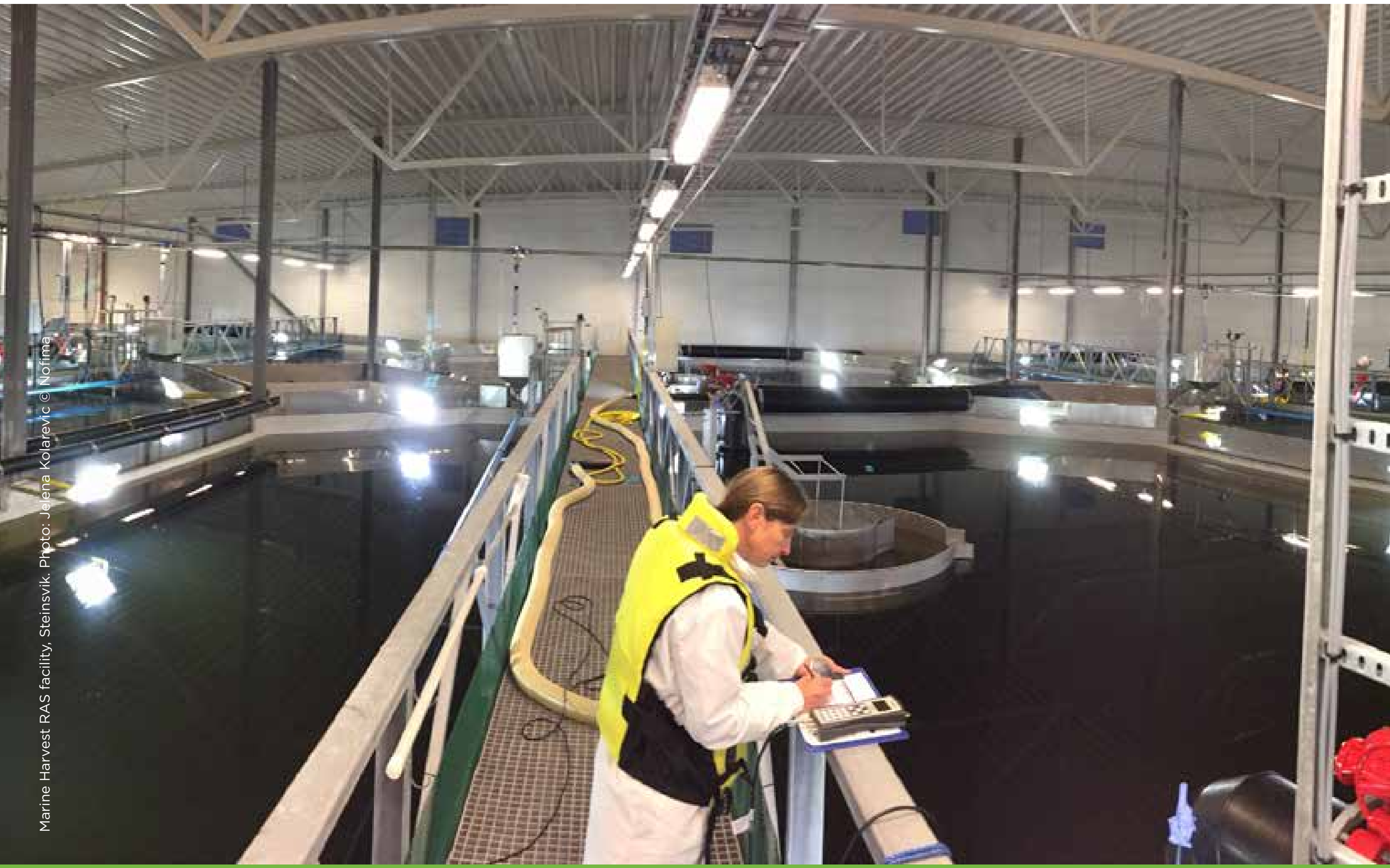
CtrlAQUA

Annual Report 2017
CtrlAQUA - Centre for Closed-Containment Aquaculture



Marine Harvest RAS facility, Steinsvik. Photo: Jelena Kolarevic © Nofima

sfi Centre for Research-based Innovation
The Research Council of Norway

AgriMarine semi-closed containment system at Gulklakken, Smøla.
Photo: Reidun Lilleholt Kraugerud © Nofima

CONTENT

Center Director Åsa Espmark, Nofima.

Photo: Terje Aamodt © Nofima

1 OVERALL PROGRESS AND SUMMARY FOR 2017

In the spring of 2015, CtrlAQUA started as a Center for Research-based Innovation. Our vision to make closed-containment aquaculture systems (CCS) a reliable and economically viable technology is as relevant as it was from the beginning, if not more so.

Results show that the controlled environment in CCS improve salmon welfare and overall condition. Additionally, infestations with sea lice and salmon escaping from net-pens are still challenges in Norwegian salmon industry. With this in mind, the further development and implementation of CCS is very relevant, and CtrlAQUA focusses on the remaining bottlenecks to optimize performance of these solutions.

In this annual report, you can read about how CtrlAQUA partners and students view the development and participation in CtrlAQUA. You will also be given information from the different research activities. However, as an introduction, I will give you an overall summary of CtrlAQUA in 2017.

In 2017, CtrlAQUA worked with 14 projects. This is less than previous years and is a result of combining more activities into fewer projects. In addition, we plan to keep most of the project names while updating the content from year to year. We believe this will make it easier for all partners to follow the projects and to be familiar with the annual plans and the work we do.

In 2017, we have worked towards five innovations as defined in the overall plan and also repeated in the annual plan. In Department for Technology and Environment, one innovation has been to work towards development and testing of semi closed-containment aquaculture systems (S-CCS). We are continuously monitoring water quality and fish health and welfare in several systems run by user partners. However, it is important to clarify that CtrlAQUA intends to work with other emerging systems as they develop. The ability to objectively compare different S-CCS systems with a control open cage system at Smøla klekkeri og settefisk has been of big scientific value. Until now, many of the S-CCS systems have not treated intake water, even though there are risks for infections of other pathogens than sea lice. In 2017, CtrlAQUA continued investigating different promising methods for cleaning intake water in land-based systems. It is important to be able to predict and fully understand the water distribution in tanks with different designs and volume, as this may affect fish performance and operations of the systems. As part of CtrlAQUA international collaboration, modelling of water distribution has given us big insights in the effects of heterogeneous water distribution and its influence of biomass. Another innovation for 2017 was to develop sensors and sensor treatment for reliable and stable measuring of water quality. One of the PhD students at the center has shown promising results with coating sensors in order to avoid fouling, and hence achieve stable measurements.

In Department of Fish Production and Welfare, one major innovation has been to define environmental requirements for Atlantic salmon in CCS, as these may differ from what we know from flow through (FT) systems. Carbon dioxide is one example of water quality parameter where threshold limits may differ between recirculating aquaculture systems (RAS) and FT. Suggested recommendations for RAS originates from a CtrlAQUA experiment showing growth penalty at lower CO_2 concentrations than the recommended 15 mg/l for FT. However, we carefully suggest that salmon are quite resilient towards CO_2 based on quite good welfare despite exposure to high levels of CO_2. The user partners of CtrlAQUA are very interested in robust protocols for how to farm salmon in CCS and best practice for transfer of fish to open sea cages. CtrlAQUA has followed a whole life cycle until slaughter where salmon were given different rearing protocols in RAS before sea transfer. This experiment ended late 2017 and concluded that there are few obvious answers to what is the best protocol regarding what fish size is the best for sea transfer, what light regime fish should be exposed to, or what salinity before sea transfer is best. However, there is little doubt that less time in open cages reduce the salmon lice pressure and escape rate. Further examples of the importance of the environment on health and welfare is elaborated from the knowledge that trained fish perform well, and we aim to establish threshold limits for optimal swimming speed. In addition, characterisation of pathogens and diseases from different CCS systems has been performed, and CtrlAQUA is very interested and dependent on that partners inform about possible outbreaks from where the project may sample valuable data to expand knowledge about infections and treatments.

In Department Preventive Fish Health the only, but highly important, innovation for 2017 has been to develop diagnostic pathogen sensors for detecting pathogens in CCS. The user partner ORP has been in charge for developing a sensor system that aims to sample and analyse pathogens in water and tissues. By the end of 2017, the system is ready for testing in commercial scale, and the ultimate goal is automatic sampling and analysing and thus serve as an early warning system.
In 2017, there have also been extensive activities in the thematic area robust fish. In June, the first PhD student graduated from the center, and amongst others she worked with gene markers for mental robustness, which have now been developed into gill reporters to facilitate analysis for the industry. Robust fish is also the key word in research on skin as barrier function. Studies performed in CtrlAQUA indicates that skin as barrier to the environment develop with age, and that there are fewer differences between production systems. The AkvaVision system of Vard is part of CtrlAQUA and aims at real time monitoring of biomass and measurement of feed intake in CCS. In 2017, the system was further developed and tested in commercial scale. Turbidity has been a challenge when using imaging systems in RAS. However, the use of yellow and/or red light source together with AkvaVision system allows measurement at higher turbidities and larger distances from the system. Interviews with Lene Sveen and Christoffer Eriksson later in this annual report will give you more insight in fish skin and AkvaVision, respectively. The biofilters in the RAS systems are sensitive towards salinity and the effects of different salinities on biofilters has been in focus in 2017 since it is important to understand how biofilter may work in RAS with salt water.

CtrlAQUA produces many results that are of interest and value for our user partners. However, the rest of the community are welcome to use our results once they are approved for vide dissemination. For internal dissemination, we arranged the Annual meeting in Bergen 9-10th May, where approximately 100 participants exchanged knowledge and experiences, and also had the opportunity to visit Sævareid Fiskeanlegg. The widest physical external dissemination happened during Aqua Nor, when more than 300 persons wanted to be audience when Nofima and CtrlAQUA invited to this seminar about closed-containment aquaculture, and six scientists presented their results in short Pecha kucha presentations. We are also proud of the interest for CtrlAQUA in the media, as there in 2017 were 77 media cases about CtrlAQUA. The dissemination of CtrlAQUA is very much thanks to all partners, researchers and students who talk about CtrlAQUA in media and at meetings and conferences. When progress-reporting CtrlAQUA in December 2017, the center reported about three Master students, eight PhD students and two Post. docs; this did not include the previous graduated students. Also, as can be seen later in this annual report, CtrlAQUA has produced an impressive amount of publications. All these actions contribute to wide dissemination of new knowledge about CCS and its importance in future farming.

February 2018
Åsa Maria Espmark
Center Director CtrlAQUA SFI

From the CtrlAQUA Annual Meeting in Bergen, May 2017. Photo: Ingvild Festervoll Melien © Nofima

Vision and objectives of CtrlAQUA – Centre for Closed-Containment Aquaculture

Norwegian salmon industry and government has a goal to increase the production in the years to come. The previous ambitions that were put forward in the report "Value created from productive oceans in 2050", have later been moderated and described in the report "Seamap towards 2050", because the degree of growth will depend on many factors, including how we manage sea lice and escapes amongst other challenges. Innovations in closed-containment aquaculture systems, where the salmon is separated from the outside environment by a closed barrier, can be important for further development of aquaculture. CtrlAQUA is a center for research-based innovation (SFI) that will work on such closed-containment systems. The main goal of CtrlAQAUA SFI is to:

"Develop technological and biological innovations to make closed-containment aquaculture systems (CCS) a reliable and economically viable technology, for use in strategic parts of the Atlantic salmon production cycle, thus contributing significantly to solving the challenges limiting the envisioned growth in aquaculture"

Post-smolts. Photo: Terje Aamodt © Nofima

Closed systems can be land-based where water is recycled (RAS), or sea-based, in which large floating tanks receive clean water from depth (S-CCS). In CtrlAQUA the research deals with both approaches.

In the center, we focus primarily on the most sensitive phases for the salmon in the production cycle, such as the first seawater phase, the so-called post-smolt stage (Figure 1.3). However, the research is also highly relevant for other strategies shown in the figure. The main innovation will be reliable and efficient production of post-smolts in closed systems on land or at sea. Thus, the industry can get a good realistic alternative or supplement to the current production technology with open cages. The center will also contribute to better production control, fish welfare and sustainability in closed-containment farms. We do this through development of new and reliable sensors, minimizing environmental impact through recycling of nutrients and reduce the risk of escape, and diseases transmission to wild stocks. These innovations will be of value to the Norwegian society, since closed systems for strategic phases in salmon farming can contribute to the foreseen growth.

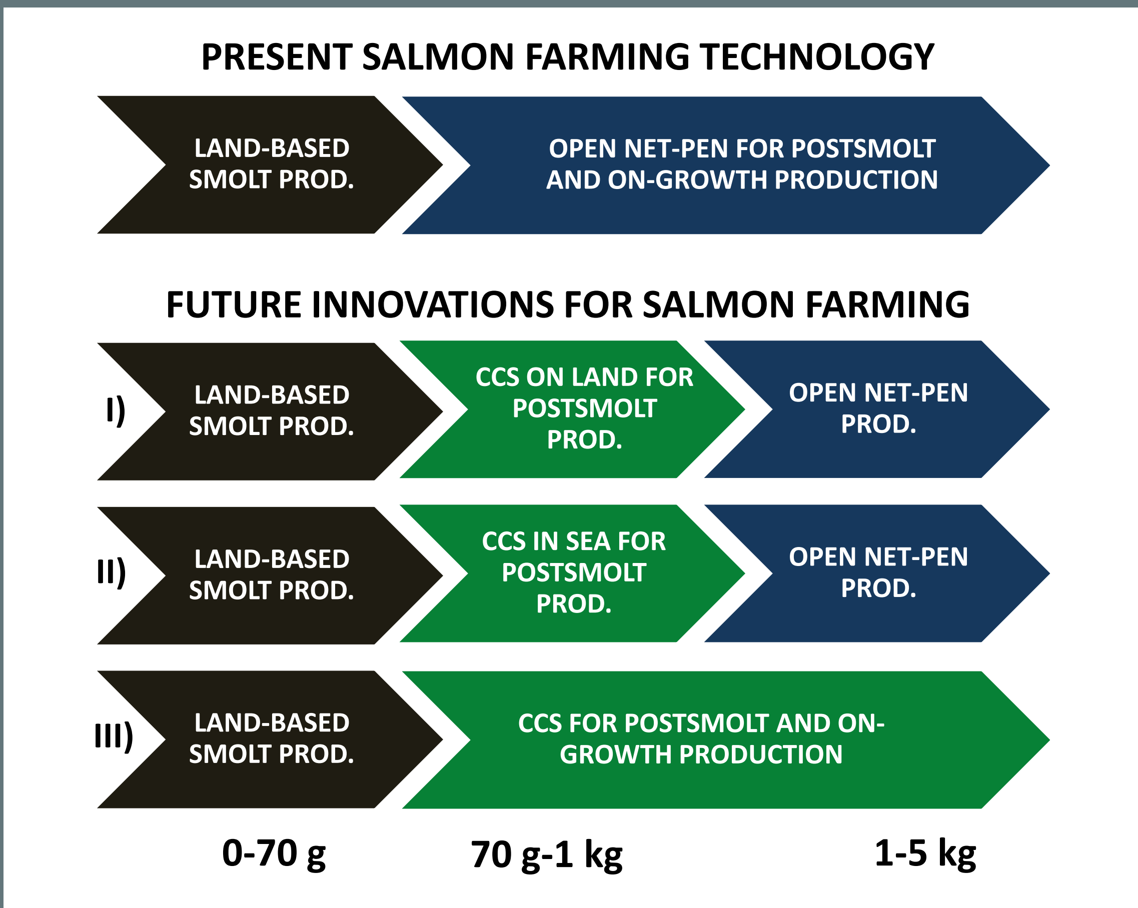


Figure 1.1. Present salmon farming technology, and future innovative strategies (I-III). CCS: Closed-containment aquaculture systems.

These two partners represent suppliers within technology and fish health. They are both of the opinion that if aquaculture production is to be increased, we need to know more about how the fish in the tanks are actually doing.

Better innovation in a Center partnership

Christoffer Eriksson,
Vard Aqua Sunndal

Photo: Terje Aamodt © Nofima

"We all know that research yields both positive and negative results. But it is the challenging measurement conditions and poor visibility in recirculation aquaculture systems that have really driven our product forward. We have updated several components on the basis of tests we have performed at CtrlAQUA, which revealed issues we might not have detected otherwise," says Christoffer Eriksen, head of technical developments at the technology supplier Vard Aqua Sunndal (formerly Storvik Aqua).

The product he is talking about is AkvaVision, which is central to CtrlAQUA's BIOMASS project. AkvaVision is a biomass measurement camera that the company first developed for use in open pens, and that has since been refined for use in closed containment systems. AkvaVision is a priority product for the company. The AkvaVision biomass estimator monitors the growth and average weight of fish, and fish farmers need accurate estimates to be able to operate efficiently.

It is easier to develop biomass estimators for open pens than for closed containment systems. This is linked to water quality, the size of the object to be measured, and the interaction between biology and technology. A huge amount of research and development work has gone into this product, including comprehensive trials with light intensity and wavelengths in Nofima's recirculation facility. Now tests are about to start to document turbidity. Eriksson explains how it works:

"A camera with a sensor takes a picture of the fish as it swims by. The size of the fish is calculated using algorithms. This happens continuously, and the device is wirelessly connected to a cloud solution where results are displayed in real time, enabling the operator to monitor the fish from the office.

The biomass estimator is soon ready for commercial launch.

Before Christmas, Vard Aqua validated the biomass estimator for fish up to 250 grams in closed containment facilities. They measured 3,500 fish in Nekton Havbruk's semi-closed concrete pen, with estimated daily growth of roughly 2 grams. The growth estimates matched actual growth with a very high degree of accuracy. Vard Aqua launched this biomass estimator on the market in 2017. Now they are in the process of validating the biomass estimator for fish ranging from a few grams up to one kilo in closed containment systems, and the plan is to get this version out on to the market in 2018.

Vard Aqua has a long history of innovation within aquaculture technology and has always collaborated with its customers on research. Through the partnership with CtrlAQUA, however, they have access to experts in a range of relevant disciplines and get to test the product they are developing for the industry in a variety of demanding conditions.

"Without a research partnership like CtrlAQUA, we would not have managed to develop this innovative device and test it. This partnership provides us with unparalleled opportunities to perform tests. We do not have access to commercial-size closed containment aquaculture facilities ourselves, and with CtrlAQUA we can conduct and document tests in a more controlled fashion than if we run trials in a commercial player's facilities.

Why is the biomass estimator so important in closed containment aquaculture?

"Having full overview of the biomass is essential to be able to make informed decisions and together with other sensors can provide better control of fish welfare and health, which will in turn result in increased profitability for the fish farmer. I believe that in order to achieve increased production, we need better control and overview in the facilities than we have today, and here new technology will play a key role," says Eriksson.

The fish comes first

Siri Vike,
Pharmaq Analytiq

Photo: Thor Brødreskift

“Once we have control over the biology, efficiency and costs will fall into place,” says Siri Vike, head of PHARMAQ Analytiq.
PHARMAQ Analytiq is a supplier of analytical services to prevent health problems in fish and is partnering with CtrlAQUA to develop fish health and welfare indicators for use in closed-containment aquaculture systems.

PHARMAQ Analytiq had several reasons wanting to join CtrlAQUA:

“We wanted to be involved in a team with a wide range of experts. We believe it's key to combine our biological knowledge with an in-depth understanding of the technology which our products are going to be used in. It's also challenging for us to have all this knowledge alone. It’s important to see the bigger picture in order to develop successful products,” Vike explains.

“Another area of interest for us is to be a part of developing closed and semi-closed aquaculture systems so they can become more competitive. If we succeed the industry can continue to grow with tighter control of fish health, fish welfare, production efficiency and costs.”

How can the industry come up with new solutions which allow control of all these factors? Vike explains that the key is through measurement:

“If we can measure it, we are most likely able to do something about it. The fish is the boss, but it cannot speak out loud, which is why we have to find other ways to communicate with it.

Vike and her colleagues in CtrlAQUA are therefore developing marker tests that enable the fish to communicate their health status before disease or adverse environmental conditions build up.

“This can be achieved by closer monitoring and performing other operational assessments based on pathogen status. The main focus is preventing outbreaks so we don't have to treat sick fish,” says Vike.

If the aquaculture industry manages this, Vike believes that fish can develop healthily in closed containment systems. Good health is also a prerequisite for the fish to grow well in closed facilities.

Communicating with the fish through marker tests

In order to communicate with the fish, PHARMAQ Analytiq and CtrlAQUA are developing marker tests where the fish’s genes indicate at an early stage how well it is doing in its current living environment, before any visible symptoms develop.

CtrlAQUA has developed the first commercial marker tests for use in closed containment aquaculture systems. Through the BENCHMARK project, they have developed “SmoltVision”, which is a gene marker test for smoltification. SmoltVision indicates the fish’s ability to regulate its internal salt–water balance, which is valuable information in closed-containment aquaculture and allows identification of the fish’s smolt status.

“If we are able to identify the relevant markers for stress and immune response, for example, and employ them actively as a decision- making tool, we can be confident that the fish are thriving.

Want an industry standard

Vike believes that the Center’s advantage is that the expertise and knowledge are brought together and focused on a common goal.

“I hope we will eventually end up with an industry standard for closed-containment systems. If we agree on which aspects to measure, we can improve the entire industry. However, when we come up with a technological solution to one problem, it can at times create new problems. This is the reason why we need to set industry standards,” concludes Vike.

Photo: Per Henning © NTNU

2 RESEARCH PLAN/STRATEGY

The Centre for Research-Based Innovation in Closed-containment Aquaculture, CtrlAQUA, commenced operations in April 2015. The Research Council of Norway's objectives in running the SFI-program are four-fold: 1) to stimulate innovation activities in strong industries in Norway, 2) to promote collaboration between innovative industries and excellent research institutions, 3) to develop industry-relevant research institutions that are leading in their field, and 4) to educate new scientists and foster knowledge- and technology transfer. These goals, in addition to the specific goals of the center, forms the basis for the work in CtrlAQUA. Through close collaboration between user partners and the R&D institutions, the center focus on closed-containment system innovations, such as new RAS process units, development and implementation of prototypes and methods for improved fish welfare and health, shown in Figure 2.1.

The work on the research plan is led by the leader group of CtrlAQUA, who uses several sources of information to develop the plan, including: the SFI Centre Description which was part of the proposal in 2014, the Letters of Intent by the user partners, meetings with the user partners, and inputs received from the partners during project and annual meetings. A Scientific Advisory Board (SAB) is appointed for CtrlAQUA, consisting of researchers and stakeholders with competencies in the fields of research in the center. An important task of the SAB is to give advice during development of the annual plans.

The annual plan consists of common projects and user-specific projects. Both types of projects contribute towards the main goal of the center. Common projects are activities that benefit all partners in the center, such as environmental requirements of salmonids in closed-systems and optimal use of sensors, securing health and welfare, and hydrodynamic modelling. User-specific projects are defined as activities that also benefit the entire center, but are particularly important for one user partner, or a group of user partners.

During preparation of the SFI Centre Description, several innovations were described and defined as innovation deliverables. These innovation deliverables are further linked to the Departments and their specific research tasks. In the annual plan, each project is linked to one or more Innovation deliverables, and this is an important tool during discussions of the research plans.

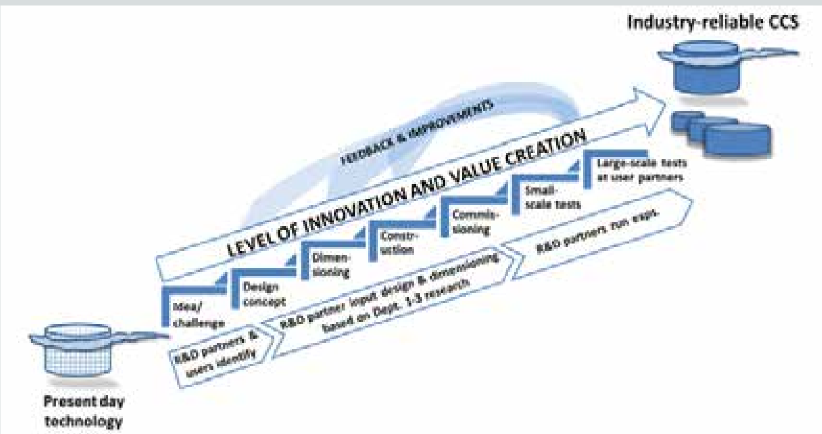


Figure 2.1. Innovation process in CtrlAQUA, from present day cage technology, to establishment of industry-reliable closed containment systems, either in-sea closed tanks or land-based RAS. Exps': experiments.

3 ORGANIZATION

Organizational structure, and cooperation between the center's partners

CtrlAQUA is organized with a Board that oversees that obligations are fulfilled, and decides on financial, partnership, and IPR issues, as well as ratifying annual research plans made by the leader group. In 2017, the Board met for two physical meetings. In addition, Kjersti Turid Fjalestad, the contact person for CtrlAQUA at the Research Council of Norway, has been observer at the Board meetings.

The leader group manages and leads CtrlAQUA, such as ensuring strategic planning and running of projects, recruitment of qualified personnel, and providing a good working environment:

- Dr. Åsa Maria Espmark (Nofima) - Center director
- PhD. Jelena Kolarevic (Nofima) - Scientific manager of Department Technology and Environment
- Prof. Lars Ebbesson (Uni Research) - Scientific manager of Department Fish Production and Welfare
- Lill-Heidi Johansen (Nofima) - Scientific manager of Department Preventive Fish Health
- Prof. Sigurd Stefansson (UiB) - Scientific manager of Department Training and Recruitment
- Prof. Sigurd Handeland (Uni Research)

The CtrlAQUA leader group. From the left: Lill-Heidi Johansen, Lars Ebbesson, Åsa Espmark, Stine Thøring, Jelena Kolarevic, Sigurd Handeland, Sigurd Stefansson. Photo: Thor Brødreskift.

Dept. Liaison, ensuring collaboration between departments. Identify sub-projects and user partners for projects
- Stine Thøring (Nofima) - Center Coordinator, technical reporting and meeting organization

The center scientific work is organised through close collaboration between three departments: Dept. Technology and Environment, Dept. Fish Production and Welfare, and Dept. Preventive Fish Health, whereas student recruitment and management are managed in Dept. Training and Recruitment. The Dept. of Liaison ensures smooth collaboration between departments and identify sub-projects and user partners for projects.

In CtrlAQUA there has been a strong focus on collaboration and knowledge transfer between the partners from the start. This collaboration has been done within the projects, and occurred between R&D partner scientists, scientists and user partners, and between user partners. The extensive collaborations are facilitated by participation from all institutions in project workshops, as well as joint experiments, sampling and analytical work. Frequent meetings are organized at Board level (each six months), Center level (annual meetings), leader group (every third week), and thematic or project level (as required). The CtrlAQUA intranet has a news feed where center-participants have posted e.g. news, links to documents, research plans, results, pictures and videos. In addition to a formal news channel, the center intranet has also been used as a social media, thus contributing to build the CtrlAQUA team spirit.

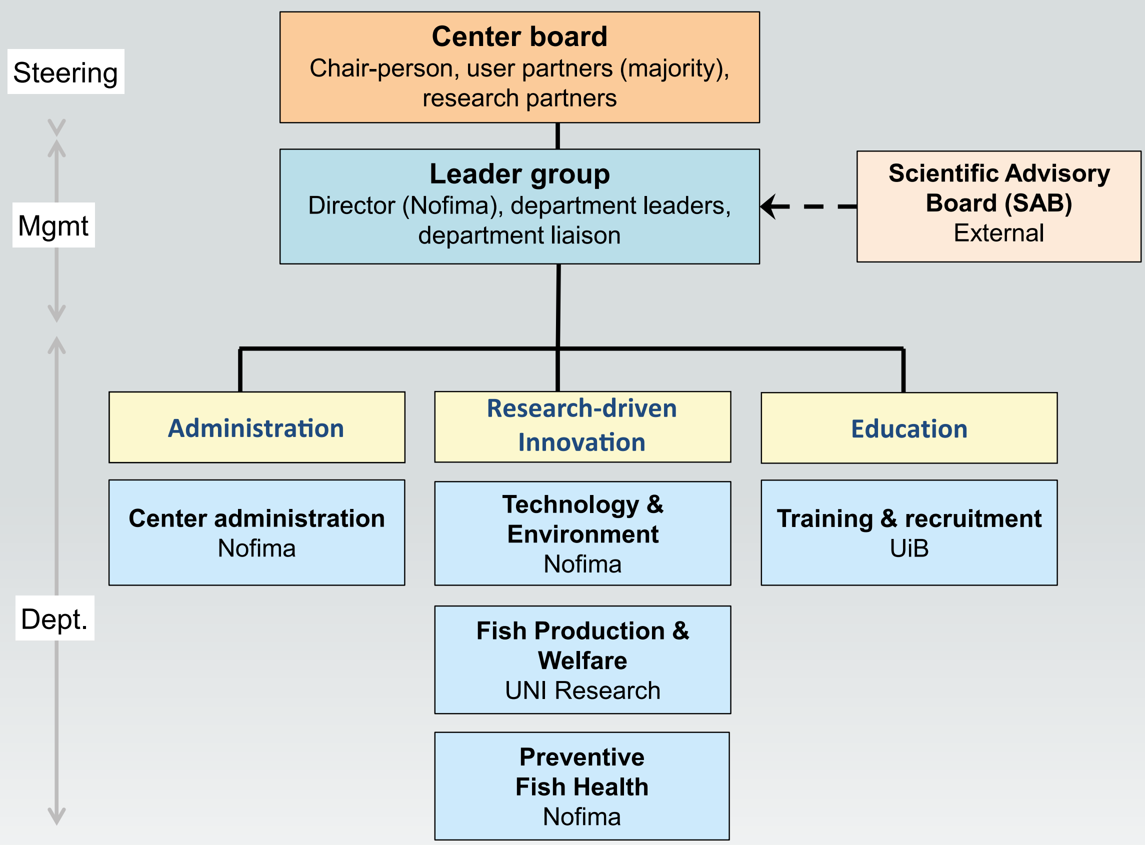
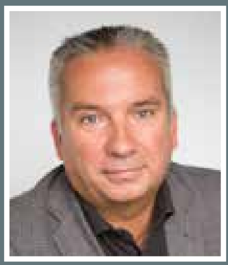
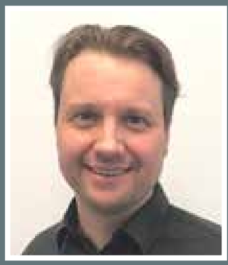


Figure 3.1. Organizational structure of CtrlAQUA.

The CtrlAQUA Board



Frode Mathisen
Grieg SeaFood
Chairperson of the CtrlAQUA Board



Harald Takle
Cermaq Group
Board Member

Knut Måløy
Vard Aqua
Board Member

Siri Vike
Pharmaq Analytiq
Board Member

Tor Solberg
UNI Research
Board Member

Mari Moren
Nofima
Board Member and representing the host institution

CtrlAQUA

PARTNERS

Per April 1st 2018, CtrlAQUA has 21 partners, including two international, where seven are R&D partners and 14 are user partners.

R&D PARTNERS

Nofima

uni Research

UNIVERSITY OF BERGEN

NTNU
Norwegian University of Science and Technology

HSN Høgskolen i Sørøst-Norge

UNIVERSITY OF GOTHENBURG

THE CONSERVATION FUND

PHARMAQ Analytiq is a Norwegian biotechnology company working with preventive fish health and welfare. Since 2015 PHARMAQ Analyitq has been a part of Zoetis – the largest global animal health company. The company offers analytical services and consultation to solve challenges faced by intensive fish production – in a preventive way by monitoring, diagnosis and interpretation of biological data. In 2008 PHARMAQ Analytiq opened a state-of-the-art real time RT-PCR laboratory for the detection of pathogens and in 2011 the laboratory was accredited by Norwegian Accreditation. Furthermore, histology extends the advisory and problem-solving capability which PHARMAQ Analytiq offers to the aquaculture industry.

In CtrlAQUA, PHARMAQ Analytiq is represented by General Manager Dr. Siri Vike, who is also a member of the CtrlAQUA Board and R&D Manager Dr. Stian Nylund. Both have an extensive research background in fish health. PHARMAQ Analytiq will contribute in development of tools for assessment of salmon post-smolt robustness, improved fish health, reduced stress and ensure functional immune system.

Since the precursors of Marine Harvest started up in 1965, they have gone from a small entrepreneurial company to the world's largest aquaculture company. With 3.8 million daily meals, Marine Harvest in Norway is the largest food producer (in proteins) through the entire value chain from feed production to brood, eggs, fish, processing and distribution to sales. Most of the salmon from operations in Norway is exported to Europe, USA and Asia. Marine Harvest develops future solutions for farming and is a key driver for innovation, both in Norway and internationally. Business in Norway include being the largest aquaculture company in Norway with over 1600 employees and with operations along the Norwegian coast from Flekkefjord in Agder to Kvænangen in Troms. The company is part of the group Marine Harvest ASA, which operates in 24 countries and is listed on the Oslo Stock Exchange (OSE). The global headquarters are located in Bergen. In CtrlAQUA Marine Harvest is represented by Global Director R&D and Technical, Øyvind Oaland and Group Manager Freshwater & Closed Production Technology, Trond Rosten. Sara Calabrese was employed in Marine Harvest as an industry-PhD student linked to CtrAQUA and defended her thesis in June 2017. In addition to the closed-containment system site at Molnes, Marine Harvest RAS sites, such as Steinsvik, also provide input and are involved in projects in CtrlAQUA.

Lerøy Seafood Group is a leading exporter of seafood from Norway and is in business of meeting the demand for food and culinary experiences in Norway and internationally by supplying seafood products through selected distributors to producers, institutional households and consumers. The Group's core activities are distribution, sale and marketing of seafood, processing of seafood, production of salmon, trout and other species, as well as product development. The Group operates through subsidiaries in Norway, Sweden, France and Portugal and through a network of sales offices that ensure its presence in the most important markets. Lerøy Seafood Group's vision is to be the leading and most profitable global supplier of quality seafood. In CtrlAQUA, Lerøy is represented by Technical Manager Harald Sveier, who has a long research background in fish physiology and nutrition. Sveier will head Lerøy's work in developing closed-containment systems, and the testing-site Samnanger.

Cermaq is one of the world's leading fish farming companies, with operations in Norway, Chile and Canada, supplying Atlantic salmon, Coho and trout to the global market. Cermaq's vision is to be the preferred global supplier of sustainable salmon. Cermaq Norway produces Atlantic salmon with operations in Nordland (22 licenses) and in Finnmark (27 licenses) with processing plants in both regions. The four freshwater sites are all located in Nordland. Cermaq sets its operations in the context of the UN Sustainable Development goals, and Cermaq is a key driver for research and innovation as well as transparency and partnerships. Fundamental to this work is Cermaq Norway's preventative health strategy for fish. This means using the knowledge of the salmon's biology, physiology and environment, to achieve the best fit between production, fish welfare and growth. In CtrlAQUA, Cermaq Norway is represented by Global R&D Manager Farming Technology Dr. Harald Takle. He has extensive background in research, R&D management, fish health and production optimization. Cermaq will also contribute with their fish health group, and closed system testing facilities.

Bremnes Seashore AS is one of Norway's leading suppliers of farmed salmon. Research and development have given them their own, patented production processes, and they established SALMA as Norway's first brand for fresh fish. Bremnes Seashore currently handles the full production chain for salmon and is one of the largest privately owned salmon farming companies in Norway. The company has farming facilities in Hardanger, Sunnhordland and Rogaland, which are spread across 23 locations in 9 different municipalities. In CtrlAQUA, Bremnes Seashore is represented by Farming Manager Geir Magne Knutsen, and the company contributes financially and with farming expertise and large-scale facilities.

Grieg Seafood ASA is one of the world's leading fish farming companies, specializing in Atlantic salmon. They have an annual production capacity of more than 90.000 tons gutted weight. The Group is today present in Norway, British Columbia (Canada) and in Shetland (UK), employing approximately 700 people. Grieg Seafood ASA was listed at the Oslo Stock Exchange (OSEBX) in June 2007. The headquarters are located in Bergen, Norway. The business development of Grieg Seafood ASA focuses on profitable growth, sustainable use of resources and being the preferred supplier to selected customers. Grieg Seafood is represented in CtrlAQUA by Director Biological Performance and Planning Frode Mathisen, who is also the chairperson of the Board of CtrlAQUA. Grieg Seafood will contribute with their long experience in salmon aquaculture and RAS, as well as running large-scale trials.

Krüger Kaldnes AS offers world-class know how and technologies for water purification in the aquaculture industry and designs tailored solutions to meet the highest standards. Krüger Kaldnes is a fully owned subsidiary of Veolia Water Technologies-Nordic Region, and provides total solutions for wastewater treatment, water treatment, sludge treatment, rehabilitation and services to Municipalities and Industries in Norway. The Kaldnes®RAS system, developed in 2008, is an example of this innovation leadership. Krüger Kaldnes develops solutions for complete deliveries of land-based fish farms, as turn-key approach, in collaboration with selected building contractors. The main focus is on high quality, biosecure fish production, and optimal logistic to create well-designed facilities, and provide complete range of support and services to customers. In CtrlAQUA, Krüger Kaldnes is represented by Business Development Manager Aquaculture Frédéric Gaumet and R&D Manager Aquaculture Andreas L. Brunstad. Krüger Kaldnes will contribute with own expertise, and prototype hardware.

Oslofjord Ressurspark (ORP) is a Norwegian commercial company delivering a point-of-care instrument and a disposable chip for automatic sample processing, sample refining and analysis of gene activity. ORP was established in 2013, and based its business on unique technology that is covered by own patents invented by the team of professor Frank Karlsen and licensed patented technology from PreTect AS. The strategy for ORP is to successfully sell and deliver products to customers in the international fish farming arena which will pave the way for other major markets in the oil, health, environment and agriculture fields. ORP is initially focusing on the supply of products on site for automatic and accurate detection of active fish genes and pathogenic micro-organisms in closed or open aquaculture facilities. In CtrlAQUA, ORP is represented by Business and Coordinator Manager Steve Hughes, and they will contribute with developing the pathogen sensor, together with CtrlAQUA partners (R&D, and user partners) for in-depth knowledge of relevant pathogens.

Smølen Handelskompani AS is a holding company placed in Smøla County, Norway. The company owns Smøla Klekkeri og Settefiskanlegg AS and Sagafisk AS that together have a production capacity of 5.5 million salmon smolt per year. Initially the company started up in 1984, and in 1999 it invested in eel farming. The farm also had a cod license, but today's activities are production of salmon smolt. Smøla Klekkeri og Settefiskanlegg is represented in CtrlAQUA by Managing Director Per Gunnar Kvenseth, and contributes with expertise on RAS and floating closed-containment systems in sea, and facilities and personnel for testing new closed-containment system concepts.

Aquafarm Equipment's ambition has been to develop a cost-effective, semi-closed fish cage that prevents the escape of fish, drastically reduces the risk of salmon lice, and reduces the release of organic nutrients and waste into the surrounding environment. For the past two years, we have worked closely with Marine Harvest to carry out a full-scale test of our semi-closed fish cage for post-smolt fish – and the results are very promising. Our fish-cage concept virtually eliminates the need for mechanical handling of the fish, as well as the need for chemicals. As a result of these factors, mortality is extremely low – less than 0.5 %. In CtrlAQUA, Aquafarm Equipment AS is represented by engineers CEO Atle Presthaug, and Business Developer Roger Thorsen, and contribute with their expertise in engineering of floating closed-containment systems in sea.

FishGLOBE AS is a company that is selling closed floating fish cages. Prototypes have been tested and now the building of a full-scale globe for post-smolt is starting. The globe is built in polyethylene which is the preferred material to use at sea. The polyethylene is a thermoplastic which work well with waves and is well-suited for fish-farming. The clue to hold the structure/form and make it strong and stiff, is to use the inlet and outlet pipes. To be able to use this material it holds to patents. The company was established in 2013, but the development of closed aquaculture technology has roots back to the late 80's. The company is located in Forsand, Norway. The vision of FishGLOBE is to develop new cost-effective solutions that makes it possible for the aquaculture industry to expand. The business concept is to offer a solution to the salmon farmers that make farming more profitable, more sustainable and with higher fish welfare. FishGLOBE entered CtrlAQUA in November 2015 and is represented by manager Arne Berge.

PHARMAQ is the global leader in vaccines and innovation for aquaculture and part of Zoetis, the world leader in animal health. The company provides environmentally sound, safe and efficacious health products to the global aquaculture industry through targeted research and the commitment of dedicated people. The vaccines are manufactured in a state-of-the-art production facility in Overhalla and Oslo, Norway. Administration and research and development activities are based in Oslo with subsidiaries in Norway, Chile, United Kingdom, Vietnam, Turkey, Spain, Panama and Hong Kong. PHARMAQ has approximately 200 employees. The company's products are marketed in Europe, North and South America, and Asia. In CtrlAQUA, PHARMAQ is represented by Technical Manager Nils Steine and Senior Scientist Are Klevan, and will contribute with expertise and vaccine development in Dept. Preventive Fish Health.

Vard Aqua Sunndal is a Norwegian equipment supplier that has worked to help customer profitability to increase in correlation with fish welfare for over 30 years. The company is, from November 2016, part of Vard Group. Through the integration with other entities in Vard Group, we have strengthened our offering and stepped up the commitment within aquaculture. Working closely with our customers, we develop vessels, fish farming technology and solutions to help build sustainable and efficient operations – inshore, offshore, at sea and on land. The products of Vard Aqua Sunndal focus on oxygen (adding, logging and adjusting), logging of environmental data, biomass measuring, tools for closed cage treatment, and feeding equipment for land and sea. In CtrlAQUA, Vard Aqua Sunndal is represented by board member Knut Måløy (also member of the CtrlAQUA Board), and Christoffer Eriksson, and will contribute to Dept. Technology and Environment. with equipment prototypes, and expertise.

Botngaard's primary focus is the supply of tarpaulins for Aquaculture. The use of tarps has increased due to a dramatic increase in salmon lice infestations in fish farming facilities. Botngaard's products are individually tailor-made. Factors that our customer's needs, cage size, durability and design are important. In this way we can deliver a product that makes the job for the fish farmers as easy as possible. In CtrlAQUA Botngaard is represented by CEO Magnus Stendal, and the daughter company Botngaard System AS, that will contribute with knowledge and experience with closed containments.

Lars Ebbesson looks into how the brain responds to the environments in CCS to better improve functional outputs in these systems.

4 SCIENTIFIC ACTIVITIES AND RESULTS

DEPARTMENT FISH PRODUCTION AND WELFARE

The main objective of Department of Fish Production and Welfare is to provide knowledge and innovations to determine environmental and biological requirements of Atlantic salmon in CCS. To this end, we have projects that 1) optimize environmental rearing conditions by identifying biological limits and optimums in small to medium scale flow-through and RAS systems (CO2RAS, BENCHMARK, OPTIMIZE (which includes PHOTO-FW, LIGHTQUAL, TRANSFER); 2) innovate new biological markers that will improve physiological and robustness assessment to reduce losses through improved adaptation to new or changing environments (ROBUST); and 3) characterize the fish performance and welfare of salmon post-smolts in large-scale in S-CCS and CCS (RIGID-SCCS) (see Figure 4.1.).

In summary for 2017, we investigated and identified new gill markers of robustness for post-smolts that will facilitate the optimisation of environments in CCS by demonstrating positive responses to environmental challenges (ROBUST). As we continue to look at biological limits of post-smolts, we studied the limits of CO_2 in RAS and physiological recovery time (CO2RAS). In RIGID-SCCS, we continue to characterise the semi-closed containment systems (S-CCS), presently in the 6th generation of Preline with Lerøy, which continues to produce robust and healthy post-smolts that also do well when transferred to sea cages. A new study was started to characterise the new Neptune system with Marine Harvest and water quality was assessed in the concrete S-CCS at Smøla. The OPTIMIZE and BENCHMARK projects demonstrated important new information about production of larger post-smolts in FW and brackish water, and their subsequent maturation, growth, and survival success. The continuation of TRANSFER showed that although post-smolts can tolerate transfers from 13°C to 4°C with no mortality in these protected

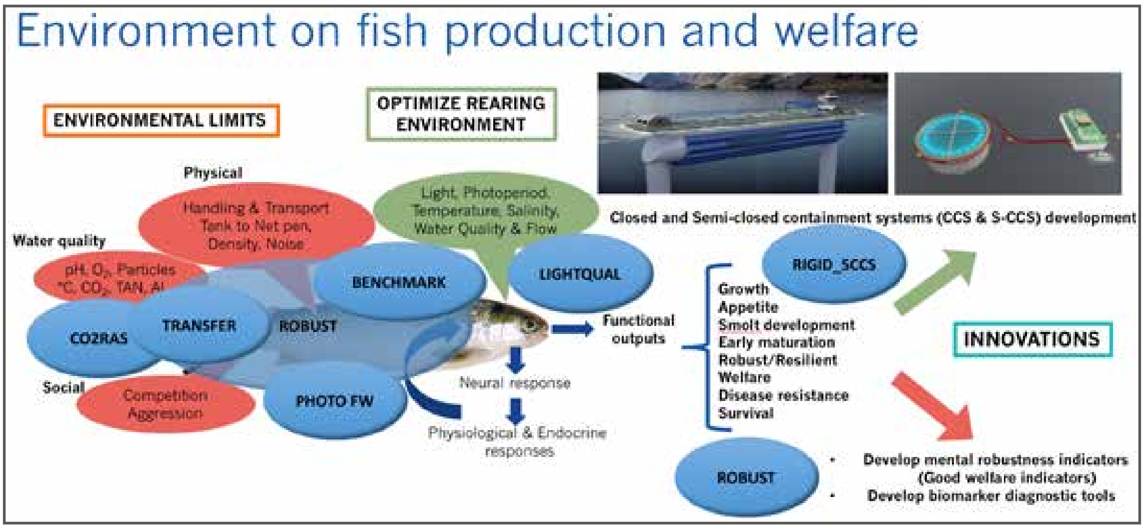


Figure 4.1. A schematic overview of the Department of Fish Production and Welfare and 2017 projects (blue ovals)

environments, impacts on growth and barrier function suggest that they would be at higher health risk if transferred to uncontrolled environments such as sea cages. Below we will present highlights of a few of these projects.

CO2RAS. The main experiment consisted of a twelve-week long CO_2 exposure of post-smolts with six CO_2 treatments (5, 12, 26, 33 and 40 mg/L) in 12 ppt salinity RAS, followed by transfer to seawater. We found a linear negative relationship between fish growth and CO_2 concentration, with a 12 % growth penalty occurring around 19 mg/L CO_2. Salmonids don't have the ability to regulate the intracellular pH (done thought the gut, kidneys and gills) and have to rely on the pH regulation mainly in their blood, which make them very sensitive to high dissolved CO_2 concentrations. Post-smolts displayed a rapid physiological compensatory response by increase exchange in plasma Cl^-/HCO_3^- within 24 hours when going from low (5 mg/L) to high (40 mg/L) CO_2 exposures, while going from 40 to 5 mg/L CO_2 exposures delayed compensatory responses, some of which took up to 6 days before reaching an acclimated state. See section under *Department Technology and Environment* for more information regarding the project CO2RAS.

LIGHTQUAL investigates the light quality requirements for post-smolts, which is an emerging theme due to environmental control possibilities in CCS, however characterisation of light on biological process in post-smolts is limited. The lighting conditions during Atlantic salmon production are important to sustain normal physiological processes and secure optimal feeding. As LED lighting is becoming more common, the biological effects of narrow wavelength lighting showed clearly that separate light wavelengths can differentially modify endocrine and neural processes associated with stress, feeding, growth and maturation. These data will be used to further identify possibilities to modulate biological function at specific times during the post-smolt production cycle with lighting.

Preline. Photo: Sigurd Handeland, UNI Research

We further surveyed light intensity conditions

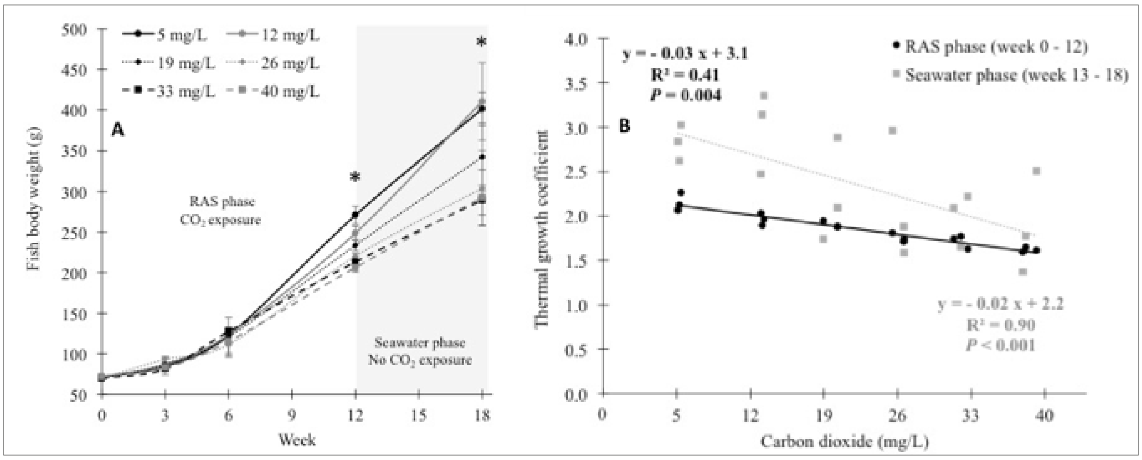


*Figure 4.2. A) growth curve for fish exposed to six CO_2 concentrations (5, 12, 19, 26, 33 and 40 mg/l) during an 18-week experimental period. Two periods shown: RAS phase (white area) with CO_2 exposure and seawater phase (grey area) without CO_2 exposure. *Indicates significant differences among CO_2 treatments. B) linear regression models between measured CO_2 in the water and thermal growth coefficient (TGC) during RAS phase (week 0-12) and Seawater phase (week 13–18). Note: Water CO_2 during seawater phase was < 5 mg/L for all fish; fish were individually pit-tag and are grouped based on the RAS phase tanks and CO_2 treatments. (Mota et al 2018, in press).*

in commercial RAS facilities. In all tanks, a variety of lighting was placed above water surface. The survey showed that lighting conditions during production of salmon are not standardized and that the knowledge on optimal lighting conditions is lacking. Increase in water turbidity causes decrease in light intensity, where already at 0,5 m depthe, light intensity is reduced by more than 80 %.

PHOTO_FW. Producing larger Atlantic salmon up to 1 kg in size in freshwater systems is a novel approach for land-based salmon production. There is a need to optimize environmental conditions to reduce early maturation and minimize losses upon transfer to sea cages. We investigated two photoperiod regimes: i) LD24:0 (i.e. 24 hours continuous light), and ii) LDN (simulated natural photoperiod, Bergen latitude) and simultaneously being

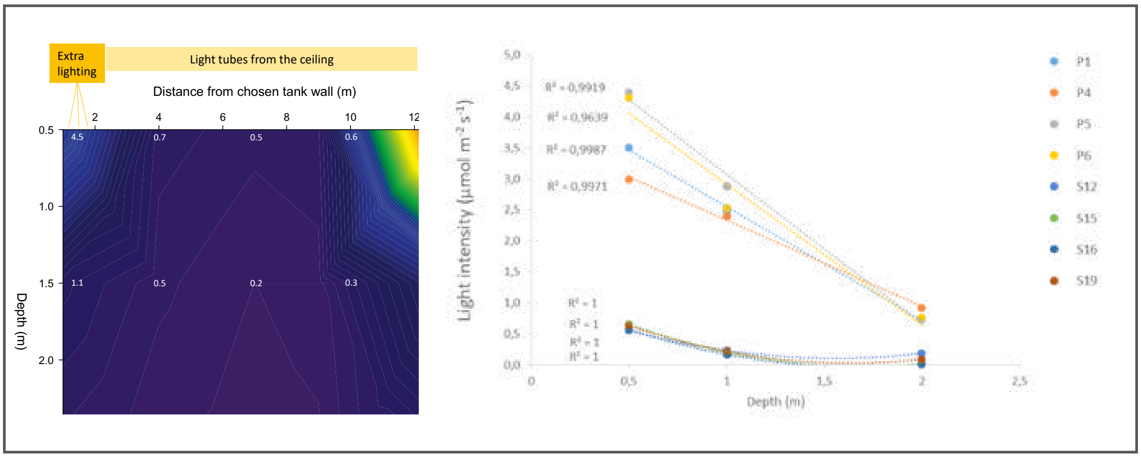


Figure 4.3. Light intensity measured at three depths (0,5 m, 1 m and 2 m) in 230 m³ circular tanks: four tanks with Atlantic salmon parr (P1-P6) and four tanks stocked with Atlantic salmon smolts (S12-S19). Turbidity in rearing tanks with parr was between 1,1 and 1,2 NTU, while in tank with smolts measured turbidity was between 2,6 and 3,2 NTU.

New trials by Nofima and CtrlAQUA show that large post-smolt don't always reach slaughter size before small smolt. Photo: Terje Aamodt © Nofima.

split into full ration (FR) and reduced (60 %) ration (RR) groups applied to Atlantic salmon post-smolts raised in freshwater systems at 13°C. At 500 g, the best growth performance was observed in the FR groups, with FR LD24:0 having the best growth overall. Statistically, both ration and photoperiod were positively associated with increased growth performance. Although no signs of maturation were observed at 500 g, by 1 kg, maturation was observed in all groups (as high as 70 % of males undergoing maturation, in the FR LDN group) except the RR LDN cohort showing no maturation.

A longer time in land facilities will result in a shorter production time in the sea and reducing the risk of sea lice and escapes. BENCHMARK characterized how fish performed if held to 200 g and 600 g in land-based systems with either freshwater or brackish water and with either continuous lighting for the entire time or a 6 week winter period.

The most efficient production regime in the recycling facility was brackish water combined with 24-hour lighting for the entire land phase. The fish with the best overall growth throughout production however, were the fish that were transferred to sea at 100 g after undergoing through traditional smoltification. The fish that were 600 g at the time of transfer had the poorest growth in sea and had higher incidence of male sexual maturation at time of transfer. These data show that today compromises exist for keeping fish longer in RAS, however data from PHOTO-FW and LIGHTQUAL indicate that environmental manipulation can reduce these compromises and improve longer production periods on land.

DEPARTMENT PREVENTIVE FISH HEALTH

The production of Atlantic salmon in Norway is influenced by a range of different micro- and macroparasites. Many of these may pose even larger problems if introduced into closed or semi closed containment (CCS/S-CCS) systems, with higher population densities and often slower exchange of water. In addition, there is a steady emergence of new pathogens and a transition from open net cages to CCS that require focus as well. The objective of this department is to contribute to inventions to prevent, detect and control disease in CCS, strengthen fish robustness and disease resistance with focus on barrier functions and cardiovascular capacity, improve pathogen control and handling of disease outbreaks in CCS and develop new or refined vaccines and protocols for pathogens representing a special threat in CCS. Some of the results achieved in 2017 are described further.

In the MICROPARASITES project, the main objective is to identify and characterize the most important known and emerging microparasites in CCS by mapping of diversity, prevalence and load, mapping of transmission routes, develop methods and technology for fast and specific identification of microparasites and identify possible virulence markers. In 2017, a new member of the family Flaviviridae, *Cyclopterus lumpus* virus (CLuV), was characterized. This virus is associated with high mortalities in production of lumpfish and is found in both southern and northern Norway. So far screening of lumpfish and farmed salmon suggest that the virus will not infect salmon. We hypothesize that S-CCS will not affect the diversity, prevalence and load of parasites compared to open production systems (OPS). Five production cycles in S-CCS have been followed, and so far, the results show that production in S-CCS do not give higher mortalities compared to OPS. Microparasite diversity and prevalence seem to vary with time of year. In general, the load of each microparasite is low, but the impact of

Sampling from PREVENTIVE-CARDIO experiment by Gerrit Timmerhaus and Carlo Lazado. Photo: Terje Aamodt © Nofima the total load of all microparasites is not known. A relatively large number of microparasites (f. ex. ISAV, IPNV, PRV, SGPV) are introduced into the S-CCS with the smolt. Salmon lice do enter existing prototype S-CCS, however densities detected are within the set limit for such systems.

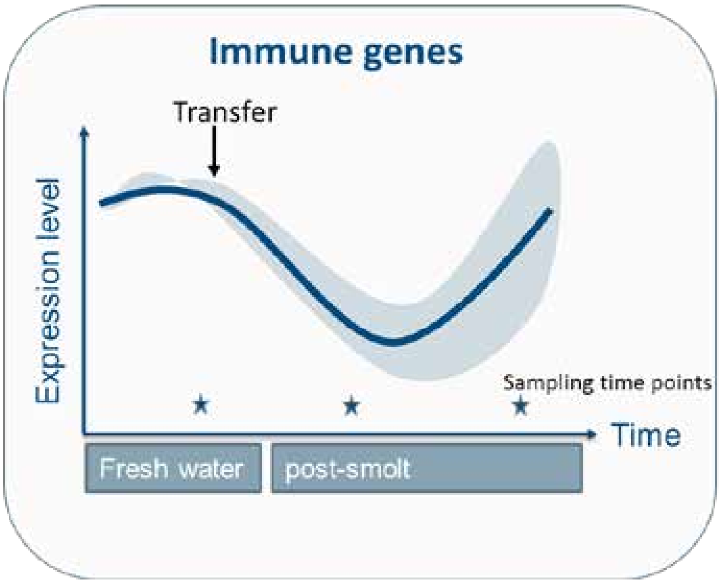


Figure 4.4. Illustration of the general expression pattern of immune genes in Atlantic salmon skin showing recovery of immune functions during the post-smolt period.

CCS are operating with higher production intensities where poorer skin health in combination with more efficient pathogen transmission represents a risk for attenuated disease resistance. The objective of project BARRIER is to understand mechanisms to enhance fish robustness with regard to host-microbial relationships and intrinsic and extrinsic mucosal tissue (skin, gill, intestine) barrier functions. In 2017, we provided evidence why Atlantic salmon could experience increased susceptibility to infectious agents and risk of diseases during the first time-period after seawater transfer (SWT). Freshwater smolts were compared to post-smolts after 1 and 4 months in seawater using two different production systems, open net pens and S-CCS (Preline). Skin analyses showed gradual morphological development in skin thickness and mucus cell numbers with growth and time post SWT. Gene expressions suggested similar processes with development of connective tissue, formation of extracellular matrix, augmented cutaneous secretion and changes in mucus protein composition. We also observed a delayed recovery of immune functions related to gradually enforced protection against pathogens. Overall, the period after SWT could be considered as a barrier recovery phase where the salmon builds resilience and robustness for further growth. This could be an important argument for using rearing facilities that reduce encounter with fish pathogens during the first months in the sea.

In the PREVENTIVE project, one of the main objectives is to identify water velocity thresholds for optimal growth and robustness of both smolts and post-smolts in CCS/RAS. In the first big scale experiment at a commercial smolt production site, increased water speeds of 0.6 body length per second ("Low speed") and 1.0 body length per second ("High speed") were tested during September 2016 – April 2017. Both weight and length increased significantly in the high-speed group during the experiment showing that higher water speeds have the potential to increase the growth rate of large smolts. More research is needed to confirm these results and optimize the water speed. There is little knowledge regarding optimal water velocities for enhanced health and performance of post-smolts during the first period in seawater and onwards. Currently we are running an experiment to identify optimum water velocities for post-smolts the first months after sea transfer in RAS to identify effects on growth and welfare. Results will be important to enable the industry to set the optimal water velocities for achieving improved cardiac health, increased robustness and disease resistance.

In CtrlAQUA we are concerned about fish performance. Illustration: Oddvar Dahl © Nofima

Accurate information about the fish biomass in the culture tanks is important for maintaining optimal condition for fish in aquaculture. In the BIOMASS project, we tested stereo camera based AkvaVision system for biomass estimation in RAS. Turbid water posed challenges to camera-based systems as it has reduced visibility in the water. We used AkvaVision together with additional lighting to improve the visibility and to optimize use of this system in RAS. Our results show that the light quality plays an important role for the accuracy of the AkvaVision. The use of yellow and red light together with AkvaVision allowed for accurate measurements of the objects at higher turbidities and at larger distances from the system compared to blue and green light. Light quality can affect physiological processes in fish and the choice of light for use with AkvaVision will be tested in 2018 during post-smolt production in RAS.

Land-based and S-CCS culture tanks for salmon in Norway are typically large and either circular or octagonal. These differences in geometry can require different approaches when water flow is introduced into the tank. These tanks sometimes use dual drains to create two advantages over a single drain tank, i.e., to concentrate a majority of settleable solids into a relatively small tank underflow and/or to shift the impulse force associated with outlet flows to help optimize water rotational velocities located in the annular region about the center of the tank. However, larger tanks make it more challenging to optimize swimming speeds for the fish, maintain a self-cleaning tank, and create homogeneous conditions with minimal gradients of dissolved O_2 and CO_2. In the HYDRO project, we used Computational Fluid Dynamics (CFD) models to optimize water hydrodynamics in 100 m^3 and 800 m^3 octagonal tanks that were calibrated against empirical data collected in tanks of equal dimensions at Nofima and at a commercial facility. In addition, a CFD model was also calibrated with empirical data to predict hydrodynamics in 74 m^3 and 3500 m^3 models of Fish Globe plus the 2000 m^3 Preline semi-closed raceway.

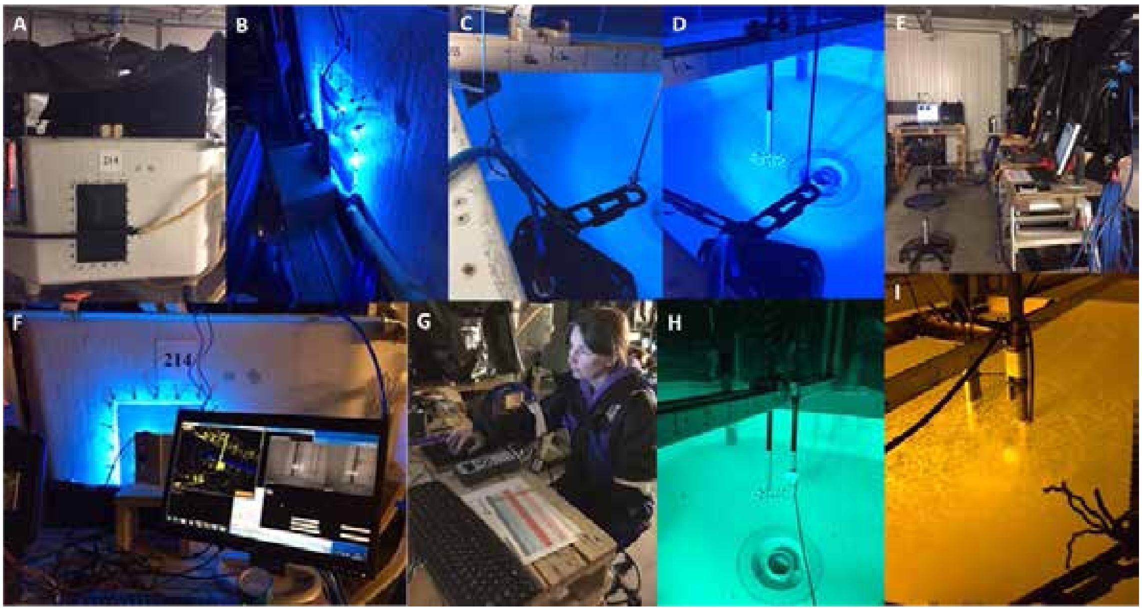


Figure 4.5. BIOMASS experimental set up at Nofima Centre for Recirculation in Aquaculture: A. Experimental Tank; B. Light source location; C. AkvaVision system location; D. Measured object; E. Working stations; F. Image view; G. Image recording; H. Light intensity measurements; I. Use of yellow light in tank with RAS water. Photos: Jelena Kolarevic © Nofima

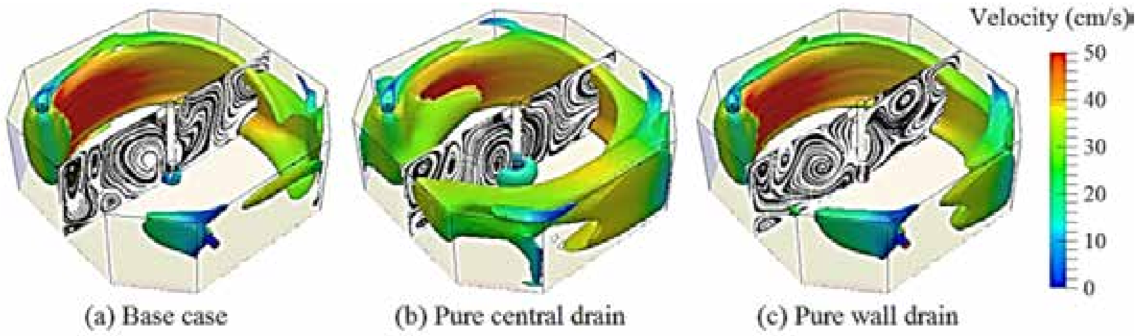


Figure 4.6. Comparison between different outflow options using integrated flowfield representation of intensified 3D turbulent kinetic energy, k, and streamline distribution on central vertical plane. Iso-surface of k is coloured on the scale of velocity magnitude. Planar streamlines highlight the prevalence of secondary vortices that promote mixing action in the tank through tea-cup hydrodynamic effect.

Biofilm formation on the surface of sensors has posed a potential threat to long time use of sensors. Biofilm can also cause inaccurate measurement due to sensor drifts. During 2017, the SENSOR project has continued the reach activity on sensor protection systems to prevent biofilm to establish on the surface of sensors. Main research has been on optimization of third-generation NH2-terminated PAMAM-dendrimer grafted onto graphite oxide. A series of new innovative protection systems based on polydimethyl siloxane(PDMS)/metal alloy nanocomposites has been developed, which has both antifouling and self-cleaning properties. The protection layers can easily be added to sensor surfaces through dip coating on grid shutter systems, which can be adapted to most types of sensors. The antifouling, wettability, morphology and composition of coating materials has been characterized and proven by confocal laser scanning microscopy (CLSM), water contact angle (WCA), scanning electron microscopy (SEM) and Fourier-transform infrared spectroscopy (FTIR) separately.

In CO2RAS, a joined project with Dept. Fish Production and Welfare, we have examined post-smolt tolerance to CO_2 between 5 and 40 mg/L in RAS over 12 weeks. We also investigated the effect of CO_2 on the physico-chemical parameters and presence of heavy metals. Iron was significantly affected by CO_2, while all examined elements (Al, As, Cd, Cr, Cu, Fe, Mn, Ni and Zn) showed increase over time, in particular Fe, Zn, As and Cd. pH was significantly affected by CO_2. The combination of low pH and low redox potential can create favorable conditions for increase in free heavy metals. This was the case when CO_2 in RAS water was 26 mg/L or higher. Low redox potential can also lead to increased amount of arsenite in water. These results highlight the complexity of the water quality in RAS and the need to investigate the interaction between different water quality parameters. See section under Department Fish Production and Welfare for more information regarding the project CO2RAS.

The shift from smolt to post-smolt implies a change from freshwater to brackish or seawater in RAS. The nitrification efficiency of RAS biofilters is severely affected by acute changes in salinity. Poor bioreactor performance can lead to ammonia and nitrite increase in the system, which is detrimental to fish health. In the EXPO project varying rates of salinity, ranging from gradual (1 ppt/day) to

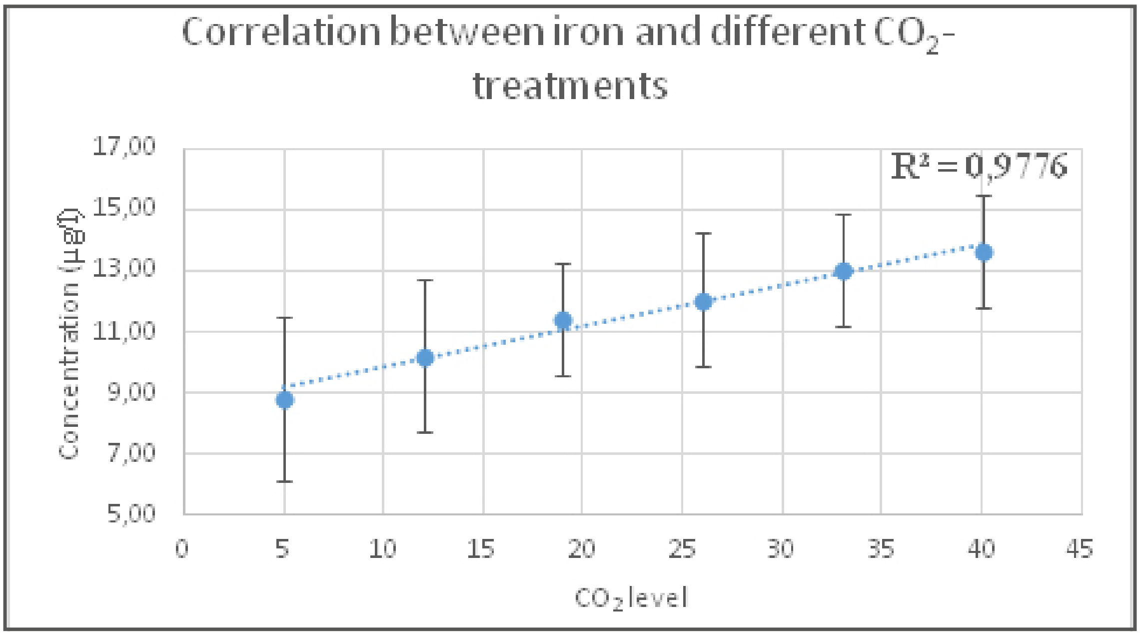


Figure 4.7. Change in concentration in different CO_2-treatments. The plot shows the positive and negative standard deviation of each data set. The correlation (R^2) is marked (Bye, G.R., 2017).

acute (15 ppt/day) change, were induced in pilot scale moving bed bioreactors that were started with freshwater RAS biomedia. The nitrification rate depended on the rate of salinity change from freshwater to seawater and dropped initially on salinity change but adapted to new salinity conditions over time. More results are expected in 2018.

PhD student Sharada Navada conducting measurements and collecting samples for analysis in the EXPO project. Photo: Chris Verstege

5 INTERNATIONAL COLLABORATION IN 2017

Researchers and user partners in CtrlAQUA have an extensive international network of contacts. In our Scientific Advisory Board, who among other things provide input to the annual plans, there are several international members, including from the European Aquaculture Society, Danish Technical University, The University of Aberdeen, and University of Maryland.

CtrlAQUA researchers have in 2017 frequently been used as session chairs or invited speakers at several international scientific meetings, such as the European Aquaculture Society's conference Aquaculture Europe in Dubrovnik in October 2017. CtrlAQUA partner Conservation Fund Freshwater Institute (USA) arranged their traditional conference «Aquaculture Innovation Workshop» in Vancouver, Canada, in November 2017, where CtrlAQUA contributed with 6 researchers and presentations.

There are two international R&D partners in CtrlAQUA, Gothenburg University (UGOT) and The Conservation Fund Freshwater Institute (FI), USA. Gothenburg University is represented in CtrlAQUA by Prof. Kristina Sundell and her research group. UGOT has in 2017 contributed to important results on effects of stress on skin barrier functions in salmon held in closed-containments. FI has continued the trials on optimal photoperiod and feed ration for post-smolts reared in RAS in their facilities. Furthermore, FI by Director of Systems Research Steve Summerfelt, is also leading the efforts on hydrodynamic measurements and development of flow models for large fish tanks in closed systems.

In 2015 CtrlAQUA opened for associated projects. Associated projects need external funding and can in addition to CtrlAQUA partners involve partners that are not regular CtrlAQUA partners. In 2017 there were two associated projects that involves international partners: CO2RAS Associated is funded by the EU project AquaExcel2020 and will run at Wageningen University. RFF TROUT is funded by Regional Research Fund (RFF) and is in collaboration with Sterling University.

Researchers in CtrlAQUA are often involved in new project proposals where international partners are included. Specifically, research by some of the CtrlAQUA-partners has helped establish AquaExcel2020, where among others Nofima Centre for Recirculation in Aquaculture (NCRA) in Sunndalsøra is included as one of the Transnational Access Points. This means that researchers across Europe can do experiments in NCRA funded by AquaExcel2020. Furthermore, partners UNI Research and the University of Bergen have been awarded a project called ExcelAqua Norway-Japan. This project is funded by the Research Council of Norway International Partnerships for Excellent Education and Research (INTPART), in aquaculture. ExcelAqua aims to develop a robust world-leading collaboration platform for outstanding research and education between the partners in aquaculture. CtrlAQUA participates here as one of the collaborative tools that will contribute to reaching the INTPART goals.

Measurement of light intensity at Grieg Seafood RAS facility, Trosnavåg. Photo: Britt Kristin Megård Reiten © Nofima

AgriMarine semi-closed containment system at Gulklakken, Smøla. Photo: Reidun Lilleholt Kraugerud © Nofima

Production hall RAS Nofima. Photo: Terje Aamodt © Nofima

6 RECRUITMENT, EDUCATION AND TRAINING

A total of 15 PhD students will be educated through the life-time of CtrlAQUA. The students are, and in the future will be, enrolled at the University of Bergen and NTNU. We are fast approaching this number and have now recruited a total of 11 PhD students to key research topics of the center and its associated projects (see table in section 8). During 2017, one of the PhD students, Sara Calabrese (industry PhD, Marine Harvest), successfully defended her thesis at the University of Bergen.

The student forum of the center was launched during the 2nd annual meeting in Bergen in May 2017. In preparation for this process we asked the students what they would like this forum to focus on, how best to organize the forum and how to keep communication going within the forum, ensuring a good flow of information. The students have chosen a structure where they get together in satellite meetings during the annual meetings, and CtrlAQUA has supported a request from the students for support for a meeting during the autumn. The students have appointed Sharada Navada as their representative, and the leader group regularly asks Navada for input to the leader group meetings.

In addition to PhD fellows, CtrlAQUA seeks to educate a number of Master students, at the University of Bergen, Göteborg University and NTNU (see table in section 8). During 2017, six MSc students completed their theses and their exams. Another four candidates are currently doing their theses in CtrlAQUA projects.

CtrlAQUA students. From the left: Sara Calabrese, Xiaoxue Zhang, Sharada Navada, Patrik Tang, Dorien Dunnebier, Gisle Roel Bye, Simen Haaland. Photo: Ingrid Festervoll Melien © Nofima

MEET THREE CtrlAQUA STUDENTS

Common for these three students is that they all work in relation to monitoring. Accurate monitoring is a prerequisite to ensure good management and fish health in closed systems.

Student Kristin Søiland. Photo: Per Henning, NTNU

Faster, more reliable ammonia analysis

"Master's student at the Norwegian University of Science and Technology (NTNU), Kristin Søiland has done experiments at Nofima's facilities at Sunndalsøra: I've learned so much from doing research work and getting to see what goes on behind the scenes. There is a vast amount of work behind each test. In collaboration with my supervisor, I'm allowed to shape what we're working on".

Søiland's work focuses on measurements – specifically, measuring nitrogen compounds in post-smolt production in brackish water. When a smolt grows to become a post-smolt in a recirculating system, it is common to phase into salt water until it becomes brackish. However, brackish water makes it more time-consuming and resource-intensive to accurately measure the nitrogen compounds in the water using ion selective sensors. This is because other ions interfere with the measurements.

Nitrogen compounds such as ammonia can be deadly for fish even in small concentrations, so accurate measurement is essential in recirculating aquaculture systems.

Before Christmas, Søiland was involved in a pilot project where she measured nitrates and ammonium using ion selective sensors at different salinities. In her master's thesis, the same sensors will be used to log nitrates and ammonium in fresh water and brackish water with the presence of smolt and post-smolt. In addition, she will be looking at biofouling of the sensors.

Over time, biofouling of the sensors by algae will make the measurements uncertain. Doctoral student at NTNU and CtrlAQUA Xiaoxue Zhang has already developed a material that can be spread on to sensor hoods, to prevent biofilm growth on the sensors that interferes with the measurements. Søiland is now testing the hoods with this material:

"I'm going to test whether this material, which contains nanoparticles of silver and has an antibacterial function, works on sensors in brackish water," Søiland explains.

The utility value of Søiland's master's project work is linked to time and accuracy.

"If the sensors are found to be reliable in post-smolt production in brackish water, time can be saved, as it will be possible to measure nitrates and ammonia in brackish water in real time. If the biofilm hoods also work, the measurements will be more reliable," says Søiland.

University:
Norwegian University of Science and Technology (NTNU)
Student status: MSc 2017–2019
Supervisor: Øyvind Mikkelsen
CtrlAQUA project: EXPO and SENSOR

This winter, Patrik Tang has been at Sunndalsøra sampling fish from the CARDIO project led by Gerrit Timmerhaus of Nofima. Tang highly values his collegial work, which is a crucial informative center to learn from each other. Photo: Terje Aamodt © Nofima

Amazed by the future of closed systems

Patrik Tang is a PhD student who is linking several projects in CtrlAQUA. His key topic is to identify how environmental factors influence the plasticity of physiological processes in post-smolt salmon, for example in osmoregulation, barrier and stress functions.

“My aim is to identify environmental-physiological thresholds for these processes, and to understand how do compromises start to emerge in physiology”, explains Tang.

“Therefore, I emphasize the importance of understanding the environmental-physiological axis of fish and associated thresholds, thereby allowing identification of suboptimal states in fish that can have dire consequences on stock robustness”, he says.

In Tang’s opinion, the technology for closed containment aquaculture is still not complete and has a somewhat long road ahead. However, Tang is a firm and positive believer that in the near future, as these systems develop and are made more efficient at lower costs, they will become a viable solution to many issues associated with aquaculture.

“For these reasons, I am deeply privileged and grateful to be a part of such an important and innovative movement”, he says.

Since starting his PhD studies, he has rapidly become interested in these systems and their great potential as a future supplier of salmon for the growing world demand, systems that he was still unfamiliar with only a year ago.

Raised in Bermuda off the coast of Florida, he moved to Finland where he studied Physiology and Neurosciences at the University of Helsinki. After his studies, he worked with fish and seal populations of the Baltic Sea, within the field of nutrition and physiology. It was quite a leap when moving to Bergen to work with closed and semi-closed containment systems for salmon:

“To be honest, before coming to Bergen, I didn’t have much of an idea about closed containment aquaculture. However, so far it has been an amazing experience and an overwhelming field to be associated with and learn about! My supervisors have been great, additionally the people I come into contact with working at farm sites or generally in this field are inspiring, not to mention, the people I sample with on site, who teach me so much valuable knowledge. Such has taught me that key is good communication among different parties involved, including both the science community as well as the people working at the farms, aspects that I find essential in achieving the common goal”, says Tang.

University: UiB
Student status: PhD 2017-2021
Supervisors: Sigurd Stefansson, Lars Ebbesson, Tom Ole Nilsen and Sigurd Handeland
CtrlAQUA project: ROBUST, OPTIMIZE, RIGID, CARDIO

Student Lene Sveen. Photo: Jon-Are Berg-Jacobsen © Nofima

Research to improve fish health

Stress slows wound healing in fish, according to doctoral work done by Lene Sveen at Nofima.

She has researched the impact of stress on fish's ability to heal and to produce mucus. These are important capabilities in both open pens and closed containment aquaculture systems. She has induced stress by catching the fish, and by varying fish density and size of the fish in the pens.

She used many different techniques to analyze wound healing in stressed and unstressed fish, including microarray. The main gene class that was affected by stress was the immune genes. Their job is to protect open wounds and remove damaged tissue. Many genes involved in wound repair also had a delayed response under stress, causing wounds to close more slowly in stressed fish.

"When a fish is stressed, its immune response changes. Not only do wounds heal more slowly – the fish will also be less able to resist disease," says Sveen.

"We also found out that when a fish becomes acutely stressed, it loses its protective mucus coating. And it takes more than a day for it to return," says Sveen.

This is bad news for the fish, as the mucous coating protects the fish against diseases.

"My message is that we must focus on preventative fish health when designing closed containment systems. I think it will be very interesting to see how the industry addresses this challenge."

"Closed containment aquaculture systems are evolving rapidly, and I can't wait to see what the fish farming industry's equivalent to the iPad will be," says Sveen.

University: University of Bergen
Student status: PhD 2014–18
Supervisors:
Sigurd Stefansson, Sigurd Handeland, Lars Ebbesson, Harald Takle, Elisabeth Ytteborg and Tom Ole Nilsen.
Projects:
SalmoFutura and OPP (associated projects)

CtrlAQUA About ▾ Departments Innovation

New leader in CtrlAQUA

13.12.2017 News

Åsa Espmark is the new Centre Director of CtrlAQUA. She takes over from Bendik Fyhn Terjesen who has headed the Centre from its inception in 2015.

CtrlAQUA is a centre for research-based innovation (SFI) whose main goal is to make closed systems for salmon up to one kilo available off the shelf by 2023.

Espmark is a senior scientist at Nofima in Norway and has long experience of research on welfare, quality and stress in farmed fish. Up until now she has also been the centre coordinator for CtrlAQUA. She is looking forward to leading the centre:

"CtrlAQUA is working with issues that we believe are going to change the course of Norwegian fish farming. It is exciting to be allowed to be part of and to contribute to this reorganisation. To lead the Centre also provides a unique opportunity to become better acquainted with and work with the industry stakeholders who are concerned about the recirculating aquaculture systems (RAS) and closed technology," says Espmark.

Researchers and commercial companies collaborate closely on innovation in the Centre. The collaboration contributes to a balance between the biological requirements of the fish, development in technology and the fish farmer's requirements for operation and profitability.

The commercialisation of closed technology is well under way and Espmark is positive about the development:

"I believe it is clearly evident that we cannot base ourselves exclusively on traditional fish farming methods if we are to solve the challenges the industry currently faces with sea lice, as well as the desire for growth. Closed technology is a preventive method against sea lice. This is the right move for the future because it means that we do not have to handle the fish, with consequent bad fish welfare", says Espmark.

Frode Mathisen of Grieg Seafood is Chairman of CtrlAQUA:

"Espmark has done an excellent job as the interim centre director. With this appointment we get both a skilled leader and preserve valuable continuity in CtrlAQUA".

About CtrlAQUA SFI

CtrlAQUA SFI has 17 partners from industry and academia. Nofima is the host institution. The Centre will lay the foundation for the development of closed aquaculture concepts in the future. Given greater control over the production process, problems related to mortality and sea lice will be reduced, as well as reducing the production time for farmed salmon.

CtrlAQUA has a budget of NOK 199 million over a period of 8 years, with the Research Council of Norway and the partners contributing half each.

IntraFish

- Mandag 12. Mar 2018 -

Forsker Audun Iversen i Nofima Foto: Anders Furuset

Tips til RAS-produksjon: Lite CO_2, mye dagslys

Matforskningsinstituttet Nofima delte noen nye funn om fiskeoppdrett i resirkuleringsanlegg (RAS) under AquaNor tirsdag. Interessen var enorm, og folk måtte bokstavelig talt snu i døra i det store plastteltet deres.

av Anders Furuset
16. aug. 2017 05:00

Del: Facebook Twitter LinkedIn Print E-mail

Tirsdag var første dag av den firedagers lange AquaNor-messen. Været var godt, stemningen god, og selgerne mange. Oppmøtet i Nofima-teltet utenfor hovedinngangen var det heller ingenting å si på – nær 300 tilhørere satt (og sto) med ørene på stilk for å få ny kunnskap om lakseoppdrett i lukkede systemer – både matfiskproduksjon og storsmoltproduksjon.

Seks forskere ga hver sin korte presentasjon om prosjekter de jobber med – noe var «gammel nytt» – annet var nye funn og foreløpige resultater.

MORGENB

KTOREN SVARER

SARA CALABRESE

disputerte 22. juni ved Universitetet i Bergen med avhandlingen *Environmental and biological requirements of post-smolt Atlantic salmon (Salmo salar L.) in closed-containment aquaculture systems.*

ukket laks

a Calabrese har forsket på laks i lukkede anlegg. Men hun det er urealistisk at all oppdrett vil bli lukket.

– Du har skrevet doktorgrad om hvordan laksen vil ha det i lukkede anlegg. Hvorfor er dette viktig å finne ut av?

– Næringen er interessert i å teste dette nå. Tradisjonelt lever smolten, smålaks, i lukkede anlegg i ferskvann på land, men flyttes til sjøen når den blir av en viss størrelse. Nå er næringen interessert i at større sjøvannstilpasset fisk, såkalt post-smolt, skal leve i lukkede anlegg.

– Hvorfor?

– For å minske risikoen for rømming og lakselus, som er de store hindrene for vekst i næringen i dag. Dessuten kan man i lukkede anlegg gjøre mer for å optimalisere temperatur og eksterne forhold i miljøet. Et bra miljø for fisken gjør den mer robust, og den vokser fortere, men vi vet lite om hvilket miljø som er best.

– Det har vært eksperimentert med lukkede anlegg i Norge før, men dette gikk man bort fra?

– Det ble testet mye på 1990-tallet, men det teknologiske var ikke på plass. I dag er det flere som tester ut dette på større fisk, for eksempel i Danmark og Canada. I Norge kan det være aktuelt å ha laksen i lukkede anlegg på land inntil de blir en kilo store.

– Helt kort, hva er et lukket anlegg?

– En oppdrettskonstruksjon der fisken skilles fra det eksterne miljøet. Det kan være i karsystemer på land, men kan også være i store enheter som senkes ned i sjøen. Man pumper da ofte inn vann fra dypet, for å slippe lusa som lever i de øverste meterne.

– Jeg mener å ha sett bilde av disse karene som ser ut som enorme egg?

– Marine Harvest og Hauge Aqua har fått forskningskonsesjon for å teste dette, det er i planleggingsfasen.

I Norge kan det være aktuelt å ha laksen i lukkede anlegg på land inntil de blir en kilo store.

– Konkret hva studerte du?

– Hvor mange fisk man kan ha i et slikt lukket anlegg. Det koster litt mer å drive et lukket anlegg, så biologien må være optimal for laksen. Jeg fant ut at man kunne ha opptil 75 kilo laks per kubikkmeter vann i lukkede sjøanlegg. Hvis man hadde mer, fikk man negative effekter for vekst og velferd. Og så testet vi hvor mye vann man må pumpe inn i slike anlegg. I kar på land så vi på optimalt saltinnhold og om trening i form av økt vannhastighet var bra for post-smolt.

– Det kommer jevnlig uttalelser fra politikere og aktivister om at lukkede anlegg er fremtiden for oppdrettsnæringen. Er det realistisk?

– Nei, jeg tror ikke all produksjonen blir lukket. Per i dag koster det for mye å produsere helt fram til matfisk i lukkede anlegg i Norge. Men gjennom å holde fisken lengre i lukket anlegg kan man minske tiden som fisken er i sjøen, og utnytte sjøanleggene bedre. Etter hvert som teknologien blir bedre og vi vet mer, tror jeg flere vil være interes-

Simen Sætre

Morgenbladet presenterer ferske doktorgrader hver uke.

7 COMMUNICATION AND DISSEMINATION ACTIVITIES

In CtrlAQUA, the overall goal with communication is to create interest around the activity of the center, and to be a strategic contribution to attain the goals of CtrlAQUA. The communication shall mirror the vision of the center.

When it comes to internal routines and systems for communication between the partners, the intranet is the most important. The intranet is the main communication channel within the center for the 100 participants now involved. The intranet has a document base, image base, message facilities, calendar and internal alerts of new findings or publications as agreed upon in the consortium agreement. Other systems for internal communication are regular meetings, and providing instructions for presenting CtrlAQUA.

The main external communication channel is the website www.ctrlaqua.no, which is designed for presenting results, activities, publications and innovations as the center develops. Also, template for fact sheet, guide for presentations, and readily available roll up and folder show externally what the center is about.

The interest from industry, the public and academia has been great. This has resulted in 77 news articles in press in 2017, many generated by the media itself. Research partners have actively made news stories covered in professional media, and all partners have been available for press to report on the progress of research and innovation in CCS in aquaculture.

In 2017 we have had high activity in disseminating progress and results at conferences, particularly towards our main target groups in industry and research.

Examples of dissemination activities in 2017 are:

- April: Five interviews with partners and students in the annual report distributed and printed in fish media and local newspapers.
- June: News about the first PhD degree in CtrlAQUA was covered in several news sites including Morgenbladet (see facsimile opposite page).
- June: Nofima researchers in CtrlAQUA wrote opinion article in the Norwegian newspaper Dagens Næringsliv.
- August: During the aquaculture fair Aqua Nor in Trondheim, Norway, over 300 visitors filled the tent to the verge where Nofima had invited six CtrlAQUA researchers to present the research.
- November: Several people in CtrlAQUA had presentations in the Aquaculture Innovation Workshop (AIW) in Vancouver, Canada. CtrlAQUA partner Freshwater Institute and others arranged the conference.
- December: The appointment of the new Center Director, Åsa Espmark, created high interest in the media.
- December: The first student film was made and distributed in January via Facebook and LinkedIn, showing research in practice in a PhD project. The film can be viewed at CtrlAQUA.no or by scanning the QR-code below with your cell phone.

8 ATTACHMENTS TO THE REPORT:

Key R&D partners in 2017

Name	Institution
Bendik Fyhn Terjesen (until 30.09.2017)	Nofima AS
Åsa Maria Espmark	Nofima AS
Jelena Kolarevic	Nofima AS
Lill-Heidi Johansen	Nofima AS
Astrid Buran Holan (until 30.04.2017)	Nofima AS
Sven Martin Jørgensen (until 28.02.2017)	Nofima AS
Trine Ytrestøyl	Nofima AS
Christian Karlsen	Nofima AS
Vasco Mota (until 31.12.2017)	Nofima AS
Jagan Gorle (until 31.12.2017)	Nofima AS
Per Brunsvik	Nofima AS
Grete Bæverfjord	Nofima AS
Elisabeth Ytteborg	Nofima AS
Gerrit Timmerhaus	Nofima AS
Aleksei Krasnov	Nofima AS
Ida Rud	Nofima AS
Lars Ebbesson	UNI Research
Sigurd Handeland	UNI Research
Tom Ole Nilsen	UNI Research
Pablo Balseiro	UNI Research
Simon Mackenzie	UNI Research
Marco Vindas (until 31.12.2017)	UNI Research
Alla Sapronova	UNI Research
Eirik Thorsnes	UNI Research
Sigurd Stefansson	Universitetet i Bergen
Are Nylund	Universitetet i Bergen
Øyvind Mikkelsen	NTNU
Frank Karlsen	HSN
Snuttan Sundell	UGOT
Henrik Sundh	UGOT
Brian Vinci	Freswater Institute, USA
Chris Good	Freswater Institute, USA
Steve Summerfelt	Freswater Institute, USA

Postdoctoral researchers in process

Name	Period	Institution
Nhut Tran-Minh	2016 - 2017	Nofima
Shazia Aslam	2016 - 2018	NTNU
Nobotu Kaneko	2018 - 2019	UiB

PhD students

Name	Period	Institution
Sara Calabrese	2013 - 2016	UiB
Victoria Røyseth	2016 - 2020	UiB
Sharada Navada	2017 - 2020	NTNU
Enrique Pino Martinez	2018 - 2021	UiB
Tharmini Kalananthan	2018 - 2021	UiB
Lene Sveen	2014 - 2018	UiB
Xiaoxue Zhang	2016 - 2020	NTNU
Bernat Morro	2016 - 2019	UiB
Patrik Tang	2017 - 2021	UiB
Patricia Aguilaraguilar	2018 - 2021	NTNU
Ingrid Naterstad Haugen	2018 - 2021	NTNU

MSc students

Name	Period	Institution
Britt Sjöqvist	2015 - 2016	UGOT
Ida Heden	2015 - 2016	UGOT
Øyvind Moe	2016 - 2017	UiB
Ingrid Gamlem	2016 - 2017	UiB
Egor Gaidukov	2016 - 2017	UiB
Hilde Frotjold	2016 - 2017	UiB
Simen Haaland	2016 - 2017	NTNU
Gisle Roel Bye	2016 - 2017	NTNU
Camilla J. Grindedal	2016 - 2018	NTNU
Kristin Søiland	2017 - 2019	NTNU
Thomas Kloster-Jensen	2017 - 2019	UiB
Gunnar Berg	2017 - 2019	UiB
Nikko Alvin Cabillon (Erasmus student)	2017 - 2018	Nofima
Claudia Spanu (Erasmus student)	2018	NTNU

Publications 2015 - 2018:

Peer-reviewed publications:

Bakke, I., Åm, A.L., Kolarevic, J., Ytrestøyl, T., Vadstein, O., Attramadal, K.J.K., Terjesen, B.F. (2016). Microbial community dynamics in semi-commercial RAS for production of Atlantic post-smolts at different salinities. Aquacultural Engineering 2016; Volume 78, 42-79.

Calabrese, S., Nilsen, T.O., Kolarevic, J., Ebbesson, L.O.E., Pedrosa, C., Fivelstad, S., Hosfeld, C., Stefansson, S.O., Terjesen, B.F., Takle, H., Martins, C.I.M., Sveier, H., Mathisen, F., Imsland, A.K., Handeland, S.O. (2017). Stocking density limits for post-smolt Atlantic salmon (Salmo salar L.) with emphasis on production performance and welfare. Aquaculture. 468: 363-370

Davidson, J., May, T., Good, C., Waldrop, T., Kenney, B., Terjesen. B.F., Summerfelt, S.T. (2016). Production of market-size (4-5 kg) North American strain Atlantic salmon Salmo salar in a commercial scale, land-based recirculation aquaculture system using freshwater. Aquacultural Engineering 74, 1-16.

Døskeland, I, Imsland, A.K.J., Fjelldal, P.G, Stefansson, S.O., Roth, B., Eriksen, K.E., Mikalsen, B., Handeland, S. (2016). The effect of low temperatures and photoperiods on growth and vertebra morphometry in Atlantic salmon. Aquaculture International 24, 1421–1434

Gunnarsson, G. G., Blindheim, S., Karlsbakk, E., Plarre, H., Imsland, A. K., Handeland, S. O., Sveier, H. and Nylund, A. (2017). Desmozoon lepeophtherii (microsporidian) infections and pancreas disease (PD) outbreaks in farmed Atlantic salmon (Salmo salar L.). Aquaculture. 668: 141-148.

Hjelle, E., Handeland, S. O., Ebbesson, L. and Nilsen, T. O. (2017). SmoltVision – et nytt analyseverktøy for vurdering av smoltstatus. Norsk Fiskoppdrett 8: 16-17.

Kamstra, A., Blom, E., Terjesen, B. F. (2017). Mixing and scale affect moving bed biofilm reactor (MBBR) performance. Aquacultural Engineering. ISSN 0144-8609. Doi: 10.1016/j.aquaeng.2017.04.004

Pautsina, A., Cisar, P., Stys, D., Terjesen, B.F., Espmark, Å.M. (2015). Infrared reflection system for indoor 3D tracking of fish. Aquaculture Engineering 69, 7-17.

Rud, I., Kolarevic, J., Holan, A.B., Berget, I., Calabrese, S., Terjesen, B.F. (2016). Deep-sequencing of the microbiota in commercial-scale recirculating and semi-closed aquaculture systems for Atlantic salmon post-smolt production. Aquacultural Engineering 2016, Volume 78, 50-62.

Skoge, R. H., Brattespe, J., Økland, A., Plarre, H., Nylund, A. (2017). New virus in family Flaviviridae detected in lumpfish (Cyclopterus lumpus). Archives of Virology. https://doi.org/10.1007/s00705-017-3643-3

Summerfelt, S. (2018). Developments in closed-containment technologies for salmonids, part 1. Recap of the 2017 Aquaculture Innovation Workshop. Global Aquaculture Advocate, 26.02.2018.

Summerfelt, S. (2018). Developments in closed-containment technologies for salmonids, part 2. Improved knowledge of closed-systems, innovations in aquafeeds. Global Aquaculture Advocate, 05.03.2018.

Summerfelt, S.T., Mathisen, F., Holan, A.B., Terjesen, B.F (2016). Survey of large circular and octagonal tanks operated at Norwegian commercial smolt and post-smolt sites. Aquacultural Engineering 74, 105 - 110.

Sveen, L. R., Grammes, F.T., Ytteborg, E., Takle. H., Jørgensen, S.M. (2017). Genome-wide analysis of Atlantic salmon (Salmo salar L.) mucin genes and their role as biomarkers. PlosOne, 13.12.2017. https://doi.org/10.1371/journal.pone.0189103

Sveen, L.R., Timmerhaus, G., Torgersen, J.S., Ytteborg, E., Jørgensen, S.M., Handeland, S.O., Stefansson, S.O., Nilsen, T.O., Calabrese, S., Ebbesson, L.O., Terjesen, B.F., Takle, H. (2016). Impact of fish density and specific water flow on skin properties in Atlantic salmon (Salmo salar L.) post-smolts. Aquaculture 464, 629-637.

Tran-Mihn, N. and Haug, B. (2018). A secure end-to-end IoT-based water sample collection system for early warning of attacks by sea lice larvae. International Journal of Information and Electronics Engineering (accepted, in press).

Ytteborg E., Karlsen K., Sveen L., Terjesen B. F. (2017). Laksens skinn - en levende sensor, Dagens Næringsliv

24.06.2017.

Ytteborg E., Karlsen K., Sveen L., Terjesen B. F. (2017). Laksens skinn - en levende sensor, Fiskeribladet Fiskaren 08.11.2017.

Book/article in book/report/abstract:

Calabrese, S., Sævareid, B., Breck, O., Joensen, R., Nilsen, T.O., Kolarevic, J., Fivelstad, S., Takle, H., Hosfeld, C., Ebbesson, L.O.E., Stefansson, S., Terjesen, B.F., Handeland, S.O. (2015). Pilot study: Post-smolt Atlantic salmon production in semi-closed sea systems. In: Book of abstracts EAS Rotterdam 2015.

Calabrese, S., Sævareid, B., Breck, O., Joensen, R., Nilsen, T.O., Kolarevic, J., Fivelstad, S., Takle, H., Hosfeld, C., Ebbesson, L.O.E., Stefansson, S., Terjesen, B.F., Handeland, S.O. (2016). Semi-closed sea systems for postsmolt Atlantic salmon. The World Aquaculture Society meeting, Aquaculture 2016, Las Vegas, USA. February 22nd-26th, 2016 (abstract ID 42049).

Ebbesson, L.O.E., Calabrese, S., Nilsen, T.O., Handeland, S.O., Gorissen, M., Flik, G., Braithwaite, V.A. (2016). Mental robustness indicators for adaptation potential and welfare assessment in fish aquaculture. In Aquaculture Europe 2016 Abstracts. Edinburgh, Scotland. September 21st -23rd 2016.

Good, C., Vinci, B., Summerfelt, S. (2017). Atlantic salmon production in land-based closed-containment systems. Swiss Fish Forum 2017. Lindau, Switzerland 17th February 2017.

Gorle, J.M.R., Terjesen, B.F., Summerfelt, S. (2016) Full-scale CFD modeling with experimental validation of large RAS tank hydrodynamics ICRA 2016, Roanoke West Virginia, USA 19 - 21. August 2016.

Gorle, J.M.R., Terjesen, B.F., Summerfelt, S. (2016). Characterization of hydrodynamics in large tanks for Atlantic salmon postsmolts using CFD (computational fluid dynamics). In Aquaculture Europe 2016 Abstracts, pp 399-400, Edinburgh, Scotland. September 21st -23rd 2016.

Holan A.B., Kolarevic, J., Terjesen, B.F. (2015). Evaluation of membrane treatment in recirculating aquaculture systems (RAS) for Atlantic salmon post-smolts (Salmo salar). In: Book of abstracts EAS Rotterdam 2015.

Holan A.B., Gorle J, Terjesen BF (2016). Water velocities in FishGLOBE. Nofima report K-77/2016, pp 11.

Holan, A.B, Kolarevic, J., Jørgensen, S.M., Reiten, B.K.M., Nerland, F., Brunsvik, P., Rud, I., Karlsen, C.R., Terjesen, B.F. (2016). Particle tolerance of Atlantic salmon post-smolts reared in recirculating aquaculture systems. In Aquaculture Europe 2016 Abstracts, pp 435-436, Edinburgh, Scotland. September 21st -23rd 2016.

Holan, A.B., Kolarevic, J., Fossmark, R., Bakke, I., Vadstein, O., Terjesen, B.F. (2015). Evaluation of membrane treatment effect on water quality in recirculating aquaculture systems (RAS) for Atlantic salmon post-smolts (Salmo salar). In: Book of abstracts 3d Workshop on Recirculating Aquaculture Systems. p. 52. 30th of September 1st October 2015, Molde, Norway.

Holan, A.B., Kolarevic, J., Terjesen, B.F. (2016). Evaluation of membrane treatment effect on water quality in recirculating aquaculture systems (RAS) for Atlantic salmon post-smolts (Salmo salar). The World Aquaculture Society meeting, Aquaculture 2016, Las Vegas, USA. February 22nd-26th, 2016 (abstract ID 42494).

Holan, A.B., Vinci, B., Handeland, S., Terjesen, B.F. (2016). Evaluation of available water treatment technologies for semi-closed aquaculture systems (in Norwegian). In Abstracts RCN Program conference Mariculture 2016, Bodø, Norway, April 18th – 20th 2016.

Jørgensen, S.M. (2015). CtrlAQUA – Improving safe and sustainable production. Kaldnes RAS Magazine: INSIDE Aquaculture, Special Edition, AQUA NOR 2015.

Kolarevic J., Espmark Å. M. (2017). Welfare and performance of Atlantic salmon post-smolt in concrete floating semi-closed containment systems and sea cage with perma skirt. EAS, Dubrovnik. Abstract.

Kolarevic, J., Iversen, R., Martinsen, S., Kvenset, P.G., Terjesen, B.F. (2016). Production of Atlantic salmon postsmolts (Salmo salar) in flexibag semi-closed containment system, The World Aquaculture Society meeting, Aquaculture 2016, Las Vegas, USA. February 22nd-26th, 2016 (abstract ID 42524).

Kolarevic, J., Sveen, L., Nilsen, T.O., Sundh, H., Aerts, J., Sundell, K., Ebbesson, L., Handeland, S., Jørgensen, S.M., Takle, H., Terjesen, B.F. (2016). Welfare and performance of Atlantic salmon post-smolts during exposure to mild chronic stress in closed-containment systems. In Aquaculture Europe 2016 Abstracts, pp 533-534, Edinburgh, Scotland. September 21st -23rd 2016.

Krasnov, A., Timmerhaus, G., Afanasyev, S. Ytterborg, E., Karlsen, C. (2017). Skin transcriptome of Atlantic salmon Salmo Salar L. reared in semi-closed marine systems: comparison of smolt batches and facilities with focus on the immune status. Oral presentation at EAS, Aquaculture Europe 2017, Dubrovnik, Croatia. Abstract

Mota, V. C., Nilsen, T. O., Ytteborg, E., Baeverfjord, G., Kolarevic J., Ebbesson L., Summerfelt, S. and Terjesen, B. F. (2017). The effect of carbon dioxide on performance, health and welfare of atlantic salmon post-smolts in recirculating aquaculture systems. Proceedings of the Aquaculture Europe "Cooperation for Growth", Dubrovnik, Croatia, 17 – 20 October 2017. Abstract

Mota, V.C., Kolarevic, J., Terjesen, B.F. (2016). Ammonia and carbon dioxide modelling in a reuse system without a biofilter. In Aquaculture Europe 2016 Abstracts, pp 655, Edinburgh, Scotland. September 21st -23rd 2016.

Multiple authors (2016) Annual Report 2015 CtrlAQUA - Center for Closed-containment Aquaculture, eds. Terjesen BF, Espmark Å. pp 76. Nofima, Norway.

Multiple authors (2017) Annual Report 2016 CtrlAQUA - Center for Closed-containment Aquaculture, eds. Terjesen BF, Espmark Å. pp 56. Nofima, Norway.

Summerfelt, S., Mathisen, F., Holan, A., Terjesen, B.F. (2016). Survey - Use of large circular tanks in Norwegian salmon smolt and post-smolt facilities. Aquaculture Innovations Workshop, August 19-21, Roanoke, Virginia, USA.

Summerfelt, S.T., Terjesen, B.F. (2017). Closed containment as a technical solution - Global overview. In: Scientist think tank - Speaking for the salmon - The protection of Pacific wild salmon - Understanding potential risk factors and seeking solutions. January 26-27, 2017, Simon Frazier University, Burnaby, British Columbia, Canada.

Sundh, H., Kolarevic, J., Nilsen, T.O., Jørgensen, S.M., Karlsen, C.R., Terjesen, B.F., Takle, H., Sundell, K. (2016). The impact of chronic stress on the barrier function of the skin in Atlantic salmon Salmo salar reared in closed containment systems. In Aquaculture Europe 2016 Abstracts, pp 992-993, Edinburgh, Scotland. September 21st -23rd 2016.

Sveen, L. R., Timmerhaus G., Krasnov, A., Takle H., Ytteborg E. (2017). High production intensities alters cutaneous wound healing in Atlantic salmon (Salmo salar L.) post-smolts. Oral presentation at EAS - European aquaculture society, Dubrovnik 2017, Croatia. Abstract

Sveen, L.R., Ytteborg, E., Timmerhaus, G., Stefansson, S., Jørgensen, S.M., Handeland, S., Nilsen, T.O., Takle, H., Terjesen, B.F. (2016). Effect of stress on wound healing and gene regulation in skin of posts-smolts (Salmo salar L.) in closed-containment aquaculture systems (in Norwegian). In Abstracts RCN Program conference Mariculture 2016, Bodø, Norway, April 18th – 20th 2016.

Sveier, H., Tangen, S., Handeland, S. (2015). Post smolt (Salmo salar L) production in floating raceway systems? In: Book of abstracts EAS Rotterdam 2015.

Terjesen, B.F. (2015). Nofima Centre for Recirculation in Aquaculture (NCRA), a research facility for the future salmon production methods. Aquaculture Europe Magazine pp. 33-43.

Terjesen, B.F. (2016). New results and plans in CtrlAQUA SFI – Centre for Closed-containment Aquaculture (in Norwegian). In Abstracts RCN Program conference Mariculture 2016, Bodø, Norway, April 18th – 20th 2016.

Terjesen, B.F., Abbink, W., Blom, E., Kamstra, A., Espmark, Å.M., Kolarevic, J., Nilsen, T.O., Ebbesson, L., Handeland, S., Sveen, L., Takle, H. 2015. Scaling of culture tanks and unit processes, relevant for Atlantic salmon post-smolt production in land based systems. In: Book of abstracts 3d Workshop on Recirculating Aquaculture Systems. p. 52. 30th of September 1st October 2015, Molde, Norway.

Tran-Minh, N., Haug, B., Roseng, L. E., Jørgensen, S. M., Terjesen, B. F., Karlsen, F. (2017). A Unique Continuous Concentration and Separation System for Large Water Volume Refining. Poster presentation at World Aquaculture, Cape Town, South Africa. Abstract

Tran-Minh, N., Karlsen, F. (2018). Computational Fluid Dynamics Approach for Modeling a Non-Newtonian Blood Flow in a Split and Recombine Micromixer. IFMBE Proceedings vol. 63, Springer Nature Singapore Pte Ltd. Editors: Van, T. V., Le, T. A. N., Duc, T. N. pp 319-323. ISSN/ISBN: 978-981-10-4361-1

Tran-Minh, N., Karlsen, F., Terjesen, B. F. (2017). Hydrodynamic Study of a Continuous Large Volume Sorting and Concentration Technology for Particles and Cells in Micrometre Range. Proceedings of the 4th International Conference of Fluid Flow, Heat and Mass Transfer (FFHMT'17). Avestia Publishing, pp. 172.1-172.5. ISSN/ISBN 978-1-927877-37-1

Zhang, X., Mikkelsen, Ø. (2016). Deposition of Silver Nanoparticles/Poly (amidoamine) Dendrimer/Graphene Oxide Nanohybrids on Sensor Surface for Anti-biofouling. Department of Chemistry, Norwegian University of Science and Technology. 13th International Conference on Nanotek and Expo (Dec 05-07, 2016 Phoenix, Arizona, USA)

Presentations (oral and posters):

Balseiro, P (2017). Training effect and higher growth potential of Atlantic salmon (Salmo salar) post-smolts reared in Preline S-CCS. 10th International Workshop on Salmon Smoltification, Bergen August 14-18 2017

Calabrese, S., Sævareid, B., Breck, O., Joensen, R., Nilsen, T.O., Kolarevic, J., Fivelstad, S., Takle, H., Hosfeld, C., Ebbesson, L.O.E., Stefansson, S., Terjesen, B.F., Handeland, S.O. (2015). Pilot study: postsmolt Atlantic salmon production in semi-closed sea systems. Aquaculture Europe, EAS, Rotterdam, The Netherlands, 20-23. October 2015.

Ebbesson, L. (2017). The making of a robust smolt. 10th International Workshop on Salmon Smoltification, Bergen August 14-18 2017

Ebbesson, L. (2018). Hvorfor er riktig lys viktig? – Lightqual. Kunnskapsoppdatering om optimal post-smolt produksjon. CtrlAQUA workshop, Bergen, Norway, 31 January 2018.

Ebbesson, L. (2018). Hvorfor er riktig lys viktig? – Optimize. Kunnskapsoppdatering om optimal post-smolt produksjon. CtrlAQUA workshop, Bergen, Norway, 31 January 2018.

Espmark, Å. (2017). Premisser for god produksjon i lukket merd. Arbeidsmøte Sintef Ocean, Trondheim December 4 2017.

Good, C. (2017). The effects of photoperiod on Atlantic salmon post-smolt in freshwater closed-containment systems. Aquaculture Innovations Workshop 2017, Vancouver, Canada.

Good, C., Summerfelt, S., May, T., Crouse, C., Ebbesson, L., Stefansson, S., Handeland, S., Jørgensen, S.M., Mathisen, F., Terjesen, B.F. (2016). Assessing photoperiod regimes for freshwater-reared post-smolts. Aquaculture Innovations Workshop, August 19-21, Roanoke, Virginia, USA.

Good, C., Summerfelt, S., Vinci, B. (2017). Atlantic salmon production in land-based, closed-containment systems. Swiss Fish Forum 2017, Lindau, Switzerland. 17th February 2017.

Gorle, J., Summerfelt, S.T., Mota, V.C., Marchenko, Y., Megård-Reiten, B.K., Terjesen, B.F. (2016). Hydrodynamic modeling of culture tanks in Norwegian salmon smolt and post-smolt facilities. Aquaculture Innovations Workshop, August 19-21, Roanoke, Virginia, USA.

Handeland, S. (2018). Optimal salinitet i RAS (1). Kunnskapsoppdatering om optimal post-smolt produksjon, CtrlAQUA workshop. Bergen, Norway, 31 January 2018.

Handeland, S. O. (2017). Norsk havbruk; En ny og innovativ næring. Inspirasjonsdag for realfagselever, Høyskolen på Vestlandet. Bergen 26 oktober.

Handeland, S. O., (2017). Ny teknologi for bedre fiskehelse og velferd. NTVA-møtet i Bergen, Nansen senteret. Bergen 14 august.

Handeland, S. O., (2017). Overview of CtrlAQUA research in post-smolt welfare, performance, and water quality in commercial scale, floating, semi-closed containment systems: CtrlAQUA Preline, Neptune, and Eco-Cage. Aquaculture Innovation Workshop. Vancouver, BC, November 29 – 30.

Handeland, S., (2015). Produksjon av laks i lukkede anlegg. Får vi dette til? Hardangerfjordseminaret 2015.

Helland, S. (2016). Spennende satsing innen havbruk på Sunndalsøra: SFI CtrlAQUA. Den lukkede fasen i lakseoppdrett. Marin Samhandlingsarene. Ålesund, 25. November 2015.

Hjelle, Elise (2018). Erfaring fra smoltifisering i RAS vist ved SmoltVision. Kunnskapsoppdatering om optimal post-smolt produksjon. CtrlAQUA workshop, Bergen, Norway, 31 January 2018.

Holan, A. (2015). Utviklingen innenfor bruk av RAS i norsk akvakultur. Farmer Day, AquaCircle, DanAqua, Aalborg, Danmark 7. October 2015.

Holan, A. (2017). Effects of seawater quality on treatment of intake water for use in closed-containment aquaculture systems. Aquaculture Innovation Workshop, Vancouver, BC, Canada, 29-30 November 2017 -

Holan, A.B. Kolarevic, J., Terjesen, B.F. (2015). Evaluation of membrane treatment in RAS for Atlantic salmon post-smolts (Salmo salar). Aquaculture Europe, EAS, Rotterdam, The Netherlands, 20-23. October 2015.

Holan, A.B., Kolarevic, J., Fossmark, R.O., Bakke, I., Vadstein, O., Terjesen, B.F. (2015). Evaluation of membrane treatment effect on water quality in RAS for Atlantic salmon post-smolts. NordicRAS Network, Molde Norway, 30. September - 1. October 2015.

Holan, A.B., Reiten, B.K.M., Nerland, F, Brunsvik, P., Kolarevic, J., Rud, I., Karlsen, C. R., Jørgensen, S. M., Terjesen, B.F. (2016). Particle tolerance of Atlantic salmon post-smolts reared in recirculating aquaculture systems (RAS). Aquaculture Europe Edinburgh, 20-23 September, 2016

Holan, A.B., Reiten, B.K.M., Nerland, F., Brunsvik, P., Kolarevic, J., Rud, I., Karlsen, C. R., Jørgensen, S. M., Ytteborg, E., Terjesen, B.F. (2016), Toleranse til partikler hos postsmolt. Fremtidens smoltproduksjon - Fjerde konferanse om resirkulering av vann i akvakultur på Sunndalsøra. 25. – 26. oktober 2016.

Holan, A.B., Terjesen, B.F. (2015). CtrlAQUA Center for Closed Containment Aquaculture. Transatlantic Science week, The Norwegian Embassy in Washington DC, Ministry of Education and Research, Ministry of Trade, Industry and Fisheries, Research council of Norway. Boston, USA, 4-6. November 2015.

Holan, A.B., Vinci, B., Handeland, S., and Terjesen, B.F. (2016). Evaluering av tilgjengelig vannbehandlingsteknologi for semi-lukkede anlegg – INTAKE. Programkonferansen Havbruk, Bodø, Norway, April 18-19, 2016.

Iversen, A., Hermansen, Ø., Terjesen, B.F., Andreassen, O. (2016). Competitiveness of new technologies in salmon farming. IIFET, International Institute of Fisheries Economics and Trade Conference 2016, Aberdeen, Scotland, 11th-15th of July 2016.

Johansen, L. (2017). Overview of CtrlAQUA research to optimize RAS for Atlantic salmon post-smolt production. Aquaculture Innovation Workshop, Vancouver, Canada. November 2017

Karlsen, C.R. (2018). Effekt av håndtering og utvikling av barrierefunksjoner i postsmoltfasen. Kunnskapsoppdatering om optimal post-smolt produksjon. CtrlAQUA workshop, Bergen, Norway, 31 January 2018.

Kolarevic J., Espmark Å.M. (2017). Welfere and performance of Atlantic salmon post-smolt in concrete floating semi-closed containment systems and sea cage with perma skirt. EAS, Dubrovnik.

Kolarevic, J. (2017). Post-smolt welfare, performance, and water quality in commercial scale, floating, semi-closed containment systems: CtrlAQUA Flexibag and concrete. Aquaculture Innovation Workshop, Vancouver, Canada. November 2017

Kolarevic, J. (2017). Production of post-smolt. Smolttinget, Smøla

Kolarevic, J. (2018). Optimal vannkvalitet - Generelle anbefalinger. Kunnskapsoppdatering om optimal post-smolt produksjon. CtrlAQUA workshop, Bergen, Norway, 31 January 2018.

Kolarevic, J., Iversen, R., Martinsen, S., Kvenset, P.G., Terjesen, B.F. (2016). Production of Atlantic salmon post-smolts (salmo salar) in flexibag semi-closed containment system, The World Aquaculture Society meeting, Aquaculture 2016, Las Vegas, USA. February, 22nd-26th, 2016.

Kolarevic, J., Reiten, B.K.M., Sveen, L., Nilsen, T.O., Aerts, J., Ebbesson, L.O.E., Handeland, S., Jørgensen, S.M., Takle, H., Terjesen, B.F. (2016). Welfare and performance of Atlantic salmon post-smolts during exposure to mild chronic stress in recirculation aquaculture system (RAS). In RCN Program conference Mariculture 2016, Bodø, Norway, April 18th – 20th 2016.

Krasnov, A., Timmerhaus, G., Afanasyev, S. Ytterborg, E., Karlsen, C. (2017). Skin transcriptome of Atlantic salmon Salmo Salar L. reared in semi-closed marine systems: comparison of smolt batches and facilities with focus on the immune status. Oral presentation at EAS, Aquaculture Europe 2017, Dubrovnik, Croatia

Mota, V. C. (2017). CO2 tolerance of Atlantic salmon post-smolts in RAS. Aquaculture Innovation Workshop, Vancouver, BC, Canada, 29-30 November 2017

Mota, V. C. (2917). Salmon CO2 excretion: a danger to recirculating aquaculture? AQUA NOR, Trondheim, Norway, 15-18 August 2017

Mota, V. C., Nilsen, T. O., Ytteborg, E., Baeverfjord G., Kolarevic J., Ebbesson, L., Summerfelt, S. and Terjesen B. F. (2017). The effect of carbon dioxide on performance, health and welfare of atlantic salmon post-smolts in recirculating aquaculture systems. Aquaculture Europe "Cooperation for Growth", Dubrovnik, Croatia, 17 – 20 October 2017.

Navada, S. (2017). Impact of environmental conditions on Moving Bed Bioreactor (MBBR) in Recirculating Aquaculture Systems (RAS). Havbruk Phd Meeting, 30 August, 2017.

Navada, S. (2017). Improving salmon production with better water quality - The Eco-Way. Oslo Innovation Week, Oslo, Norway, 30 August 2017

Navada, S. (2017). Lower energy need with better biofilter. Nofima seminar, AQUA NOR, Trondheim, Norway, 15-18 August 2017.

Navada, S. (2107). Secrets of a biofilter - Why microscopic things matter. Forskningsrådet, AQUA NOR, Trondheim, Norway, 15-18 August 2017.

Nilsen, T.O. (2018). Effekt av høye CO2 nivå hos postsmolt i RAS. Kunnskapsoppdatering om optimal postsmolt produksjon. CtrlAQUA workshop, Bergen, Norway, 31 January 2018.

Nilsen, T.O. (2018). Intensiv produksjon - temperatur og tidlig pubertet hos post-smolt en utfordring? Kunnskapsoppdatering om optimal post-smolt produksjon. CtrlAQUA workshop, Bergen, Norway, 31 January 2018.

Nilsen, T.O., Sundh, H., Andersson, E., Stefansson, S.O., McCormick, S.D., Taranger, G.L., Schulz, R.W., Fjelldal, P.G., Ebbesson, L.O.E., Handeland, S.O., Sundell, K., (2016). Osmoregulatory changes in sexually maturing Atlantic salmon post-smolt and adults. 12th International Congress on the Biology of Fish, San Marcos, Texas, USA, June 12-16.

Nilsen, T.O., Sundh, H., Andersson, E., Sundell, K., Stefansson, S.O., McCormick, S.D., Taranger, G.L., Melo, M., Fjelldal, P.G., Ebbesson, L.O.E., Norberg, B. and Schulz, R.W., (2016). Effects of androgens on osmoregulatory mechanisms in Atlantic salmon (Salmo salar L.). 28th conference of European Comparative Endocrinologists, Leuven, Belgium, August 21-25th 2016.

Nylund, A. (2018). Mikroparasitter i S-CCS; Prevalens, tetthet og diversitet. Kunnskapsoppdatering om optimal post-smolt produksjon. CtrlAQUA workshop, Bergen, Norway, 31 January 2018.

Stefansson, S. (2018). Optimal salinitet i RAS (2). Kunnskapsoppdatering om optimal post-smolt produksjon, CtrlAQUA workshop. Bergen, Norway, 31 January 2018.

Summerfelt, S. T. (2017). Production of Atlantic Salmon to Harvest Size on Land in the USA. In: CtrlAQUA Seminar. August 15, AquaNor 2017, Trondheim, Norway.

Summerfelt, S. T., Good, C., Vinci, B. J. (2017). Engineering for Biosecurity. In: Lofotseminaret 2017, June 14-15, Nusfjord, Norway.

Summerfelt, S., Mathisen, F., Gorle, J., Terjesen, B.F. (2016). Survey of large tanks operated at Norwegian commercial smolt and post-smolt sites (in Norwegian).

In RCN Program conference Mariculture 2016, Bodø, Norway, April 18th – 20th 2016.

Summerfelt, S., Mathisen, F., Holan, A., Gorle, J., Terjesen, B.F. (2016). Dimensioning and operation of large culture tanks in Norwegian smolt and post-smolt facilities. Havbruk 2016, April 18-20, Bodø, Norway.

Summerfelt, S., Mathisen, F., Holan, A., Terjesen, B.F. (2016). Survey - Use of large circular tanks in Norwegian Salmon smolt and post-smolt facilities. Aquaculture Innovations Workshop, August 19-21, Roanoke, Virginia, USA.

Summerfelt, S.T. (2016). New Emerging Challenges and Solutions in RAS for Salmonids. 4th Conference on Recirculating Aquaculture – Smolt Production in the Future. October 25-26, Sunndalsøra, Norway.

Summerfelt, S.T., Terjesen, B.F. (2017). Closed Containment as a technical solution - Global overview. In: Scientist think tank - Speaking for the salmon - The protection of Pacific wild salmon - Understanding potential risk factors and seeking solutions. January 26-27, 2017, Simon Frazier University, Burnaby, British Columbia, Canada.

Sveen, L. R., Timmerhaus, G., Krasnov, A., Takle, H., Ytteborg E. (2017). Effect of stress on wound healing and gene regulation in the skin of posts-smolts (Salmo salar L.) in closed-containment aquaculture systems (in Norwegian). Mariculture 2017, Bodø, Norway

Sveen, L. R., Timmerhaus, G., Krasnov, A., Takle, H., Ytteborg E. (2017). High production intensities alters cutaneous wound healing in Atlantic salmon (Salmo salar L.) post-smolts. Oral presentation at EAS - European aquaculture society, Dubrovnik 2017, Croatia.

Sveen, L. R., Timmerhaus, G., Krasnov, A., Takle, H., Ytteborg E. (2017). My skin don`t lie. Aqua Nor, Trondheim 2017.

Sveier, H., Tangen, S., Handeland, S. (2015). Postsmolt of Atlantic salmon (Salmo salar L.) production in floating raceway system? Expectations and preliminary results. Aquaculture Europe, EAS, Rotterdam, The Netherlands, 20-23. October 2015.

Terjesen, B. F. (2017). Lukkede anlegg land og sjø som tiltak mot lakselus. Rensefiskkonferansen og medikamentfri lakseluskotroll 2017. Trondheim 7. – 9. februar 2017.

Terjesen, B.F. (2015). Can the salmon industry grow with closed-containment systems? Nofima AquaNor seminar. Trondheim, 18th August 2015.

Terjesen, B.F. (2015). How do we farm salmon in the future? Sunndalskonferansen, Sunndalsøra, 23rd June 2015.

Terjesen, B.F. (2015). Is the future land-based? Invited speaker and panel participant. SpareBank1 and BEWI seminar on salmon aquaculture. Trondheim, Norway, August 20th, 2015.

Terjesen, B.F. (2015). Post-smolt production in closed-containment systems: CtrlAQUA SFI and other relevant RCN projects. The Research Council of Norway AquaNor exhibition stand. Trondheim, 19th August 2015

Terjesen, B.F. (2016). Closed-containment aquaculture systems, what solutions exist? Invited speaker to the conference Wild salmon in the North. Alta, Norway, February 12th, 2016.

Terjesen, B.F. (2016). CtrlAQUA research to optimize RAS for Atlantic salmon post-smolt production. Invited speaker to the Aquaculture Innovation Workshop 2016, Roanoke, Virginia, U.S. August 19th – 20th 2016.

Terjesen, B.F. (2016). Research on Atlantic salmon postsmolt production in closed-containment systems. Invited speaker to the Salmonview Media seminar "Growing larger fish in RAS systems" at Aquaculture Europe 2016, Edinburgh, Scotland, September 22nd 2016.

Terjesen, B.F. (2016). Research on smolts and postsmolts in RAS. Invited speaker to the Veterinary Days 2016, Aquamedicine session. Hamar, Norway, 9th-11th of March, 2016.

Terjesen, B.F. (2016). SFI CtrlAQUA – closed and semiclosed plants. North Atlantic Seafood Forum, Zero Lice workshop, Bergen 1st March.

Terjesen, B.F. (2016). Status closed containment systems on land and in sea – CtrlAQUA SFI as a tool against sea lice. Invited speaker to the workshop

Non-medicinal tools for prevention and control of sea lice, organized by the Norwegian Seafood Research Fund. Gardermoen, Norway, January 12th, 2016.

Terjesen, B.F. (2016). The path towards full control of the fish in RAS. Smolt Production in the Future - Fourth Conference on Recirculation of Water in Aquaculture. 25th – 26th October 2016, Sunndalsøra, Norway.

Terjesen, B.F. (2016). Water quality and fish welfare in closed-containment systems. Invited talk at Seminar on animal welfare for farmed fish. Nordic Council of Ministers, the Nordic Working Group for Microbiology & Animal Health and Welfare (NMDD) Bergen, Norway, 4th-5th October 2016.

Terjesen, B.F., (2015). Presentasjon av CtrlAQUA, Forskningsdagene, Sunndalsøra, september 2015

Terjesen, B.F., (2015). Presentasjon av CtrlAQUA, Forskningstorget, Oslo, september 2015

Tran-Mihn, N. and Haug, B. (2018). A secure end-to-end IoT-based water sample collection system for early warning of attacks by sea lice larvae. 7th International Conference on Information and Electronics Engineering (ICIEE 2018). Vietnam, February 25-27 2018.

Tran-Minh, N., Haug, B., Roseng, L. E., Jørgensen, S. M., Terjesen, B. F., Karlsen, F. (2017) A Unique Continuous Concentration and Separation System for Large Water Volume Refining. Poster presentation at World Aquaculture, Cape Town, South Africa

Tran-Minh, N., Karlsen, F., Terjesen, B. F. (2017). Hydrodynamic Study of a Continuous Large Volume Sorting and Concentration Technology for Particles and Cells in Micrometre Range. 4th International Conference of Fluid Flow, Heat and Mass Transfer (FFHMT'17), August 21 - 23, 2017, Toronto, Canada

Ytrestøyl, T. (2017). Health and performance of Atlantic salmon post-smolt when using novel production protocols. Aquaculture Innovation Workshop, Vancouver, Canada. November 2017

Ytrestøyl, T. (2018). Betydning av produksjonsbetingelser i RAS for ytelse i RAS og i sjø. Kunnskapsoppdatering om optimal post-smolt produksjon. CtrlAQUA workshop, Bergen, Norway, 31 January 2018.

Ytrestøyl, T. (2018). Optimal salinitet i RAS - resultater fra OPP. Kunnskapsoppdatering om optimal post-smolt produksjon. CtrlAQUA workshop, Bergen, Norway, 31 January 2018.


Photo: Terje Aamodt © Nofima