CRIMAC

Annual report 2021


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Summary

Nils Olav Handegard

CENTRE DIRECTOR

I took over as centre director after Egil Ona in October 2021, and, first, I would like to thank the board for the opportunity to take on this responsibility. It is a challenging and rewarding task.

We have been able to initiate projects across different institutions despite the challenges due to the pandemic. Online workshops have been extensively used and online tools allow us to work across different institutions. Although collaboration within research groups has suffered due to the pandemic, working across institutions has been less challenging. We are actively using online tools like GitHub, cloud computing services etc. to achieve this. I believe that this has permanently changed our working style and that we will continue to use these tools to facilitate good collaboration across institutions.

The annual meeting was held in Horten, and we were able to meet in person. I would like to express my gratitude towards Kongsberg for hosting the meeting. Although new working styles allow us to work across institutions electronically, meeting in person once every year is crucial to further knit the teams together.

Despite still being early in the project, we have published several publications in peer reviewed journals. These papers also demonstrate collaboration across the institutions as well as with other SFIs, especially the Visual Intelligence SFI where we have a good working relationship. We have also written a couple of chronicles and opinions pieces, as well as a few technical articles. The CRIMAC centre has been presented at several conferences, but most of these have been online meetings. One exception was the American acoustical society meeting in December 2021.

We have been able to attract media attention and several news articles have been published in various outlets reporting on the results from the CRIMAC project.

The link between the user projects and the science partners are particularly important, and we have established a work package to strengthen this link. This has been very useful for identifying and refining the expectations from the user partners and will constitute the starting point for refining the work plan for next year. In this report we have presented several highlights where the results from the centre are being taken up by the users.

Three PhD students have been hired by the centre and we are currently seeking 2 further PhD students. We have several master students associated with the centre as well as one bachelor student. We have also initiated a process of setting up a student community.

In conclusion the centre has got a good start and I look very much forward to the continuation. There are a lot of interesting results in the pipeline, and there is a good working atmosphere between the different partners in the centre.

BOARD

2021 has been the first full year for SFI CRIMAC. Despite the pandemic, CRIMAC has been able to progress well. In 2021 CRIMAC has successfully hosted the first annual gathering and successfully completed a scientific survey, new PhD and master's students have started, and papers have been published. This is impressive, and the board would like to thank all participants who have contributed making these achievements possible under challenging conditions.

The role of the board is to "ensure that the intentions and plans underlying the Contract for the project are fulfilled, and that the activities discussed in the project description and the funding plan are completed within the approved time frame. The Board will further ensure that the interaction between the Centre, the Host Institution and the other Consortium Participants functions smoothly." Within the board, we have established a good collaboration including two board meetings in 2021. An important activity to ensure participant expectations are fulfilled in CRIMAC is the new focus of WP6 "Extracting Gains for Science and Industry". This work package will be an important forum to express and align expectations, encourage collaboration, guide activities, and support transition of science to products and services. We also welcome the establishment of the Communication group which will be essential for communicating CRIMAC news, achievements, and other relevant information.

2021 also included a change in the position as director for the CRIMAC centre. We would like to express our deep appreciation to our former director, Egil Ona, who has been essential in establishing and starting CRIMAC. Thank you Egil! We would also like to send a warm welcome to our new director, Nils Olav Handegard. We are confident that Nils Olav will be an excellent leader for CRIMAC going forward.

In 2021 the operational framework for CRIMAC has been established, new students and collaboration among participants has started, exciting new theory and algorithms are being developed, and new products and services are in the pipeline. It is now important, that we continue to explore, utilize, and build upon the existing framework. All partners will continuously update and share their expectations and continuously strengthen collaboration with other partners. Continuous recruitment and integration of new and existing students will require a special focus since this is essential to the success of CRIMAC.

The progress which has been made in CRIMAC in 2021 on data handling, processing, and machine learning is very promising and of high interest to user partners in CRIMAC. The results from CRIMAC are followed closely by scientific institutions and industries world-wide and the board is excited to participate in the next chapter of CRIMAC.

Vision

Sustainable, healthy food production and clean energy production for a growing population are important global goals. Important elements to achieve these goals are technology development and know how, and CRIMAC will contribute to these by obtaining accurate underwater observations of gas, fish, nekton and other targets.

Underwater observations are challenging both due to the additional spatial dimension compared to terrestrial systems and the unfavourable optical properties of the water. To overcome this, advanced underwater acoustic systems offer both range, observation volumes and resolution for descriptive and quantitative observations of the ocean interior. A game-changer, both for research and the fishing industry, occurred recently with the introduction of commercially available scientific broad band echo sounders and sonars. It represents an expansion of the current multifrequency methods both in the frequency domain and in the time domain, enabling improved acoustic classification of targets and increased resolution.

CRIMAC will contribute to the understanding the new echo spectra, how to process them and how to utilize them in a range of different sectors relevant to Norway and internationally. Improved quantification and classification of targets and mixtures may prevent unwanted bycatch and suboptimal fish size for the fishing industry, provide information on key parameters for modern aquaculture farms, indicating size, density, growth and animal welfare, improved identification of gas releases in the ocean floor relevant for, e.g., CO2 sequestration for the energy sector, and monitor key features like abundance and distribution of key species in a changing marine ecosystem

OBJECTIVES

The primary objective of the SFI is to advance the frontiers in fisheries acoustic methodology and associated optical methods, and to apply such methods to 1) surveys for marine organisms, 2) fisheries, 3) aquaculture and 4) the energy sector.

This will be achieved via the following secondary objectives:

1. Improve automatic interpretation of (wideband) fisheries acoustics, including sizing of targets (fish and bubbles), target identification and increased spatial resolution.

2. Aid the target classification of fish and zooplankton by experimental measurements of known target and backscatter modelling.

3. Collect reference data for machine learning projects on research vessels and in the commercial fishery with similar, calibrated instrumentation.

4. Develop better verification methods using optical systems and dropped probes and working-drones.

5. Develop automated classification systems based on modern machine learning methods.

6. Work with the user partners to apply the techniques and instruments developed in 1) to 4), in scientific surveys, for sizing and species classification in fisheries, for sizing, growth and behavioural measurements in aquaculture, and improved gas and bubble detection systems for the energy sector

RESEARCH PLAN

The research plan is updated annually and follows the work package structure. The current tasks in the plan are reported under the "scientific activities" chapter.

Organisation

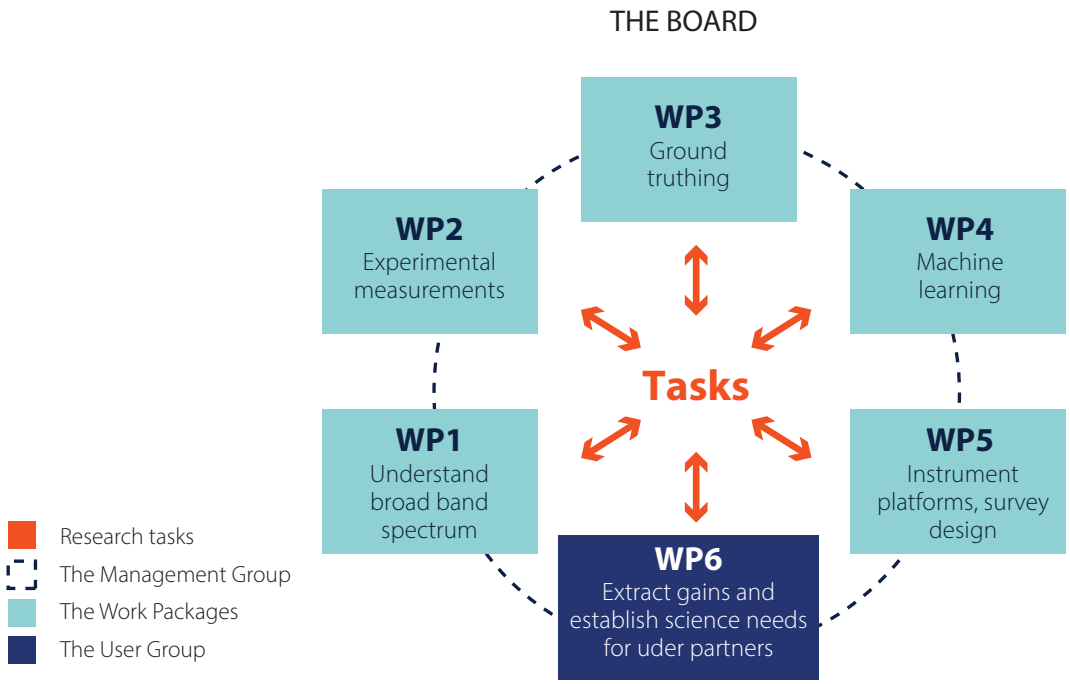


Figure 1. Relationships between work packages. The science WPs (1-5) will cover the different scientific fields and maintain the overview of state of the art within each field. The management group will set up research tasks to deliver methods and knowledge. The tasks may be fundamental science projects as well as projects that facilitates the implementation and uptake by the industry. The feasibility of the methods and the needs from the user partners industry will be assessed by WP6.

ORGANISATIONAL STRUCTURE

The research tasks and scientific methods are structured into work packages (Figure 1) which follow five research frontiers (WP1-5), plus a work package (WP6) that will keep the track of the user needs and facilitate uptake of the methods by the user partners. The remaining work package (WP0) coordinates and manages the proposed centre and outlines the governing structure of the project in more detail.

Centre leader and project coordinator

Nils Olav Handegard is appointed centre leader. Turid Loddengaard is appointed project coordinator and will assist the centre leader in administrative matters.

Work Package leaders

Each of the work packages will have a WP manager appointed by the Board. Each work package leader will be responsible for maintaining an overview of state of the art within the field the WP is covering. Geir Pedersen (IMR), Tonje Nesse Forland (IMR), Maria Tenningen (IMR), Nils Olav Handegard (IMR) and Espen Johnsen (IMR) is leading WP1-5. WP6 is led by Tonny Algrøy (KM) representing the user partners.

The Management Group (MG)

The MG will be responsible for the day-to-day operation of the Centre. The MG consists of the WP leaders and centre leader, the leader of the Marin Ecosystem Acoustics research group at IMR, and one representative from NORCE (Inge Eliassen), NR (Olav Brautaset) and UiB (Audun Pedersen) to ensure at least one representative for each science partner. A major responsibility of the MG will be to develop annual work plans with budgets and oversee the activities. The MG could also start new activities to respond to new developments within the field.

Annual accounts 2021

Tasks

The centre will establish a set of dynamic tasks that is associated to a work package. The WP leader is responsible for the tasks. A task leader will be assigned to each task. Personnel from several partners will ideally be involved in each task, and part of the work should ideally be carried out while staying at the centre. Each task reports briefly to the MG on the weekly update meetings.

CRIMAC – THE BOARD

Chairman
Lars Nonboe Andersen, Simrad

Board member
Puben Patel, CODELAB

Board member
Per W. Lie, Lie-Gruppen

Board member
Pål Cato Reite, EROS AS

Board member
Øyvind Frette, UiB

Board member
Helge Hammersland, Scantrol/ Scantrol Deep Vision

Board member
Geir Huse, HI

Board member
Annette F. Stephansen, Norce

Board member
Anne-Sofie Utne, NRS

Board member
Andre Teigland, NR

Board member /observer
Lars H Andersen, NFR

Centre leader
Nils Olav Handegard, HI

Secretary
Turid S. Loddengard, HI

The board

The Board will approve the appointment of the Centre director and project managers and will be responsible for decisions on annual work plans and budget. All partners will be represented on the Board, chaired by the partner contributing most economically (Kongsberg Maritime).

The International scientific advisory committee (ISAC)

The committee will consist of three persons and will be appointed by the board. The ISAC will provide a report to the board at the annual meeting to assist the board in terms of the scientific performance of the centre. The ISAC members are Dr William Karp (USA), acoustics and survey implementation expert, Director, Dr. Paul Winger (Canada), trawling and fisheries expert and professor Laura Uusitalo (Finland), expert in Machine Learning and Artificial intelligence.

Host institution, location, and facilities

IMR will serve as the host institution. IMR will provide the necessary administrative support systems for the Centre. IMR will provide office space to the Centre, including offices for industry partners and visitors from the international cooperating research institutes.

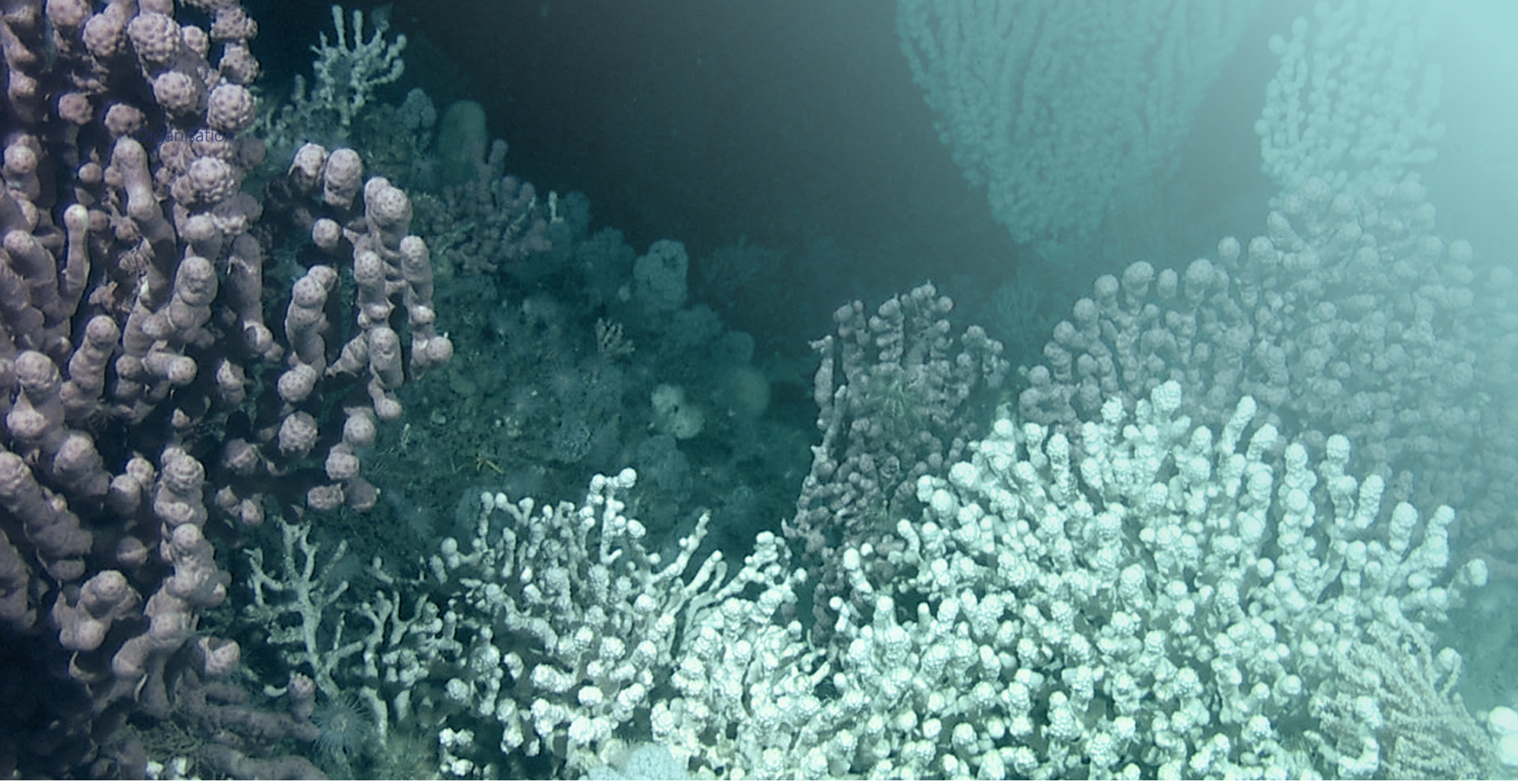
Meeting schedules

There will be a weekly update meeting for everyone working actively on a task, and the task leader will be responsible for providing a brief update. A bi-monthly MG meeting will be held, but the meeting frequency may be higher during the development of the annual plans etc. There will be an annual "fagsamling". There will be 1-2 board meetings a year.

RESEARCH PARTNERS

The Institute of Marine Research

The Institute of Marine Research is one of the largest marine research institutes in Europe with approximately one thousand employees. Our main activities are monitoring, research, and advice for the marine environment.



IMR's head office is in Bergen. We also have a department in Tromsø and research stations in Matre, Austevoll and Flødevigen. In addition, we operate a fleet of research vessels. These vessels are an important tool for collecting acoustic data and will be central to CRIMAC.

IMR has a strong track record for innovation and method development within the field of fisheries acoustics. This includes the first scientific publication utilizing underwater acoustics on fish distributions, the development of the echo integrator commonly used worldwide in acoustic trawl surveys, and experimentally establishing the basic acoustic linearity principle.

IMR has worked extensively with scientific multibeam sonars and echosounders in cooperation with KM and IFREMER. IMR has been a driving force for international cooperation within the field, e.g., by hosting the ICES fisheries acoustics symposium several times and through significant contributions to the development of acoustic methods trough several ICES Cooperative Research Reports

CRIMAC will support the continuation of this effort.

NORCE

NORCE is an independent research institute with around 750 employees that undertakes research for both the public and the private sector. NORCE has a long tradition for cooperation with IMR, UiB and KM within the topic of SFI CRIMAC, due to a strong competence within acoustics and data science.

NORCE has been a key contributor for the development and implementation of acoustic methods in postprocessing systems, and the effect of nonlinear loss in fisheries acoustics. Together with IMR, NORCE has developed the software LSSS which is used by several hundred researchers for better to monitor and analyse fish resources. NORCE will contribute to broadband spectrum modelling, develop methods/use machine learning for broadband noise removal and automatic categorization of backscatter. They will also be involved in training and education of researchers and PhD students.

The Norwegian Computing Center

The Norwegian Computing Center (NR) conducts research and is one of Europe's largest environments within statistical modeling and machine learning.

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We carry out research assignments for Norwegian and international business, the public sector and within national and international research programs, with a vision to contribute with research that is used and seen.

We have more than 30 years of experience in developing image analysis methods for automatic analysis and extraction of information from various types of image data. Our strategy is also to contribute with specialist expertise in image analysis to other research environments in Norway.

CRIMAC fits very well with this strategy. Here we will especially work with image analysis based on artificial intelligence to extract information about the occurrence of fish and fish species from fishing acoustics.

The work in CRIMAC builds on collaboration that was started with the Institute of Marine Research in this field a few years ago. We also have a long-term collaboration related to statistical modeling for stock estimation. Through CRIMAC, we look forward to a further strengthening of this successful collaboration.

The University of Bergen

The University of Bergen (UiB) is among the world leading universities in the marine area. UiB participates in CRIMAC by three departments: the Department of Biology, the Department of Physics and Technology, and the Department of Mathematics.

The Department of Biology contributes with (i) supervision and education of 2 PhD candidates (one financed by UIB, and one financed by the Research Council of Norway), and (ii) supervision and education of master candidates; all in the field of "Ground truthing methods" of which organisms and targets that generate broadband acoustic backscatter.

The Department of Physics and Technology contributes with (i) supervision and education of 2 PhD candidates (one financed by UIB, and one financed by the Research Council of Norway), and (ii) supervision and education of master candidates; all in the field of fisheries acoustics.

The Department of Mathematics contributes with (i supervision and education supervision of one PhD candidate (financed by the Research Council of Norway), and (ii) supervision and education of master candidates in dynamic modelling and machine learning.

UiB has a long history on close collaboration with the Institute of Marine Research (IMR) and other

> "There are a lot of interesting results in the pipeline, and there is a good working atmosphere between the different partners in the centre. Nils Olav Handegard

centre partners. The master and PhD candidates are supervised in a collaboration between UiB, IMR, and relevant centre partners.

INDUSTRY PARTNERS

Kongsberg Maritime

Kongsberg Maritime (KM) is a Norwegian based technology company with a diversified portfolio of products and services that spans applications from the deepest oceans to the space. With over 7 300 employees and an installation base of more than 30 000 vessels worldwide the company is positioned in both traditional and new ocean-based industries.

Sustainable development of the oceans and its resources have been an integrated part of KM's strategies for many decades already, through the commercial fishery and marine research sector. The main reason for KM's participation in SFI CRIMAC is to further improve our offerings to these sectors as well as to bring this competence into other marine industries such as offshore energy production and aquaculture.

The KM contribution to the CRIMAC center is mainly focused at wideband acoustics and sensors for catch monitoring, and how products in these areas can be improved through the introduction of new digital infrastructure for machine learning and seamless data flow. This applies to both vessels as well as alternative sensor platforms such as marine drones and stationary observatories.

SFI CRIMAC is a natural development of a research and scientific based collaboration with center partners such as the Institute of Marine Research and the industrial partners which we believe will continue to believe innovative solutions to both marine industry and ocean management. Through CRIMAC KM wishes to position as highly relevant supplier of scientific based products and solutions for users of the coastal and ocean areas

Scantrol and Scantrol deep Vision

Scantrol AS and Scantrol Deep Vision AS are located in Bergen, Norway. Scantrol has delivered control systems to trawls and cranes all over the world for more than three decades and has an extensive experience with developing technology for the marine research and trawl fisheries markets.

Scantrol was a partner in the CRISP Centre for Research-based Innovation (SFI) led by the Institute

of Marine Research in Bergen. The Deep Vision trawl camera and sorting technology was developed in this center and led to the spin-off company Scantrol Deep Vision. Today, the technology is commercialized for marine research and used to sample fish from images in the trawl without bringing any catch onboard. The technology is being further developed into a catch identification and sorting device for commercial trawlers.

In CRIMAC, the companies will leverage the force of collaboration between leading scientific institutions and private companies to bring the successful technology even further. Deep Vision will both complement and support the interpretation of acoustic data.

Liegruppen

Liegruppen, located in Øygarden outside the city of Bergen has been in the fishing industry for more than 120 years. Liegruppen has throughout its history always had a strong focus on development and innovation in fisheries as well as in vessel construction.

Today the company are operating 2 purse seiners/pelagic trawlers. One of them – MS Libas is the world's most environmentally friendly fishing vessel. In addition, Liegruppen have one more "green" vessel under construction. MS Libas, delivered in march 2021 is the first purse seiner/pelagic trawl vessel using primary LNG when sailing, saving the environment for significant CO2 and NOX-emission. MS Libas is also constructed and well equipped for doing scientific research. It is planned to use MS Libas in the CRIMAC-project.

Liegruppens role in the CRIMAC project is to test acoustic sonars and echo sounders in fishery. Improved quality of such instruments will make the fisheries more efficient and sustainable.

Liegruppen fishery are employing about 50 fishermen/crew in addition to 7 persons in the office.

Eros AS

EROS AS is a fishing company based in Fosnavaag with a history going back to 1917. Todays «Eros» is the seventh vessel carrying the same name. The vessel is a 77 metre modern pelagic trawler/purse seiner fishing for Herring, Mackerel, Capelin and Blue Whiting in the North Atlantic, Norwegian Sea, North Sea and Barents Sea.

«Eros» is equipped with a drop keel and echo sounders/sonars for doing scientific research and

has over the last 15 years been employed both by the Norwegian Marine Institute and the Greenland Nature Institute on a number of research trips. The vessel has an experienced crew with more than 20 years fishing experience. Eros AS is also operating the pelagic trawler «Herøyfjord» and is involved in the white fish business being the majority shareholder of the factory trawler «Ramoen» producing fresh frozen fillets of Cod, Haddock and Saithe for the Norwegian and International markets.

Our obligation to the consortium is to test acoustic sonars and echo sounders in a real fishery and in specific surveys when hired as a reserch survey by CRIMAC. Improved quality in such instruments will make the fisheries more efficient as it put the industry in a better position with respect to selecting the correct fish species, estimation of the biomass, size of the fish and movement of the fish prior to shooting the fishing gear.

Norwegian Royal Salmon

Norway Royal Salmon ASA (NRS) is a norwegian company group within the salmon farming industry. NRS is listed at Oslo Euronext. Our farming activities are in northern Norway (region Troms & Finnmark) and on the Westfjords of Iceland. NRS is also a large salmon exporter for several Norwegian salmon farmers. In 2020 NRS produced 30 500 tons (HOG) and exported approximately 90 000 tons to 50 different export markets.

NRS are continuously aiming to improve our biological performance and aim to be at the front edge of development. We are working on a novel farming technology suitable for more exposed coastal farming areas ("offshore"). The concept is a semi-submersible offshore fish farming system, designed for harsh environments and wave conditions beyond tolerance levels for farming equipment which today is "industry standard" (www.arcticoffshorefarming.no). One of the challenges in modern salmon farming is, to observe the farming environment and the behaviour of the fish inside the net pens, day and night. The behaviour during feeding and eating, for our new technology also swimming patterns and observations related to balancing the swim bladder.

We plan to use echo sounders and acoustic transmitters implanted in a group of fish in both net pens, to study the fish behaviour in the net pens both in service and operation draft. This will support visual observations/ CCTV, and the functionality of the air-pockets in operation draft.

New instruments, that may be developed in the CRIMAC programme and suitable for the Norwegian salmon farming industry, will be very much of interest to test in our commercial /full scale farming units, and especially for a semi submergible farming technology.

CodeLab

CodeLab is a small software company specializing in advanced software developmentfor marine science, energy sector, and health.

CodeLab have expertise in near real time data processing, acoustic wideband processing, and machine learning. They have an ambition to develop software solutions for the fishing industry and aquaculture, using algorithms developed by the research partners on data both from optical sensors and acoustic sensors. They deliver both self-standing products and libraries that can be interfaced into, e.g. KM's, software.

Scientific activities and results

WP1

WP1 UNDERSTAND THE BROADBAND ECHO SPECTRUM FOR CLASSIFICATION

Scientific questions: *What are and how do the various parts of marine organisms contribute to broadband backscatter, and how can we improve the amount of information extracted from the acoustic signal?*

WP1 focuses on understanding how the complex broadband frequency responses from marine organisms are generated and how to enhance the amount of information which can be extracted from marine backscatter. Knowledge of the broadband backscatter contributes to the development of methods for automatic classification of marine targets. Further development of broadband acoustic signals and processing will enhance the amount of information available for classification. Numerical modelling of backscatter and *in situ* and *ex situ* measurements from individual and groups of marine organisms carried out in WP2 forms the basis for understanding the broadband response.

Task 1.1. Fundamentals of broadband echosounding

Understanding of broadband signals and signal processing (pulse shape, interference simultaneous transmission etc.) is fundamental for all other tasks in CRIMAC. The initial aim in this task is to understand current signal processing and to enable low-level signal processing in open-source software (Python). A paper and open-source code has been developed and will be made publicly available in 2022. This provides a starting point for further developments and also serve as an educational tool. A processing method extracting equivalent CW data from FM was verified through simulations and measurements and will be published in 2022. This will allow for collection of broadband acoustic data on routine surveys, maintaining time series of acoustic abundance.

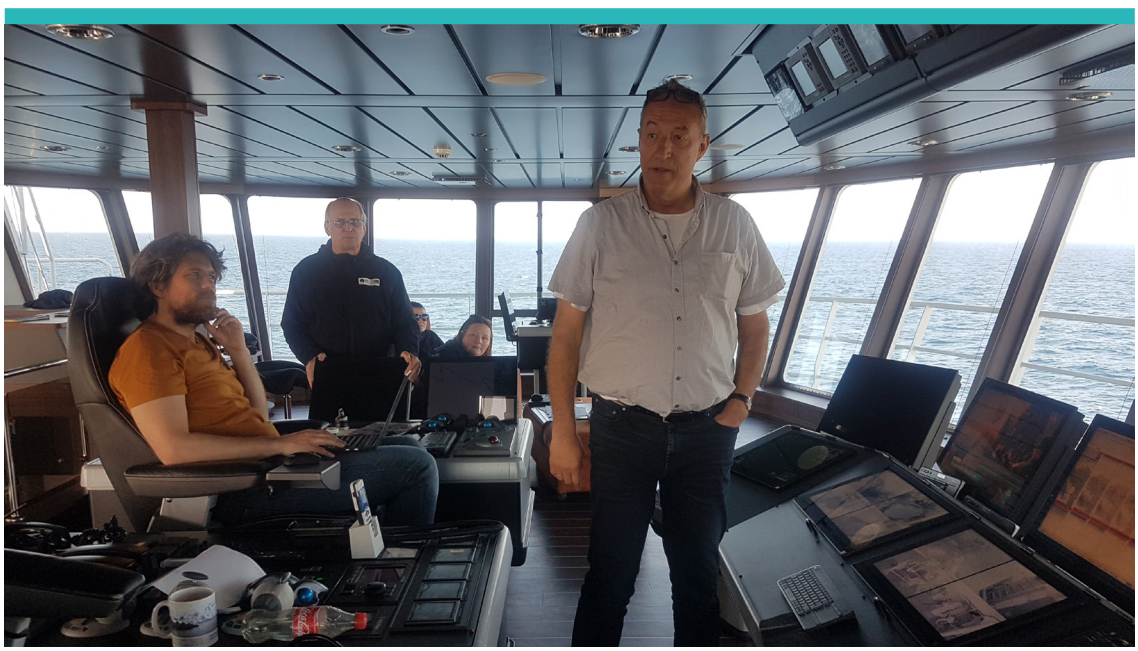


Figure 1. Spheres for broad band calibration.

Task 1.2. Methodology for numerical modelling of acoustic backscattering by individuals and aggregations

The ability to accurately model backscattering from marine organisms is important for data interpretation, for gaining deeper insight into the mechanisms of acoustic scattering, and for generation of simulated data for training classifiers. Under this task we further develop methods for modelling broadband backscattering by individuals and aggregations. Initial subtasks include identifying to what level and complexity we need to model classes of scatterers, with an initial focus on fluid scatterers (scatterers lacking swimbladder) such as sandeel and zooplankton. Together with international partners we have worked on validating numerical methods (BEM/FEM), with approximate and analytic approaches, to model individuals and aggregations as a function of size, orientation, and frequency. Investigations of new and efficient numerical methods for simulations of acoustic scattering in unbounded domains, e.g., BEM FMM, k-space pseudospectral method, and coupling of methods for composite objects (e.g., FEM/BEM) was initiated. Finally, through 2021 and 2022 we interact with the international fisheries and modelling community and contribute to the preparation and execution of the Workshop on Acoustic Backscatter Models (WGFAST-WKABM) 2021 and 2022.

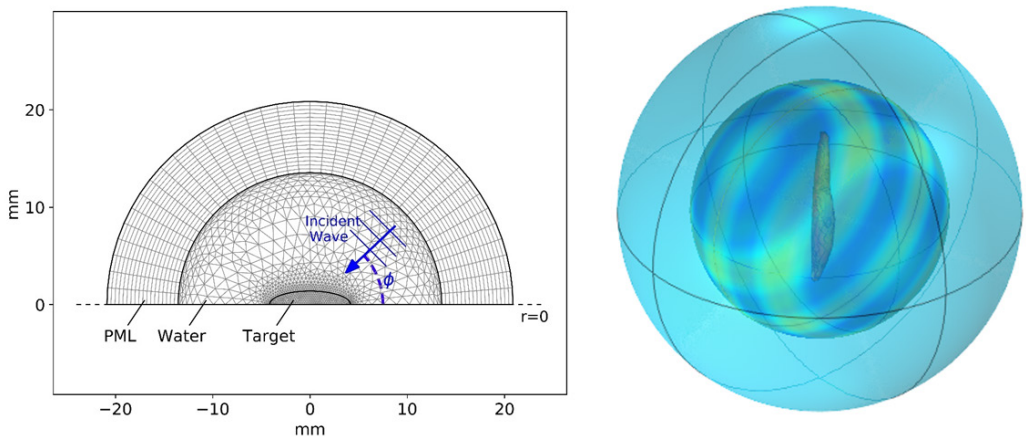


Figure 2. Modelling of acoustic targets.

Task 1.3. Enhanced detection and classification of demersal fish

This task was in 2021 devoted to collecting broadband data on demersal fish and seafloor properties during the 2021 CRIMAC fall cruise (November). The collected data will allow for testing of new algorithms and methods for detecting and classifying the seafloor and benthic habitat, as well other processing algorithms and to potentially improve classification of demersal fishes.

WP2

WP2 **EXPERIMENTAL MEASUREMENTS OF BACKSCATTER**

Scientific questions: *What are the broadband frequency responses of marine organisms and other scatterers?*

This WP are developing methods for controlled measurements of broadband backscatter from a wide range of marine organisms and other scatterers. Important categories of organisms and targets are fish, gas bubbles, fish larvae, krill, copepods, and jellyfish. Existing knowledge about these organisms have been reviewed and are used to prioritise our efforts. Experimental measurements will occur in the large tanks and net pen mesocosms at IMR's Austevoll and Matre research facilities and at-sea from vessels using hull-mounted echo sounders and close-range probing systems.

Figure 3. Deploying broad band echosounders in the net pens to study fish welfare.

Task 2.1. Design and build experimental setup for controlled measurements on backscatter from marine organisms

IMR is building net-pen based infrastructure at Austevoll which will be ready late 2022. CRIMAC are collaborating with this process and have given input to ensure that the net pens will have the adequate infrastructure for CRIMAC experiments. This task is also in collaboration with Smart Ocean SFI that will instrument the net-pens with oceanographic sensors. There will be several versions of the CRIMAC experimental setup for different cases like tethered fish or free-swimming fish seen from lateral, dorsal, ventral aspect. A setup for monitoring free swimming fish in a netpen from below was designed and used at Matre with 70, 120 and 200 kHz broad band transducers mounted in a gimbal facing upwards under a net pen.

Task 2.2. Early detection of swimbladder deflation in farmed salmon using BB FM pulses

Salmon lice is a challenge for the aquaculture industry, and a proposed solution to prevent sea-lice infestation is submerged net-pens. Submerged net-pens forces salmon below the upper water column where sea lice larvae are distributed. This prevents infestation, but salmon is a physostomous fish where the swimbladder needs to be refilled daily at the surface. Deprived from access to air, the Salmon swimbladder will lose buoyancy leading to increased energy consumption and associated fish welfare challenges. In Matre we have used split beam broad band echosounders to monitor salmon in submerged net-pens during day and night for about 30 days. We prevented salmon access to air for 23 days to identify early signs of fish welfare problems associated with the air deprivation. The objective is to establish an alarm for early signs of lack of air supply/air uptake.

Task 2.3. The fine scale frequency spectrum from of fish

This task has collected broadband data on individual and aggregations of NSS herring, lesser sandeel, and other relevant species (sprat, Norway pout, blue whiting) from vessel and auxiliary platforms (e.g., target strength probe, autonomous vehicles, and stationary platforms). The broadband backscattering data is analysed with respect to acoustic signatures and the potential for elucidating information on species, size, and behaviour. Specifically, whether broadband increases our capabilities (vs multifrequency) to identify these species and behaviour, and to what degree of accuracy can we size and group relevant species with broadband.

Figure 4. Operation during calibration of the target strength probe used to obtain broad banded spectrum of individual targets..

WP3

Figure 5. Working with the trawl to get the optical system above the sand cloud.

WP3 GROUND TRUTHING METHODS

Scientific questions: *What are the organisms and targets that generate broadband backscatter?*

This WP will develop and implement techniques for identifying and measuring the sources of broadband backscatter detected in WP2, including optical verification tools, such as stereo cameras and high-resolution optic imaging systems. The WP will also evaluate and further develop sampling methods for acoustic surveys. This will involve improved video-trawling methods as well as sampling methods for autonomous acoustic surveys. The work will require biological understanding of fish reactions to fishing gears and controlled trawl positioning in relation to targeted fish aswell as development and implementation of improved communication channels, data integration onboard, and processing methods and tools. The WP involves close cooperation with the industry partners and aims to identify applications to commercial fisheries (e.g., video-trawling with active selection and automatic and dynamic trawl steering).

Task 3.1. Develop image-based methods in trawls near bottom

Clear images from in-trawl camera systems are necessary for using optical methods in bottom trawls both for commercial and scientific purposes. The height of the trawl generated sediment cloud and its effect on image quality was measured in the Barents Sea fishing grounds. Data were collected with sonar and echosounder on a towed underwater vehicle and cameras at different heights above seabed. A commercial bottom trawl was modified to keep the camera system above the sediment cloud (8-10 m above seabed) and trawl performance was tested in the field. Preliminary trials were also made with Scantrols prototype version of DV camera system for commercial fisheries.

The next step is to publish results on the effects of sediment cloud on image quality from in-trawl camera systems and continue the development of methods for video trawling near seabed.

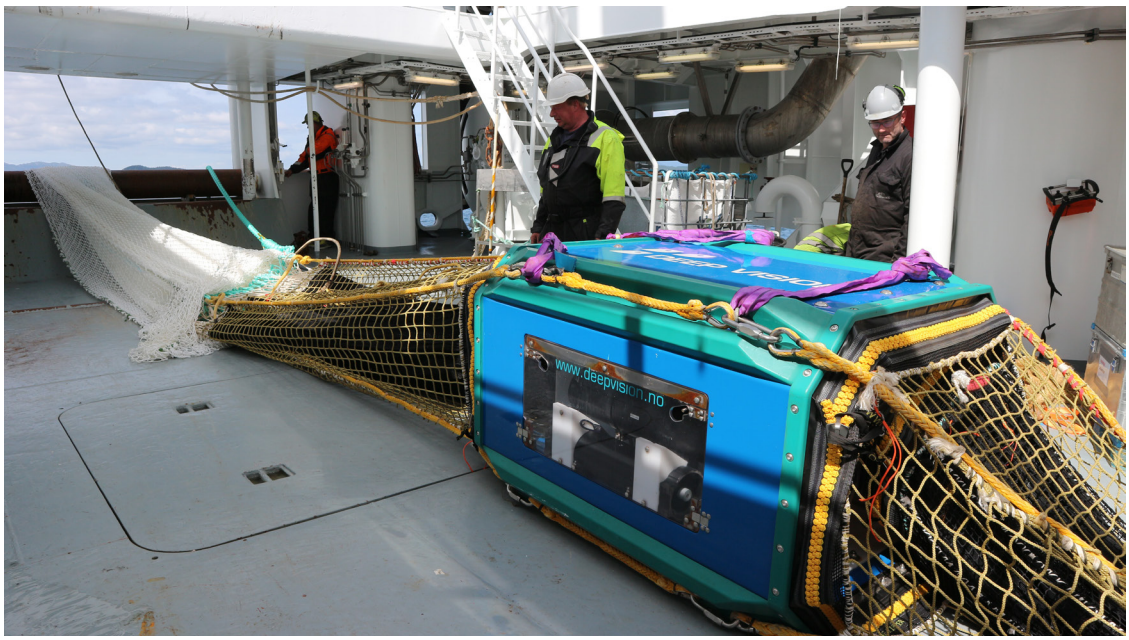


Figure 6. The deep vision system.

Task 3.2. Developing and implementing automatic image analyses methods for in-trawl camera systems

Automated counting and length measuring by species is needed for practical use of in-trawl camera systems in scientific surveys. Algorithms for counts by species were applied to and tested on data collected in the IESSNS international mackerel-ecosystem survey in 2021. The algorithm performed well on species identification but struggled with correct counts of fish when densities were high. A concern for implementation is that camera systems may affect trawl performance and catch efficiency. Preliminary investigations suggest no significant effects on geometry or catch efficiency. To make data processing more efficient and user-friendly image-analyses algorithms have been implemented into the Scantrol DV camera system. The new deck unit will be tested by IMR in April (IMR NSS herring survey). An automatic species identification algorithm is currently being developed for mesopelagic species.

Figure 7. Developing automated imaging methods for in trawl camera systems.

WP4

WP4 MACHINE LEARNING AND SPECIES CATEGORIZATION METHODS APPLIED TO FISHERIES ACOUSTICS AND GROUND TRUTHING DATA

Scientific questions: *Can machine learning techniques reliably and accurately categorize acoustic backscatter?*

This WP will apply machine learning tools on large volumes of acoustic data, with a focus on categorizing acoustic backscatter. This includes supervised methods, using a combination of historical labels, experimental data, and ground truthing information (WP3) as well as semi-supervised and unsupervised methods to extract classes that are not the target species. This will be particularly relevant for gas seep detection, plankton layers and other non-labelled categories. Classes also includes bottom detections and samples dominated by noise. By clustering historical data and comparing the classes with the classes derived using broad band data, we expect to see an improvement in acoustic target classification.

Task 4.1. Data Infrastructure

Datasets from major IMR acoustic surveys, both multifrequency and broadband, are being prepared for efficient access for modern machine learning libraries. This includes conversion and exposure of the data through open data formats and data servers. Similarly, existing labels are being converted to open formats and exposed through the same infrastructure.

A CRIMAC data processing pipeline have been developed and modules in the pipeline are published. The processing modules have been successfully integrated with the Kongsberg Blue Insight platform. This allows us to deploy algorithms on autonomous vehicles as well as vessels of opportunity. The system have been successfully deployed on the tall ship Statsraad Lehmkuhl during the One Ocean expedition.

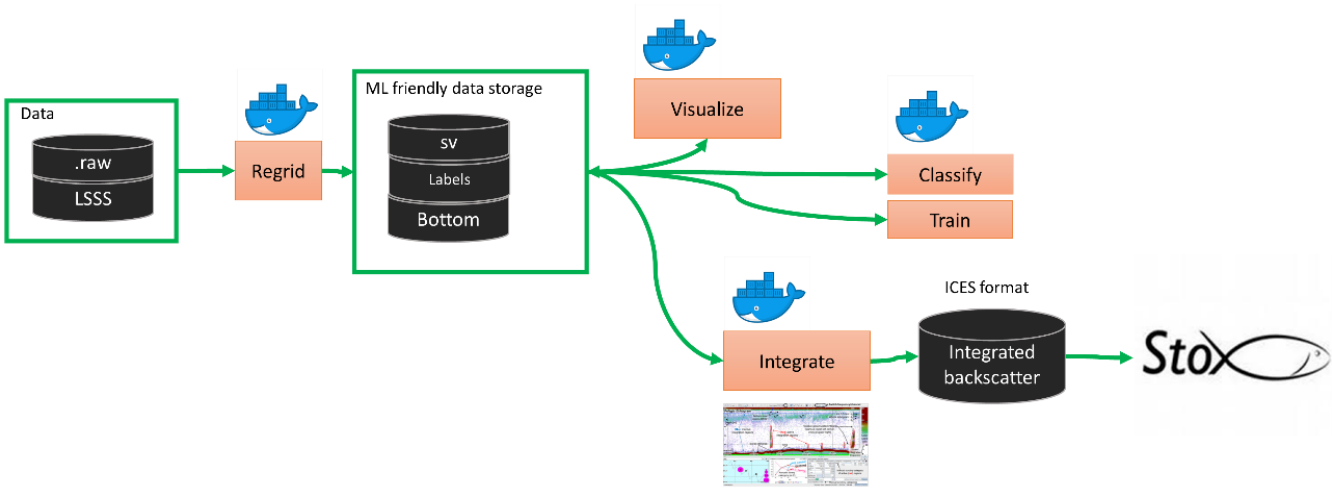


Figure 8. Components of the CRIMAC data processing infrastrcture.

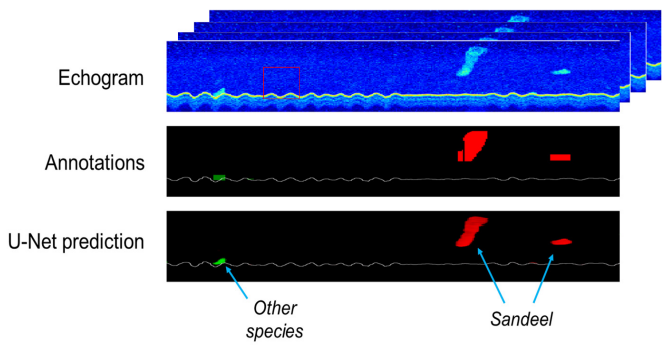


Figure 9. The U-net algorithm predicting Sand eel schools.

Task 4.2. Test and revise the U-net algorithm on Sand eel

Deploying deep learning algorithms for acoustic target classification on acoustic trawl surveys and adapting the u-net algorithm to the CRIMAC data processing pipeline. This allows us to train the algorithm on new data sets, and we are working on adapting this to the Sand-eel survey as well as the spring spawning Herring survey. The output is being compared to that of the manual data processing process, and adjustments to the network is performed accordingly. The comparison ensures that the method provides the same output as the manual process, which is a prerequisite for implementing these methods ss a component of the data processing pipeline for fisheries advice.

The next step will be to develop methods to evaluate the uncertainty in these predictions and how that will propagate to the Abundance estimates.

Task 4.3. Weakly supervised learning on acoustic data

The annotations used in acoustic target classification are often not "pixel" or region based. These weak labels are common in cases where the fish are distributed in layers as opposed to dense aggregations (schools). In this task we are using the integrated backscatter by acoustic category over the integration distance used in the survey, typically 0.1 or 1.0 nautical mile, instead of pixel-based annotations for training. This task carried out in collaboration with

the Visual Intelligence SFI as well as the COGMAR project. We are using the Sand Eel data as starting point (since pixel-based labels exist), and we simulate weak labels for training, and we use the pixel-based annotations for validation and testing.

Task 4.4. Adding auxiliary data to DL ATC models

Adding auxiliary information may assist the classification achieved through machine learning networks. Currently, these data are not directly available through the pixels going into the machine learning models, and different strategies for including these data have been developed. This works also includes various strategies for pre-processing the data and fitting the data sets into standard deep learning frameworks.

The next step in this task is to include the trawl information to help the acoustic target classification.

Task 4.5. Bottom and noise detection algorithms

Bottom and noise detection algorithms are important components of an acoustic data processing pipeline. We have been working on improving the bottom detection algorithms and integrating them with the CRIMAC data processing pipeline. A working version is available through GitHub and is adapted to the climate pipeline.

The next step in this task is to start working on noise detection algorithms. Detecting noise is important to remove unwanted signals from the data and different kinds of noise exist. The objective is to classify the noise and the bottom similarly to conventional acoustic target classification, which allows us to run the different algorithms on top of the data and then ultimately integrate the backscatter to the correct acoustic classes without including bottom samples and noise in the estimates.

WP5

WP5 IMPROVING PRECISION BY AUTONOMOUS PLATFORMS AND SURVEY AND EXPERIMENTAL DESIGN

Scientific questions: *How to utilize acoustic sensors on autonomous platforms, assess uncertainty and utilize the effect of behaviour on acoustic backscatter?*

WP5 is responsible to establish methods for utilizing autonomous or remotely operated platforms as an efficient way for deploying acoustic sensors. The platforms can either be run stand-alone or in conjunction with ships. They can also be used in a range of different applications, including scouting vessels for fishing operations and to augment research vessel based acoustic surveys. Different approaches to utilize these platforms will be explored, including various static and adaptive survey designs. How the uncertainty in automated acoustic target classification propagates to the use cases will be addressed, and WP5 will use survey time series from a range of IMR surveys to test the impact of automating target classification.

Task 5.1. Establish a list of standard settings for calibration and EK80 data recording settings for broadband echosounders to be used in standard IMR acoustic surveys.

Broadband echosounders provide enhanced possibilities for high-resolution long-range monitoring of marine organism and detailed information of the acoustic properties of targets to be used for identification. However, the settings of the echosounder recording affects how the data can be analysed as each setting has strengths and limitation.

Based on the collected data in Task 1.3 and WP2, an updated list of optimal settings for efficient broadband sizing and identification are established. This has been submitted to IMRs acoustic forum as a standard protocol for IMR surveys.

Task 5.2. Direct measurements of the migration speed of spawning herring

The new Kongsberg acoustic doppler current profiler (ADCP) offer the possibility to monitor movement of fish during standard fish surveys. ADCP data has been recorded during several surveys on herring when they migrate along the Norwegian coast towards the spawning grounds. We have established methods to measure the swimming speed and direction of the herring schools and we have identified how the migration speed differ. These results are of importance as a standard abundance survey estimate is biased without any correction of variable migration.

Task 5.3. Survey designs for autonomous platforms

Sandeel is a key-species in the North Sea and the coastal waters of Norway as an important prey for fish, seabirds, and sea-mammals. The management of sandeel is dependent of high-quality acoustic-trawl survey estimates. These surveys have been in front when testing and implementing of new survey designs, implementing of standard multi-frequency acoustic identification procedures, target strength experiments and testing of saildrones and machine learning of acoustic categorization.

CRIMAC has been involved in designing the roadmap for implementing the use of USVs, machine-learning and adaptive survey designs for future sandeel surveys.

Figure 10. Kayak drone used during the sprat survey.

Task 5.4. Establish acoustic survey designs of fjord sprat using drones, research vessels and machine learning methods for acoustic scrutinizing.

Sprat is a key-species in the ecosystems of the Norwegian fjords and is a focus species in coastal ecosystem surveillance programs. Recent experiments show that traditional research vessels based acoustic surveys on sprat is not able to measure important parts of the densities distributed near surface, near the shore or in shallow waters. The CRIMAC is therefore invited to establish new survey designs using a combination of drones and research vessels. In a similar way as for capelin and sandeel, there is a need to establish survey estimates of absolute abundance.

Task 5.5. "EchoIBM". Further develop the Echogram Individual Based simulation Model using acoustic properties of multiple individual targets.

Unbiased ground truthing information using trawling or optical methods are not possible due to species and size selectivity and avoidance, and variable environmental affected behaviour of fish and zooplankton. Therefore, in a similar way as used in other scientific fields, there is a need to establish a simulated "true" population tool. The "EchoIBM" can produce echograms by beams and frequencies based on target attributes such as backscattering properties received from WP1 and WP2, position, depth and tilt, and polarization of targets in schools. The acoustic categories can be labelled, and the echograms can be utilized for the machine learning in WP4.

WP6

WP6 AND USER STORIES **EXTRACTING GAINS FOR SCIENCE AND INDUSTRY**

The overall goal of WP6 is to link the ongoing research and development in the CRIMAC SFI with the needs of the centre user partners. The consortium spans both scientific and industrial end users as well as suppliers, meaning that quantified gains would cover both new methods as well as the commercialization of solutions from the centre. The goal of the SFI is to foster innovation and value creation. CRIMAC has identified four key sectors to target, on which the success of this work package will be measured:

- Science & Management
- Commercial Fishery
- Aquaculture
- Marine Energy

The stories below highlight some examples of relevance for this work.

User stories

USER STORY:
BLUE INSIGHT; A DIGITAL FUTURE FOR OCEAN RESEARCH & INDUSTRIES

Already in the first year of CRIMAC, user partner Kongsberg Maritime has launched the first version of a commercial cloud-based solution for ocean data called Blue Insight. While the launched product was built on existing digital technology in the company, reaping benefits from previous projects such as Frisk Oslofjord, the CRIMAC SFI has presented both a clear use case for the product as well as providing mechanisms for development and testing of product functionality together with experienced end users.

In short, Blue Insight provides an open, modular platform for the collection, processing, visualization and sharing of ocean data built on FAIR data principles. Kongsberg plans to continue developing functionality on this platform throughout the CRIMAC duration, and some of the areas specifically relevant for CRIMAC is highlighted below.

EK80 is Kongsberg's scientific wideband echosounder system. Data from this system is essential for much of what is done in CRIMAC. Traditionally echosounders have been operated by humans physically being onboard the vessels themselves, relying on active human operation when recording data. New acoustic data platforms bring new challenges, and

Figure 11. Blue Insight is a sensor and platform agnostic solution, designed for efficient collection and sharing of ocean data.

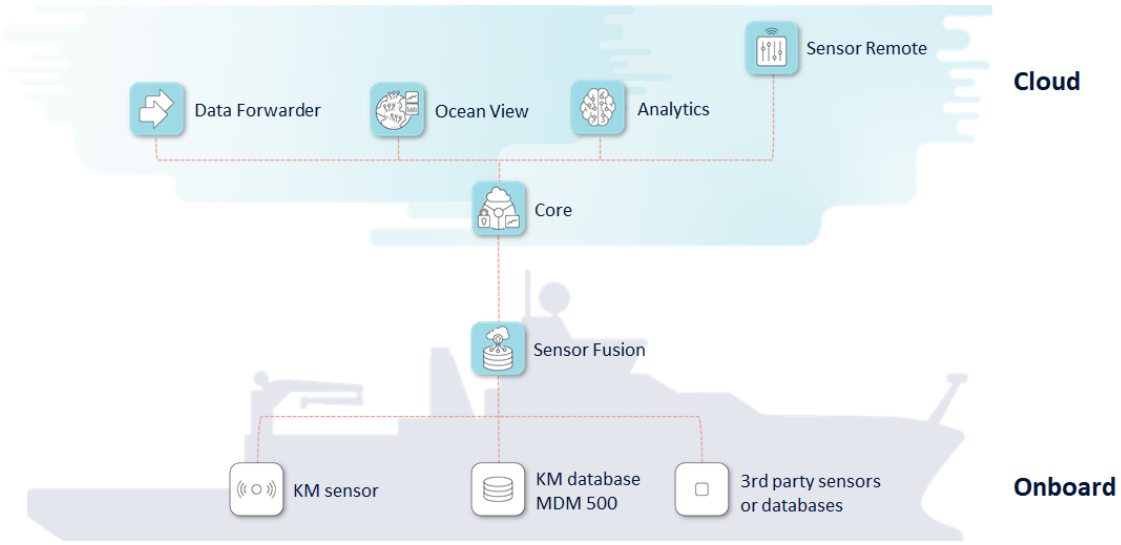


Figure 12. Principal sketch of Blue Insight with dedicated modules.

by removing the human element from the platform several things need to be automated. A dedicated module in Blue Insight called Sensor Remote has been developed to address this aspect, and the first version of the module with basic EK80 functionality has been launched. Going forward more functionalities will be added, and it will be possible to do both quality control as well as change system setup even on limited bandwidth carrier networks.

Automated classification of fish through machine learning techniques lies at the heart of CRIMAC WP 4 and seen as key for user partner IMR to be able to utilize autonomous or remotely operated platforms as an efficient way for deploying acoustic sensors in the future. The data processing pipeline highlighted in WP4 is deployed remotely through the Blue Insight infrastructure, allowing users to utilize published algorithms from CRIMAC or deploy their own.

By relying on published algorithms and active use of docker containers Blue Insight target flexibility for users across a wide range of user types in the year to come.

Launched in October 2021 Blue Insight is still in its infancy. The idea behind the product is not to create yet another ocean database but rather to provide a one stop solution for more efficient collection and distribution of such data across users and databases, in line with what will be required from the Blue Economy going forward.

USER STORY:
NEW INFRASTRUCTURE FOR AUSTEVOLL RESEARCH STATION – COMMON INTERESTS AND COLLABORATION ON TEST FACILITIES

The institute of Marine Research is building a new netpen based infrastructure at the research station at Austevoll. Both SFI CRIMAC and SFI Smart Ocean, as well as other user partners, were invited to provide input at the planning stage. In meetings between IMR and the two SFI's we have identified several common interests for the infrastructure. The SFI Smart Ocean is developing underwater internet and smart sensors for underwater environmental monitoring and will test this equipment in Austevoll. This requires solutions for power, dataflow and communication network, and a similar setup is also needed for the dataflow in the CRIMAC experiments. The same netpens can be used by both SFIs, and CRIMAC can measure the scattering properties for marine organisms in the same netpen setups as SFI Smart Ocean is testing their sensors. CRIMAC have given input on our needs for the net pen experiments and are following up the new infrastructure which will be ready late 2022.

IMR is also in general interested in acoustic monitoring of fish regarding aquaculture, especially with broad band acoustics. This overlaps with the WP2 in CRIMAC which has focus on measuring the broad band frequency spectrum from several fish species. Here we have common interests for much of the equipment.

The main advantage in net pen measurements is that we have full control over the species and the size distribution of the fish. In the new infrastructure, CRIMAC plan to do measurements on both tethered and free-swimming fish. Using broad band echo sounders this allow us to study how the backscatter, and especially the frequency spectrum, can be used to find information about species and size. We will also use the infrastructure to test several pulse types to, e.g., to see if we can improve single target detections, get a better signal to noise ratio for a wider frequency spectrum, and to reduce bottom blind zones.

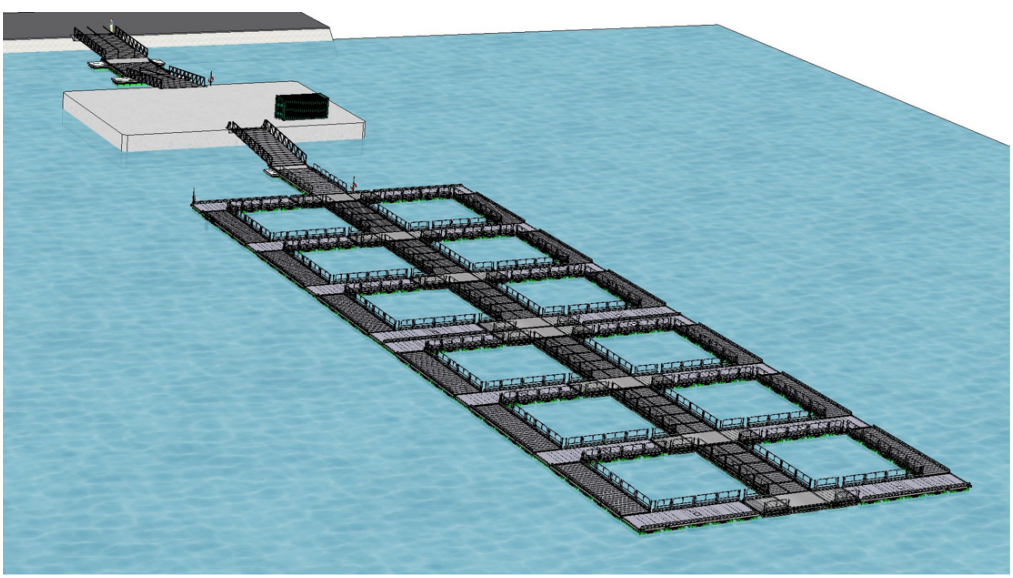


Figure 13. The new net pen facilities at Austevoll aquaculture station.

Figure 14. The Kongsberg Sounder platform.

USER STORY:
CRIMAC PLAYS AN IMPORTANT ROLE IN THE FUTURE ECOSYSTEM MONITORING

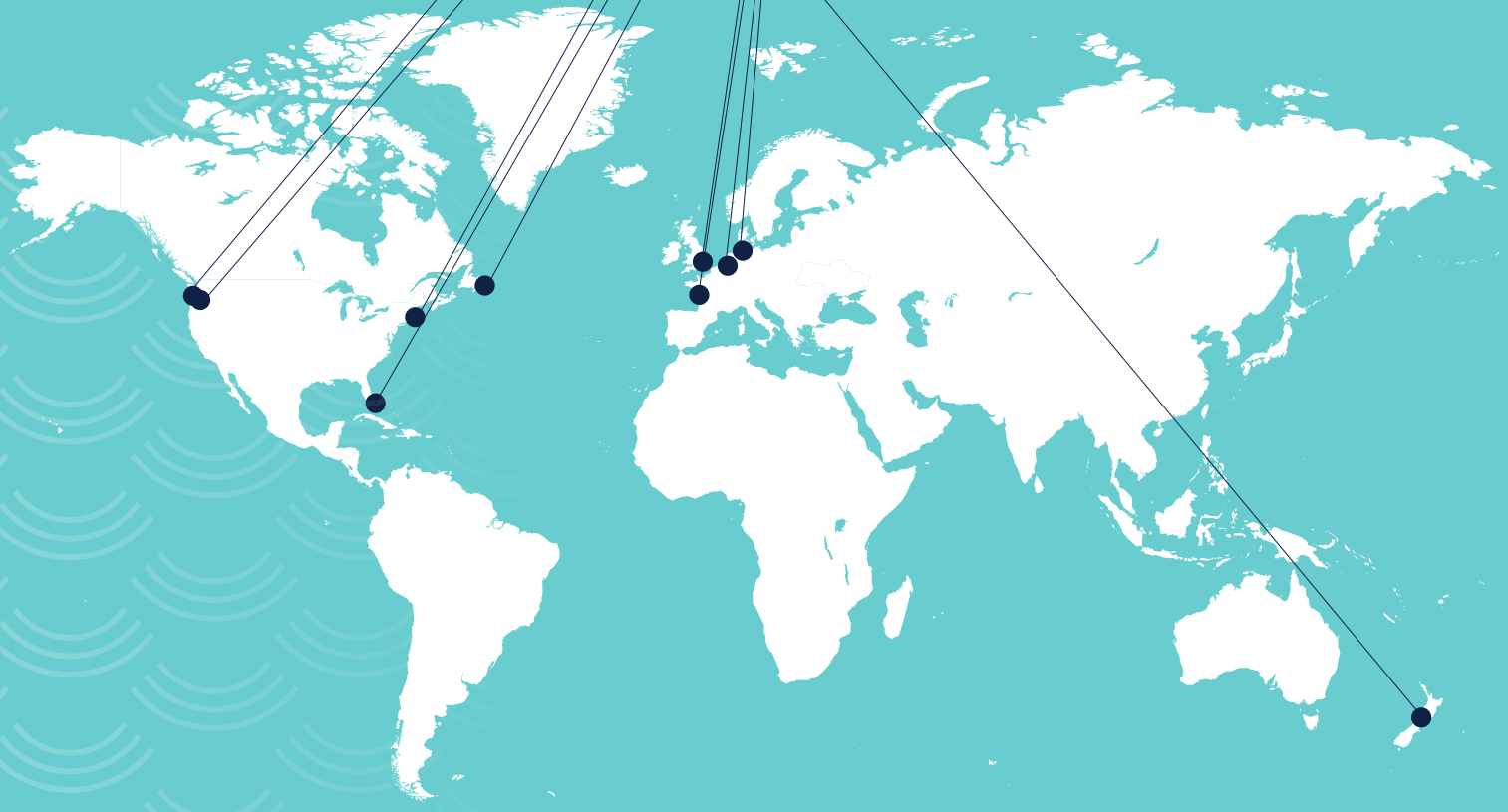
The lesser sandeel is a key-species in the North Sea ecosystem, and acoustic surveys carried out by conventional research vessels provide valuable input to the Norwegian area based sandeel management. CRIMAC is an important partner when the Institute of Marine Research plans to improve the survey quality and make these surveys more cost-effectively and environmentally friendly by using the next generation of unmanned surface vehicles (USV).

All the working packages are involved in this work, as an efficient process from data collection to advice and management is dependent of a well-defined data path, reliable acoustic classification through modelling and in deep understanding of the of backscattering (echo) signal. CRIMAC will be responsible to set up survey designs and build systems for onboard machine learning and automatic classifications of the acoustic targets. The first trial survey on sandeel using the new Sounder USV platforms will be carried out under the control of CRIMAC in spring 2023. To compensate for reduced biological sampling from the research vessel, CRIMAC has started the work of utilizing data from the commercial sandeel catches to estimate length structures in the sandeel population. If successful, the fully automated USV survey method can be expanded into other coastal and marine ecosystems.

Cooperation

INTERNATIONAL COOPERATION

- Alaska Fisheries Science Centre, NOAA, Seattle, USA
- Northwest Fisheries Science Centre, NOAA, Seattle, USA
- Woods Hole Oceanographic Institution, Woods Hole, US
- Florida International University, Miami, USA
- Memorial University of Newfoundland, Saint Johns, Canada
- Imperial College, London, UK
- Ifremer, Nantes, France
- Wageningen University & Research, Wageningen, Netherlands
- Thünen Institute, Bremerhaven, DE
- Aqualyd Limited, Nelson, New Zealand



PhD candidates

Ahmet Pala

Sakura Komiyama

E. H. Taraneh Westergerling

RECRUITMENT

Recruiting PhD student students is an ongoing process. We have successfully hired 3 within biology and mathematics and two further positions are being opened in physics. We are also active in attracting master students to the centre, and we have participated in student events at university of Bergen and the Arctic University of Tromsø.

Ahmet Pala has a master's degree in Industrial Engineering on machine learning and is currently continuing his Ph.D. in Applied Mathematics at UiB. Ahmet also holds a bachelor's degree in Naval Architecture and Marine Engineering. In his studies, he mostly focused on the applications of machine learning in the marine field. He is included in the work package 4 of the CRIMAC Project and aims to apply machine learning/deep learning methods on acoustic data and analyze the uncertainty.

Sakura Komiyama received her second master's degree in biology and currently works for the CRIMAC project as a PhD research fellow. She has also worked for the sandeel project at IMR for few months before starting her PhD programme. Her overarching interests are fish behaviour and species interaction within marine ecosystems, observing through up-to-date instruments such as broadband echosounders and unmanned surface vehicles.

E. H. Taraneh Westergerling is a PhD Research Fellow at the Department of Biology of the University of Bergen. She completed an international Master's program in Marine Biological Resources (IMBRSea) in 2021 with a thesis focused on the Deep Vision in-trawl camera system. Her topic of research breaches the fields of fish capture technology and fisheries acoustics. Her PhD in CRIMAC's work package 3 under the supervision of Maria Tenningen.

COMMUNICATION AND DISSEMINATION ACTIVITIES

Disseminating our activities and results to selected target audiences as well as the broader public is central to achieving CRIMAC's objectives. A dedicated communications group has been established with participation from the partner institutions and a dissemination plan has been worked out. This work will continue to have high priority in the centre's work going forward, as new activities are initiated and more results are published.

In addition to CRIMAC's own web page, stories and updates from the centre are regularly featured on IMR's web page and social media channels, where they reach a wide audience. To name one example, a post on IMR's Facebook page featuring CRIMAC's participation on the 2021 sandeel cruise reached an audience of more than 12 000 individual users. The centre has been featured in two articles in Kongsberg's The Full Picture Magazine for an English-speaking audience. The centre has also attracted attention from media outlets focusing on fisheries and technology, such as Fiskeribladet, which have featured several of CRIMAC's researchers and projects.

Media coverage overview:

Title	What
Forskerne er i full gang med å bruke kunstig intelligens i trålen. Målet er mindre bifangst.	*Interview with Vaneeda Allken and Shane Rosen, Fiskeribladet*
Fisken som leikar i havet	*Op-ed by Nils Olav Handegard, Fiskeribladet*
Greier man å telle størje med sonar?	*Interview with Hector Peña, Kyst og Fjord*
Arbeidet hans sparer forskerne for store ressurser, og åpner for et selvstyrt fiskeri	*Interview with Changkyu Choi and Nils Olav Handegard, Fiskeribladet*
Bjørn har ansvar for at informasjonen som Statsraad Lehmkuhl innhenter på jordomseilingen blir sikret	*Interview with Bjørn Arvid Sætren (IMR Digital), Fjordenes Tidende*
Betre ekkolodd vil gi betre forståing av våre marine økosystem	*Op-ed by Nils Olav Handegard, Tonny Algrøy and Egil Ona, Skipsrevyen*
Ny teknologi kan gjøre at forskerne slipper å ta fisken om bord	*Interview with Hege Hammersland (Scantrol Deep Vision), Fiskeribladet*
Nå kan sonarer beregne hvor mange tonn fisk som er i stimen	*Interview with Héctor Peña, Fiskeribladet*
Dei nye breibandsekkolodda fangar opp enorme mengder informasjon frå vannsøyla	*Feature story on IMR's Facebook page*
Digital Future for Ocean Research	*Interview with Geir Huse and Nils Olav Handegard, The Full Picture*
Har gitt sonaren evne til å beregne hvor mange tonn fisk den ser	*Interview with Héctor Peña, Kystmagasine*
Skal telle krabbe med droner	*Interview with Geir Huse, Kyst og Fjord*
God havovervåkning gir de beste rådene	*Interview with Geir Huse, Kystmagasinet*
Tuning in to the sound of the sea	*Interview with Egil Ona, The Full Picture*
Vil lære seg sildas dialekt	*Interview with Egil Ona, Norsk Sildesalgslag*
Stor glede over nye sentere for forskningsdrevet innovasjon	*Interview with Sissel Rogne, Fiskeribladet and Intrafish*

Appendices

Publications

An up-to-date list of publications can be found here:
https://crimac.no/publikasjoner

Peer reviewed publications

Khodabandeloo, Babak; Agersted, Mette Dalgaard; Klevjer, Thor A.; Pedersen, Geir; Melle, Webjørn Raunsgård Mesopelagic flesh shear viscosity estimation from in situ broadband backscattering measurements by a viscous-elastic model inversion. *ICES Journal of Marine Science 2021 (1054-3139) Vol. 78 (9), s. 3147-3161*

Choi, Changkyu; Kampffmeyer, Michael; Handegard, Nils Olav; Salberg, Arnt Børre; Brautaset, Olav; Eikvil, Line; Jenssen, Robert Semi-supervised target classification in multi-frequency echosounder data. *ICES Journal of Marine Science 2021 (1054-3139) Vol. 78 (7), s. 2615-2627*

Allken, Vaneeda; Rosen, Shale Pettit; Handegard, Nils Olav; Malde, Ketil A deep learning-based method to identify and count pelagic and mesopelagic fishes from trawl camera images. *ICES Journal of Marine Science 2021 (1054-3139) Vol. 78 (10), s. 3780-3792*

Khodabandeloo, Babak; Ona, Egil; Macaulay, Gavin; Korneliussen, Rolf Nonlinear crosstalk in broadband multi-channel echosounders. *Journal of the Acoustical Society of America 2021 (0001-4966) Vol. 149 (1), s. 87-101*

Allken, Vaneeda; Rosen, Shale Pettit; Handegard, Nils Olav; Malde, Ketil A real-world dataset and data simulation algorithm for automated fish species identification. *Geoscience Data Journal 2021 (2049-6060)*

Feature stories

Handegard, Nils Olav; Algrøy, Tonny; Ona, Egil Betre ekkolodd vil gi betre forståing av våre marine økosystem. *Skipsrevyen 2021 (0800-2282)*

Lorentzen, Erlend Astad Har gitt sonaren evne til å beregne hvor mange tonn fisk den ser. *www.hi.no 2021*

Handegard, Nils Olav Fisken som leikar i havet. *Fiskeribladet 2021 (0805-5289)*

Articles

Handegard, Nils Olav; Algrøy, Tonny; Eikvil, Line; Hammersland, Hege; Tenningen, Maria; Ona, Egil Smart Fisheries in Norway: Partnership between Science, Technology, and the Fishing Sector. *Journal of Ocean Technology 2021 (1718-3200) Vol. 16 (2), s. 11-18*

Handegard, Nils Olav; Eikvil, Line; Jenssen, Robert; Kampffmeyer, Michael; Salberg, Arnt Børre; Malde, Ketil Machine Learning + Marine Science: Critical Role of Partnerships in Norway. *Journal of Ocean Technology 2021 (1718-3200) Vol. 16 (3), s. 1-9*

Conference contributions

Palermino, Antonio; Pedersen, Geir; Korneliussen, Rolf; De Felice, Andrea; Leonori, Lole Application of backscattering models for targetstrength measurement of T. mediterraneus and S. colias in the Mediterranean Sea. *Scandinavian Symposium on Physical Acoustics 2022, 2022-01-31 00:00:00.0 - 2022-02-01 00:00:00.0*

Khodabandeloo, Babak; Ona, Egil; Macaulay, Gavin; Korneliussen, Rolf Acoustically induced nonlinear crosstalk in broadband echosounders. *Scandinavian Symposium on Physical Acoustics 2022, 2022-01-31 00:00:00.0 - 2022-02-01 00:00:00.0*

Handegard, Nils Olav Deep learning models for fisheries acoustic target classification. *Scandinavian Symposium on Physical Acoustics 2022, 2022-01-31 00:00:00.0 - 2022-02-01 00:00:00.0*

Handegard, Nils Olav; Forland, Tonje Nesse; Johnsen, Espen; Pedersen, Geir; Tenningen, Maria; Ona, Egil CRIMAC - Center for Research-based Innovation in Marine Acoustic Abundance Estimation and Backscatter Classification. *ICES WGFAST and ICES-FAO WGFTFB 2021, 2021-04-19 00:00:00.0 - 2121-04-23 01:00:00.0*

Ordonez, Alba; Utseth, Ingrid; Eikvil, Line; Handegard, Nils Olav Using model averaging ensembles in semantic segmentation of marine echosounder data for acoustic classification of species . *NOBIM 2021 0, 2021-09-13 00:00:00.0 - 2021-09-14 00:00:00.0*

Ona, Egil Echo sounder developments during my scientific life, - from EK38 to EK80, some significant steps . *ICES WGFAST and ICES-FAO WGFTFB 2021, 2021-04-19 00:00:00.0 - 2121-04-23 01:00:00.0*

Khodabandeloo, Babak; Ona, Egil; Macaulay, Gavin; Korneliussen, Rolf Nonlinear higher harmonics and crosstalk in broadband multi-channels echosounders. *ICES WGFAST and ICES-FAO WGFTFB 2021, 2021-04-19 00:00:00.0 - 2121-04-23 01:00:00.0*

Ona, Egil; Zhang, Guosong; Handegard, Nils Olav; Berg, Sverre; Andersen, Lars N Direct measurements of the migration speed of spawning herring. *ICES WGFAST and ICES-FAO WGFTFB 2021, 2021-04-19 00:00:00.0 - 2121-04-23 01:00:00.0*

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Utseth, Ingrid; Ordonez, Alba; Eikvil, Line; Brautaset, Olav; Salberg, Arnt-Børre; Handegard, Nils Olav Improving marine acoustic target classification with context information. *Visual Intelligence Days 2021 0, 2021-10-19 00:00:00.0 - 2021-10-20 00:00:00.0*

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Ona, Egil; Handegard, Nils Olav; Johnsen, Espen; Kubilius, Rokas; Korneliussen, Rolf; Pedersen, Geir; Totland, Atle; Rosen, Shale; Underwood, Melanie; Andersen, Lars N mfl. CRIMAC cruise report 2020116. *2021*

Handegard, Nils Olav; Andersen, Lars Nonboe; Brautaset, Olav; Choi, Changkyu; Eliassen, Inge Kristian; Heggelund, Yngve; Hestnes, Arne Johan; Malde, Ketil; Osland, Håkon; Ordonez, Alba mfl. Fisheries acoustics and Acoustic Target Classification - Report from the COGMAR/CRIMAC workshop on machine learning methods in fisheries acoustics. *2021, 25 ss.*

PERSONELL

KEY RESEARCHERS

Name	Institution	Main research area	Gender
Egil ONA	IMR	Center leader until July 2021	M
Nils Olav HANDEGARD	IMR	New Center leader and WP4 manager	M
Geir PEDERSEN	IMR	WP1 manager	M
Tonje N. FORLAND	IMR	WP2 manager	F
Maria TENNINGEN	IMR	WP3 manager	F
Espen JOHNSEN	IMR	WP5 manager	M
Ketil MALDE	IMR	Researcher	M
Shale ROSEN	IMR	Researcher	M
Frode OPPEDAL	IMR	Researcher	M
Sindre VATNEHOL	IMR	Researcher	M
Rokas KUBILIUS	IMR	Researcher	M
Hector PENA	IMR	Researcher	M
Guttorm ALENDAL	UIB		M
Per LUNDE	UIB		M
Audun Oppedal Pedersen	UiB		M
Anne Gro V. SALVANES	UIB		F
Rune ØYERHAMN	NORCE		M
Inge K. ELIASSEN	NORCE		M
Arnt-Børre SALBERG	NR		M
Olav BRAUTASET	NR		M
Alba ORDONEZ	NR		M
Ingrid UTSETH	NR		F

KEY RESEARCHERS, TECHNICIANS, RESEARCH INSTITUTES

Turid S. LODDENGAARD	IMR	Centre management - Finance	F
Atle TOTLAND	IMR	Sonar Technology and Fisheries Instrumentation	M
Liz B.K. KVALVIK	IMR	Engineering, instrument development	F
Erik SCHUSTER	IMR	Engineering, instrument development	M
Arill ENGÅS	IMR	Reseacher	M
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Ronald PEDERSEN	IMR	Sonar Technology and Fisheries Instrumentation	M

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Name	Institution	Main research area	Gender
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Thor BÆRHAUGEN	Kongsberg Group	Sonar technology and fisheries instrumentation	M
Martin TOLLEFSEN	Kongsberg Group	Sonar technology and fisheries instrumentation	M
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Kristoffer LØVALL	Scantrol Deep Vision AS	Visual fish classification	M
Frode GAUPÅS	Scantrol AS	Visual fish classification	M
Eirik Svoren OSBORG	Scantrol Deep Vision AS	Visual fish classification	M
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Ruben PATEL	CodeLab	Low impact trawling	M
Anne-Sofie UTNE	Norway Royal Salmon ASA	Low impact trawling	F
Per Magne Eggesbø	EROS AS	CEO	M
Per William Lie	Lie-Gruppen	Captain	M

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Taraneh Westergelink	Germany	2021-2025	F
Sakura Komiyama	Japansk	2022-2025	F

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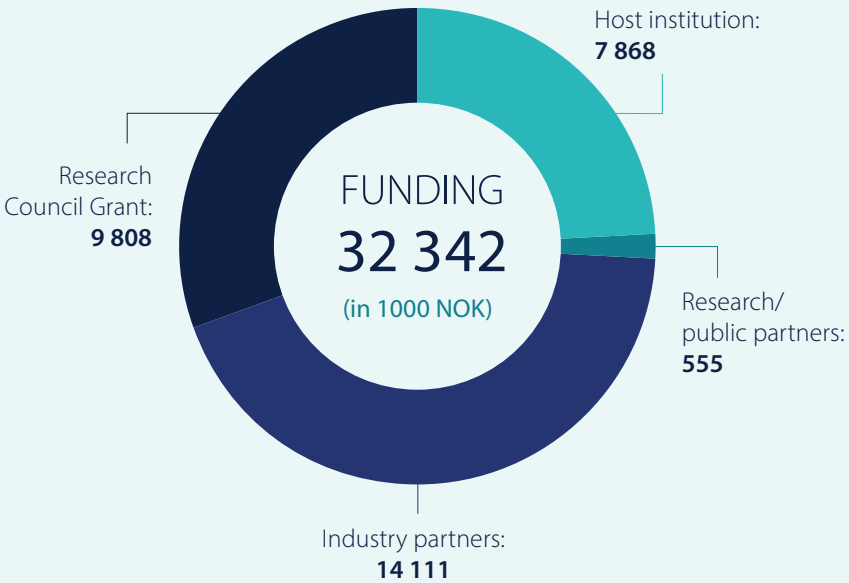
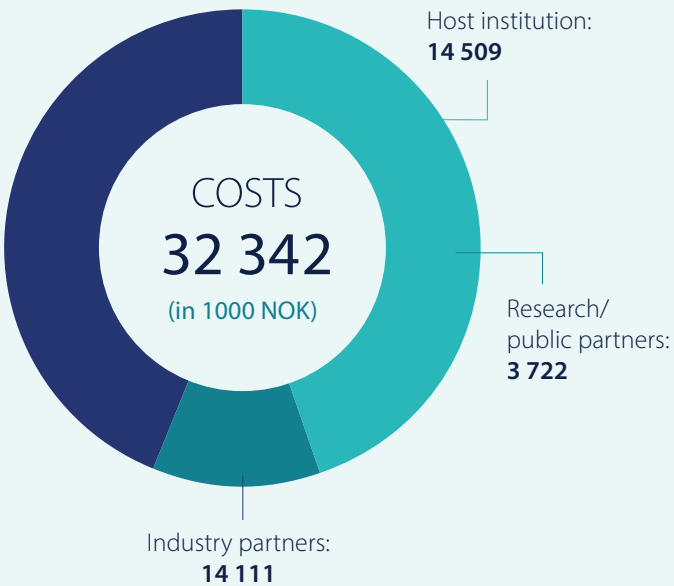
Annual accounts 2021

Host institution:
Havforskningsinstituttet

Research/public partners:
Universitetet I Bergen, Norce, Norsk Regnesentral

Industry partners:
Simrad, Scantrol, Scantrol Deep Vision, Lie Gruppen, EROS, CodeLab, Norway Royal Salmon





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