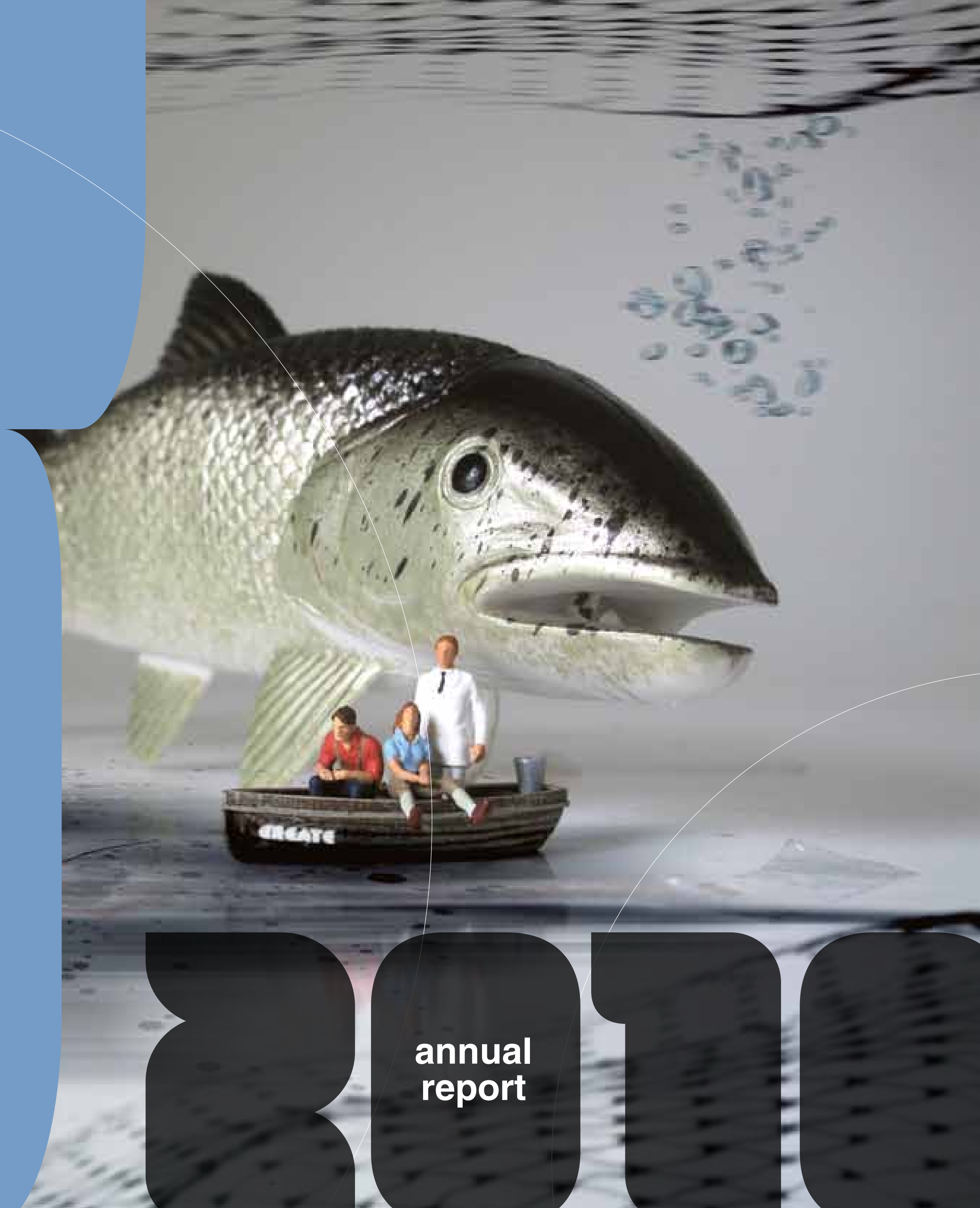
CREATE

Centre for research-based innovation in aquaculture technology



2010 annual report

Contents

CREATE, the Centre for Research-based Innovation in Aquaculture Technology, conducts research to assist in the innovation of technology, products and solutions specifically to improve the grow-out phase of marine fish culture. A wide range of scientific disciplines are necessary to develop understanding of fish behaviour and needs, understand the biological process, fish farming processes, loads and motion of flexible fish farm constructions and to use this basic knowledge to develop fish farming technology and systems for the future. CREATE is a multi-disciplinary centre, with scientific disciplines covering fish ethology, fish feed nutrition, marine hydrodynamics, marine structures engineering, information and communication technology, marine biology and industrial design.

The centre have completed four year of work, and is presently running eight projects, ranging from fundamental research to acquire basic knowledge on biology for technology development to development of new technological solutions. The centre is presently engaged in thirteen PhD and two postdoctoral fellowships. CREATE researchers have so far published 34 articles in international, peer-reviewed scientific journals, such as Aquaculture, Aquaculture Engineering, Aquaculture Environment Interactions and Ocean Engineering and contributed numerous peer-reviewed book chapters. As well as a range of primary articles produced within the centre's projects, these contributions have included major reviews on the technological status of the modern fish farming industry (Fredheim and Langan 2009), the environmental drivers of fish behaviour in sea-cages (Oppedal et al. 2010), and the causes of escapes and measures to prevent their escape (Jensen et al. 2010).

Some of the research highlights to date are:

- Understanding of behaviour of salmon being submerged to different depths at different time periods. This is a breakthrough results, showing that salmon can be submerged for short periods of time, which will be important for further expansion of salmon farming into more exposed and offshore locations.

- Basic understanding of characteristics of hydroids, like settlement preferences and results showing low effect of traditional in situ washing methods. Under development is a novel system for more effective bio-fouling control and removal, based on this knowledge.

- Knowledge on tolerance limits of fluctuating hypoxia for salmon and water flow through and around fish cages with fish. These results are valuable for development of management protocols, feeding control, understanding of fish welfare and development of control and planning systems for fish farming.

- Development of an individual-based numerical model of salmon behaviour of in a net cage, enabling simulations at both the individual and group level. The model at present simulates the effect of water temperature, light, feed and other individuals. The model demonstrates that schooling of salmon in net cages may be an emergent effect of simple behaviour rules of not colliding with close individuals and aligning with individuals that are further away.

- The Simulation and optimization framework (SimFrame) project. A system approach to build a framework for easy integration of knowledge, biological and technical models and monitoring equipment. The aim is to simulate, monitor and optimize all aspects of modern fish farming to develop better control and decision support systems. Tools from the fields of knowledge based system/artificial intelligence is used for identifying deviations, analyze probable causes for deviations, and suggest corrective measures.

- Knowledge of the correlation between physical properties of feed, breakage in the feeding systems and its effect on biological response on fish. Showing that feed with good quality for the feed system is not necessary giving the best growth of the fish.

At the end of 2010 the three large fish farming companies Marine Harvest, Salmar and Lerøy Seafood group joined CREATE as industry partners. This extend the competence and resources in CREAT and will be a valuable contribution towards meeting the vision and goals of the centre.

Vision and objectives

Vision: Understand, innovate and apply - creating technology for cultivation of the sea.

Objective: To combine world-leading fish farming companies and technology suppliers with prominent scientific research institutions into a centre with a common focus to innovate technology, products and solutions specifically to improve the grow-out phase of marine fish farming.

Secondary objectives

1 Understand fundamental biological preferences and behaviour of fish to set criteria for technology development
2 Develop improved management and operational protocols and systems based on the needs of the fish.
3 Develop equipment and systems to improve performance and safety of fish farming operations
4 Develop a framework for simulation, optimization and monitoring of all aspects of fish farming

Research plan and strategy

Fish farming is a truly multi-disciplinary industry, involving live animals living in floating farm constructions where they are fed and taken care of by humans using equipment and machinery. Modern, industrial-scale fish farms lie in coastal waters; they contain up to a million fish, which are fed high energy diets daily by automatic feeding systems. For successful farming, broad knowledge from a range of scientific disciplines such as veterinary science, nutritional science, biology, engineering, and information and communication technology is essential.

To develop new and improved solutions for marine finfish farming, the complex needs and behaviour of fish must be understood. This knowledge can then be used to develop operations, procedures and protocols to design technology and systems. This design approach is a strength of the centre and serves as the core research philosophy of CREATE. The wide range of expertise among the centre's partners, within both biological and technological aspects of fish farming, enables true multi-disciplinary research and development.

Each CREATE project involves personnel from several partners and project personnel physically work together at the centre and in the field, to ensure joint involvement, creativity and transfer of knowledge. At least two industry partners and two R&D partners are involved in all of the major research projects.

All the projects are organized with a project leader and a Steering Committee. The project leader will normally be selected from among the R&D partners. The Steering Committee will have members from relevant industry and R&D partners and CREATE management. The leader of the Steering Committee is normally selected from one of the industry partners.

CREATE focuses research and development within three main research pillars:

Equipment and constructions
The physical equipment used to farm fish.

Operation and handling
The process of executing and carrying out operations necessary to farm fish.

Farming intelligence
Control of the total process of farming by understanding the integrated use of equipment and the process of operations and combining this with knowledge of biological issues and the physical environment.

Within these three research pillars CREATE presently runs eight main projects, has thirteen PhD students and two post-doctoral researchers working within the centre. Figure 1 show the present projects (orange), PhD (blue) and post-doctoral topics (light blue), and their relation to the three main research pillars of CREATE.

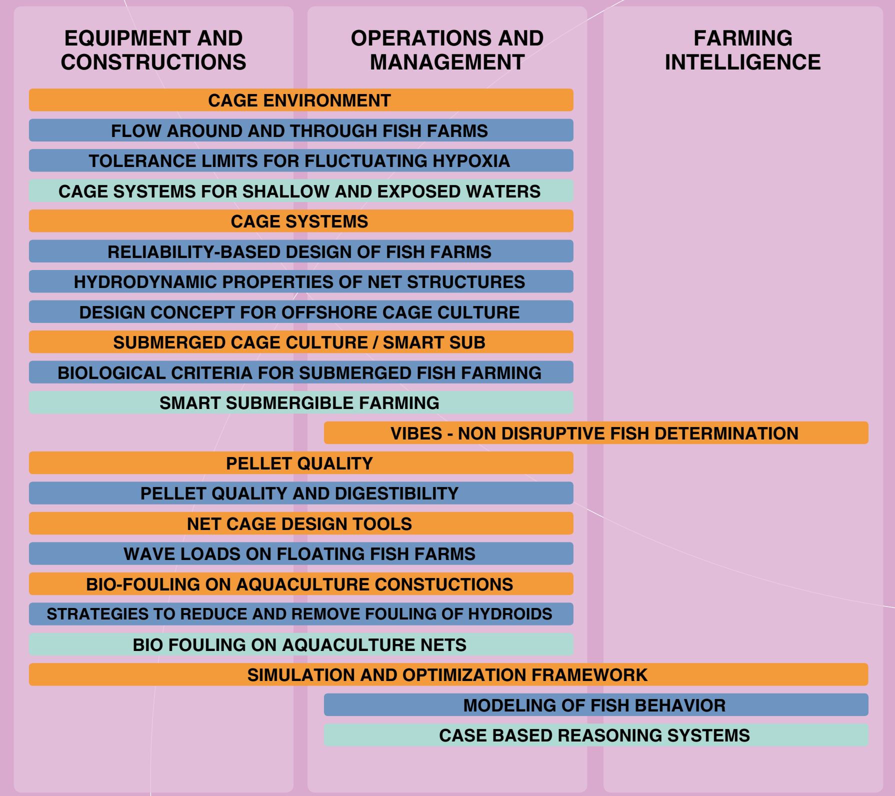
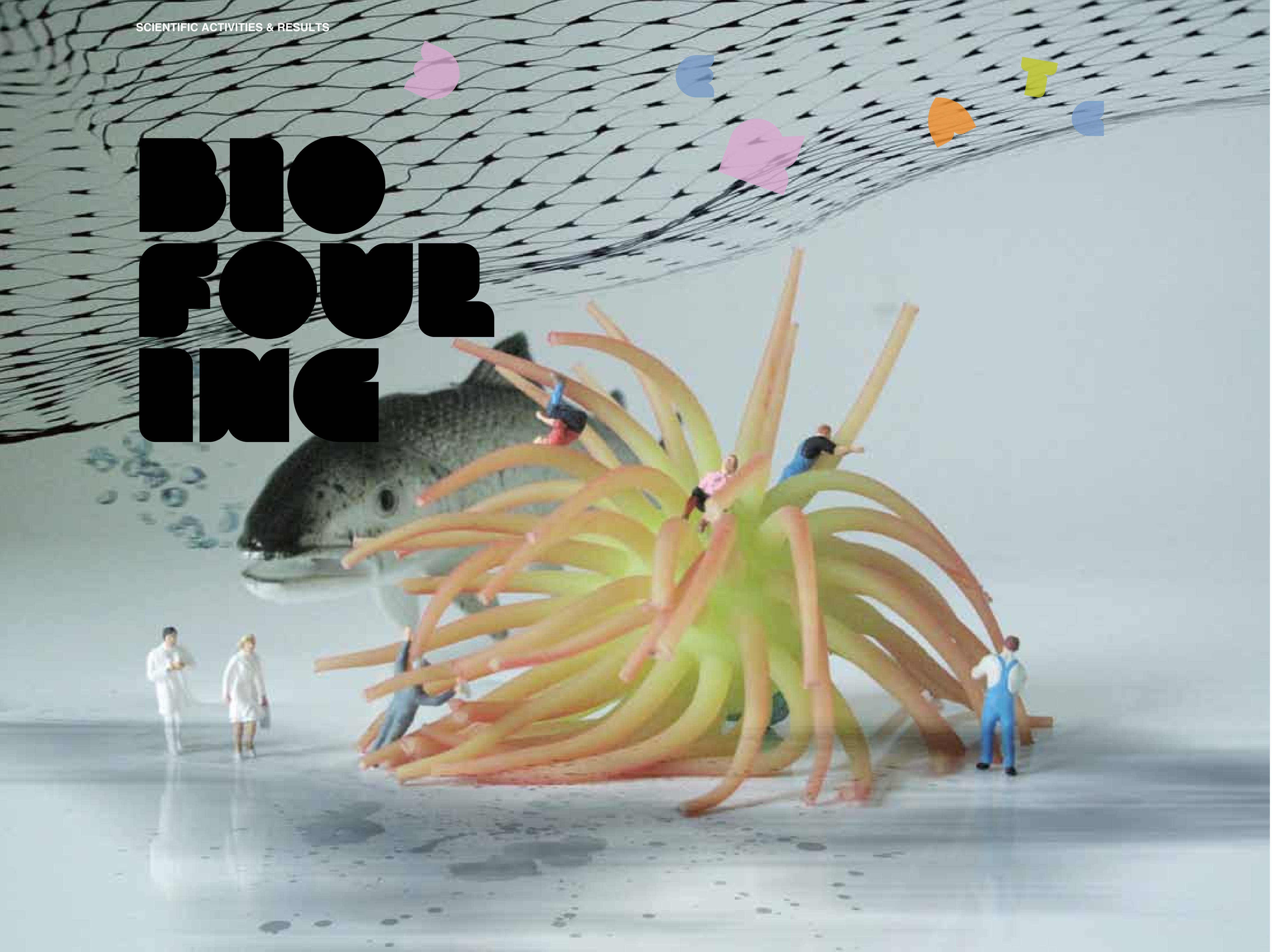


FIG. 1 : Overview of projects, PhD and Post-doc topics and demonstrators within CREATE



SCIENTIFIC ACTIVITIES & RESULTS

Biofouling on aquaculture nets

Researchers

Jana Guenther, Nina Bloecher, Isla Fitridge, Leif Magne Sunde

CREATE partners

AKVAgroup, Egersund Net, SalMar, NTNU, SINTEF Fisheries and Aquaculture

Additional collaborators

Steen-Hansen Maling, James Cook University (Australia)

Background

Biofouling poses a serious problem to finfish aquaculture worldwide, due to its negative impacts on cage deformation and structural fatigue, the restriction of water exchange across the net, and the reduction of water quality and subsequently fish health. Fish farmers use a multifaceted approach to control biofouling on nets, including the use of antifouling coatings on nets, underwater or shore-based net cleaning, net drying or changing, and the use of biological controls. The colonial hydroid Ectopleura larynx (syn. Tubularia larynx) poses a problem for the Norwegian finfish industry, because it occurs in large numbers on coastal fish farms in Southwest- and Mid-Norway from July to November. During the peak of the biofouling season, fish farmers need to clean their nets every 2 weeks, which is a resource-demanding task. Therefore, the aim of this project is to understand the settlement preferences, growth and feeding biology of the hydroid E. larynx using both laboratory and field experiments, and develop strategies to reduce, control and remove hydroids on aquaculture nets in a more efficient and sustainable way.

Methods

As part of the PhD study, a 1-year field study at the ACE facility at Tristein was conducted to determine the effects of immersion time, mesh size and cage on the accumulation of biofouling on net panels. The wet weight, net aperture occlusion, species composition and abundance on the nets were measured.

We also investigated the effects of the underwater cleaning of nets on the biofouling community. A preliminary experiment was conducted at a salmon farm near Frøya, and fouled net panels were cleaned after 9 and 11 weeks of immersion. In another experiment, coated and uncoated nets were cleaned 20 and 40 times and then immersed at the ACE facility for 14 weeks. The wet weight, net aperture occlusion and the major fouling groups were recorded.

To contribute to the development of novel cleaning methods to better control the growth of hydroids, the effects of heat and acetic acid treatments on the settlement of larvae, and the survival of juvenile and adult hydroids were determined.

Results and discussion

The biofouling species on the net samples of the 1-year study at Tristein are currently being identified, sorted and weighed. So far, over 80 fouling species have been identified. Preliminary results show a strong correlation between fouling wet weight and season, and all three factors (immersion time, mesh size and cage) play a role in determining the biofouling composition on the nets.

The preliminary experiment on the effects underwater cleaning showed that the majority of the hydroid-dominated biofouling could be removed, but some hydroids remained on the nets. Within 2 weeks, the cleaned nets accumulated the same weight of biofouling again, while the weight of the biofouling on the control nets doubled. In the second experiment, uncoated nets always had more biofouling than coated nets. Interestingly, while the amount of biofouling was higher on cleaned coated nets than the control nets, the number of cleanings (20 and 40 times) did not affect the amount of biofouling on the nets.

Short term immersions, ranging between seconds to minutes, in heated seawater (50 and 60 C) or acetic acid solutions (0.2 and 2.0%) were effective at preventing the settlement of larvae and reducing the survival of juvenile and adult hydroids. Novel cleaning methods and devices may utilise these results to effectively kill E. larynx on aquaculture nets. Further studies are needed to determine the necessity of removing the dead hydroids before further biofouling accumulates on the nets. This study will be conducted by NTNU Masters student Jemimah Etornam Kassah in 2011.

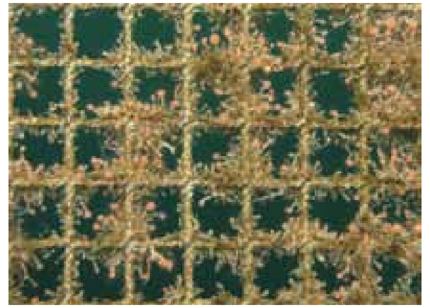


FIG. 2 : The problematic hydroid Ectopleura larynx on salmon cage nets.

Morten Malm

Title research project:
CREATE Board manager / Biofoul bioclean project

Education:
MSc

Company/insitution:
NTNU

Place of residence: Oslo, Norway
Place of birth: Oslo
Nationality: Norwegian

Leisure activities:
Outdoor activities Bicycling / Cross country skiing

3 research keywords:
R&D organising, Underwater light systems, Net maintenance

3 keyword about yourself:
Open minded, but goal oriented

Mohsen Bardestani

Title research project:
Wave and Current Loads on a Floating Aquaculture Cage

Education:
Msc in Marine Engineering

Company/insitution:
CeSOS

Place of residence: Trondheim, Norway
Place of birth: Busher, Iran
Nationality: Iranian

Leisure activities:
Jogging, Swimming, Fishing

3 research keywords:
Hydrodynamics, Numerical Simulation, Model Test

3 keyword about yourself:
Social, Responsible, Easy-going

PELLET QUALITY

SCIENTIFIC ACTIVITIES & RESULTS

Pellet Quality - optimal conveying and biological response

Researchers

Torbjørn Åsgård, Maike Oehme (PhD student), Mette Sørensen and Turid Synnøve Aas (project leader)

CREATE Partner:

AKVA Group, Nofima Marin, Lerøy Seafood Group, Marine Harvest, Salmar

Background

Feeds with high physical quality are required in order to minimise pellet breakage and dust formation during transport and storage of feed in modern aquaculture. However, in a previous CREATE-project (in collaboration with BioMar), we showed that the physical feed quality affects the biological responses in fish. The results showed that the most durable pellet type may not be optimal for the fish. We have also shown that during pneumatic conveying of feed from storage silo to sea pen, pellet breakage increases when increasing the air speed in the system. High air speed in the feeding system is commonly used to spread the pellets in the cage. A large spreading area of the feed is believed to be beneficial for feed intake and growth in the fish.

In the present trial, the aim was to measure the spreading of 7, 9, and 12 mm feed pellets in a pneumatic feeding system with rotor spreader at three different air speeds (20, 25 and 30 m/s). Two different spreaders were tested, both with two positions of the spreader outlet.

Methods

Three commercial feeds (provided by Skretting) of 7, 9 and 12 mm size was tested in a fish farm with 24 m^2 square steel cages, with the Akvasmart pneumatic feeding system. Ten kg sample was fed at each run, and the pellets were collected in styroform boxes that were placed from centre (at the spreader) and across the cage in two opposite directions (see Fig. 4). The spreading was measured at the air speeds 20, 25 and 30 m/s, and with the spreader outlet tilted up (normal) or tilted slightly down, and two different rotor spreaders were compared.

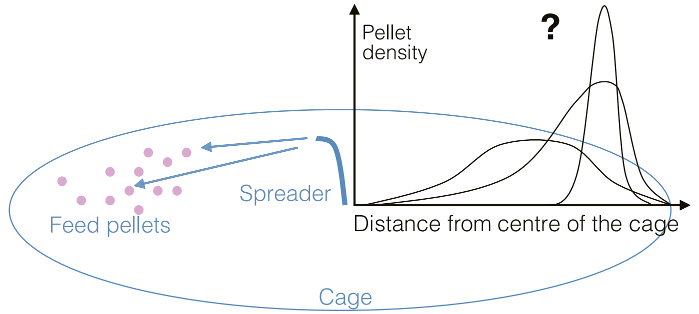


FIG. 3 : How are the feeds pellets distributed in the sea cage?

FIG. 4 : The pellets were collected in styroform boxes lined in a row across the cage.

Results and discussion

The feed was not distributed evenly in a symmetrical circle around the spreader, probably because of the stiffness in the pipe that transports the feed that caused the spreader to rotate in an asymmetric manner. This resulted in concentrated pellet distribution on one side of the spreader, and more diffuse pellet distribution on the other side (Fig. 4).

The distribution of feed pellets in the cage was similar for the three pellet sizes tested. The results show that the air speed increased the pellet spreading radius, particularly on the side with the diffuse diffusion (Fig. 5). A new spreader was tested, and showed larger spreading area than the original spreader. This is an improved version of the original rotor spreader, and the results showed that with this new spreader, lower air speed can be used to spread the feed, compared to using the other spreader. Tilting the spreader outlet down reduced the spreader area for both spreaders compared to the normal tilting position of the spreader outlet.

This work will be part of Maike Oehme's PhD thesis.

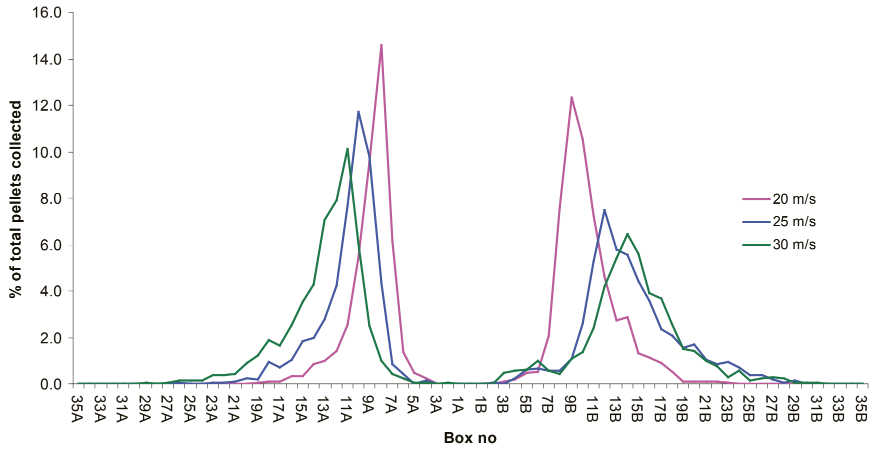


FIG. 5 : Amount of pellets (% of total pellets collected) in each box at three different airs speeds. Boxes on one side of the spreader are denoted A, boxes on the other side are denoted B, and the spreader was in the centre.

Tore Kristiansen

Title research project:
Smart submergence of sea cages with salmon and cod to improve profitability, minimise environmental impact and ensure welfare (SMARTSUB)

Education:
Fisheries biologist. Dr. Scient

Company/insitution:
Institute of Marine Research

Place of residence: Vikersund, Norway
Place of birth: Molde, norway
Nationality: Norwegian

Leisure activities:
Mountain hiking, skiing, reading

3 research keywords:
Fish welfare, behavior, aquaculture

3 keyword about yourself:
Curious, broad interests, patient

Zhao HE

Title research project:
Fish Farming Constructions

Education:
Msc. in School of Naval Architecture, Ocean and Civil Engineering, Shanghai Jiao Tong University

Company/insitution:
Institute of marine technology in NTNU

Place of residence: Trondheim, Norway
Place of birth: China
Nationality: China

Leisure activities:
Ski, table tennis, football, Chess

3 research keywords:
Aqualture, Wave current interaction, CFD

3 keyword about yourself:
Patient, Passionate, Persistent

Simulation and Optimization Framework - SimFrame

CREATE partners

SINTEF Fisheries and Aquaculture (SFH) – project leader

Institute of Marine Research (IMR)
NOFIMA Marin
NTNU
SINTEF ICT
AKVAgroup
Egersund Net
Erling Haug
SALMAR

Background

The overall goal of the SimFrame project is to develop a framework for simulation, optimization and monitoring of all aspects of modern fish farming. This will enable researchers and industry to build more complex models by utilizing standardized interfaces and standard components. While keeping the overall goal in mind, it has been deemed important to illustrate the concept of such a framework by developing demonstrators. The demonstrators are used both for gaining experience and analyzing functional requirements, as well as a basis for discussions with CREATE partners and others. As the scope of SimFrame is the grow-out phase in floating fish farms, the demonstrators focus on decision support tools on a regional level. To ensure that this work addresses issues that are important for the industry, close cooperation with SalMar Farming is established. This cooperation includes functional requirements as well as access to operational data from SalMar sites.

The demonstrator which is targeted is shown in Fig. 6.

Methods

Usage scenarios for decision support systems have been the basis for the demonstrator development. These scenarios were developed as part of the 2009 SimFrame activities. Analysis and reduction of mortality was selected as a focus area, and the need for additional data/increased data detail compared to current industry practice was analyzed in cooperation with SalMar Farming. Methods and tools from knowledge based systems

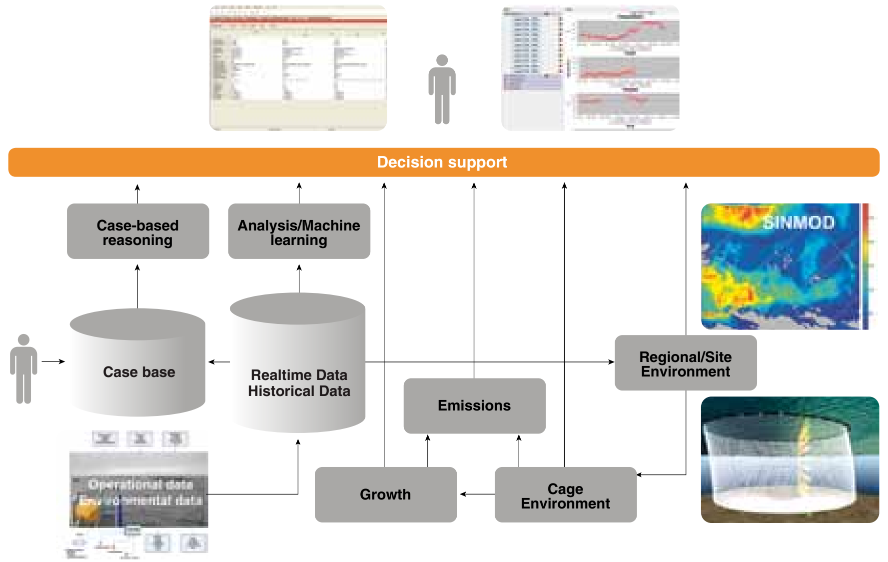


FIG. 6 : Decision support demonstrator

were investigated with respect to the mortality area, and Case-based Reasoning (CBR) was tested and chosen for further development in 2011. A student project at the NTNU Department of Computer and Information Science also investigated whether machine learning methods could be feasible within this area.

The work on developing common ontology and data models has been the basis for establishing integration of data from various sources. A pilot database has been implemented in order to provide historical and current data flows for the demonstrator. The database incorporates geo-location of data and is currently receiving operational and environmental data from the ACE (AquaCulture Engineering) industry scale research site. This database will also be a basis for future model development and validation.

The demonstrator is developed using agile development methods and Open Source tools where applicable.

Results and discussion

The method of developing demonstrators as a basis for designing the framework has provided valuable input for functional requirements. It has also provided a basis for selecting and testing software components for a more detailed description of recommended framework architecture. Detailed demonstrator development focus on two main areas:

- Integration of numerical models
- Knowledge based systems (CBR) with mortality as an example (Fig. 7)

The following models are chosen for integration (see also figure X1):

- SINMOD, capable of simulating sea currents, temperature, oxygen levels, propagation of infective agents etc. (developed at SINTEF for several decades, using various development platforms)
- IMR growth model (developed using MatLab)
- NOFIMA emission model (developed using Stella)

The demonstrator will use predictions from SINMOD as input for the growth and emission models, and provide the user (regional management) with prognosis data in addition to historical trends. The CBR mortality part combines detailed analysis data from operations with environmental data. A simple application for recording more detailed data on operations like deployment, sorting, de-licing and delivery will provide more data for further development and testing of methods and software components.

To ensure a good basis for discussions, the demonstrator user interface is developed to a level where it is possible to illustrate future applications. This will also be a basis for CREATE industry partners for evaluating possible new products.

The continued step-wise development of an industry demonstrator will ensure focus on important issues and short-term results, as well as contributing to the long-term goal of establishing a simulation and optimization framework. This will ensure innovation through:

- Providing a platform for development of new types of models, including model validation and recommended tools for development
- Lay the foundation for new products for industry partners
- Testing and development of new methods as a basis for future solutions

In addition to the demonstrator and framework activities, there will be an increasing focus on dissemination and publications.

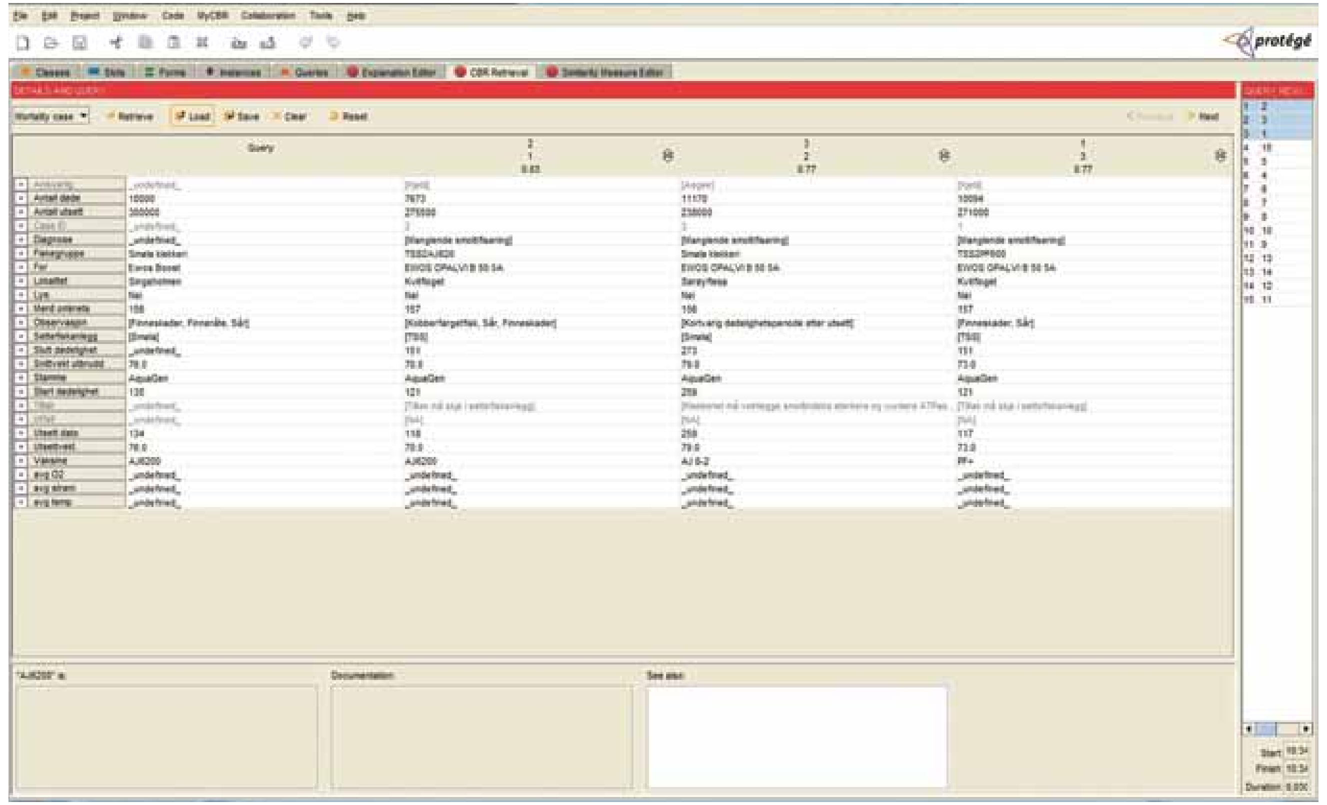


FIG. 7 : CBR system for mortality

Peng Li, 26

Title research project:
Hydroelastic behaviour of the floater of an aquaculture cage in waves and current

Education:
Ph.D candidate in Department of Marine Technology NTNU. MSc in Naval Architecture and Ocean Engineering from Harbin Engineering University, China.

Company/insitution:
Department of Marine Technology, NTNU

Place of residence: Trondheim, Norway
Place of birth: Hei Longjiang, China
Nationality: Chinese

Leisure activities:
Skiing, table tennis and badminton

3 research keywords:
Fish farming, hydroelastic, waves and current

3 keyword about yourself:
Perseverance, meticulous and friendly

VIBES laser triangulation for fish size measurement – a feasibility study

Researchers

Morten Malm and Bjørn Pommeresche at AKVAgroup, Trine Kirkhus, Kirstin Kaspersen, and Tom Kavli at SINTEF ICT.

Background

Knowing the size and size distribution of fish in each cage in a fish farm is of importance to optimize the farming. Knowing the size distribution is a useful tool for feeding, knowing when to split cases, do the slaughter, and to be able to meet posted sales orders.

Methods

Laser triangulation uses a laser plane combined with a camera to measure 3D profiles of the fish. As the fish swim trough the laser illumination plane we can build up a complete 3D image of the fish and thereby better segment individual fish in a shoal.

Results and Discussion

To measure fish sizes and the distribution of size, a representative selection of individual fishes needs to be segmented and measured. A model widely used for this needs input about the nose-tail length and the belly-back thickness to calculate the fish's weight. Due to the large variety in light reflection form fish skin both within one fish and between fish; we have previously concluded that segmentation of the fish based on stereo cameras is hard to automate in dense fish shoals. Therefore we have confidence in measuring the 3D profile of fish instead using a laser triangulation system.

Challenges in using laser triangulation for measuring fish under water are:

- reflection from the fish's skin is unpredictable due to large range in color and intensity of the skin and its highly shining surface
- influence from strongly varying surrounding light
- scattering of light by particles in the water
- near infra red wavelengths which is invisible to the fish and to humans are also greatly attenuated in water
- estimation of the fish' swimming velocity

Tests have been performed using dead fish in water in an aquarium at SINTEF. The main results are:

- By acquiring a sequence of 3D profile of the fish, chances of getting enough good data to estimate the fish size based on the models used by AKVAgroup today.
- Tests in real world environment are suggested to reveal other potential challenges as early as possible in the project.

Future work will consist of testing in real fish farming environment.

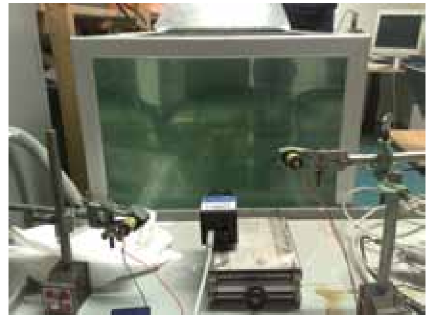
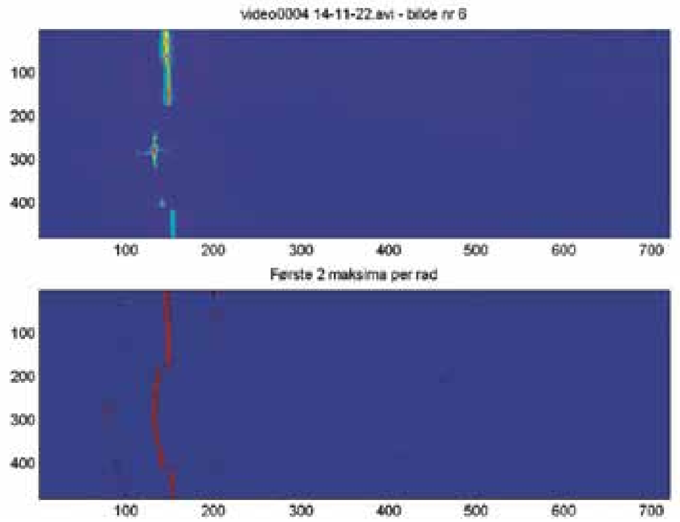


FIG. 8 : Test in aquarium of laser triangulation. A fish is submerged into the tank, laser and camera is used to measure the fish's profile.

FIG. 9 : Upper image is a camera image showing the projected laser plane used for triangulation and 3D measurement. Below is the laser line reflected from the fish automatically segmented.



Modelling and simulation of fish behaviour in aquaculture production facilities

PhD fellow
Martin Føre, SINTEF Fisheries and Aquaculture

Supervisors
Jo Arve Alfredsen, Department of Engineering Cybernetics, NTNU

Tim Dempster, SINTEF Fisheries and Aquaculture/Department of Zoology, University of Melbourne

PhD-focus
Investigating the behaviours of Atlantic salmon (Salmo salar L.) in aquaculture production facilities through individual-based techniques (mathematical modelling and acoustic telemetry).

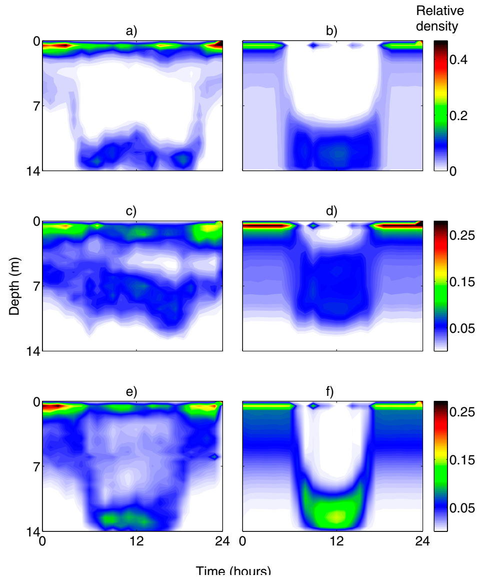
Background
The first part of this project concerned the development of an individual-based mathematical model of the behaviour of Atlantic salmon in sea-cages. This model was based on both qualitative knowledge on fish behaviour from literature and data collected on the group/population level in salmon farms, and has been verified against data collected by the IMR. Due to the individual-based nature of the model, it is possible to derive behavioural data on both individual and group levels. Possible applications of the model include estimation of welfare, in silico testing of new management strategies and technologies, and investigations into possible emergent effects arising due to changes in e.g. fish density or cage size.

The second part of the thesis revolved around the development of novel acoustic transmitter tags that were designed to observe the feeding behaviour of individual salmon in a cage-rearing situation. The transmitters were tested in both small cages holding low densities of fish (controlled experiments), and larger cages with higher fish density (commercial scale experiments). Possible future uses of the developed transmitters include obtaining novel information on the individual feeding behaviours of salmon or other species and as components in a system for monitoring or controlling feeding strategies.

Methods
Modelling: The mathematical model simulates the way in which individual salmon respond toward the cage structure, feed, water temperature, light, and other individuals. Each of these response patterns were computed separately and summed using a weighted sum to simulate trade-offs between external influences. As a consequence of lacking data on individual salmon, some of the parameters had to be derived by tuning the model output to group level data assembled at fish farms.

Telemetry: Based on video recordings of salmon engaged in feeding activities and literature studies, vertical movement dynamics and activity levels were identified as two of the most promising behavioural traits with respect to reflecting feeding activity. Consequently, one of the transmitter types was based on depth sensors, while the other type contained an accelerometer. Suitable algorithms for the two transmitter types were developed on basis of the video recordings and laboratory investigations.

FIG. 10 : Observed and simulated vertical distribution of salmon in sea-cage for three periods in autumn. a), c) and e); observations by Johansson et al. (2006), b), d) and f); model simulation data. The vertical axes denotes cage depth, the horizontal axes represent time in hours, while different colours mark different fish densities.



Results and Discussion

The mathematical model was able to predict the patterns of vertical distribution observed by Johansson et al. (2006) in a 15m deep cage with relatively high precision. Fig10 displays a comparison between the data from Johansson et al. (2006) (left column) and the model predictions (right column). As the environmental conditions registered during the original experiment were used as input to the model, this result suggests that the model replicated the mechanisms behind the behavioural response.

Furthermore, the model was able to predict the formation of schools in Atlantic salmon populations based on a set of simple rules, which dictated the fish to avoid hitting their neighbours while also avoiding the cage wall. These rules were based on the assumption that schooling in salmon is a behaviour emerging due to density-dependent effects rather than the result of a cognitive desire of the salmon to swim in school formation. Fig. 10 shows the swimming trajectories of 10 fish selected at random from a population of 1000 individuals simulated over 1000 seconds. The fish were initially randomly distributed (Fig. 11 a), and eventually ended up swimming in a circular schooling pattern (Fig. 11 d).

The depth based acoustic transmitter tags showed promise in discerning between feeding behaviour and behaviours in the absence of feed (Fig. 12). A review of the entire dataset from the experiments revealed that feeding events often were accompanied by individuals exhibiting fluctuations in the vertical positions of the fish (Fig. 12 a, b) and high vertical movement speeds (Fig. 12 c, d). Such patterns in the telemetry data generally occurred more frequently in the presence of feed than outside feeding events, suggesting that they reflected feeding behaviour.

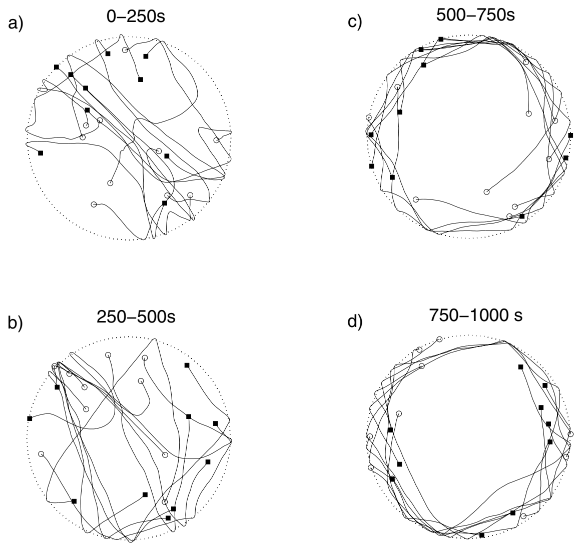


FIG. 11 : Swimming trajectories (solid lines) for ten fish randomly selected from a population of 1000 fish simulated in a sea-cage (dashed line) over four 250 s time intervals. Open circles denote initial positions, while filled squares mark end positions.

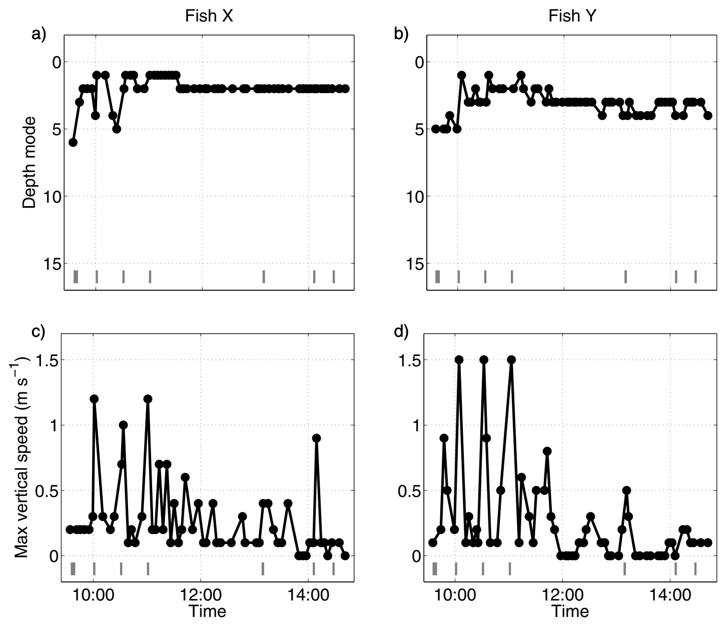


FIG. 12 : Telemetry data from two fish during a hand-feeding experiment (09:30 – 15:00) containing seven feeding events. Horizontal axes represent time, while vertical axes denote most frequently occupied depth (a and b) and highest vertical movement speeds (c and d) since last transmission. Grey bars denote feeding events.

Hans Vanhauwaert Bjelland

Title research project:
CREATE Simulation and optimization framework (SimFrame)

Education:
MSc. Industrial design, PhD Interaction design

Company/insitution:
SINTEF Fisheries and aquaculture AS

Place of residence: Trondheim, Norway
Place of birth: Lørenskog
Nationality: Norwegian and Belgian

Leisure activities:
Being with my three young children

3 research keywords:
Decision support systems, Human Factors, and interdisciplinary research

3 keyword about yourself:
Curious, engaged and structured

Lars Gansel

Title research project:
Influence of porosity and continuous blowing on the flow around bluff bodies (Fish cages)

Education:
Environmental scientist

Company/insitution:
SINTEF Fisheries and Aquaculture

Place of residence: Trondheim, Norway
Place of birth: Oldenburg, Germany
Nationality: German

Leisure activities:
Cycling, Snowboarding, Music

3 research keywords:
Hydrodynamics, fish welfare and water exchange

3 keyword about yourself:
Creative, practical and social

Cage Environment

Researchers

Frode Oppedal (IMR), Mette Remen, Rolf Erik Olsen, Thomas Torgersen, Jan Aure, Jannicke Vigen, Jason Bailey (IMR), Pascal Klebert, Pål Lader (SINTEF Fisheries and Aquaculture), Lars Gansel (NTNU) and Turid Synnøve Aas (Nofima).

CREATE Partners

Egersund Net AS, Erling Haug AS, AKVAgroup, Institutte of Marine Research, SINTEF Fisheries and Aquaculture, Centre for Ships and Ocean Structures (CeSOS)

Background: Fluctuating hypoxia and flow field in sea cages.

The overall objective is to improve standards for oxygen management in marine net cages through the establishment of limiting oxygen levels and understanding of water flow around and through the combined net, cage and fish biomass. These findings will aid to ensure fish welfare and efficient production during grow-out phase in seawater.

The combined effects of variable flow of incoming waters, uneven oxygen consumption by the fish, dynamic changes in fish biomass and seasonal oscillating abundance of oxygen create fluctuating hypoxia within salmon cages today. To date, conditions of constant hypoxia have been investigated in respect to important production parameters while the impact of fluctuating hypoxia on the fish is largely unknown. To date, flow dynamics through net panels have been studied to a limited degree, while extensive description of the flow dynamics through the cage and cage configurations are absent. In particular, effects on the flow from the fish biomass itself and their behaviour are lacking.

Experimental cages, tanks and methods

Fluctuating oxygen levels effect on salmon production parameters, physiology and welfare were investigated in large seawater tanks within the Tank Environmental Lab at IMR-Matre. Habituation and acclimation rates were studied at repeated fluctuating hypoxic levels from 40 to 70% oxygen saturation. Cage structure, net panels, fish biomass and behavioural effects on water flow were studied using multiple facilities: experimental cage environmental lab and commercial cages; tank environmental lab; experimental flow through tanks; towing tanks. A range of instruments were used to monitor environment and flow patterns.

Results from fluctuating hypoxia trials

From the first experiment it is revealed that 40-70% oxygen saturation (DO) is within the zone of environmental hypoxia for Atlantic salmon post-smolts fed to satiation at 16°C. The impact of hypoxic periods on feed intake and physiology increased rapidly in accordance with hypoxia severity, and appetite proved to be a sensitive indicator of hypoxia. Based on feed intake, 70% was considered as a mild hypoxia that can be accepted in periods, 60% was considered as a moderate hypoxia that can be tolerated if hypoxic periods are short (<2 hours) and not too frequent (<4 times per day), while 50 and 40% DO represented levels that cannot be accepted based on growth, health and welfare. Severe inhibition of appetite, strong stress response, lesions and even mortalities were observed. Based on feed intake the ability to cope with hypoxia did not increase over time at hypoxic levels of 40 and 50%, but the initial stress response diminished and the ability to utilize normoxic periods for feeding improved (Fig. 13). The 60 and 70% groups displayed stronger compensatory feeding during normoxic periods that may be explained by a habituation to the frequent and regular occurrence of hypoxic periods. The innovative aspects of the results will be improved production and welfare of farmed Atlantic salmon.

Results from flow through and around stocked cages

Fish schooling behaviour reduced the water flow within cages, changed flow direction and generally generated hypoxic levels compared to reference measurements outside. Changes in the flow field around a circular cage stocked with salmon forming a circular school with most fish swimming in the same direction were pronounced. Analyses indicated a horizontal outward flow from the centre of the cage, a negative vertical flow in front of the cage combined with a positive vertical flow behind the cage. The caged fish appear to have an influence on the flow previously not described. Experiments using colour dye (Fig. 14) illustrate the effect of fish movement. The photo sequence demonstrate how surface water masses are pulled in and down in the centre of the cage. The results revealed an unexpected flow pattern created by the fish themselves that may aid in water exchange during slack conditions.

International cooperation

Øystein Patursson at research station of Fiskaaling, Faroe Islands has taken part in some of the field measurements during 2009 and will publish the results in cooperation. Siri Rackebrandt used data from the project for partial fulfilment of her Bsc at Carl von Ossietzky University Oldenburg, Germany. Kim Thompson at University of Stirling, Scotland took part in immunological method development within fluctuating hypoxia trials.

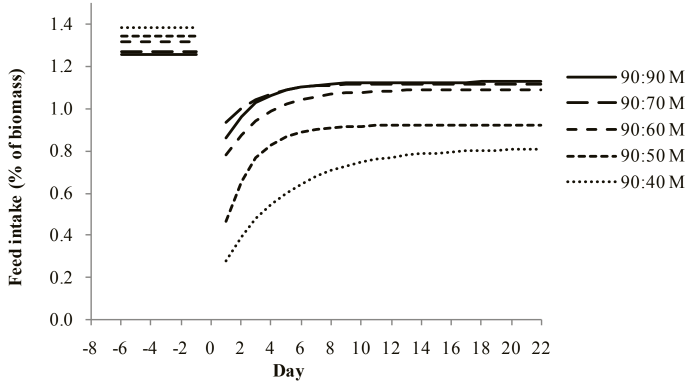


FIG. 13 : Three-parameter asymptotic exponential curves fitted to the average total feed intake per day (% of biomass) in Atlantic salmon post-smolts at 16 °C exposed to fluctuating levels of hypoxia for 2 hour periods at levels from 40 (90:40) to 70% (90:70) compared to control group at constant 90% (90:90) oxygen saturation. Day 0 is commencement of the fluctuating hypoxia regime.

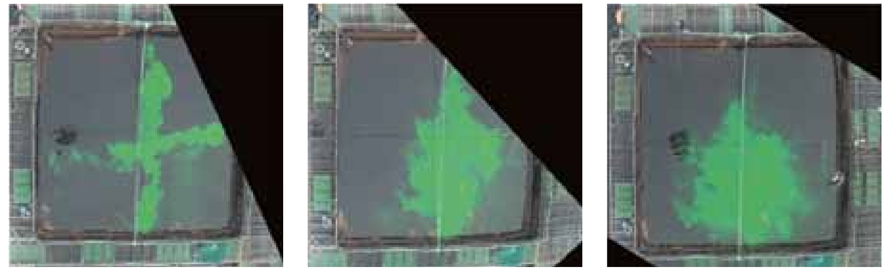


FIG. 14 : Colour dye is distributed as a cross over the centre of a cage and during the following minutes the surface water display a circulating pattern with down-dwelling water into cage centre set by the schooling of the salmon biomass few metres below surface. Photos: Lars Gansel.

Mohamed Shainee

Title research project:
Optimum design concept for offshore fish farming

Education:
MSc. in Marine Technology &
MSc. in Marine Management

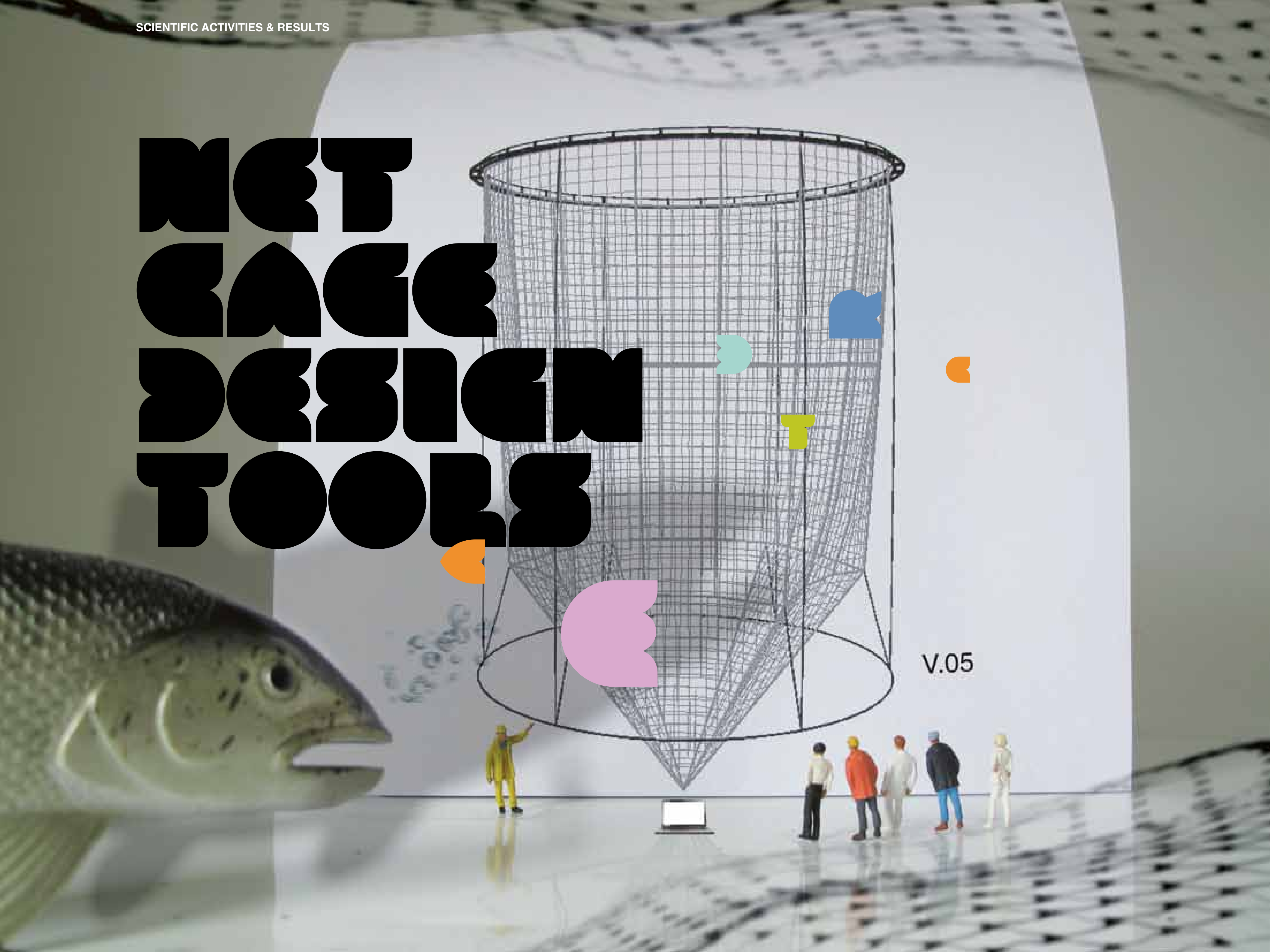
Company/insitution:
Department of Marine Technology, Norwegian University of Science and Technology (NTNU)

Place of residence: Trondheim, Norway
Place of birth: Maleí, Maldives
Nationality: Maldivian

Leisure activities:
Various sports and travelling

3 research keywords:
Offshore aquaculture, Cage design, Design framework

3 keyword about yourself:
Active, social and wise



NetCageDesignTools

Researches

Finn Olav Bjørnsen, Martin Føre, Brad Schofield, Østen Jensen

CREATE Partners

Egersund Net, SINTEF Fisheries and Aquaculture

Background

Existing commercial software is not suitable for designing net cages. The main reason is that they are in general focusing on verification of forces in the entire farm, including mooring and cages. This leads to long simulation times, limited number of design options and often very coarse and simplified net models. Egersund Net desired a numerical tool for easy and quick design of new net cages. The numerical tool should also give results that can be used when certifying the net cages.

Methods

The main method used for the project has been a scrum inspired agile method. The project group has had regular meetings every two weeks where we have looked at a list of requirements for the software and prioritized what is feasible to implement during the next two week period. To ensure feedback from the customer we have had a meeting with Egersund Net where we presented the software so far and gathered feedback on wanted functionality and future priorities.

Results and Discussion

The result so far is a demonstrator currently at version 0.5. The demonstrator consists of a graphical user interface where users can specify the physical dimensions of a net cage, the physical properties of the net and ropes, and environmental loads like current and waves. The software takes this input and translates it to an input xml file for the fhSim Core 1.0, which then takes over and runs a simulation on the specified net structure. Currently we can simulate circular nets, these nets can be coned and stretched. Supportropes can be added vertically and horizontally. The weight system can be either individual weights connected to the crossropes or a sinkertube, the weights can be calculated automatically or given manually. The demonstrator supports environmental conditions through current simulations on the net structure as well as regular and irregular waves.

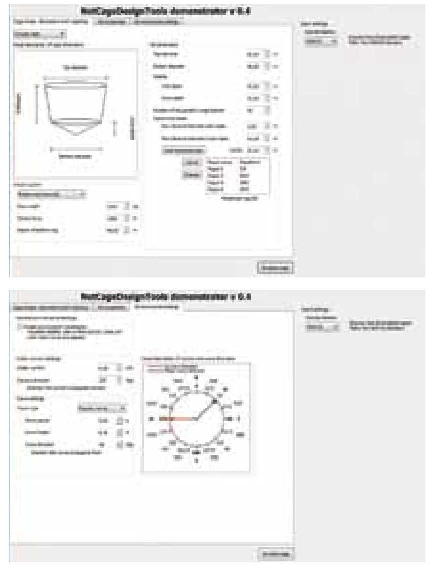


FIG. 15 : Screenshot of tabs in the NetCageDesignTools demonstrator GUI.

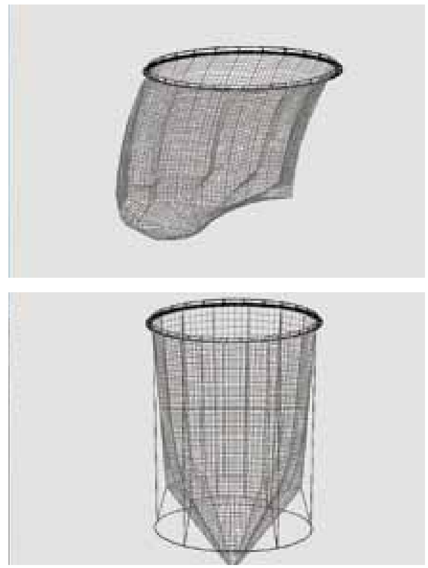


FIG. 16 : Results from simulation

Individual variation in vertical swimming behaviour and growth in Atlantic salmon (Salmo salar L.) subjected to submergence in sea-cages

PhD fellow
Øyvind J. Korsøen (IMR)

Supervisors
Dr. Tim Dempster (SFH), Dr. Tore S. Kristiansen, Dr. Frode Oppedal

Background

Individual variation in behaviour and growth rates is likely to provide greater insight into the coping ability and welfare status of salmon under submerged culture. To study variation in individual ability to cope with negative buoyancy, and relationships between behaviour and growth, we implanted pressure sensor data storage tags (DSTs) in salmon in submerged and control cages to measure swimming depths. We hypothesized that submerged individuals with low growth rates would exhibit atypical vertical positioning and lower feeding responses than submerged individuals with high growth rates and fish in the control cages with surface access. Large individual variation exists in the coping repertoire of Atlantic salmon (Salmo salar) in response to environmental changes in sea-cages. We compared the growth and behaviour of individual salmon within and between submerged (no surface access) and standard cages (with surface access), using high resolution data storage tags (DSTs).

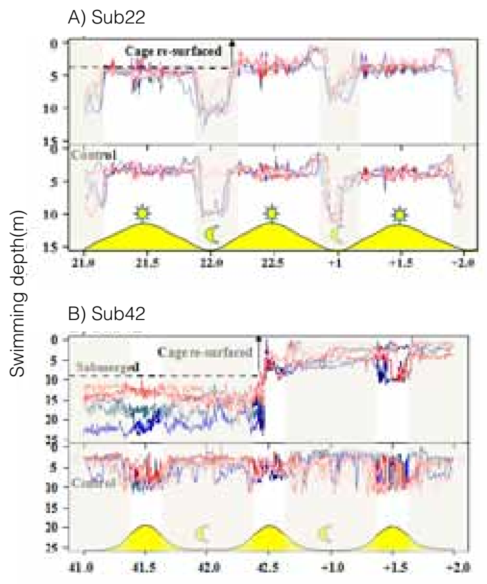
Methods

Two commercial-scale experiments involving different challenges were conducted; one with 0.5 kg salmon (n = 2300), submerged below 4 m for 22 days with 24 h continuous light (Sub22), and the other with 4 kg salmon (n = 4800) submerged below 10 m for 42 days with natural light (Sub42).

Results and Discussion

Shallow, short and illuminated submergence permitting structured schooling during the night resulted in a diurnal pattern similar to control fish (Fig. 17a), although with slightly less variation among individual swimming depths at night and more variation during the day. Individuals with highest growth rates tended to swim deeper at night at end of the period of submergence. Salmon exposed to longer, deeper and dark submergence conditions displayed more irregular diurnal swimming patterns (Fig 17b). Large variations in coping abilities were evident, likely as a result of differing levels of negative buoyancy among fish, possibly caused by deflated swim bladders. Submerged individuals with high growth rates swam either with a large amplitude diurnal cycle, or deeper during the day compared to fish with lower growth rates. In addition, submerged fish with high growth rates displayed more vertical activity during feeding. Short-term, illuminated and shallow submergence resulted in little behavioural deviation compared to the control fish, indicating that it did not compromise welfare. However, the more challenging deep, dark and long-term submergence with large differences in individual coping abilities and shifts in diurnal swimming patterns compared to control fish, suggest compromised welfare for individual fish that coped poorly.

FIG. 17 : Swimming depth for fast and slow growing salmon at the end of the experimental periods in the two experiments A) Sub22 and B) Sub42. The upper frame is the submerged cage and the lower frame is the control cage with constant access to the surface. The bluish lines show faster growing fish, and red/pink show slower growing individuals. Grey areas and the moon indicate nights and white and sun are the days. The horizontal dotted lines indicate the net roof on the submerged cages.



Smart submergence of sea cages with salmon and cod to improve profitability, minimise environmental impact and ensure welfare - SMARTSUB (2010-2013)

Researchers

Tore S Kristiansen (project leader), Øyvind Korsøen (postdoc), Frode Oppedal, Jan Erik Fosseidengen, Tim Dempster, Østen Jensen.

CREATE Partners

Instiutte of Marine Research, SINTEF Fisheries and Aquaculture, AKVA Group

Background

Submergence of fish farms may solve several of the substantial operational challenges that exist in surface-based fish farming, including those related to heavy storms, ice, algal and jellyfish blooms, salmon lice infestations, unsuitable temperatures, and bio-fouling of net cages. As salmon have an open swim bladder, they need to fill the swim bladder by gulping air at the surface. Experiments within CREATE with cages of salmon submerged for long-term below 10 m depth for 42 days showed that this negatively affected the fish behaviour and performance (see project SUBFISH). This was related to deflating of the swim bladder over time, creating increasing negative buoyancy and tilted swimming during night. However, cages submerged below 3 m depth in 22 days and given artificial light did not alter salmon behaviour and performance significantly.

Farmed cod sexually mature at sizes of 1-1.5 kg leading to reduced appetite, negative or stagnant growth, increased mortality, longer production time and poor welfare. Thus, reduction of sexual maturation in cod aquaculture is a critical for cost-effective and sustainable farming. Continuous light treatment in indoor tanks stops sexual maturation in cod, but the same treatment in sea-cages has proved only partly effective; the maturation process is delayed for several months but most fish become mature prior to harvest. It appears that artificial light manipulation is ineffective in surface-based sea-cages as natural sunlight levels override the artificial light field during the day and thus the fish still receive a seasonal photoperiodic cue. By submerging sea-cages below 20 m depth, natural illumination levels are reduced by at least 90% and artificial light may be experienced as true continuous light by cod. This opens a new possibility: combining submergence with artificial lights to stop sexual maturation of cod.

Methods

1 : Do salmon in deep submerged cages perform well over time given artificial light or opportunities to refill their swim bladders? This question will be solved through 3 times 2-month trials at IMR-Matre to test and validate deep, long-term submergence where salmon are also given 1) artificial light, 2) submerged surface (air pocket), or 3) periodical surface access The experiments will start in autumn 2011.

2 : Does artificial photoperiodic treatment given to cod in deep submerged cages reduce sexual maturation and what are the implications for cost-effectiveness and welfare? Further, are the suggested lifting and lowering rates of sea-cages suitable? These questions will be addressed through a 1-year cod trial with artificially illuminated cages sub-merged below 20 m which started in July 2010 at IMR-Austevoll.

Results and Discussion

The salmon experiments has not started, but the cod experiments already show promising results, where artificial illumination in submerged cages resulted in stopped or very little gonad maturation in cod with corresponding improved growth rates and performance, compared to untreated fish in similar cages. However, it is too early to tell how strong this will effect be in across 1-year of production (see Fig.18). This experiment will continue for another 6 months to control for delayed maturation and overall performance.

FIG. 18 : Female gonads sampled on 23 February 2011 in light treated (to the right, small) and control cages (to the left, big gonads).

Organization

The centre is organized as an independent part of SINTEF Fisheries and Aquaculture, with its own Board, a Scientific Committee and a Centre director. CREATE have activities within three areas: Research Projects, Education and Innovation. Figure 19 show the organisation and relationships of the centre. The organisation and implementation of the centre is governed by a consortium agreement, describing the obligations and rights of the partners, as well as roles and responsibilities of the different parts of the organisation. CREATE is physically located at SINTEF Sealab, SINTEF Fisheries and Aquaculture is the host institution for the centre, and the Centre Director is employed at SINTEF Fisheries and aquaculture.

The Board of directors are has a majority of members from the industry partners and consists of in total six members, one member representing the Host Institution, one representing the research partners and four members representing the industry partners. The Board takes the decisions on organisation, budget, activities and working plan for CREATE.
In 2010 the following people were members of the board:

- Morten Malm, AKVA group ASA, Chairman of CREATE
- Karl A. Almås, SINTEF Fisheries and Aquaculture
- Tore Kristiansen, Institute of Marine Research
- Ove Veivåg, Egersund Net AS
- Bjørn Karlsen, Erling haug AS
- Arnfinn Aunsmo, Salmar ASA

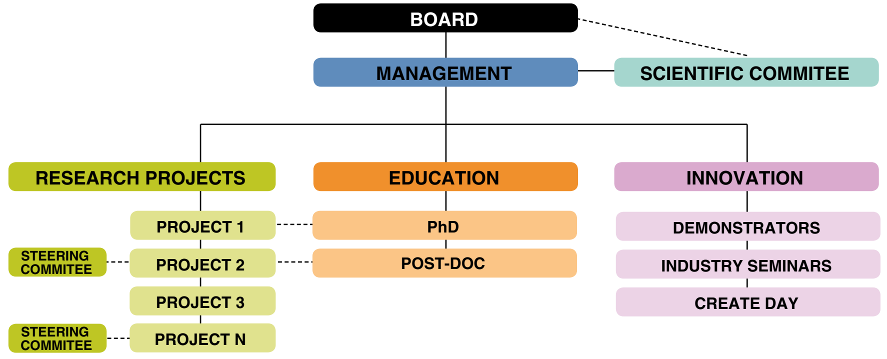


FIG. 19 : The organization of CREATE

The Scientific Committee (SC) has members from all partners, research and users. The mandate of the Scientific Committee is to ensure development of new project ideas, new projects, and overall quality and scientific control of the research carried out in the centre. The Scientific Committee makes recommendations for the research plan and projects to the Board of directors. In 2010, the following people were members of the SC:

- Kristine Brobakke, Erling haug AS
- Geirmund Vik, Egersund Net AS
- Morten Malm, AKVA group ASA
- Olav Breck, Marine Harvest Norway AS
- Harald Sveier, Lerøy Seafood group ASA
- Arnfinn Aunsmo, Salmar ASA
- Torbjørn Åsgard, NOFIMA Marin AS
- Pål Lader, SINTEF Fisheries and Aquaculture
- Tom Hansen, Institute of Marine Research
- Tom Kavli, SINTEF Information and Communication Technology
- Jo Arve Alfredsen, Department of Engineering Cybernetics, Norwegian University of Science and technology (NTNU
- Torgeir Moan, Centre for Ships and Ocean Structures (CeSOS), Norwegian University of Science and technology (NTNU)

The projects are set up with a project leader and a Steering Committee (SteCo). The project leader has the responsibility for carrying out the project, while the Steering Committee has the responsibility to follow up on progress and objectives. Normally, the project leader is selected among the research partners and the leader of the Steering Committee is always from one of the user partners. The number of people in the Steering Committee depends on the size and type of the project, and ranges from two to seven. The Centre Director is a member of all Steering Committees.

Education

Centre for Ships and Ocean Structures and NTNU Department of Engineering Cybernetics have the main educational responsibilities for PhD and MSc candidates. In addition, PhD and MSc candidates are educated at University of Bergen through collaboration with Institute of Marine Research and Norwegian University of Life Science through collaboration with NOFIMA Marin.

Innovation

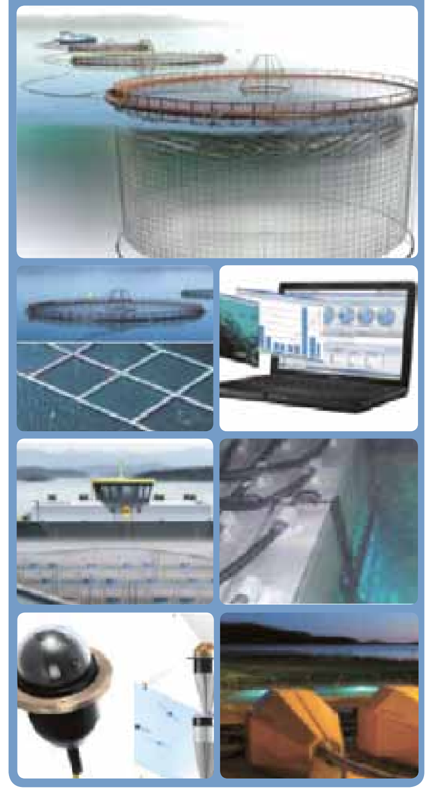
Once every year CREATEday is organized, which serves as a meeting place for innovation, presentation of results, exchange of ideas and creation of new projects.

SINTEF Fisheries and Aquaculture - facts

- Vision: Technology for a better society
- Perform basic and applied research for commercial customers as well as governmental institutions and bodies
- Contributes to solutions along the whole value chain

AKVA GROUP - facts

- The leading aquaculture technology supplier
- Only supplier with global presence
- Offices in 12 countries and staff of around 600
- The largest supplier to the aquaculture industry
- High growth company
- Profitable
- Industry consolidator



Partners

SINTEF Fisheries and Aquaculture (SFH) has knowledge and broad competence in the field of the utilization of renewable marine resources. The institute contributes to solutions along the whole value chain - from biological and marine production, aquaculture and fisheries to processing and distribution. SFH perform basic and applied research for commercial customers as well as governmental institutions and bodies, the Norwegian Research Council, the European Union, the United Nations (FAO), and others – more than 80% of revenue come from research contracts and among those, contract research for industry dominates.

AKVA group ASA is a leading supplier of technology to the world's fish farming industry. The technology supplied comprises products ranging from steel and plastic cage systems for fish farms to feeding- and information systems. The Company's headquarter is in Bryne, Norway. AKVA group also has offices in Trondheim, Brønnøysund, Averøy and Mo i Rana (all located in Norway) in addition to offices in Denmark, Scotland, Canada, Chile, Turkey and Thailand. AKVA group has organized its technology and product offering into two business areas, Farm Operations Technology, comprising centralized feed systems, sensors and camera systems, recirculation systems and process control-, planning and operations software, and Infrastructure Technology, comprising steel and plastic cages as well as certain other related products such as feed barges and floating rafts. AKVA group is targeting fish farming companies worldwide with main focus on the present main salmon farming countries, Norway and Chile, as well as other salmon producing countries and the Mediterranean region.

Egersund Net AS has since the early 1970's, been one of the leading producer and supplier of nets for the fish farming industry in Europe, with modern production plants in Norway and Lithuania. Product development has always been a very important activity in Egersund Net. Their goal is to be a front leader of any technical development in manufacturing nets and netting, and also in design and testing of new models. Research and development in collaboration with customers and partners, like CREATE, makes the company able to continue its work for a better product, better quality and a better result for the fish farmers.

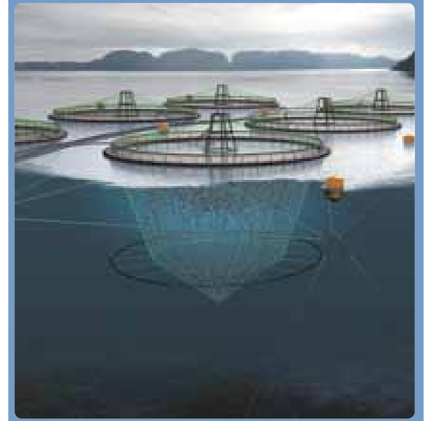
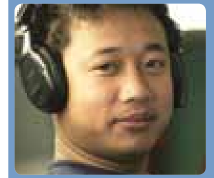
Erling Haug AS is located in offices in Trondheim, Kristiansund, Harstad, Ålesund, Florø and Puerto Montt, Chile. Our business areas range from the offshore industry, land based industry, retailers, the maritime industry and the aquaculture industry. Erling Haug provide the aquaculture industry with products related to complete mooring systems, components for mooring systems, lifting equipment and life saving equipment as well as several other product groups.

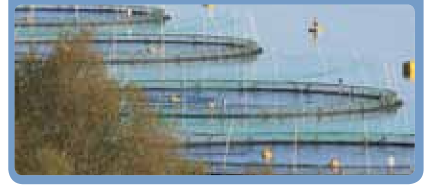
Erling Haug AS is part of the Axel Johnson Group. Customers range from private consumers to international companies, and products range from groceries to high-tech products. Foresight, entrepreneurship and creativity have been the watchwords of their past and will be the lights of the future. The group has around 15000 employees. Innovation has been part of the Erling Haug AS philosophy from the beginning. Key components in mooring systems are self-made based on experience and research. In the last 15 years the company have had an ongoing development of the EH Quick Coupling and the EH Plough Anchors. The latest generation plough anchor is the EH Megahold ® (pat. pend.)

Lerøy Seafood Group ASA is the 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.

EGERSUND NET - facts

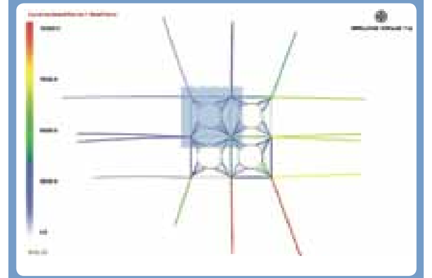
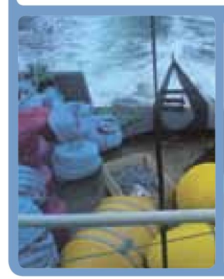
- Leading supplier for the fish farming industry
- Nets and bird nets
- Antifouling
- Service Equipment
- Quality products and experienced staff
- Profitable



ERLING HAUG - facts

- Quality mooring components
- Dynamic analysis of mooring systems
- Flexible engineered mooring solutions
- Provides lifting- and HSE products, lice-skirts and LED marking buoys


Lerøy - facts

- Distribution, sale and marketing of seafood
- Production of salmon, trout and other species
- Product development



Marin Harvest - facts

- Farmed salmon
- Porcessed seafood
- Operates in the whole value chain



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. The Group's task is to satisfy the customer's requirements for cost-effective and continuous supplies of a wide range of high-quality seafood products.

Lerøy Seafood Group`s vision is to be the leading and most profitable global supplier of quality seafood.

Marine Harvest is the world's leading seafood company offering farmed salmon and processed seafood to customers in more than 70 markets worldwide. The company is present in all major salmon farming regions in the world and the biggest producer of farmed salmon with one fifth of the global production. In addition to fresh and frozen salmon, Marine Harvest offers a wide range of value added products such as coated seafood, ready-to-eat meals, delicious finger food and smoked seafood. Though salmon is the main farmed product, the company also farms trout and white halibut.

Marine Harvest has salmon farming and processing activities in Norway, Chile, Scotland, Canada, Ireland and the Faroes. Value adding processing activities take place in the US, France, Belgium, the Netherlands, Poland and Chile. In addition Marine Harvest has several sales offices worldwide.

Salmar AS is one of the world's largest and most efficient producers of farmed salmon. SalMar's vision is to be the most cost effective supplier of salmon and salmon products while maintaining high standards with respect to biology, ethical production and quality. Salmar owns 67 licenses for marine production of Atlantic salmon in Norway and owns 50% of Norskott Havbruk AS, which owns 100% of Scottish Sea Farms Ltd, Great Britain's second-largest salmon farmer with production capacity in excess of 30,000 tonnes gutted weight.

The company wishes to continue investing in biological development to enable further industrialisation. Moving forward creating and developing secure, interesting and profitable workplaces will remain an important objective for SalMar.

Centre for Ships and ocean Structures, CeSOS, at the Norwegian University of Science and Technology, integrate theoretical and experimental research in marine hydrodynamics, structural mechanics and automatic control. Research at CeSOS aims to develop fundamental knowledge about how ships and other structures behave in the ocean environment, using analytical, numerical and experimental studies. This knowledge is vital, both now and in the future, for the design of safe, cost effective and environmentally friendly structures as well as in the planning and execution of marine operations.

The scientific and engineering research carried out in the Centre takes account of future needs, and extends current knowledge in relevant disciplines. The emphasis is on hydrodynamics, structural mechanics and automatic control, and in the synergy between them. In each of the past years, the research projects of CeSOS have proved valuable basis for the innovative design of structures, risers and automatic control systems.

Department of Engineering Cybernetics (DEC), Norwegian University of Science and Technology (NTNU) is responsible for the Master of Science and doctoral education in engineering cybernetics at NTNU. DEC is also the dominant national contributor to both theoretical and applied research in engineering cybernetics. The Department currently employs an academic staff of 23 professors and a techn./adm. staff of 13. In a typical year approximately 80 MSc's and 5-10 PhDs graduate from the DEC, with specializations in control systems engineering and industrial computer systems. The students apply their specialized knowledge to a multitude of application areas. In keeping with the department's tradition of performing research in areas of national importance, researchers at DEC have been

ABOUT CREATE

targeting a wide variety of scientific and technological challenges present in the fisheries and aquaculture sector over the last 35 years. Based on this activity, DEC offers educational specialization and research opportunities for its candidates on the application of cybernetic principles and technology to the fisheries and aquaculture industry (fisheries and aquaculture cybernetics).

NOFIMA is an industry focused research corporation which aims to increase the competiveness of the food industry, including aquaculture, catch based fishing and the agriculture sector. The corporation is organized into four business areas: Marin, Food, Ingredients and Market. NOFIMA has its head office in Tromsø with research centres at Ås, Stavanger, Bergen, Sunndalsøra and Averøy.

Nofima Marin (www.nofima.no) engage in R & D, innovation and knowledge transfer for the national and international fisheries and aquaculture industry. The primary professional areas cover breeding and genetics, feed and nutrition, fish health, sustainable and effective production as well as capture, slaughtering and primary processing.

The Institute of Marine Research (IMR) is with a staff of almost 700, Norway's largest centre of marine science. The main task is to provide advice to Norwegian authorities on aquaculture and the ecosystems of the Barents Sea, the Norwegian Sea, the North Sea and the Norwegian coastal zone. For this reason, about fifty percent of the activities are financed by the Ministry of Fisheries and Coastal Affairs. IMR's headquarters is in Bergen, but important activities are also carried out at departments in Tromsø, at the research stations in Matre, Austevoll and Flødevigen and on board IMR's research vessels, which are at sea for a total of 1600 days a year. IMR is also heavily engaged in development aid activities through the Centre for Development Cooperation in Fisheries.

IMR has high competence in the fields of aquaculture, fish behaviour, and fish physiology, including modelling and fisheries acoustics. The team has access to facilities at Matre and Austevoll Aquaculture Research Stations, including all life stages of Atlantic salmon and cod. This includes freshwater and seawater tank facilities with extensive control of water quality, photoperiod and waste feed, as well as a cage-environment laboratory with high temporal and spatial screening of environmental parameter and behaviour.

SINTEF Information and Communication Technology (SINTEF ICT) provides contract research-based expertise, services and products within the fields of micro technology, sensor and instrumentation systems, communication and software technology, computational software, information systems and security and safety.

Contracts for industry and the public sector generate more than 90% of our income, while 7% comes in the form of basic grants from the Research Council of Norway.

Salmar - facts

- Interactions between biology, environment and technology
- Focuses on a sustainable salmon industry
- In-house processing

CeSOS - facts

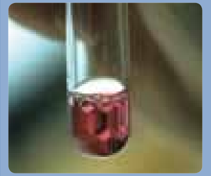
- Centre of Exellence initiated by RCN in 2003
- Internationally recognised research on ships and ocean structures
- Higly interdisciplinary approach
- About 100 affiliated PhD candidates and researchers
- More than 100 scientific publications per year

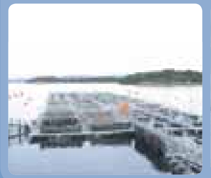
Department of Engineering Cybernetics - NTNU - facts

- Engineering Cybernetics is the science of control and communications in dynamic systems.
- One of Europe's most renowned research groups in the cybernetics field.
- 27 permanennt employees and about 40 PhD students ad temporary academic staff.
- Graduates 75 MSc and 10 PhD each year.
- Cybernetics is a science with a very wide range of applications.

NOFIMA MARIN - facts

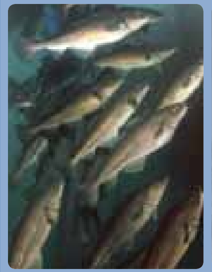
- R&D, innovation and knowledge transfer for fisheries and aquaculture
- Breeding and genetics
- Feed and nutrition
- Fish health
- Efficient and sustainable production
- Seafood processing and product development
- Marine bioprospecting




INSTITUTE OF MARINE RESEARCH - facts

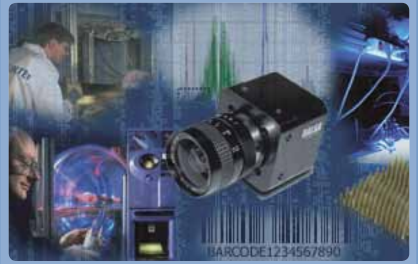
- Owner: Ministry of Fisheries and Coastal Affairs
- Norway's largest marine research institute
- Marine biology and population dynamics
- Physical and biological oceanography
- Experimental biology and population genetics
- Welfare friendly and sustainable aquaculture
- Research and advice for sustainable use of oceanic and coastal environments and resources

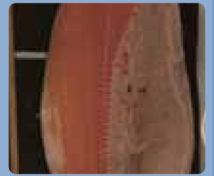
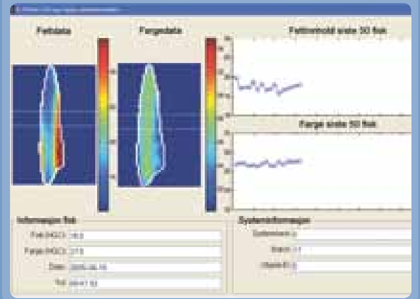




SINTEF ICT - facts

Information and Communication Technology (ICT) provides research-based expertise, services and products ranging from microtechnology, communication and software technology, computational software, information systems and security and safety. Work ranges from simple technical analysis to complete systems



Research facilities of the centre

CREATE has access to several research facilities through its research partners, including:

SINTEF Sealab is the host location of the centre. SINTEF Sealab houses laboratories with a sea-water system and tanks, designed especially for the marine research activities within SINTEF. The newly established SINTEF Sealab facilities for Simulations, Surveillance and Operations (Sealab SSO) is an important tool for studying remote operations, control and planning systems.

The SFH Flume Tank in Hirtshals, Denmark, is the second largest in the world and its size makes it possible to use large models with "full-scale" netting panels in tests. Experimental activities where steady currents are the main focus are carried out in the flume tank.

Aquaculture Engineering (ACE) provides industrial-scale testing facilities, including locations with and without fish and with different energy environments. ACE is ideal for testing of all kinds of fish farming equipment like cages, nets, monitors, feeding systems and also for operational systems and management procedures. ACE provides valuable quality controlled production data for bio-statistical analysis and development of control systems.

Institute for Marine Research, Cage Environment Laboratory, Matre. The Cage Environment Laboratory is a fjord-based full-scaled fish farm for studies related to fish behaviour and water flow dynamics and has a basic set-up of ten 12 x 12 x 15 m deep cages where behavioural and environmental screening can be carried out with high resolution in time and space in all cages.

NOFIMA Marin, Sundalsøra Research Station. The station comprises more than 600 research tanks in different shapes and sizes, ranging in size from a first feeding unit (diameter 20 cm) through to pools for broodstock (diameter 11 m). A large variety of sea and fresh water is available.

Marine Technology Centre. This is a unique laboratory infrastructure, comprising the world's largest ocean basin, towing tank, wave flumes and other marine technology related laboratories for hydrodynamics and structural mechanics studies.

AKVA group and Marine harvest is part owner together with Skretting in the Cage Aquaculture Centre, a research facility for feeding technology and feed.

Key researchers

NAME	INSTITUTION	MAIN RESEARCH AREA
Arne Fredheim	SINTEF Fisheries and Aquaculture	Marine hydrodynamics/ Fish farming constructions
Egil Lien	SINTEF Fisheries and Aquaculture	Marine structures
Tim Dempster	SINTEF Fisheries and Aquaculture	Fish behaviour
Jana Günther	SINTEF Fisheries and Aquaculture	Bio fouling
Gunnar Senneset	SINTEF Fisheries and Aquaculture	System modelling
Tore Kristiansen	Institute of marine research	Fish welfare and behaviour
Frode Oppedal	Institute of marine research	Fish welfare and behaviour
Torbjørn Åsgård	NOFIMA Marin	Fish feed and nutrition
Turid Synnøve Aas	NOFIMA Marin	Fish feed and nutrition
Trine Kirkhus	SINTEF Information and communication technology	Image analysis and statistical analysis
Professor Odd M. Faltinsen	CeSOS/NTNU	Marine hydrodynamics/ Fish farming constructions
Associate Professor Jo Arve Alfredsen	NTNU	Engineering cybernetics

Visiting researchers

NAME	AFFILIATION	NATIONALITY	SEX	DURATION	TOPIC
Dr. Shim Kyujin	Post. Doc.	Korean	M	2008-2009	CFD simulation of flow through fish cage
Dr. Fukun Gui	Post. Doc.	Chinese	M	2009-2010	Design of cage systems for exposed shallow waters
Dr. Shixiao Fu	Shanghai Jiao Tong University	Chinese	M	2010	Structural analysis of large interconnected structures

Postdoctoral researchers

NAME	AFFILIATION	NATIONALITY	SEX	DURATION	TOPIC
Dr. Bailey Jason		Canadian	M	2007-2008	Cage environment
Dr. Guenther Jana		German	F	2008-2010	Bio fouling on aquaculture constructions
Dr. Axel Tidemann		Norwegian	M	2009-2011	Case based reasoning systems for aquaculture operations
Dr. Øyvind Johan Korsøen		Norwegian	M	2010-2012	Smart submergence of sea cages with salmon and cod

PhD students

NAME	NATIONALITY	PERIOD	SEX	TOPIC
Korsøen Øyvind Johan	Norwegian	2007-2010	M	Biological criteria for successful submergence of physoclistous Atlantic cod and physostomous Atlantic salmon reared in sea-cages
Føre Martin	Norwegian	2007-2010	M	Modelling and simulation of fish behaviour in aquaculture production facilities
Remen Mette	Norwegian	2008-2011	F	Effects of fluctuating oxygen levels on welfare and growth of salmon (Salmo salar) in net cages
Lubis Enni Lisda	Indonesian	2008-2012	F	Reliability-based design of Aquacultural Plants
Nina Blöcher	German	2009-2012	F	Bio-fouling on marine cage systems
Maike Oehme	German	2010 - 2013	F	Quality - optimal conveying and biological response
Bardestani Mohsen	Iranian	2009 - 2012	M	Wave and current loads on fish farms
Peng Li	Chinese	2010 - 2013	M	Hydroelastic behaviour of the floater of an aquaculture cage in waves and current
Gansel Lars	German	2007-2011	M	Flow through and around fish cages
Mohamed Shainee	Maldives	2010 - 2013	M	Design considerations for offshore fish farms
Zhao He	Chinese	2010 - 2013	M	Current effects on an aquaculture cage

Master degrees

NAME	NATIONALITY	PERIOD	SEX	TOPIC
Vigen Jannicke	Norwegian	2007-2008	F	Oxygen variation in cages
Carl Christina	German	2007-2008	F	Bio-fouling
Harendza Astrid	German	2007-2008	F	PIV on inclined cylinder shaped fish cages
Håkon Raanes	Norwegian	2008-2009	M	Next generation subcage - concept development
Henriette Flathaug Ramberg	Norwegian	2010	F	Interaction between the net structure, the weight system and the floater of a fish farm
Håkon Ådnanes	Norwegian	2010-2011	M	Consequence for dimensioning of mooring system
Per Christian Endresen	Norwegian	2010-2011	M	Wave forces on floating fish farms

Pål Lader

Title research project:
Cage environment

Education:
Dr.ing. (Marine hydrodynamics)

Company/insitution:
SINTEF Fisheries and Aquaculture

Place of residence: Trondheim, Norway
Place of birth: Kristiansund
Nationality: Norwegian

Leisure activities:
Photography, drawing, reading, skiing and biking

3 research keywords:
Water in motion

3 keyword about yourself:
Tall, argumentative, father

Geirmund Vik

Title research project:
Industrial partner

Education:
Aquaculture and Food science

Company/insitution:
Egersund Net AS

Place of residence: Ålgård, Norway
Place of birth: Finnøy, Norway
Nationality: Norwegian

Leisure activities:
Skiing, Traveling and Food

3 research keywords:
Biofauling, Cage environment, Cage technology

3 keyword about yourself:
Innovative, Impulsive, Impatient

International co-operation

USA

Create has had a fair amount of international cooperation since its beginning, and The University of New Hampshire has been an active international collaborator the whole time. Prof. Hunt Howell and Michael Chambers from the Open Ocean Aquaculture program have participated in project development and discussions at each of the annual CREATE days (2007-2011), and Chambers have also in 2010 been involved in the preliminary development of a warm water species project to be proposed for CREATE. CREATE researches have also an active collaboration with Assoc. Prof. David Fredriksson at the United States Navel Academy (USNA) and has in 2010 conducted a series of model scale experiments of a system of fish farm cages in current and waves at the USNA towing tank facilities (see Fig. 20).

China

During 2010 Professor Shixiao Fu, from Shanghai Jiao Tong University have cooperated with CREATE researchers on the planning of a series of model tests for fish farms to be conducted in 2011. Professor Shixiao had a short visit to CREATE in the fall of 2010, and a return visit is tentatively planned for 2011 in connection with the planned experiments. Dr. Fukun Gui of Zhejiang University has been a visiting post-doctoral fellow at the centre for 2009-10, and collaborated on projects to design new cage systems for warm water aquaculture.

Australia

In 2010, CREATE established a new international collaboration with the Sustainable Aquaculture Laboratory – Temperate and Tropical (SALTT) based at the University of Melbourne, Australia. SALTT researchers Dr. Tim Dempster & Isla Fitridge are currently participating in CREATE projects within the research themes of behavioural studies to underpin new technologies and biofouling control. During 2010, CREATE researchers have also continued the ongoing cooperation with Prof. Rocky de Nys, James Cook University in Australia. This cooperation has had the scope to develop more environmentally friendly antifouling surfaces for the finfish aquaculture industry. This project investigates the effects of surface characteristics, such as hydrophobicity and texture, on the settlement and growth of one of the main fouling species on aquaculture nets in Norway, the hydroid Ectopleura larynx. The collaboration involves both laboratory and field-based testing of surfaces with varying hydrophobicities and micro- and nano-textures in inhibiting the settlement and growth of E. larynx.

In 2011 CREATE will further develop the established international relationships, but will also have a focus on establishing new relationships. CREATE have an ongoing dialogue with several research groups in Europe, Asia and Australia that are highly relevant for future project collaboration.

FIG. 20 : Model experiments at the large towing tank at The United States Naval Academy in Annapolis, Maryland. The experiments were conducted with three 1:40 scaled fish cage models in a full system mooring setup.

Statements of Accounts 2010

(All figures in 1000 NOK)

Funding	2010	2009	2008	2007
The Research council	**11 490**	12 453	9 934	5 709
The Host Institution	**2 616**	1 770	1 325	481
Research Partners	**2 562**	2 665	3 002	860
Enterprise Partners	**6 452**	4 603	4 925	3 774
Total	***23 120***	*21 491*	*19 186*	*10 824*

Costs	2010	2009	2008	2007
The Host Institution	**9 980**	8 507	5 460	3 049
Research Partners	**6 608**	6 012	6 460	2 982
Enterprise Partners	**6 452**	6 900	7 136	4 694
Equipment	**80**	72	130	99
Total	***23 120***	*21 491*	*19 186*	*10 824*

Journal Papers

Aquaculture technology - structures

Jensen Ø, Wroldsen AS, Lader PL, Fredheim A, Heide M	2007	Finite element analysis of tensegrity structures in offshore aquaculture installations.	Aquacultural Engineering 36: 272-284
Lader P, Olsen A, Jensen A, Sveen JK, Fredheim A, Enerhaug B	2007	Experimental investigation of the interaction between waves and net structures - Damping mechanism.	Aquacultural Engineering 37(2): 100-114 1
Lader PF, Jensen A, Sveen JK, Fredheim A, Enerhaug B, Fredriksson D	2007	Experimental investigation of wave forces on net structures.	Applied Ocean Research 29(3): 112-127 1

Aquaculture technology - nets

Lader PL, Dempster T, Fredheim A, Jensen Ø	2008	Current induced net deformations in full-scale sea-cages for Atlantic salmon (Salmo salar).	Aquacultural Engineering 38: 52-65
Moe H, Olsen A, Hopperstad OS, Jensen Ø, Fredheim A	2007	Tensile properties for netting materials used in aquaculture net cages.	Aquacultural Engineering 37(2): 252–265 1
Moe H, Hopperstad OS, Olsen A, Jensen Ø, Fredheim A	2009	Temporary-creep and post-creep properties of aquaculture netting materials.	Ocean Engineering 36: 992-1002
Moe H, Fredheim A, Hopperstad OS	2010	Structural analysis of aquaculture net cages in current.	Journal of Fluids and Structures (in press)

Biofouling

Guenther J, Carl C, Sunde LM	2009	The effects of colour and copper on the settlement of the hydroid Ectopleura larynx on aquaculture nets in Norway.	Aquaculture 292: 252-255
Guenther J, Wright AD, Burns K, de Nys R	2009	Chemical antifouling defences of tropical sea stars: Effects of the natural products hexadecanoic acid, cholesterol, lathosterol and sitosterol.	Marine Ecology Progress Series 385: 137-149
Guenther J, Misimi E, Sunde LM	2010	The development of biofounling, particularly the hydroid Ectopleura larynx, on commercial salmon cage nets in Mid-Noway	Aquaculture 300: 120-127
Guenther J, Misimi E, Sunde LM	2010	Spatial and temporal effects of the underwater washing of salmon cage nets on the net aperture occlusion due to biofouling.	Aquaculture 300:120-127
Carl C, Guenther J, Sunde LM	in press	Larval release and attachment modes of the hydroid Ectopleura larynx on aquaculture nets in Norway	Aquaculture Research

PUBLICATIONS AND DISSEMINATION

Fish behaviour

Dempster T, Juell JE, Fosseidengen JE, Fredheim A, Lader P	2008	Behaviour and growth of Atlantic salmon (Salmo salar) subjected to short-term submergence in commercial scale sea-cages.	Aquaculture 276: 103-111
Dempster T, Korsoen Ø, Oppedal F, Folkedal O, Juell JE	2009	Submergence of Atlantic salmon (Salmo salar) in commercial scale sea-cages: a potential short-term solution to poor surface conditions.	Aquaculture 288: 254-263
Føre M, Dempster T, Alfredsen J-A, Johansen V, Johansen D	2009	Modelling of Atlantic salmon (Salmo salar) behaviour in aquaculture sea-cages: a Lagrangian approach.	Aquaculture 288: 196-204
Johansson D, Ruohonen K, Kiessling A, Oppedal F, Stiansen J-E, Kelly M, Juell J-E	2006	Effect of environmental factors on swimming depth preferences of Atlantic salmon (Salmo salar L.) and temporal and spatial variations in oxygen levels in sea cages at a fjord site.	Aquaculture 254: 594-605
Johansson D, Ruohonen K, Juell J-E, Oppedal F	2009	Swimming depth and thermal history of individual Atlantic salmon (Salmo salar L.) in production cages under different ambient temperature conditions.	Aquaculture 290: 296-303
Korsøen Ø, Dempster T, Fjelldal PG, Oppedal F, Kristiansen TS	2009	Long-term culture of Atlantic salmon (Salmo salar L.) in submerged cages during winter affects behaviour, growth and condition.	Aquaculture 296: 373-381
Korsøen Ø, Dempster T, Fosseidengen JE, Fernö A, Kristiansen T	2010	Behavioural responses to pressure changes in cultured Atlantic cod (Gadus morhua): defining practical limits for submerging and lifting sea-cages	Aquaculture 308: 106–115
Oppedal F, Dempster T, Stian L	2011	Environmental drivers of Atlantic salmon behaviour in sea-cages: a review	Aquaculture, Volume 311, Issues 1-4, 3 February 2011, Pages 1-18
Oppedal F, Vågseth T, Dempster T, Juell J-E, Johansson	In press	Fluctuating sea-cage environments modify the effects of stocking densities on the production and welfare of Atlantic salmon (Salmo salar L.).	Aquaculture
Føre M., J. A. Alfredsen and A. Gronningsater	2011	Development of two telemetry-based systems for monitoring the feeding behaviour of Atlantic salmon (Salmo salar L.) in aquaculture sea-cages	Computers and Electronics in Agriculture. In press.
Kristiansen, T.S., Stien, L.H., Fosseidengen, J.E., Strand, E., Juell, J.-E.	2011	Voluntary responses and limits of tolerance to pressure reduction and swimbladder expansion in farmed Atlantic cod	Aquaculture International (1 October 2010), pp. 1-12. doi:10.1007/s10499-010-9377-9

Aquaculture-Environment Interactions

Bustnes JO, Lie E, Herske D, Dempster T, Bjørn PA, Nygård T, Uglem I	2010	Salmon farms as a source of organohalogenated contaminants in wild fish	Environmental Science and Technology 44: 8736–8743
Dempster T, Uglem I, Sanchez-Jerez P, Fernandez-Jover D, Bayle-Sempere J, Nilsen R, Bjørn PA	2009	Coastal salmon farms attract large and persistent aggregations of wild fish: an ecosystem effect.	Marine Ecology Progress Series 385: 1-14
Dempster T, Sanchez-Jerez P, Uglem I, Bjørn P-A	2010	Species-specific patterns of aggregation of wild fish around fish farms	Estuarine, Coastal and Shelf Science 86(2): 271-275
Dempster T, Sanchez-Jerez P, Fernandez-Jover D, Bayle-Sempere, Nilsen R, Bjørn PA, Uglem I	2011	Proxy measures of fitness suggest coastal fish farms can act as population sources and not ecological traps for wild fish	PLoS One
Jensen Ø, Dempster T, Thorstad EB, Uglem I and A Fredheim	2010	Escapes of fish from Norwegian sea-cage aquaculture: causes, consequences, prevention	Aquaculture Environment Interactions 1: 71-83
McClimans, T.A., A. Handå, A. Fredheim, E. Lien, K.I. Reitan	2010	Controlled artificial upwelling in a fjord to stimulate non-toxic algae	Aquaculture Engineering 42 (2010) 140-147
Moe H, Dempster T, Sunde L M, Winther W, Fredheim A	2007	Technological solutions and operational measures to prevent escapes of Atlantic Cod (Gadus morhua) from sea-cages	Aquaculture Research 38: 91-99
Sanchez-Jerez P, Fernandez-Jover D, Bayle-Sempere J, Valle C, Dempster T, Tuya F, Juanes F	2008	Interactions between bluefish Pomatomus saltatrix (L.) and coastal sea-cage farms in the Mediterranean Sea.	Aquaculture 282: 61-67
Uglem I, Dempster T, Bjørn P-A, Sanchez-Jerez P, Økland F	2009	High connectivity of salmon farms revealed by aggregation, residence and repeated movements of wild fish among farms.	Marine Ecology Progress Series 384: 251-260

Feed quality and nutrition

Aas TS, Oehme M, Sørensen M, He G, Åsgård T	2011	Analysis of pellet degradation of extruded high energy fish feeds with different physical quality in a pneumatic feeding system	Aquacultural Engineering, Volume 44, Issue 1, January 2011, Pages 25-34
Aas TS, Terjesen BF, Sigholt T, Hillestad M, Holm J, Refstie S, Baeverfjord G, Rørvik K-A, Sørensen M, Oehme M, Åsgård T	In review	Nutritional value of feeds with different physical qualities fed to rainbow trout (Oncorhynchus mykiss) at stable or variable environmental conditions.	Aquaculture Nutrition

PUBLICATIONS AND DISSEMINATION

Published Conference Papers

Dempster T, Moe H, Fredheim A, Sanchez-Jerez P	2007	Escape of Marine fish from sea-cage aquaculture in the Mediterranean Sea: status and prevention.	CIESM workshop Monograph no. 32.
Gansel LC, McClimans TA, Myrhaug D	2009	Flow around the free bottom of fish cages in a uniform flow with and without fouling.	Proceedings of the 28th International Conference on Ocean, Offshore and Arctic Engineering OMAE 2009, Hawaii, USA, June
Gansel LC, McClimans TA, Myrhaug D	2010	Average flow inside and around fish cages without and with fouling in a uniform flow.	Proceedings of the 29th International Conference on Ocean, Offshore and Arctic Engineering OMAE 2010, Shanghai, China, June
Aas TS, Terjesen BF, Sigholt T, Hillestad M, Holm J, Refstie S, Baeverfjord G, Rørvik K-A, Sørensen M, Oehme M, He G, Åsgård T,	2010	The optimal pellet quality is a trade-off between durability and responses in the fish.	The 14th International Symposium on Fish Nutrition and Feeding 2010, Qingdao, China, June 1st-4th 2010.

Books

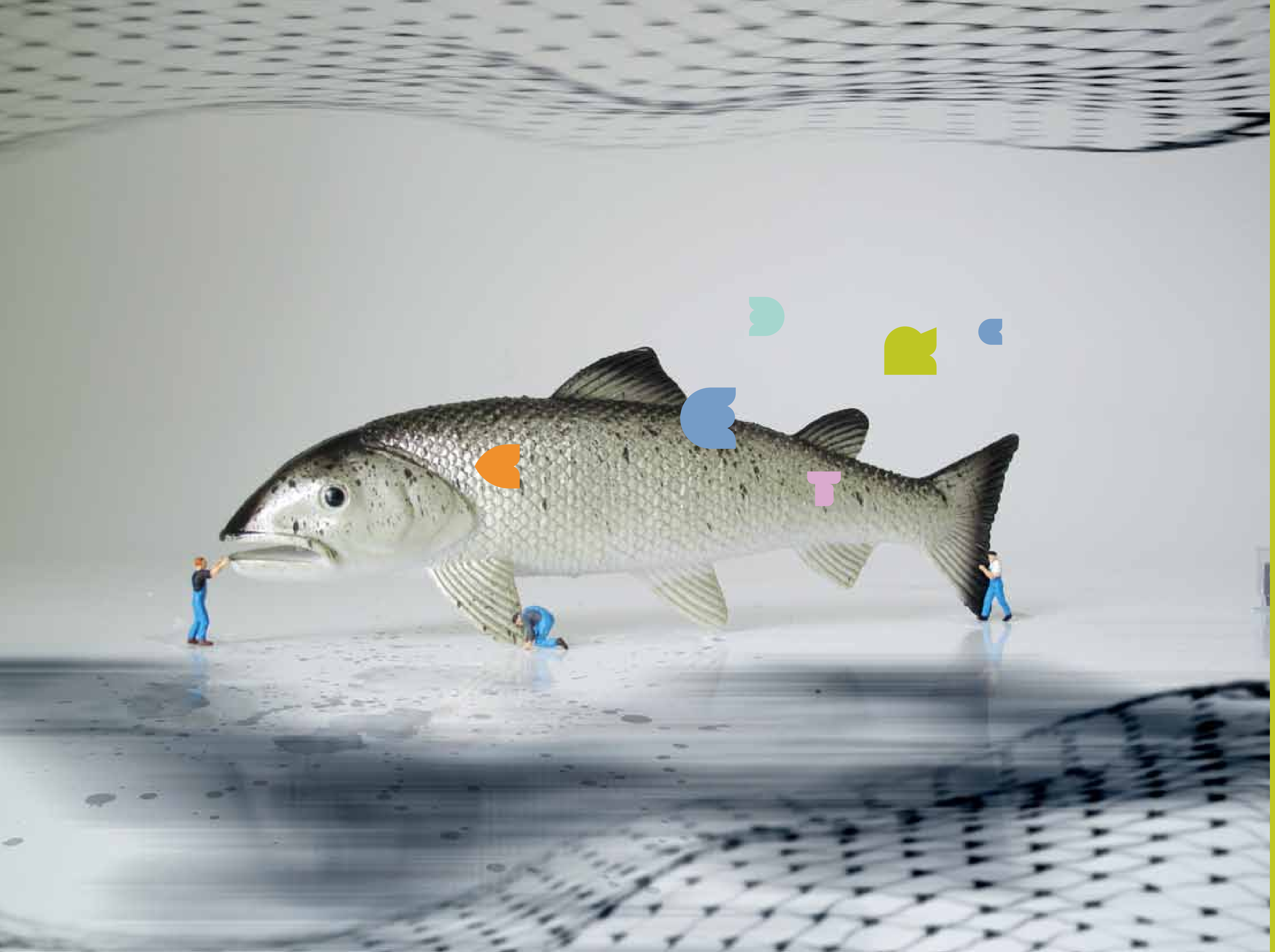
de Nys R, Guenther J	2009	The impact and control of biofouling in marine finfish aquaculture.	In: Advances in marine antifouling coatings and technologies. Eds.: Hellio C, Yebra D. Woodhead Publishing ISBN 1845693868
de Nys R, Guenther J, Uriz MJ	2009	Natural fouling control.	In: Biofouling. Eds.: Durr S, Thomason J. Blackwell Publishing. ISBN 9781405169264
Fredheim A, Langan R	2009	Advances in technology for offshore and open ocean aquaculture.	In: New technologies in aquaculture: Improving production efficiency, quality and environmental management. Eds: Burnell G & Allen G, Woodhead Publications 2009, Cambridge, UK
Sanchez-Jerez P, Fernandez-Jover D, Uglem I, Arechavala P, Dempster T, and 3 others	2010	Coastal fish farms act as Fish Aggregation Devices (FADs): potential effects on fisheries.	In: Artificial Reefs in Fisheries Management. Eds.: Steve Bortone et al., Taylor and Francis/CRC Press

Reports

Aure J, Oppedal F, Vigen J	2009	Hva bestemmer vannutskifting og oksygenforhold i oppdrettsmerder?	Kyst og Havbruk 2009, Fisken og Havet, særnummer 2-2009, 169-171
Fredheim A, Jensen Ø, Dempster T	2010	Escapes of fish from Norwegian sea-cage aquaculture: causes, consequences and methods to prevent escape	OECD report
Dempster T, Thorstad E	2010	Impacts of aquaculture escapees on native populations and fisheries: European summary	Technical Report for the Fisheries and Aquaculture Organisation of the United Nations
Dempster T, Sanchez-Jerez P	2010	Impacts of aquaculture on fisheries resulting from changes in habitats and resource availability: European summary	Technical Report for the Fisheries and Aquaculture Organisation of the United Nations
Juell JE, Nilsson J, Olsen RE, Fridell F, Kvamme BO, and 5 others	2007	Dyrevelferd i akvakultur og fiskeri et nytt fagområde i rask vekst.	Kyst og Havbruksrapporten, Fisken og Havet, Særnummer 2, 20
Korsøen Ø, Dempster T, Oppedal F, Folkedal O, Kristiansen T	2008	Nedsenkede merder – en del av fremtidens lakseoppdrett?	Kyst og Havbruk 2008 kapittel 3 Havbruk
Kristiansen TS, Johansson D, Oppedal F, Juell J-E	2007	Hvordan har oppdrettsfisken det i merdene.	Kyst og Havbruk 2007, Fisken og Havet, Særnummer 2, 2007: 151-154.
Moe H, Sunde LM, Winther U	2009	Effekter og tiltak – rømt fisk. Valg av not til oppdrettstorsk.	Kyst og Havbruk 2009, Fisken og havet, særnummer 2-2009, ISSN 08020620: 148-150
Aas, T.S., Remen, M., Oppedal, F., Hjertnes, T.J.	2011	Feed utilisation in Atlantic salmon kept at fluctuating oxygen saturation	Nofima report 5/2011. ISBN 978-82-7251-848-5 (printed) / 978-82-7251-848-2 (pdf). 15 pp.

PhD Thesis

Korsøen, Ø.J.	2011	Biological criteria for submergence of physostome (Atlantic dalmon) and physoclist (Atlantic cod) fish in sea.cages	Dissertation for the degree of philosophia doctor (PhD), University of Bergen, Norway, 11. March 2011



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CREATE

SINTEF FISHERIES
AND AQUACULTURE

MAIL:
P.O. BOX 4762 SLUPPEN
7465 TRONDHEIM, NORWAY

VISITING:
BRATTØRKAIA 17 C

CONTACT:
ARNE.FREDHEIM@SINTEF.NO
+47 93 45 97 21

WEB:
WWW.SINTEF.NO/CREATE

ISBN: 978-82-14-04944-2

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