NORWEGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY (NTNU)
MARINE STRATEGIC AREA
ANNUAL REPORT 2012

NTNU – Trondheim
Norwegian University of
Science and Technology

NTNU is Norway's centre for technological education and research, with a solid foundation in the natural sciences. With more than 20,000 students, seven faculties and 53 departments, NTNU educates 80 % of Norway's graduate engineers, and many alumni hold senior positions in industry and the public sector.

The vision of NTNU is

Knowledge for a better world

NTNU aims to create the basis for the development of knowledge and to create value – economic, cultural and social. The university's main profile in science and technology gives it a particular responsibility to develop the technological foundation for the society of the future. Making best possible use of this profile, of its academic breadth, and of its interdisciplinary expertise, NTNU will contribute to solving complex problems and to increase the understanding of relationships between technology, society and environment. These qualifications will also promote innovation and develop the knowledge base for sustainable value creation and a competitive business sector.

As a university, NTNU has a particular responsibility for long-term basic research and academic development. Research-based education is offered at all levels, emphasizing professional study at master's degree level and doctoral degrees.

It is anticipated that the answers to the complex questions of the future must be searched for through interactions across the classical disciplines. Among the university's strengths are its strategic areas, described below, offering international-calibre interdisciplinary research and education:

- Energy and petroleum – resources and environment
- Information and communication technology
- Marine and maritime technology
- Materials
- Medical technology
- Globalization

The Marine Strategic Area has two main pillars:

1. Centre for Ships and Ocean Structures (CeSOS), Centre of Excellence, funded by the Research Council of Norway and NTNU
2. NTNU Marine Coastal Development (NTNU MCD)

NTNU Marine Coastal Development will create knowledge for a sustainable coastal development through holistic and multidisciplinary research and education.

Visit us at www.ntnu.edu/marine

Photo front page: Crestock

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Museum of Natural History and Archaeology:	Øyvind Ødegård

CONTACT

Alexandra.Neyts@ntnu.no

MARINE THEMATIC RESEARCH AREA – CORE ACTIVITIES

The marine strategic area covers the three main domains along the marine value chain:

This report is a compilation of activities, events, programmes and projects that have been performed by members of NTNU marine strategic area in 2012. Its objective is to indicate the type of scientific expertise, research opportunities and educational focus available within the marine field. If any more detailed information is required, please contact Alexandra.Neyts@ntnu.no

OCEAN SPACE RESEARCH

Ocean Space Research

Marine surveillance systems

Energy from the ocean

Marine ecosystems

Eco-toxiology

Marine archaeology and cultural history

Coastal zone development and infrastructure

Infrastructure

RV Gunnerus

Trondhjem Biological Station

Marine Technology Centre

ACE

NTNU and SINTEF Sealab

Monitoring of the marine environment and its resource through observations and measurements has evolved into a new scientific era with the generation of multiple data of high accuracy. NTNU has contributed to this development through research on surveillance technology and communication systems. Mounted on sub-sea installations or mobile platforms like the Gunnerus research vessel, remote operated vehicles, autonomous underwater vehicles and gliders, they offer complete marine observation systems. New tools become hence available both to marine ecologists and archaeologists.
A sustainable management of the marine ecosystem also requires a better knowledge of the marine processes, such as species diversity, genetic resources, biology, hydrodynamics, chemistry and ecology, and of societal issues related to coastal zone development. The understanding of the effects of marine food web exposure to toxic compounds and CO_2, in particular in polar areas, has received special attention.

Applied Underwater Robotics Laboratory (AUR-Lab)

AUR-Lab was established in 2011 in order to strengthen ocean space research and education by integrating technology and science. Its properties are described under the "Available Research Infrastructure" chapter of this report. Below, a number of research activities that were carried out in 2012 are described.

www.ntnu.no/aur-lab

NTNU AUR-Lab and Norwegian Defence Research Establishment joint research cruise

In December 2012 NTNU AUR-Lab together with The Norwegian Defence Research Establishment (FFI) conducted a research cruise in Trondheimsfjorden. Based on NTNU's research vessel RV Gunnerus a multidisciplinary research group could deploy both AUV Hugin HUS and ROV Minerva to explore and investigate the ocean space in one of Norway's largest and deepest fjords. The Hugin system is the result of a collaborative effort between FFI and Kongsberg Maritime, and is commercially available in the high-end market for both civilian and military purposes. The Hugin HUS is specially designed for scientific purposes, and is configured with a long range of sensors. Of particular interest for this cruise was the HiSAS 1030 Synthetic Aperture Sonar system. With unprecedented range and resolution, this sonar is the ultimate tool for

Photo: NTNU/FFI

seabed mapping and documentation. NTNU's ROV Minerva – one of the three ROVs operated by AUR-Lab – was used to complement the AUV by doing close up investigations of targets discovered by Hugin HUS. Minerva was deployed with a dynamic positioning system developed at NTNU's Department of Marine Technology, enabling high precision operations and measurements. Having the world's most advanced robots and instruments at disposal three separate missions were chosen to maximize the scientific outcome of the cruise. A television team (NRK) was on board during the whole cruise making several features for the science program "Schrödingers Katt".

Contact: Dr. Martin.ludvigsen@ntnu.no

Mapping the coral reef at Tautra in Trondheimsfjorden
The marine biological mission in the NTNU AUR-Lab and FFI joint research cruise was to survey the deep water corals at the Tautra Reef in the middle of Trondheimsfjorden. The coral reef has long been known to marine biologists, but until now the extent of the reef, dominated by the reef building coral *Lopehelia pertusa* population has not been known. After a few hours in the water, the AUV Hugin HUS yielded high resolution synthetic aperture sonar (SAS) imagery revealing that the coral reef is about three times larger than previously estimated. In addition to SAS imagery and still camera photographs acquired with Hugin HUS, the ROV Minerva was also deployed to document parts of the coral reef in HD video. Utilizing Minerva's dynamic positioning system video capture of the reef could be geo-referenced and compared to corresponding data from Hugin HUS. In just one day huge amounts of high quality scientific data from the coral reef was collected, ready to be transformed into valuable ocean space knowledge by researchers, MSc- and PhD-students.

Contact: Professor Geir.Johnsen@ntnu.no

Photo: NTNU/FFI

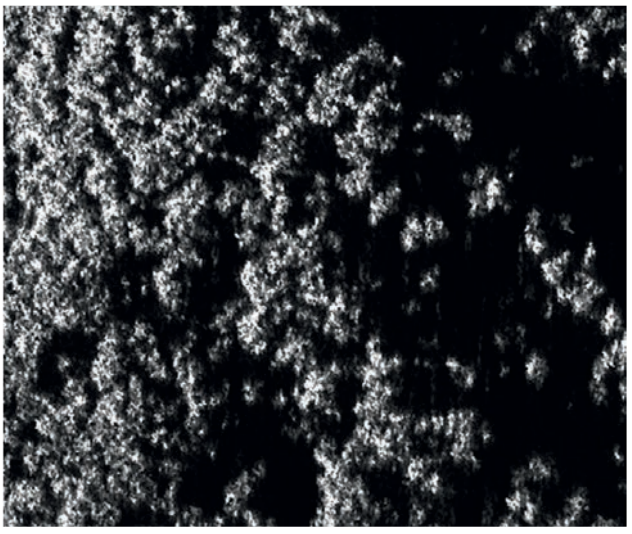


Photo: NTNU/FFI

Searching for Nazi war crimes in the deep
One of the missions on the NTNU AUR-Lab and FFI joint research cruise was to look for evidence of war crimes committed at the end of world war II. In early May 1945 German soldiers spent two nights secretly exhuming an unknown number of POWs executed at Falstad concentration camp earlier during the war. The bodies were loaded on to an old barge filled with rocks and sunk, presumably in deep waters. Based on an eyewitness report researchers from NTNU could narrow down the probable location to an area manageable for the AUV Hugin HUS and its synthetic aperture sonar system. In four consecutive dives over two days Hugin HUS mapped 15 square kilometers of the seafloor at around 400 meters depth in very high resolution. Over 30 targets were detected as possible objects of interest. With limited time the ROV Minerva could only inspect three of the targets, and the "Falstad boat" was not among them. AUR-Lab intends to return to the area at a later stage to investigate more targets.

Contact: Professor Asgeir.Sorensen@ntnu.no

Marine Archaeological investigations in Trondheim Harbour
The last mission of the NTNU AUR-Lab and FFI joint research cruise was to test the performance of AUV Hugin HUS and its Synthetic Aperture Sonar for marine archaeological purposes. Trondheim was the first capital of Norway, and is considered by many to be its first real city. The main reason the city was placed there over a thousand years ago was undoubtedly the favorable harbor conditions in the river Nidelva, providing protection for ships and boats in bad weather. During the 16th-17th centuries the river became too shallow for the modern sailing ships that had considerably deeper draft than the medieval clinker built vessels, and the city's harbor was moved outside the river mouth. With less protection from wind and weather more than one ship anchoring outside Trondheim have lost anchor hold in storms and met their fate against the Lade rocks. After a few hours under water Hugin HUS had covered an area

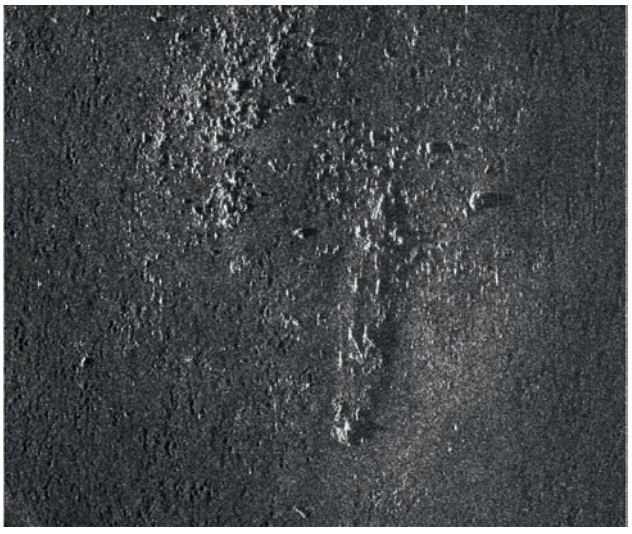


Photo: NTNU/FFI

with two known historical wrecks in a lawn mower pattern, gathering data from multiple passes of each wreck at different angles and ranges. The Synthetic Aperture Sonar system produces both imagery and bathymetry in high resolution, providing AUR-Lab's marine archaeologists with very valuable scientific data. As an extra bonus three previously unknown wrecks were discovered during the mission.

Contact: Oyvind.Odegard@ntnu.no

Arctic DP

The project "Safe and green dynamic positioning (DP) operations of offshore vessels in an arctic environment" was awarded by the Research Council of Norway to NTNU and industry partners Kongsberg Maritime, Statoil and DNV for a project period 2010-2014. Its vision is for Norwegian industry to attain world leading competence and knowledge of DP system technology and operation developed for safe and environmentally robust DP operations in Arctic regions. The main focus is on understanding the physics of DP vessel motions in arctic sea-ice, development of corresponding mathematical models and numerical simulators, and use of automatic control theory within instrumentation, estimation, and development of observer, guidance, and control algorithms. Five PhD students and two Post-docs have been working on the project in 2012. ROVs have been used to qualify subsea sensors for use as underwater ice sensors. A test campaign with an AUV is planned for demonstrating underwater sea-ice observations.

www.marin.ntnu.no/arctic-dp
Contact: Prof. Roger.Skjetne@ntnu.no

Illustration: Bjarne Stenberg, Copyright: NTNU

CeSOS

CeSOS is the national Centre of Excellence for Ships and Ocean Structures, located at the Marine Technology Centre in Trondheim. Research at CeSOS aims at developing 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 engineering research carried out is inspired by the technology outlook, in a 20-25 years perspective, and involves topics within hydrodynamics, structural mechanics and automatic control relevant for the design and operations planning of ships as well as offshore structures for oil and gas, ocean renewable energy and aquaculture. The formal 10 year period of CeSOS ended on 30 November 2012. The Centre will continue on for a few more years e.g. to ensure the graduation of the remaining 40 PhD candidates who are being financed by funds beyond the RCN's CoE support. At the seminar celebrating the Centre's 10 years of operation, Henrik O. Madsen, DNV Group CEO, and the Director General of the Research Council of Norway Arvid Hallén expressed that CeSOS has succeeded beyond expectations.

www.cesos.ntnu.no
Contact: coe@marin.ntnu.no

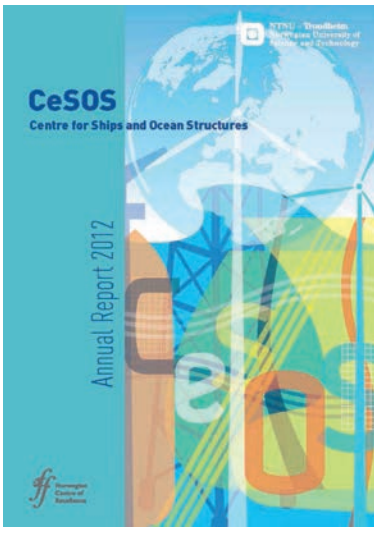


Illustration: Bjarne Stenberg, Copyright: NTNU

CSR – Competence network for innovation

The CSR competence network aims to increase the competence on Corporate Social Responsibility (CSR) in the intersection between education, research and the industry. The network is a collaborative project between companies and knowledge partners from Mid-Norway. Seminars, lectures and workshops were used to share and create new knowledge within this field. The network was established in 2011 and will continue to operate through 2013. Core partners are Innovation Norway, NHO, Sparebank 1MN, Fokus Bank, the Norwegian Center of Expertise – Maritime, Pharmaq,

NTE. The network is financed partly by the Research Council Norway under the program BIA. Among the activities in 2012 are seminars on the following topics: "CSR and Innovation in SMEs", "Environmental management and CSR", " CSR: Strategic vision or obligations?, "CSR in project management" and "CSR in the Boardroom".

www.csr-norway.no and www.csr-region.no
Contact: Professor Annik.Fet@iot.ntnu.no

Ecological effects of offshore wind on the marine environment

The main goal of the project is to investigate the population dynamics of mobile organisms and sensitive species that often use offshore wind power as new habitats. Several ecological investigations have been carried out in the Lillgrund wind farm in Sweden by marking of marine organisms (shore crab and eelpout) and recapture studies. Additionally, stress response of the viviparous eelpout (*Zoarces viviparous*) has been investigated in the Lillgrund offshore wind farm to find out if that species is a suitable bioindicator for disturbances in the wind farm area. This project is financed by Statkraft Competitive Wind Power Program that covers on- and offshore wind, focusing on the Nordics and UK and the Department of Biology, NTNU.

Contact: Dr. Olivia.Langhamer@ntnu.no,
Professor Gunilla.Rosenqvist@ntnu.no

Photo: Olivia Langhamer

Effects of oil dispersions in the marine environment

At Sealab, several experiments were carried out in 2012 related to the following research projects:

- Effects of dispersed oil in the water column: addresses its biological effects in near-shore waters, especially with regard to filtrating organisms (in collaboration with Sintef Materials and Chemistry, Aquaplan Niva – Tromsø; funded by Statoil petroleum ASA, Shell Technology Norway AS and ENI Norge AS).
- Understanding fitness-related effects of dispersed oil on *Calanus finmarchicus:* addresses its possible biological, physiological and genetic effects, using tools such as metabolomics and genomics (in collaboration with SINTEF Materials and Chemistry, Sintef Fisheries and Aquaculture, Altins BioTrix, NIVA and Stockholm University; funded by Norwegian Research Council).
- Decision support tool for marine oil spills: evaluates the fate of spilled oil in near-shore waters after treatment with dispersing agents. Involved mechanical, chemical and biological mechanisms are considered, whereas numerical modeling is based on general environmental information (in collaboration with SINTEF Materials and Chemistry, Statoil petroleum ASA, Shell Technology Norway AS, ENI Norge AS; funded by Norwegian Research Council and participating oil companies). One PhD (NTNU, IBI) is affiliated to the project.

Contact: Anders.J.Olsen@ntnu.no

Photo: Ida Beathe Øverjordet

Effects of ocean acidification and climatic stress on Calanus finmarchicus

The aim of this Norwegian Research Council project (2010 - 2014) is to reveal if *Calanus finmarchicus* may be sensitive to predicted ocean acidification scenarios and potential additive effects from raising seawater temperatures and oil spills. To address these questions a dedicated CO_2-wetlab has been installed at NTNU SeaLab. The sophisticated experimental setup has been designed to allow controlled manipulation of CO_2-concentration, temperature, light and feeding regime over long therm. The project is run in collaboration with SINTEF. Results from the experiments will be implemented in a model to be used for prediction of effects on population levels along the coast of Norway.

Contact: Dr. Sindre.Pedersen@bio.ntnu.no

Photo: NTNU, Dept of Biology

EUR-OCEANS

EUR-OCEANS considers the relevance and impacts of climate and global change on the oceans. NTNU is one of the 19 core members contributing financially and scientifically to the European consortium. EUR-OCEANS facilitates and promotes:

- Collaborative research on the impacts of anthropogenic and natural forcings
- Optimal use of shared technical infrastructures and scientific facilities
- Activities to spread excellence, such as traning and knowledge dissemination

The scientific topics that have been dealt with include the changing biogeochemical cycles of the oceans, the loss of biodiversity as a consequence of increasing temperature and acidification or harvesting, the role of small scale interactions in energy transfer and in carbon export, the widening of sub- and anoxic ocean regions, and the links between ecology and genomics, evolutionary and life history. In 2012, the launch of a new venture, EuroMarine+, was prepared, integrating three major European marine networks: EUR-OCEANS, MarBEF and Marine Genomics Europe.

www.eur-oceans.eu
Contact: Associate Professor Murat.V.Ardelan@ntnu.no

Harvest

The goal of HARVEST was to assess stocks of plankton and quantify ecological consequences of harvesting at lower trophic levels. The main partners in the project were the Institute of Marine Research and SINTEF. The contribution from NTNU to this project was to clarify biological mechanisms and variables as input to mathematical models. Results from Harvest are being used to construct ecological models to be implemented for management of plankton fisheries.

Contact: Oystein.Leiknes@ntnu.no

Historic marine science study revived

A study of the reverend, naturalist and geographer Hans Strøm was initiated. More closely, this review looked at his treatise on the topography, biology and economy of the district Sunnmøre (Northwest Norway) from 1763. A transcription of the 600-page Volume 1 (general part) from Danish Fraktur (Gothic) Script to Latin script was finalized by the end of 2012. A preliminary draft of a translation into modern Norwegian has been carried out and will, after its conclusion, be followed by a translation into English.

Contact: Professor Egil.Sakshaug@bio.ntnu.no

HYDRALAB IV

HYDRALAB is a unique European network in the hydraulic research community and has large experience in co-operating since its start in 1997. Currently, 30 partners and associated partners from 15 countries participate in Hydralab IV (2010-2014), aiming at structuring the access to unique research infrastructures for studying interactions between water and environmental elements, sediment, structures and ice. NTNU offers transnational access and full-scale field research opportunities at the land-locked Bay of Hopavågen in Mid-Norway. Here, an interdisciplinary project team of ecologists, sedimentologists and marine engineers are brought together to bridge the gap between field observations of benthic algae and physical models of plants and animals. By comparing the results obtained from the environmental simulator at the University of Hull with the field data from the coastal bay, a better practice for experimental modelling is to be developed. In August 2012, the Bay of Hopavågen was accessed by a transnational group of researchers (CNRS at Brest, NOC Southampton, University of Hamburg, DTU-Aqua, University of Bremen and University of Munich) carrying out mesocosm experiments to assess the extent to which organic matter produced within different food webs is retained in the upper ocean food web.

www.hydralab.eu/
Contact: Alexandra.Neyts@ntnu.no

Photo: Adrian Teaca

Photo: Christina De La Rocha

Impact of oil discharges on light- and temperature-adapted behaviour in the marine calanoid copepod Calanus finmarchicus

The project is aimed to investigate the vision ability of *Calanus finmarchicus* with regard to sensitivity, wave-length range and response pattern, and whether or not petrogenic oils may affect the vision or visual response. Vertical migra-

tions are assumed to be vital for growth and maintenance in copepod populations, and light is believed to be the main cue, still there is much debate regarding the mechanisms governing the migrations. The project is a laboratory study carried out in a custom-made exposure system at NTNU Sealab, with assistance from SINTEF Materials and Chemistry, and Biotrix. One PhD candidate (NTNU, IBI) is affiliated to the project. The project is funded by VISTA.

Contact: Anders.J.Olsen@ntnu.no

Photo: Ida Beathe Øverjordet

Innovation in Global Maritime Production - 2020 (IGLO-MP2020)

The IGLO-MP 2020 knowledge-building project (KMB) has been a collaboration between different departments at NTNU (Dept. of industrial economics and technology management and Dept of production- and quality management) and Marintek. The industrial partners Ulstein International AS, Pon Power AS, Siemens AS and Fiskerstrand Verft AS have been active throughout the project period that lasted until the end of 2012. The project draws on the expertise in international institutions, on Roll Royce Maritime and the Norwegian Center of Expertise Maritime in Ålesund (NCE Maritime). The overall focus of this KMB has been to strengthen the competitive capabilities of the Norwegian maritime industry in order to improve competitiveness. IGLO-MP 2020 has identified a few key areas and themes, which the consortium members perceive as critical for future development and sustainability of the maritime industry in Norway. These are elements which are believed to provide Norwegian ship owners, ship designers, ship consultants and maritime equipment suppliers with competitive advantages in years to come. Two PhDs have been financed through this project.

Photo: Annik Fet

www.iglo-mp2020.no
Contact: Professor Annik.Fet@iot.ntnu.no

Low Emission Design of Ships (LEEDS)

Energy usage for ship propulsion lead to emission of greenhouse gases (GHG). It is estimated that in order to achieve stabilisation at 2°C above pre-industrial levels, GHG emissions need be reduced in the order of 50 % - 85 % in 2050. These ambitions will also affect maritime transportation as international shipping is responsible for approximately 3 % of global CO_2 emissions. To achieve the ambitious emission reduction targets, radically new ways of designing ships are required. The objective of the LEEDS project is to develop knowledge for concept design, system design and technology options to be used for radical ship design for low energy consumption and GHG emission. The baseline for energy usage and emission level is to a large degree set with the ship design, hence a continuous line of new ship designs are required. The LEEDS project will contribute both with new knowledge of low energy and emission ship design, as well as the education of personnel with confidence and background to challenge low energy and emission ship design that can become key personnel in the maritime industry for developing novel solutions for energy and emission reduction.

Contact: Professor Bjorn.E.Asbjornslett@ntnu.no

Ocean Space Centre (OSC)

Ocean Space Centre is a new world-leading cross-disciplinary knowledge centre for development of ocean space science and technology that can contribute to global food, energy and environment challenges. In particular, OSC aims to contribute to:

- educate the future specialists within ocean space technology,
- make sure industry and society have access to leading edge expertise and infrastructure related to harvesting, use and management of ocean space,
- the effective utilization of national expertise and knowledge through cooperation with Norwegian and foreign institutions and businesses,
- increased innovation within ocean space technology.

Alternative concepts for development of Ocean Space Centre at the current location of the Marine Technology Centre at Tyholt in Trondheim have been developed.

Through the independent quality assurance that all government investment projects above 500 mill NOK needs to go through, i.e. KS1, it has been confirmed that the proposed centre will be profitable for the society. This confirmation is an important step towards the realization of the new centre.

www.oceanspacecentre.no
Contact: Atle.Minsaas@marintek.sintef.no

Seabed characterization

The objective of the project is to characterize the upper part of the sediment by studying the interaction of the acoustic wave with sea bottom and development of effective forward model and model-based geoacoustic inversion for estimation of seabed properties, especially the shear wave velocity profile in the sediments. The research in this area is directly related to offshore geotechnical applications.

Contact: Professor Hefeng.Dong@iet.ntnu.no

ShipSoft

ShipSoft is a pre-project where the opportunities for integrating system analysis in marine systems design were explored. By investigating the informational, computational and analytical requirements for assessing marine design, opportunities and barriers for adopting such methods in the industry were identified. The project is connected to IGLO-MP 2020 with partners from Ulstein Design and Solutions, Pon Power, Fiskerstrand Shipyard and Fjord1. The project period was extended to mid 2013. Especially results from investigations of ship-recycling practice will be taken into consideration in the models. The project activities have also resulted in further project activities, such as the KMB-project "Decision support for sustainable production of offshore ships in global fluctuating markets" involving the NTNU departments of industrial economics and technology management, production and quality management and marine technology, as well as leading industries. This project will start in spring 2013 and environmental life cycle management will be a cross work-package activity.

Contact: Professor Annik.Fet@iot.ntnu.no

Strategic fleet planning: optimization of fleet size and mix (MARFLIX)

Composition of the fleet is a major strategic decision for most shipping companies. The MARFLIX project will establish quantitative methods for analyzing such decisions improving the decision support for ship owners. In any given market situation, the number of vessels (fleet size) and the variety of vessel types (fleet mix) will determine the profit potential for the company. Operational optimization in terms of capacity utilization can only be done within the bounds imposed by the available fleet resources. History has shown that being positioned with the right fleet is even more important for profit than operational excellence.

The basic inputs for a fleet size and mix problem are the potential vessels for inclusion in the fleet and the future transport volume demand. If these were known, the task of finding the optimal fleet to fit the demand would still be challenging, but manageable. Unfortunately, there is a lot of uncertainty that needs to be taken into account. When building expensive vessels that need to operate for 25-30 years, future demand, fuel prices, rates and ship technology are all uncertain factors. It is therefore important that the risks involved are addressed and that the fleet composition decision-making is robust.

Contact: Professor Bjorn.E.Asbjornslett@ntnu.no

Fig: Bjørn Egil Asbjørnslett

Sustainable Arctic Sea Transport

Offshore activities and shipping in Arctic regions are increasing significantly due to the vast amount of natural resources found in the high north. However, the distinct conditions of the Arctic Sea, such as remoteness or the lack of marine infrastructure, represent a challenge to be surpassed in order to ensure safe and economical

Photo: Sören Ehlers

feasibility of high north transport and operations. Furthermore, the assessment of the parameters and their sensitivity influencing the ship design for Arctic conditions, and thereby the safety of life at sea, are of utmost importance. Especially, the description of the environmental conditions including single and multi-year level ice, ice ridges, drifting ice, icebergs and general extreme weather conditions in a format suitable for design are of significant importance. This research group is actively contributing to the identification of the required safety level for arctic ship-based transport and further identifies risk-mitigation measures and arctic sea specific risk-based design methodologies. The activities involve international and national research projects, PhD projects and courses as well as master level education. The main professorship involved in this research is held by Sören Ehlers. The position is currently sponsored by the Norwegian Ministry of Trade and Industry as part of the maritime knowledge hub.

www.knowledgehub.no
www.ntnu.edu/sast
Contact: Professor Soren.Ehlers@ntnu.no

Underwater Acoustic Communication

The objective of the project focuses on the system design and development of signal processing methods, adaptive modulation techniques and signalling methods for underwater acoustic communication and verification of the developed methods and techniques by experiments in the sea using Acoustic Underwater Laboratory facilities and NTNU research vessel R/V Gunnerus. In 2012, several experiments were carried out in the Trondheim fjord for verification. The master students in course Marine Acoustics, exchange and PhD students also participated in the experiments.

Contact: Prof. Hefeng.Dong@iet.ntnu.no

Photo: Svenn Ove Linde

University Technology Centre (UTC)

The UTC "Performance in a Seaway" is a co-operation between Rolls-Royce Marine, MARINTEK and NTNU. The centre aims at promoting research with a commercial potential, in particular development of propellers, propulsion systems, ship designs, and various types of ship equipment. Current research in the centre focuses on:

- The interaction between hydrodynamic loads and mechanical response of azimuthing thrusters in extreme operating conditions, including strongly oblique inflow and in-and-out-of-water.
- Speed loss and change of propulsive characteristics of ships travelling in waves.
- Reduction of fuel consumption and improvement of motion characteristics of ships by use of foils as auxiliary propulsion devices (see www.wavepropulsion.com).

Contact: Professor Sverre.Steen@ntnu.no

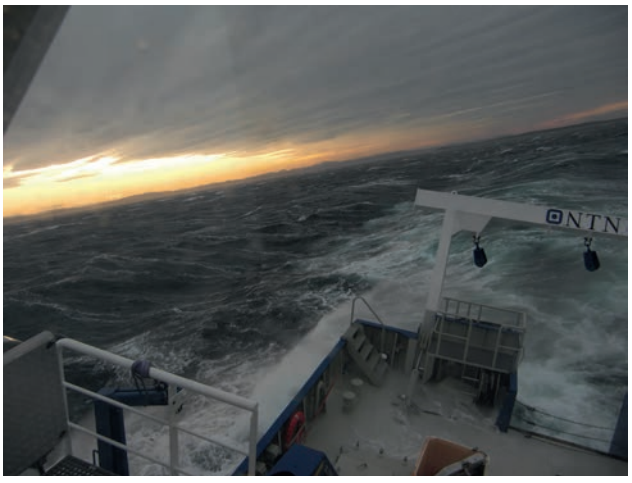


Photo: Siv Etter

FISHERIES AND AQUACULTURE

Fisheries and Aquaculture

Aquaculture engineering

Sustainable marine aquaculture and societal aspects

Biological basis of marine aquaculture

Marine harvesting technology

Sustainable fisheries

Social strategies of fisheries

Infrastructure

NTNU and SINTEF

Sealab Flume Tank

RV Gunnerus

ACE

Marine Technology Centre

There is a clear trend that, whereas catches from the wild are stagnating, any future increases in seafood provision are to come from sea-based aquaculture. Although the situation for the fisheries and aquaculture industries is very different, both sectors need to focus on environmental sustainability and consumer attitude when developing further.
Aquaculture at NTNU has its main focus on aquaculture engineering of land- and sea based production systems, the sustainability of these systems, and the fundamental biological sciences of aquaculture engineering. By taking full advantage of the knowledge and developments made in other sciences and industries, such as the offshore oil industry, considerable technological progress can be obtained within this young industry. A better understanding and control of environmental impacts is crucial both from a production and a consumer perspective.
The goal of fisheries research at NTNU is to promote active multi-disciplinary problem-solving research, through close interaction among engineering, natural science and social sciences. Through the development of low energy catching technology, improved fishing gear, on board catch handling and flexible logistic- and distribution systems fisheries can gain efficiency. At the same time, it is important to counteract over-fishing problems through improved management strategies, catch monitoring, and sustainability documentation. Scientific approaches for the maintenance of sustainable coastal communities is also a focus area for fisheries research at NTNU.

AQUAEXCEL

Photo: Elin Kjørsvik

AQUAEXCEL (AQUAculture infrastructures for EXCELence in European fish research) is a EU-funded project under the 7th Framework Research Infrastructures programme. It provides the aquaculture research community with a platform of top class research infrastructures. The objective of AQUAEXCEL is to integrate, on a European scale, key aquaculture research infrastructures, in order to promote their coordinated use and development. In total, 17 partners collaborate to offer access to 23 experimental facilities, and to provide better tools for aquaculture research. NTNU provides access to the CodTech laboratory. This automated start-feeding rig is one of the most advanced cultivation hatchery units in Europe. The facility is equipped with automatically controlled feeding, water exchange and online measurements and control of live feed density and environmental variables. AQUAEXCEL operates with approximately 2 calls for access proposals each year until 2014.

www.aquaexcel.eu
Contact:
Associate Professor Jo.Arve.Alfredsen@itk.ntnu.no

Aqua-tnet

Aqua-tnet is the European Thematic Network in the field of aquaculture, fisheries and aquatic resources management. The network is funded under the European Commission Lifelong Learning Programme, and has been active since 2008, with funding for phase 3 through 2014. The network aims at reaching a greater compatibility and comparability of the systems of higher education in Europe. The Aqua-tnet web portal contains databases on mobility and opportunities, course databases, and innovative teaching resources.

www.aquatnet.com
Contact: Professor Elin.Kjorsvik@ntnu.no

AQUAGAMETE

"Assessing and improving the quality of aquatic animal gametes to enhance aquatic resources" deals with the need to harmonize and standardize evolving methodologies, and improve transfer from academia to industry. AQUAGAMETE is a European network of researchers and producers. It was established in the fall of 2012, and it is funded by Food and Agriculture COST Action FA 1205. The aim of the pro-

posed AQUAGAMETE COST Action is to reach a consensus on protocols and guidelines (using internationally defined terminology, units of measurement and format of reporting) that permit the use of results in relational databanks for sound and common application in aquaculture research and commerce.

http://aquagamete.webs.upv.es/
Contact: Professor Prof. Elin.Kjorsvik@ntnu.no

Carbon footprint of seafood

This activity was initiated by Standards Norway together with researchers from SINTEF Fisheries and Aquaculture, NTNU and Østfold Research. Experts from the university are involved in the process collaborating with colleagues from institutions like the Norwegian Seafood Export Council, DNV, the Ministry of Fisheries and Coastal Affairs, Aker Seafoods, Nofima. The result achieved in 2012 is a draft standard for Product Category Rules (PCR). The aim is to obtain an approved PCR by the end of 2013. In parallel to this project, the experts have participated in an initiative led by British Standardization resulting in a new standard: PAS 2050-2 Assessment of life cycle greenhouse gas emissions - Supplementary requirements for the application of PAS 2050:2011 to seafood and other aquatic food products. The project leader is Erik Hognes at SINTEF.

Contact: Professor Annik.Fet@iot.ntnu.no

Characterization of the microbiota in the digestive system of wild cod *(Gadus morhua)*

A healthy gastrointestinal (GI) microbiota is important to the host's health. The possibility to control or modulate the GI microbiota of cultivated fishes is an attractive alternative to antibiotic treatments. However, knowledge is needed about the composition of the microbiota in healthy individuals and about the factors and processes determining the composition. In this study we apply barcoded amplicon pyrosequencing of bacterial 16S rDNA to investigate the composition of the GI microbiota of wild cod from Trondheimsfjorden. More specifically, variation between individuals and temporal stability will be characterized.

Contact: Dr. Ingrid.Bakke@ntnu.no

CINTERA - A Cross-disciplinary Integrated Eco-systemic Eutrophication Research and Management Approach

CINTERA is designed to improve knowledge of ecosystem response to eutrophication and management of eutrophication in different marine fjord ecosystems and zones in Norway and Chile. The outcome of the field studies will be the determination of the most pronounced chemical and bio-indicators of eutrophication in different conditions; this knowledge will give us the ability to improve monitoring activities in the future for early detection and management of the eutrophication problem. The project seeks to develop indicators for safe levels of nutrient and organic matter loads that are systemic-sensitive, useful for managers, and designed to prevent ecological and socio economic impact from increasing aquaculture activities in the Norwegian coastal system in line with the EU MSFD (Marine Strategic Framework Directive) standards and its GES (Good Environmental Status) and the WFD (Water Framework Directive). Employing methodologies of participatory model building (constructing mental maps and estimating the probability of various scenarios – see figure) will also examine the socio-economic aspects of eutrophication brought on by aquaculture by examining the adaptive capacity of given communities to aquaculture /eutrophication, particularly the level of social conflict that may be associated with it. CINTERA is a cross-disciplinary study with close cooperation among natural and social scientists in three countries – Norway, Chile, and the United States.

Contact: Professor Jennifer.Bailey@svt.ntnu.no;
Associate Professor Murat.V.Ardelan@ntnu.no

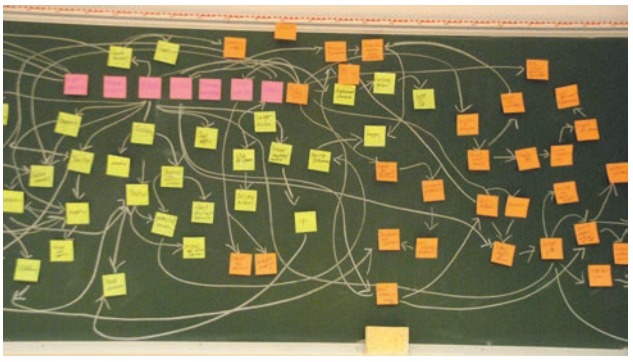


Photo: Rachel Tiller

Cod Development (CODE)

CODE is a national knowledge platform for studies of the development of biological processes in early stages of Atlantic cod, linked to nutritional, environmental and management aspects. CODE brings together a broad mass of leading Norwegian scientists from nine partner institutions and several international partners, and is funded by the Research Council of Norway (2010-2014).

Contact: Professor Elin.Kjorsvik@ntnu.no
www.uib.no/rg/mdb/projects/code-cod-development

Photo: Elin Kjørsvik

CREATE

CREATE is a Centre for Research-Based Innovation (SFI) funded by the Research Council of Norway. 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. Research and development is focused 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.

NTNU is a core partner in CREATE.

Contact:
Associate Professor Jo.Arve.Alfredsen@itk.ntnu.no

Dialogues on Aquaculture: Nature-Technology-Governance

This dialogue process began in 2011 as a joint initiative by the Dept. of Sociology and Political Science and the Dept. of Philosophy to bring together researchers in the social sciences and humanities to discuss issues arising out of the management of natural resources. A key area is the management of marine resources, particularly aquaculture. The project has a main objective to facilitate a cross-disciplinary dialogue on today's key aquaculture issues. It forged links between two different strategic areas at NTNU, i.e. Marine/Maritime and Globalization, and enhanced involvement of social sciences and humanities in research issues where natural sciences and technology have been dominating. By addressing important social, economic, ecological and technological issues and controversies, the dialogues are an important platform to develop strong, well-anchored, cross disciplinary research projects and publications on aquaculture.

www.ntnu.edu/dialogueonaquaculture
Contact: Professor Jennifer.Bailey@svt.ntnu.no, Professor May.Thorseth@hf.ntnu.no

EATiP – European Aquaculture Technology and innovation Platform

EATiP is the European Technology Platform assembling stakeholders from the entire European aquaculture value chain. "The Future of European Aquaculture" took successfully place on 30th October 2012 in the Royal Belgian Institute of Natural Sciences, Brussels. The event focussed on presenting the EATiP Vision, which has been developed through the widest consultation ever made on European aquaculture and supported by the European FP7 project 'Aquainnova'. Experts from the aquaculture profession, research and development, universities, NGOs, the European Investment Bank, the European Commission and other stakeholder interests debated key questions on forecasts and needs of the sector in 2030. The EATiP Strategic and Innovation Research Agenda was finalised, with involvement from NTNU experts in the thematic areas "Integration with the environment" and "Knowledge management".

www.eatip.eu
Contact: Professor Yngvar.Olsen@ntnu.no

Environmental Documentation Nordmøre

The project was initiated by the aquaculture industry in order to document environmental effects resulting from aquaculture activities in Western Norway (Nordmøre). NTNU contributed, in collaboration with SINTEF, to the work dealing with release and evaluation of environmental impacts of nutrients released from aquaculture. The main objective was to quantify emissions of inorganic nutrients from fish farms to water masses and to undertake an impact study to determine if emissions had negative chemical and ecological effects on the planktonic ecosystem, in accordance with the European Water Framework Directive (WFD). An overall conclusion was that the concentrations of nutrients, the biomass of phytoplankton and algal physiological indicators all indicated intact ecosystems of full integrity (State: Very good). The chemical and the functional state of the planktonic ecosystem were accordingly not negatively affected. In addition, research was performed on the modeling of flow and discharge of nutrients, lice and viruses.

www.moreforsk.no/default.aspx?menu=737&id=1065
Contact: Professor Yngvar.Olsen@ntnu.no

EPICONCEPT

"Epigenetics and Periconception Environment" looks at the periconception environment as an epigenomic lever for optimising food production and health in livestock. Parental stress before, during and after conception (i.e. the periconception period) induces epigenetic changes in gametes and embryos. Such epigenetic changes may adversely affect the future health, development, productivity and fertility of those offspring. While there is increasing evidence for this in agricultural species, most of this knowledge derives from epidemiological studies in humans and controlled studies in laboratory animals. In this Food and Agriculture COST Action FA1201, time frames and mechanisms during which the gametes and early embryo are susceptible to epigenetic modifications will be determined in livestock in order to optimize their health and productivity. This COST Action will identify stressors and molecules which induce, modulate

or remove epigenetic marks on genes that are relevant for different applications in farm animals. Public engagement activities are planned during the COST Action to inform the general public on the importance of the epigenome via the periconception environment in future food production, health and welfare. Research on epigenetic control of development is being performed by different groups in the EU, but efforts need to be coordinated in order to avoid duplication, set targets and guidance for future research and to standardise protocols in this field through a large collaborative EU network.

cost-epiconcept.eu
Contact: Professor Elin.Kjorsvik@ntnu.no

EXACTUS

Keeping track of the exact biomass of large-scale salmon farms, expressed as the size distribution and the total number of fish, has proved to be a surprisingly challenging task. The EXACTUS project has addressed this issue over the last three years seeking to obtain new knowledge, procedures and technology that can form the basis for a future biomass measurement system that satisfies industry requirements regarding accuracy, reliability and operational efficiency. NTNU has conducted a feasibility study with respect to employing advanced model-based estimation principles for salmon biomass determination. A framework has been developed that combines a mechanistic mathematical model of salmon biomass growth with sporadic and uncertain data from biomass related measurements in the cages (biomass frames, fish counts and manual sampling), in order to obtain optimal estimates of biomass in terms of fish size distribution and numbers. The EXCACTUS project has been managed by SINTEF Fisheries and Aquaculture, and supported by the Norwegian Research Council and several industry partners.

www.sintef.no/Projectweb/EXACTUS
Contact:
Associate Professor Jo.Arve.Alfredsen@itk.ntnu.no

EXPLOIT - Exploitation of nutrients from salmon aquaculture

The Norwegian Government has stated that fish farming should be performed without any negative environmental effects ("Strategy for an environmentally friendly sustainable aquaculture industry", 2009). The concern is mainly directed at eutrophication effects related to nutrients from salmon cage aquaculture. One possible solution for this is to include extractive cultures to remove these nutrients. The Research Council of Norway prioritised, through the call for projects in 2012, research on exploiting nutrients originating from fish farming, for instance through Integrated Multi-trophic Aquaculture (IMTA). The two main objectives of this project are to study the release and fate of inorganic and organic nutrients from salmon farms, and to investigate the possibility for removing these nutrients by extractive and filtering aquaculture. The project will deliver fundamental knowledge regarding IMTA productivity and design under Norwegian coastal conditions as well as consider socio-economic aspects of such production. A social science component deals with public perceptions of cage aquaculture. Prior to the Exploit project NTNU has allocated PhD and post.doc. scholarships within IMTA research and has a long R&D research activity on seaweed. In the exploit project NTNU will allocate one PhD position and host one post doc position, as well as educate 3-4 MSc-students within seaweed cultivation.

Contact: Associate Professor Kjell.I.Reitan@ntnu.no,
Professor Jennifer.Bailey@svt.ntnu.no

Gemini Centre for plankton technology and ecology

The main activity of this interdisciplinary Gemini Centre is located at SeaLab, where NTNU and SINTEF have several aquatic laboratories. Scientists and technicians from six NTNU departments, from SINTEF Fisheries and Aquaculture, and from SINTEF Materials and Chemistry participate in relevant activities. The aim is to develop joint strategies and a strong working partnership between biological and technological disciplines, to promote a high-level and robust research and educational community within the field of marine fish larval and plankton cultivation, as well as utilisation and ecology. The Gemini centre was granted a new period from 2012 to 2015. The activities are concentrated around coordination and policies for joint initiatives for new projects and conferences, joint management of laboratories, and to carry out joint project research and joint supervision of MSc students. In 2012, the recirculation system in the CodTech laboratory was upgraded.

www.ntnu.edu/geminicentre/mtp
Contact: Professor Elin.Kjorsvik@ntnu.no;
Associate Professor Jo.Arve.Alfredsen@itk.ntnu.no

GEMINI Center for Sustainable Fisheries

GeminiFish is a cooperative venture between NTNU and SINTEF Fisheries and Aquaculture to promote research

Photo: Svenn Ove Linde

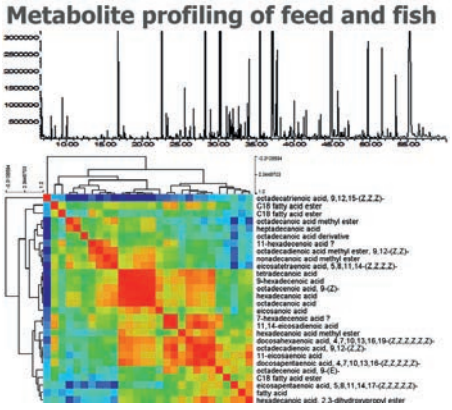
into sustainable fisheries. The Gemini Center serves as a meeting point between the two institutions, and as a forum for the sharing of research and application opportunities. The Gemini Center also hosts presentations and other opportunities for the further development of expertise.

geminifish.org
Contact: info@geminifish.org

Health in each pellet – Biologically active compounds in raw materials and effects in fish

The goal of the project is to develop salmon diets without fishmeal or other animal protein ingredients, thereby avoiding negative effects on lipid metabolism and immune function. Under the management of BioMar AS and in cooperation with Norwegian School of Veterinary Science, Karolinska University Hospital and NTNU/ Dep. Biology, the project aims to identify relationships between changes in aquafeed composition, turnover of bioactive compounds, fish digestion and fat metabolism and immune responses using classical and molecular biological methods. Tasks at the Dep. Biology comprise comprehensive metabolite profiling of raw materials, diets, and fish tissue, following data integration and multivariate-statistical analyses. Results will be used to formulate feed without fishmeal and/or animal protein materials where the addition of identified bioactive components ensures improved fish nutrition and fish health.

Contact: jens.rohloff@ntnu.no



Hydroelastic analysis of the floater of a fish farm

Open cage fish farms are the most common type of plants used for farming Atlantic salmon and Atlantic cod today. A cage of an aquaculture plant consists of a floater, the net, the weight and mooring systems. One important part of fish farm structures is the floater. A plastic collar is considered as the floater. The floating collar provides the main buoyancy for the cage system. Being square or round, it floats on the water surface, making it hard to decide the corresponding hydrodynamic coefficients. Our objective is to develop a low-frequency slender body theory for the added mass and damping and wave excitation loads on a circular plastic collar used as a floater of an aquaculture plant with a vertical cylindrical net cage.

Contact: Peng.Li@ntnu.no

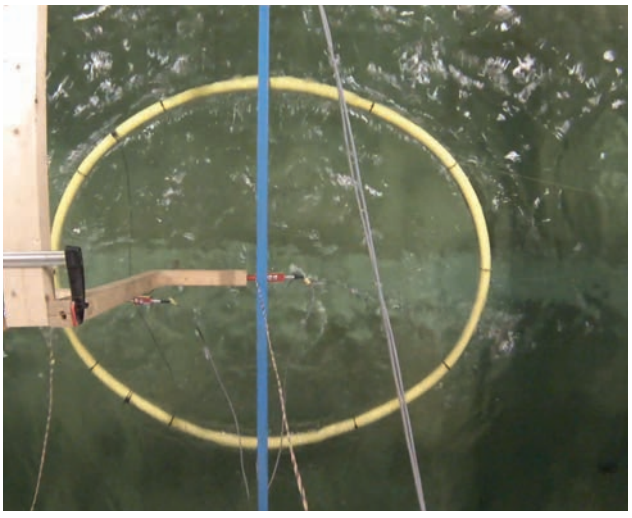


Photo: Peng Li

JANUS - Modeling an Interdisciplinary Early Warning System for Future Fisheries Scenarios: A socio-bio-economic value-chain evaluation

JANUS addresses a serious problem in several Norwegian fjords including the Trondheimsfjord: the recent superabundance of the lower trophic level jellyfish species *Periphylla periphylla*. This species competes effectively with commercial Norwegian fish species for a wide variety of pelagic organisms including redfeed (*Calanus finmarchicus*), a key species in the coastal ecosystem and a particularly important food item for all codfishes in coastal waters. Redfeed is also of potentially great importance to

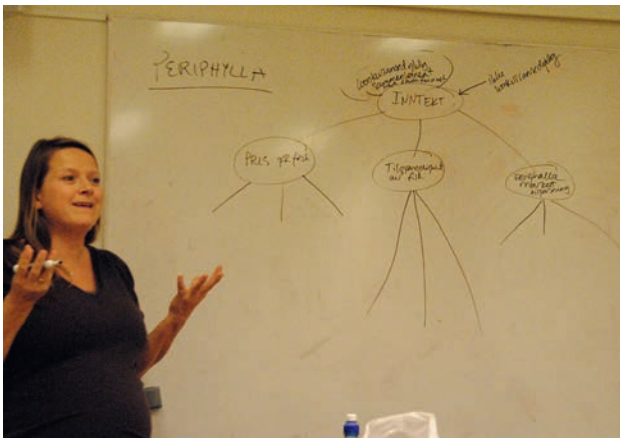


Photo: Jennifer Bailey

the aquaculture industry in Norway. *Periphylla* has, on the other hand, some properties which makes it a potentially valuable new resource in Norwegian waters. The question addressed here is how to manage this jellyfish in a manner

that is rational from both socio-economic and ecological perspectives. JANUS will create an interdisciplinary (bio-economic) model for these three species and move towards creation of a decision support tool to help the fisheries manager to make rational choices based on both ecological and socio-economic criteria. An integral part of the process will be the assessment of the adaptive capacity of local communities in the Trondheimsfjord region to impacts related to changes in P. periphylla - redfeed. JANUS will lay the groundwork for an Early Warning System (EWS) for managers. The figure shows Rachel Tiller leading a workshop for fishermen in Trondheimsfjord.

Contact: Professor Jennifer.Bailey@svt.ntnu.no

LarvaNet

LarvaNet is a European network of researchers and producers working with fish larvae, funded by COST Action FA0801. It intends to integrate knowledge obtained in national and European research projects, as well as practical experience, in order to improve the quality of fish larvae used in aquaculture. It is funded through the European Commission COST action. The network offers training schools and travel funds for young scientists. It also hosts workshops in collaboration with international conferences such as Aqua 2012.

www.larvanet.org
Contacts: Professor Elin.Kjorsvik@ntnu.no

LeppeProd - Production of Ballan wrasse

The salmon industry currently uses large amounts of wrasse to delouse salmon in cages. Use of wrasse is an environmentally gentle method for removing salmon lice, but extensive capture of wild wrasse to the farming industry is not sustainable. The aim of the project is to develop knowledge to contribute to a stable and predictable commercial production of Ballan wrasse. The project is a collaboration between NTNU, SINTEF, Nofima, Institute of Marine Research, and Nifes, and the researchers at the


Photo: Elin Kjørsvik

four institutions have extensive experience developing production of new marine species. The project is funded by the Norwegian Seafood Research Fund (FHF). All wrasse farms (Marine Harvest Labrus, Profunda, Nordland Leppefisk) and their owners were actively participating in the project in 2012. During the project period, eleven MSc-students will have participated in the project for their thesis work.

Contact: Professor Elin.Kjorsvik@ntnu.no

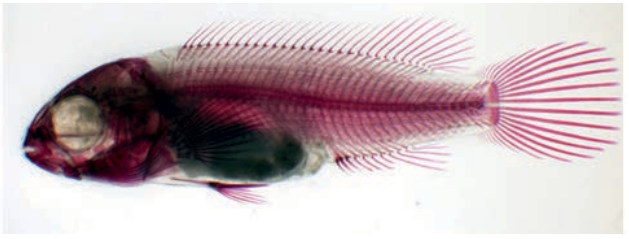


Photo: Maria Sørøy

Membrane filtration in aquaculture recirculation systems

Accumulation of particles is a challenge in recirculating aquaculture systems (RAS) and there is a need for a more advanced particle removal system. Integrating a membrane bioreactor (MBR) can potentially improve water quality by removing the colloidal and fine suspended solids from the system. The MBR concept combines a bioreactor using the moving-bed-bioreactor with a submerged ultrafiltration membrane reactor. To assess the ability of MBR to improve water quality several investigations were conducted through two studies. The first study evaluated the production of the live feed organisms calanoid copepod (*Acartia tonsa*) and rotifer (*Brachionus 'Cayman'*) in marine RAS, and the second study evaluated RAS production of Atlantic cod larvae (*Gadus morhua L*). Potential effects from improved water quality were investigated by looking at the performance (i.e. survival, growth and robustness) of the aquatic species, change in microbial communities and number of bacteria, and capacity of the biofilter. The potential benefits of a recycling system incorporating membrane filtration were successfully demonstrated.

Contact: Dr. Per-Arvid.Wold@ntnu.no


Photo: Astrid Buran

MYFISH- (Maximizing yield of fisheries while balancing ecosystem, economic and social concerns)

Maximum Sustainable Yield (MSY) is a concept which emerged from fisheries cience in the middle of the 20th century. Achieving MSY has been incorporated into inter-

national and national policy documents, including at the EU level. However, achieving MSY has proved elusive in Europe and elsewhere. MYFISH reexamines the variants of MSY (Multiple Sustainable Yield) , looking at the impact of environment, economy and society on these variants with the aim of suggesting MSY variates and procedures rendering the MSY approach robust to such changes. MYFISH is a research project funded by the ECs 7th Framework Programme.

myfishproject.eu/index.php
Contact: Professor Jennifer.Bailey@svt.ntnu.no

Regional collaboration "Brohode Frøya"

The coastal region of central Norway is a highly dynamic and productive area when it comes to salmon aquaculture. The companies in the region cover the complete marine value chain range, i.e. consultants, technology providers, feeding companies, salmon producers, processing plants, sales and export firms, in addition to smaller, pioneering companies, looking into the possibilities to exploit new resources using better and more sustainable methods and technologies.
In May 2012, NTNU signed a cooperation agreement with the secondary school at Frøya, situated in the heart of the aquaculture business. The ambition is to develop a truly knowledge-based aquaculture sector, through the following activities:

- Develop a regional marine business platform
- Perform student and research projects in collaboration with companies
- Offer student excursions in order to increase the relevance of the studies and the understanding of the sector
- Organise bi-annual conferences where researchers, students, companies, organisations, authorities meet each other and the public

In the autumn of 2012, a conference was organised in Frøya for more than 100 participants. It consisted of scientific and company presentations, company visits, and a speed dating session between students and companies.

Contact: Professor Yngvar.Olsen@ntnu.no


Photo: Hitra-Frøya


Photo: Jennifer Bailey

PRO-EEL

The PRO-EEL project aims at breeding European eel (*Anguilla anguilla*) in captivity. Reproduction of eel in culture has become a focus research area due to a severe decline of natural stocks and an increasing interest to breed eels for a self-sustained aquaculture. PRO-EEL is an international research project supported financially by the European Commission, with 15 international partners. The objective of the project is to expand the current knowledge on the eel reproduction and develop standardized protocols for production of high quality gametes (eggs and sperm), viable embryos and feeding larvae of European eel. Methodology and technology will be established using small scale tests and validated in full scale experimental facilities.

www.pro-eel.eu
Contact: Professor Elin.Kjorsvik@ntnu.no

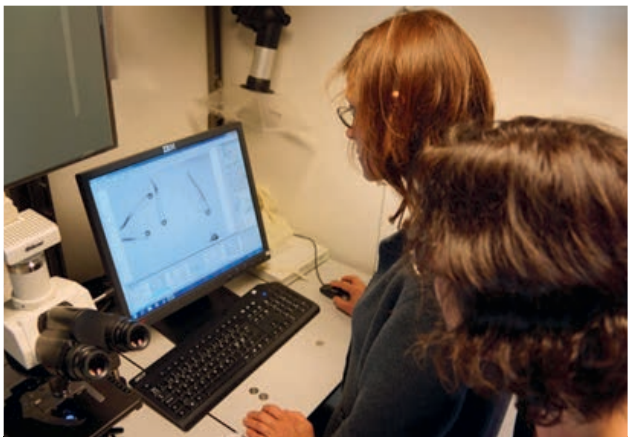


Photo: Elin Kjørsvik

PROMICROBE

In this EC-funded project, seven international research partners study "Microbes as positive actors for a more sustainable aquaculture". Through systematic experimental studies including gnotobiotic systems, novel information on microbial interactions in aquaculture ecosystems and new concepts for microbial management will be devel-

oped. These results will be translated into new or adapted protocols to rear aquaculture organisms in a biological stable and economical efficient way.

www.promicrobe.ugent.be
Contact: Professor Olav.Vadstein@ntnu.no

Technology akvARENA

akvARENA is a unique business cluster located in Mid-Norway. The cluster focuses on R&D activities within aquaculture and has members from the supplier industry, research institutions and fish farming companies. Through collaboration on specific areas, the cluster seeks to increase the value-generating activities among its members. The joint vision of akvARENA is "World class technology for sustainable aquaculture". In addition to innovation projects, the cluster initiates and organises workshops and other events in order to stimulate innovation through collaboration. The annual meeting gathered about 50 representatives from producers, suppliers, organisations, research institutions at a 2 day event where relevant issues were discussed. In November 2012, a study tour to Denmark was organised with focus on recirculation technology, treatment of slam, and industrial animal production. In 2012, RE NTNU was represented in the akvARENA board.

www.akvarena.no
Contact: Alexandra.Neyts@ntnu.no

Photo: akvARENA

Telefish

Telefish is a three year lasting project funded by the Norwegian Research Council with AquaCulture Engineering AS (ACE) as the project owner. Project partners are SINTEF Fishery and Aquaculture, NTNU, Thelma Biotel, TelCage, Salmar Farming and University of Melbourne. Telefish aims to develop telemetric solutions for monitoring fish welfare by the use of in vivo hydroacustic tags at full scale aquaculture farms. Data will be transmitted from the tags to receivers located inside the cage and linked to the operator's barge or further to a land base. Information from the tags can be either real time and online or stored locally for later use. Elements like heart rate, muscle activity, speed and vertical position are some of the parameters that can be investigated by using this technology. The project will also look into the possibility to use this technology for monitoring movement and forces at sea farm constructions during full scale operation. Also for this work package the goal is to transmit the information real time and online to the farms operator, so action can be taken quick to avoid damages to the construction.

Contact:
Associate Professor Jo.Arve.Alfredsen@itk.ntnu.no;
for ACE: Guttorm Lange (gla@aceaquaculture.com)

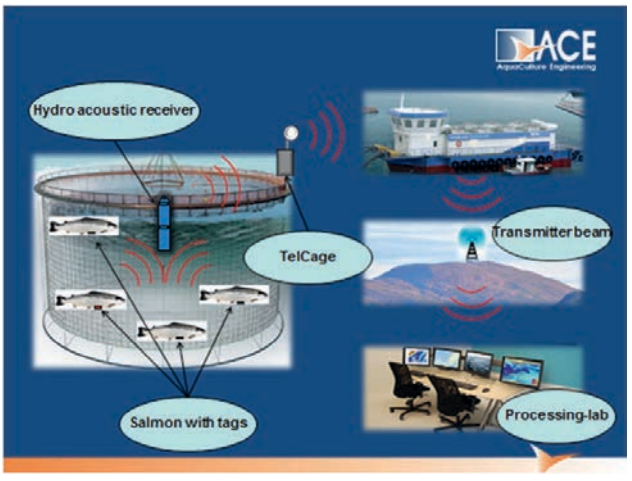


Figure: ACE

MARINE RESOURCE PROCESSING

Marine Recources Processing

Raw materials for high value products

Process engineering and tailoring

Genetic resources and biopolymers

Energy efficiency

Design methodology for sustainable systems

Value chain management

Infrastructure

SINTEF Sealab

NTNU – SINTEF process laboratories at Gløshaugen

Biopolymer laboratory at Gløshaugen

An increasing demand for high quality fresh seafood products, and the high competitiveness on industry level creates new requirements for higher efficiency and optimised design of equipment and systems. NTNU research teams have contributed significantly to innovations on automation, chilling, freezing and drying of marine raw materials through enhanced process engineering and tailoring solutions. In addition, a more efficient management of the supply chain is planned through a holistic approach, involving production processes and traceability systems.

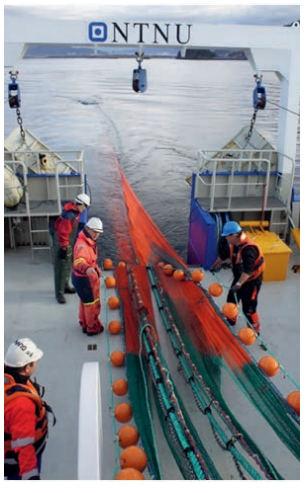
Techniques within blue biotechnology make it possible to extract novel products of high value from marine biomass and macromolecules, and to isolate genetic resources and biopolymers of the oceans. Research groups at NTNU focus on a better exploitation of by-products and unexploited marine organisms, and on bio-prospecting, which involves the search for new exploitable (micro-)organisms.

DANTEQ

DANTEQ is a project on "Development & assessment of technology improving fishing operation & on board processing with respect to environmental impact & fish quality". The main goal of this project is to improve the fishing vessel operation, energy system design and the on board fish processing with respect to fish quality and environmental impact. The project is led by SINTEF Fisheries and Aquaculture. It is funded by the Research Council of Norway (2010 – 2013), with 11 research and industrial partners.

Contact: Professor Elin.Kjorsvik@ntnu.no

Photo's: Elin Kjørsvik



Food for life – National Technology Platform

NTNU is a partner in the Norwegian Food for Life branch of the European Technology Platform. The platform focuses on the development of joint research and development priorities and strategies, the dissemination of scientific results and the collaboration between national and European research institutes in the field of food science, including the blue sector.

www.f4l.no
Contact: Professor Turid.Rustad@ntnu.no

SEAFOODplus

The mission of the SEAFOODplus research platform is to initiate, stimulate and encourage international integrated multidisciplinary seafood research covering the whole production chain from aquaculture and fisheries to consumers' health and well-being. Further to influence the European research agenda with focus on seafood research related to human health, consumers' perception and well-being, process and product quality, product development, safety and aquaculture as source of seafood and to promote project ideas via the channels of the European Commission in addition to existing Technology platforms. NTNU participated in several of the 2012 meetings.

Photo: Einar Brendbø

www.seafoodplus.org
Contact: Professor Turid.Rustad@ntnu.no

SOLBIOPTA

The Biotechnological Production of Materials for Optimized Solar Cell Efficiency (SOLBIOPTA) project studies the production and use of novel bio-nanomaterials from the microalgal group diatoms in solar cell applications. We study basic aspects of frustule anatomy and optical characteristics, and possible applications such as alteration of chemical composition of frustules and use of frustules as templates. In addition to the material aspect, the project also includes microarray studies of gene expression, to increase the understanding of biological fundaments of silicate uptake and frustule synthesis. The project is funded by the Research Council of Norway.

Contact: Associate Professor Gabriella.Tranell@ntnu.no;
Professor Olav.Vadstein@biotech.ntnu.no

Stresscod

The main objectives of the Stresscod project have been to determine effects of handling stress combined with storage conditions on quality of farmed cod (*Gadus morhua*), and to determine which biochemical changes that are important for the resulting sensory quality. During the project it was confirmed that cod can be stressed with a clear physiological response without a reduction in quality. Storage time and temperature were found to be more important for the quality properties than the handling stress. Sensory analysis has been used for quality analysis in addition to biochemical and instrumental parameters. Proteome analysis has been used to determine the proteins which are important for the texture properties of cod.

Contact: Professor Turid.Rustad@ntnu.no

AVAILABLE RESEARCH INFRASTRUCTURE

Research vessel Gunnerus

In 2012 R/V Gunnerus had yet another year with full occupancy. A little more than 80% of the capacity was used by NTNU research and education. The last 20 % of the cruise capacity was done by or in cooperation with Shell, EMGS (Electromagnetic Geoservices), SINTEF, NINA (Norwegian institute for nature research), Statoil, Kongsberg Maritime Seatex, Kongsberg Maritime Dynamic Positioning & Navigation, Rolls Royce Marine, FFI (Norwegian Defence Research Establishment), Woods Hole Oceanographic Institution.
A huge variety of cruises has been completed in fishery research, marine biology, underwater technology, marine chemistry, marine archeology, marine technology, ship maneuvering and marine acoustics.
Annual vessel maintenance was this year placed at Westcon shipyard, Nesna in Nordland. The shipyard has a covered dry dock (length 100m x width 28m x depth 7,5m). Among a huge number of maintenance jobs, the whole area of the stern and trawl port was sandblasted and metalized. Working deck and trawl port was also rebuilt to accommodate special container for the Kongsberg HUGIN AUV.
In cooperation with Kongsberg Maritime the Dynamic Positioning system has been upgraded both hardware and software.
In health, safety and environmental (HSE) work, the vessel has installed a Bridge Navigational Watch Alarm System (BNWAS) complying with IMO (International Maritime Organization) performance standards. The fire alarm installation onboard was extended to include containers for ROV etc. Audits were performed by Shell and Statoil; both companies accepted the vessel in their R&D work.

www.ntnu.edu/marine/gunnerus
Contact: Svenn.Linde@ntnu.no

Photo: Svenn Ove Linde

NTNU Centre for Fisheries and Aquaculture (Sealab)

The multidisciplinary NTNU Centre for Fisheries and Aquaculture consists of an experimental aquatic facility and analytical laboratories. It is a meeting place for marine scientists and students from five different faculties at NTNU. It is also a main node for marine cooperation between NTNU and SINTEF. In 2012, many experiments were performed with fish (cod, salmon, ballan wrasse, goldsinny), and zoo- and phytoplankton, focusing on biological and technological aspects of aquaculture, ecotoxicology, environmental change, and ecophysiology. The "CodTech" laboratory, probably one of the most technically advanced larval rearing facilities worldwide, had further upgrades of it's recirculation system in 2012. More than 50 scientists and PhD students from 10 NTNU departments, and nearly 80 MSc-students used the NTNU Sealab facilities in 2012, involving about 30 research projects. The Centre hosts lectures and laboratory classes for marine courses from Bachelor to PhD level. In 2012, 13 NTNU courses had scheduled teaching at Sealab.

www.ntnu.edu/marine/sealab
Contact: Professor Elin.Kjørsvik@bio.ntnu.no,
Manager Arne.Kjosnes@ntnu.no

Photo: Elin Kjørsvik

Photo: Elin Kjørsvik

Trondhjem Biological Station (TBS)

The station is located at seaside premises close to Trondheim. It is the centre for marine biological research at NTNU, offering good office and laboratory facilities, and direct access to the Trondheimsfjord ecosystem. TBS offers 600 m^2 of wet lab space with a constant supply of sea water from 100 m depth and 800 m2 of well equipped standard laboratories. It houses four temperature-controlled rooms, several seawater tanks, a large outdoor basin and a number of service boats. The pier right in front of the station makes it convenient to perform tests and measurements from land, and to handle sampled material between the vessel and the laboratories. All ROVs and AUVs are stored at and operated from TBS.

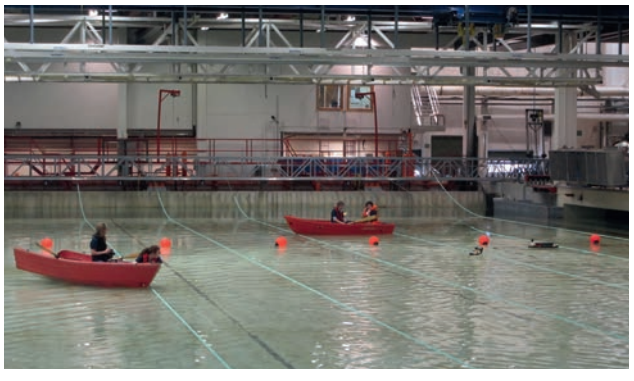
Contact: Professor Jarle.Mork@bio.ntnu.no
www.ntnu.edu/biology/about_tbs

Photo: NTNU

Marine Technology Centre

The centre houses both the NTNU Dept of Marine technology and MARINTEK, which is the Norwegian Marine Technology Research Institute – a limited company in the SINTEF Group. Research at the Marine Technology Centre encompasses activities tied to Norway's largest exporting industries, such as oil and gas extraction, fisheries technology and aquaculture, marine engineering and the associated industries.
The department graduates 60-80 masters of engineering

Photo: Dept. of Marine Technology



students every year, and is the largest in its field in the western world. The Centre offers a unique range of experimental laboratories: an ocean basin laboratory, a cavitation tunnel, a circulating water tunnel, a machine lab, a marine cybernetics lab, a marine structures lab, and towing tanks. Students have access to the laboratories for demonstrations and exercises in topics related to hydrodynamics, and use the laboratories for projects and masters theses. In particular, both the small towing tank and the student workshop are available for students in their elective experiments.

www.ntnu.edu/imt/labs
Contact: imt-info@ivt.ntnu.no

Applied Underwater Robotics Laboratory (AUR-Lab)

Environmental mapping and monitoring of the ocean surface, water column and seafloor are of utmost importance for a sound management of the marine resources. AUR-Lab was created because functional engineering solutions demand a strong technical and scientific expertise. Its scientific focus areas are:

- Development of technology for guidance, navigation and control of underwater vehicles (ROVs and AUVs)
- Underwater acoustic communication
- Environmental monitoring and mapping at sea surface, water column, and sea bed
- Operations under ice in the arctic
- Study of any object of interest (bio-geo-chemical objects)
- Inspection/surveillance for environmental agencies, oil industry, ecotoxicology
- Evaluation of seabed properties and habitat
- Complex deepwater underwater operations including inspection and intervention
- Deep water archeology

The cooperation between marine technology and science in research-based education through use of the AUR-Lab is a tool for further development of underwater robotics and sensors.

www.ntnu.no/aur-lab

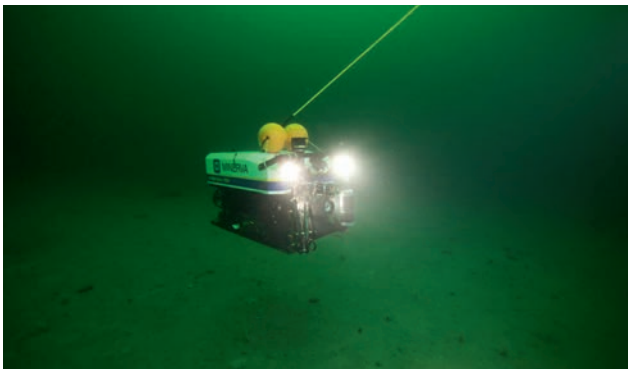


Photo: AUR-lab, Jussi Evertsen

AquaCulture Engineering – ACE

ACE unites aquaculture industry, engineering companies, researchers and students by combining science, technology and experience in an arena for innovation. The aim is to find sustainable solutions for the aquaculture industry. Large-scale salmon production units with modern facili-

ties and monitoring equipment at a variety of sea locations provide a unique opportunity for researchers and technology providers to perform experiments that combine scientific research methods with high relevance. The ACE industrial scale facilities and practical experiences have provided research and innovation opportunities for more than 15 R&D and test projects in 2011, focusing on exposed farming, safe constructions, salmon lice, escapes, monitoring of cages and fish, large scale methods, and R&D infrastructure. In 2012, a new location for the sea-based test site and office/workshop facilities was acquired on the island of Frøya.

www.aceaquaculture.com
Contact: Alexandra.Neyts@ntnu.no;
fvw@aceaquaculture.com

Photo: ACE

Sletvik field station

The station is located at the shore of the Bay of Hopavågen, which functions as a natural experimental basin. It is ideal for eco-hydrodynamic and transport studies relevant for marine chemists, biologists, physicists and geologists. The Bay is also well suited for mesocosm experiments and for testing of instruments and monitoring devices.

Photo: Adrian Teaca

The station is used both for field research experiments within marine ecology and monitoring, for meetings and seminars, and for field courses in botany, ecology and zoology. It can accommodate a total of 50 people. It holds bedrooms, a kitchen and dining room, lounge, lecturing rooms and laboratories.

www.ntnu.edu/biology/sletvik-field-station

Photo: Christina De La Rocha

Acoustic Underwater Laboratory (AUL)

The Lab provides a system for underwater acoustic experiments, consisting of

- Low to high frequency transmitters (850Hz, 12kHz and 40 kHz)
- Power amplifier
- Broadband vertical receiving hydrophone arrays (one 6-element array & three 8-element arrays)
- 32-channel filter
- 24-channel amplifier
- 32-channel data acquisition system

Combining with NTNU's research vessel R/V Gunnerus one can get real data from sea experiments for supporting research and educational programs. Such facilities are rarely found in academic institutions and makes therefore NTNU/Acoustics an attractive partner in national and international research projects.

Contact: Professor Hefeng.Dong@iet.ntnu.no

Photo: Guosong Zhang

EVENTS

AQUA2012

From 1 to 5 September, the European Aquaculture Society and World Aquaculture Society jointly organised the conference with the theme "Securing our Future". About 10 conference presentations were given by NTNU researchers, at sessions dealing with larval rearing and juvenile production, cage culture, environmental interactions, biotechnology, recirculation system technologies, microbial communities, integrated multi-trophic aquaculture and knowledge transfer. At the aquaculture business fair, taking place at the same time, NTNU, SINTEF and ACE operated a joint booth.

www.easonline.org
Contact: Alexandra.Neyts@ntnu.no

Photo: Alexandra Neyts

Building competence for a sustainable Norwegian maritime industry

This conference took place at Ålesund University College, 5. June 2012. It was supported by the Norwegian Research Council MAROFF-program and was organized jointly by NTNU, Marintek, Ålesund University College and the Norwegian Centre of Expertise (NCE) Maritime. The aim of the conference was to share the activities and outcomes of following three R&D projects:

- Ship-4C – Conceptual Design of Complex Customized Vessels
- Integrated Marine Operations, theory for design, simulation, training and evaluation
- IGLO-MP 2020 – Innovation in Global Maritime Production 2020

The conference was designed to share the activities and research results achieved under each of these projects. In addition, the conference was intended to discuss the further challenges in strengthening and improving the competitive capabilities of the Norwegian maritime industry. Each project was allotted a presentation slot, with a special keynote and a panel discussion.

www.iglo-mp2020.no
Contact: Professor Annik.Fet@iot.ntnu.no

Collaboration within marine biopolymers in China

In November 2012, a delegation from NTNU visited relevant research group working with marine biopolymers at the Ocean University of China (OUC), Qingdao. The objective of the meeting was to stimulate PhD exchange and project collaboration. Researchers at the Shandong Provincial Key Laboratory of Glycoscience and Glycoengineering, Key Laboratory of Marine Drugs (OUC) are focusing on the search for new bioactive carbohydrate-containing molecules originating from the marine environment. The laboratory was well equipped for analysis of the monosaccharide components and for more sophisticated methods for oligosaccharide structure analysis. Discussions on possible future collaborations on projects in relation to marine oligosaccharides / polysaccharides were initiated. This included the possibilities of applying research results for new natural bioactive products from the marine environment.

Contact: Professor Kjell.M.Varum@ntnu.no

Expert Workshop on Greenhouse Gas Emissions Strategies & Methods in Seafood

This FAO workshop joined fisheries and aquaculture experts, Life-Cycle Analysis and Greenhouse Gas (GHG) specialists and industry practitioners. Professor Annik Fet from NTNU was part of the expert group as Life-Cycle Analysis specialist. Together they initiated the process on the development of an agreed methods framework to assess GHG emissions, and to assess the implications of different method choices in the quantification of GHGs from seafood production systems. This was accomplished through two workshops. The first workshop developed methods and approaches for data collection and analysis. Following the collection of data from specific seafood production systems, the second workshop focused on presentation of the findings, validation and confirmation of potential methodologies for wider use. Experts also discussed the potential for reducing GHG emissions through changes in technology and practices and the impacts such changes may have on the system.

Contact: Professor Annik.Fet@ntnu.no

Nor-Fishing

The Nor-Fishing exhibition took place in Trondheim from 14 to 17 August 2012. Almost 15 000 visitors from 50 different nations came to the event. The number of exhibitors amounted to 480, representing stakeholders from 20 different nations. A number of mini-conferences and seminars were organized in parallel with the exhibition. One of them was the "Future prospects for fisheries" seminar on trends in fisheries operations and seafood processing, organized by the Nor-Fishing Foundation, SINTEF and NTNU.

Photo: Alexandra Neyts

Launch of foresight study

During the Nor-Fishing event, the brand new report on "Value creation based on a productive ocean in 2050" was presented. The study draws some very optimistic prospects for the sector, amongst others a multiplication by five of the aquaculture production in Norway by 2050. The report was the product of a working group established by the Royal Norwegian Science Society and Norwegian Technical Science Academy. NTNU was represented in the expert group by Prof. Yngvar Olsen.

The report can be downloaded at www.sintef.no/home/Publications/Publication/?pubid=SINTEF+A23299
Contact: Professor Yngvar.Olsen@ntnu.no

Researcher's Night 2012

Researchers' Night is the annual youth's research night at NTNU, and is taking place on the last Friday in September. It is funded by NTNU and the Research Council of Norway, and is part of the "National Research Week" aiming at increasing the public interest for science and research. More than 950 students and teachers from upper secondary schools were participating in the Researcher's Night event at the Science Building (Realfagbygget), where about 180 NTNU employees were actively demonstrating their activities. The research group at NTNU Center for Fisheries and Aquaculture (NTNU Sealab) were demonstrating zoo- and phytoplankton with the topic "In a Drop of Water".

www.ntnu.no/forskningsdagene/night/tilbakeblikk
Contact: Professor Elin.Kjorsvik@ntnu.no

Photo's: Per Henning

Sommerlarm 2012 at Sealab

"Sommerlarm" is the NTNU Science Museum's Summer Club for Research Aspirants (pupils in primary schools), and they visit different institutions during the school summer vacation. About 15 young scientists visited NTNU Sealab one day in late June 2012, where they could study planktonic animals and and have a look at fish.

www.vm.ntnu.no/sommerlarm/
Contact: Professor Elin.Kjorsvik@ntnu.no

Photo's: Elin Kjørsvik

EDUCATION

International Master of Marine Coastal Development (MACODEV)

MACODEV is a two-year international multidisciplinary Master of Science programme. It is especially designed to give the students a broad understanding of the complex interactions in the marine sector. The programme offers three specializations which include an individual research project with publication of a Master Degree thesis according to international standards, i.e.

- Aquaculture
- Fisheries and Marine Resources
- Marine Biology and Biochemistry

www.ntnu.edu/studies/msmacodev
Contact: studier@bio.ntnu.no

Photo: Svenn Ove Linde

International Master in Marine Technology

The two year Master of Science degree in Marine Technology gives students a challenging and exciting education for the future. Marine Technology is an ideal specialisation for first-degree engineers with technical interests. This is an education that provides innovative, professional challenges and lead to a variety of career possibilities. The Master programme offers two international specialisation options:

- Marine structures: choose between the profiles Marine Structures, Marin Hydrodynamics, or Marin Cybernetics
- Marine systems: choose between the profiles Marine Operation Technology, Marine Machinery, Marine Systems Design, or Renewable Marine Resources

www.ntnu.edu/studies/msn1
Contact: studier@ivt.ntnu.no

Photo: Kristin Lauritzsen

Nordic Master in Aquatic Food Production – Safety and Quality

This master's programme provides knowledge about the whole value chain for aquatic food from harvesting and production of aquatic resources through processing to the consumer. The main focus throughout will be on safety and quality. The programme gives the foundation needed for a global understanding of the aquatic food production value chain.
The Nordic Master is a collaboration between five different universities in the Nordic countries, and results in a double degree. Students will spend one year each in two of the collaborating universities, taking 60 ECTS at each of the institutions.

www.ntnu.edu/studies/msaqfood
Contact: studies-master@nt.ntnu.no

Photo: Geir Mogen

Other marine related studies at NTNU

The university offers a number of different marine educational programmes both on Bachelor and Master level. The main marine-oriented programmes at NTNU are:

- Bachelor in Marine Biology and Aquaculture (3 years) www.ntnu.no/studier/bbi/studier/biologi/marinakva
- Master in Marine Technology (5 years) www.ntnu.no/studier/mtmart
- Master in Fisheries and Aquaculture Cybernetics (2 years) www.ntnu.no/itk/studieinformasjon/studieoppbygning/havbrukskybernetikk
- Nordic Master in Maritime Engineering (2 years) www.ntnu.edu/studies/msnmme
- Master in Coastal and Marine Civil Engineering (2 years) www.ntnu.edu/studies/mscoastmar
- Master in Subsea Technology (2 years) www.ntnu.no/studier/miuvt
- Master in Biotechnology (5 years/2 years) www.ntnu.edu/studies/msbiotech
- Master in Industrial Ecology (2 years) www.ntnu.edu/studies/msindecol
- Master in Ecotoxicology and environmental chemistry (2 years) www.ntnu.edu/studies/msenvitox

An overview over the international Master's programmes at NTNU can be found at www.ntnu.edu/studies/international/master

Contact: studentservice@adm.ntnu.no

Photo: Kristin Lauritzsen

PhD education

NTNU provides extensive programmes for a doctoral degree in most marine disciplines. PhD students at NTNU are offered cutting edge research training, collaboration with fellow PhD candidates, and highly specialized instruction. Candidates must be admitted to a specific PhD programme, and undertake both research and coursework in order to earn a degree from NTNU.

www.ntnu.edu/studies/phd

Photo: NTNU AUR-Lab, Geir Johnsen

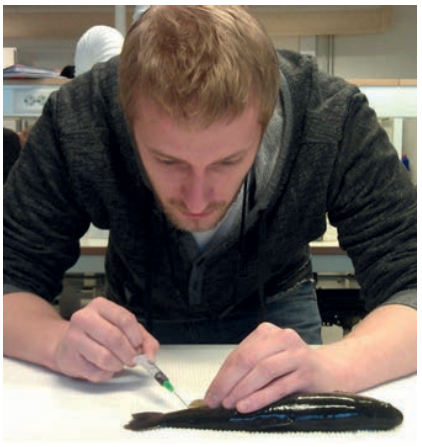


Photo: Elin Kjørsvik

Marine projects in secondary schools

Project-based learning material was developed aimed at secondary school pupils. The objective is to stimulate young people's interest in science and technology. The material fits into the subject natural science and environment, and into the newly launched optional subject of technology and research in secondary schools.
In the marine area, NTNU is offering pupils with interest

Photo: Tora Bardal

in natural sciences and technology two different school projects:
"The young naval designer": a popular project aiming at designing a well-performing model ship with energy-efficient properties. The "Ocean Space Technologies" book provides teachers and pupils with the necessary background information. The best teams from all over Norway meet in Trondheim for the final competition in the ocean basin – the Ocean Space Race (see below).
"Cultivating live feed organisms": rotifers are cultivated in small units at school under different conditions over a period of time. The project was performed as a pilot at three different secondary schools and was launched as a nationally available offer in 2012.

Contact:
Haavard.Holm@ntnu.no, Jan.Ove.Evjemo@bio.ntnu.no

Ocean Space Race 2012

Friday the 9th of March, the Ocean Space Race 2012 competition took place at the Marine Technology Centre. Totally 350 pupils and 30 teachers from 19 different High schools of Norway were competing in the ocean basin laboratory, about having the fastest, most operative and stabile ship models. Prior to this event, the participants had been working half a year to design and build their ship models. Additionally, there were lectures about ongoing research, student's life and work possibilities in the marine industry. This competition has been arranged annually for five years at the Marine Technology Centre. The aim is to increase the interest among pupils at primary and secondary school levels for studying mathematics and physics, and in particular for studying ocean space technology.

www.ntnu.no/sf-marin/osr

Photo: Lars K. Steen

"Sett Sjøbein"

The national project "Sett Sjøbein" is dedicated to increase recruitment to the marine sector, to improve the qualifications of its employees, and to enhance the attractiveness of a marine education at all levels. The project is supported by the Ministry of Fisheries and Coastal Affairs (FKD) and by the Fishery and Aquaculture Industry Research Fund. Decisions are taken jointly by representatives from the Norwegian industry organizations, schools, training institutions and universities. NTNU joined the recruitment events in Trondheim and Frøya, and represented the higher education sector in Sett Sjøbein steering committee.

www.settsjobein.no
Contact: Alexandra.Neyts@ntnu.no

Photo: Alexandra Neyts

Departments at NTNU involved in the marine strategic area, and their main fields of competence (in alphabetical order).

NTNU DE PARTMENT MAIN EXPERTI SE	
Archaeology and Religious Studies	Marine archaeology, maritime history, cultural heritage
Architectural Design and Management	Harbour architecture
Biology	Marine biology, biological oceanography, aquaculture, eco-toxicology, coastal ecology, behaviour
Biotechnology	Marine biopolymers, biochemistry, chemical engineering, processing, marine biotechnology
CeSOS	Centre of Excellence for Ships and Ocean Structures
Chemistry	Trace metal chemistry, metal pollution
Centre for Rural Research	Regional policies, regional development, coastal communities, resource use/management, coastal industries
Civil and Transport Engineering	Coastal engineering, infrastructure, geotechnique
Electronics and Telecommunications	Acoustics, underwater communication
Energy and Process Engineering	Processing engineering, energy and value chain management
Engineering Cybernetics	Aquaculture and fisheries cybernetics, instrumentation, telemetry
Engineering Design and Materials	Design methodologies, sustainability and simulation. Structural integrity, metal forming and composites, collaborative engineering
Geography	Coastal geography, societies
History and Classical Studies	Fisheries and aquaculture history
Hydraulic and Environmental Engineering	Water processing technologies
Industrial Economics and Technology Management	Value chain management, Life Cycle Assessment (LCA), environmental management and innovation
Interdisciplinary Studies of Culture	Cultural perspectives of coastal communities
Marine Technology	Marine constructions, marine systems and operations, fisheries and aquaculture technology
Mathematical Sciences	Bio-modelling, statistics
Museum of Natural History and	Marine archaeology, maritime history, cultural heritage, marine
Archaeology	biodiversity
NTNU Social Research, Studio Apertura	Organisation studies, work processes and management in aquaculture
Physics	Marine optics
Production and Quality Engineering	Food technology and manufacturing
Sociology and Political Science	Fisheries politics, risk evaluations
Urban Design and Planning	Ecological based planning of coastal land use

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