Annual report

2007

Introduction

Fish products are vital to the world's supply of animal proteins and aquaculture will be increasingly important in meeting the growing gap between supply and demand for seafood products. The FAO recognizes that technological development will play a major role in future expansion of the industry. New technologies must improve the efficiency of production and operations, the safety of handling fish farming gear and the economics of production. They must also minimize social conflict with other users of the marine environment and reduce environmental impacts such as escapes, diseases and nutrient pollution.

CREATE - Centre for Research-based Innovation in Aquaculture Technology - carry out research and development to enable innovation of technology, products and solutions specifically to improve the grow-out phase of marine fish culture. SINTEF Fiskeri og havbruk AS are the host institution for the centre. The three Norwegian companies AKVA group, Egersund Net, Erling Haug AS are all word-leading suppliers of equipment and technology in their respective market segments and make up the industry partner group. The five internationally recognized research institutions NOFIMA Marin, Institute of marine research (IMR) , Centre for Ships and Ocean Structures (Centre of excellence) and Department of Engineering Cybernetics at the Norwegian University of Science and Technology and SINTEF Information and communication technology are research partners in the centre. The centre also has collaboration with the Open Ocean Aquaculture (OOA) Engineering group at the University of New Hampshire, USA (UNH).

1 Vision and objective

Vision

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

Objective

The main objective of CREATE is to combine world-leading companies that supply equipment and technology 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 culture.

2 Research plan and strategy

CREATE combine world-leading Norwegian companies that supply equipment and technology with prominent international scientific research institutions into a centre with a common focus to develop and prepare the ground for commercialization of new technology. CREATE focus research and development within the following three main research pillars and aim to integrate knowledge between them:

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.

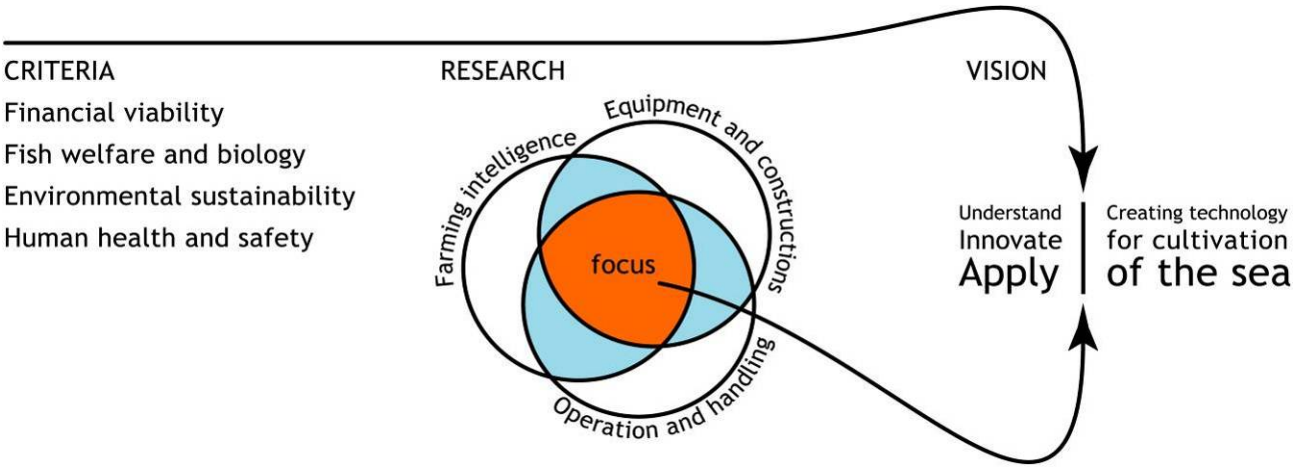

Figure 1 Vision and research pillars for CREATE

CREATE addresses nine research topics, which have been chosen because of the potential for innovation that lies within the ‘interaction space’ (Figure 2) between the three research pillars. They represent major obstacles for financial viability, fish welfare and biology, human health and safety, and environmental sustainability. The nine research topics are:

- Reducing escapes and pollution
- Monitoring and optimisation of Fish well-fare
- Prevention and control of bio-fouling
- Monitoring and control of water quality
- Net handling and operations
- Control and optimisation of production
- Increased feeding efficiency
- Traceability
- Increased sea load exposure

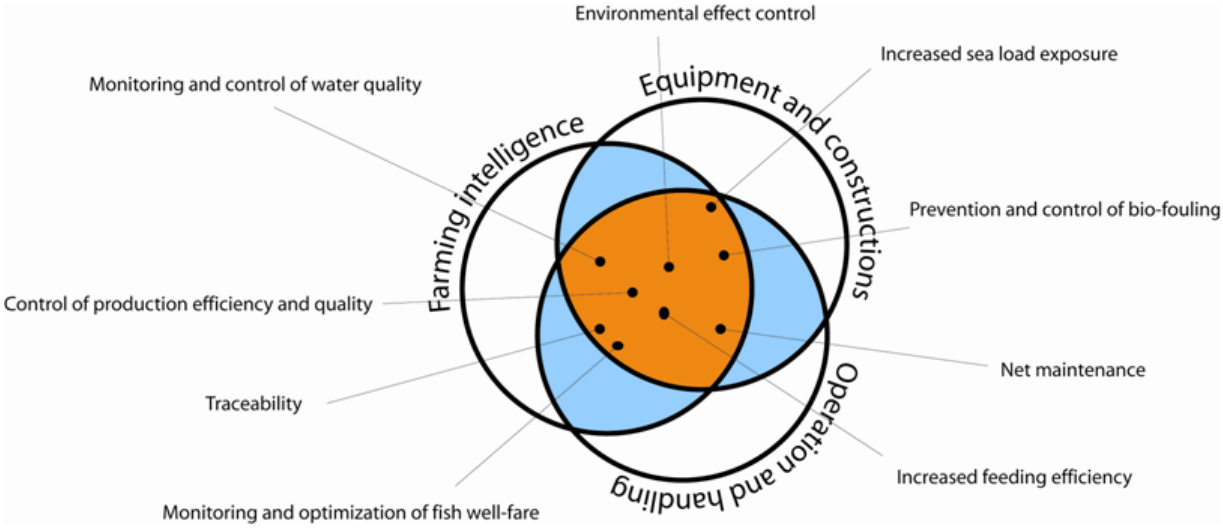

Figure 2 Interaction between the three main research pillars of CREATE and research topics.

Presently seven research projects are running within CREATE:

Bio statistical analysis

The main objective is to develop a cage-by-cage analytical tool capable, by applying standard and relevant statistical procedures, of identifying main explanatory factors involved in the differential performance of fish populations in cages.

Modelling for intelligence

The main goal for this pilot study is to establish the foundation for future theoretical work on information models, ontology and systems architectures for use in the aquaculture

industry. This work will facilitate systematic and consistent data acquisition through the whole lifecycle from roe to fillet.

Submergible cage farming and technology
The objective is to improve reliability of cage sinking-floating process by means of process control, automation and remote controlling.

Cage environment
The objective is to develop improved standards for oxygen management in marine net cages to secure fish welfare and efficient production.

Bio-fouling on net constructions and solution for antifouling control
Develop a knowledge-fundament, capacities and solutions on biofouling, biofouling control, biofouling loads and biofouling sensors dedicated to net constructions.

Non disruptive fish weight determination and video surveillance
Assess and demonstrate the feasibility of automatic analysis and estimation of fish weight distribution based on images obtained from the Akvasmart VICASS system.

Physical properties of feed, hardness and durability
Development of feedback systems to minimize physical damage of feed during transport in feed systems.

3 Organization

CREATE is organized as an independent part of SINTEF Fiskeri og havbruk, with its own Board, Scientific committee and management.

The Board of directors have the responsibility for decisions on project activities and budget. It has a majority of members from the industry partners. The Board consist of five members with representatives from the host institution, all the industry partners and Institute of Marine Research. In 2007 the following people were members of the board:

- Patrick Dempster. AKVA Group ASA. Chairman of CREATE. Until July 2007

- Jone Gjerde. AKVA Group ASA. Chairman of CREATE. From July 2007
- Karl Almås. SINTEF Fiskeri og havbruk AS.
- Jon-Erik Juell. Senior Scientist Institute of marine research. Until May 2007.
- Tore Kristiansen. Senior Scientist Institute of marine research. From May 2007.
- Svein Ove Rabben. Egersund Net AS.
- Joachim Buarø. Erling Haug AS

Scientific Committee

The main task of the Scientific Committee is to review and develop project proposals and research plan for CREATE. The Scientific Committee makes recommendations for research plan and projects to the board of directors. The scientific committee have eight members, one from each of the industrial partners, one from NTNU, one from IMR, one from AKVAFORSK and one from SINTEF.

Management

The management have responsibility for the daily run of the centre. Dr. Arne Fredheim is the Director of the centre and Lillian Tronsaune Administrative Coordinator.

Project leaders

For each project, a project leader is appointed, and is selected from among the industry partners, R&D partners or personnel already at the centre.

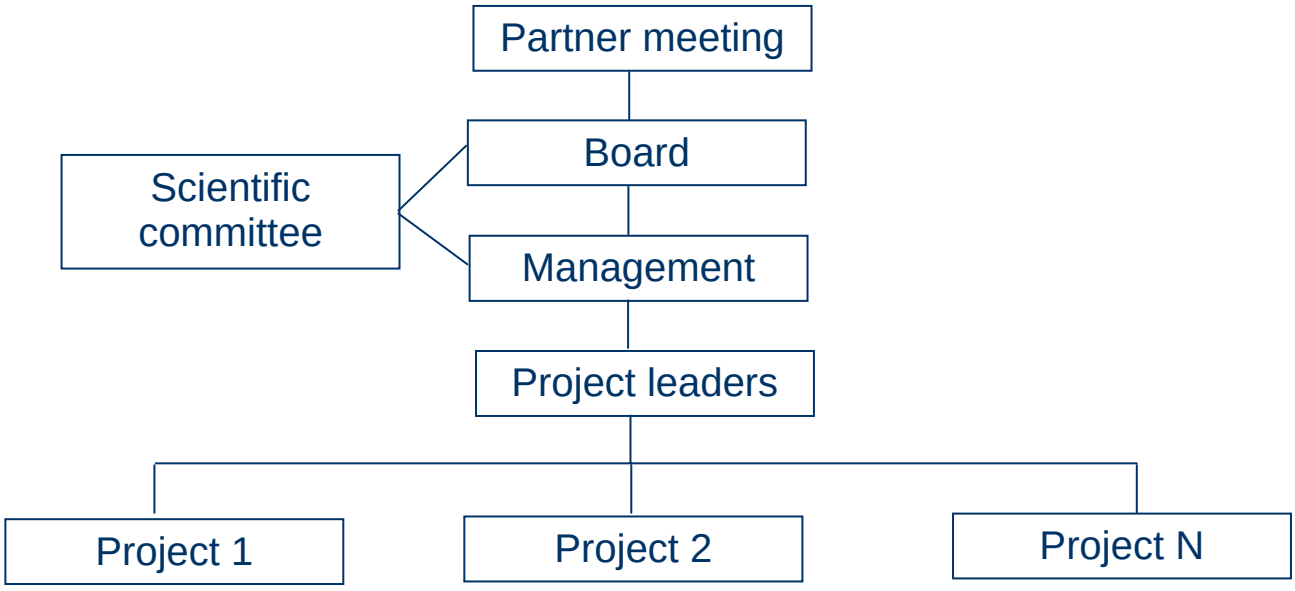

Figure 3 Organization structure of CREATE

Research

CREATE has as a philosophy to involve personnel from several partners in each project and it is an aim to have project personnel physically working together at the centre, to ensure joint involvement, creativity and transfer of knowledge. At least two industry partners, one R&D partner and SFH staff should be involved in all projects.

CeSOS and NTNU Department of engineering cybernetics share the educational responsibility for PhD candidates.

CREATEday

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

Figure 4 Break out session at CREATEday

CREATE is physically located at SINTEF Sealab at the waterfront in Trondheim, Norway. SINTEF Sealab houses new facilities and laboratories designed especially for the marine research activities within SINTEF.

Marine Technology Centre Experimental research related to hydrodynamics and structural mechanics is conducted at the Marine Technology Centre in Trondheim. This is

a unique laboratory infrastructure, comprising the world's largest ocean basin, towing tank and wave flumes.

The SFH Flume Tank in Hirtshals, Denmark Experimental activity where steady currents are the main focus, and observations of model can be made, is carried out in the SFH flume tank. The flume tank is the second largest in the world and its size make it possible to use large models with "full-sized" netting panels in tests.

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

CREATE Research and Industry partners

SINTEF Fiskeri og havbruk AS (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 our revenues come from research contracts and among those, contract research for industry is the bulk.

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.

Figure 5 Products by AKVA Group ASA

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.

Figure 6 Model scale test of net cage by Egersund Net.

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.)

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.

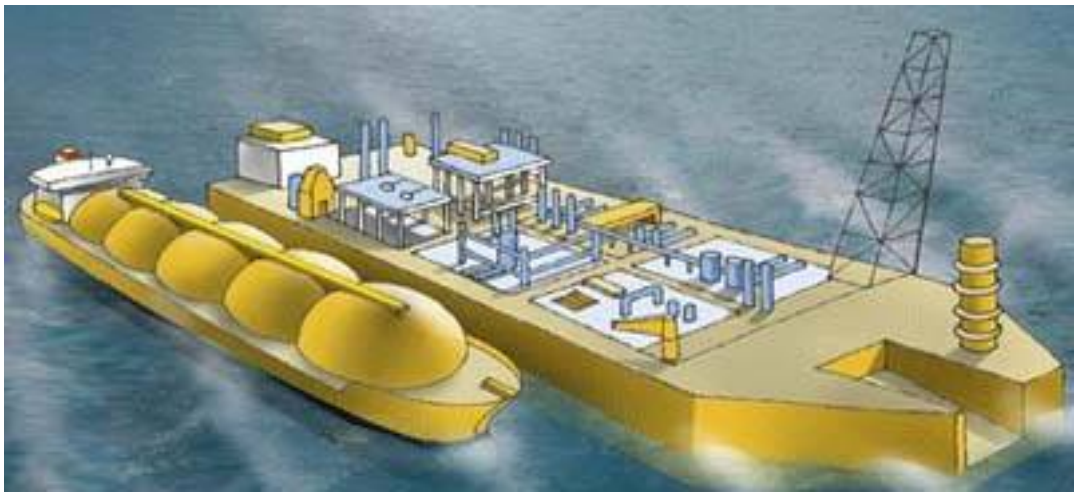

Figure 7 Illustration by CeSOS.

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 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).

Figure 8 Fish with implanted transmitter used in research

NOFIMA is an industry focused research corporation who will increase the competiveness of the food industry, including aquaculture, catch based fishing and agriculture sector. The corporation consist of previously Akvaforsk, Fiskeriforskning, Matforsk and Norconserv. The business activity is organized into four business areas, Marin, Food, Ingredients and Market. The corporation have its main office in Tromsø and activities at Ås, Stavanger, Bergen, Sunndalsøra and Averøy.

Nofima Marin, 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. More info at www.nofima.no.

Figure 9 Extruded fish feed

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 are 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 aquaculture, fish behaviour, 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.

4 Scientific activities and results

Physical quality of fish feed

In modern fish farming, pneumatic conveying systems are commonly used to transport the feed from a storage silo to the sea pens, implying that the feed is transported through a pipe system by an air stream. This transportation causes attrition on the pellet particles due to collisions between the pellets and the pipe wall, and a portion of the pellets will break during transportation. Undersized particles and dust will not have any feed value and, therefore, represent feed loss and add nutrients to the water. Consequently, commercial feeds are produced with a high physical quality. The physical properties may, however, affect the nutritional value of the feed. Akvagroup and Nofima (former AKVAFORSK) will through the CREATE project develop research based technical solutions which harmonise the demand for technical feed quality, the design and operation of feeding equipment and the fish' requirements.

The first experiments planned to be carried out are:

Feed pellet durability in pneumatic conveying systems for fish farming. Three commercial diets with known differences in physical qualities will be evaluated in the pneumatic conveying system. The aim is to optimise the settings of the feeding system so that pellet breakage can be minimised. In order to find critical points in the conveying system, changes to the settings of air speed and feeding rate are intended. With the collected data a model should be developed, which allows an adjustment of the setting of the conveying system depending on the physical parameters of a pellet. The work will be performed in 2008, and will be the basis for a master thesis for a student at the Norwegian University of life sciences, scheduled to be finished during the spring 2008. This will consist of an experiment where feed samples are transported through a feed conveying system to measure the generation of small particles, and, further, evaluate the physical quality of the experimental feeds by several techniques. The aim is to find physical measurements which corresponds to the feeds' ability to withstand breakage during handling in the feeding system, and also are relevant for the nutritional value of the feed. The pellet breakage will be investigated primarily:

a) where feed enters the system from the silo, and through the pipe

b) at the spreader in the cage

Relation between physical and nutritional quality of fish feed. How the nutritional feed quality is affected by the physical quality will be determined by estimating feed intake and nutrient digestibility in fish fed pellets which differ in physical quality. A fish trial using feeds with different physical properties will be carried out, and feed intake, nutrient digestibility and rate of digestibility, are planned to be evaluated.

Cage environment: Oxygen and water flow variation in cages and impact on fish. Water flow through the cage provides oxygen and helps remove waste, however, little is known about how the fish biomass and behaviour associated with farming might affect the flow and oxygen levels. So far, fluctuating oxygen levels has been seen between sites and cages while the effect of such on the fish remains unknown. The first field trials of this project investigated variation in water current and oxygen within one cage.
This was done at the Institute of Marine Research's Cage Environment Lab and at a commercial farm from July to October 2007. Water current flow patterns were analysed over 50-hour periods on an empty sea cage and two commercially stocked cages. In addition, the water flow was stopped in a cage and flow and oxygen measured in detail. The water current depth profiles outside the cage were measured in three reference points using profiling current meters. Within the cage the water current depth profiles was estimated in 5 horizontal positions as on a dice by single point current meters continuously hauled up and down by an automatic winch. At a reference point and the 5 positions within the cage CTD's with oxygen probe measured oxygen, temperature and salinity. The observed fish density was logged using an echo-sounder under the cage pointing upwards, while the fish swimming behaviour was monitored by cameras and infra-red light sources.

The results so far indicate that current flow was somewhat affected by the empty net, creating slower rates of current flow within the cage, and altered rates of flow "behind" the cage with respect to the prevailing current. The fish swimming speed averaged 0.6 fish lengths per second at day and was 0.3 at night. Both day and night the fish formed a circular school. At day the swimming depth was predominately from 3 to 10 m depth while at night the fish generally swam closer to surface. Water current flow and direction within the cage were compared to a reference point just outside the cage at the prevailing incoming end. As an example the average changes in water velocity caused by the empty cage and by the cage with fish for one position within the cage for the entire 50-hour periods are shown in Figure 1. While the net had a small effect on the current flow velocity,

the deflection of the current was minimal. However, the presence of fish caused forceful changes in the current flow and deflection. Correspondingly, the greatest changes in current flow were seen at the depth of the fish. The oxygen varied within the cage and was lower compared to the reference point but the data need further analysis in order to discuss the findings in details.

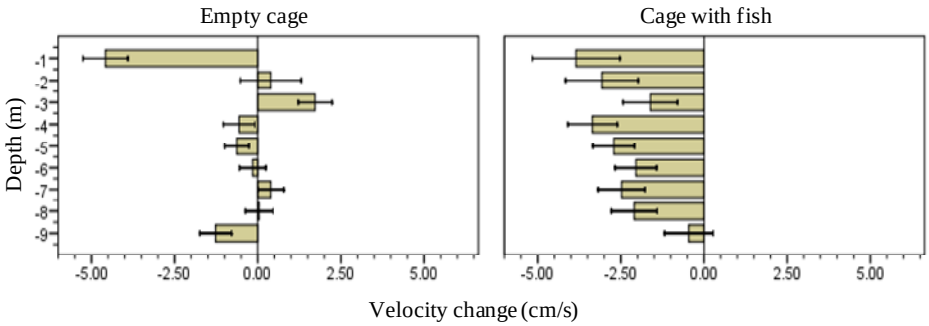

Figure 10 Average (± standard deviation) of the current flow velocity change at 1 m depth intervals over 50-hour period in the centre of an empty cage (left) or cage stocked with 17.5 kg m^{-3} (right) of salmon. In the upper metre reference flow direction was variable, while there was a prevailing direction below.

A sufficient supply of oxygen is crucial for normal functioning of the farmed fish and to ensure fish welfare. The water flow is the main supplier of oxygen to the fish in the cages. For the first time, a reducing effect of the fish biomass on the water current velocity is seen in the present study. This needs to be taken into account in future management when deciding levels of biomass and number of fish kept in sea cages. Site- and cage-specific capacity models will be further developed in order to avoid suboptimal levels of water current and oxygen conditions during commercial farming practice.

Bio-fouling on aquaculture nets

Bio-fouling on the aquaculture nets is known as a significant problem for the global fish farm industry. The water exchange across the net is decreased by bio-fouling due to reduced mesh size. Thus, the waste removal and the oxygen transport are restricted and the water quality within the enclosures reduced. Another negative effect observed on the farming equipment is additional drag. These additional loads on the system decrease the flotation capacity and the life spans of mooring lines. Maintenance of the net constructions is labour intense and connected to high costs. The Norwegian aquaculture faces an increasing hydroid problem, which consists of rapid re-growth and re-colonization after the washing procedure.

Figure 11 Hydroid Tubularia larynx on a net (Photo: Christina Carl, University of Oldenburg / SINTEF)

Figure 12 Close up picture of Tubularia larynx

(Photo: Jana Guenther, SINTEF)

The research within CREATE concentrates on the hydroid *Tubularia larynx* as a critical biofouling species on aquaculture nets in Norway. Knowledge is gained to understand the biofouling on nets and to develop solutions for more effective removal and control of biofouling. A greater understanding of the settlement preferences, feeding biology and reproduction of hydroids from both lab- and field-based observations will facilitate the development of novel strategies and technologies to reduce, control and remove hydroids on aquaculture infrastructure in an efficient and environmentally sustainable manner.

Non disruptive fish weight determination and video surveillance - Feasibility study

This project was a feasibility study for automating fish weight estimation. Two video cameras are used in stereo to create a three dimensional area to enable measure the size of the fish. With an exact model of the measured fish, the weight can be estimated. Currently this is done manually, and the goal of this project is to automate this process.

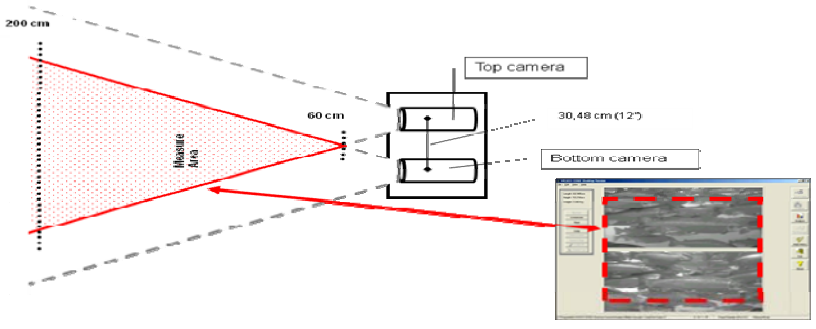

Figure 13: Stereo camera with setup

The project has developed a new image capturing design where fish is tried to automatically segmented from the background.
A first evaluation software has been created, and work continues to improve the algorithms. The second camera prototype was designed, and will be operational in 2008.

Figure 14: Segmented fish in a shoal

SubFish – Biological criteria for successful submergence of fish

Through three successive experiments at the Cage Environment Laboratory, Matre, we investigated the effects of submergence on swimming speeds, schooling, feeding and surface-oriented behaviours, body and fin condition and growth rates of salmon in full-scale sea-cages with simultaneous monitoring of environmental conditions.
Experiments 1 and 2 assessed the affect of submergence to shallow depths (cage roof at 3-5 m) for periods from 17 (Experiment 1) to 22 (Experiment 2) days on fish of average sizes of 1.7 kg (Experiment 1, 500 fish per cage) and 0.5 kg (Experiment 2, 3500-4000 fish per cage). In both experiments, salmon in submerged cages swam 1.5 -1.6 times faster (0.85 BL s^{-1}) than salmon in surface control cages (0.55 BL s^{-1}) and schooled more tightly. No evidence of acute buoyancy control problems was observed in the submerged fish and submergence did not affect feed intake. Small reductions in growth were found in the submerged fish in Experiment 1, relative to control fish, however, submerged fish also experienced lower temperatures which likely contributed to this difference. No differences in growth rates were found between submerged and control fish in Experiment 2 when control and submerged fish experienced similar environmental temperatures. Salmon appeared to tolerate submergence in commercial scale cages by swimming faster, possibly as a behavioural adaptation to generate lift to counter negative buoyancy. These results contrast with the strongly negative effects on submergence found by previous trials that used small-scale enclosures in which fish did not have sufficient room to swim freely.
The third experiment, assess the effects of submergence on large salmon (3.5 kg, 2200 per cage) subjected to 6 weeks of submergence to 10 m deep during the dark of winter. Preliminary results indicate that prolonged submergence may affect swimming behaviours mostly at night when the typical circular schooling pattern observed in cages may break down due to a lack of light. During darkness, these larger salmon appeared to compensate

for negative buoyancy through tilted swimming (head up, tail down). The submerged fish ate at a slower rate after around 3 weeks, and fish weights after merging was 4.46 kg and 4.09 kg respectively for the control and submerged fish. The feed convertion seems not to be affected by submergence. However, results of the three experiments indicate a clear potential for submerging salmon for periods of several weeks without strong negative effects on behaviour or growth.

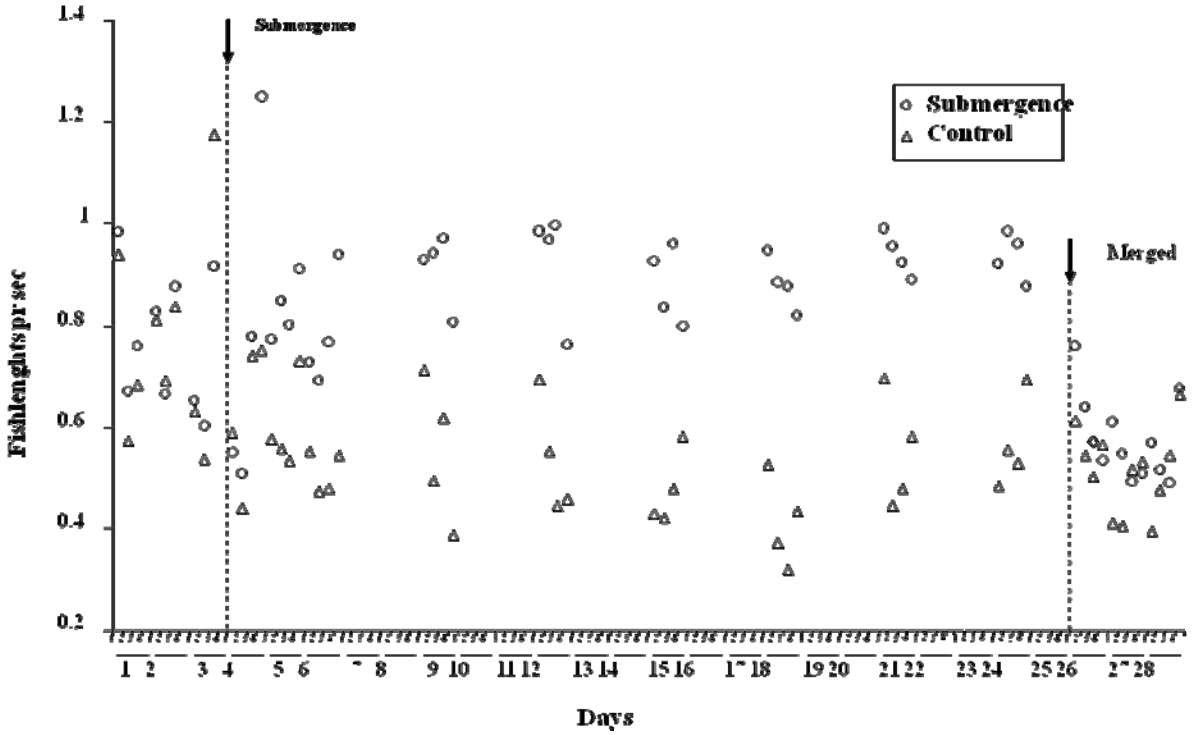

Figure 15. Experiment 2, average swimming speed (body length/second) for Atlantic salmon in two traditional sea-cages held at the surface (control) and two sea-cages submerged for 22 days. Each point gives the mean speed of 30 fish in two cages.

Figure 16 Night time view of the sea-cages at the Solheim experimental site with underwater lights at 10 m deep.

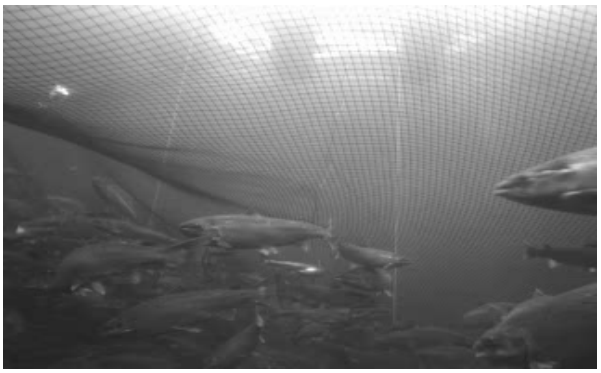

Figure 17 Salmon beneath the roof of a submerged cage without lighting.

5 International co-operation

The Open Ocean Aquaculture group at University of New Hampshire is an active partner in CREATE. They are involved in the SUBfish project and participate in consortium activates like yearly meetings.

CREATE has initiated an EU proposal on the topic preventing escape of fish. Research partners are involved in existing EU projects and new initiatives towards FP7.

6 Recruitment

Post doctoral fellows

Dr. Jana Guenther completed her PhD degree in Aquaculture at James Cook University, Australia, under the supervision of Prof. Rocky de Nys in 2007, and started a post doctoral position within CREATE in January 2008. Jana has 5 years of research experience in the elucidation of natural fouling defences of pearl oysters and sea stars, the description and quantification of fouling communities, larval biology and bioassay development. Her current work focuses directly on controlling biofouling on aquaculture constructions in Norway.

Dr. Jason Bailey was employed as a postdoc from September 2007 but unfortunately left us in January 2008. He has a PhD in aquaculture from University of Umeå in Sweden and was in charge of the water flow measurements in the field trial. The data collected is still being analysed and published by Bailey and Oppedal with co-authors.

PhD fellows

Martin Føre commenced his education at the Norwegian University of Science and Technology in 2001, and graduated with a Master of Science (“Sivilingeniør”) in Engineering Cybernetics with specialisation in biological modelling in 2006. In autumn of 2006 he started as a PhD student within CREATE where he is engaged in developing mathematical models of fish behaviour and physiology in aquaculture. Potential application areas for such models include predictive tools for production planning and model-based *in silica* estimation of e.g. biomass in sea-cages. He is now in his second year and expects to finish his degree in 2010. Fields of interest include: numerical modelling, simulation and estimation, mathematics, biology, fish behaviour and programming.

Mette Remen has been employed as a technician from July 2007 and will start as a PhD student from April 2008 and continue the postdoc position of Bailey as a PhD. She has a Master degree in aquaculture from University of Bergen, department of Biology. Mette will investigate how fluctuating oxygen (hypoxic level, duration, frequency) affect salmon welfare through measurements of feed intake, feed conversion, growth, cortisol release rates, behaviour and more through 2-3 tank studies during the following three years.

Master degree students

Christina Carl has been studying Marine Environmental Sciences at the Carl von Ossietzky University of Oldenburg/ Germany since October 2002. She gathered work experience in the field of sustainable aquaculture at the James Cook University, Australia, in the laboratory of Prof. Rocky de Nys in 2006/07. Christina started her Diploma thesis within CREATE focussing on hydroid growth on aquaculture nets in October 2007 and will be finished in July 2008.

Jannicke Vigen is a Master student in aquaculture at the University of Bergen, department of Biology. She has a Bachelor in Marine Science at Murdock University, Perth, Australia. She was in charge of the oxygen measurements in the field trial. The master thesis will be written up by this summer.

Visiting scientist

Dr. Shim Kyujin is a visiting scientist from Gyeongsang National University, Tongyeong City, Korea. Dr. Kyujin has ha PhD in the field of Computational Fluid Dynamics.

7 Financial statement 2007

All figures in 1.000 NOK

Cost	
Personnel- and indirect cost	3.049
R&D cost	2.982
Equipment	100
Operating cost	4.694
Total cost	**10.824**

Funding	
Host institution	481
Public funding	860
Privat company funding	3.774
Norwegian Research Council grant	**5.709**
Total funding	**10.824**

8 Publications

Scientific publications

Dempster T, Juell JE, Fredheim A, Lader P, Fosseidengen JE (2008) Behaviour and growth of Atlantic salmon (Salmo salar) in commercial scale sea-cages subjected to short-term submergence. Aquaculture doi:10.1016/j.aquaculture.2008.01.018

Juell, J.E., Nilsson, J., Olsen, R.E., Fridell, F., Kvamme, B.O., Oppedal, F., Humborstad, O.B., Mangor-Jensen A, Stien, L.H., Kristiansen, T.S. 2007. Dyrevelferd i akvakultur og fiskeri – et nytt fagområde i rask vekst. Kyst og Havbruksrapporten, Fisken og Havet, Særnummer 2. 2007.

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