 150-MED., herein referred to as "FEED BARGE". The FEED BARGE will have only a bare minimum of basic outfitting for the base model. All other outfitting and custom specifications will be added as optional equipment.

Main dimensions/data

Length overall	13,33m
Hull length	13,33m
Beam overall (hull)	12,1m
Height overall	7,20 (without mast)
Height, hull to main deck	3,2m
Min. allowed freeboard	0,926m (at max. 278 tons displ.)
Hull plate upgrade	8mm (from 6mm)
Air cooling pipes	2 cooling pipes outside hull (110mm)
Watertight bulkheads	3
Max. approx. feed capacity	150t (based on 650kg/m³)
Number of feed silos	6
2nd floor control room	23m² (approx.)
1st floor kitchen / lunch room	32m² (approx.)

Watertight compartments

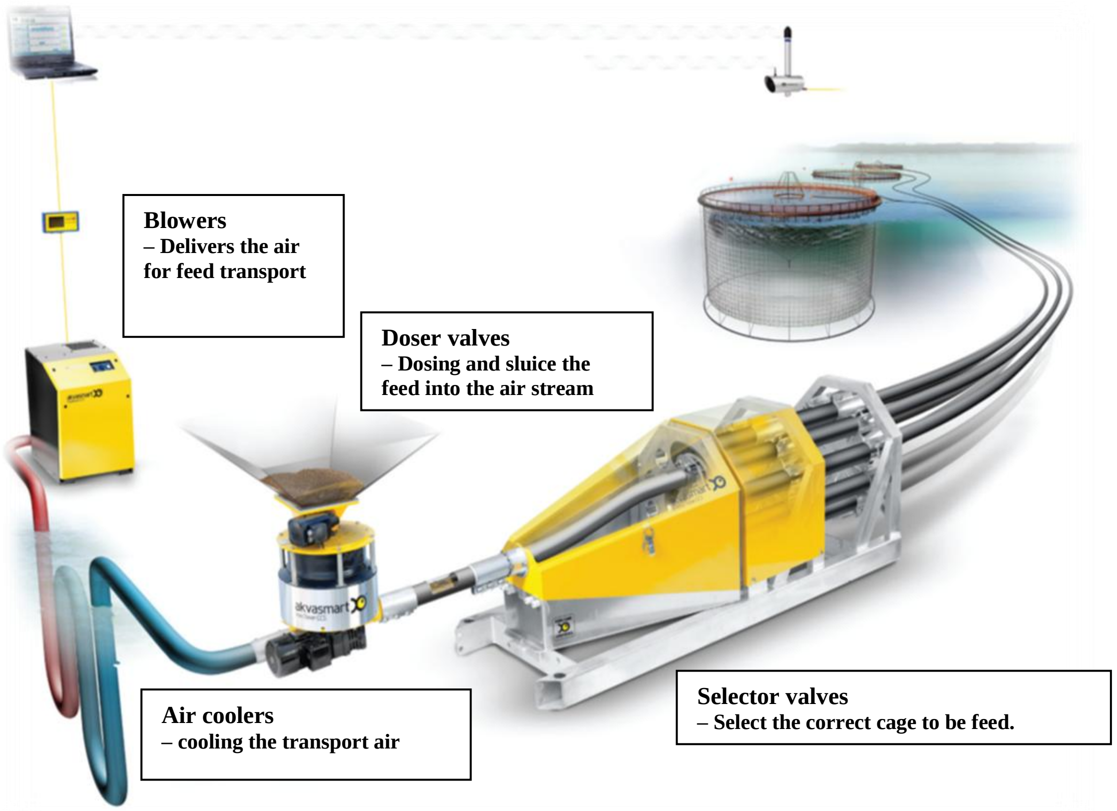
The area below the main deck is divided into 5 (subject to final design) watertight compartments in order to fulfil stability and safety requirements of the FEED BARGE:

- Engine room (aft)
- Large silo room (centered)
- Small wing tank (port side)
- Small wing tank (starboard side)
- Large storage room (forward)

In total 5 marine doors are installed
Boarding ladders and staircase
There are 1 external boarding ladder on the aft and two on corner of hull in forward end of the FEED BARGE.
Fenders (all optional)
Fendering of the FEED BARGE is optional, but the hull must be prepared for proper fastening of two parallel rows of truck type tires (approx. 1000mm diameter), using Ø10mm galvanized chain and shackles.
Painting and surface treatment
Standard paint is Duratek optional is International/Hempel
Cathodic protection
The barge will have sacrificial zinc anodes must be fitted according to DnV recommendations for zinc anodes "Recommended Practice RP B401 –Cathodic protection design" and installation of anodes to be in accordance with drawing from AKVA.
Electrical outfitting
The electrical system, equipment, components and materials to be designed, produced and installed in accordance with applicable specifications, proven marine practices, class requirement and local electrical codes.

2. Product specification Akvasmart CCS feeding system

The feeding systems in the barge are an Akvamarina CCS feeding system that's able to feed the number of cages that's actual on each site.
Concept
The feeding system consisting of a PC for man-machine interface (MMI) an electrical control cabinet, a control computer and various mechanical parts for transporting the feed from the silos to the cages. A twin system consists of two air blowers, two air cooler and two selector valves, and each silo is equipped with a Doser. A twin feeding system line can feed in two cages at the same time. Each silo is connected to one of the feeding line. The AkvaControl Software is the process control software for the Akvasmart feeding system.



Specifications
Specification on the main components in the Akvasmart CCS feeding system:

Blower CF90/22kW
Material: painted steel
Cabinet: silenced
Power consumption: 22kW

Doser CF4000/90mm
Material: Painted casted iron/ Stainless steel / POM
Power consumption: 0,75kW
Max feeding rate: 110kg/min at 400m transport distance (9mm pellet)

Selector CF90/24L
Material: Painted sea water resistant aluminium
Power consumption: 0,35kW
Number of outlet: 24
Pipe size: 90mm PEHD feeding pipe

or more general information pls. find this in our 2010 Product Catalogue

Rotor Spreader CS90-C
The Rotor Spreader CS90-C is designed to provide excellent feed spread in cages.
Strong feed pipe connection floating on the surface minimizes mechanical loads on the feed pipe.

3. Total Investment

Product	**Amounts**
Wavemaster AJ 150-MED x 1 units (Or AJ96)	1
Generator	
Crane for filling the silo	1
Twin Akvasmart CCS feed system	Twin 90mm system
Feeding pipe	Locally delivered
Rotor Spreader CS 90-C	12

5. Feeding pipes

Polarcirkel Feeding Pipes of high quality and durable for aquaculture. Dimension 90 mm with wall thickness of 7 mm. Delivered in coil lengths of 200 or 300 meter. Locally delivered according to AKVA spec.

6. Idema Net Cleaning System

Principals for Net Cleaning

In Net Cleaning, filtrated sea water under high pressure is used to remove growth on the nets. The cleaning process starts with submerging the cleaning rig along the inside of the net, using only sea water under high pressure for cleaning. Idema Net Cleaners use rotating cleaning discs mounted on cleaning rigs in different shapes and combinations. We offer rugged, tailor-made high-pressure washers to supply enough pressurized seawater to the cleaning discs.

The cleaning process is done while moving the cleaning rig down-and upwards on the inside of the net, using only filtrated sea water under high pressure. Idema Cleaning Systems do not use chemicals or rubbing, so they are environmentally friendly, whilst not causing any damage to the nets.

Effective Net cleaning ensures optimum oxygen levels and faster growing biomass.
The large Net Cleaners can be operated in semi-automatic mode by two persons via a crane, winch, cap stand or as a mounted option on ROV (Remotely Operated Vehicle).
The smallest Net Cleaners can easily be operated from the cage by a single person.

On the larger Idema rigs we can offer tailor-made camera and video systems that provide a full overview, and the possibility to inspect the nets. A camera mounted directly on the Net Cleaner will give you crystal clear video images that can be saved and copied for later inspection and cleaning of the nets.

Our Net Cleaners are supplied with Heavy Duty Cleaning Disks. They are perfectly smooth disks with stainless steel curved front that give low friction against the water and thus a high rpm –from 750 to 1500 rpm dependent on water pressure, water flow and diameter on the cleaning disk. The actual cleaning speed is determined by the combination of water flow and working pressure. The Heavy Duty Centre Bearing is a new development that gives you enhanced service intervals and a simple maintenance schedule.

We recommend a Quint Head Net Cleaning System for the main and periodic cleaning of the nets. The unit with 5 disks is the most suitable one for your use, with a majority of cages ranging up to 200 m circumference. The rig is delivered together with a camera package and a K-136-300 SD aggregate.

Diesel powered high-pressure Netwasher K-136-300		
Cleaning capacity	Cleaning area: 2 m width Performance is like 1.5 hours cleaning one net 80 m circumf. 10 m deep	
High pressure pump	Pratisolli MSB 36 Duplex (1500-rpm) 750 rpm giving 136 liter at 300bar	
Cabinet	Noise reduction cabinet in stainless Steel, integrated diesel tank of 330 liter. Length: 390 cm - Width: 120 cm - Height: 190 cm-Weight: ca 2.500 kg	
Diesel engine	John Deere 6068 TF 220	150 hk-1500 rpm
Net cleaning rig	Idema 5 disk Head.	

	5 pcs/40 cm disks produced in stainless steel and carbon fiber.	
Rig camera **DVR Recorder** **Flatscreen**	2 pcs color camera on rig to control the washing process. DVR (digital video recorder) for record of washing process and control of net after finished process 19" flat screen, can be connected to 230v ac or 12v dc.	
Start up at site	**Control, start up and testing of complete system onboard boat, after system installation. This is a part of the delivery and has to be executed by our Service engineer. Included, 2 days travelling + 1 full day at site**	

7. Sensor Systems

Installation of one oxygen sensor in each cage together with cameras and monitoring, we have made "frameworks" which fits your need (CSU, Base, etc.)
Super HR Feeding Camera, 12 pcs
Oxygen Sensor, 12 pcs

8. Fishtalk production planning software / Example

Fishtalk Control in short:

- Role based in order to adjust to the working environment of the different operators, and for securing the company's assets - the fish stock.
- Stock Control; Add information on the daily activities on the site, and Fishtalk will at any time give you the updated stock.
- Add information of origin, environment, health, quality etc, and the system will keep track of for example the environment history of the fish.
- Data from feeding system and all environmental sensors can be logged automatically.
- Traceability can at any time be reported and visualized, in order to fulfill information needs from the market.
- The report generator can give anything from a simple status report, to advanced analysis between contribution factor and result. Feed and vaccination may be set up against growth, health and quality and shows you the well-being and welfare of the fish.
- Reporting levels can be both on the fish; year class, batch etc. or on infrastructure; cage, site, company etc.

Fishtalk Value Chain Planner in short

- Plan biological production from eggs to harvest included movement of fish between tanks/cages, sites and harvest.
- This plan gives the need for feed (how much when) and other input factors needed in the production, as transportation, as need for personnel etc.

- Plan within the given limitations in production license, transport, and harvest capacity etc, in order to maximize utilization of equipment, personnel and infrastructure.
- The visualization of these limitations is extremely important information in order to streamline the production.
- Economic result of the biological plan - budget.
- Make different scenarios (bad - likely - good) to see the effects of price/cost fluctuations in feed, in the fish you sell, in the fingerlings you buy etc.
- Deviation reporting actual vs. planned - where do we need to focus?
- Integrate accounting and report actual numbers on biology and economy combined.

Scope of Delivery:
Software investment:
Investing in- and use of Fishtalk Software is priced in two parts:
- License investment based on production volume
- License maintenance, 30 % per year of license investment.

(Maintenance fee is not included)

9. Installation, Supervising, start-up and training

Product	
Supervision, startup and training – Barge	
Travel and accomodation	Not included
Installation of mooring system	
Installation of mooring systems barges	
Assembly cages 400, 12pcs	

10. Freight

Containers, amounts & numbers	**NOK**
x 40″ + x 20″ containers delivered CIP town??	

Need more final discussion of all transport needed

Appendix 2: Cost and production efficacy factors used in profitability analysis

(The related number of sites, distances and number of production units are introduced in figure 7)

General cost factors	Personel cost €/h	Fuel cost €/l	Interest %	Deprecation years average
	20	1,50	5,00 %	7,66
Cage costs	€/Cage 100 ton/300 ton	€/Cage 100 ton/600 ton	€/Cage 100 ton/1000 ton	
	156000	124 000	92 100	
Boat cost factors	Offshore vessel with feeding	Offshore vessel	Normal vessel	Fast maintenance boat
	1 080 000	720 000	540 000	120 000
Fish and cage transfers	Personel	Capacity feed ton	Consumption l/h	Speed km/h
	2	20	50	25
Fish and cage transfers	Personel	Capacity cage transfer fish ton	Consumption l/h	Speed km/h
	4	100	50	5
Feeding method options	Capacity ton	Investment €*	Investment per site	Worktime h/ton
Pendel feeding (Option A)	1	150 000	10 000	0,5+
Blast feeding from boat (Option 1)	4	135 000		1+
Feeding ferry (Option 2)	90	816 000/ 950 000/1 050 000	2 000	0,125+
**Includes 120 000€ production planning system, investment value for 300ton/600ton/1000ton*				