University of South-Eastern Norway

An evaluation of wellboats capabilities

An exploratory study on capabilities found on wellboats

Candidate name: Kine Malene Sletnes

University of South-Eastern Norway
Faculty of Technology, Natural Sciences and Maritime Sciences

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Abstract

Fish farming industry is important for Norway. Wellboats, or live fish carries, are an important part of this industry with transporting live fish from shore to cages, if needed treat them, before they get transported to harvest.

An exploratory study has been done on the wellboats, and research questions the study is done on is: *What capabilities are in the wellboat fleet today?* In addition to this there is also three sub questions that is explored during this research. These are:

SQ1: What kind of means of transport is a wellboat providing? What kinds of functions does wellboats have?

SQ2: How can the different capabilities be categorised?

SQ3: Why are there different types of boats in the fleet?

The findings are shown using a model that is based on the literature review, and the capabilities that are found are categorised into five categories: size, fish treatment options, sailing and manoeuvring capabilities, fish handling equipment and contracts.

The purpose of the study is to investigate different capabilities that are in the wellboat fleet, and to explain why they matter and are important for the fleet and the industry.

The thesis aims to be an addition to the academics about wellboats. There has been little focus on this market in research earlier, therefore a lack of information about this fleet of boats.

Keywords: Wellboat, Live fish carrier, capability, exploratory study, fish treatment, fish handling.

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I also want to thank my family and friends giving me support under the hectic writing months and for giving me motivation to keep going on. My dogs as well needs to be thanked for being there at all times, and ensuring me to have breaks when the writing is difficult.

Kine M. Sletnes
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AGD – Amoebic gill disease, a disease that affect salmon. Can be treated with fresh water and H2O2.

Lice – Salmon lice which is small lice that is found on salmon.

1 Introduction

This master thesis marks the end of the Master in Maritime Management with technical specialisation taken at University of South-Eastern Norway. Topic that is chosen is based on the interest, and the experience and knowledge I have built over the year working in this industry. The topic is wellboat and their capabilities, and this will be an exploratory study with the aim to contribute with more research on the topic.

In this introduction chapter it will be a brief look on the challenge, before I will introduce my research problem, before a brief introduction on the history of wellboats and at the end of this chapter the outline of the thesis will be laid out.

1.1 The challenge

In this section the challenge with the topic is presented, and why this topic is relevant to write about.

There is limited academic writing about the wellboat, a market that is in rapid growth both in boat size, fleet size and technology. The last years this topic have been getting an increased focus, with more student writing their thesis about the topic and more research completed, but still there is more academic research on the fish farms then wellboats.

Not everyone has ever heard about this type of boat before, but there was in 2018 80 wellboats owned by 20 companies in Norway. (Lorentzen, 2018) This number of boats are growing, and more fish farming companies have decided to build their own boat, to mention some is Alsaker, Nordlaks and Erko Seafood. The ships are to be seen along the coast from south of Norway to North of Norway, in Scotland, Canada, Chile, Tazmania and so on. They pass between narrow straight, over shallow water and sometimes they are longer away from the coast visiting offshore fish farms.

The topic is with other words very relevant for the maritime industry, but it can also be related to many of the courses in my master program in courses, for example Innovation Projects, Strategic Analysis, Maritime Economics, Ship Operations, and Research Methods.

1.2 Research question

As mentioned in the start of this chapter, the purpose of this thesis is to write an exploratory study on the capabilities of the wellboats. Since it has been a big development of the boats that is in the fleet today, I decided to write about different capabilities that is found within the fleet of wellboats. This will hopefully be a help for both people that is new in the industry, and for further research in the future.

My research question for this thesis is therefore:
What capabilities are in the wellboat fleet today?

To be able to answer this question there are different sub questions that is needed to be answered. These are:
SQ1: What kind of means of transport is a wellboat providing? What kinds of functions does wellboats have?

SQ2: How can the different capabilities be categorised?

SQ3: Why are there different types of boats in the fleet?

To answer these questions, it is needed to do deeper research on the field, and see where it leads. As this is an exploratory study, this means it not sure where this thesis ends up in the end, and therefore these kinds of research method does not use hypothesis.

1.3 Background

The ocean is about 71% of the Earth's surface, and only 20% of it is visible since rest is under det surface. Actually, more surface on the moon and Mars is mapped than the ocean floor (National Geographic). The ocean stands for 2% of our calorie intake, but it also have half of the biological production on Earth. (SINTEF).

In 2016 OECD (The Organisation for Economic Co-operation and Development) wrote an report, The Ocean Economy in 2030, on how they expect the ocean economy to go the next years until 2030, here they wrote that they expected the global fish food demand to grow the next decades, due to the population in the world is also increasing. People in the world earn more and more, and therefore have the economy to buy food and fish. According to OECD's report FAO (Food and agriculture organization) expect a growth on 4,3% until 2022, while World Bank's expected 2% growth per year until 2030. (OECD, 2016)

In Norway there is a saying; "*Laks er viktig for Norge*", this means that salmon is important for Norway. This saying the Norwegian aquaculture industry use a lot, and when showing the numbers and the impact the industry has for Norway there is not without reason. Fish farming is the most effective production method for protein, and in 2013 it was used 21,09 square kilometers, 573 farms, to produce 1 243 000 ton of salmon and trout. These fishes gave an export revenue on over 42 billion NOK, this is 70% of the total seafood export in revenue. The fish farming industry uses about 34,3 billion NOK on goods and services in Norway as well. (Andreassen & Robertsen, 2014)

So how did Norway end up with this industry? This adventure started by learning about artificial inseminating of fish to increase the numbers of wild fish, this was done by Halvor H. Rasch and Marius G. Hetting, and this is shown to be in 1853. In Denmark they had started with ponds of rainbow trout in their fields where they had made different solutions to get circulation of water. They had about 300 pounds in 1914, but due to war it was only 10 left in 1919. Erling Osland built in 1964/1965 a cage system, figure 1, in Norway, that is seen as the start of today's cage system. Osland lost a lot of money in the start, but after a few years he started earning money on it with trout. In 1966 he was able to get his hands on salmon. After this there have been different kinds of innovations, MOWI in 1968 used a farm in Flogøykjøplo where they had a 50 000 square meter area where they had made a gate to keep the fish inside. This was the start of this adventure. (Hovland et al., 2014)

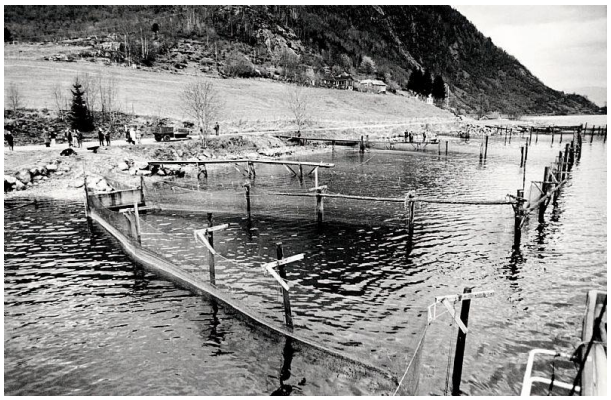
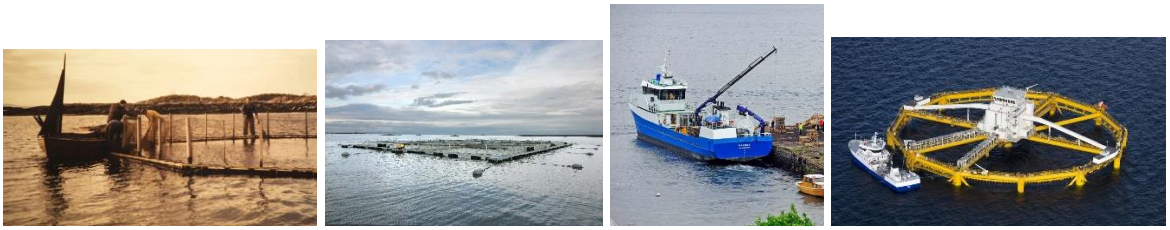


Figure 1: Erling Osland's first cage, Picture: (Sunde)

To show how the development have been I have made a timeline in figure 2, which shows the development of cages and wellboats. In 1970 when the first cages was made there was used rowing boats as boat wellboats and service vessels, while around 1980 fishing boats was rebuilt to work as a wellboat. In the end of the 80's the first wellboats was built, and these was around 15m long and had a well capacity around 50 – 100m3. After this the boats have grown, 34m long in 1994, 50m long in 2002 to 116m long in 2020.

The cages as well have the last 50 years gone from floating wood to offshore constructions, and this would not be possible without having wellboats that have capabilities to service the farm.



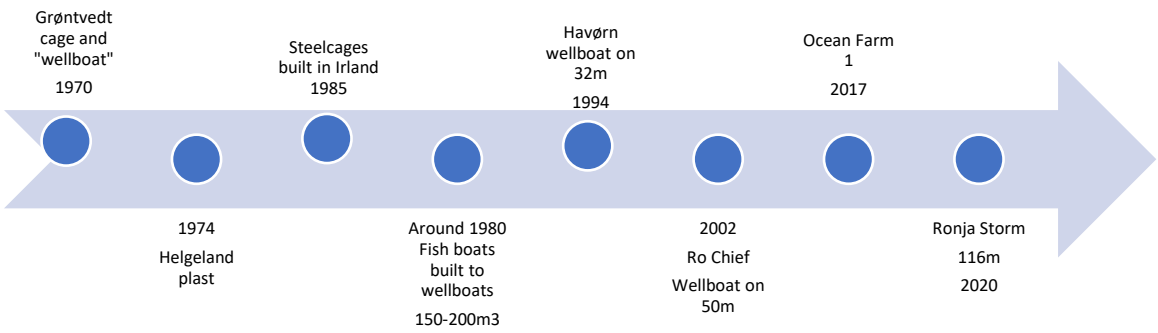


Figure 2: Timeline for development of wellboats and cages.
Sources: (Adresseavisen, 2017; AKVAgroup; M. Berg, 1972; Helgelandholding; Lorentzen, 2018; Maritimt Magasin, 2020; Sunnmørsposten, 2016; Valderhaug, 2002)

1.4 Thesis outline

The last section of the introduction will be the outline of the thesis, to help navigate in this thesis. The thesis has 6 chapters, and these will help understanding the topic and research question in different ways.

Chapter 1: Introduction, here the topic is established, research question made, and background of the thesis is explained.

Chapter 2: Literature review, this chapter contain information that is known in the literature today. It includes a brief explanation about the wellboat and some of the systems on board. This chapter have two different assessments methods that can be used to assess, but also to categorise and explorer capabilities that will be highlighted in chapter 4.

Chapter 3: Research method, in this chapter the recipe for the thesis is given, with information about research design, sampling, data collection and ethical considerations.

Chapter 4: Findings, here the results about the capabilities is presented.

Chapter 5: Discussion, this is where I will be discussing my findings.

Chapter 6: Conclusion, here the conclusion and suggestion for further research will be displayed.

2 Literature review

This chapter is about the information on the topic that is known today, and it also includes two different literature reviews that can be used to answer the research question. It will start with some brief information about what is a wellboat, special characteristics, functions that the wellboat have with transport and treatment methods, logistical assessment method and sustainability assessment method.

2.1 What is a wellboat?

A wellboat is actually a very complex boat with a lot of different equipment, and to be able to understand all of this I have done a literature review to gather some of the basic knowledge. It will start with explaining the name and the two main types of wells that is found, and how the fish is alive inside the boats. Then it will be a brief section about other design characteristics that is seen on wellboats. Thereafter I will mention some types of jobs a wellboat carry out. At the end of this section is a short introduction to different treatments methods that is used today.

The wellboat has two main jobs for a fish farmer. The first one is to transport fish and the second one is to treat the fish. I will now explain a bit further what these two means and how it is done.

A wellboat is a ship that have one or more wells/ tanks inside with water where the live fish can swim around. The ship can have two types of well, one is round and the other one is rectangular. The most common type is the rectangular, but there are some with round tanks as well.

Figure 3: Round wells in Havtrans., Source: (Havyard, 2015)

Figure 3 shows a screen shot from a film clip that explain the technology on using round wells. This is *Havtrans* that is built at Havyard with MMC equipment.

Figure 4 is showing a rectangular well. This picture is a screen shot from a film explaining how the water was kept clean using skimmers on wellboats owned by Sølvtrans. This

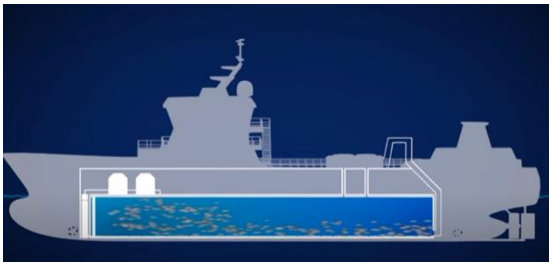


Figure 4: Rectangulare well in Ronja Harvester, Source: (Sølvtrans, 2013)

technology is exchanged for better solutions for Co2 strippers today.

All the wells have circulation to ensure that the water is always circulating. If there is open circulation the water will be changing continuously with new seawater. On a closed system, this means that it will not be pumped in or out any fresh water, so the fish requires the water to be circulated to ensure all fish have enough oxygen. When the wells are on closed system there is not any fresh water coming in, and since they are breathing in oxygen and give out CO2 the levels of CO2 can get high. (Rosten, 2010). CO2 is toxic and dangerous for the fish in higher levels. (Grefsrud et al., 2021). Due to this most of the boats today have CO2 strippers that beat or air out the CO2, which leads to less CO2 in the water to the fish. Oxygen is also added in the wells.

Figure 5: Aqua Gripfisk, Source: (Tulloch, 2020)

When wellboat enthusiast speak about wellboats they often speak size, what total size the wells have. The small once is about 630m3 as *Aqua Gripfisk*, figure 5, which was amazing in 1997, (Aasmek.no), and the world largest in 2019 was 7450m3, *Ronja Storm*, figure 6. (Vadset, 2020). The bigger wells they have the more fish they can take, how much depends about the fish size and why they are on board. If they need to have the well closed for a long time during treatment they might want to have less fish, compared to if the job is to splitting and moving fish to different cages with open system.

Figure 6: Ronja Storm, Source: (Pless, 2020)

2.2 Some design characteristics with a wellboat

The ship has mainly two condition, one is full wells and the other one is with empty wells. When a well is full it is full of water, since the live fish replaces the water load and adds no extra weight. The freeboard will change a bit if it is empty or full, as seen on other ships like a tanker. Freeboard is defined as distance measured from the waterline to the upper edge of the deck plating at side of the freeboard deck amidships. (Wärtsila). Figure 7 and 8 are of the same ship, *Ro Fjord*, but figure 8 shows the boat with wells full of water, and figure 7 is with empty wells. The measure from the waterline to the “hose deck” is less when the tanks are full of water. When fully loaded the fresh water the boat will be a bit lighter and not as deep as when loaded with salt water due to the density of the water.

Figure 7: Ro Fjord with empty wells, Source: (Lyngstad, 2019)

Figure 8: Ro Fjord fully loaded wells, Source: (Lyngstad, 2019)

Shelterdeck is defined as a continuous deck above the freeboard deck (Wärtsila). This for wellboats are meaning that some have a shelterdeck instead of a fully open freeboard deck or hose deck as it is also called. Instead of having equipment outside, like *Ro Fjord* in figure 7 and 8, they have the equipment inside the shelterdeck as shown on figure 9 of *Ronja Viking*, which only have the hoses outside on the hose deck, while other equipment is inside the sheltedeck, or on the deck above to be protected for waves and weather. *Ronja Viking* have been in transportation around the Hebrides for many years, which have a very rough weather at times and therefore the shelterdeck is crucial for them. The shelterdeck also gives the engineer a dry and safe passage to the engine room, where he would need to walk outside on boats without shelterdeck, on a gangway (called stormbridge) that is placed over the freeboard / hose deck.

Figure 9: Ronja Viking, Source: (Gunn, 2014)

2.3 Types of transportation of fish executed by the wellboat

The wellboat have three major types of transportation. Smolt, harvest fish and moving/splitting fish.

Smolt is baby fish that can be from 80g – 1000g. When they are up to 1 kg it is called post smolt. (nofima.no). This fish comes from tanks onshore where they have been living in fresh water. There are different types of methods used to load smolts, for example there is often used pipes directly from the tanks to the boat, trucks can transport the smolt to the ship, and even helicopters have been used. When it is loaded on board it sometimes needs to be counted on bord trough special made smolt counter, the normal counter on board is not able to count this size of fish that accurate. Then the boats go out to the farm the smolts are going to grow up in, and they get unloaded to a cage. Often the fish needs to be counted out as well if the well is getting split into more than one cage.

Moving / splitting of fish is often done when the fish have grown bigger and need more space, and there is a biomass regulation they need to follow. Or it can be done when the fish is graded on board to have more homogenously fish sizes together, often it is to get better prices when slaughtering the fish. The grader is a special deck equipment with rollers where small fish goes through and big fish is kept on top, these are eighter going into a well or back to the cage. On figure 10 there is a picture of a grader. This grader is a three-way grader which means that there is two grader in one, where the first grader can grade out the smallest fish, normally the cleaner fish. On the second grader is the main grade between small and big fish. It works with the small fish falling between the rollers, and thereafter it goes into the well or the cage.

Figure 10: Grader, Picture taken by author in Scotland

Harvest fish transportation is done by loading the fish straight into the well, and then transported to an onshore facility to deliver the fish. Here it is unloaded to waiting pens or direct to the harvest station. To unload the fish there is two different methods. One method is to use pressure of the wells with circulating extra water in to the well. The other method is using vacuum. If the fish have any illnesses it is not allowed according to Norwegian rules to put it in a waiting pen, and it needs to be directly discharged to avoid any illness spreading to locations in the area.

2.4 Types of treatment methods of fish on board a wellboat

When the fish is growing up it might get lice or AGD. In Norway there are laws that regulate how many lice it can be on the fish before the farmer must start treatment. Not all countries have these kinds of laws, but lice will impact the fish welfare and the end quality of the fish. Fish with much damage will be down graded regarding the quality. AGD can be treated by using H2O2 or fresh water.

There are two main categorizes of treatments mechanical and bath treatment. In 2016 the Norwegian government had a campaign on responsible use of medical treatment, that is often used as a bath treatment method, which gave an increased activity with mechanical and reduced use of medicine to avoid resistance. The government also recommend the fish farmer to keep using different methods to avoid a situation in the future where lice is resistance against one method (Ministry of Trade. Industry and Fisheries, 2017)

2.4.1 Mechanical treatment methods

This is the treatments methods which do not uses any medicine. There are two main categories, and some popular products which uses the different types. There is also a lot more special modifications of these two types, which I will not go into. This method is preformed by puming the fish on board to a machine before it was a merry go-around and ending up in the cage again, it will not be in the well and therefore many have built their own treatment barges with this equipment on.

Thermal

This is a way to treat for lice using heated seawater. The fish is pumped on board, goes through a dewatered before it goes to the heated seawater, and then out to the cage again. It is two popular designs with this method in the market today, Optilicer and Thermolicer. The different between them is how the fish is guided through the heated seawater. Both is showing good effect on movable lice and is having an effect on 94-98%. (T. Berg, 2017)

Mechanical

There are more kinds of treatments that goes under this category. Most common method used for this type of treatment is that the fish gets pump on board and through a dewater. After the dewater it gets flushed with low pressure, and then it will be pumped out to the cage again. The three most known methods is SkaMik, FLS and Hydrolicer. The different between these are:

SkaMik uses first a flushing chamber before they go through a brushing chamber with rotating brushes.

FLS uses only flushing while the fish is in the seawater, and therefore it does not have to be stressed with going over the dewater.

Hydrolicer is much alike the other methods, and only uses one flushing nozzle. (T. Berg, 2017)

2.4.2 Bathing treatment

There are two different types of bathing treatments that is done when having fish on board the wellboat. These are fresh water and medical.

Fresh water

Fresh water treatment is a treatment which can be used against lice and AGD. This is just having the fish dropped into fresh water in the wells for some time before returned to the cage. This is seen to be the most natural way for the fish to get rid of lice, and a lot of wild salmon is seeking into the rivers to both do the spawning and to get rid of lice. (Mattilsynet, 2016)

The fresh water is loaded from on shore to the boat, from fresh water pens through the loading hoses (not all boats are able to do this), or the boat has it owns fresh water generators / osmosis.

Norwegian Seafood Research Fund have done tests on this method and found that 86% of all types of lice was removed using this treatment method. They found out that some was moved mechanical when loaded on board using dewater, but also that many was very sensitive when it had gone 3 hours, so the effect is both mechanical and due to freshwater. (Reynolds, 2013)

Medical

It is many different types of medical treatment that can be used against lice. I will mainly mention H2O2 / Hydrogen peroxide which is the only treatment that needs it own equipment on board with pipes and dosing units. The process for using H2O2 is to pump the fish on board, let it settle for some time to be calm, and then put in the required dose of H2O2. Test performed by Akvaplan – niva in north of Norway shows that this H2O2 and other treatments used in bath treatments is hurting and in worst case killing the crayfish and shrimps in the fjords. (Markusson, 2020) (Trana & Sae-Khow, 2018). These medical treatments can be preformed with wellboats or by using tarp around the cage. By using wellboats it is possible to flush the treatment water outside the fields with shrimps.

2.5 Logistic assessment method

Logistic planning is not the core competency for eighter the wellboat companies or the farmers, and therefore it can be linked to the offshore vessels in 2009. Aas (2009) described in his article “The role of supply vessels in offshore logistics” about the platform supply vessels role and their task in the offshore logistics with a logistic view. (Aas, 2009)

Upstream logistics is in a Supply chain is all the logistical activities before the production process. This means that upstream logistic is providing a company with products.
Downstream logistics is all the activities that take place after the production process. This is mostly the storage and delivery of finished products. (GEFCO)
Downstream logistics in oil and gas industry is defined to bringing oil and gas to onshore costumers. Upstream logistic in oil and gas industry is to provide the offshore drilling and production units with necessary supplies. (Aas, 2009)

Another important fact in this planning of logistics it to know about the vessel itself, and how it performs and how the fleet will be combined. To look back to the supply vessel Aas (2009)

he was looking into the features that he meant was important for the logistics of the supply vessel and this was:

- **Reliability and operational capability**.
  Making sure the ship is in good order, and do not have any technical issues. This capability is not easy to assess without having any prior knowledge about the vessel itself, as the owners often will not share this information.

- **Carrying capacity.**
  Since the supply vessel is carrying both bulk and deck cargo, and this is the main purpose of the ship, it is important to assess the ship based on this.
  It is assessed with first finding how much is to be transported, then how many vessels, and which size is needed to have in the fleet. If they base it on the average they might not be able to handle fluctuations, but having an bigger fleet than necessary will be more expensive due to rent and is not environmental friendly. The same goes with the vessel size, a bigger vessel can have lower impact on environment as it has lower emission per unit on a fully loaded ship, and the transport unit cost will also drop. In a scenario with bad weather, it will also be able to bring out more cargo, but this often means that it will visit more offshore units and therefore might take longer time to get the cargo.

- **Sailing capability.**
  The ability of the vessel to sail under different conditions. This will be regulated by the weather which can make it impossible to deliver the cargo in one piece if the weather is not taken in consideration when finding the best speed out to the offshore unit. Here advantage and disadvantage using higher speed must be weighted, faster delivery vs higher fuel consumption, and if there is willingness to pay more for more power in the machinery. Most of the vessel in the North Sea is designed to sail with same speed. And todays hull design is very weather sensitive, and therefore transit time will increase.

- **Loading / unloading capability.**

  This is about both the offshore unit, but also the capability for the vessel to keep the position under the unit. This is restricted much by regulations and the weather, current, waves and visibility. This capability is also about how much machinery the vessel has, as it is said in the article that the vessel must not use more than 50 percent of its machinery to keep the position, to be able to handle unforeseen problems that might arise.

  This is seen as the bottleneck, therefore designing the ship to be able to keep their position for a long time is important. It is also important to see if it possible to do improvement with more technology for example not needing deck crew to hook / unhook on deck.

To do this type of assessment there is need for more knowledge about the vessel itself, and the job that it preforms. It will also be needed to take into consideration on how the different vessels work together as a fleet. A good fleet composition regarding the fleet size and composition of a heterogenous fleet is essential in logistic planning. (Aas, 2009).

2.6 Sustainability assessment method

This methodology, that will be described in this part, is made based on marine technologies- The assessment is to find out if a marine technology is sustainable or not, based on economic, environmental and social factors. This method is made of eight steps and is made by Oihane Basurko and Ehsan Mesbahi.

Step 1: Define the scope of the study

The first step is to define the objectives to be achieved by the study and the technology to be considered. This step should include the information regarding the system description and the characteristic of the technology, as well as the system boundaries, limitation and assumption that are to be considered within the study. (Basurko & Mesbahi, 2012)

Step 2: Identification of impact vectors

Analyze each technology / system from the life cycle perspective to identify the vectors (variables and parameters) that might impact the environment, the economy with added cost, and if it is anything that will impact the social, especially the safety for those on board.

(Basurko & Mesbahi, 2012). These vectors can be icebreaking capability, scientific capability, logistic capability and size. (Müller & Schøyen, 2021)

Step 3: Data collection

Compile data to the vectors from step 2. In this step it is important to get enough quality date that can be used for the assessment. (Basurko & Mesbahi, 2012)

Step 4: Assessment of inventory

Here it is three different types of assessment to be done on the different part. The model describes how to assess the impact of the technology have on; environment, economic and social. (Cabezas-Basurko, Mesbahi, & Moloney, 2008)

Step 5: Environmental, economic and social impact modelling

To create at estimation model to facilitate sustainable studies in an easier manner. This is created based on the assessment, which can be used to make a mathematical model for pollution, cost and safety. (Basurko & Mesbahi, 2012)

Step 6: Sustainable indices.

This step uses the results from model and/or assessment to give an indication of the sustainability performance of the different dimensions. This gives the researcher a possibility to compare different results in this dimension. This will have three different outcomes, environment, economic and social. (Basurko & Mesbahi, 2012)

Step 7: Weighting

Step 7 is to weight the different outcomes the researcher got in step 6, and this is done regarding the priorities, if it has present political, legislative or user in mind. When this is done, it is possible to get a holistic sustainability numerical index. This will be the index of sustainability. (Basurko & Mesbahi, 2012)

Step 8: Comparison with the established requirements

The last step is to the decision step. Here it is decided if the assessment was satisfying or not, and if it is fulfilling the requirements. (Basurko & Mesbahi, 2012)

3 Research method

In this chapter I will look into the methodology for this thesis. I will show what research design and methodology that is relevant for the thesis, how I preformed my data collection, and how I decided what sampling group I used. In the end of the chapter, I will also investigate the ethical considerations I have about this paper. First there will be a general introduction of what is method and why it is important in a thesis.

What is method, and why is it important?

A scientific methodology is a system of rules and procedures which lays the foundation for researchers to conduct research and evaluate claims to knowledge. It is not infallible and there is many methods that can be used, and still there is new ways of doing research being implanted into these rules and procedures. (Frankort-Nachmias, Nachmias, & DeWaard, 2015) Methodology is like a recipe for how the research is done, and it can be looked at like knowledge acquisition with an empirical and structured method. The research should be able to repeated based on the information and design. (Mallam, 2019)

In the method chapter it should be mentioned who participates in the research, what materials and tools are used, how measurements are preformed and what procedure is used. Participates can be grouped by age, work, height, location and so on. Materials and tools means if there is used any laboratory or special systems, like virtual reality. Measurement is what is measured in the research, like time, speed, length or heartrate etc. Procedure is how the experiment was preformed from start to end. (Mallam, 2019)

3.1 Research design

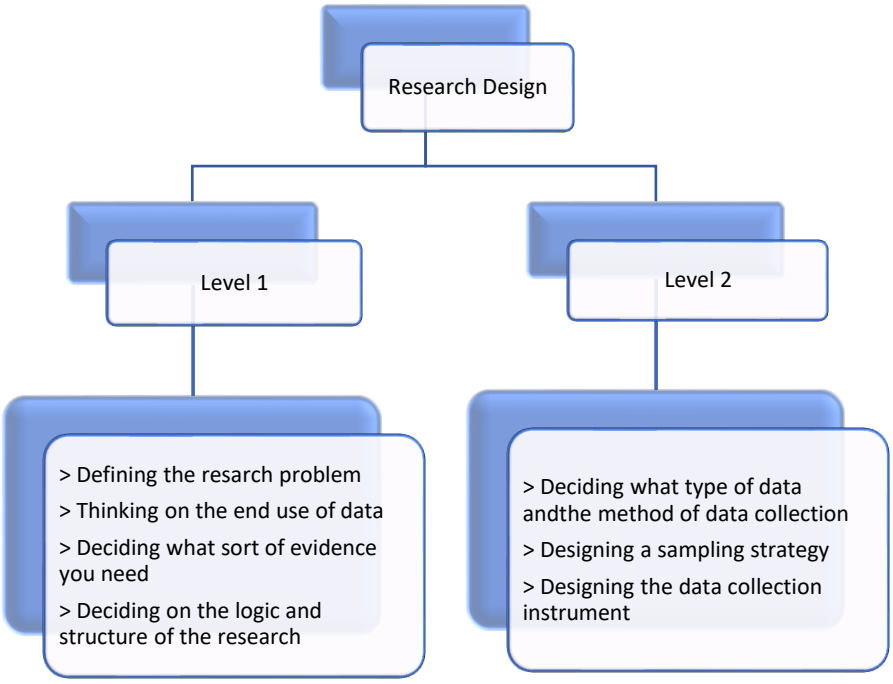


Figure 11: Research Design, adapted from (Chandra & Hareendran, 2018)

In

In this section I will speak about level one, while level two will be divided into two section one with focus on data collection, and the other with sampling, as stated in figure 11.

A good research design should be flexible, appropriate, efficient, economical, minimise bias and maximise reliability. There is three major categorises with different research designs, these are exploratory, conclusive and experimental research design. The conclusive research designs have different sub groups, and is often seen as statistical test, advanced analytical techniques and larger sample sizes. Conclusive research design is also as the name says conclusive, and the aim is to find results that can be used for the decision making. Experimental research design is using experiments with two groups, one control and one test group, and is therefore quantitative research design. Exploratory is a more flexible research design where the aim is to dig up new ideas and get better insight. Exploratory research design does not have an goal of finding one result as the results is tentative, and the outcome will normally be more exploratory or conclusive research on the topic. ((Basurko & Mesbahi, 2012; Chandra & Hareendran, 2018)

The purpose of this thesis is to find out more about the wellboat, to gain a bigger insight about the different kinds of wellboats, and what capability they have, but also to explorer methods that can be used to assess this fleet. There is not much information about this in the

academics, and therefore the thesis needs to use some observation and conversations with expert on the field. The research design of this thesis is exploratory, where the aim is to provide insights and understandings, and there is a lot of flexibility in this type of design. When doing exploratory studies it is often conducted using a search of the literature, talking to experts in the fields, and / or conducting focus group interviews. (Gray, 2014)

When deciding the structure of the thesis the approach or process needs to be decided, and by approach it is if the thesis uses an induction or deduction approach. Often exploratory studies have an inductive approach, this means to have a bottom up approach. The researcher in an inductive process starts with collecting much data before being able to make conclusions about them. (Gray, 2014). This thesis have an theoretical framework that is already been presented, and therefore have a road map and theoretical foundation. This is showing the deductive process where there is a top to bottom approach where it start with existing theories and combining these.

3.2 Data collection

As figure 11 shows, data collection is on level two of the research design, therefore in this section I will show the methods I have used to collect data, and which of type data I have used.

In a researcher's point of view there is two categories of data, primary and secondary data. Figure 12 shows which type of data is used in this thesis, and how they are categorised.

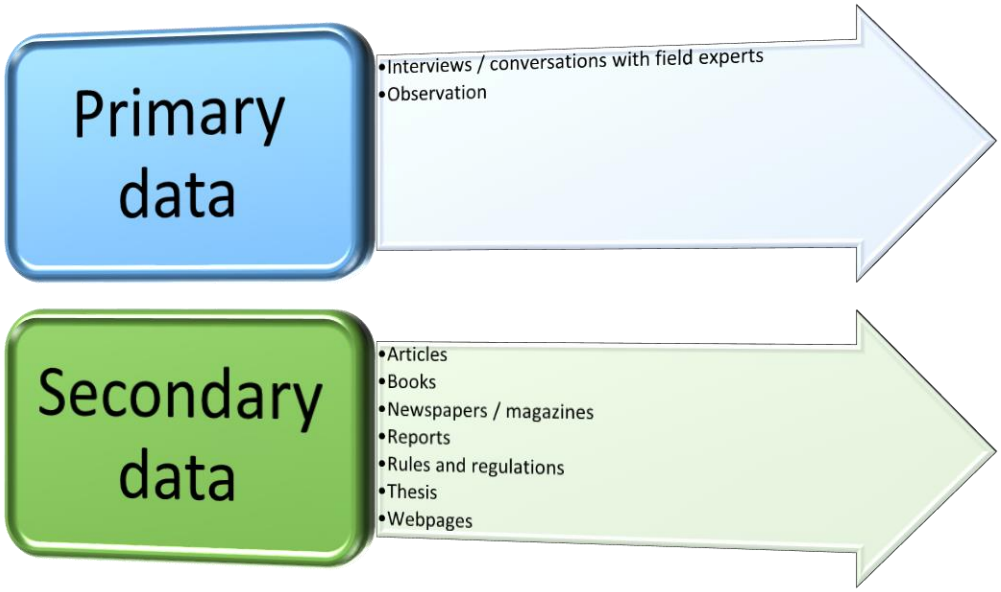


Figure 12: Types of data, made by author

Data collection method can be grouped into two different methods, which are qualitative and quantitative. Quantitative method gives numerical results and uses collection methods like surveys and experiments. Qualitative on the other hand is about gathering information from methods like interviews, observations and literature search. (Frankort-Nachmias et al., 2015)

Qualitative method is used in this thesis, and it used different types of this method.

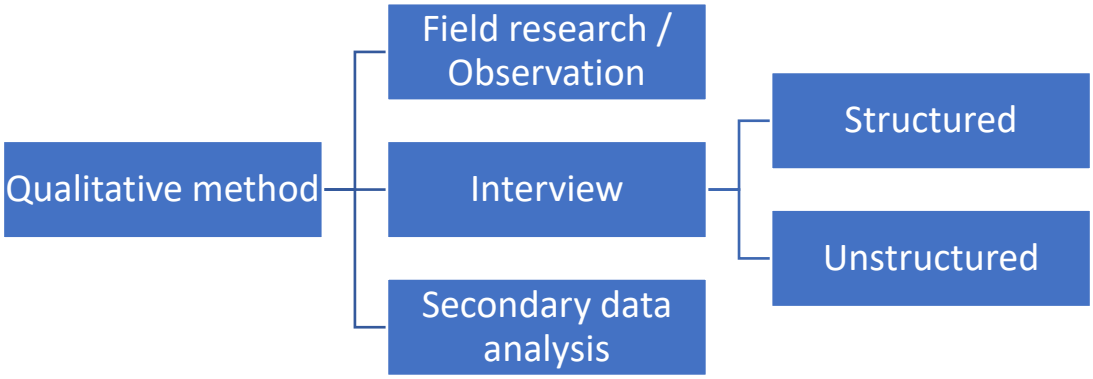


Figure 13: Types of qualitative methods, made by author.

Figure 13 shows the methods used in the thesis, but how are they used?
Interview or conversation have been used in a large-scale during observations, but also during the writing time to collect ideas and information about the topic from different perspectives. Most of these have been unstructured and with open ended questions, but also probing question, to get general and moderate specific answers to build on further. More specific question could be asked if there was an special interesting part of the answer. An structured interview will have more standard set of questions prepared (Chandra & Hareendran, 2018), and this method have somehow been used when collecting information from farmers and companies.

Observation have been a huge help to write this thesis, as I have been working in the fish farming industry for several years. It can be seen as a participant observation, but due to the fact that the work was there before the research it is difficult to say this is a method for data collection, but it is definitely one kind of field research. A big part of the information and knowledge that have contributed to making this thesis is coming from these observations and conversations done over the years, and this have also inspired to write many of the assignments over the years, a bachelor thesis about this topic and now the master thesis.

The last method used for data collection is secondary data that is earlier mentioned to be newspaper, magazines, webpages, reports, thesis, articles, books, rules and regulations. When

using this method different search engines have been needed to use to be able to collect as much as possible. Search words and search engines that is used is found in chapter 3.3.2, sampling of secondary data.

3.2.1 Validity and reliability

Validity can be asked as a question: *"Am I measuring what I intended to measure?" (Frankort-Nachmias et al., 2015).* There are different types of validity, content validity, empirical validity and construct validity.

Content validity is that I collect what I try to collect and being open for all of the information. That I try to ask the questions openly, and not being bias in the way the questions are asked, also that I collect different information.

Empirical validity is the difference between what I want to measure and the outcome. Since the topic of the thesis is a narrow topic there is not much information, and the exploratory study allows all of the information to be relevant in some way.

Construct validity is to be able to connect it to a theoretical framework. As I have presented in chapter two I have a theoretical framework to work on, and this is very much used in the findings, and is giving the structure and backbone to the thesis.

"*Reliability refers to the extent to which a measuring instrument contains variable errors." (Frankort-Nachmias et al., 2015).* It means if there are a wide spread of the information, or if everyone are agreeing. As mentioned, the topic is narrow and the information is little, and this could have been leading to one reference says apples is red and the other one says apples is green, but in this topic the references is homogenously agreeing on the basic of wellboats. Therefore, reliability of the data collected is good.

3.3 Sampling of data

In this section I will present the data I have sampled. This is put in to three groups with how I have sampled the primary data with interviews and conversation, as well as how I have been doing observations. The next topic will be how the sampling of secondary data have been done, what search word have been used and what search engines. Last topic will be possible sampling bias due to the method I have collected my data.

3.3.1 Sampling of primary data

As shown in figure 12 my primary data consist of observation and interviews / conversation from working in the industry from 2017 to 2021. I have been working on wellboats and slaughter boat, in booth Norway and Scotland. I have been doing observation on different boats I have been on, but also with visiting different boats and speaking with colleagues from different boats and companies. There is also some magazines and newspapers that often write about the boats and the industry, and these have been read over the years, and also used as a secondary source. When working on a wellboat, and during delousing, there is often conversation with the farmers about how they feel the different boats affect the fish, and their experience with them. Often this way of exchanging knowledge is very useful to learn about equipment and methods that is not used onboard the boats I have been sailing, and also a way to gain knowledge on the field for new equipment.

How to decide who to speak with? During collection of data from work and from different companies it is not uncommon to hear two different meanings. For instance, during interviews with some farmers I asked if they used bleeding / process boats in their company, where one said they used with good results, while the other was against it and had found bad results in using it. Therefore it is important in this exploratory thesis to explore all the sides of the different components, and be neutral. The subjects I have had conversations with comes from different companies, and they have taken the time to answer my questions in their busy days. It was a surprise that it would be that hard, and that so few that had the possibility to take the time to answer. From all the fish farmers I have asked, half of them replied, but only 25% took time to answer my questions.

To cross check and back up these conversations and observations I used some of the secondary data. The sampling of the secondary data will be described in the next section.

3.3.2 Sampling of secondary data

Sampling of secondary data is not easy eighter, with the lack of academical data on wellboats, I had to use a lot of fish farming data. In this section I will highlight search words I used, and search engines.

Search words: Brønnbåt, akvakultur, laks, fiskeoppdrett, wellboat, live fish carrier, aquaculture, salmon, fish farming.

Since the wellboat companies are mainly Norwegian, and since fish farming in Norway is world leading most of the results was given on the Norwegian search words, and especially

brønnbåt gave most of the relevant results. All of the titles that was found when searching for wellboat, brønnbåt and live fish carrier was skimmed through, and many was found not relevant for the thesis. Not being relevant for the thesis means that it was focused on economics, fish welfare or just not about the topic at all. Some was also found, especially regarding thesis, to be very conflicted or missing data when compared with data from articles or interviews and was therefore not used.

There was also used search word to find specific topics like information about treatment methods, and these were also conducted in Norwegian, and on google. When searching for information about treatments, fish farming and so on using academical platforms most of the results is about fish welfare, where the methods and the boats is not very central and often only mention with one sentence. Information about wellboats was sampled using the companies webpage, shipyards webpage, but also magazines and newspaper like Maritimt Magasin, Skipsrevyen and Ilaks, which all have relevant and reliable information about the boats when they were build. Unfortunately there is little information if any new equipment is on board the boats.
Search engines used was different, and I tried using more international like the one in endnote and google schoolar, but these gave little to none relevant results. Instead, I mainly used USN library, ORIA, and google. These where the once giving me good reports, articles and thesis as well as webpages.

3.3.3 Possible sampling bias

There are different kinds of biases in research, to mention some there is design bias, selection / participant bias, data collection and measurement bias, analysis bias and publication bias.

Due to my experience on the topic, as explained in chapter 3.3.1, I believe it is important to mention bias and how it can be avoided. The aim of the thesis is to highlight different capabilities, and these will not involve putting something over another, and therefore there should not be any big issues regarding bias. There is also used different sources to back up and cross-check some of the statements made in the thesis, as described in 3.2 with secondary data sampling. To mention an example as shown in chapter 4.2.3.3. I used secondary sources on my experience about how the weather impact the cage, wellboat and the fish.

Chapter 2 gives and academic background from the literature, and this is to be used as a guide to organize what I have learned, seen and talked about with others. This gives the information an back up, with having it in the bottom.

There is limited availability of sources and literature, and therefore this can be seen as bias in analysis since much is from the same sources, but this is a limitation of the research. There might be a bias as well in some of the conversations I have had since the technology evolves and everyone in will always evolve and learn more. Due to the evolution and the constant learning humans do, it might be bias in that I have misunderstood what I have read and what I have learned, even though I have tried to avoid this with asking if anything is unclear and to read over again.

To avoid having bias in my thesis I have had discussions with my supervisor and friends, who have also read this thesis to give input, and to cross check and proofread some of the information given. This have been people with knowledge about wellboats and without.

3.4 Ethical considerations

Ethics can be seen as a norm of conduct for what is right and wrong, acceptable and unacceptable. Ethics can be seen as a method, procedure or perspective that tells us how to act and analyse problems and issues. Ethics is important to be able to promote research with knowledge, truth and to avoid error. It is important that the researcher shows ability to collaborate, have trust, take accountability, have mutual respect, and shows fairness. (Resnik, 2011)

Ethical consideration in this topic can be many, but the consideration in this thesis is anonymity and privacy for those who have contributed with information for this thesis, and that these har kept confidential. There is not any sensitive data collected in this study, as the few emails used are all company mails and not tracked to any special person. Therefore, this thesis is not reported to NSD. The thesis is a seek for the truth, and everything that is stated in this thesis is what I consider as the truth, this might of course change in a few months or years.

3.5 Limitations

In this last section of the method chapter, I will mention some of the limitations I have decided during my work, and some I needed to set from the start. This is a very wide topic if every capability on a wellboat is to be explored, and therefore there are some areas that is not highlighted. There is not much focus on the equipment in the wells, and the different methods

of loading and unloading of the fish. There is much more information left to write about, but there was not time to write about everything in this thesis.

Norwegian owned and operated boats have the focus in this thesis. There are more companies outside Norway that have wellboats as well, but Norway is to be considered the leaders in the market. Some of the ships and cases mentioned is from Scotland as well, since many of the Norwegian ships is sometimes in Scotland doing different tasks. The boats used in this thesis is chosen based on that their age, size and capabilities. I have tried to pick boats from different companies and with different functions. But this is a small number of ship compared to the fleet world wide.

Rules and regulations are an important topic in this industry but is in this thesis a limitation that was made due to time, and that there is different rules and regulations in different countries where the Norwegian wellboats operate.

Environmentally friendly engines, with hybrid, battery, LNG and so on is also left out of this thesis, as this is a huge topic in itself, and deserves more information that possible to give in this thesis for this subject alone. The first hybrids are built and delivered in these days, so the future looks very exciting.

The workers, sailors, on the wellboats have a lot of knowledge and experience from different places. Many of the older generation do not need measurement to see if the fish is ok or not, and they see that the fish is missing oxygen or to high CO2 and so on without measurements. They also have an enormous knowledge about places and the depth, and some even have the experience to know where there are rocks and reefs underwater even though they are not marked on the map. Much of the feedback from farmers as well shows the importance of good and knowledgeable wellboat workers, on deck, in the wheelhouse and in engine. If I was to add information about these it would be hard speaking about specific boats as these people changes boats, and some of the new people is lucky enough to actually learn these skills.

Ship construction with hull design is another limitation in my thesis. With many different kinds of hull, and the reasons and the science behind them it would be outside my field of expertise and would also be needing more time to implement this.

Fish welfare is very important to all wellboats and fish farmers, good and healthy fish gives better quality on the meat and therefore better prices. This is yet another limitation in this thesis, since this is a topic that is very wide, and is to be mention as a suggestion to further study.

The ships I have chosen to highlight in my thesis is due to the experience with them, or that they have special contributes or equipment. As an example in chapter 2.1, What is a wellboat, I have mentioned different kinds of ships due to their special well solution, size or other characteristics.

Most of my limitation is as mentioned due to time, and cost regarding data collection, but also due to the lack of academical writing on the topic.

4 Findings

In this chapter I will present my findings from my research. I will try to answer two of the sub questions in this chapter, SQ2 and SQ3.

SQ2: How can the different capabilities be categorised?

SQ3: Why are there different types of boats in the fleet?

The chapter will start with explaining the assessment model that is based on the assessment methods from chapter 2.5 and 2.6. Then the capabilities I have found will be represented in five different categories. In the last section of this chapter there is presented a few boats, which some of them is used as an example in earlier chapters.

4.1 Assessment model

In this section I will present the model to be used to do an assessment of these boats in this thesis. This will be a version based on the models presented by Basurko and Aas in chapter 2.5 logistic assessment method and 2.6 sustainability assessment method.

Wellboats is a part of the upstream logistic in the Supply chain with transporting and treating fish in the production process. The value chain can from a fish farmers perspective be seen as hatchery / smolt, to growing up in the cages and at the end to harvesting and slaughter. The wellboat is an important part in all of these steps with being the transporter of the smolt and the harvest fish and can treat the fish if it is needed during the growing up in the cages.

Müller and Schøyen, 2021, used a adaption from Basurko, 2012, with six steps which is scope, data, assessment, indices and presentation to assess icebreakers. This is adapted into my assessment model, together with the other models mentioned in chapter 2.5 and 2.6.

Step 1 – Scope	Explaining the purpose and aims of the study	Chapter 1
Step 2 – Identification of impact vectors	Categories for the capabilities	Chapter 4.2
Step 3 – Data Collection	Collecting information for the research	Explained in chapter 3 Shown in chapter 2 and 4.
Step 4 – Assessment	Schematic assessment of the boats	Chapter 4.3
Step 5 – Discussion	Discuss the results of the assessment	Chapter 5

Table 1: Assessment method, adapted from (Basurko & Mesbahi, 2012; Müller & Schøyen, 2021)

As shown in the table 1, not all the steps from Basurko are used.

The assessment of the wellboat uses booth Boolean type data (which means if it is present or not present), and numerical data. They will not be weighted, as this is not a single case study assessing the fleet of a company, and therefore it will not be possible to say that a boat is better than another. This is an exploratory study to show the differences in the fleet of wellboat, and to explain why there is a difference.

4.2 Capabilities

In this section I will present the five categories I have given the capabilities. These are:

- Size
- Fish treatment
- Sailing and manoeuvring
- Fish handling equipment
- Contracts

These will be presented in their own section. Where I will present what kind of capabilities are placed in these categories, and why they are important to mention.

4.2.1 Size

When speaking about size of a wellboat, it can be divided into two main groups, the well and the actual size of the vessel. This is naturally connected since the bigger well the bigger boat. Today there is different shapes of the boats with Gåsø Høvding having a wellsize of 7 500m3, and the ship itself being 83,72m long and 30,90m breath (Froygruppen.no), compared to *Ronja Storm* with her 7 450m3 well and ship size being 116m x 23m.

4.2.1.1 Well capacity

First main group to be mentioned is well capacity, and the categories of these.
Well capacity means the volume of the well, and when looking on the newbuilding program is mostly bigger boats being built for freshwater treatment, with having bigger wells they can take a whole cage. Dess Aqua ordered two new 6000m3 wellboats (Berge, 2020) that will be able to treat 80% of all the cages for their costumer, without splitting cages due to biomass.

There is also a generation switch when speaking about wellsizes, since most of the older ships is 1000m3 and under, while the newest built is bigger.

Four well sizes categories:

1. 0 – 2500 m3
2. 2500 – 3500m3
3. 3500 – 6000m3
4. Over 6000m3

Then taking the fleet information from the webpages from the three biggest wellboats companies in Norway, it is possible to see the differences in their fleet.

Group	Rostein	Sølvtrans	Frøy
<2499	6	15	7
2500-3499	3	7	9
3500-6000	7	1	1
>6000	0	1	1

Table 2: Different categories of wellboats. Sources: (Frøy Gruppen; Rostein; Sølvtrans)

4.2.1.2 Actually ship size

Much of the well capacity is decided by how big boat it is possible to build the boats. It is possible to think that bigger is better, but there is limitations due the manoeuvring abilities required and the places they need to sail. In this section I will explain some of these limitations.

Many locations that the wellboat operate is close to shore, and the harvest stations and smolts producers is designed for the old and small boats and placed on places that might be hard for new bigger boats to go into. Some places have a limit due to small piers / quays, water depth on the area, and / or narrow places. Some examples where some of the Norwegain boats is operating is in Øklandsvågen (Harvest station, Bremnes Seashore), Trosnavåg (Smolt, Grieg Seafood), Inner Loch Eport (Fish farm, Scottish Salmon Company) and Mallaig (Harvest tation, Mowi Scotland).

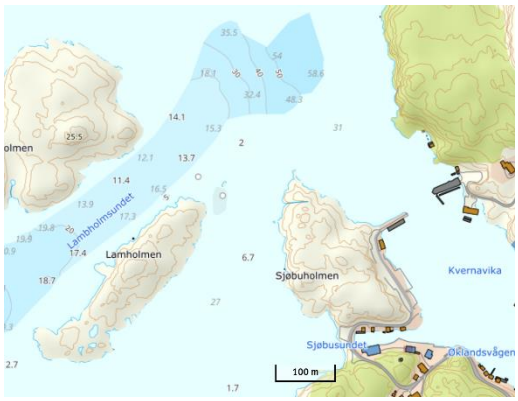


Figure 14: Overview map of Øklandsvågen. Source: (Kartverket, 2021)

Øklandsvågen have a tight narrow strait (Lambholmsundet) before a 90 degree turn toward the molo where there is placed cages where healthy harvest fish can be discharged from the wellboat. Figure 14 shows an overview over area with the strait, while figure 15 shows the area of where the waiting pens are placed.

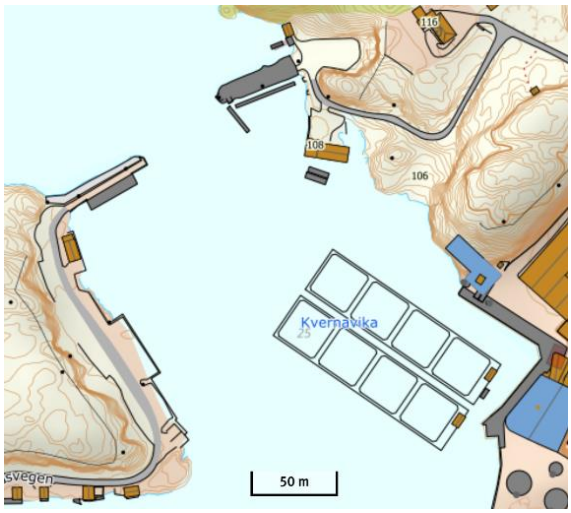


Figure 15: Map of Øklandsvågen, Source: (Kartverket, 2021)

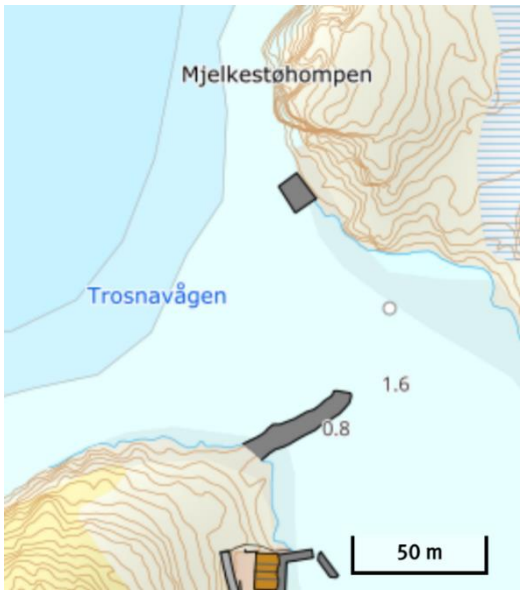


Figure 16.: Map over Trosnavågen. Source: (Kartverket, 2021)

Next location is Trosnavåg which is where many smolts gets hatched and delivered from. As figure 16 show there is a very short quay, maybe around 20m long. The ships here normally moored to bollards that is in the rocks onshore, as figure 18 shows. As seen on figure 16 there is not much depth, and the 10m depth contour is outside the quay (which is the grey box), this means that there is less than 10m depth here. There is also a molo that can be seen on the map. This is also one of many places with not a lot of depth and not much place to manoeuvre.

Figure 17: Overview map of Trosnavågen.
Source: (Kartverket, 2021)

Figure 18: Øydrott loading smolt Trosnavågen,
Source: (Aksdal & Grieg Seafood, 2018)

The other two examples that is mentioned is Mallaig and Inner Loch Eport, both in Scotland. Both have the same challenge, with having a very narrow straight, rough weather in the right direction, and very shallow water. In Scotland there is big tide variations as well, which often gives strong tidal streams. In Mallaig the biggest boats today (around 1 800m3, 70m x 12m and about 5-6m depth) need to go in when the tide is rising, and leave before the tide is on the lowest, or they will be grounded. Inner Loch Eport on the other hand is not possible to be manned with bigger boats than those like *Ronja Viking*, due to the depth in the area. There is many fish farms locations without good chart data, and I have been sailing around fish farms where the chart says the boat is far up the mountain.

4.2.1.3 Challenges with ship size alongside cages

A fish farm normally contains a set of cages, and there are different types as seen in the introduction chapter.

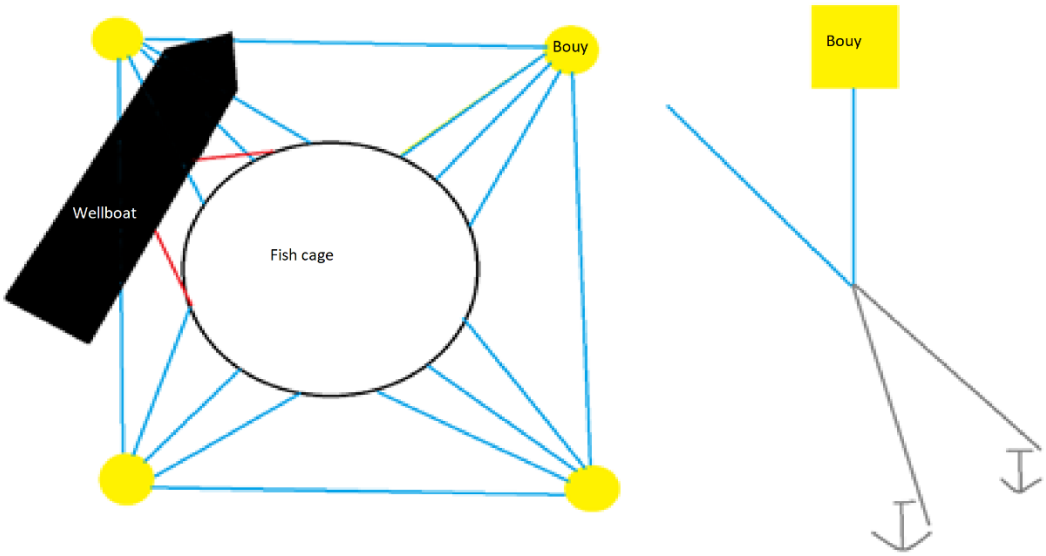


Figure 19: Overview of moorings and wellboat at cage, made by author.

Figure 19 is to show the moorings for the cages, as well as how the wellboat would normally place themselves in the structure. To the right I tried to show how the ropes / chains is under the buoy (in yellow). On the left there is a cage (circle in black), with the mooring (marked with blue). These moorings are the same in all four corners, and the line from the cage to the buoy that is called "hanefot" or bridle / bridal in English. This is placed normally 7 – 7,5m under water, (Ellefsen, 2014), the same is with the moorings that goes from buoy to buoy. As the yellow bouy and lines to the right is showing, the mooring for the cage is placed here 7-7,5m down, and then linked to an anchor. This is normally the lines that gives deep wellboats problems, but there are no rules on how they deep they can be, and some farms have deeper moorings. The other problem with size and fish farms is the distance between the buoys. Frame size, as the distance between the bouys is called, is often 70m x 70m, 80m x 80m or something like this. Due to these frame sizes it is not easy with a ship that is 80m long when the frame is 70m. This is the reason the wellboats navigators often maneuver the wellboat as seen above, this will also keep the propeller outside of the frame. When the propeller is outside the frame, there is not any dangers to get the mooring inside the propeller. It has happened many times that the mooring is not as deep or tight that expected.

4.2.2 Fish treatment methods

In this section the focus is fish treatment, and the different methods and equipment that is used to treat the fish. This is based on the knowledge from chapter 2.4, where there is more basic information about the equipment. There is also mentioned specialization in this section,

this is due to some boats having their specialty with treating, while others might have it with smolt transport.

Specialisation can be a good solution to avoid sickness during transportation with having a special boat. With these types of specialisation, the boat crew will also have the possibility to be better with fish handling within these operations. This type of specialisation is seen more with treatment boats which is often bigger to be able to treat a whole cage at once, but now it is also seen with smolt.

4.2.2.1 Specialisation

There are different types of specialisation boats in the fish farming industry with everything from service boats, treatment barges (barges or boats with mechanical treatments on them), harvest vessels, process / bleeding vessels, fish feed carriers and so on. These are not taken into measurement in this thesis. When mentioning specialisation in the wellboat segment the focus is the boats that is used for one main task.

Today there are more and more post smolt facilities, which is a facility that keeps the smolts on shore for a longer period until the smolt become around 1 kg. This is giving a smolt season that is longer and an all year around season, compared to the traditional smolt which is only a few hundred grams before they are sent out in the cages. (Nofima.no, 2014). Since this is all year around activity it is possible to have a own boat to only transport smolts, and this gives the advantage of having a disease free boat since the smolt is seen as free from diseases when coming from onshore. (Bremnes Seashore, 2021)

Another type of specialisations boat we have is the treatment boats, these are often the biggest boats and have often special equipment like freshwater production plants. The reason these are often the biggest boats, is to be able to get the whole cage in at one load, instead of splitting the cage due to biomass.

4.2.2.2 Mechanical treatment

As mentioned in chapter 2.4.1. there are different types of mechanical treatment options, and which one is best is a big discussion and not the topic of this thesis. It was also mentioned that the government is recommending using different kinds to avoid resistance in the lice. Therefore, it might be an advantage to have a specialised barge in the company if it is big enough, since the mechanical treatments do not need any well capacity.

4.2.2.3 Freshwater treatment

Freshwater is a very useful treatment option and gives no chemical residues to the nature. It is also the natural method for the fish, as mentioned in chapter 2.4.2. Most boats can do freshwater treatments, but not everyone have the systems for reuse of water, which means they can discharge fish and load new fish without needing to get a new load of fresh water between. Not all boats have the equipment to be able to take freshwater from a freshwater pen eighter. A freshwater pen is a cage with a tarp inside and pipes from a lake or river on shore that fills up the tarp.

There are also some boats that have the capability of producing their own freshwater with freshwater generators, often placed on deck. There are different sizes on these systems, but most of them is reversed osmosis, which means that there is membranes and high pressure that removes salt and other materials from the water. (NorWater)

4.2.2.4 Chemical treatment

Chemical treatment, and especially H2O2 have been a big discussion in Norway because of the side effects, as mentioned in chapter 2.4.2. It is still used, and therefore mentioned in this thesis. There are also other chemicals that is not mentioned, but these does not require any special equipment from the wellboat. H2O2 is delivered on ISO tanks, and the wellboat carries their own, or get the tanks lifted on board. They can be refilled later on. They are connected to pipes that leads to a dosing unit which adds a given amount of the chemicals over a given time. These need to be prescribed from a veterinary before use.

4.2.2.5 Other equipment available

It is often found that ships have other types of treatment systems on board, and this can be for example bleeding functions of mini bleeders on board for emergency harvest, these are found on some big wellboats. (Cflow) Other wellboats can have the possibility to add a structure on the deck which allows them to use the ship as a bleeding / process boat.
Grader is another equipment which is used to split the fish in different sizes.

4.2.3 Sailing and manouvering capabilities

Sailing and manouvering capabilities is a difficult topic regarding the wellboats. They are as earlier mentioned operating almost everywhere, and they deal with different situations in narrow and shallow fjords to offshore locations. When meeting a wellboat, and when looking on marine traffic they are all keeping the speed around 10 kn (+/- 2 kn), and therefore this will not be a capability that makes a difference between the boats today. The hull designed is

impacting how they can maneuver and sailing speed. What do make a difference in the wellboats is if they have dynamic positioning, shelter deck, what thruster power they have and their depth. The depth and size were handled under the size category, and this is limited by the area the ship will operate in. Therefore, in this section I will present sailing in rough weather and maneuvering.

4.2.3.1 Sailing in rough weather

From time to time bad weather comes and goes, and how bad it is depends on where you are. The waves can be big in the middle of North Sea, while they are hardly visible in the fjords. This section is about how rough weather is impacting the wellboats.

On ships without shelterdeck, more equipment can be damaged during rough weather. Shelterdeck is described in chapter 2.2. This is specially seen in Shetland / Scotland where there is no shelter for the ships, and like mentioned before *Ronja Viking* have less damages than other ships without the shelterdeck. This is shown with the boats from Sølvtrans. There has also been an accident that lead to death of a able seaman due to unexpected bad weather in a fjord where the weather can be bad. If that ship had a shelterdeck, this might not had happened. (Havarikommisjonen, 201)

Another factor that needs to be mentioned when speaking about rough weather is that the fish can be more stressed when transported when there are big waves. It is also seen that there is higher mortality when smolt is transported in big waves over 3m, and that the harvest fish is more stressed. (Hvas & Oppedal, 2019)

4.2.3.2 Maneuvering in general

In this section I will present some of the main capabilities that impact the maneuvering ability in general. This will be the thruster power, and an addition system that is called dynamic positioning (DP). I will also give an brief overview of three different propulsion systems that is found on board wellboats today.

There are three common propulsion systems on the wellboats, most common is the mechanical and diesel – electrical, and the new that is seen more and more on newbuilding is hybrid.

Mechanical system with direct drive works with having a main engine that is connected through a shaft generator to the propeller. This means there is a shaft connecting the propeller to the engine, so if the engine fails, there is no propulsion. (Wound & Stapersma, 2017)

Diesel electric is often used when having different, and often smaller, engines that is used for

the propulsion. This means that the engines single purpose is to be a generator, which give power to the circuit board before it is given to an electric motor which will make the propeller turn. This is giving a flexibility in which and how many engines is running at one time. (Wound & Stapersma, 2017)
Hybrid is the third solution, and this means that it is a combination of the above, and often this is used if they have installed batteries to take the peak loads. (Wound & Stapersma, 2017)

Dynamic positioning (DP) is a system that is used daily in the offshore market on all the different kinds of ships there. DP keeps the boat in a steady position, and the system controls the thrusters to always keep the position. It is starting to be a bigger subject in the fish farming industry as well, and there is seen that more newbuilt wellboats have this feature on board. Normally there is class to these systems, but the boats today have unclassed as a help to stay in position when loading or unloading. This will give the moorings of the fish farms less tension, and still keep the boat steady in one position. It is also required when doing fish transport to the ocean farm using DP, since there isn't possible to use moorings the same way as in traditional fish cages. (Salmar)

Thruster power is what keeps the boats in position on DP, but it is also used when maneuvering. During conversations with wellboat skippers and mates I have never heard about a boat with too much power, just about all those who have too little power. There isn't easy since a wellboat is packed with equipment, and therefore not much space for the thrusters.

4.2.3.3 Challenges alongside fish farms

What challenges is there when maneuvering alongside fish farms? Why is it important to have the technology mentioned in the last section, and are there any issues with these?

Most farms are placed where there is good circulation of water, and thereby current. Some locations are also more impacted of weather than other. Research shows that the structure gets the biggest impact from the boats when the waves, current and wind is on the side of the boats. The structure of the cages seams to tolerate more if it is only current and wind, but this again depends on the strength of the moorings. (Hegerstrøm, 2016).

Another factor that needs to be considered before operating in bad weather is that with big waves the fish will be dragged down in the cage, and therefore might be harder to lift. The safety for the fish farmers is also worse when working on a floating cage in waves. There is a

bigger impact for the fish with having heavy current from the thrusters from the wellboat. In worst case the cage net can be ruptured by the thrusters, since it is only kept in place by some weights in the bottom, and is moving a bit. In worst case the thrusters can also drag in the mooring of the fish farm if they are loose due to weather. (Ellefsen, 2014)

According to a survey done by SINTEF the fish farmers had a focus on boats that arrived alongside the cages to be better and safer. In the report they also mention that the fish farmers on the cage had a responsibility to decided when the weather was too bad for the wellboat and the safety for everyone. This is not always easy due to the schedule the wellboat have to deliver harvest fish or delousing. (Sandberg, Lien, Sunde, Størkersen, & Stien, 2012)

4.2.4 Fish handling equipment

With fish handling equipment it the equipment on board that impact the fish indirect or directly.

Some of the equipment is mentioned in chapter 2.1, What is a wellboat? I have therefore listed up some of the equipment that is found on board different boats.

- Oxygen.

  To be able to live the fish need oxygen. In the cage there is a natural circulation of water, and a good area so the fish can seek fresh water. In the well there is not that good space, and the circulation is needed. When there is not circulated enough fresh seawater oxygen must be added. This is done with having eighter a generator on board or by using a oxygen battery, or with both.

- CO2 strippers

  When the fish is inhaling the oxygen it exhales CO2 as a residue. To avoid poisoning the fish with having an high CO2 level in the well there is a need to have a CO2 stripper that air out the CO2 from the water.

- Measurement

  To control the water quality there is different sensors to give information about the water quality. These are often some oxygen sensors different places in the well, and sensors in a “lab room” over the well that often will tell pH, salinity, orp (ozon levels)

and CO2. These can vary in quality of the reading results, and is therefore also possible to do manual measurements.

- Washing system

  Before the wells got washed manually, by hand, of the able seamen. Today most wellboat have automatically washing systems, which means that most wellboats can press play and the wells gets clean. There is often a few blindspots that needs to be taken manually, depending on the system. The washing system also include soap and disinfection, and the time the system uses vary. Manual washing often takes longer time.

  To get a well approved it needs to be washed and disinfected, and to control the wash it can be used an ATP test. ATP is a bacteria measurement where it is used a svab test and a special instrument to read out the bacteria level.

- Ozon

  This is another disinfection method often used on board. Ozon is O3. This means it is unstable oxygen, and this kills bacteria. This requires an ozon generator as well as the oxygen generators, and the advantages is that it will circulate in the pipes and you will get to clean everything where the water can float. It will also not leave any chemical residues in the water when emptying the boat.

- Circulationpumps

  This is about how well the circulation in the well is, and this depends on the power of the pumps as well as pipe dimensions and construction in the well. This can be important to take into consideration for the fish welfare.

- RSW – refrigerated seawater

  This is a system that is much used to chill water and thereby also the fish. It is seen on many wellboats, and fish boats in general. (Frio Nordica). It is often used to chill fish as a calming effect before delivery to harvest, but also used to chill the water if there is a big difference in the water temperature. (Haanæs, 2012)

- Lice filter and UV

  Lice filter is a filter that collects lice and other particles in the water when they are running. They prevent lice from getting out of the boat again.

  UV is a way to disinfect the water, and is used to disinfect transport water before loading healthy smolt, or when discharging water from sick fish. (Nilsen & Biering, 2011)

- Hoses / pipes for loading and discharge

  This is the last point about the fish handling equipment with the hoses and pipes the fish goes through. When speaking about hoses it is the diameter in inches, with bigger hose more fish can pass through without being crowded. Number of hoses and pipes should be considered. Often a wellboat uses about 1- 2 hour to discharge one well (depends on number of fish, health of fish and size). If there is only one discharging hose / pipe then the boat will use 2-4 hours to discharge two wells, while having two hosed they can use half the time.

4.2.5 Types of contracts

There are different types of charters or contracts in shipping industry. Voyage charter is where the charter is to transport one specific cargo from one port to another. The second type is bareboat where they charter the boat itself without anything, often seen investors that lend out a ship to a company which will operate as its own. The third one is time charter, and this is mostly seen in the wellboat market, where the ship is in commercial control by the charter within a time limit. (Stopford, 2009)).

In the wellboat market there is seen two types of the time charter contracts, long term and short term.

First one is the long time charter, this is in wellboat market seen as around 5 years, where a company will be using the vessel as agreed in the contract (treatment, smolt and harvest fish equipment is normally all included) (Berge, 2016)

The second one is the short time contracts which is short period of time. Often the boats getting these types of contracts is on the spot market, and there they can get both voyage and time charters.

4.3 Assessment of different ships

In this section I have performed an assessment of 6 different wellboats, most of them have been mentioned before in this thesis. They are from different companies, have different charters, and are very different in size and building year. There was not possible to get all information about every boat, due to time and lack of information online. I tried asking people in the different companies as well, but they did not have all the information for me due to lack of knowledge about the boats.

	Aqua Gripfisk LIQX3	Ronja Viking LAKA	Ronja Christopher LFVA	Ro Fjord LFEI	Havtrans LFAL	Ronja Storm LACP8
Year built	1997	2006	2020	2009	2014	2019
Owner	Aquaship	Sølvtrans	Sølvtrans	Rostein	Frøy	Sølvtrans
Size						
Well size	630m3	1000m3	2500m3	2800m3	3250m3	7450m3
Vessel size	40,3m x 9,5m	57,07m x 12m	69,96m x 17,8m	72,2m x 15m	84,8m x 16,9m	116,2m x 23,0m
Vessel depth	5,0m	5,1m	5,9m	6,9m	8,0m	11,2m
Treatment option						
Type of mechanical treatment	No	No	No	No		No
FW reuse	No	No	Yes	No		Yes
FW producing	No	No	No	No	No	Yes
Grader		Yes	Yes	No	Yes	Yes
Smolt counter	Yes		Yes	Yes		
Other?	Portable bleeding station					
Sailing / maneuvering						

Dynamic position	No	No	No			
Shelterdeck	No	Yes	No	No		Yes
Thruster power Fore + aft		300kw + 300kw	450kw + 300kw	450kw + 450kw	800kw + 600kw	2x590kw + 2x590kw
Fish handling equipment						
Oxygen generator		Yes	Yes	Yes	Yes	Yes
Washing system	Manual washing	Manual washing	Auto	Auto	Auto	Auto
CO2 stripper		Yes	Yes	Yes	Yes	Yes
Lice filter			Yes	Yes	Yes	Yes
RSW	Yes	Yes	Yes		Yes	Yes
Contracts						
Length of contract		Long term	Long term	Long term	Long term	Long term

Table 3: Assessment of boats
Sources:(Aquaship; Berge, 2021; Bremnes Seashore, 2021; Ellingseter, 2011; Frøy Gruppen; Maritimt Magasin, 2020; Norwegian Maritime Authority, 2021; Rostein; Skipsrevyen, 2006, 2009, 2014; Sølvtrans; Vadset, 2020; Aas Mek., 1997)

5 Discussion

In this chapter I will discuss my findings and see if there is an answer to my research questions. The aim for the study was to find more information about capabilities found in the wellboat, and not to get an answer for the questions.

SQ1: What kind of means of transport is a wellboat providing? What kinds of functions does wellboats have?

This question was pretty much answered in chapter 1 and 2, with the introduction to the history, and with introduction to the wellboat today. A wellboat is transporting and provided treatment to live fish. To do this they have wells, therefore the boats are named *live fish carrier* or *wellboat*. There are different types of jobs a wellboat can carry out, as it can transport smolt into the sea, do treatment using fresh water, medical or mechanical, grading and moving of fish and then in the end there is transport to the harvest stations. There is a difference on the boats for what kinds of equipment they have, and they therefore have different roles in the fleet.

SQ2: How can the different capabilities be categorised?

There are many ways to make different categories that would work fine for categorising the capabilities. These was made much based on the groups and vectors that is stated in the literature review and based on both the logistic assessment method and the sustainability method.

Size about both the well size and the actual ship size. There is a change going on here, and to show and explain why there is not only huge wellboats in the market I felt the category to be important. I have first-hand experience with being on a boat that is a little big for the locations of fish farms, cages and other places the boats need to sail to be able to their job.

Fish treatment was to capture the treatment methods that is on the different boats, but also to highlight that the market has specialisations. Now there is more ships with specialisations, and in the future, it is possible that it is only specialised boats that operates in the fish farming industry.

Sailing and manoeuvring capabilities is harder to assess since there is difference between the designs and boats, and limited available information. Therefore, I highlighted 3 capabilities that makes a difference between the boats and is interesting seeing the evolution of the boats. For instance, if you search on dynamic positioning on a wellboat there were a few boats that

had this before, but they were not able to use it in a good way. Today there is more and more boats coming with DP, and they use it different than before.

Fish handling capabilities is about the systems on board that impact the live fish. There is many systems and equipment on board a wellboat, and this section is especially interesting since this equipment is found in the older boats as well as the newer boats. Technology change is actually amazing if you go from Gripfisk which was amazing in 1997, a big revolution then, to Ronja Christopher, both is built on the same ship yard with 13 years apart.

Contracts is the last category, and this is to show how the wellboat market works. It is also showing that most of the ships actually have long term contracts, and that is not just built boats without contract that some things. There is many discussions if there will be to many boats in the market.

SQ3: Why are there different types of boats in the fleet?
The operating area and jobs the wellboat have today is complex. There is a need for different boats for each farmer. Small farmers might use one boat for all operations from smolt, treatment and harvesting, while bigger farmers used different boats for the different operations and have the possibility to have specialisation boats.
The different requirements for the location and places the boat needs to sail as well is a limit for many farmers. In chapter 4.2.1.2 I have mentioned some of the places I have had the opportunity to try manoeuvring and sailing in. It is not always chart data on every place the wellboats operates, and there are many groundings of wellboats due to this.

This brings us to the research question itself. *What capabilities are in the wellboat fleet today?* Is not possible to mention all the capabilities in on thesis, that there are capabilities for different kinds of treatments for the fish, there are different kinds of equipment to handle the fish in the gentlest way possible. Different kinds of capabilities for surveying the fish, controlling water quality. Then there are the design capabilities on the boats, machinery, and equipment on deck. Those mentioned in the thesis is just a handful and a start to be able to bring more knowledge about these fully packed boats that is always developing.

The aim of the thesis was to explore and explain some of the capabilities that is found in the fleet of wellboats, and this is answered. I have also tried to explain why there is the difference between the boats, and how to split them based on capabilities. The assessment of the six boats shows that there has been an evolution over the years regarding size, and the technology

have gotten a lot better. The fundamental is the same, and much of the equipment used in 2000 is still used today in 2021, just as a more modern version. The newest boats today have more automatic in their system, and for example to adjust the gap of the bars on the grader you can touch a screen, while for a few years ago you needed to turn a wheel on the grader manually.

I believe that the technology will further develop in all areas on board the wellboat, and this will happen rapid, so in 5-10 years the wellboats then would be different from todays wellboat with new technology and other rules and regulations to be complying to. Capabilities is always changing in this industry, which makes it very exciting to be in it.

5.1 Suggestion for further research

In this section I will suggest some further research on the topic. In chapter 3.5. limitations I mentioned the limitations I have had on the thesis, and these are many to have further research on.

Fleet assessment where there is an assessment more based on the logistic model from chapter 2.5, to see how the different boats regarding size and capabilities is functioning together to cover the need a fish farmer have. There is also to be conducted study on how the wellboats can operate together with barges, service vessels, process and slaughter boats.

International fleet to assess and study the boats that is owned and operated by companies in other countries, to mention some countries that have their own wellboats is Scotland / Shetland, Chile, Canada and Australia / Tazmania.

Fish welfare and how the wellboat impact this is not mentioned in this study but should be carried out. To see how different equipment and different wells impact the welfare of the fish. This is also to describe and find out more about fish handling systems, and if there is more systems to cover in depth.

Sailors and the workers on board wellboats on how they impact the operation, and how the human element is important in the operation. It would be possible to do study on how to make a course that is design to get a better understanding and competency for the wellboat operations, not only the fish welfare.

Ship construction with how the wellboat is designed, if there is more effective designs that can fit the same amount of equipment in less place, or if there is possible to have an arrangement where it is easy for the engineer to change pumps and pipes when needed. The ship owners often want the biggest wells and the smallest boats.

Environmentally friendly ships are important today with new rules and lower emission goals. To research how the wellboats can become more environmentally friendly, and how to make the emission as low as possible.

Rules and regulations are not always easy to follow. Now there is rules for where water from sick fish that is transported to harvesting can be dumped, and there are rules on use of UV. The suggestion is to make a research to see if it is possible to follow these rules, while being in on a schedule? Or if the rules are not possible to comply with.

Ship safety to research the underlaying causes there is so many groundings with wellboats, and how to avoid them if possible. There is other accidents that have happened, and how they have impacted the rules and regulations, and surveys of the wellboats regarding safety. As example there is the drowning mentioned in chapter 4.3.2.1, and there have been accident with the well hatches losing the hydraulic and killing a man. There is also fish death that could been avoided due to human error or measurement error.

6 Conclusion

This was an exploratory study with the aim to enrich the academic literature on wellboats and their capabilities. The research question "*What capabilities are in the wellboat fleet today?"*, was answered with a assessment model. Five categories were chosen to be able to do the assessment, these are size, fish treatment method, sailing and manoeuvring, fish handling equipment and contract.

I used three sub questions to support the main research question, and these have been answered during the thesis. Sub question 1, "*What kind of means of transport is a wellboat providing? What kinds of functions does wellboats have?*" These was answered during the literature review in chapter 2, with the concept the wellboat is, how they operate and what kinds of functions is found.
Sub question 2, *"How can the different capabilities be categorised?"* and sub question 3, *"Why are there different types of boats in the fleet?"*. Were answered together in chapter 4, with making the different categories for the assessment model, and to search for the different capabilities and finding out why they matter. Some of the capabilities that are not mentioned in this thesis is mentioned in the limitation chapter, and as well suggested as further research.

The thesis has explored a few ships to see in practice what kinds of capabilities they have, and to see the differences between them. Also, to understand how the development have been over the years, and how capabilities have been evolving over years with technology change.

Reference list

Adresseavisen. (2017). Snart klar for 1,6 millioner laks. Retrieved (10.02.2021) from https://www.adressa.no/nyheter/okonomi/2017/09/15/Snart-klar-for-16-millioner-laks-15312949.ece

Aksdal, T. I., & Grieg Seafood. (2018). Øydrott laster smolt på Trosnavåg. Retrieved (24.02.2021) from https://www.facebook.com/watch/?v=1939818609663173

AKVAgroup. Steel cages in Irland. Retrieved (10.02.2021) from https://www.akvagroup.com/pen-based-aquaculture/pens-nets/steel-pens

Andreassen, O., & Robertsen, R. (2014). *Nasjonale ringvirkninger av havbruksnæringen* Retrieved from https://nofima.no/wp-content/uploads/2015/01/Rapport_49-2014_-_Nasjonale_ringvirkninger_av_habruksnaeringen.pdf:

Aquaship. Live fish carrier. Retrieved (10.04.2021) from https://www.aquaship.no/eng/live-fish-carriers#aqua-gripfisk

Basurko, O. C., & Mesbahi, E. (2012). Methodology for the sustainability assessment of marine technologies. *Journal of Cleaner Production*.

Berg, M. (1972). Grøntvedt merden Retrieved (10.02.2021) from https://no.wikipedia.org/wiki/Hitra#/media/Fil:Gr%C3%B8ntvedt-br%C3%B8drenes_laksemerd_(1972).jpg

Berg, T. (2017, 31.05.2017). Slik fungerer avlusninga - og så mye koster den å utføre. *Ilaks*. Retrieved from https://ilaks.no/slik-fungerer-avlusninga-og-sa-mye-koster-den-a-utfore/

Berge, A. (2016, 23.09.2016). Lander fem - års kontrakt for ny brønnbåt. *Ilaks*. Retrieved from https://ilaks.no/lander-fem-ars-kontrakt-for-ny-bronnbat/

Berge, A. (2020, 01.10.2020). DESS Aquaculture Shipping bestiller to nye brønnbåter forberedt for nullutslipp. *Ilaks*. Retrieved from https://ilaks.no/dess-aquaculture-shipping-bestiller-to-nye-bronnbater-forberedt-for-nullutslipp/

Berge, A. (2021, 22.01.2021). Her sjøsettes verdens største brønnbåt. *Ilaks*. Retrieved from https://ilaks.no/her-sjosettes-verdens-storste-bronnbat/

Bremnes Seashore. (2021). Smoltekspressen "Ronja Christopher". Retrieved (15.04.2021) from https://vimeo.com/526134949

Cabezas-Basurko, O., Mesbahi, E., & Moloney, S. R. (2008). Methodology for sustainability analysis of ships. *Ships and Offshore Structures, 3*.

Cflow. Systemer og Produkter for akvakultur. Retrieved (24.04.2021) from https://www.cflow.com/no/systemer-og-produkter-for-akvakultur

Chandra, S. S. V., & Hareendran, S. A. (2018). *Research Methodology*: Pearson India Education Services.

Ellefsen, K. E. S. (2014). *Prinsipper for overføring av fisk mellom brønnbåt og oppdrettsmerder.* (Master). NTNU, Retrieved from https://ntnuopen.ntnu.no/ntnu-xmlui/bitstream/handle/11250/241958/740206_FULLTEXT01.pdf?sequence=3&isAllowed=y

Ellingseter, P. B. (2011). *Aasverve 100 år, Jubileumsskrift til Aas Mek. Verksted 1911 - 2011*. Aas Mekaniske Verksted

Frankort-Nachmias, C., Nachmias, D., & DeWaard, J. (2015). *Research methods in the Social Science* (8th ed.).
Frio Nordica. RSW systemer. Retrieved (24.04.2021) from https://www.frionordica.no/no/Article/RSW-SYSTEMER-7955
Froygruppen.no. Gåsø Høvding. Retrieved (10.03.2021) from https://froygruppen.no/portfolio/gaso-hovding/
Frøy Gruppen. Brønnbåter. Retrieved (10.03.2021) from https://froygruppen.no/flate?id=index-831527593&ucat=20
GEFCO. Upstream logistics. Retrieved (16.03.2021) from https://www.gefco.net/glossary/definition/upstream-logistics/?fbclid=IwAR0rnnsjyFmaaNd7p7__7krb7sWXoGWppU8plSXwP7LS1GjZqpi2Z5iN5l4
Gray, D. E. (2014). *Doing Research in the real World* (third edition ed.): SAGE.
Grefsrud, E. S., Karlsen, Ø., Kvamme, B. O., Glover, K., Husa, V., Hansen, P. K., . . . Svåsand, T. (2021). *Risikorapport Norsk fiskeoppdrett 2021 - Kunnskapsstatus*. Retrieved from hi.no: https://www.hi.no/hi/nettrapporter/rapport-fra-havforskningen-2021-7
Gunn, D. (2014). Ronja Viking. Retrieved (10.03.2021) from https://photos.marinetraffic.com/ais/showphoto.aspx?photoid=2184016
Havarikommisjonen. (201). *Rapport om sjøulykke - fall over bord fra brønnbåten Øysund 16. november 2017*. Retrieved from https://havarikommisjonen.no/Sjofart/Avgitte-rapporter/2018-03
Havyard. (2015, 08.06.2015). MMC Circular tank live fish handling system. Retrieved from https://vimeo.com/130070462
Hegerstrøm, C. (2016). *Marine Operations in the Aquaculture industry with focus on Safe Wellboat Operations.* (Master Thesis). NTNU,
Helgelandholding. PolarCirkel merder. Retrieved (10.02.2021) from https://www.helgelandholding.no/referanser/408/
Hovland, E., Møller, D., Haaland, A., Kolle, N., Hersoug, B., & Nævdal, G. (2014). *Over den leiken ville han rå, Norsk Havbruksnærings Historie*: Fagbokforlaget.
Hvas, M. F., Ole, & Oppedal, F. (2019, 12.11.2019). *Havbasert oppdrett - hvor mye vannstrøm tåler laks og rensefisk?* . Retrieved from https://www.hi.no/hi/nettrapporter/rapport-fra-havforskningen-2019-37#sec-9
Haanæs, Ø. R. (2012). Laks tåler bråkjøling. *Forskning.no*. Retrieved (24.04.2021) from https://forskning.no/mat-de-regionale-forskningsfondene-fisk/laks-taler-brakjoling/678057
Kartverket (Cartographer). (2021). Norgeskart Retrieved (23.04.2021) from Norgeskart.no
Lorentzen, B. (2018). *Brønnbåten i havbruksleddet - Teknologiutvikling og drift*. Retrieved (20.01.2021) from https://docplayer.me/115677808-Bronnbaten-i-havbruksleddet-teknologiutvikling-og-drift.html
Lyngstad, M. (2019). Ro Fjord. Retrieved (10.02.2021) from https://www.marinetraffic.com/en/photos/of/ships/ships
Mallam, S. (2019, Spring 2019). [Lecture notes from Research Methods].

Maritimt Magasin. (2020). Ronja Storm. Retrieved (10.02.2021) from https://maritimt.com/nb/batomtaler/ronja-storm-022020
Markusson, H. M. (2020, 04.05.2020). Kjemikaliene som dreper lakselus, skader fisk, reker og miljøet. *Forskning.no*. Retrieved from https://forskning.no/fiskehelse-framsenteret-kjemi/kjemikaliene-som-dreper-lakselus-skader-fisk-reker-og-miljoet/1675744
Mattilsynet. (2016, 20.09.2016). Fakta om lakselus og lakselusbekjempelse Retrieved from https://www.mattilsynet.no/fisk_og_akvakultur/fiskehelse/fiske_og_skjellsykdommer/lakselus/fakta_om_lakselus_og_lakselusbekjempelse.23766
Ministry of Trade. Industry and Fisheries. (2017). *Handlingsplan mot resistens mot legemidler mot lakselus*.
Müller, F., & Schøyen, H. (2021). Polar research and supply vessel capabilities - An exploratory study *Ocean Engineering*
Nilsen, A. G., Stine, & Biering, E. (2011, 26.08.2011). *Utvikling av fremtidens brønnbåtteknologi - smittehygiene og fiskevelferd*. Retrieved from https://www.vetinst.no/rapporter-og-publikasjoner/rapporter/2011/utvikling-av-fremtidens-brnnbtteknologi--smittehygiene-og-fiskevelferd/_/attachment/download/e0218cdf-16ca-419f-81ac-0585ff40b536:ee547f68a39e60253c4ffad5489ad39b899b3574/2011_13_Utvikling%20av%20fremtidens%20br%C3%B8nnb%C3%A5tteknologi-smittehygiene%20og%20fiskevelferd.pdf
nofima.no. Mindre svinn med større smolt. *Prosjektår 2014.* Retrieved (01.02.2021) from https://nofima.no/forskning/naringsnytte/mindre-svinn-med-storre-smolt/
Nofima.no. (2014). Mindre svinn med større smolt. Retrieved (20.03.2021) from https://nofima.no/forskning/naringsnytte/mindre-svinn-med-storre-smolt/
NorWater. Large systems. Retrieved (24.04.2021) from https://norwater.no/large-systems/
Norwegian Maritime Authority. (2021). Skipsregisteret Retrieved (15.04.2021) from https://www.sdir.no/skipssok/
OECD. (2016). *The Ocean Economy in 2030*. Retrieved (25.01.2021) from OECD Publishing: https://read.oecd-ilibrary.org/economics/the-ocean-economy-in-2030_9789264251724-en
Pless, W. (2020). Ronja Storm. Retrieved (10.02.2021) from https://www.marinetraffic.com/en/photos/of/ships/ships
Resnik, D. B. (2011). What is Ethics in Research & Why is it important? *National Institue of Environmental Health Sciences*.
Reynolds, P. (2013). *Ferskvannsavlusning i brønnbåt*. Retrieved (20.01.2021) from https://www.fhf.no/prosjekter/prosjektbasen/901006/:
Rostein. Båter. Retrieved (03.04.2021) from https://www.rostein.no/bater/
Rosten, T. (2010). Forutsetninger for optimalisering av systemer for transport av levende fisk i brønnbåt. *Vann, 03 - 2010*. Retrieved (17.04.2021) from https://vannforeningen.no/wp-content/uploads/2015/06/2010_808461.pdf
Salmar. Havbasert fiskeoppdrett. Retrieved (20.04.2021) from https://www.salmar.no/havbasert-fiskeoppdrett-en-ny-aera/
Sandberg, M. G., Lien, A. M., Sunde, L. M., Størkersen, K. V., & Stien, L. H. K., Tore. (2012). *Erfaringer og analyser fra drift av oppdrettsanlegg på eksponerte lokaliteter*.

Retrieved (29.03.2021) from SINTEF: http://www.akvarena.no/uploads/Rapporter/SINTEF%20Erfaringer%20og%20analyser%20fra%20drift%20av%20oppdrettsanlegg%20p%C3%A5%20eksponerte%20lokaliteter.pdf
SINTEF. Havbruk. Retrieved (01.02.2021) from https://www.sintef.no/ocean/tema/havbruk/#/
Skipsrevyen. (2006). Ronja Viking. Retrieved (12.04.2021) from https://www.skipsrevyen.no/batomtaler/m-s-ronja-viking/
Skipsrevyen. (2009). Ro Fjord. *Skipsrevyen*. Retrieved (15.04.2021) from https://www.skipsrevyen.no/batomtaler/m-s-ro-fjord/
Skipsrevyen. (2014). FS Stormy. *Skipsrevyen*. Retrieved (15.04.2021) from https://www.skipsrevyen.no/batomtaler/m-s-fs-stormy/
Stopford, M. (2009). *Maritime Economics* (3rd ed.): Routledge.
Sunde, H. (01.02.2021). Fortellinger om kyst-Norge
Sunnmørsposten. (2016). Slinningsbålet i trøbbel. Retrieved (01.02.2021) from https://www.smp.no/alesund/2016/04/25/Slinningsb%C3%A5let-i-tr%C3%B8bbel-12649205.ece
Sølvtrans. Flåte. Retrieved (03.04.2021) from https://www.solvtrans.no/flate/
Sølvtrans. (2013, 19.04.2013). Sølvtrans Wellboats for Salmon and Trout / Skimmer Ronja Harvester. In T. Bergen (Ed.). https://www.youtube.com/watch?v=2JIw0xwbwMg.
Trana, K., & Sae-Khow, N. (2018, 10.09.2018). Lusegift farligere enn antatt - over 120.000 tonn dumpet i havet de siste årene. *NRK*. Retrieved from https://www.nrk.no/trondelag/ny-forskning-viser-at-lusegiften-hydrogenperoksid-er-langt-farligere-for-miljoet-enn-antatt-1.14196994
Tulloch, L. (2020). Aqua Gripfisk. Retrieved (10.02.2021) from https://www.marinetraffic.com/en/photos/of/ships/ships
Vadset, K. W. (2020). Ronja Storm (02/2020). *Maritimt Magasin*. Retrieved (05.02.2021) from https://maritimt.com/nb/batomtaler/ronja-storm-022020
Valderhaug, H. M. (2002). Ro Chief Retrieved (10.02.2021) from https://maritimt.com/nb/batomtaler/ro-chief-082002
Wound, H. K., & Stapersma, D. (2017). *Design of Propulsion and Electric Power Generation Systems*: The Institute of Marine Engineering, Science and Technology
Wärtsila. Encyclopedia. Retrieved (01.03.2021) from https://www.wartsila.com/encyclopedia/term/shelter-deck

https://www.wartsila.com/encyclopedia/term/freeboard
Aas, B. (2009). The Role of Supply Vessels in Offshore Logistic. *Maritime Economics & Logistics*
Aas Mek. (1997). M/S Gripfisk. Retrieved (04.02.2021) from https://www.aasmek.no/vare-solide-bygg/bronnbater/ms-gripfisk/

Addition there is used information from different people from fish farms, wellboats both shore personell and boat crews.