Nordic Salmon

Workshop in Olfus Cluster, Iceland 17th of October 2021

Challenges and solutions in salmon farming within the Nordic region

Gunnar Thordarson

Gunnvør á Norði

Report Matís 06-22
January 2022
ISSN 1670-7192
DOI 10.5281/zenodo.5930938

Skýrsluágrip Matís ohf
Icelandic Food and Biotech R&D

Report summary

ISSN: 1670-7192

Title	**Nordic Salmon - Summary Challenges and solutions in salmon farming within the Nordic region**		
Authors	Gunnar Thordarson and Gunnvør á Norði		
Report no.	06-22	*Date:*	February 2022
Project no.	(215)-2020-NordSalmon		
Funding:	Nordic Council of Ministers - Working Group for Fisheries (AG-Fisk)		
Executive Summary:	The project was supported by AG-Fisk and managed by six people with knowledge on the subjects or relation to the industry. The group came from Iceland, Norway, Faroe Islands, Denmark and Finland. The workshop aimed to gather experts in specific fields of salmon farming in the Nordic countries. Areas of uppermost importance for the Nordic salmon aquaculture were identified as; salmon- and sea louse challenges, optimal feed composition sources, and production of large smolts. Four specialists in sea- and salmon louse and preventive measures against these parasites came from three countries, Iceland, Faroes Islands and Norway. Four experts in new sources and optimal compositions of feed for different environments came from three countries, Iceland, Norway, and Finland. And tree experts in smolt hatcheries (RAS) discussed large smolts production from two countries, Iceland, and Denmark. There were 60 people at the meeting held in Olfus Cluster in Thorlakshofn, a fisheries community in Sothern Iceland. Olvus Cluster is a collaborative project by entrepreneurs planning large production of land-based salmon farming. The guests of the meeting had it in common of working in the aquaculture business, serving the industry or being a public body. Information was communicated at the meeting, by the project web page (https://matis.is/frettir/nordic-salmon-vinnufundur-i-matis/) and in this report.		
Keywords:	*Large smolts, Salmon and fish louse, feed, optimal composition, feed sources*		

Table of contents

Project management

- Gunnar Thordarson, project leader, Matís, Isafjordur, Iceland
- Björgolfur Hávardsson, NCE Seafood Innovation Cluster AS Norway
- Gunnvør á Norði and Jóhanna Lava Kötlum, Fiskaaling, Faroe Islands
- Kurt Buchmann, Department of Veterinary and Animal Sciences, University of Copenhagen, Frederiksberg, Denmark
- Henrik Henriksen, The Danish Aquaculture Organisation, Aarhus, Denmark
- Marko Koivuenva, Finnish Fish Farmers' Association, Helsinki, Finland.

The project opened a website (https://matis.is/frettir/nordic-salmon-vinnufundur-i-matis/) with information about the workshop, including all presentations from the meeting.

The speakers

Ólöf Dóra Bartels Jónsdóttir and Albert Imslamd

Dr. Ólöf Dóra Bartels Jónsdóttir has a PhD in population genetics from the University of Bergen, Norway and works as a senior scientist in genetics at Akvaplan-Niva. She leads the genomic work in the first commercial breeding programme on lumpfish, CYCLOSELECT.

Dr. Albert Kjatan Dagbjatarson Imsland has a PhD in Aquaculture from the Department of Fisheries and Marine Biology, University of Bergen. Thesis title: "Growth mechanisms in turbot (*Scophthalmus maximus* Rafinesque 1810): aspects of environmental and genetical regulation". Specialized in biostatistics and extensive contact with the aquaculture industry. In addition to PhD in aquaculture, he holds a cand. scient. degree in biostatistics and has specialized in experimental designs and interpretation of data in aquaculture, and has extensive practical experience in analysing and interpreting large amounts of biological data. From December 2001, he has worked as an R&D manager in aquaculture at Akvaplan-Niva AS.

Esbern Patursson

Esbern Patursson is Biological Developer at the fish farming company Hiddenfjord. He holds a Master of Engineering in Aquatic Science and Technology from DTU Aqua, Denmark, and has worked in the Salmon farming industry for approximately seven years. As a Biological developer, he has focused on controlling the Salmon lice infection pressure at the sea farming sites, and the company has been successful in significantly reducing infections from sea lice. He also collaborates with research institutes in projects addressing various issues in the production of farmed fish in an experimental manner.

Tróndur Kragesteen

Dr. Tróndur Kragesteen has a PhD in modelling Salmon lice infection pressure from DTU Aqua, Denmark. He is in a Post. Doc. position at Fiskaaling, where he develops a model for detailed prediction of Salmon lice infection pressure at the various commercial fish farming sites in the Faroe Islands. The project is conducted in close collaboration with the Salmon farming industry.

Sussie Dalvin

Dr. Sussie Dalvin has a PhD in cellular and molecular biology from the University of Copenhagen and works as a senior scientist at the Institute of Marine Research, Bergen, Norway. Her work on salmon louse ranges from genomics and molecular mechanisms to physiology and interaction with the fish. She has led a range of projects in close collaboration with the aquaculture industry and contributes to management advice towards regulatory authorities.

Sigurjón Arason

Professor Sigurjon Arason is Chief Engineer of Matís ltd. and Professor at the University of Iceland. He has been involved in fish industries worldwide in various studies on fish processing, focusing on physical properties and chemical changes throughout the whole processing chain. He has worked with almost every process and sector in the fishing industry, both ashore and on board, as well as optimization of logistics, packaging technology and storage of products that optimize the storage life and quality of finished products. He has extensive expertise in improving the utilization of the side raw materials obtained in seafood and aquaculture fish processing. He has been involved in the development of a processing line for farmed fish and in the development of feed and feed production. He has over forty years of experience in this field.

Turid Mørkøre

Dr. Turid Mørkøre is a professor at Norwegian University of Life Sciences (NMBU)· Department of Animal and Aquacultural Sciences (IHA)

Kalle Sinisalo

Mr. Kalle Sinisalo has a MSc in Technology from Aalto University, Finland and a Master of Resources Management in Coastal and Marine Management from the University of Akureyri, Iceland. He works as a Research Scientist at Natural Resources Institute Finland (Luke). His main areas of research are new technological innovations and instrumentations in marine aquaculture with main focus on submersible aquaculture. In 2022, he will switch focus from marine aquaculture to RAS as a Research Engineer at Luke's recirculating aquaculture development environment in Laukaa, Finland.

Gunnar Örn Kristjánsson

Gunnar Örn holds a BSc in Fisheries Science from the University of Akureyri in Iceland and is the manager of Laxa Fishfeed in Iceland. Gunnar was from 1995 to 2007 involved in fish industries in Iceland and Norway as a processing manager and factory manager, both in wild and farmed Cod and as well farmed Salmon and farmed Halibut.

Gunnar has Since 2007 been manager for Laxa Fishfeed that, is the leading fish feed producer in Iceland and located in Akureyri. Gunnar is experienced in all parts of fish feed production, from purchase of raw material to sales of fish feed, including production, recipes, development, and quality. Gunnar has participated on behalf of Laxa in several EU projects as well as Icelandic projects with his expertise in fish feed formulation and raw materials.

Sigurður Pétursson

Sigurður is the founder of LAX-INN and today holds the position of president of the board of this educational and innovation centre for aquaculture in Iceland. He is also the founder of the fish farming company Arctic Fish in Westfjords of Iceland and the production and distribution company Novo Food in France.

Sigurður holds an M.Sc. degree in fisheries and B.Sc. degree in marine biology and has gathered knowledge and experience in the whole value chain of fish farming and related entrepreneur projects within the industry.

Jónatan Þórðarson

Founder and manager of business development for Ice Fish Farm and Rifos hf.

Line Topp Olsen

Line Topp Olsen has been working in the AKVA group for five years. She started as a Project Engineer, projecting the systems that the project department received from sales. After a year, she became a project manager and oversaw the construction of RAS systems in Canada, Chile and the Faroe Islands. After three years as project manager, Line requested to start in the sales department working as a Sales Engineer. Here she is using her experience and knowledge gained during four years in the project execution department, helping clients identify their needs and making the first drafts of what the RAS can look like.

The meeting

Around 60 guests attended the Nordic Salmon Workshop. There were some last-minute changes in location due to Covid 19 and some drop-offs, but the management managed to find suitable replacements for the planned lectures, even though it was short notice.

The meeting was hosted by Olufs Cluster in the town hall in Thorlakshofn, Iceland. It was also recorded on video.

Olfus Cluster is a collaborative project in Thorlakshofn, a town on the South Coast of Iceland. The parties work together to build up land-based aquaculture in Olfus municipality and are planning to establish annually production of 80 thousand tonnes of farmed salmon in the area.

Meeting agenda

1. **Opening of the meeting**
    a. Einar Kristinn Guðfinnsson, former minister of fisheries and Speaker of the House of Parliament, was supposed to address the meeting after formal opening. Einar Kristinn has been working for Fisheries Iceland as an adviser in fish farming. Unfortunately, he was put in Covid quarantine the day before the workshop and therefore unable to attend.
2. **New development in sea- and salmon louse**
    a. Lumpfish genetic research (salmon - and sea lice), Dr. Ólöf Dóra Bartels Jónsdóttir, Iceland
    b. Fish welfare to prevent sea lice issues, Esbern Jóannes Patursson, Biological Developer at Hiddenfjord, Faros Islands
    c. Dispersion of sea lice, connection between farms and economic cost, Dr. Tróndur Kragesteen, Researcher, Fiskaaling, Faroes Island
    d. Salmon lice biology, Dr. Sussie Dalvin, Senior Researcher, Institute of Marine Research, Bergen, Norway
3. **Feed: New sources and optimal composition for different environments**
    a. Special feed production from pelagic production, Sigurjón Ararson, Chief Engineer/Professor emeritus, Matis/University of Iceland, Iceland
    b. Salmon Feed, Turid Mørkøre,
    c. Kalle Sinsalo, Research Scientist, Natural Resources Institute (Luke), Finland
    d. Gunnar Örn Kristjánsson, General Manager, Laxá Fishfeed, Iceland
4. **Production of large smolts in hatcheries**
    a. Large smolts, Sigurður Pétursson, Laxabóndi, Lax-inn, Iceland
    b. Construction of a juvenile farm at Rifos and Kopasker, Jónatan Þórðarson, founder of IFF, manager and business development for Rifós, Iceland
    c. Large Smolt RAS – Design and Development, Line Topp Olsen, Sales Engineer, AKVA Group Land Based, Norway[1]

[1] Appendix I

Subjects

New developments in sea- and salmon louse treatments

Several options already exist for chemically treating salmon lice in sea cages. However, there are two main problems with this approach. Firstly, there are negative environmental impacts, as these chemicals negatively affect many crustacean's species, which play an important role in maintaining healthy fjord ecosystems. Secondly, lice have developed resistance to many of the available chemicals currently being used. Some of the solutions are causing negative side effects; lice treatments are the main cause of salmon escapes; use of chitin inhibitors are controversial drugs and could increase resistance to medical treatments etc. A high share of the escape incidents, and the mortality rate, are caused by rough mechanical lice treatments. The Norwegian Scientific Advisory Committee for Atlantic Salmon has identified salmon lice as the second largest threat to wild Norwegian salmon. The annual loss of wild salmon due to lice was estimated to be 50,000 adult salmon between 2010-2014, equalling 10% on a national level.

New approaches to control the sea lice issues are desperately needed by the industry. Integrated pest management is widely used within the sea cage farming of Salmon. Several species are being used, such as several Wrasse species and Lumpfish. These fish are often referred to as cleaner fish, as they eat the lice and offer a sustainable and environmentally friendly method of reducing lice infections in sea cages. The challenges with current methods for controlling salmon and fish lice in aquaculture were discussed, and novel methods were introduced in the workshop.

Feed: New sources and optimal composition for different environments

Salmon feed is a very dynamic area of research and development. Feed requirements of salmon growing in extreme environmental conditions, such as low temperature, are not fully understood. Furthermore, technical solutions to minimize movements of fish in sea cages during the coldest periods in winter could improve the conditions of fish during the coldest months. In addition, several novel sustainable and locally sourced feed sources are emerging, such as single cellular algae, which are currently being tested as a feed source in aquaculture. It is essential to share the findings of ongoing research in this subject among the leading aquacultures.

Production of large smolts in hatcheries

One solution to overcome various problems in sea cage farming of salmon is to grow the smolts to a larger size within land-based hatcheries before they are released to the sea pens. This is in many ways an appealing solution, as it shortens the time that adult salmon are exposed to sea lice and can improve overall robustness towards other organic or inorganic stressors. It has even been proposed to grow salmon up to 1 kg in hatcheries before realising them to sea cages. However, many challenges are associated growing salmon to such a large size in hatcheries. Reduced lead time and higher turnover ratio. Norwegian authorities have recently repealed the maximum smolt size restrictions, allowing farmers to produce a larger share of the biomass on land in modern RAS facilities. In these facilities, smolt producers can provide ideal conditions for sustainable biomass growth, with complete control over temperature, nutrition levels, fish health and the quality of the water. By deploying post smolts of 1,000 grams, producers may be able to reduce production time in sea from 16-22 months to only 10 months. Reducing lead time in sea also enables producers to reduce the spread in biomass throughout the year. This may be one of the most sustainable ways of maximising utilisation of licenses. However, there are several barriers that may halt the development of post-smolt production in RAS facilities. Increased resilience towards viruses and lice-attacks Larger post-smolts are considered more resilient towards virus attacks than their "smaller siblings. This may in turn reduce the mortality rate and will contribute to increased utilisation of the MAB capacity. Development in this field will be discussed in the workshop.

Presentations

Session overview: new development and treatment in sea- and salmon louse

1. **Several options already exist for chemically treating salmon lice in sea cages**
2. **However, there are two main problems associated with treating lice in such a way. Firstly, there are negative environmental impacts, as these chemicals negatively affect many species of crustaceans, which play an important role in maintaining healthy fjord ecosystems. Secondly, lice can and have developed resistance to many of the available chemicals currently being used**
3. **The challenges with current methods for controlling salmon and fish lice in aquaculture will be discussed and novel methods will be introduced at the workshop**

Lumpfish genetic research

Olof Dora Bartels Jónsdóttir from Akvaplan-niva:

Akvaplan Niva, in co-operation with NIBIO, is analysing the genome of lumpfish to better understand the factors like health and behaviour of the fish. Currently, 60% of lumpfish used to graze lice do not eat them, but this percentage might increase with a better understanding of the link between genotypes and phenotypes (genes vs physical traits). Our research has shown a difference in traits between families, i.e. some lumpfish families have higher grazing occurrence than others, and some have better general health. We also raise the question if it is possible to teach lumpfish to eat lice by introducing them to frozen marine food. Both methods look promising.

If it is possible to raise the gazing to 70-80%, we will increase the sales values of the lumpfish fry produced considerably. If possible, the estimate of its value to industrial partners would be around 5-10 m NOK annually per one million fry under the first and second generation of the breeding project. The trials show that it is possible to significantly increase lice gazing through genetic selection with a clear effect on disease resistance and survival.

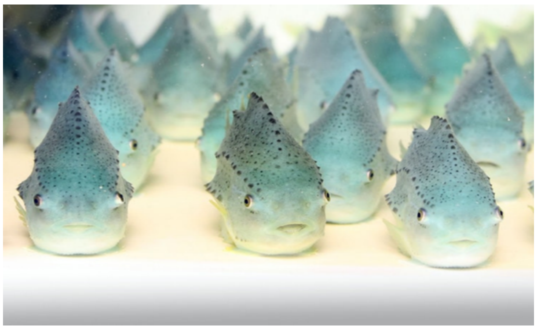

Figure 1 Lumpfish juvenile

Akvaplan Niva has also been focusing on understanding the genetic structure of wild lumpfish in the Norwegian waters as well as in the Atlantic Ocean. Research using both microsatellite genetic markers (g-STR and EST-STR) as well as single nucleotide polymorphisms (SNPs) has increased our understanding of the genetic structure of lumpfish populations. The results will be useful for optimal management and to minimize the risk of genetic translocation of reared lumpfish.

Fish welfare to prevent sea lice issues

Esbern Patursson

Esbern presented the strategy of the fish farming company Hiddenfjord to ensure fish welfare and prevent sea lice issues. Hiddenfjord operates in the worlds most exposed farming sites. Esbern explained the difference between internal and external infection of salmon lice and how exposed farming avoids internal infection pressure. Hiddenfjord has a preventative sea lice strategy, which is one of the main reasons the mortalities of the salmon have been steadily decreasing.

According to Esbern, Hiddenfjord have several ways to protect against lice:

- Shorter time in the sea – Large smolts of good quality, and fast growing in pens
- Using lumpfish for grazing lice
- Strategical deployment – fewer salmon on problematic sites
- Planning and research – Knowing the hydrodynamics and the population dynamics of sea lice of the farming sites
- Sea lice modelling
- Appropriately strict regulations
- If necessary – chemical treatment

With larger smolts stocking mortality have been going down at Hiddenfjord, reaching an all-time low of 1.4% the first three months at sea. Growth at sea has increased, and the duration of the sea cage phase is reduced to less than 11 months on average before slaughtering.

Larger smolts with fewer/equal number of salmon give:

- Increased production
- Fewer sea lice
- Less handling of the salmon
- Lower biological risk

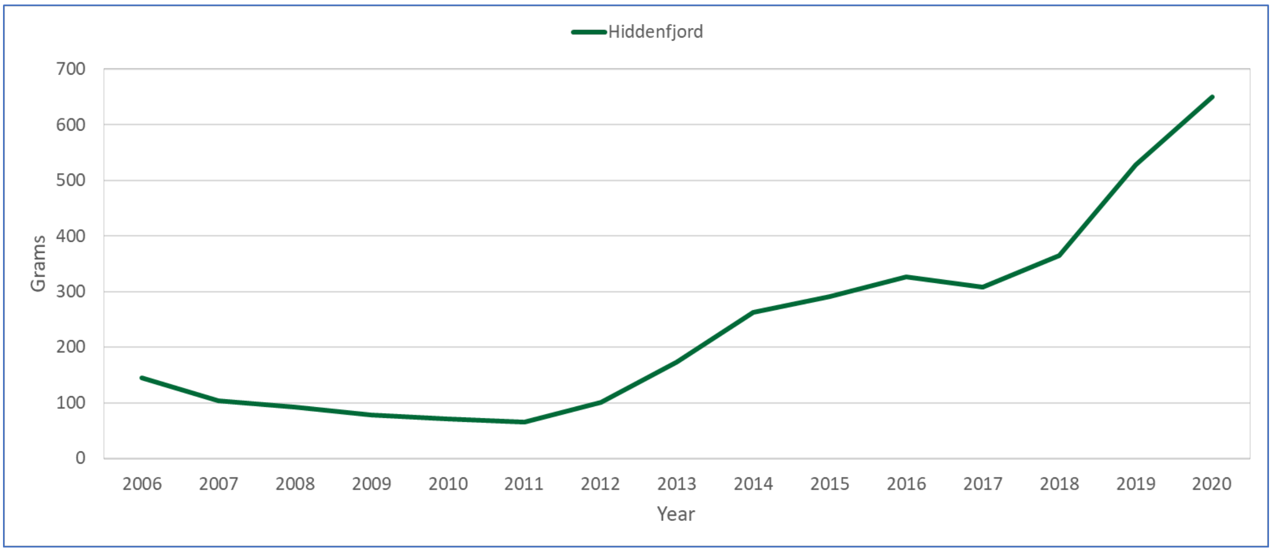

Figure 2 Average smolt weight at transfer to sea cages

Hiddenfjord looks at sea lice as a common enemy for the industry, travelling all the way around the Faroes in their infective stage. Thus strict regulations are needed to avoid the tragedy of the commons.

The industry should focus on:

- Large smolts of good quality
- Fewer/equal number of smolts
- Fast growth on sea
- Lumpfish research – focus on getting mortality down!
- Genetics
- Sea lice modelling
- Strict sea lice regulations – Hiddenfjord wants 0,2 adult female limit
- Exposed farming
- Semi closed containment systems.

Dispersion of sea lice, connection between farms and economic cost

Tróndur Kragesteen

Tróndur's presentation explained the overall aim to develop a tool for optimal salmon lice management:

- Lice dispersion
- Connectivity
- Salmon lice population dynamics
- Lice economics

Tróndur explained the life cycle of salmon lice by time and temperature. He introduced a connectivity matrix around the Faroe Islands, including 24 farm sites and a connectivity simulation for salmon louse. Salmon lice cost the industry around 0.5 to 0.039 Euros/kg. The global annual production in the salmon industry is about 2,7 million tonnes, and therefore the cost of salmon lice has been estimated to be about 675 billion Euros. Government regulation on louse authorized treatments is required, with varying thresholds for lice treatment between countries. Below are the treatment thresholds, i.e. the average number of lice per fish in sea pens that trigger treatments for Norway, Scotland and the Faroe Islands

- Norway; 0.5 adult female per salmon (0.2 in migration periods).
- In Scotland, 0.5 adult females per salmon are recommended, while 8 adult female lice per salmon mandate intervention.
- Faroe Islands; 1 adult female per salmon (0.5 in migration periods).

Tróndur posed the question of what the optimal treatment threshold for salmon lice would be and introduced a conceptual bioeconomic model. Isolated farms profit most with a high treatment threshold, while farms that are connected and infect one another profit most with low treatment thresholds. Salmon lice are the tragedy of the commons in such systems, spreading between farm sides, harming farmers treating their salmons against lice from non-treating farmers.

Dispersion and connectivity within the Faroe Islands go by the clockwise currents, but with the southernmost island relatively isolated. The farms form a complex and highly connected farm network, and strict regulation is needed when managing with a low treatment threshold. A powerful tool is required to combat or control salmon lice in aquaculture. This requires further work in:

- Hydrodynamics models
- Connectivity
- Biological knowledge of salmon lice
- Salmon lice population dynamics
- Treatment efficiency

The questions are:

1. What are the optimal lice management strategies in salmon farm networks?
2. How can salmon lice growth be modelled in the Faroe Islands?

Salmon lice biology

Sussie Dalvin

The salmon louse life cycle has eight stages, separated by smolt and production of a new exoskeleton. There are three planktonic larval stages and five parasitic stages on fish. Adult females are long lived, and egg production is continuous. The effect of salmon louse on fish is highly dependent on number of lice per gram of fish. Heavy infection and the resulting extensive grazing of skin cause wounds, osmotic problems, and negative effects on fish health. Salmonid fish are tolerant to fewer intensive infestations, but problems can quickly escalate as each salmon louse produces many offspring (one female produces approximately 40 larvae per day).

Figure 3 Skin erosions on head of post smolt Atlantic salmon infected with salmon lice

Management is necessary to prevent lice epidemics, considering cost and logistics, environmental impact and fish welfare. This should be built on prevention, infrastructure, planning, and production methods. All this is based on biology. The successful management of a difficult parasite is based on:

- Awareness in the industry
- Regulatory authorities
- Researchers
- Fishermen, NGOs

Communication is the keyword with everybody contributing with long term plans.

Session overview: Feed -New sources and optimal composition for different environments

1. **Salmon feed is a very dynamic area of research and development**
2. **Feed requirements of salmon growing in extreme environmental conditions, such as low temperature, are not fully understood**
3. **Furthermore, technical solutions to minimize movements of fish in sea cages during the coldest periods in winter could improve conditions of fish during the coldest months**
4. **In addition, several novel sustainable and locally sourced feed sources are emerging, such as single cellular algae, are currently being tested as a feed source in aquaculture**
5. **It is important to share the findings of on-going research in this subject among the leading aquacultures**

Special feed production from pelagic production

Sigurjón Arason

The nutritional need for fish for growth and health is protein, amino acids, fatty acids, vitamins, minerals, and energy for the metabolism. The role of raw materials in feed formulation is the supply of nutrients, ensuring enough energy, minimizing the content of anti-nutritional factors and harmful substances to the fish and the consumer. *All organisms need proteins according to their genetic amino acid composition and not a specific need for certain raw materials.*

The optimization of feed is to know the nutritional needs:

- Crude protein (Nitrogen)
- Indispensable amino acids
- Indispensable fatty acids*
- Vitamins and minerals

And to know the composition of raw materials:

- Nutrient content
- Availability of the nutrients
- Presence of anti-nutritional factors

The materials for fish meal production are whole fish, bycatch and by-products from fish processing. The important factors for quality are nutritional quality (water, protein, lipid and ash) and freshness (total volatile nitrogen TVN). The effects of spoilage on the quality of the raw material are protein fraction and lipid fraction.

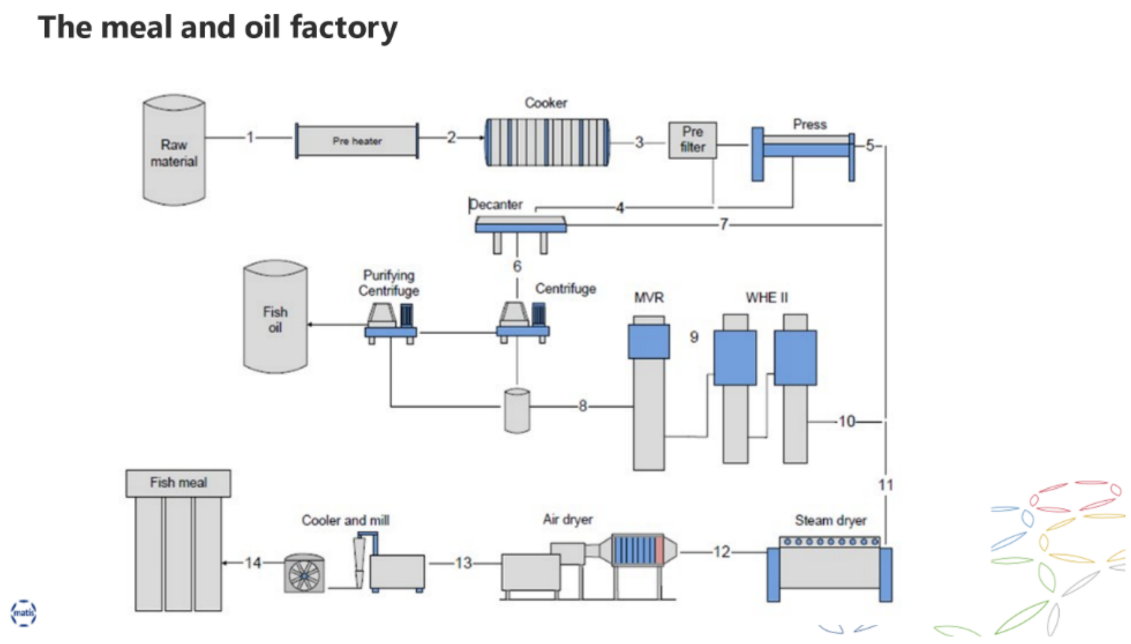

Figure 4 The meal and oil factory

The quality criteria of fish meal production are:

- Protein content
- Protein - amino acid composition
- Lipid content
- Water soluble protein
- TVN
- NH3-N
- Biogenic amines (Histamine)

The temperature used for the processing is vitally important for quality. To high processing, temperature destroys the proteins.

Biorefinery

- New processing equipment
- Easily changeable processing line
- Mobility
- Improved services by Matís for the Icelandic food industry
- Increased utilization of raw materials for innovation
- Development of technological solutions and value creation
- Separation
- Membrane filtration
- Spray drying
- Production of:
  - Oils
  - Bioactive compounds
  - Protein powders

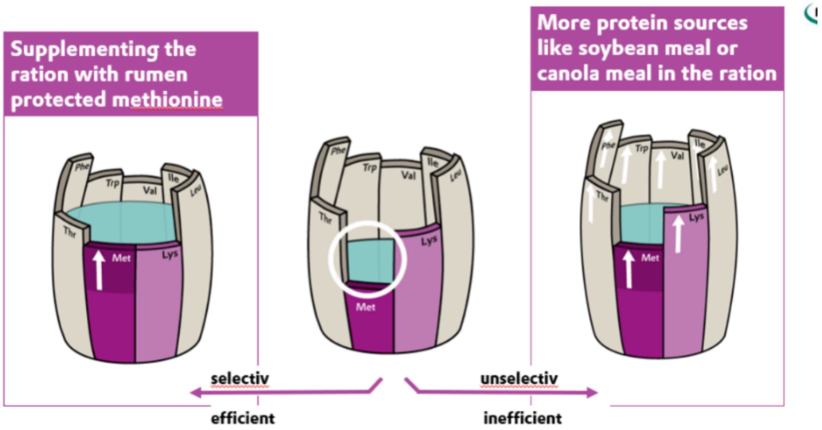

Figure 5 Liebig´s barrel illustrators

Liebig's barrel illustrates the usefulness of targeted amino acid supplementation.

A targeted approach to improve feed efficiency is to supplement the most deficient amino acids. In the barrel metaphor, this corresponds to increasing the length of the shortest staves to efficiently improve capacity rather than inefficiently increasing the length of all staves by feeding e. g. more soybean meal.[2]

Feed for salmon – with focus on RAS

Turid Mørkøre

Historically, the two most important ingredients in fish feed have been fish meal and fish oil. The use of these two marine raw materials in feed production has been reduced in favour of ingredients such as **soy, sunflower, wheat, corn, beans, peas, poultry by-products** (in Chile and Canada) and **rapeseed oil**. This substitution is mainly due to heavy constraints on the availability and high prices of fish meal and fish oil.

Salmonid feed raw material has changed a lot in the last two decades, with marine protein sources and fish oil inclusion decreasing from over 90% to 25% in 2016. At present, there are salmon feeds on the market with even higher inclusion levels of plant raw materials.

A main strategy for the salmon industry is to grow a healthy fish fast at the lowest possible cost. Feed is the most important input factor in salmon aquaculture, and the shift from marine ingredients to plant ingredients is economically beneficial as it has allowed the industry to grow. It is, however, important to be aware that high inclusion levels of certain plant ingredients in salmon diets may have adverse effects on fish health and welfare, biological performance, and fillet quality due to imbalanced nutrient composition and anti-nutritional factors.

[2] https://www.feednavigator.com/News/Promotional-Features/Reducing-nitrogen-emissions-in-animal-husbandry-with-amino-acid-enriched-feed

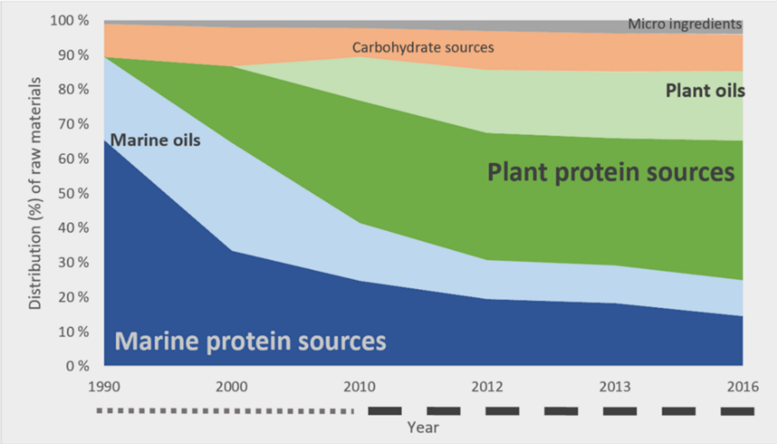

Figure 6 Nutritional factors for fish feed Adapted from Aas et al. 2019.

Recirculating Aquaculture Systems (RAS) are common production forms for land-based farming of salmon in a highly controlled environment that aims to use water more efficiently, decrease environmental impacts, improve biosecurity, and obtain healthy, fast-growing fish with superior product quality.

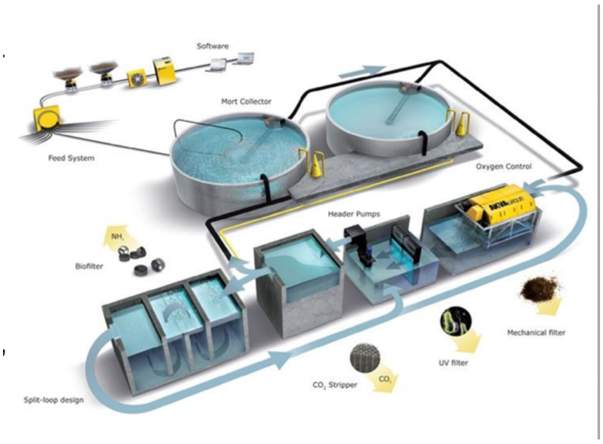

Figure 7 Drawing of a RAS system

- A RAS feed must not only satisfy the fish's nutritional needs but also have physical properties that minimize contamination of the water.
- Both pellets and feces must be solid so that they can be removed efficiently by the mechanical filter
- Pellets must be firm and durable, so they can withstand the friction that occurs in feeding and transport systems – hence dust that pollutes the water and damages the gills is minimized
- The pellet should sink slowly so that the fish have time to catch the feed
- High water stability means that uneaten feed is removed by the mechanical filter without affecting the water quality.
- Loose stools, dust, and pellets that dissolve have negative effect on the bacteria in the biofilter so that they cannot do their job (feeding must be reduced).

Poor technical feed quality and issues with faecal matter are two major challenges for running a successful RAS fish farming.

Conditions at the Baltic Sea for Rainbow Trout and for Finish Aquaculture

Kalle Sinisalo

Overview of the Finnish Aquaculture:

- Max production in 1991
- Inland vs Marine aquaculture
- ~80 % of production in the marine environment
- ~95 % of production is rainbow trout

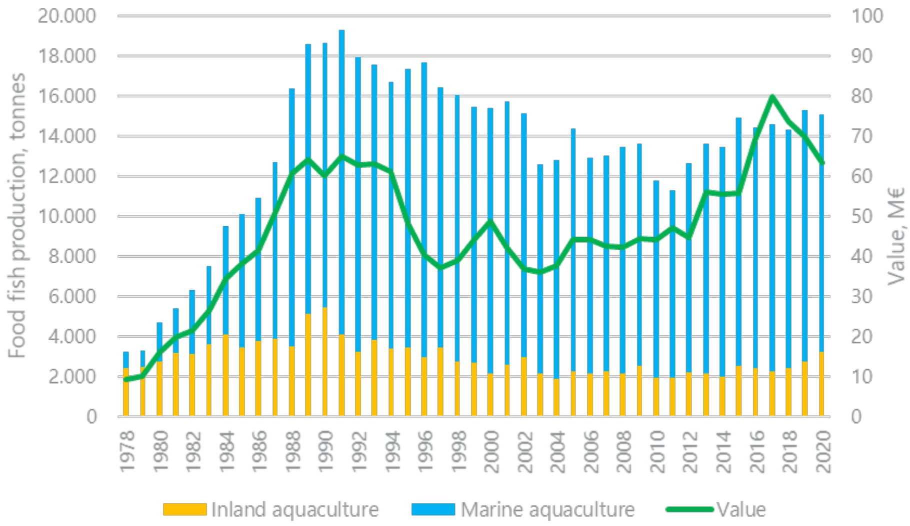

Figure 8. Historical overview of the development of aquaculture in Finland

Seasonality plays a great role and is a major challenge in Finnish aquaculture. Short annual production periods, fluctuating seasonal temperatures and fingerling production, which is mainly located inland far from food fish production sites, challenge the industry and causes seasonal market peaks. During winter, there is a challenge of transporting fish and aquaculture gear along with limited areas for overwintering the fish (i.e. areas where ice doesn't move and water is not prone to supercooling). Environmental restrictions (permitting) are also a challenge for the Finnish aquaculture industry. Permitting process is long, and a lot of uncertainty lies in getting a license. The main restricting parameters for aquaculture license are phosphorous and nitrogen loading from production (eutrophication). The current trend in food fish production is towards licenses for RAS and less sheltered areas (offshore).

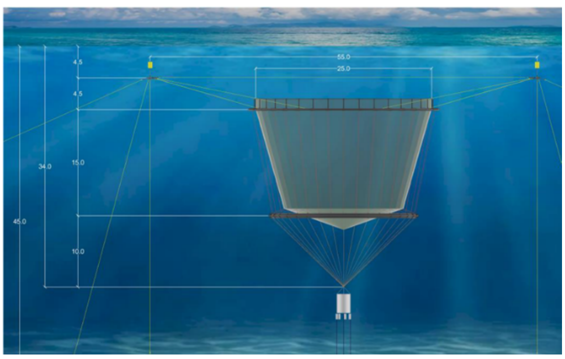

Figure 9 Submerged system for rainbow trout

The main challenge for Baltic Sea fish feed is that it recycles the nutrients within the Baltic Sea water body, so the mass balance of nutrients would be unchanged. Fish feed from other sources than the Baltic Sea will add nutrients to the area, while fish feed made from sources harvested from the Baltic Sea will recycle existing nutrients. Ideally, the amount of nutrients in fish feed raw material would correspond to the nutrient emission from aquaculture. The recycling fish feed concept has not been totally accepted with no legal status in permitting the process. The use of compensatory tools are not directly mentioned in legislation and not necessarily considered in licensing procedure.

Offshore farming is an ongoing research matter: Moving production (and winter storage) to more exposed areas require new technologies. Researchers are working on submersible net cages to avoid drift ice and enable more flexible production planning. Last winter (2020-2021), rainbow trout were submerged at an exposed site for overwintering with poor results, and research is ongoing.

Challenges in feed production for salmon in the future

Gunnar Örn Kristjánsson

Laxa Fishfeed Ltd has been in operation since 1987, producing and selling fish feed. In the early years of operations, it was as part of Skretting but was established as an independent company in 1991. The production volume is 20 thousand tons a year with nine employees.

Laxa Fishfeed has distinguished itself on the market by using more fishmeal in its product than its competitors, with around 34% of its product ingredients. Fish oil is around 17%, wheat 11%, corn around 11%, soja around 14%, rapeseed meal 3%, rapeseed oil 6%, vitamin 2% and wheat gluten 2%. All the fish meal and oil are processed in Iceland from fish caught within FAO 027 in North Atlantic Ocean.

Laxa states that the best raw material for fish feed is fishmeal and fish oil, both regarding nutrition and production. But there is concern about its sustainability and future availability. It will be necessary to replace marine resources with plant-based material in the future, but such replacements need to:

- Give same or better nutritional effect
- Give same or better technical effect in productive in big volume
- Be priced reasonable
- Be possible to grow domestic or in the western part of Europe
- Have a minimal effect on food production for humans
- Have low undesirable content like toxins
- Have low carbon footprints.

The future source for this for fish feed material will come from:

- GMO plant meal
    - Higher protein content increase EPA/DHA fatty acid and decrease anti nutritional substance
- Krill
    - Dispute about environment and cost of taking out large biomasses from the lower part of the food chain
- Micro Algae
    - Interesting with a lot of good effect in nutrition but still expensive and limited volume
- Macro Algae
    - Low in protein and high in undesirable substances that are expensive to reduce in process
- Bacteria's - Yeast Bacteria
    - Expensive and low volume
- Mushrooms – Fungus
    - Expensive and low volume

Insect meal is one possibility, produced commonly by using the Black Soldier Fly or Mealworm, using organic waste as a feed source. This would be a sustainable and environmentally friendly approach and a good way of utilizing organic waste. This product has promising nutritional composition and is a natural feed for salmonids species. But now, the volume is limited, and it is expensive in production.
Other possibilities are single cell protein (SCP) meal, such as SylPro, made from waste wood from the forest industry, which utilize fungi or bacteria to produce Single Cell Proteins. It is an interesting raw material for fish feed and has proven to have better or same performance as plant meals. It is high in protein like plant meals and is reasonably priced. Scandinavia could be a suitable production area, and it is environmentally friendly and has a low carbon footprint.

Session overview: Production of large smolts in hatcheries

1. **One solution that is being developed to overcome various problems in sea cage farming of salmon is to grow the smolts to a larger size within the land-based hatcheries before they are released to the sea pens**
2. **Reducing lead time in sea also enables producers to reduce the spread in biomass throughout the year. This may be one of the most sustainable ways of maximising utilisation of licenses**
3. **Increased resilience towards viruses and lice attacks.**
4. **Larger post-smolts are considered more resilient towards virus attacks than their "smaller siblings**

Figure 10 Short distance from tanks to well boat

Large smolt production in Iceland

Sigurður Pétursson

There are opportunities and challenges in farming large smolts for salmon production. For RAS farming in Iceland, geothermal heat is used to keep the water at optimal temperature. For a lower carbon footprint of a product, the supply of green energy is also important. Good access to boreholes for fresh water and access to clean and pristine seawater is also of great importance. There are also challenges in the transportation of large smolts to the farming site, and a setup close to the farming site is preferable.

Arctic Fish has experience in using larger smolts (220 grams and above) from RSA hatchery from 2019. The fish in 2020 spent only 16 months in the sea and reached an average weight of 6.5 kg., with 3.4 TGC (Thermal Growth Coefficient). The thermal growth coefficient (TGC) appears to be a good predictor of the expected mean growth of Atlantic salmon within the temperature range of 4–14 °C.

In 2021 output of smolts, the results from spring output in October showed a survival rate of 99% or an average monthly mortality of 0.2%, compared to the industrial average of 1%. For the end summer smolt output, the cumulated survival rate in October was 99.8% survival rate or average monthly mortality of 0,01% (versus 1% in industrial average).

To achieve such a performance, a company needs good staff, adaption to the environment and a concept with large smolts in RAS systems close to the sea farming sites.

Construction of a juvenile farm at Rifos and Kopasker

Jónatan Þórðarson

Rifos Ltd operates two RAS smolt farms at Rifos and Kopasker, Iceland. Farming at Rifos started in 1971 by Norwegian investors under the name of ÍSNO. In 2012 Rifos started farming Arctic charr in the lagoon, but in 2018 Ice Fish Farm acquired 70% of the company for farming smolts for its sea cates operation on the East coast of Iceland. Today's production capacity is four million 400 g smolts, using natural hot water, 12-14 °C, making it the biggest smolt producer in Iceland today. The distance from the farming tanks to the well boats is short.

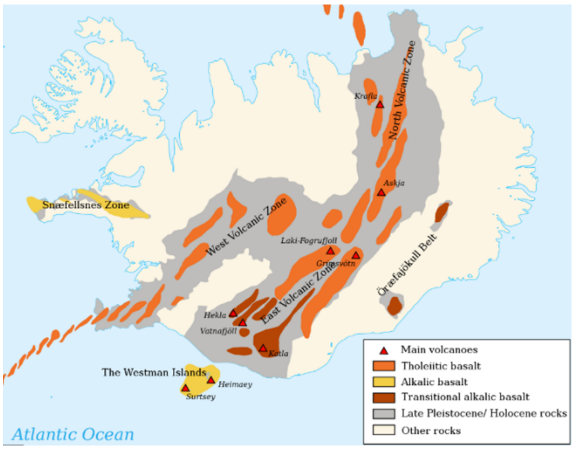

Figure 11 Mid Atlantic Ridge, constructive plate boundary across Iceland

Before the smolt are released at sea, the tanks are cooled down for 7 -14 days down to current ocean temperature. This increases the smolt window to eight months, from April to December. The norm in Iceland is four-five months. This is to manage to utilize station better and licenses in the sea and lower risk for operations. All wastewater is treated before release to the sea.

There is a plan for future construction at Rifos and Kopasker, housing for staff, tank houses, backup generators, oxygen production and for controlling.

RAS for Large Smolt – Design and Development

Line Topp Olsen

Way are large smolt interesting? To make the most of recirculation! Using large smolts reduces life cycle lengths by 3-4 months. The farming time in open farms is reduced by 6-7 months, lowering the risk of parasites and diseases in the open sea.

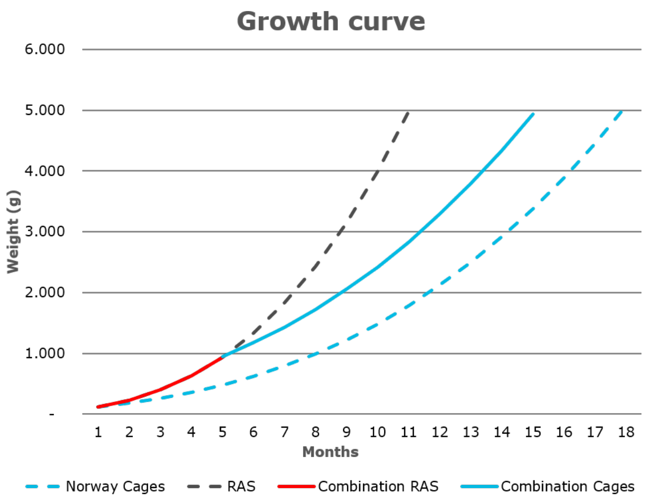

Figure 12 Growth curve for different farming methods, Norway Cages, RAS, Combination RAS and Combination Cage

The challenge of upscaling the system is that land-based farming has a larger footprint. It also requires a lot of cleaning the many biofilters, and there is a need of oxygenating the large water flow in big tanks, around exchange the volume 2 times pr. hour. Placing the degassing on top of the biofilter reduce the footprint by 30% for the RAS module. AKVA uses hybrid biofilter systems to allow continuous cleaning of the bio media and fixed bed for microparticle retention and improvement of water quality.

The AKVA Module for Post Smolt are:

- 4 x 2000 m3 fish tanks
- 500.000 kg @500g
- 62 kg/m3 fish stock density
- 8000 kg feed/day
- 15.500 m3/h flow
- 15 ppt Salinity
- 15 mgCO2/l ▪ 300 litre makeup water/kg feed

AKVA group have designed and built four new smolt production for large smolts in RAS:

Tytlandsvik AQUA

- 3 x Post Smolt system
- Size 1000 grams
- Total 25.500 kg Feed/day
- Total Volume; 24.000m³
- Smolt @1000g / year
- Target; Total Freshwater consumption in operation = 42,5m3/h or 12 l/s

Svaberget

- New system under construction
- Entire system designed and built by AKVA
  - Hatchery, Start feeding, Smolt
  - 2 x Post Smolt system
- Post Smolt size 500 g.
- Total 15.000 kg Feed/day
- Total volume; 13.700m^3
- 7.500.000 @500g / year
- Total Freshwater consumption in operation = 25 m3/h or 7 l/s

Ænes – New system under construction

- All systems designed by AKVA
  - AUX systems: Intake water, Heating/cooling system, Feeding system
  - Hatchery, Start feeding, Parr and Smolt
- 2 x Post Smolt system
  - Total 13,000 kg Feed/day
  - 6.600.000 @400g/year
  - Total Fresh water consumption in operation = 25 m3/h or 7 l/s
- Size 1000 grams
- Total 25.500 kg Feed/day
- Total Volume; 24.000m^3
- Smolt @1000g / year
- Target; Total Fresh water consumption in operation = 42,5m3/h or 12 l/s

Svaberget

- New system under construction
- All systems designed and built by AKVA
  - Hatchery, Start feeding, Smolt
  - 2 x Post Smolt system
- Post Smolt size 500 g.
- Total 15.000 kg Feed/day
- Total volume; 13.700m^3
- 7.500.000 @500g / year
- Total Freshwater consumption in operation = 25 m3/h or 7 l/s

Ænes – New system under construction

- All systems designed by AKVA
  - AUX systems: Intake water, Heating/cooling system, Feeding system
  - Hatchery, Start feeding, Parr and Smolt
- 2 x Post Smolt system
  - Total 13,000 kg Feed/day
  - 6.600.000 @400g/year
  - Total Fresh water consumption in operation = 25 m3/h or 7 l/s

Appendix I

Wednesday 27th of October

Ölfus Cluster, Hafnarberg I, 815 Þorlákshöfn

Sponsored by AG Fisk

08:30 Opening the workshop

08:45 Address: Einar Kristinn Guðfinnsson

09:00 **New development in sea- and salmon louse**

1. Lumpfish genetic research (salmon sea lice), Dr. Ólöf Dóra Bartels Jónsdóttir, Iceland
2. Fish welfare to prevent sea lice issues, Esbern Patursson, biological Dveloper, Faroes Islands
3. Dispersion of sea lice, connection between farms and economic cost, Tróndur Kragesteen, Faroes Islands
4. Salmon lice biology, Sussie Dalvin, Norway

10:30 Coffee break

11:00 **Feed: New sources and optimal composition for different environments**

1. Special feed production from pelagic production, Stefán Eysteinsson, Iceland
2. Salmon Feed - Turid Mørkøre, Norway
3. Kalle Sinisalo – research scientist, Finland.
4. Challenges in feed production for salmon in the future, Gunnar Örn Kristjánsson, Iceland

12:30 Lunch

13:30 **Production of large smolts in hatcheries**

1. Large smolts, Sigurdur Petursson, Iceland
2. Construction of a juvenile farm at Rifos and Kopasker, Jónatan Þórðarson, Large Smolt
3. Large Smolt RAS - Design and Development: Line Topp Olsen, Denmark

15:00 Coffee break

15:30 Discussions

16:00 Round up

17:00 Refreshments at Lax-inn Mýrargötu 26

19:00 Dinner