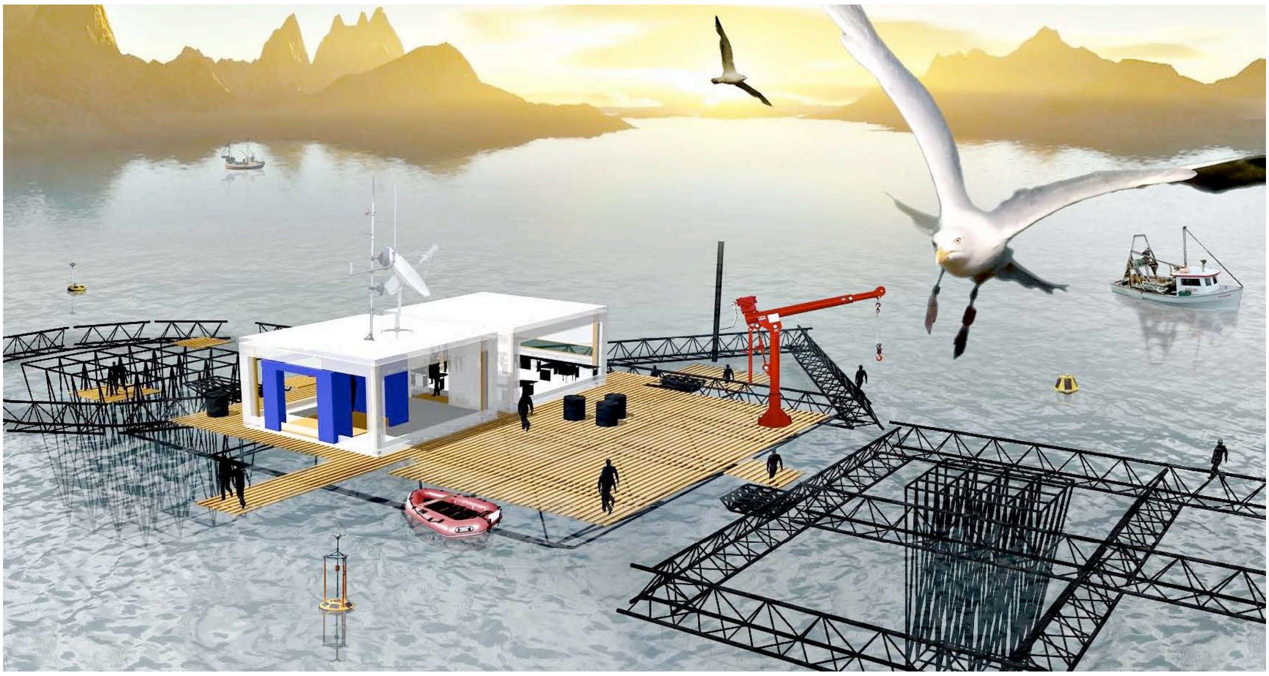
Report

Sea-based fish farming in the future – Technological constrains and challenges

A Scandinavian workshop arranged by the EU projects OATP and DesignACT at Gardemoen 21.juni 2007



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1 Executive summary

The workshop “Sea-based fish farming in the future – Technological constrains and challenges” was arranged in co-operation between SITNEF Fisheries and Aquaculture and the Norwegian University of Science and Technology, in relation to the two EU projects Evaluation of the promotion of Offshore Aquaculture through at Technology Platform (OATP) and DesignACT. The workshop was also supported financially by the Research Council of Norway. The aim of the workshop was to involve stakeholders from the fish farming industry, governmental administration, NGO and research in ongoing EU strategic processes. Results from the workshop will be used as background for plans for a European Aquaculture Centre of Technology and to the future European road map for technological research in aquaculture.

The workshop was organized as a mixture of presentations and round table discussions. The first part consisted of seven excellent talks presented by a mixture of industry and research stakeholders. After lunch the participants was divided into five groups, each discussion a specific topic. 26 people attended the workshop.

1.1 Trends in sea-based aquaculture

The industry is undergoing continuous changes with respect to operations with the aim to reduce production costs. As a result, the number of farms is decreasing, while the production capacity is increasing. In the salmon industry the average production in one farm per cycle is 2-300 tons, and it is expecting that this will further increase to 5-7000 tons in a few years. To find the optimal locations with respect to water quality and current flow will be very important.

In Denmark, sea-based fin fish aquaculture has been problematic, both due to available technical solutions suitable for local conditions and public regulations as means of restrictions to nutrient release. But the development recent years has been promising and it should be possible to make sea-based fish farming economically viable also in Denmark.

There is some competition with respect to access to areas at sea, but there are regional differences. It is least coastal zone conflict in Norway, with more in Sweden and Denmark.

The sea-based fish farming industry are facing large challenges with potential new demands as a result of the introduction of EU water directive. The water directive can limit the allowed release of nutrient to the sea, limiting the possible volume of fish to be farmed at individual locations. IT will be important with further investigation and research into the extent and consequence of nutrient release from existing farms, and to make future requirements based on scientific knowledge and not political demands. Nutrient release from existing farm in Norway will most likely be neglectable compared to the natural background levels.

It is expected that larger companies and larger farming units will reduce the probability for escape of fish, since larger companies also has increase capability to use resources and set focus on escape prevention. Escape of fish from the fish framing industry need to be solved to allow for a sustainable growth of the industry.

Similarly is fish welfare an increasingly important topic. Consumers demand ethical treatment and slaughtering of animals and proof that the animal has not experienced unnecessary harm.

2 Background

The workshop "Sea-based fish farming in the future – Technological constrains and challenges" was arranged as a part of the two EU projects DesignACT and OATP, to receive input and feed back from stakeholders from the aquaculture industry in Scandinavia, on needs and interests for different topics related to fish farming in the sea. Results from the workshop will be used as input to the planning of a new European full scale test centre for aquaculture technology and towards the European roadmap for research on fish farming in the sea. The task will be coordinated with corresponding seminars in other European regions. The European Commission wishes to use such information as a base for its selections and priorities within aquaculture research and industrial development. The European Commission wishes to use such information as a base for its selections and priorities within aquaculture research and industrial development.

The event was cooperation between SINTEF Fisheries and Aquaculture and the Norwegian University of Science and Technology (NTNU), through the EU projects Offshore Aquaculture Technology Platform (OATP) and DesignACT. The seminar was accomplished with economic support from the Norwegian Research Council.

Evaluation of the promotion of Offshore Aquaculture through at Technology Platform (OATP) (www.offshoreaqua.com) is a European project aiming to map interests, possibilities, approaches, and obstructions to aquaculture in exposed localities. Here, offshore aquaculture is defined as all aquaculture along our coast, also comprising aquaculture in existing localities. The platform is based on industry, with partners such as trade associations, farmers and product suppliers. It is lead by the Marine Institute (Ireland), SINTEF Fisheries and Aquaculture (Norway), and Cetmar (Spain). OATP is also a part of the European Aquaculture Technology Platform (EATP) (www.eatpnet.eu).

The EU project DesignACT contains a plan for the establishment of a European research centre within aquaculture technology, intending to provide full-scale installations, equipment, instruments and operation methods for testing, development and training. The facilities will be open to industrial actors and both national and international research groups. For more information and results, see www.designact.org.

The seminar was free to participants, with lunch and refreshments included. The target audience was all those interested in future technology within aquaculture.

3 Agenda

1. Session – The challenges of tomorrow

09.30	Registration and coffee	
10.00	Opening	Arne Fredheim, SINTEF Fisheries and Aquaculture (NO)
10.10	Towards larger units (production, logistics, surveillance, and control)	Knut Utheim, Marine Harvest
10.30	Increasing exposure (materials, design, regulations)	Kurt Malmbak Kjeldsen, KMK ApS and Karl Iver Dahl-Madsen, DHI Water and Environment (DK)
10.50	Aquaculture and the marine environment	Yngvar Olsen, NTNU (NO)
11.10	Design and aesthetics (from a coastal zone perspective)	Gunnar Stenberg, Bergersen Arkitekter (NO), Steffen Wellinger, NTNU (NO)
11.30	***Coffee break***	
12.00	Presentation of the technology platform (OATP/EATP)	Yngvar Olsen, NTNU (NO)
12.15	Design of the centre of Aquaculture Engineering (ACE)	Alexandra Neyts, NTNU (NO)
12.45	ESFRI: European roadmaps	Jon Børre Ørbæk, NFR (NO)
13.00	**Lunch**	

2. Session – Group and plenary discussions

14.00	Introduction of discussion topics: I Facilities and equipment needs at ACE II Design of ACE III Organisation of ACE IV Conditions for offshore aquaculture V Technological challenges from aquaculture in climatically exposed localities	Alexandra Neyts, NTNU (NO)
14.15	Group discussions	
15.45	Plenary discussions	Finn Victor Willumsen, ACE Aquaculture Engineering (NO)
17.00	Closing	Arne Fredheim, SINTEF Fisheries and Aquaculture (NO)

4 Participants

	First name	Last name	Company	Type	Country
1	Peder Anders	Rød	Storvik AS	Equipment	Norway
2	Helge Abildhauge	Thomsen	Danmarks Fiskeriundersøgelser Danmarks Tekniske Universitet Afd. for Havøkologi og Akvakultur	R&D	Denmark
3	Geir A.	Haugum	Innovasjon Norge	Government	Norway
4	Gunnar	Nybø	Marine Rådgivningstjenester AS	Consulting	Norway
5	Finn Victor	Willumsen	ACE Aquaculture Engineering	R&D	Norway
6	Steffen	Wellinger	NTNU	Education	Norway
7	Ola	Børseth	Myklebust AS	Engineering	Norway
8	Kristine Suul	Brobakke	Erling Haug AS	Equipment	Norway
9	Friederike	Ziegler	SIK, The Swedish Institute for Food and Biotechnology Environment and Process Engineering	R&D sustainable seafood prod.	Sweden
10	Willy	Ona	Cflow Fish Handling AS	Equipment	Norway
11	Noralf	Rønningen	Aqualine	Equipment	Norway
12	Jonny	Nikolaisen	Mainstream	Farming	Norway
13	Paul	Thomassen	NTNU	R&D	Norway
14	Erik	Sterud	Standard Norge	Government	Norway
15	Anna	Olsen	SINTEF	Organizer	Norway
16	Leif Magne	Sunde	SINTEF	Organizer	Norway
17	Arne	Fredheim	SINTEF	Organizer	Norway
18	Alexandra	Neyts	NTNU	Organizer	Norway
19	Knut	Utheim	Marine Harvest	Speaker	Norway
20	Kurt Malmbak	Kjeldsen	KMK ApS	Speaker	Denmark
21	Karl Iver	Dahl-Madsen	DHI Water and Environment	Speaker	Denmark
22	Yngvar	Olsen	NTNU	Speaker	Norway
23	Gunnar	Stenberg	Bergersen Arkitekter	Speaker	Norway
24	Frode	Meland	NFR	Government	Norway
25	Jon Børre	Ørbæk	NFR	Government	Norway
26	Roar	Mentzoni	NOFI	Equipment	Norway

5 Presentations

A total of seven presentations were given during the seminar.

Knut Utheim (Marine Harvest, Region Mid) presented the company's vision of future aquaculturing. Continuous development on the operational side has led to a change from ca 100 small farming sites around the region, into 20 medium-sized farming sites with production capacity of 2-3000 tons of fish per unit. Increasing concentration towards fewer farming sites of a larger size (5-7000 tons produced per unit) is a probable development. The localities for such large units will be carefully assessed regarding optimal water quality and minimal environmental influence.

A tendency towards larger units implies stronger demands to construction, technology and operation. The Norwegian Standard (NS9415) is central in the development of a new concept, and a knowledge transfer from the petroleum industry will be valuable. Operational tasks such as net handling, transfer of fish, sorting and veterinary consultations will become more comprehensive and will receive greater attention. Frequent inspection of farming sites and continuous risk assessments will be important. Inspection of net and mooring can be performed e.g. by ROVs.

Feed capacity of the farming site must be assessed continuously from an economic point of view. Maintaining large storages can promote "dead" capital, while frequent deliverances of feed directly from the fabric provides a better solution of constant flow of goods and money. This, however, requires advanced routines of logistics, and suitable boats and equipment.

There is a tendency towards services being hired from external sources, particularly those that demand special competences. In combination with rationalization, this may lead to a more effective working process and a reduction in the probability of accidents. Health & Safety routines will be carefully examined and maintained.

Karl Iver Dahl Madsen and Kurt Malmbak Kjeldsen presented the situation from Danish aquaculture. In Denmark, aquaculture is mainly land-based, and comprises in particular European eel and trout. Marine aquaculture is limited in Denmark, due to political and natural reasons.

Kurt Malmbak Kjeldsen is experienced in farming industry, and his opinion is that sea-based farming can be profitable. However, a transfer of Norwegian technology into Danish aquaculture has been problematic. The ordered equipment did not meet the demands, and conditions in Store-Belt (shallow water of 12 metres depth, maximum wave height of 6-8 metres, strong currents up to 2 m/sec, and sandy bottoms) offered new challenges compared to deep Norwegian fjords. A long process of trial and errors has been necessary to learn more.

Yngvar Olsen presented approaches related to carrying capacity and the farming industry, and future implications of the implementation of EUs Water Framework Directive. As a consequence, this directive can set a limit for the release of nutrients from a farming site. It will be important to develop models and demonstrate that such releases are of little effect to the existing ecosystem. Also, the approved levels of releases must be based on scientific knowledge, not political demands. Usually, nutrient releases from fish cages are not significant compared to background values, and there may also be positive effects on the ecosystem.

Yngvar Olsen also participates in the cooperation with SINTEF Fisheries and Aquaculture in the establishment of EATP (European Aquaculture Technology Platform). This is a network of industry and science actors that promote their interests and focus area to the European Commission. OATP (Offshore Aquaculture Technology Platform) is also a part of EATP.

Gunnar Stenberg (architect on the DesignACT project) is involved in design of the new full-scale aquaculture site ACE. Form and functionality together create a unit that is typical and easily recognizable in the society, such as e.g. a pier. One of the challenges is to provide the unit with an aesthetic look that fits into the natural surroundings and together with other existing buildings. **Steffen Wellinger** (NTNU) has developed the ideas that Gunnar presented, showing how form and functionality can be used to create aesthetic buildings, and at the same time achieve a higher production efficiency. Examples from existing buildings (wine production) and futuristic buildings (farming towers for pigs) may provide the aquaculture farming industry with impulses, in order to develop new ideas on functionality, design and aesthetics.

Alexandra Neyts presented DesignACT: the road to a European Centre for Aquaculture Technology. Challenges, both in Norway and Europe, has led to the definition of high-priority topics in research, defined through the strategic plan of FHF (The Fishery and Aquaculture Industry Research Fund), and initiative areas within EATP. Existing research infrastructures have, to a large extent, specialized in approaches related to biology, while there is also a technology component within the challenge areas. Development and innovation has not been given high priority in aquaculture technology, and responsibility has been put upon the producers of technology themselves. With DesignACT, the aim is to offer a research centre that provides large-scale facilities consisting of:

- Dedicated Technology Test Sites (DTTS): for reproducible and controlled testing of new technological tools or new application (without fish or shellfish)
- Dedicated Operation and Management Sites (DOMS): for technological testing of technology and operational methods in combination with fish/shellfish and humans (salmon, cod or mussels)

The company AquaCulture Engineering AS (ACE) has been established, and the aim is to organize it as an inter-European company.

Jon Børre Ørbæk (The Norwegian Research Council) made a short presentation of the European Strategy Forum for Research Infrastructures (ESFRI), which created a roadmap of European research infrastructures. An updated version is coming, and the possibilities of establishment of a European research facility for aquaculture technology are being discussed.

6 Team work: topics and discussions

All participants were organized into five groups, to discuss the following topics

6.1 Facilities and equipment needs within technological development and testing

Leader: Leif Magne Sunde (SINTEF Fisheries and Aquaculture)

Participants:
Peder Anders Rød (Storvik AS), Jonny Nikolaisen (Mainstream AS), Ola Børseth (Myklebust AS)

Topics:

- What do we need to facilitate testing and development in aquaculture technology?
  - Frames for development (large-scale facilities)
  - Time series of measurements / Surveillance / Documentation
  - Field studies / large scale studies, how can they be linked to model experiments

    - and numerical modelling?
    - May the results be transferred directly to commercial production?
- Which environmental variables must be surveyed?
    - To which level of detail?
    - Data treatment
    - Data access / ”open innovation”?
- Equipment benchmarking, how can it lead to industrial development?
- What is the value of large-scale experiments, and how should it be performed?
- How to use model species in technological development (link between biology and technology)?

Discussion:

- A centre must consist of both exposed and sheltered localities (regarding the weather).
- The development of procedures and methods for operation on a true scale is just as important as the technology itself.
- Combination of theory and practice. Measurements in practice are necessary to construct theories. Field studies are important to provide measurements for verification of theoretic work (analyses, modelling, model scale testing). Important to provide knowledge that link simulations and practical testing, analysis tools must be seen in connection to practical results. Verification of environment and farming site - test to improve models. Develop sensors, also solutions that can be used in common farming sites; e.g. technology that can reveal how close to damage a farming site has actually been - to learn from the situations where a breakdown is close but the damage is not complete.
- Lack of engineers. Lack of technical competence both in farming companies and technology producers. Realize that "things happen" but have no theoretical knowledge to understand why. Farmers must be trained in order to increase their knowledge so they can make demands. Education of engineers with thorough knowledge in marine subjects and construction issues is needed, also in companies of the farming industry.
- Establish knowledge of construction lifetimes, e.g. plastic materials used in floatation devices.
- Today, there is a lack of technological documentation, and technology must be documented in the future. Producers are unaccustomed to documentation of technology, and farmers are not used to seek documentation. Technology producers must know what they are selling.
- Standards, national and international. Provide an absolute minimum through standards. There is a lack of facilities where a neutral part can obtain fundamental knowledge from practical work, to be included in standards.
- Manuals – in the future, it becomes more important to provide manuals that describe all issues regarding the technology that is delivered, both for technical descriptions and operational use. There will also be a need for testing and documentation of the properties and performances of technological solutions, and also before selling. Examples are materials and composition in nets, methods for net handling, ”Washing instructions" for nets is one suggestion; nets shrink, and to counteract this the net will be produced in a shape that is unlike the desired form. In the future, the responsibility for a delivered technology will be placed on the supplier, including complete operational management. Documentation and description of actual handling will be in demand.
- Production in larger units, making operations more complicated. Development of knowledge and procedures, e.g. protocols for removal of lice, fish sorting and delivery.
- Benchmarking technologies. Protocols, independent testing of technology protocols (e.g. within loss of feed: crushing pellets - currents, voltage loss, temperature, etc.)
- Lack of engineers to test stability of rafts

- Placing of farming sites becomes more complicated, need to establish knowledge. Improve calculation models to ensure relevant and reliable results.
- Need facilities for testing (solutions for measurements of biomass, oxygen , currents, etc.) so the farmers can receive information founded on facts regarding the product properties. Example: documented reliability and service needs for current sensors, that they can in fact be placed in seawater for three months (as promised in marketing of the product).
- Two basic tasks to start with:
  - Need to know what is in the pen
  - Strength calculations for net, moorings, and farming units
- Become a place where innovation is provoked when the technological development is slowing down.
- To teach "best practice", special training courses and documented further education, e.g. within:
  - Maintenance of moorings
  - Maintenance of nets
  - Health & safety
  - Boat usage (great forces involved, link theory and practice)

6.2 Shaping and design

Leader: Alexandra Neyts (NTNU)

Participants:
Kurt Malmbak Kjeldsen (KMK ApS), Gunnar Nybø (Marine Rådgivningstjenester AS), Steffen Wellinger (NTNU), Gunnar Stenberg (Bergersen Arkitekter)

Topics:

- Will the aquaculture industry be able to create a proper identity through product design?
  - Conservative or radically innovative?
- Combine functionality with aesthetics
  - Integrate facilities and landscape: hide or stand out?
  - How to combine different functions (feeding, mooring) in an aesthetic way?
  - Assess the design of a farming site as a whole (buildings, raft, boats, cages, mooring, and equipment)
- Design that fulfil the users requirements
  - How to detect new requirements?
  - How to guarantee flexibility, without reducing the quality?
  - New demands in Health & safety issues (regarding larger units in more exposed localities): is there a need for new design?
- Logistic challenges
  - How to test different types of technology in a limited area?
  - Will different landscapes create a need for different shaping (inshore vs. offshore)?

Discussion:

The group assessed the design of a feed barge in details: why is it shaped the way it is today, is this the most functional form? The conditions are that the barge must contain a storage room for feed, working place and room for farmers. The order of priority is feed (= capital) and humans (= Health & safety). The silo must contain different chambers to store different types of feed, and the feed must be kept cold. It is also important to ensure that the pumping of feed into the nets is an easy manoeuvre. They buoy volume must be placed as far below the surface as possible.

Rafts are exposed to great wave impact, and the impact increases with increasing raft size. In exposed areas, the raft surface should be at least 12 m above the surface, to avoid the highest waves. There is a potential for improvement of raft material and moorings.

The major challenges come from wave exposure and aesthetics. This group suggested designing the raft as a tower, with housing and offices on the top, working platform at sea level, feed silo below the water, and ballast in the bottom. This shape will ease the impact from waves and currents, it is stable in the water, it provides a better view of the farming site to the crew and it keeps the feed cool. Adding a latticed collar around the vertical structure can increase the working platform at sea level. Feed storages can be built with both an inner tank and outer structure. Stabilizers and skirts may increase the stability, and prevent resonance with high wavelengths. Pumping of feed into the pens is performed through a tube that has a contra valve.

6.3 Organizing an European centre

Leader: Finn Victor Willumsen (ACE Aquaculture Engineering)

Participants:
Jon Børre Ørbæk (NFR); Geir A. Haugum (Innovasjon Norge – only for a short while); Karl Iver Dahl-Madsen (DHI Water & Environment); Paul Thomassen (NTNU); Helge Abildhauge Thomasen (Danmarks Fiskeriundersøkelser)

Topics:

- Continuous communication with the industry (changing requirements): what is the best way to achieve this?
- Cooperation between different companies on generic approaches, what are the best ways to cooperate?
- Is the industry ready for "open innovation”? If not, how to stimulate this?
- How important is integrity to the users?
- Which organization models/working forms can be used across the borders?
- Species as a model for generic research: relevant for other countries? Is there a need for sister companies in other regions?

Discussion:

Clarifying the needs and finding alternative solutions at a lower cost:

- What can be achieved from calculations, models, and tank testing?
- What is needed in terms of localities, amount of fish, type of fish/biological material, structure?
- Important to assess size from scientific criteria
- Such assessments easily turn into a plan for development, and usually only limited activity directly relevant to the research is generated
- Important to combine research, development and operations

Terms for success:

- High level of integrity and openness from the beginning
- Establish clear distinctions between open and enclosed experiments

- Users should be involved from the beginning
- To ensure trust and access, it is important to focus on independency (regarding owners)
- A European syndicate is a possible owner structure
- Research (including basic research) must be explicit, to ensure scientific substance
- Construction in modules ensures flexibility

Teaching and training:
- Educate new scientists (PhDs and so on) to ensure knowledge development and recruitment, also in transfer between theory and practice
- Knowledge transfer and dissemination of scientific results is needed, publication of articles
- Education should comprise both national and international needs

Suitable for other geographic regions?:
Today, salmon is the leading model species for industrial farming, and it may therefore work as a basis for technology for other species, assuming the necessary adjustments are made when other species are being industrialized.

Open innovation in the industry:
Not relevant for most areas, maybe for some larger areas that are considered as common within the industry and therefore not competing

Sister companies in foreign countries:
It will be useful to create sister companies in other countries to ensure special adaptations that are obligatory

6.4 Conditions for offshore aquaculture

Leader: Arne Fredheim (SINTEF Fiskeri og havbruk)

Participants:
Roar Mentzoni (NOFI AS), Friederike Ziegler (SIK Sverige), Yngvar Olsen (NTNU), Willy Ona (Cflow Fish Handling AS), Knut Utheim (Marine Harvest AS), Frode Meland (NFR)

Topics:

- Trends within Scandinavian farming
  - Towards increased exposure – searching for better current conditions?
  - larger units – how to optimise water quality?
- Coastal zone issues
  - Moving further out, will it make things easier or more difficult?
  - Offshore - a solution to potential coastal zone conflicts?
  - Management - need new rules?
- Environmental impacts
  - Escaped fish – offshore, a solution or a problem?
  - increase the distance from "salmon fjords" (where wild salmon are fished)?
  - nutrient release?

Discussion:

Trends

- In Norway, the tendency is to increase the sizes of farming sites, and transfer them to localities of higher exposure to currents, wind and waves. The best localities are sought, and focus is set on increasing the amount of biomass in these areas, compared to less suitable localities. Sweden and Finland, for comparison, have little development in farming, and there are few changes in where the sites are placed and the size of farming sites.
- Main considerations for development in technology and size of farming sites, are production costs and overall economy.
- Change towards increasing use of specialized vessels for different operations, this development is enhanced by the increasing sizes of farming sites.
- New and less expensive technology improves the surveillance of farming sites and biomass.
- Larger units open up for increased investments in equipment for handling, maintenance, and operation such as ROV, surveillance, etc.
- Specialized service companies are established, to handle parts of the management and operation of farming sites

Problems related to coastal zones

- There is some competition about access to suitable areas in Norway, there are major regional differences regarding conflicts of interests in the coastal zone. In Sweden, however, the conflicts are greater and fewer areas are available for sea-based farming.
- To protect the wild salmon, some Norwegian fjords are termed "salmon fjords" and farming is not allowed here
- Area conflicts usually arise when wild salmon or tourism are involved.

Environmental impacts

- Important to assess the public view on the industry. Important to understand these mechanisms, and to present facts in a way that can be understood. E.g. stories of heavy metals in feed, and escaping salmon
- Larger companies and larger units should lead to a decrease in the probability of escapes. Large companies can invest more in surveillance, crowding, equipment, etc.
- Increased size of the farming sites means more fish and larger consequences in cases of accidents, and it is therefore important to prove that larger units reduce the risk probability and thereby a reduction in the risk.
- Animal welfare is an important topic in the future, and it should be possible to demonstrate to the consumer that no animal is suffering unnecessarily.
- The problem of escapes must be solved for the industry to be able to develop as it wishes.

6.5 Technological challenges in aquaculture from weather-exposed areas

Leader: Anna Olsen (SINTEF Fiskeri og havbruk)

Participants:
Kristine Suul Brobakke (Erling Haug AS), Noralf Rønningen (Aqualine AS), Erik Sterud (Standard Norge)

Topics:

- Required development in cage technology?
  - Cages, nets and moorings
- Operation of farming sites in exposed localities
  - A major challenge?
  - How to ensure regularity and access to sites

  - Surveying the fish
  - Cleaning and changing nets
  - Disease treatment
- Feeding
  - How to ensure safe and regular feeding in rough weather
  - Challenges in terms of feed barges or rafts
- Escaping fish – is offshore farming a solution or a problem?

Discussion:

What are the needs for development in cage technology?

- Existing cage technology is used onwards
- Need new solutions for lath expansion of nets
- New concepts for e.g. immersible cages must be developed
- New ideas for moorings (Kevlar)
- Net – new materials, secondary solutions
- Make use of offshore competence on moorings: single-point mooring
- Connecting points – weak points
- Actual forces, rather than safety factors in NS9415
- The farming site ought to be considered as a whole

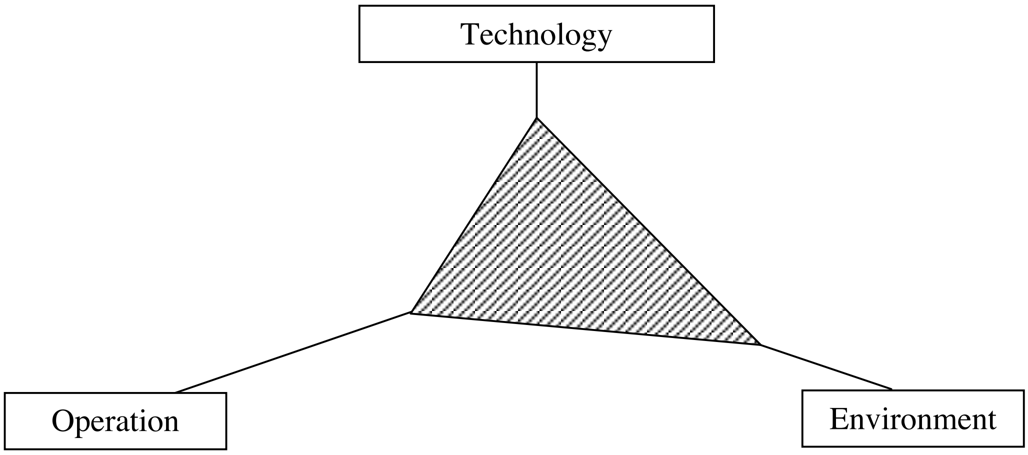
Operation in weather exposed localities

- Survey of environmental parameters, positions, and forces is a major challenge with great importance.
- Net handling is a challenge: change, washing, elevating, laths for regulation of size under varying weather conditions
- Need high capacity vessels (crane, storage)
- Operation barge with proper mooring, to receive well boats, feed boat (when it is not safe to approach the cages) in order to reduce the forces that affect the mooring system
- Take into consideration the difficulties of maintaining regular operations, also in economic terms
- More focus on Health & safety: possible to evacuate e.g. by helicopter
- Remote operation of the site

Escapes

- Problems with escaping fish are difficult to solve
- Recapture is difficult
- Must develop proper solutions to avoid escapes
- Tagged individuals

The following scheme was suggested by Erik Sterud: Assuming the area of a triangle is constant, while the three corner points can be moved along axes "Environment", "Operation" and "Technology"; the optimal combination can be found, where the environmental impact on a locality is low, high-tech adaptations to the surroundings, and operational routines are maintained with regularity and with focus on the workers' safety.



7 Plenary discussions

7.1 Assessment of aquaculture technology

The process of establishing the NYTEK system and creating a Norwegian standard (NS 9415) has been going on for a long time, and there are still some limits regarding the use of existing technology. The certification is established, and the standard is being revised. It is becoming more and more important to have a well functioning certification process. The International Standard Organisation (ISO) has appointed a committee for development of standards for use in the fisheries and aquaculture industry. One possible solution could be to make the NS9415 internationally valid. Furthermore, climate changes may lead to a need for new standards that take this matter into consideration.

Increasing size of farming units has led to increasing risk of escapes or breakdowns. It is important to ensure that the equipment is safe, and new equipment or new methods must be followed by documents to prove their performance.

Today, evaluation of localities is based on models from the offshore industry, and not real numbers. In order to obtain realistic results, it is important to have access to data from coastal areas.

7.2 Knowledge needs

Traditionally, large amounts of knowledge has been generated through ”trial and error” methods. Today there is a great lack of engineers within aquaculture, and more specifically the industry is in need of knowledge on how to model the forces that work upon net and rings.

Surplus of knowledge and documentation is better than a lack, and knowledge can be seen as insurance to the industry as a whole: one cannot base the work on speculations. In Turkey, several companies are no longer allowed to run their farming business in coastal localities; instead they have to move out into exposed areas. Solid knowledge on offshore aquaculture makes the transition smooth from today’s situation (dominated by inshore activities) and towards the future situation.

The precautionary principle applies also here, and research on forehand is beneficial compared to a situation were the investigations are made after an accident has happened. In case of an accident, it is important to understand the mechanisms behind the incident, find the cause and a way to avoid it and also technological and operational solutions to prevent the same thing from happening again. It is necessary to have a plan for cases of escapes.

The insurance business has not been pushing for the development of better solutions. A recently established commission for escapes in aquaculture (Rømmingskommisjon for Akvakultur) is documenting cases and produces a report on the course. It is important to be prepared and establish routines to handle escapes.

The communication must be improved, so that similar incidents will not happen in other localities or with other companies. A better network between actors may be a way to learn from the experiences of others. Freely accessible knowledge that exists already should be collected and verified.

7.3 Numerical modelling and field experiments

The development of new knowledge is based on mathematical calculations, which are tested with models and finally in the field. This is a necessary combination, since numerical models must be verified by field experiments. The link between technology and environment (e.g. current and wind) can be modelled in a satisfying way. Links between technology, operation and environment, however, cannot always be modelled, especially when it comes to operations under rough conditions. A 'golden average' can be defined, where results cannot be calculated but have to be tested. During an operation such as mooring, maintenance, or handling, there are also other elements that affect the situation (e.g. instability, environmental variables) and they cannot be modelled. It is therefore important to test equipment under real-life conditions.

Can other industries teach us something? Did they obtain results thanks to large-scale experiments, which could not have been obtained in other ways? Such examples may be use to justify the use of large-scale experiments.

7.4 Offshore aquaculture

What kind of localities is truly weather-exposed? Extremes must be defined. Offshore sites are not always more exposed. There is not enough knowledge on the size of forces that may arise, and many questions remain unresolved. Rough conditions may also lead to a situation where operation is impossible.